In order to test more closely the existence of an eleven-year periodicity, I counted the numbers of earthquakes of each intensity in the years 1755, 1766, . . . , 1887; 1756, 1767, . . . , 1888; and so on, and took five-yearly means of these eleven sums, with the following results, the first subsequent year of least sunspot frequency being 1765:

Intensity.	First Maximum Epoch.	Amplitude.
III. . .	1764	0·16
II. . .	1762–63	0·12
I. . .	1763–64	0·09

Thus, in destructive earthquakes of every intensity, the maximum-epoch of the eleven-year period occurs shortly before the epoch of least sunspot frequency; and the amplitude increases with the intensity of the shock. It may be added that the epochs are almost exactly the same for the same three classes for the separate intervals 1701–99 and 1801–99, and for all three intensities together for the interval 1501–1698, and for each season of the interval 1701–1898.

It is interesting to notice that the same periodicity holds in widely separated regions. Taking the three intensities together, the maximum occurs in 1764 in Europe, in 1763–64 in Asia, in 1764 in Italy, in 1764–65 in China, and in 1763–64 in the island groups of the western Pacific. Even in the slight earthquakes of Great Britain, the same period is present with its maximum in 1763–64. Thus, by a somewhat different line of evidence, Milne's remarkable generalisation seems to be confirmed.

In addition to the eleven-year period of destructive earthquakes, there are other clearly marked periods of 19, 22, and 33 years, the maximum epochs of which (1754, 1760, and 1757) agree closely in widely distant regions of the northern hemisphere. Some of these maxima seem to be responsible for clusters in the above table, especially for those of the years 1791, 1847–48, 1880–81, and about 1887. To the occurrence of their minima about the years 1798, 1833, and 1878, the absence or slightness of clusters is probably due.

During the present century, the maxima of the 11, 33 and 19 year periods occurred in 1918, 1922 and 1925; those of the 11, 22 and 33 year periods are due in 1951, 1958 and 1955; and those of the 11, 22, 33 and 19 year periods in 1984, 1980, 1988 and 1982. The times of unusually frequent earthquakes are thus, 1918–25, 1951–58 and, especially, 1980–88. The first of these intervals is notable for its very numerous earthquakes, some of which, such as the Chinese earthquake of 1920 and the Japanese earthquake of 1923, were of great violence.

Invention as a Link in Scientific and Economic Progress.[1]

By Sir JAMES B. HENDERSON.

INVENTION forms the natural link between physics, chemistry, and engineering, and every advance in one or other of these produces a reflex action on the other. For example, a discovery in physics which increases accuracy of measurement by providing an indicator more sensitive than any previously known, is soon embodied in an engineering instrument carefully designed and manufactured for sale at a price which makes it available to every physicist for use in further research. Thus modern research in physics and chemistry is carried out with accurate apparatus which would be available only at a prohibitive price if it had been made for the particular research alone. The assemblage of apparatus used in a modern research is sometimes like an engineering installation, and is in marked contrast with the cruder, home-made apparatus, designed *ad hoc*, which was common a generation ago.

The closer the intercourse between the physicist, the chemist, and the engineer, the greater will be the fertility in invention and the faster the economic progress. The physicist working continually in a laboratory where everything is specially designed to facilitate accuracy of measurement and to eliminate disturbance, is apt to forget how artificial his working conditions really are, and that before any of his beautiful experiments can have a practical application in industry a great deal of invention is required.

As an example of successful invention involving an accurate measurement to be made under practical conditions unsuitable to accuracy, I may cite the Barr and Stroud range-finder, which was invented by two young professors in the Yorkshire College, Leeds. The problem consisted in measuring with great accuracy, say to a second of arc, the small angle subtended at a distant target by a short fixed base placed at the observer. At the time when this invention was made, some forty years ago, the only scientist who normally measured angles to seconds of arc was the astronomer with his large telescopes mounted on great concrete foundations, with graduated circles from three to six feet in diameter and microscopes to read the scales. It seemed, therefore, impossible to contemplate the measurement of angles with anything like equal accuracy on board a rolling ship and with no expert operator.

Yet the two inventors, seeing an advertisement in the pages of *Engineering* announcing competitive trials of range-finders to be held by the War Office, took this seemingly impossible task in hand. There was little time to spare. The first instrument was designed in outline in a week, and much of the subsequent success is attributable to the sound physical principles underlying this

[1] Continued from p. 553.

design and to the very ingenious design of all the constructional details, due to the happy combination of an engineer and a physicist, both of whom were men of imagination with a *flair* for invention. Their range-finder was constructed in the College buildings and, to indicate the amount of time that was available, the final adjustment of the instrument was made on a star from the railway platform at Rugby on the way to the trials at Aldershot.

