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THE PLACE OF PHYSICS IN THE MODERN WORLD[1]

THE subject on which I am to speak is without doubt a very appropriate one for this occasion. It has the one drawback that I can not hope to say anything upon it that will be new to this audience. Under these circumstances I could wish myself to be a word artist, having powers to clothe familiar figures in a new imagery. As it is, I shall have to content myself with passing before you in parade some old facts, bare and unadorned.

We are living at a time when science has won for itself a prominent place on the stage of human interests. The great benefits conferred upon the world by scientific discovery are generally recognized. The applications of science touch our lives at every point and at every turn. It is not too much to say that science has not only transformed the manner in which we live but has changed also in good measure the very subject of our daily thoughts.

The last fifty years are without precedent in physics as regards the number of far-reaching discoveries which have been made and as regards the new insight gained into the processes of nature. These years are unequalled in the number and importance of the applications of science which have been perfected.

One not conversant with the situation might well ask, "Can this expansion go on indefinitely, and are we not now approaching the end?" The same question could have been asked with even greater force thirty years ago. No one can look far into the future. Our answer to the question must be read in the fact that never before in all time has science invaded the realms of the unknown at so great a pace as it is now doing. There are no limits in sight. So rapidly does advance follow on advance that new achievements are proclaimed daily by the press. A special science service has been organized to interpret the significance of new findings to the people. Moreover, industry has never before leaned so heavily on what science has to tell.

It is not my purpose to allot credit for what has been accomplished, among the different sciences, or as between science and its applications. The different

[1] An address given November 30, 1928, at the dedication of the new physics laboratory of the University of Minnesota.

branches of science all contribute greatly to our welfare. There is much interdependence among them and their fields overlap to such an extent that it is impossible to say where one science ends and another begins.

If I shall in my remarks attribute to physics what more rightly belongs elsewhere, or if I shall seem to imply that when all is said and done physics serves man most, you will understand, I feel certain, that this is an occasion when it is expected of me to extol the science whose newest temple we have come here to dedicate.

Modern life stands in marked contrast with the old largely because of what science and invention have evolved in the intervening years. These agencies have given us a new outlook on life. They have brought invaluable aids with which to carry on the work of the world. They have surrounded us with innumerable comforts and luxuries with which to enjoy our daily life. So accustomed are we to these advantages that we scarcely ever stop to think what it would mean to be without them.

It is a noteworthy characteristic of science that the discoveries of one generation are passed on to the next and thus become a permanent heritage of mankind. The things of most value are not all consequences of recent labors. Some though old and simple are nevertheless of paramount importance.

I may cite as an example the magnetic compass. Before its invention, the peril of the sea was a real peril. By this simple device, for these hundreds of years, myriads of vessels bearing people and commerce have been guided safely in their course and gone with full assurance where previously it would not have been prudent to venture.

As another example of a simple discovery of far-reaching effect I shall mention the invention of spectacles, which occurred some six hundred years ago. It would be difficult to estimate even the commercial value of this invention as measured by the increased efficiency of those millions who without glasses would not have been able to undertake many of the tasks they have done. Who, then, could evaluate the increased enjoyment of life that spectacles have brought to these same individuals, and more especially since the advent of the printing press?

I intend to dwell at some length on these commonplace practical values of science. These values mean so very much to the modern world that unless emphasis is placed upon them we shall get a distorted view of the place that science holds. It is by these values too that we must mainly justify the expenditures necessary for further scientific progress. Moreover, it is the industries that are calling for a constantly increasing number of scientific men. The universities, in laboratories like this, must be prepared to train for this purpose more men than they are now doing. These men must be taught the principles involved in the processes now in operation. They must be trained so that they can improve and extend these processes. In laboratories like this, under the guidance and by the example of experienced investigators, men must acquire the spirit of research.

There is to my mind no single invention that has made so great a contribution to our modern world as has the steam engine. With its coming man entered upon a new era. It introduced into the world of industry a great giant of almost unlimited power. This giant has relieved man of many of his most arduous labors. He does much that previously had been impossible of accomplishment.

As a direct consequence of this new power, the use of machinery has multiplied and multiplied up to its present stupendous scale.

