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PHYSICS, HISTORY

By Walter Prescott Webb

AS I examined the program of the February 1954 meeting of the American Physical Society I was struck by the exclusive concern of the members with what may be called immediacy. The papers seem to deal primarily with problems now in the process of solution. Nowhere did I find that the physicists are concerned with perspective, past or future, with where their subject came from or whither it is going. The practicing physicists seem little concerned with the relation of their subject to the world that lies around it. I shall attempt here to place the subject of physics in its historical context, to show that it arose under peculiar historical conditions, that it grew to its present importance under conditions singularly favorable to it, that those happy conditions are now being modified, and that physics in the future may find the going much harder than it has been during its whole history as a science.

It is not strange that physics has thus far disregarded its own history, and that of civilization itself, because it has been too busy making history and shaping the civilization. The first contributions of physics were wholly favorable to mankind. As long as physics worked in constructive ways—as it did for a considerable time—the men who set its forces in motion could go about their business, tend their laboratories and not worry about consequences so beneficial. But when the consequences began to threaten the welfare, and even the existence of civilization, the physicists can no longer be indifferent. When, however, they seek a broader view, trying to see the relationship of what they have done and will do to all that is around them, to civilization itself, they become historians, and they enter into a realm quite different in both its intent and method from the one in which they have been accustomed to operate.

In approaching physics historically, it is necessary to state the historian's function and his method. His func-

tion is to view society—dispassionately if he can—and explain its past actions with as much reason and as little passion as possible. He is, as distinguished from the physicist, severely handicapped in his method. His handicap is that he must seek truth without benefit of laboratory. Since he has no laboratory, can in the nature of his material have none, has no possible way of demonstrating by experiment, the historian can never prove anything in the sense that the physicist can. The historian does collect evidence, usually in the form of records of what happened, but he can never prove that the records are infallible or that he has all the pertinent evidence. Furthermore, he can never divest himself of his own point of view. For these reasons the historian's conclusions are always tentative, never universally accepted, and are almost certain to be discarded partially or totally by his successors. This whole procedure must seem highly unsatisfactory—and unscientific, as indeed it is—but the historian has no choice but to use it. For him there is no other method.

What the historian does as he peers into the kaleidoscopic past is this: He tries to see relationships among the varied past activities of man. He searches for connections, appraises forces and treats them as causes operating to produce resultant effects. If the historian looks at the shifting scene long enough—never directly but through other men's records—he begins to see patterns forming; a sort of crystallization seems to occur as the lens of his mind takes focus. Though these may be lovely patterns, they are more intangible than the stuff physicists deal with. The patterns can never be touched or tested by the senses; they can only be described as they appear to the informed and questing mind. Since the historian must depend on the skill of his description, the clarity of his exposition, he must give more attention to the art of presentation than his scientist brother needs to give. If he is less of a scientist, he may be more of an artist.

and FATE

Once the patterns form, the historian begins to seek out the one pattern for special attention, usually the one that seems to him to dominate the age he is trying to understand. This pattern takes on importance for him; he is likely to think that he has discovered some force or influence that controlled some things, that seemed to touch and color everything in the society that it accompanies.

At this stage the historian is likely to become excited, if not slightly possessed, at the prospect. If he be daring enough, and disregardful enough of his reputation for safe mediocrity, he does what the real scientist does: he sets up a working hypothesis which holds that a certain ingredient of history, the factor that concerns him, has helped to shape mankind's action and helped direct history throughout the period of its presence. Having formulated the hypothesis, the historian hunts all available evidence to support it, refute it, or modify it. If the evidence does in general support the hypothesis, if nothing is found to refute it, the hypothesis is launched as a thesis in a book or an article for the critical appraisal of colleagues and the scholarly world.

It would be a great comfort to the historian if he could bolster his case with a record of controlled experimental demonstrations all of which point to his major conclusions. This he can never do; he must always submit his case to the court on circumstantial evidence. It is not often that a scientist launches a thesis that he has not proved, that he has not demonstrated in the laboratory, that he has not supported by figures as convincing as the multiplication table. It may be suggested, however, that there are exceptions, and notable among them are Charles Darwin and Albert Einstein.

The question arises as to how a thesis supported by circumstantial evidence ever achieves validity. *How* does the high court decide whether the interpreter has made his case? *When* does the court decide? The last

question as to *when* is easiest answered. There is rarely, if ever, a quick decision. The court—which is the public—ponders the case a long time, often engages in acrimonious argument and the best the historian ever gets is a split decision.