During the trials the instrument worked well at first, but after the sun came out it commenced to read ' as thousands of yards ranges which were palpably a few hundred ' and the inventors discovered that their beautiful angle measurer was also a thermometer and a sunshine recorder combined. They were not surprised to have it rejected, and they might actually have abandoned it entirely if they had not been asked by the Admiralty some time later to submit an instrument for naval use. Then followed ten years of most patient struggle against physical and engineering difficulties, not to mention financial difficulties, for the inventors acted as their own promoters and the financial side of the business must have taxed their resources to the utmost. But at last they succeeded, and their range-finder is now the standard instrument in the British Army and Navy, and in other countries as well, and has been the foundation of one of the best firms of scientific instrument makers in the country. As student or as assistant I had the honour to serve under both Prof. Barr and Prof. Stroud, both of them great teachers, versatile inventors, and most lovable men, and I am happy to be able to pay this small tribute to them and to their great achievement.

THE DIFFICULTIES OF INVENTION AND THEIR REMEDY.

I wish it to be understood that where I have used the word ' invention ' I am dealing with the great inventions, and not with the thousand and one minor and comparatively unimportant, though useful, inventions which flood the Patent Office every year. The latter are generally simple affairs, a minor improvement in a known mechanism or a new way of performing an old simple function. I do not wish to belittle these minor inventions in any way. They serve their purpose in our everyday lives, and all are traceable more or less directly to some major invention of the past, but the distinction which I wish to draw is that in very few cases is their manufacture or development a matter of difficulty. I am therefore dealing solely with the big inventions and their development, and it is to the question of the obstacles that are too often encountered in their development that I wish to draw particular attention. I wish now to examine the question of how to eliminate, or at least minimise, these difficulties that obstruct the inventor and so retard the march of progress.

The first way that suggests itself to me is by means of education. Our educational policy in schools on the scientific side deals with physical laws as facts, and the teacher generally deals only with phenomena with which he can afford to be dogmatic and ignores the enormously greater range of phenomena about which science knows little or nothing. This system inevitably breeds in the student and in the general public the impression that Nature acts according to certain definite laws and that there is nothing about these laws which is not known to science. In actual fact, the more the scientist knows about these laws the more he is impressed with his ignorance and the failure of science to fathom the complexity of Nature. Much of the misunderstanding of invention and its difficulties is due to this method of teaching, and will endure so long as this method is maintained. If it were possible to teach physical and chemical science historically, much could be done to counteract this injurious effect.

The experimental laboratory tends to modify the dogmatic teaching of the schools because the student there finds out for himself how exceedingly difficult it is to prove experimentally some of the simplest of the physical facts which he learned in the lecture room, and he thus gains a first-hand knowledge of the order of accuracy of physical measurements and of the difficulty in attaining it. Science taught historically would be infinitely more interesting and instructive, but time is the great obstacle. In a recent leading article in the *Times* the teaching of the history of science was advocated as a subject for general culture, and comment was also made on similar recommendations emanating from an American writer. Such a study would introduce a better understanding of the science of invention among those who have not given particular attention to it, and the inventor might come to be regarded as a necessary and valuable cog in the wheel of industrial progress, and not, as he is too often regarded, as a freak. After all, the inventor is simply trying to make things simpler and easier and safer for his fellow-men, and he is succeeding beyond belief. Surely that object is worthy of recognition and encouragement.

A second possible remedy to encourage invention and minimise its difficulties is by means of legislation. I hesitate to enlarge on this point because the question of patents is a controversial one among scientists, and between inventors and the outside public, but it seems to me anomalous that a man who makes an epoch-making invention which is going to revolutionise an industry and add millions to the wealth of the nation, receives exactly the same degree of protection for his invention as the man who invents a new kind of shirt button. In the first case the invention will take years to develop, and may cost thousands of pounds in the process, and by the time it reaches the productive stage the patent may have expired. In the case of the shirt button, a term which I use figuratively, there are no difficulties to overcome, practically no expense, no loss of time, and a clear sixteen years' trade monopoly.

