character; to be undertaken early enough to be of some value in comprehending, if not controlling the situation. We have seen that the blight might have been kept out of the country in the first place by inspection, or, once in, that it might have been destroyed, or at least checked, before it had gotten widely distributed. But instead it was permitted to enter, and to spread for many years without scientific notice, and for several more years without any organized attempt to control it, or even to study it seriously. Are we doing any better now with reference to the future?

GENETICS

While perhaps not having the same direct bearing upon pathological problems, still it may be worth pointing out that fungi appear to offer one of the simplest and easiest points of attack on the general problems of evolution, such as mutation, variation, and inheritance; in fact, the various problems of genetics. Here we have organisms comparatively simple in structure, either asexual or at least not complicated by possible hybridization and capable of rapid reproduction and cultivation under controlled conditions.

Coming finally to questions of prevention and control of diseases caused by parasites, it is only stating a truism to say that whatever success may be attained in this direction must depend chiefly upon the completeness of our knowledge of the parasite in all its aspects and relations.

Finally, mycologists, pathologists and all real scientists are searchers after truth. This implies not only large opportunities, but also obligations. "Noblesse oblige" is particularly applicable to the scientist. In these days of storm and stress it is, if possible, more important than ever that we should live up to the highest ideals of truth, and make individual and united effort to establish the universal reign of justice, peace, and brotherly love among mankind.

An excellent example of what the scientist should strive to be in all his human relations has been given us by Professor Charles E. Bessey, the distinguished botanist and beloved teacher, whom death has so lately taken from us. He not only sought truth and taught truth, but lived it, making the world not only wiser and richer, but better. May we all leave as noble a record when called to lay life's burdens down.

C. L. Shear

EDWARD WESTON'S INVENTIONS

The pioneer work of Dr. Edward Weston is not easy to describe in a few words. His restless inventive activity has been spread over so many subjects, has intertwined so many interlocking problems, that in order to understand its full value, it would be necessary to enter into the intimate study of the various obstacles which opposed themselves to the development of several leading industries which he helped to create: the electro-deposition of metals, the electrolytic refining of copper, the construction of electric generators and motors, the electric illumination by arc- and by incandescent-light, and the manufacture of electrical measuring instruments. An impressive list of subjects, but in every one of these branches of industry, Weston was a leader, and it was only after he had shown the way in an unmistakable manner, that the art was able to make further progress and develop to its present-day magnitude.

But why was Weston able to overcome difficulties which seemed almost unsurmountable to his predecessors and coworkers in the art?

The answer is simple: He introduced in most of his physical problems a chemical point of view—a chemical point of view of his own; a point of view which was not satisfied with general statements, but which went to the bottom of things. He did not get his chemistry wholesale as it is dispensed in some of our hot-bed-method educational institutions. He had to get at his facts piecemeal, one by one, adjust them, ponder over them—collect his facts with much effort and discrimination; he did not acquire his knowledge merely to pass examinations, but to use it for accumulating further knowledge.

It seems rather fortunate for him that one of the first employments he got in New York was with a chemical concern which made photographic chemicals. This was the time of the wet-plate, when photographers made their own collodion, their own silver bath, their own paper. Whoever went through those delicate operations knew the difficulties, the uncertainties which were caused by small variations in the composition of chemicals or in the way of using them. Photochemistry is excellent experience for any young chemist who is disposed to generalize too much all chemical reactions by mere chemical equations. Whoever has to deal with those delicate chemical phenomena, which occur in the photographic image, knows that many unforeseen facts can not easily be accounted for by our self-satisfying but often superficial generalizations of the text-books.

Weston's tendency to observe small details in chemical or physical phenomena led him to improve the art of nickel-plating and electrolytic deposition of metals to a point where it entered a new era. When he undertook the study of the difficulties in this art, he took nothing for granted, but by close observation he succeeded in devising methods not only of improving the physical texture of the deposit, but for increasing enormously the speed and regularity with which the operations could be carried out; all these improvements are now embodied in the art of electro-typing, nickel-, gold- and silver-plating.