The industries which use this machinery are deeply rooted in scientific soil. As new discoveries call for improvement in present methods or for new processes, industry seeks more and more aid from science. Manufacturers are constantly knocking at university gates for knowledge. More significant still is the fact that industrial organizations are finding it advantageous to maintain at great expense large research laboratories of their own.

Many successful processes even now used in manufacture are not fully understood. A given procedure is sometimes followed although it is not known what steps in it are essential and what ones not essential.

I know of an instance where hogsheads of water were regularly imported at great expense from Sheffield, England, for quenching purposes in hardening steel. It was thought by the workmen who came from that city that the secret of Sheffield's eminent position in cutlery is due to some special quality of its water.

The only safe thing to do in cases like these is to acquire more knowledge. The new spirit in industry, if I sense it aright, is that owing to the magnitude of its investments it must safeguard the future. It does this by constantly improving its methods on the advice of scientific men trained to understand its processes and needs.

It is by service like this that science has become the guide and mainstay of industry.

Equally important is the service that science does for industry in creating for it by basic discoveries great opportunities in new fields.

The steam engine made possible the railroad and the steamship. These in turn opened up markets which before could be reached only with difficulty, if at all.

The invention of the dynamo and the general utilization of the electric current have given birth to a great host of new industries. The electric light has dispelled gloom from street and building, and brought everywhere increased comfort and efficiency. The telephone, the telegraph and wireless knit community to community and country to country. Business is vitally affected by them. Our personal contacts are extended to wide limits. We are constantly seeing new marvels in the field of communication. Some of them would have been considered beyond man's reach less than a generation ago. We may now talk to a person hundreds of miles away and at the same time see his animated face. It is no exaggeration to state that, in effect, a dog baying at the moon may soon hear the echo of his reflected voice.

To my mind one of the most wholesome influences in our lives to-day comes from the opportunity we possess through electric communication of keeping in close touch with what is going on in the world. This intimacy increases our interest. It broadens our outlook. It deepens our sympathies. It helps us get away from the narrowing effect of single lines of endeavor. When great problems are agitating nations, we follow the course of events in their solution. In times of war, we live through the battles. When adventures are afoot, we join the expeditions—at our fireside. A short time ago we all flew thus over the north pole in an air-ship and looked down upon the masses of ice almost at the same time as did those aboard. More recently we lived for weeks with men lost on the polar ice. We listened to a recital of their plight and watched the heroic attempts at their rescue.

We are even now looking forward to the great adventure at the south pole. We shall follow the progress of events day by day and we shall thus feel a personal interest in the whole undertaking.

It is well within my memory that gasoline was looked upon as a dangerous substance. It had a habit on occasion of exploding with great violence. Its main use was as a cleansing agent. Then in 1885 along came a man to whom violence meant power. He learned how to tame the fluid, and the internal combustion engine was invented. The once shunned liquid is now sought so eagerly in every quarter of the globe that international peace is at times threatened.

The new engine was found adaptable to many new uses. With it, for example, the farmer pumps water, saws wood, tills the soil, harvests and threshes his grain. By its use the town and its markets are brought within his easy reach. The extent to which the automobile has come into use is nothing short of amazing. With it our nation seems to have gained a new freedom. It is a victory over space. A single invention has transformed markedly the habits of a people.

The internal combustion engine has also made possible human flight. Man has long dreamed that some day he might duplicate in a measure the unique performance of birds. Now in a few years, aided by most intensive scientific study, he has made such advances that he can fly much faster and much higher than any bird known. The airplane is assuming a place of responsibility in human affairs. Aside from the rapid transport of passengers and mail we are seeing it used, for example, in mapping a country, as a forest fire patrol, and as a rapid means of protecting crops against harmful insects.

A pressing need of the airplane for long flights is a less bulky fuel. Gasoline is not powerful enough. In recent years we have been hearing of how rockets were to be sent to the moon. We have heard of an automobile run by a rocket motor. We must not be surprised therefore if the future brings us motors run by materials more powerful than dynamite or T. N. T. Indeed there are men to-day searching for a means to bring material of a very high energy content, under control, for motor use. When this search succeeds, as it doubtless will, it may be possible to course around the world on a few pounds of fuel.

