HOW PROGRESS IN SCIENCE IS DEPENDENT UPON TECHNICAL MEASURES AND MANUFACTURERS

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It has been frequently said that the modern developments of science are gradually destroying many of the poetical elements of our daily lives, and in consequence are reducing us to a dead level of prosaic commonplace, in which existence is scarcely worth having. The first part of this rather sweeping assertion is perfectly true, but, the second is absolutely untrue.

Science has certainly destroyed, and is destroying, many of the poetic fancies which made a part of daily life. Perhaps one of the prettiest legends in Natural History is that of the Paper Nautilus, with which so much poetry is associated. All remember Pope's lines, "Learn of the little Nautilus to sail," and many people are quite incredulous when told there is just as much likelihood of seeing a mermaid curl her hair as to see a nautilus under sail. It is, therefore, partially true that science does destroy romance. But, though she destroys, she creates, and she gives infinitely more than she takes away, as shown in the many late discoveries which have transformed the whole system of civilized life.

Let us take one analogy of shattering the legend of the nautilus. Nature produces a marine animal which really does sail, and does not appear to be able to do anything else. I refer to the Velella, a type of jelly-fish, remarkable for having a sort of skeleton, if it may be so called, consisting of two very thin and horny plates giving almost an exact imitation, or perhaps I had better say, precursor, of a raft propelled by a sail. These are often found after being driven in by a rough sea, in quantities, on the shore of Tenby, so well described by Gosse. They are called by the natives "Sea-butterflies" and by sailors "Sally-man," i. e., Salleeman.

No doubt the first idea of locomotion in water, independently of swimming, was the raft, and the development was from it to the boat. A Kruman's canoe into the *Leviathan,* or a modern ironclad vessel, is simply a matter of time. We well know the use of a tree-trunk in the water, how we added a second to prevent turning over from our weight, then spacing them and cross-bar nailing; this to avoid upsetting of the raft. And this still survives in that curious mixture of the raft and canoe, the outrigger boat of the Polynesians, which no gale of wind can upset. It may be torn to pieces by the storm, but nothing can capsize it as long as it holds together. No doubt this construction was based, even then, on the theory of displacement.

Nature's teachings have had their bearings in almost everything we do or make. We know air expands when heated. Liquids, metals, etc., do the same, and we take advantage of this principle in the formation of the thermometer, or "heat-measurer." This expansion by heat is so powerful in iron, that it is utilized in many ways. An example, wheel-making, and the placing of tires. In buildings where iron is used, as in beams and bridges, it is necessary to make allowance at both ends, so as to permit the iron to expand on a hot day and contract on a cool day. Buildings formed of stone and iron were once thought to be safe in the case of fire. Today, they are known to be just the contrary, the stone flying with the heat, and the iron expanding. Here we have learnt to study the values of building stone by the advance of geology, the metallurgical researches of alloys, steel, value of X-rays for the detection of stress, faults which are not visible to the naked eye. When we add that instrument of precision, the miscroscope, we soon learn there is hardly any industry or science branch that can be understood without it. It may seem a long way from the fossil-beds of the Paleontologist to the oil-wells of motor power; from the depths of the ocean to the fish-foods, to the knowledge in hydrographic work by these small organisms, that we are on their best feeding grounds for certain types, that the ocean bed has changed, to their use in buildings. Such is the case, for diatomite is used in nearly every branch, from the making of fireproof brick, chemical filtering, refrigeration, retaining heat, tooth-powders, cleaning, scouring, drying, to making explosives, and giving a peaceful study of the beauties of the Creator's work, under microscopic examination, to the mathematical arrangement of the well-known "Group-slides." From their wonderful structure the testing of object-lenses has required more perfection of glass-making, methods of mounting, more accurate knowledge of the management of the instruments used and their mathematical principles. Optics, lighting, the use of better media with accurate index of refraction higher than balsam, etc., to the use of our new synthetic resins from the study of coal-tar products.