At this time, attempts had already been made for the commercial refining of copper by means of the electric current. But this subject was then in its first clumsy period, far removed from the importance it has attained now amongst modern American industries. Here again, Weston brought order and method, where chaos reigned. His careful laboratory observations, harnessed by his keen reasoning intellect, established the true principles on which economic, industrial, electrolytic-copper-refining could be carried out. Professor James Douglass[1] referred to this fact in a recent address:

> I suppose I may claim the merit of making in this country the first electrolytic copper by the ton, but the merit is really due him (Weston) who in this and innumerable other instances, has concealed his interested work for his favorite science and pursuits under a thick veil of modesty and generosity.

The whole problem of electrolytic refining, when Weston took it up, was hampered by many wrong conceptions. One of them was that a given horsepower could only deposit a maximum weight of copper regardless of cathode- or anode-surface. This fallacious opinion was considered almost an axiom until Weston showed clearly the way of increasing the amount of copper deposited per electrical horsepower, by increasing the number and size of vats and their electrodes, connecting his vats in a combination of series and multiple, the only limit to this arrangement being the added interest of capital and depreciation on the increased cost of more vats and anodes, in relation to the cost of horsepower for driving the dynamos.

The electro-deposition of metals forced Weston into the study of the construction of dynamos. Until then, the electric cur-

[1] Commencement address, Colorado School of Mines, *Metallurgical and Chemical Engineering*, Vol. XI., No. 7, July, 1913, page 377.

rent used for nickel-, silver- and gold-plating, as well as for electro-typing, was obtained from chemical batteries. Weston says that it was almost a hopeless task to wean electroplaters from these cells to which they had become tied by long experience and on the more or less skillful use of which they based many of the secrets of their trade.

If the dynamo as a cheap and reliable source of electric current was advantageous for nickel-plating, it became an absolutely indispensable factor for electrolytic copper refining. At that time, the dynamo was still at its very beginning—some sort of an electrical curiosity. It had been invented many years before by a Norwegian, Soren Hyjorth, who filed his first British patent as far back as 1855. Similar machines had been built both in Europe and America, but little or no improvement was made until Weston, in his own thorough way, undertook the careful study of the various factors relating to dynamo efficiency.

In 1876, Weston filed his first United States patent on rational dynamo construction, which was soon followed by many others, and before long he had inaugurated such profound ameliorations in the design of dynamos that he increased their efficiency in the most astonishing manner. Heretofore, the dynamos which had been constructed showed an efficiency not reaching over fifteen to forty per cent., gross electrical efficiency, but the new dynamos constructed after Weston's principles increased this to the unexpected efficiency of ninety-five per cent., and a commercial efficiency of eighty-five to ninety per cent. He thus marked an epoch in physical science by constructing the first industrial machine which was able to change one form of energy, motion, into another, electricity, with a hitherto unparalleled small loss. As the improvements in dynamos depend almost exclusively on physical considerations, and have little relation with the field of chemistry, I shall dispense with going further into this matter. But I should be permitted to point out that the first practical application of electrical power transmission for factory purposes in this country, was first utilized in Weston's factory; the success of this installation induced the Clark Thread Works, also located in Newark, to adopt this method of power transmission for some special work; a method which now has become so universal. For this purpose, Weston had to invent new devices for starting, and for controlling, as well as for preventing injuries to motors by overload.

In Weston's factory also the electric arc was used for the first time in the United States for general illumination.

In fact, from 1875 to 1886, Weston was very energetically engaged with the development of both systems of arc- and incandescent-illumination by electricity. We see him start the manufacture of arc-light-carbons according to methods invented by him, and thus he became the founder of another new industry in America. He continued this branch of manufacture until 1884, at which epoch this part of the business was transferred to another company, which has made a specialty of this class of products, and has developed it into a very important industry. Here again, Weston introduced chemical methods and chemical points of view. Amongst the many objections which the public had against the electrical arc was the bluish color of its light. Women especially complained that the blue-violet light did not bring out their complexion to the best advantage. Weston first tried to use shorter arcs which gave a whiter light, but this was only a partial remedy. He soon found a more radical and more complete cure by the introduction of vapors of metals or metallic salts or oxide in the arc itself, so as to modify at will the color of the light, and thus he became the inventor of the so-called "flaming arc." It is noteworthy that it took about twenty years before electricians and illuminating engineers became so convinced of the advantages of the flaming arc, that it had to be "reinvented" during these late years, and now it is considered the most efficient system of arc-illumination.