One of the far-reaching consequences of man's utilization of the various forms of mechanical power may be seen in what has thereby been brought within the reach of the average man. By the use of this power even a relatively poor man has the means to command the labor-equivalent of a large number of skilled hand workmen. Owing to this circumstance he can live in a better home; he can eat more wholesome food; he can give his children better advantages than ever before and still have some leisure for whatsoever his nature craves. The world may confidently look to science for the discovery of even greater powers by the use of which the effort necessary for healthful existence may be lessened still more.

What I have said serves to show that physics has played a leading part in the advancement of our prosperity.

It must be admitted that the men who brought to light the basic principles which made these great material gains possible did not have in view as a rule any utilitarian ends. The scientist delves but to learn the truth. He seeks to unravel the secrets of nature because the quest fascinates him. He is doubtless pleased to learn that the things he has discovered are of some use in the world.

It is interesting to note how often the unearthing of a single abstruse fact in one branch of physics proves to be of great service in other branches of the same science and equally so in fields apparently not related. The discovery of X-rays is a case in point. This discovery stimulated work on electrical discharges in gases, from which the electron emerged as a common constituent of atoms. The X-rays inspired experiments that led to the discovery of radioactivity, which overthrew the old idea about the permanence of atoms and made us accept transmutation of elements as a fact.

To-day the physician uses the X-rays to explore the inner regions of our anatomy. He uses them to destroy unhealthy tissue and to stimulate the growth of new. The surgeon uses the rays to locate foreign objects in our bodies and to determine the nature of fractures in our bones. Calculate if you can the value of this last service to the millions injured in war and in the accidents of peace.

X-rays are used to locate flaws in metal castings. The plumber uses them to locate pipes in the partitions of our buildings. With them the customs officer looks for contraband in trunks. The rays are used to determine the ways in which the constituent parts of crystals arrange themselves. The regular sequence in the frequency of certain X-rays when they originate within different chemical elements disclosed the importance and meaning of atomic number, and told us how many elements remained undiscovered. I shall mention but one more thing in this connection and that is the very important discovery by Arthur Compton of a change of frequency suffered by these rays on reflection from electrons, work which gives us direct evidence of a change of momentum of a light quantum and has important bearing on the corpuscular aspect of radiation.

I can only allude in passing to the important influence that physics has had and is having on the other sciences.

The subject-matter with which physics deals is of such a basic character that it necessarily follows that new discoveries in our science find immediate application in the other sciences. Even our hypotheses and speculations are not without interest to them. The instruments and apparatus they use come from the physical laboratory or are special adaptations of such apparatus. The compound microscope, for example, finds important use in every science. One may safely say that whole fields of biology and medicine are built around its revelations.

Physics has a large problem in seeking to understand the universe. Experience has taught that most if not all of our so-called physical laws have only a limited range of validity. Physics must therefore have a broad vision, penetrating on the one hand to infinitesimal magnitudes and on the other stretching its imagination to the infinite.

We have in recent years been much concerned about radiation. This interest made it imperative that we know something more about the atom where the radiation originates. We finally arrived at a picture in which each atom is thought to be a miniature universe having parts separated by distances which compared to their size resemble the proportions between the sizes and distances involved in our own solar system. Among these new worlds the physicist wanders in spirit and seeks to learn what relations govern their actions. He strives especially to find where the atom keeps hidden those quantum packages of energy that are so characteristic a part of it. Why are these quanta of energy so closely associated with frequency? What does it all mean? There lies the mystery.

In an ancient city of India stands what is often called the most splendidly poetic building of the world. It is the far-famed Taj Mahal, which was built by the emperor Shah Jahan as a final resting-place for his favorite wife, Mumtaz Mahal. One of the princes of India some years ago told me the following story regarding it. When the mausoleum was being built the architect was authorized to embody in the structure some memorial to himself. He kept his own counsel and when the edifice was completed it was found that his memorial consisted in this—that whenever it rains from high up in one of the domes three drops of water fall in succession to the floor below. No matter how hard it rains or for how long, three drops and only three descend to bear testimony of the architect's wisdom. For nearly three hundred years men have puzzled in vain to learn by what artifice this result was accomplished, and the secret still lies hidden within the marble masonry of that dome.