The thesis or interpretation can eventually find a measure of acceptance by meeting certain tests. The chief test is whether the explanation offered gives *meaning* to the past, whether it proves useful in enabling others to see some order in the welter of facts and conflicting opinions. If it does establish a sort of intellectual life line, a control point from which the mind may take off and to which it may return, the hypothesis is likely to find wide acceptance. If things fit into the explanation, fall into place like blocks in a puzzle, and if there are not too many blocks left over, the thoughtful reader will say: "This stuff makes sense to me". If it makes enough sense to enough readers, then in time the work may be referred to as standard, a classic. This is what has happened to the theses of Adam Smith, William Graham Sumner, and Charles Darwin. We still do not know that the histories written by these men are correct, but what they wrote has been so useful, so illuminating and so suggestive that they are still spoken of with great respect. They have achieved a practical validity, but by a process much slower and more tentative than is often the case in demonstrable science.

The method of investigation described above is one I followed in launching some months ago the thesis of the Great Frontier. The high court is now wrangling mildly over it, and only time—about twenty years—will tell as to its fate. Naturally I think the thesis has validity in that it explains some things about the modern world better than other interpretations. Naturally I would have to hold this opinion to justify the years spent in elaborating the idea and tracing out the pattern of the Great Frontier.¹ My view of physics and other modern sciences is that which one gets when these subjects are viewed from the vantage point of the Great Frontier.

The thesis advanced is that one of the powerful forces operating on western civilization since 1500 has been the Great Frontier. And the Great Frontier is identified as all the new lands of the western world discovered by Columbus and his associates around 1500. It comprised North and South America, Australia, a large part of Africa, and thousands of islands scattered over the oceans. In a brief span of time the discoverers brought these continents and these islands and laid them as a free gift in the lap of impoverished and crowded Europe. As a physicist might view it, they brought a new element, a strong ingredient of gigantic proportions, a new force of immense power and strength, and suddenly injected it into the society of western civilization. These new lands—the Great Frontier comprising half of the earth—consisted of a vast body of real estate

¹ *The Great Frontier*, Houghton Mifflin Company, 1952.

and wealth of all descriptions, lands thinly occupied by primitive peoples whose claims were lightly regarded. In effect, these continents and this wealth became the property of the nations of western Europe in an historical instant.

As a result of the injection of such an ingredient, there occurred a tremendous shift in the historical currents. Before the injection, the main forces of western history lay *within* Europe. After the injection Europe was but one factor while another of equal potency and quite different character lay outside in the Great Frontier. These were two poles of a new, enlarged, and electric field. The drama of western history from then until now—for four and one-half centuries—has been in the interaction between these two poles and the culture we know today is largely the product of that interaction.

Let us change the figure of speech and represent modern history as a tapestry woven in a continental frame, the continent of Europe on the right and the Great Frontier on the left. The interaction is like the shuttle going to and fro down the centuries—in migration, trade, commerce and war—weaving fantastic patterns of man's activities over a vast area and a long period of time. In the varied patterns of that tapestry we see blended the elements of the Metropolis of Europe and elements of the Great Frontier, the warp and woof of modern western culture.

Against the background of the tapestry woven of these components, we see modern man devising institutions, ideas, and practices suitable to the new situation, such institutions as capitalism and democracy, the novel idea of progress, the practices of rampant individualism and the marvelous unfolding of a romantic literature to glorify through the imagination all that was going on. We also can see, if we look for it, the rise of most unusual opportunities for the rapid development of pure and applied science. It is the situation existing in this age that gave physics and chemistry their big chance to become profitable and practical arts.

THIS Age of the Great Frontier, extending from 1500 to 1950, falls into two divisions. The first may be called the Age of the Open Frontier, a long period lasting from 1500 to about 1900. The second, the one we are now in, may be called the period of the *closing* frontier, a mere introduction to a longer period that lies before us, the Age of the Closed Frontier. Since we are now only in its beginning, we cannot with any confidence foretell what the Age of the Closed Frontier will bring. But there is one thing of which we can be quite sure: the Age of the Closed Frontier will be very unlike what we have known in modern times. We are now in revolution in the western world, a revolution marking the transition from the Age of the Open Frontier to that of the Closed Frontier. In retrospect this revolution may appear as our fumbling attempts to adjust our lives and institutions to the imperatives of a frontierless society.

Let us turn now to consider the first and longer pe-

riod when the frontier was open. We like to say that it was dynamic, capitalistic, and democratic. Each of these features of the modern age can be related to the Great Frontier.

A dynamic society is one that is moving, going places, and doing things. Of such a society we say—and the term is quite modern—that it is making progress. Physics teaches that dynamism or a current sets up in the physical world when for any reason there is an imbalance. Who will doubt that the sudden injection of the Great Frontier into the fairly stabilized society of western Europe created just such an imbalance, destroyed equilibrium, and set in motion currents of adjustment which made the society dynamic? A clear example of this imbalance may be found in the upset land-man ratio. Late medieval Europe had a fairly stabilized ratio of about 26 persons per square mile. Then came the Great Frontier, making available more than twenty million square miles of land occupied by very few people. The old equilibrium was destroyed, and the currents of migration began to flow from Europe to the new lands to restore the balance and this flow, unchecked until after World War I, created a dynamic situation.