I know that a patent is granted only for a new method of manufacture, which has to be described in the patent specification so that any one skilled in the art may put it into practice at once. In simple inventions which form the subjects of the great majority of patents this is actually the case, but there are undoubtedly cases where what appears to the inventor to be a practical scheme, and was honestly described by him as such, proves afterwards to be difficult to put into effect on account of technical difficulties which he had not foreseen, and the remedy for which may not be patentable. Such obstacles and their remedy cannot be recorded in the patent, because they have not been encountered when the specification is written. Under our present system a period of nine months is allowed between filing the provisional and complete specifications, which period, while ample in the case of most inventions, is inadequate for full investigation of the really great inventions, and it is to this difference between major and minor inventions that I wish to direct attention.

In America it is possible for an applicant for a patent, by filing periodical amendments of his specification, to keep the application pending in the Patent Office for a number of years, during which he can be developing the invention and adding to the specification any further explanations which may be called for in the light of the experience gained. Then when the patent is eventually issued, it runs for seventeen years from the date of issue, whereas a British patent dates from the date of application. In addition to this, an American patentee, on any question of priority of invention, is allowed to produce any evidence that may be available to show conception of the invention up to not more than two years anterior to the date of his original application. In this way an American inventor can spend several useful years perfecting his invention before his patent is granted, while the British inventor has often to watch the most useful years of his patent being eaten up in unproductive development.

I admit that the American system has drawbacks from the point of view of an industry, but it has certain undoubted advantages, and I suggest that the British system does not meet the needs of great inventions, between which and the ordinary minor inventions there ought in my opinion to be some discrimination. Merely as a suggestion, I see a possible solution in an extension of our present system of granting Patents of Addition, that is, a patent for an improvement on a prior patented invention, the Patent of Addition being granted during the lifetime of the original patent and running conterminously. If a Patent of Addition could be granted to an inventor in approved cases on production of evidence of genuine difficulties encountered and successfully overcome, these difficulties and their remedy to be fully described in the patent for the guidance of the industry, and if this Patent of Addition could be made valid for a definite term of years, one of the main fears of a patentee would be overcome.

It will be noticed that in this last suggestion I have stipulated that the specification of a Patent of Addition such as I suggest should contain not only a description of the finished invention but also of all the difficulties encountered in its production and the steps taken to surmount them. In fact, it is mainly for this reason that I make the suggestion at all. I am trying to devise a means to prevent future inventors and industry from being handicapped in a way that has been all too common in the past. I have already touched on what must be the large volume of valuable scientific information that has been lost through lack of records of past difficulties. Patent specifications are in many cases the sole record of inventions, yet in the cases of the type I have mentioned they tell us nothing of the difficulties, simply because the specification is written before the difficulties are encountered. I therefore suggest that if any additional protection be given to a patentee in virtue of work done in converting his invention into a practical mechanism in face of unsuspected obstacles, the grant should be absolutely conditional on his placing on public record for the guidance of others a complete history of his efforts so that no one may have to contend with the same troubles again.

I have one more suggestion to offer. On this question of assisting future inventors by increasing the store of knowledge at their disposal, I see a possible sphere of usefulness for the British Association and kindred institutions by encouraging the great inventors of to-day to place on record and publish through the medium of the Association or institution an account, even a brief one, of the main historical features of their inventions. If considerations of patents or of personal diffidence make it undesirable to publish these records at the time they are written, that need not impede the scheme, as publication could be made afterwards at a more convenient time or, say, after the inventor's death. The main thing is to have some authentic record from the inventor or discoverer himself recording the origin, growth, and development of his idea, the difficulties that beset him, and the manner in which they were overcome.

Nor do I think we should stop there. In my opinion too much attention has been paid in the past to success and too little to honest failure. It is one of our human frailties to look with something of contempt on the man who has failed to reach his goal, but this is not the attitude of the great minds, nor should it be the attitude of modern science. On one occasion Lord Kelvin was shown a report by a professor on a research carried out by a research scholar, in which the professor had made some rather contemptuous remarks on the results attained because these results were mainly negative. Kelvin was highly indignant. All he looked to was the fact that the young scholar had done his best on a subject which merited investigation and in face of undoubted difficulties, and it amazed him that any scientist should speak slightingly of the results, simply because they were negative, when the real thing of value was the earnest and diligent search after truth.