In relation to this invention, it is interesting to quote the following extract of the specifications from his United States Patent 210,380, filed November 4, 1878:

This rod or stick may be made of various materials, as, for example, of so-called "lime glass," or of compounds of infusible earths and metallic salts, silicates, double silicates, mixtures of the silicates with other salts of metals, fluorides, double fluorides, mixtures of the double fluorides, fusible oxides, or combinations of the fusible oxides with the silicates—the requirements, so far as the material is concerned, being that it shall be capable of volatilization when placed on the outer side of the electrode to which it is attached, and that its vapor shall be of greater conductivity than the vapor or particles of carbon disengaged from the carbon electrodes. The foreign material added to the carbon may be incorporated into the electrode by being mixed with the carbon of which the electrode is composed, or it may be introduced into a tubular carbon; but I have found it best to place it in a groove formed longitudinally in the side of the electrode, as shown.

In his endeavors to make the electric incandescent lamp an economic possibility, we see him introduce over and over again, chemical methods and chemical considerations. He first tried to utilize platinum and iridium, and their alloys, which he fused in a specially constructed electric furnace, devised by him, antedating the furnace described by Siemens. This is probably the first electrical furnace, if you will except the furnace which Hare used in his laboratory in Philadelphia.

But these platinum metals showed serious defects aside from their high cost, and by that time, Weston had become so familiar with the properties of good carbon that like other inventors, he became convinced that the ultimate success lay in that direction.

And now we see him join in that race of rivalry among inventors who all engaged their efforts in search of the real practical incandescent lamp. Among this group of men, the names of Edison here in the United States and that of Swan in England, have been best known. To go in the details of this struggle for improvement is entirely outside of the scope of this short review.

Edison succeeded in making incandescent lamp filaments by carbonizing selected strips of bamboo. But even a carbon made of this unusually compact and uniform material was far from being sufficiently regular and homogeneous. Indeed, all the then known forms of carbon conductors had the fatal defect of a structural lack of homogeneity. On account of this, the resistance varied at certain sections of the filament, and at these very spots, the temperature rose to such an extent that it caused rapid destruction of the filament; this is somewhat similar to the chain which is just as strong as its weakest link.

These irregularities in the filament reduced enormously the term of service of any incandescent lamp. Weston tried to solve this difficulty by means of his chemical knowledge. He remembered that as a boy, when he went to visit the gas works to obtain some hard carbon for his Bunsen cell, this carbon was collected from those parts of the gas retort which had been the hottest, and where the hydrocarbon gas had undergone dissociation, leaving a dense deposit of coherent carbon.

In this chemical phenomena of dissociation at high temperature, he perceived a chemical means for "self-curing" any weak spots in the filament of his lamp. The remedy was as ingenious as simple. In preparing his filament, he passed the current through it while the filament was placed in an atmosphere of hydrocarbon gas, so that in every spot where the temperature rose highest on account of greater resistance, brought about by the irregular structure of the material, the hydrocarbon gas was dissociated and carbon was deposited automatically until the defect was cured, with the result that the filament acquired the same electric resistance over its whole length. But this invention, however brilliant, did not limit his efforts. He had become imbued with the idea that the ideal filament would be an absolutely structureless, homogeneous filament, with exactly the same composition and the same section throughout its whole length. He reasoned that such a filament could not be obtained from any natural products, neither from paper nor bamboo, but that it had to be produced artificially in the laboratory from an absolutely uniform, structureless chemical substance. After various unsuccessful attempts, he finally secured this result by applying his old knowledge of the days when he used to make collodion. He produced a homogeneous, structureless transparent film of nitrocellulose by evaporating a solution of this material in suitable solvents. As he could not carbonize this film on account of the well-known explosive properties of so-called "gun-cotton," he obviated this difficulty by eliminating the nitrate group of the molecule of cellulose-nitrate by means of ammonium-sulphydrate. This gave him a flexible, transparent sheet, very similar in appearance to gelatine; this material he called "Tamidine." Such films could be cut automatically with utmost exactitude, producing filaments of uniform section, which then could be submitted to carbonization, before fastening them to the inside of the glass bulb of the incandescent lamp.