In a like manner the Great Architect has so built the atoms of which the universe is composed that under excitation, regardless of its magnitude, radiant energy is given out in definite quanta. Men have labored for years to learn the secret of the process but it still rests hidden within the atom. It is more than likely that a search of three hundred years will solve the mystery. A solution will, however, only open up new problems still more mysterious. The search is endless. The ultimate is ever beyond our grasp. The scientist works toward a final goal that he well knows can never be reached, but this only makes the search more enticing.

As a boy I used to roam through the then primeval forests of this state. The farther I penetrated the more wonderful it all seemed. Had I ever come out on the other side I should have felt a keen disappointment and loss. Most of the fascination would have disappeared.

The best laboratory does not always satisfy the needs of the physicist. He wishes to know how things behave under greater pressures and at higher temperatures than those under his command. He goes to seek these conditions in the heavens. The aid of the astronomer is sought, since he is also looking for the very things we want to know.

Let us enter a great observatory. We stand in a mighty presence. The mysteries of unmeasured space look down upon us. The greatest of telescopes, soon to be surpassed, has a light-gathering power nearly a half million times that of our eye. Aided by the cumulative action of the photographic plate it reveals for study in our own galaxy some forty billion burning suns. In these suns are in progress physical experiments on a scale incomparably more vast than we can here hope to imitate. The record of their progress is being rushed into the object-glass of the telescope at the greatest speed the law allows, inscribed indelibly on a discredited ether. We stop to read the latest message from a certain nebula, and behold, our news is nearly a million years old, so long has our fleet and tireless messenger been on his way. How can our finite minds comprehend these immense stretches of space? Does space go on forever or does it have a definite but colossal limit? What are we, in all of this gigantic vastness?

But one by one, the stars are giving up their secrets. We know much about their distances, their motions, their composition, their relative ages, their masses and sizes and densities. One as large as the whole orbit of Mars is as tenuous as a high vacuum. One, though gaseous, is more than two thousand times as dense as our most dense earthly substance—platinum. Astonished we may be, but we must not quarrel with facts. Some of the stars have surface temperatures of nearly 20,000° C., and computed internal temperatures of 40,000,000° C. This internal heat energy creeps to the surface whence as radiant energy it passes out into space. What is the source of this energy? That is an old problem concerning which there has been much speculation. Various answers have been proposed in the past. A new conception is now taking root that energy is so intimately related to mass that it is possible for one to be transformed into the other. It is supposed that under the extraordinary conditions of temperature and pressure in the interior of a star we are having such a direct transformation of mass into heat energy. Accordingly, the stars and our sun as well are losing their own substance in this process of radiation. The fact has been expressed by saying that our sun loses four million tons of heat every second. Even at this enormous rate of loss, so great is the mass of the sun that in the last billion years it would have radiated away only 0.01 per cent. of itself. Such ideas as this strike deep at the meaning of our fundamental physical concepts. For a long time matter was supreme and indestructible. It was supposed to be made of impenetrable atoms. The space between them became permeated with caloric and with the light-bearing ether and with electric fluids. The caloric vanished into molecular motion, the ether got to be regarded as an unnecessary luxury, and the electric fluids condensed themselves into units of electricity, attached like leeches to the material atom. Not long since, the parasitic atoms of electricity consumed completely their material hosts, bringing the advent of the electrical theory of matter. According to this, all material is made up simply of the two kinds of electricity, the positive proton and the negative electron. Are these then the ultimate entities? No. We must go at least one step farther. Recent experiments on the scattering of electrons by matter have shown that electrons have associated with them systems of waves. These waves are now on the way to sinking the old electron out of sight. Some scientists are led to think of electrons, now, as mere singularities in space, places where wave systems of infinite extent meet in the same phase. Others there are who would not leave us the comfort even of this indefinite picture of an electron. They seem to fear that if we draw any picture at all we are almost certain of putting something into it that does not belong there, and which later will hamper us in our race after the truth.

And finally we are to contemplate the spectacle of the proton and electron dissolving into each other and reappearing in the form of radiant energy. What was their former substance is scattered to the ends of space. Since we have become accustomed to the wave aspect of electrons, this action need not surprise us greatly.

