in these institutions is about one hundred million dollars, and this is about one tenth as much as was expended in a recent year in this country for candy or one eighth as much as was expended for cigarettes or one seventh as much as was expended for perfumery and cosmetics.

The federal appropriation for state experiment stations is about one and one third million dollars annually or almost the same amount of money as one manufacturing concern spends in one year for advertising in about thirty leading magazines and papers, one brand of soup. The federal appropriation of about six million dollars toward the support of extension work is almost the same amount as is paid for advertising the products of one automobile concern.

The amount of taxes is always important and the reduction of taxes is always desirable. But the fair distribution of the tax burden and the honest and efficient use of tax funds are still more important. These questions are now very prominent. More knowledge should be secured through research and the knowledge we have should be more widely distributed.

Patriotic citizenship is mentioned as the fifth requirement of the ideal permanent agriculture. This implies no criticism of farmers. The whole nation is subject to criticism when only half the voters come out to vote at a presidential election, but probably farmers are least at fault. The whole nation is subject to criticism in reference to law observance and here again probably farmers are least at fault. We need a revival of our spirit of patriotism and of our devotion to the ideals of the founders of our nation and we need to increase our genuine sympathy for our neighbor. Who can or will set a better example in these phases of good citizenship than the farmer?

V

With an increasing abundance of knowledge, whether gained through accident or painstaking research or from long practice, and with our great organizations for dispensing this knowledge, agriculture still will be handicapped until that knowledge which is most needed is accepted and put into use by rural people. No one thinks that all farmers should be college graduates nor that all business men should be college graduates, but sometimes we are asked, "How many farmers should be college graduates?" The question might be answered in this way: There should be as many college graduates in a given number of farmers having a given capital as are found in a similar group of business men having approximately the same total capital. Certainly there should be at least as many well-educated farmers in an average agricultural community as the number of well-educated doctors, lawyers, storekeepers, insurance agents and others who are dealing constantly with the farmers.

This nation wants to avoid peasantry. Men and women of the farm because of their equal ability should take places side by side with urban residents in public affairs and in the public service. In some states and localities this fine relationship already exists and in not a few cases the farmers are doing more than their fair share. In other places the opposite is true. No one should be disqualified simply because he is a farmer.

Only a few of the many adaptations of research and education to present agricultural problems and needs have been mentioned. Excellent progress has been made and much more needs to be done. Enough has been said to show the need of a thorough study of this whole question as was first recommended in this paper.

We must keep our faith in agriculture and strive always to bring it more near to the ideal permanent agriculture which will be as great a benefit to all the people as to the farmers themselves.

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FUNDAMENTAL CONCEPTS IN PHYSICS IN THE LIGHT OF RECENT DISCOVERIES[1]

THE EIGHTEENTH CENTURY: THE CENTURY OF MATERIALISM

THE physical scientists of the eighteenth century were diligent discoverers in an unexplored field. The facts they established remain for the most part with us to-day, but the point of view has completely altered. The mental attitude of the eighteenth century scientist may be characterized as materialistic to a degree which is difficult to realize at the present time.

Most of us have been taught that the subject-matter of physics is twofold—matter and energy. That was the orthodox nineteenth century doctrine, but the attitude of the eighteenth century was different. The scientists of that day studied matter only. The concept of energy was not recognized. Forces of all kinds—gravitational, mechanical, electrical and magnetic—were regarded as properties of matter. The concept of force was strictly subordinate, secondary and auxiliary to that of matter.

Gravitation in fact, continued to be thus regarded

[1] Abstracts of a series of three public lectures at the Carnegie Institute of Technology on January 6, 7 and 8.

up to recent years, when Einstein suggested that it was not a property of matter at all, but a space property (of which more later); and electricity has now gone so far as to reverse its former relation and to claim matter as merely an electrical phenomenon.