Notable amongst these are phenolic bodies and aldehydes, of which phenol and formaldehyde are, respectively, the best known, through the work of Bayer, in 1872. Not till 1909 did an American chemist, Baekeland, produce a resin of great value, and superior in quality. Indeed, this is one of the wonders of chemistry, that such a product could be made from such raw materials and become a universal utility. Over a hundred years ago, Sir Robert Peel, the great English statesman and financier, said that the future belonged to the nation which could produce the most coal. A German writer in 1910 said, "The future belongs to the nation which makes the best use of its coal resources." As Professor Goode said in a lecture before the Sigma Delta Epsilon group at the University of Chicago: "This city is in the iron and coal belt, with its water-ways, its rail-centre, its industrial opportunities, its institutions of learning, *it must* become the City of the Future." To this I would add coke, for in its making we get the by-products from which thousands of new products indispensable to present day standards of living are produced.

To whom must we turn? To those who are not only engaged in educational work but also to all manufacturers who are vitally concerned with the question of physics and technical methods as applied to industry. This means they must create departments in which the use of instruments to carry out these experiments have to be designed, also to test for perfection, to see they are metallurgically correct to stand use in shops; by perfect tempering to withstand varying temperatures. An important factor is cost, which in science research must unfortunately be high. For unless the instrument is one for general use, few are made; hence the designing costs are to be considered. Fortunately, we could train, if we would, our youth better in manual arts, to take laboratory positions in technique, and which should be attached to every institution and hospital. One working there sees the need and can often design a simple practical tool that surpasses the manufacturer's because its use is better understood. It frequently happens that instrumental methods are valuable for researches of quite a different character from that for which they were developed, and workers who may be interested in apparatus as distinct from results obtained may never see them or know of their existence.

The field of research is so wide few can keep up with the possibilities of new methods and instruments; also it is difficult to obtain definite information as to construction, capabilities, and limitations. The importance of the knowledge of methods of measurements depend on their accuracy, sensitivity, tempering of metals used, and the student. One may not be mechanically inclined to construct the machine he needs to carry out the work on which to found such an analysis.

An example may illustrate: The Einthoven string galvanometer, with photographic recording, was developed primarily for physiological purposes, in order to investigate the minute differences of potential generated between different parts of the body in synchronism with the action of the heart. During the war it displaced several other methods of recording the small intervals between the times of arrival, at a number of accurately located telephone transmitters, of the air wave produced by the firing of artillery or the bursting of a shell, by which their positions could be determined to a few yards. Later it has been applied to the measurement of several types of transient and periodic phenomena, for which it is frequently more suitable than other types of oscillograph.

Methods of measurement and instruments are becoming of great interest to the biologist and physician, who are making wide use of physical methods in their studies, and are naturally in need of guidance as to the values of such methods, with which they may not be familiar. Here is a point for exhibitors, who can show what the tools can be capable of doing. Watching these demonstrations often suggests new methods that may be of untold value, to both. A manufacturer would rather learn an instrument can be used for several methods, and so aid in selling and reducing costs. Inventions are therefore most desirable if they can be proved usable and valuable to warrant the cost of production. Many of the maker's difficulties in design and construction would be diminished or removed by cooperation and good demonstrations and literature. State-aided research has added to the importance of a work of this nature.

Most problems resolve into physical, or chemical, such as measurements of mass, temperature, density, polarimetry, colorimetry, etc. They require the assistance of engineers, biologists, physicists, chemists and microanalysts, to apply the methods to the problems provided by the living creature. Physiology is a study of dynamics, in its widest sense, of life, confined within the cell, single or multiple. Microscopic development has grown through the needs of biology, and probably has had the greatest influence in the study. Again, in colloidal solutions, i. e., of the media in which living processes occur. Improvement in dye-reactions, methods, the use of the ultra-microscope and violet light, photographic plates, films, and color-screens. Now research of muscle has become more of a physical and chemical study into causes of muscular activity and its effects.