If, therefore, my suggestion be adopted by the

British Association, would it not be in the best interests of science to remember the failures as well as the successes, and to encourage all serious workers in important fields of research to furnish in the common cause a record of their work, even when their aim has not been achieved, giving a faithful account of all the difficulties and all the efforts made to surmount them? Who knows but that many of the so-called failures of yesterday may only be waiting for other hands to-day to carry them on to a greater success than the world has yet known? Left to themselves they will lie in oblivion, yet, for all we know, two of them may fit together and provide the answer to one more of the riddles of the universe.

Knowledge forms the working tools of science, and my proposal is in no way aimed at giving the scientific workers of to-morrow an easy task. They will probably have a far more difficult task than ours, but I do not think it fair to condemn them to spend part of their time in a preliminary and possibly fruitless search for tools which we have forged and hidden.

"As one lamp lights another, nor grows less," science of to-day will partly fail in its clear duty if it fails to pass on to to-morrow any of the knowledge which it has been privileged to acquire, or if it forgets that it is for to-morrow, rather than to-day, to assess the true value of to-day's success and failure.

Obituary.

PROF. W. EINTHOVEN, FOR. MEM. R.S.

PROF. WILLEM EINTHOVEN, whose death on Sept. 28 at the age of sixty-eight years has been announced, was one of the foremost of modern physiologists. For nearly forty-two years he has been professor of physiology at Leyden, Holland, being invited to succeed Heynsius in November 1885, and actually taking up his duties, after passing his final State examination in medicine, on Feb. 24, 1886. For the first twenty years of his office the chair of physiology was combined with that of histology.

Einthoven was born in Semarang, in the Dutch Indies, where his father was in medical practice. After his father's death, his mother with her six children settled in Utrecht, where Einthoven was educated at school and as a medical student in the University. He spoke with gratitude of his teachers there, particularly of the physicist Buys Ballot, and then of the anatomist Koster, the ophthalmologist Snellen, and the physiologist Donders. His first scientific investigation was carried out with Koster on the mechanism of the elbow joint; he assisted Snellen both in private practice and in the clinic; and in 1885 his dissertation, "Über Stereoskopie durch Farbendifferenz," was approved by Donders for the degree of doctor of medicine.

Einthoven's investigations cover a wide range, but they are all notable for the same characteristic —the mastery of physical technique which they show. Einthoven, in spite of his medical training and his office, was essentially a physicist, and the extraordinary value of his contributions to physiology, and therewith indirectly to medicine, emphasises the way in which an aptitude—in Einthoven's case a genius—for physical methods can aid in the solution of physiological problems. His papers are published in the *Nederlandsch Tijdschrift voor Geneeskunde*, *Archives Néerlandaises*, *Archives Internationales de Physiologie*, *Brain*, *Quarterly Journal of Experimental Physiology*, *Annalen der Physik*, and especially in *Pflüger's Archiv für die gesammte Physiologie*. He wrote an article in Heymann's "Handbuch der Laryngologie und Rhinologie," and edited ten volumes of "Onderzoekingen Physiologisch Laboratorium, Leiden."

Einthoven's name is connected chiefly with the string galvanometer and the electrocardiogram. The potential differences involved in the electrical phenomena of the heart beat are fractions of a millivolt and occur in thousandths of a second. The problem of recording these small and fleeting changes, previously attempted without complete success with the capillary electrometer, was solved in 1903 by the invention of the string galvanometer; to-day there are hundreds, probably thousands, of these instruments all over the world, and they have been applied not only to their original purpose of registering the action current of the heart (and incidentally of muscles, nerves, and retina), but also to such diverse uses as finding the velocities of shells, receiving and recording wireless signals, and locating enemy guns; and I believe it is true that Einthoven never received any material profit from his invention. In 1909 he published the first complete description of the instrument, while in the last few years, employing fibres of almost ultra-microscopic size working in a high vacuum, he has succeeded, in collaboration with his son, an electrical engineer, in recording potential changes of frequencies of the order of 100,000 per second. It may be mentioned also that recently, by means of fibres of extreme thinness, he was able to register directly, and with very little distortion, sound waves of more than 10,000 vibrations per second.

Einthoven's most important work, for which he was awarded the Nobel Prize in 1924, was his discovery of the mechanism, of the manner of production, of the electrocardiogram and its characteristic waves. In many directions the diagnosis of maladies of the heart has improved in recent times, but the greatest single advance was made by Einthoven in applying the string galvanometer to the investigation of the electrical phenomena of the normal heart-beat. This work was followed up, particularly by Sir Thomas Lewis in London, and has resulted in a clearer understanding of the cause of some common disorders of the heart, and in improvement in their treatment.