The idea that all forces were to be regarded as properties of matter was supported by what was known as the doctrine of imponderables. The mechanical force exerted by moving bodies could be readily enough explained as a material property, arising from the inertia and impenetrability of the moving mass. Other forces, more obscure in their action, such as electrical attraction, were not to be so simply explained. To account for these forces the existence of various kinds of imponderable matter was assumed. These imponderables were believed to be kinds of matter as real as water or air, but of a density so small that it could not be measured. In this, there was nothing absurd to the eighteenth century. It was known that air had weight, but this fact had been ascertained not so very long before. Previous to the invention of the air pump it was supposed that air had no detectable weight, that it was an "imponderable." And so great a difference was found between the weight of air and that of the lightest known solid or liquid that it was natural to ask: "Why may there not be a class of bodies with a density as much less than air as air is lighter than cork?"

Such an imponderable fluid was postulated to account for the phenomena of heat. It was called caloric. All bodies were believed to contain caloric soaked up in their pores as a sponge holds water. And just as a sponge, though apparently dry on the surface, may yield water on squeezing, it was supposed that cold bodies, by squeezing, rubbing or hammering, had their capacity for holding caloric reduced and in consequence some of this imponderable fluid was brought to the surface where it might be recognized by the sense of touch.

The phenomena of light were similarly accounted for by supposing light to be constituted of exceedingly minute particles of matter emitted from luminous bodies. It was recognized that such emission of particles must eventually result in a diminution in weight of the body emitting the light. Failure to detect this was taken merely as an indication of the inconceivable minuteness of the corpuscles.

We consider it ultra-modern in these days to speak of stars dissolving into light. The principal difference, however, between the modern concept and that of the eighteenth century is in the philosophical point of view. The older concept was thoroughly materialistic; that of our day is the opposite.

The phenomena of electricity were likewise explained by the assumption of an electric fluid, or rather, two fluids, soaked up in matter just as caloric was supposed to be. An excess or deficiency of one or the other of these fluids disturbed the balance and gave rise to the phenomena of electrification.

A similar imponderable fluid or effluvium was supposed to be the cause of magnetic attraction. Writers of that period express wonder that this emanation from the magnet should be able to pass through a sheet of glass or a board, and affect a compass needle on the other side.

Such materialistic views made up the attitude of the eighteenth century toward the phenomena of nature.

To this statement we must now hasten to make an exception.

There was one of these forces, namely, what was called the "vital" force, which stood in a class by itself. While all the other forces were regarded materialistically this one force could not be so regarded. They all looked at it with a sort of superstitious awe. This matter was perhaps of more interest to chemists than to physicists, though there was then not so sharp a line of distinction drawn between them as now. In organic compounds and living tissues there was thought to be some force acting which could not be reproduced in a laboratory. It was believed that it was under the influence of this vital force that a plant was able to synthesize its carbohydrates and water from their elements. This theory was overthrown when Wöhler made the first synthesis of an organic substance, urea, which he obtained by heating ammonium cyanate. This, chronologically, occurred in the nineteenth century, in 1828, but scientifically the centuries overlap considerably.

The doctrine of a vital force died hard. In fact, it did not die at all—it emigrated. When many other organic syntheses had been achieved, and it was finally recognized that organic chemistry was only a complicated kind of inorganic chemistry, the doctrine of vital force retreated before the advancing frontier of knowledge into the less known regions beyond, namely, into the biological sciences. Here the complexity of phenomena was (and still is) so great that among the shadows of the virgin forest the vital force could still find a retreat. There are vitalists and mechanists among the biologists to-day; the controversy rages violently. I can not see anything in it but history repeating itself.

In this we may see a second characteristic of eighteenth century science: a tendency to relapse into the supernatural. Many of the scientific works of the time read more like religious homilies with illustrations from the physical sciences than treatises on natural philosophy.