It is interesting to note here that the modern Tungsten lamp, in all its perfection, made of ductile tungsten, is after all, the fullest development of the principle of an entirely structureless homogeneous chemical filament. The Tungsten-filament can stand much higher temperatures than carbon and this property gives it higher lighting efficiency, but the former tungsten filaments of a few years ago, which had a granular structure, had the same defect as the earlier carbon lamps, namely, a non-homogeneous texture and correspondent short life.

While Weston was wrestling with all his electrical problems, and more particularly with the construction of dynamos and motors, he was handicapped continuously by the clumsy and time-consuming methods of electrical measurements which were the best existing at that period. Up till then, these methods had been found good enough for physical laboratories, where the lack of accuracy did not result disastrously in hitting the pocket of the manufacturer, or where time—abundant time for observations and calculations—was always available. But progress in the electrical industries lagged behind the delay and uncertainties caused by electrical measurements. So Weston was compelled to invent for his own use a set of practical electrical measuring instruments. It was not long before some of his friends wanted very badly duplicates of his instruments; before he knew it, he was giving considerable attention to the construction and further development of these instruments. Just about this time, the electric light and dynamo construction enterprise entered into a new period, where they began to develop in large unwieldy commercial organizations, requiring public franchises and which had to be backed by vast amounts of new capital. In its boards of directors, business men, or financial men and corporation lawyers, became paramount factors and eclipsed in importance the technical or scientific men, who, in earlier days, had almost exclusively contributed to the development of the art.

Following his natural inclinations, Weston soon abandoned his former business connections in order to entrench himself in a field where individuality, science and technology were of almost unique importance, and which he could develop without the necessity of incurring financial obligations beyond what he could master personally. Thus he dropped his connections with the electric light and dynamo enterprises, and we see him now, heart and soul, in another new industry which he created—the art of making accurate, trustworthy and easy-to-use electrical measuring instruments. Did he foresee at that time that this art would attain the magnitude to which he has brought it to-day? Did he dream that his early modest shop was to develop into one of the most remarkably equipped factories in the world; an institution which seems the embodiment of what industrial enterprises may look like in future days, when scientific and liberal-minded management will have become the rule instead of the exception?

In his factory in Newark, Weston seems to have instilled some of his own reliability and accuracy in the minds of the men and women he employs.

In fact, has it occurred to you that even a man with the widest knowledge and the highest intelligence, who is not scrupulously reliable and careful, who is not the soul of honesty personified, could not make honest and trustworthy measuring instruments nor create reliable measuring methods?

What Stas did in chemistry for atomic weights, Weston did for electrical measuring; he created radically new methods of measurement, and introduced an accuracy undreamt of heretofore. Do not forget that his problems were not easy ones. When the British government offered a prize of $100,000 for the nearest perfect chronometer, the problem of a reliable chronometer involved considerably less difficulties and fewer disturbing factors than any of those encountered in devising and making electrical measuring instruments. But here again, even at the risk of monotonous repeating, I want to impress you with the fact that the success of the methods of Weston was found in almost every case in the application of chemical means by which he tried to solve his difficulties.

When he took up this subject, the scientists, as far back as 1884, accepted implicitly the belief that the definition of a metal and a non-metal resides in a physical distinction; that for metals the electrical resistance increased with temperature, while for non-metals, their resistance decreased with temperature. This was another one of those readily accepted axioms which nobody dared to refute or contest because they were repeated in respectable textbooks. And yet, this unfortunate behavior of metals was the greatest drawback in the construction of accurate measuring instruments. Indeed, on account of the so-called temperature coefficients, all measurements had to be corrected by calculation to the temperature at which the observation was made. This seems easy enough, but it was time-consuming and often it is more difficult to make rapid accurate observation of the temperature of the instrument itself. First of all, the thermometers are not accurate, and have to be corrected periodically, and furthermore, it is not an easy matter to determine rapidly the temperature of a coil or an instrument. Moreover, by the very passage of the electric current, fluctuating changes in temperature are liable to occur, which would make the observations totally incorrect. All this led to hesitation and slowness in measurements. Weston wanted to correct this defect, but he was told that the very laws of physics were against his attempts. Before he was through with his work, he had to correct some of our conceptions of the laws of physics; now let us see how he did it:

Weston knew that the favorite metal for resistances was so-called German-silver. Strange to say, he was the first one to point out to the Germans themselves that "German-silver" is a word which covers a multitude of sins, and that the composition of German-silver varies considerably according to its source of supply. The result was that he soon proposed a standard-copper-and-nickel-and-zinc-alloy containing about 30 per cent. of nickel, and which had a resistance of almost twice that of ordinary German-silver and a much lower temperature coefficient. Not satisfied with this, he took up the systematic study of a large number of alloys. The first batch which he undertook to study amounted to more than three hundred different alloys. Since that time, he has considerably increased this number, and is still busy at it. Every one of these alloys he made himself in his laboratory, starting from pure materials, and controlling the whole operation from the making of the alloy to the drawing of wires of determined size. By long and repeated observations, on which many years have been consumed, he was able to determine the electrical behavior of each one of these alloys at different temperatures. After awhile, he began to observe remarkable properties in some manganese alloys he compounded. He managed to produce an alloy which had sixty-five times the resistance of copper. But getting bolder and bolder, he strove to obtain an alloy which had no temperature-coefficient whatever. He not only succeeded in doing this, but finally produced several alloys which had a *negative* temperature-coefficient. In other terms, their resistance, instead of increasing with rise of temperature, decreased with increasing temperature. He also showed that the resistance of these alloys depended not only on their composition, but on certain treatments which they undergo, for instance, preliminary heating. And since that day, the physicists have had to bury their favorite definition of metals and non-metals. The present generation can hardly realize what this discovery meant at that time. I could not better illustrate this than by reminding you of the fact that in 1892, at the meeting of the British Association for the Advancement of Science, where it was urged to found an institution similar to the Deutsche Reichsanstalt, Lord Kelvin said in his speech:

The grand success of the Physikalishe-Reichsanstalt may be judged to some extent here by the record put before us by Professor von Helmholtz. Such a proved success may be followed by a country like England with very great profit indeed. One thing Professor von Helmholtz did not mention was the discovery by the Anstalt of a metal whose temperature coefficient with respect to electrical resistance is practically nil; that is to say, a metal whose electrical resistance does not change with temperature. This is just the thing we have been waiting for for twenty or thirty years. It is of the greatest importance in scientific experiments, and also in connection with the measuring instruments of practical electric lighting, to have a metal whose electrical resistance does not vary with temperature; and after what has been done, what is now wanted is to find a metal of good quality and substance whose resistance shall diminish as temperature is increased. We want something to produce the opposite effect to that with which we are familiar. The resistance of carbon diminishes as temperature increases; but its behavior is not very constant. Until within the last year or so nothing different was known of metals from the fact that elevation of temperature had the effect of increasing resistance. The Physikalische-Anstalt had not been in existence two years before this valuable metal was discovered.

Then followed this colloquy:

PROFESSOR VON HELMHOLTZ. The discovery of a metal whose resistance diminished with temperature was made by an American engineer.

PROFESSOR AYRTON. By an Englishman—Weston.

LORD KELVIN: That serves but to intensify the position I wished to take, whether the discovery was made by an Anglo-American, an American-Englishman, or an Englishman in America. It is not gratifying to national pride to know that these discoveries were not made in this country.

The misinformation of Kelvin was due to the fact that after the Weston patents had been published, his alloy was called *manganin* in Germany, and a good deal of publicity had been given to its properties with scant reference to its real inventor, an occurrence which, unfortunately, is not infrequent not only among commercial interests but in technical or scientific circles as well.

No less important was the invention of the Weston cell, which in 1908, by the international commission for the establishment of standards of electrical measurements, has become the accepted universal practical standard for electromotive force. Here again, this physical standard was obtained by chemical means.

Until Weston researches on standard cells, the Clark cell had been the standby of the electricians and electrochemists of the world, as the standard of electromotive force. It required the keen analysis of a Weston to ascertain all the defects of this cell and to indicate the cause of them. Later, he drew from his careful chemical observations, the means to construct a cell which was free from the defects of its predecessors—a cell that had no temperature-coefficient and had no "lag."