But the living cell is the means to the end. And whether the instruments, technique, can be made to yield not only form, but chemical and physical constitutional activities, is the problem. The Braggs have shown by direct physical means in large objects, that molecular arrangement can be detected. Whether any application of their methods, or of the microscope, could be made to show the regularity existing in the structure of the living cell, we do not know; if it could, we might be nearer solving one of the most fundamental problems in physiology. Bayliss (Proc. Roy. Soc., 91B, p. 196, 1920) using intense dark-ground illumination, showed that the pseudopodia of *Amoeba,* which are apparently clear, are filled with numerous minute particles in Brownian movement, and that their movement can suddenly be stopped by electric stimulation. To those who have seen the production of the "Canti Film" little more need be said.

The applications of these or other physical methods to microtechnique, e. g., the use of short ultra-violet light and higher magnification, the advance of instantaneous and color photography, or a more accurate study of how far vital or non-vital stains and fixatives produce effects, may yield future results. Also the question of foods and chemical metabolism and modern lighting appliances to the microscope must be noted; for at present the microscope is not able to render the aid the physiologist or biologist requires of it, as it is still imperfect. Some of the most beautiful and successful physiological work was that done by the late Keith Lucas who was almost a wizard in designing, making apparatus for the particular problem he wished to solve. The smallness of the units in use where the changes take place requires finer apparatus, also more speed; hence photography is displacing other methods of recording physiologic changes. By this greater magnification, and making working parts lighter, smaller in size and more simple, recording becomes easier, and reduction to micrographs can be done for preservation. Various "graph" methods need improvement. Here the optical recording is an advance. If *times could* be required accurately, for example, the interval between the electrocardiogram and pulse, or as in an investigation of the velocity of the pulse wave, an electrical method is very effective.

Here is a field for the electrician, and today we find many instruments of this nature. Electric methods are used in the study of the physico-chemical properties of the body fluids, e. g., hydrogen-ion concentration of blood, and a really effective electrode would be a benefit. The X-ray needs to be studied in its application to the effects of the rays themselves on the living cells, and this might lead to some results upon the physical-chemical organization of the latter.

Perception of sound, color, and other senses opens many problems in research. Helmholtz, who was eminent both in physics and physiology, gave his life to further such research. To Edison, Michaelsen, Compton, Einstein, Roentgen, Eastman, Mees, Curie, Pasteur, Ehrlich, our physiologists, biologists, and chemists and other masters of research, we offer our gratitude for their sacrifice to make the struggle of life more beneficial and give comforts never dreamed of in past days. Progress in science is by the efforts of those who group themselves together, giving all and, oftener than not, receiving little for their devotion, passing on with no thought of sacrifice for their own, but for the world at large.

Perhaps it may not be out of place to mention the value of wire cloth, as filter cloths and centrifugal linings are fast becoming leaders in chemical and other industries. This cloth is, and may be, designed to meet specific purposes. Several patents have been secured on filter cloths; in each case there have been reasons for their designs. One was on a cloth designed to compete with, and overcome the deficiencies found in, other filtering mediums. Under the heading of wire cloth there may be numbered over ten thousand different meshes, sizes, and grades. This industry originated in Scotland, and the first plant in the United States was started at Belleville, N. J., some 100 years ago, by Scotch immigrants. There is still in operation one of the old original hand looms. To give an idea of the possibility of weaving from wire a square mesh, the following comparisons are given: A mesh of 2½ x 2½ inches can be made of as heavy rod as a one-inch diameter and can be made of as light a wire as 0.177 inch. Between these two limits are listed 14 different sizes of rod and wire. The mesh then gets finer until it reaches 250 meshes to the linear inch, fabricated from a wire 0.0015 in. in diameter. From this one notes the wide range of differences.

For some time about 80 per cent of our wire cloth came from Europe, Germany leading, while France, England and Scotland followed. A large portion of manufacturers were in Alsace-Lorraine, now rated as French. The finest on record for a time was 350 mesh, but in 1914 a firm in Elberfeld, Germany, started to make a 400 mesh, but none was seen here. The finest in the United States is 250 mesh, in the U. S. Bureau of Standards. About 1912, the Edison laboratories produced a piece of 200-mesh cloth 34 inches wide and 100 feet long complete, using Monel metal wire of a diameter of 0.0021 in. It was used to filter wax. Other uses are backings for tank strainers, centrifuges, filters, malt floors, and washers. It is important in the paper industry; and during the war most important in the chemical industry. We find it extensively used in ordnance manufacture; explosives, mills, cement, paper, glue, and pottery manufacture; dyestuffs production, drug houses, colorworks; food production; and last, but not least, ammonia oxidation.