As a third characteristic of the century I think we may mention a failure to lay emphasis upon the quantitative aspect of phenomena where it might naturally be expected by modern scientists. An instance of this was the curious phlogiston theory of combustion, which held sway for nearly the whole of the century until disproved by the experiments of Lavoisier with his balance. On this theory combustion was believed to be due to a certain substance called phlogiston, contained in all combustible bodies, and which could not be isolated on account of its great tendency to combine with air. Sheltered by matter, it might remain inactive; but if the matter were heated to a certain point some of the phlogiston was forced out and immediately combined with the air. The resulting heat forced out more phlogiston until the matter was completely calcined or burnt. The slightest quantitative consideration would have shown the inconsistency of this theory; but no emphasis seems to have been laid upon this point until Lavoisier's day.

THE NINETEENTH CENTURY: THE CENTURY OF CORRELATIONS

Looking back over the nineteenth century, as it is beginning now to fall into perspective, the principal accomplishment of the century may be said to have been the correlation of the inheritance received from the eighteenth century. This, it will be remembered, consisted of a number of isolated and distinct concepts—matter, heat, light, electricity, magnetism, and forces of various kinds—all such forces (except the so-called vital force) being regarded as properties of matter of some kind, ponderable or imponderable. The nineteenth century reduced these concepts to two: matter and a new concept, energy.

This was a large task, and took the whole century. In fact, it overlapped at both ends, beginning with Lavoisier and Davy in the eighteenth century, and extending well into the twentieth century before Einstein showed the correlation between inertia and energy.

A typical example of one of these correlations is the development of the theory of light. At the very beginning of the nineteenth century two kinds of invisible light were discovered, the ultra-violet, or chemical rays, and the ultra red, or heat rays. For a time these were considered as three separate entities; but gradually they were shown to have the same properties, obeying the same laws of reflection, refraction and polarization, and the three concepts gradually became regarded as one, ether-waves differing only in wave length. The last piece of experimental evidence for this correlation was obtained as late as 1907, when it was shown experimentally that the speed of travel of the visible and the ultra-violet rays was the same.

Another correlation, of the first magnitude in importance, was that between heat and work. This was begun, chronologically, in the last few years of the eighteenth century, by Davy and Rumford, but its complete development did not appear for nearly half a century. With this development two names are connected: those of Mayer and Joule. The result of this correlation was the introduction of a new concept, energy. This concept was built up out of the "imponderables" of the previous century, heat, light, electricity. This concept, from its fruitfulness and far-reaching consequences, became equal to that of matter in importance, and it is to be noted that it is definitely immaterial in its nature. The establishment of this concept marks a definite tendency away from the materialism of the previous century.

One of the corollaries of the doctrine of energy carries with it consequences of poetic grandeur. This is the principle of the dissipation of energy. According to this principle, the various forms of energy in the universe are continually suffering transformations from one form to another, but with a gradual accumulation in the form of heat, in which form all the energy of the universe is apparently destined to remain forever in a form unavailable for any practical use. The activity of the universe is thus doomed to end in stagnation. A way of escape from this conclusion was sought by a number of scientists (Maxwell, Arrhenius), but the first satisfactory solution came only with the twentieth century, when it was shown from considerations of statistical mechanics that the universe must be regarded as capable of indefinite self-perpetuation; that heat not only could, but actually did run up hill on a microscopic scale, and that it was only a question of time and probability for it to execute this miraculous feat on a scale of sensible size.

Another correlation, of the first importance from an engineering standpoint, was that between electricity and magnetism, due to the experiments of Oersted and Faraday.

With the correlation between electricity and light, shown by Maxwell, and experimentally demonstrated by Hertz, the scheme of correlations was almost complete. One important thing yet remained uncorrelated with any other physical fact, in spite of many and heroic attempts to bring this about: gravitation at the end of the century was just where Newton left it two hundred years before. The final correlation of gravitation with other phenomena was to be one of the principal contributions of the twentieth century to science.

A second great accomplishment of the nineteenth century was the establishing of the atomic concept of matter on a firm foundation. This concept was not new; Newton and Boyle had held it, to mention only two of the greater names. With the atomic theory the name of Dalton is usually connected. What did he do to warrant this? He did something characteristic of the nineteenth century: he made the concept quantitative; he introduced the idea of definite weights for the atoms of different materials, and introduced on this atomic basis the laws of definite and of multiple proportions into chemistry.