A second imbalance set a current of a different character flowing in the opposite direction. The Great Frontier was a land of vast resources much desired by those who remained in Europe. So, as the surplus people went out to the Great Frontier the wealth of that fabulous land began to flow back on Europe, and the stream mounted continuously until all Europe—and especially those portions which had access to the new lands—was inundated with prosperity. In the general ferment the philosophers advanced the idea of progress and new classes arose to overturn old governments and set up new ones more in harmony with the needs of a dynamic and thriving society.

As for capitalism, it comes easy when both men and wealth have such high mobility. Capitalism is an acquisitive game played by men who are free to act. The game was possible because the potential wealth was so abundant and because the real wealth was increasing faster than the population was growing. The game of playing for profit was interesting, exciting and rewarding. The circumstance of vast potential wealth in one place and many poor but eager people in another justified the coming and going and made possible the return of enough successful winners to keep the tables full. There was, temporarily, sufficient potential wealth in the Great Frontier for everybody to play at getting some of it.

The rise of capitalism was further stimulated by the introduction of frontier gold and silver in quantities unknown before. The first act of the Europeans was to tap the gold and silver storehouses of the New World. From 1500 to 1650 the precious metals poured into Europe, not by the ship load but by the fleet load. Whole armadas were used by the Spaniards to transport it. This flood of gold and silver upset the ratio existing between the amount of money and the number of peo-

ple to share it, between the amount of money and the quantity of goods available. The result was a price revolution based on metals comparable to the one we have had in the last generation based on paper. In the ups and downs of that revolution, according to John Maynard Keynes, modern capitalism was born.

The over-all effect of the advent of the Great Frontier may be summed up by saying that the sudden injection of excess land, excess wealth, excess gold and silver into an acquisitive society created a general boom of gigantic proportions and long duration. The boom lasted so long that we have come to think of it as the normal state, but in reality it was—as all booms are—abnormal. The frontier kept it going for four centuries because it kept the currents of wealth pouring back on the acquisitive and eager society. In this boom men came to believe they had hit the high road to eternal progress and ever increasing prosperity. In the exceptional circumstances and excitement the laws relaxed, the old restraints fell away, and the individual as the principal actor attained an importance he had rarely known before and may not know again. Democracy was born, became the favorite form of political organization, and made its way steadily against all other forms. The accelerating wealth was sufficient to pay for any mistakes, to permit laxity in government, and to provide broad tolerance for human frailty. All deficits were made up by cutting the Great Frontier up into shares and selling the stock on a rising market. Our present economic, political and social institutions formed themselves in and around the boom and served well that which nourished them. There, in a paragraph, is the over-all view of this dynamic western society during the long period when the frontier was open, say from 1500 to 1900 or 1914.

It was in this booming period that the art of physics had its origin and its first opportunity to serve mankind in practical ways. That booming world so full of the stuff that physics works with was an ideal world, made to order with a high premium on what physics had to offer. That world was a physicist's paradise. So much for the rise.

During this abnormal period of expansion and boom two assumptions, both false, came to be accepted as truth. The first was that there would always be a frontier, that it was permanent and not temporal. The corollary to this was that the sources of wealth were also unlimited, and that all we need be concerned with was the method and means, provided largely by applied physics, of acquisition and use. Supply, it was assumed, would automatically equal demand. The second assumption was that the boom was normal, so normal that most men did not realize its existence.

Turning to the period of the closing frontier, the last half century, we find ourselves standing face to face with our previous assumptions, beginning to see how utterly false they are. There will not always be a frontier, and there cannot be an everlasting boom derived from a source that is disappearing. True there is still an imbalance of population between the Metropolis

of Europe and the Great Frontier countries, but immigration laws have cut off the current of adjustment. There is still an imbalance of wealth, the frontier countries having most of the raw materials; the currents of adjustment are still flowing from here to there, but so sluggishly that we have resorted to the force pump. The natural dynamics that operated effectively during the centuries of the open frontier have either been stopped artificially or made to flow artificially. Under these changed conditions, our boom-born institutions have run into crisis after crisis. Both democracy and capitalism have been in trouble since the first world war, and both have given ground for the first time in the modern era. There is now little excess room for the explosive increase in population and there is not enough food in the world for what we have. Who will say that the present situation would not be relieved if some Columbus would enter here and announce that he had brought us three or four rich and empty continents? Then we could be sure of a new lease on the life of the frontier boom, a new lease on the same kind of life we have been accustomed to lead. As it is we find ourselves dressed up in frontier clothes, fully equipped with a fine set of frontier ideas and institutions, and nowhere to go. We are now arrived near the end of an adventurous and exciting age, and our main problem is one of making adjustments to another age that is quite different in character.