The trade names of wire cloth are many. A few: Metallic filter-cloth, bolting cloth, brass lawn-fly screen, Dutch cloth, Fourdrinier wires or paper machine cloths, washer-wires, centrifugal liners, etc. Care must be taken in knowing this wire cloth before ordering as there are different ways of measuring. And it is well for users to write makers for their catalogues giving details of sizes, openings, etc. The term "mesh" means the number of meshes or openings per linear inch each way, measuring from centre to centre of wire. In the heaviest 4 x 4 mesh the opening measures 0.115 in., whereas in the lightest the opening would measure 0.222 in. So in order to get a $\frac{1}{4}$-in. space, the size of the wire must be specified along with the size of opening. An example: A wire cloth of 0.083 in. wire with an opening of 0.250 in. would be a 3 x 3 mesh. A difference of 0.001 in. in the diameter of wire would make a considerable difference in the finished product, both from a manufacturing and working standpoint. Hence, accuracy in manufacturing is a necessity, and the Bureau of Standards the proof.

The value of Monel cloth is shown in replacing old-type fabrics, as jute, hemp, cotton, it being more easily cleaned, stronger, and impervious to weak acids, alkali-proof solutions. Monel has stood solutions with from 7 to 10 per cent sulfuric acid. Only one case of failure was in a press using cast-iron plates and Monel metal filter leaves for the precipitation of potassium permanganate. In this case the filter leaves rapidly decomposed because of the electrolytic action set up. A most interesting microscopic-ground glass screen view can be seen of the filtering of various micro-organisms through the cloth. This type of cloth is being extensively used as lining for centrifugals, is strong, easily cleaned, with a weight of about 9 ounces to the square foot. Its weaving principle uses 500 wires in one inch of space, which are spirally overlapped. I believe its alloy is composed of Ni 67.5 parts; Cu 30.5; Al 0.5; Fe 1.5.

And so it goes. I have only attempted to touch on a few of many important questions which the title of this paper has raised. For instance, there are many romantic sidelights to every industry or profession and many are complex to ours.

The optical needs but the pen of a chronicler to make a fascinating narrative. One of these is the use and history of corundum, which is, next to the diamond, the hardest natural substance. It is used as an abrasive for grinding glass, rocks, etc. South Africa yields the finest so far known, in trade called "Premium ore" and costing about one English pound a ton more. One dealer tells his deposits are 12 miles from the railroad in a direct line, but he is forced to go 60 miles on account of the deep ravines. Briefly, the preparation is to put the ore through large crushers to about 1½-inch size or finer, then through small crushers, to give ½ inch, ¼ inch or finer. Now through sieves, rolls and screens to sizes needed, these being controlled by hummer-screens, in the rolls. From the hummer into wet mulls, agitated, and washed about 2½ hours. In the mull it is pounded to separate the grains, to make them the proper shape and texture as a commercial abrasive. From the mull, shovelled to draining boards, to driers, to storage, then to the grading room. Here screening is done to get the grades for commerce. A firm that manufactures optical goods, microscopes, physical apparatus must further break down the corundum, wash it, purify, and grade most carefully if used for lenses. Here the operations are *most* precise and carefully controlled. When I mention that over 30 grades are selected, with the difference in size between some of the smaller being about .003 mm., you can understand how the progress of science depends upon technical methods and manufacturers as well as the professional workers.

Those who crave fame and fortune we hope will find both, if they will only produce the solution to certain important problems, which are worth everything to human progress. The fields of biochemistry, physiology, optics, medicine, sanitation are all open to those who can solve the perplexing question vital to the world at large. The discoverer should be repaid with more than thanks and a few medals, for he needs to preserve his body and maintain health, also his family. Let the future equal if it cannot surpass the results of Lister, Pasteur, Trudeau, Manson, Gorgas, Wood, Curie, Steinmetz, Edison, and many others.