A further attempt at correlation was made by Prout early in the century, who suggested that the different atomic weights were all multiples of that of hydrogen. With the progress of exactitude in atomic weight determinations this was regarded as an untenable hypothesis; but the twentieth century has completely vindicated Prout.

For several years prior to 1895 a curious pessimism overspread the minds of physicists everywhere. It was widely believed that the great discoveries of physics had all been made, that the science of the future was to be a science of residuals, of farther decimal places, of second order effects. To this there was at least one honorable exception. Lodge, in his "Modern Views of Electricity," (1889) placed himself on record as a thorough optimist. He said:

> The present is an epoch of astounding activity in physical science. Progress is a thing of months or weeks, almost of days. The long line of isolated ripples of past discoveries seems blending into a mighty wave, on the crest of which one begins to discern some oncoming magnificent generalization. The suspense is becoming feverish, at times almost painful. One feels like a boy who has long been strumming on the silent keyboard of a deserted organ into the chest of which an unseen power begins to blow a vivifying breath. Astonished, he now finds that the touch of a finger elicits a responsive note, and he hesitates, half delighted, half affrighted, lest he be deafened by the chords it would seem he can now summon forth almost at will.

The nineteenth century may be said to have closed, scientifically speaking, with the year 1895, in which Roentgen discovered what he called "a new kind of light." With this discovery, followed quickly by that of radioactive bodies, the crest of the oncoming wave broke upon us. In the ensuing turmoil we are still struggling for a foothold. Some, Lodge (it must be confessed) among the number, are clutching desperately at straws; others of us, equally at a loss for a solid foothold, are swimming as best we can, awaiting the quieting of the sea, when a new and firmer footing will doubtless be found.

The general progress of the science of physics in the nineteenth century may be said to have been steadily away from the materialism of the eighteenth century. At the end, we find the two main concepts of physics, matter and energy, equally dividing the ground between materialism and its opposite.

THE CENTURY OF HOPE

Though the twentieth century is but one fourth past, we may notice three contributions of the first magnitude which it has already made to the science of physics: the electrical theory of matter (including the inertia of energy), the quantum theory and the theory of relativity.

The nineteenth century closed with rather vague ideas current as to the nature of electricity. While some regarded it as an independent entity of unknown nature, others supposed it to be a state or condition of the ether of space, and hence a form of energy, like light. In the closing years of the century our ideas regarding electricity began to trend rather definitely in a certain direction, namely, toward a correlation of electricity and matter.

The first step toward this was taken when it was recognized that a moving body, when given an electric charge, acted as though its mass had been increased in consequence of this charge; that is, that an electric charge in motion possessed inertia. The questions then arose: May not the whole mass of the body be thus explained? is not ordinary matter only an electrical phenomenon? There was the opposite possibility to consider: electricity might be only a state or condition of matter; but the early years of the twentieth century saw the triumph of the first idea. Matter became merely an electrical phenomenon.

The atom of matter is now regarded as a minute planetary system, with a central positive nucleus and a number of negative electrons circling round it. On this theory, due to Rutherford and Bohr, the nucleus of the atom is responsible for its mass-properties, and the number and arrangement of the circulating electrons for its chemical and physical properties. The accuracy with which this atomic model fits the facts is uncanny.

This subordinating of the concept of matter to that of electricity is a long step away from the materialism of the eighteenth century. Another equally long step was taken when it was shown that matter and energy were close akin. This doctrine, known by the name of the inertia of energy, was first announced by Einstein as a consequence of the principle of relativity, but he later showed that it was a hitherto unrecognized corollary to Maxwell's electromagnetic theory, than which there is nothing more classical. This theory states that energy, like matter, possesses inertia; that when a glowing body cools off, emitting light and heat, it actually loses mass in the process.