And now that our glorious universe is slowly wasting away, we may again ask what is this radiant energy that is to be the end of all. We know that it is related to a frequency through a certain universal constant, designated as h. That is all we know, and that isn't much. Still, it is a beginning.

But must we lose our universe forever once it is gone? Is there no way to bring it back or still better to prevent its going? Millikan and Cameron by a recent pronouncement are showing a way out of our difficulty. They conclude that cosmic rays which they have been studying must originate in the cold regions of interstellar space. The rays are of such frequencies that they may consistently be supposed to arise from a union of electrons and protons into atoms of our well-known chemical elements. And how do the electrons and protons get out there into space? It is supposed that they themselves are formed in the same region, somehow, by a condensation of radiant energy.

In these cold regions, then, our material universe is thought to be rebuilding itself. Unfortunately, the complete process involves the absorption of heat at a cold source and its evolution in a hot region. We should have to disregard for this region, then, the second law of thermodynamics which has always held before us the sad specter of a universe in its final state, cold and dead.

Let us be frank and admit that in some of these speculations we are as yet skating on very thin ice.

The leaning tower of Pisa has long been looked upon as a shrine for the physicist. Here Galileo started a new science by finding that different objects dropped from the top all reached the ground in the same time. Recently Italian engineers have discovered that the foundations of the famous building are watersoaked and weakened. Concrete is being injected into them to ensure the tower's safety.

The science of physics has been building a wonderful structure. With the passage of time we have added a wing here and a tower there. As we viewed the edifice from the outside we have admired its noble conception and its grand proportions. As we walked through its halls and chambers we rejoiced at the richness and splendor of their appointments.

In recent years, however, some of our suspicious members began to dig around the foundations and discovered that the whole structure was built on sand. The breadth of the building is all that has kept it from showing a tilt long ago. The engineers have been getting their heads together to see what should be done. Much concrete has been injected into the sand, and yet all is not well. The fundamental concepts of space and time and mass and energy have been carefully scrutinized. Under the pressure of this process, space first became somewhat warped. Now it has started to turn into a mathematical matrix. Time has lost some of its individuality, and mass and energy, as already stated, are thought to be related and mutually transmutable. The air is filled with speculations. We have even begun to wonder whether our finite minds are equal to the task of a full understanding.

The philosophers have become actively interested in our foundation problem because they live next door on the same lot, and so our problem is also their problem. Not long ago the physicist was inclined to think that there is not much in common between physics and philosophy. Many felt that one was dealing with real things whereas the other was quibbling over imagined niceties. Now those imagined niceties have loomed into importance, and we realize that involved in them somewhere may be elements necessary for further advance. Here the two fields have come to overlap. The philosopher now talks about relativity, and the physicist ponders over the relation of sense impressions and objective reality.

Some years ago during the heat of a discussion with one of my former colleagues, having exhausted what arguments I had in defense of a stand I had taken, I was driven to say that somehow I felt the truth of my position from the very depth of my bones. Ever since that day these poor old bones of mine have been carted from one end of this country to the other and exhibited unnamed for public ridicule. Well, I again need the support of those same bones and so I have brought them with me.

The simple argument I wish to give is this. We all realize the fact that our knowledge of things external to us comes to us through our senses. I am ready to admit that the interpretation of our sense perceptions is often faulty. It may be that only as a most plausible hypothesis can we assume there is really anything external to us which corresponds to our sense impressions. But when exact proof is lacking one may still have a conviction. So somehow deep in my bones I feel that there is a real world corresponding to our sense perceptions. I feel that out beyond my touch there is a real audience. I believe that Minneapolis is a real city and not simply a city of my dreams.

It is not surprising that the applications of science, spectacular as some of them are, should excite popular interest. It is more significant that this interest extends to discoveries having at present academic value only. We do not wonder that X-rays created a great stir when discovered, because their application to surgery was immediate. It is remarkable, however, that the theory of relativity should have caught the public fancy, and that to-day it becomes of interest as international news to announce that a renowned scientist is on the verge of a great discovery in theoretical physics.