He detected that the choice of a saturated solution of sulphate of zinc in which was suspended an excess of crystals of this salt, was an unsuitable electrolyte and one of the principal causes why the indications of the Clark cell varied considerably with the temperature. It is true that this could be obviated by placing the cell in a bath of constant temperature. But this involves new difficulties due to the proper determination of the real temperature. Furthermore, there is always a "lag" in the indications due to the fact that at varying temperatures it requires a certain time before the solution of the salt has adjusted itself to the coefficient of saturation for each newly acquired temperature. By studying the comparative behavior of various salts at different temperatures, he came to the conclusion that cadmium-sulphate is more appropriate and this was one of the several important improvements he introduced in the construction of a new standard of electromotive force.

Dr. Weston assures me that he has succeeded in making his alloys to show only a change of one millionth for a variation of one degree centigrade. The metallic alloys he discovered are used practically in nearly all kinds of electrical measuring instruments throughout the world. Weston instruments and Weston methods are now found in all properly equipped laboratories and electrochemical establishments of the world. On a recent trip to Japan, I saw them in the University of Tokio, as well as in the Japanese war museum, where their battered remains attested that the Russians used them on their captured battleships. I have worked in several laboratories in Europe equipped with instruments said to be "just as good" as those of Weston, but in most instances, they were imitations of Weston instruments and it was significant that they kept at least one Weston instrument to be used to correct and compare their national product.

Like many inventors, Weston has been engaged extensively in patent litigation. To uphold some of his rights, he had to spend on one set of patents nearly $400,000, a large amount of money for anybody, but as he told me, he begrudges less the money it cost him than all his valuable time it required—a greater loss to an inventor thus distracted from his work. What is worse, most of this litigation was so long-winded that when finally he established his rights, has patents had aged so much that they had lost, in the meantime, most, if not all, of their seventeen years' terms of limited existence. And here I want to point out something very significant. In the early periods of his work, between 1873 and 1886, Weston took out over three hundred patents. Since then, he has taken considerably less, and of late, he has taken out very few patents—after he became wiser to the tricks of patent infringers. Formerly, as soon as he published his discoveries or his inventions, in his patent specifications, he was so much troubled with patent pirates that instead of being able to attend to the development of his inventions, he was occupied in patent litigation. As an act of self-preservation, he has had to adopt new tactics. He now keeps his work secret as long as possible, and in the meantime, spends his money for tools and equipment for manufacturing his inventions. In some instances, this preparation takes several years. Then by the time he sends any new type of instruments into the world, and others start copying, he has already in preparation so many further improvements that pretty soon the next instrument comes out which supersedes the prior edition. He had to utilize these tactics since he found how impractical it was to rely on his patent rights for protection. That inventors should have to proceed in this way is certainly not a recommendation for our patent system; it kills the very purpose for which our fundamental patent law was created, namely, *the prompt publication of new and useful inventions.*

L. H. Baekeland

NOTE ON THE ORBITS OF FREELY FALLING BODIES

In No. 975, Vol. XXXVIII., N.S. (September 5, 1913), of this journal, I gave a semi-popular account of an investigation on "The orbits of freely falling bodies" published in Nos. 651, 652 of the *Astronomical Journal*, August 4, 1913. Soon after the appearance of these papers several correspondents challenged the result I derived for the meridional deviation of the falling body, all of them maintaining that this deviation is toward the equator instead of away from it, as I had concluded. Being preoccupied with affairs somewhat remote from the fields of mathematical physics, I have not been able to give this apparent discrepancy adequate attention, although its origin was indicated in an informal communication to the Philosophical Society of Washington in April, 1914.

In the meantime, two noteworthy contributions to the already extensive literature of this subject have been published by Professor F. R. Moulton[1] and by Professor Wm. H. Roever,[2] respectively. These contributions are not only important for originality of methods and for painstaking attention, especially to mathematical details, but they may seem to the casual reader to have exhausted the subject by demonstrating in the most approved mathematical fashion of our day that the postulates

[1] "The Deviations of Falling Bodies," *Annals of Mathematics*, Second Series, Vol. 15, No. 4, pp. 184–94, June, 1914. This investigation is specially remarkable in that but one kind of latitude is used. It is likewise remarkable in that no explicit statement is made as to which of the various latitudes (astronomic, geocentric, geodetic or reduced) is used.

[2] "Deviations of Falling Bodies," *Astronomical Journal*, Nos. 670–672, pp. 177–201, January 22, 1915.