This loss is very small, far too small to pick up experimentally on a laboratory scale; but in the case of bodies like our sun it may amount to a large figure. The energy radiated per second by the sun is enormous. Converted into its energy value it gives the rather surprising figure of four million tons per second! But so super-enormous is the sun's total mass to start with that he is good for this expenditure for something like ten million million years!

In this identification of the material concept of matter with the immaterial concept of energy we have taken another long step away from the eighteenth century position. In the light of this correlation of matter and energy it is but natural that the quantum concept should have arisen, for if matter is atomic and only an aspect of energy, then energy should be atomic also.

The quantum theory atomizes energy into indivisible units, and as a consequence explains several discrepancies that had previously existed between theory and experiment. Great as are its successes in this line it can not be regarded as the last word in the matter, for it is in contradiction with a considerable body of experimental fact which is still best explained by the classical theory. Perhaps the ultimate solution will be found in some broader concept of which the two opposing theories are special cases.

The theory of relativity will be treated here only so far as it is concerned with still another important correlation, that of gravitation with other physical phenomena.

At the beginning of the twentieth century gravitation was a great mystery. In spite of much experimenting and more theorizing, the phenomenon of gravitation stood apart, refusing to show any correlation to other phenomena. In the year 1900 our knowledge of gravitation was just where Newton had left it, two centuries before. It was left for Einstein to point out that which when once seen is never forgotten—the correlation of gravitation with inertia.

But great as are the coordinating and correlating properties of the theory of relativity, it can not be regarded as the last word in its line any more than can the quantum concept; for the theory of relativity begins to fail us when applied to rotating bodies. Here, as Eddington says, it stops explaining phenomena and begins explaining them away. It is, however, a great step in advance, and much of it will remain permanently in the theory of physics even when it shall be supplanted, as it must be, by some broader and better concept.

Where, then, has the progress of three centuries in physical science brought us? Of the many distinct concepts of the eighteenth century not one is left. The sole concept of modern physics, energy, was not known in the eighteenth century, and this concept is above all things immaterial. The theoretical structure of our science is left without material means of support. The twentieth century so far is a century of bewilderment. But it is young yet; may we not call it the century of hope? Who knows whither it will lead us?

PAUL R. HEYL

U. S. BUREAU OF STANDARDS

THOMAS LEONARD WATSON

DR. THOMAS LEONARD WATSON, Corcoran professor of geology at the University of Virginia from 1907 to the date of his death, head of the department of geology since 1910, and state geologist and director of the Virginia Geological Survey since 1908, died on November 10, 1924. He was born in Chatham, Pittsylvania County, Virginia, September 5, 1871, and was the descendant of an old and well-known Virginia family. His early education was obtained in the public schools of Pittsylvania County, and in 1890 he was graduated from Virginia Polytechnic Institute, Blacksburg, Virginia, at that time known as the Virginia Agricultural and Mechanical College. Chemistry was his chosen profession and, after a year's residence at the University of Virginia, he served as assistant chemist at the Virginia Experiment Station in Blacksburg, from 1891 to 1895, and at the same time was instructor in geology at his *alma mater*. During this later period of residence in Blacksburg, Dr. Watson became more deeply interested in geology, particularly on the chemical side. He perceived the great opportunity for service to his native state in the study of its natural resources and intricate geology, and accordingly resolved to forsake his allegiance to chemistry and devote his life to geology, with the hope of service to Virginia, a hope that was to be immeasurably fulfilled. Accordingly he entered Cornell University and received the doctorate in June, 1897, his thesis being on glacial geology, a branch of geology that he never afterwards pursued to any extent.

After leaving Cornell, Dr. Watson went to Georgia as assistant state geologist, where he remained until 1901, when he resigned to become professor of geology at Denison University. In 1904, he resigned the professorship at Denison to return to Virginia Polytechnic Institute as professor of geology, where he remained until 1907, when he was appointed professor of geology at the University of Virginia, and in 1908