The world is looking for new visions to serve as guiding stars, and physics is constantly supplying these new visions. Visions stir men to great effort and they lead the mind to a contemplation of eternal truths. In this sense physics is a great spiritual force. Looking at the universe from its minutest detail to its infinite magnitudes we see amid the great complexity an order whose source we can not fathom. The knowledge that this law and order has served as a safe guide for science has had a steadying influence on mankind. Superstition has been dissipated. There is in the world a profound respect for physical laws. This respect has matured because the consequences of physical action are so sure and prompt and definite. In contrast, people constantly think they can evade the laws of biology. They do not have full faith in them because the consequences of these laws follow less promptly and less definitely.

There are some who believe that the great material advancement made possible by science has resulted in less attention being paid to the higher things of life.

Some new evils have come, but these always accompany radical changes in the habits of people. We must learn how best to counteract them. So much has been added to the world in a short time that it is difficult for us as yet to put each thing into its proper place. We shall have to learn to accommodate ourselves more quickly to new conditions. If necessary, we must, by education and organization, see to it that old activities of lasting value are not crowded out of our leisure hours by mere useless pleasures. The ways of the world have changed, but in the great essentials of life we have gone forward and not back. The millennium has by no means arrived. I believe, however, that there is now less selfishness and more love of man for man than ever before. Charity, though organized, is no less real, and more effective. Men have never given so freely for purposes designed for the common good. When tested by the measure of service placed before self, the world dominated by science is not found wanting.

Dissatisfaction often arises because methods of getting things done have changed rather than from lack of accomplishment. The churches have learned to extend their influence by broadcasting their services by radio. They realize that if a human soul is moved to repentance by words entering the home from space, the result is fully as valuable as it would have been were the message received amid the beautiful surroundings of a consecrated temple. Let those who decry the present, instead of railing at it, adopt its methods and use them for whatever noble ends they have in view.

The tide of scientific progress sweeps relentlessly on. It will engulf any who oppose its flow. The old world is gone, never to return. So long as men exist there will be those among them who will sacrifice all to search for truth, and there will be others who will apply new truths to their own ends and to the benefit of mankind.

John Zeleny

Yale University

BASHFORD DEAN

1867–1928

Bashford Dean, former curator of the department of arms and armor at the Metropolitan Museum of Art, New York City, honorary curator of the department of ichthyology, American Museum of Natural History, and late professor of zoology, Columbia University, died on December 6, 1928, at Battle Creek, Michigan, aged sixty-one years.

Bashford Dean was born in New York City, October 28, 1867. His families on both sides were "Old Americans." The Deans were of English and "Holland Dutch" derivation and had lived in the region of Tarrytown since before the Revolution, his paternal great-grandfather, John Dean, having been a captain in the American Revolutionary army. His mother's family was of English and "French Huguenot" stock, of Yonkers and New Rochelle.

His sister, Miss Harriet Martine Dean, states that his interest in armor appears to have originated when he was about five or six years old, when he saw a beautiful helmet in the residence of Carlton Gates, of Yonkers. This object fascinated him and he asked and received permission to examine it closely. It seemed to make a deep impression on him. Later, when he was about ten or eleven years old, the owner of the helmet died, and he attended the executor's sale of the household effects and attempted to purchase the helmet, which to his deep disappointment was sold to some one else. He purchased, however, two very beautifully engraved daggers with scabbards, which he always treasured. In later years he made numerous unsuccessful attempts to trace and locate the helmet, which he felt was a very valuable one and to which he attributed his first interest in the subject.

His interest in fishes began when he was about seven years old, through the influence of an old friend of his father's, Professor Edward S. Morse, of Salem, Mass. At this time he made a drawing of a fish, showing the heart and blood vessels.

He attended the College of the City of New York, where he came under the influence of Dr. John Draper and of Professor William Stratford, a noted teacher of zoology, being graduated in 1886 at the age of nineteen. He then entered Columbia College, where he studied geology and fossil fishes with Professor John Strong Newberry, whose labors on the Devonian fishes of New York and Ohio he was destined to carry on in later years. In 1890, at the age of twenty-three, he received the degree of Ph.D. from Columbia University, his dissertation being entitled "Pineal Fontanelle of Placoderm and Catfish," the title indicating the thorough fusion of zoological and paleontological concepts which characterized all his work.

He began his teaching career in zoology immediately after his graduation in 1886, when he was appointed tutor in natural history at the College of the City of New York. At the same time he became an assistant in the New York State Fish Commission, for which