THUS far I have said little about physics, though I have tried to picture the conditions surrounding its origin and accompanying its development. I have said that this booming world, full of movement and loaded with materials, was a physicist's paradise, but I also suggested that this paradise was abnormal, a pleasant purgatorial anteroom to a less abundant future state. It is not unthinkable that physics, like democracy and capitalism, may be given pause by the closing of the frontier and the end of the boom, that it too may bog down.

In the midst of the boom physics found unlimited opportunity to become practical, to apply its abstract principles to daily tasks. In its early stages it was concerned primarily with two elements, which I will make bold to call substance and energy. Its practical task was to apply the energy to the substance in such a manner as to procure or produce what would be useful to men. It performed this task so well that it set off a current in history that accelerated the revolution in human living more than anything else known. I refer to the industrial revolution, the first stages of which belonged almost exclusively to applied physics.

What I wish to call attention to is the close connection that existed between applied physics and the Great Frontier. I have said that applied physics deals with energy and substance. The energy used in the modern age has been mainly from the fossil fuels. The Great Frontier is rich in the fossil fuels, having about 56% of the world's coal and 54% of its petroleum. Europe has coal, but is almost destitute of petroleum. As for

substance, stuff to be fabricated and moved, the United States probably has more than Western Europe. In short, the Great Frontier has supplied more than half the energy and a far greater proportion of the substance with which applied physics has worked its magic.

It was in the frontier, in the United States, that physics found the most favorable conditions for a practical demonstration of what it could do. Here men were few, laborers scarce, wages high, and resources abundant. Consequently there was a premium on any device that would convert the resources into wealth with a minimum of human labor. Energy and substance being abundant and demand being great during this period, men could incur any expense that would create machines and provide the power to drive them. As a result the United States in the nineteenth century became an enormous laboratory of applied physics, and a further result of that was an accumulation of wealth equaled only by the destruction of resources.

During this happy period physics—or physicists—shared the false assumptions that both energy and substance were unlimited, that there was plenty more on the frontier, and that there would always be a frontier. Under present conditions applied physics faces the task of performing its services in a world of disappearing fossil energy and of declining substance.

Let us look at energy as represented by the fossil fuels. We may not know how much of it there is, but we do know that the total in storage is an absolute amount and that it cannot be increased by any art yet known to man. We also know that our use of fossil fuels is comparatively recent, and that its destruction is proceeding at an ever accelerating rate. Its total destruction, under the present process, is not only inevitable but in sight. Waldemar Kaempffert in *The New York Times* of September 20, 1953 wrote:

Palmer Putnam of the Atomic Energy Commission turned up at Madison, Wisconsin, last week to tell the American Institute of Biological Sciences the now familiar story of the day when there is no more coal, no more oil, no more gas. What shall we do then for energy? . . . Putnam saw no salvation in atomic energy. . . . We have about three centuries to engage in research and experimenting . . . time enough to devise something that will work. There is no doubt that when the world stands face to face with no combustible fuel and no uranium or thorium, it will sink its differences in the common cause of keeping its factories going.

What the scientist is saying is that within three centuries the sources of energy on which our present civilization is based will be approaching depletion.

The case with the second element, the substance with which applied physics works, is not much different from that of energy. Many of the sources of our essential materials are being depleted in this rich country, and we are now importing some that we formerly exported. At the present rate of use in the face of increasing demands we should find ourselves bankrupt of our key materials at about the same time we are bankrupt of our accustomed form of energy. Looking back three

hundred years, we see that physics played its role in the midst of increasing plenty; looking forward three hundred years, we see that it must in all probability play its role in increasing scarcity of both energy and substance.

From the vantage point of the present we see physics appear between the Metropolis of Europe and the Great Frontier, riding high on the boom when conditions were unusual and abnormal—and highly favorable to this science. Thus far it has been a prime creator of the wealth and luxury we enjoy. In reality physics has in all that time created nothing. It has moved things from one place to another and it has fabricated them, but it has not created any substance. On the contrary physics appears as the great destroyer of both energy and substance. In its first centuries—up to now—physics discounted the future for the present to help give us what Vernon L. Parrington called the Great Barbecue, paid for with irreplaceable capital.

In an imaginative exercise let us view physics in the role of fate. A master tragedian might represent it as a character with uncanny skill and evil intent concealed under the pleasing cloak of preliminary good works. Master of a magic formula for combining energy and substance, physics, like the Pied Piper, has lured men on to the luxury and extravagances of the Big Barbecue. But in doing this, it has progressively destroyed the very elements of its own magic. Seeing men turn on one another—as they have been doing since 1914—for what is left, physics, realizing that its own game is up and that its magic formula can no longer work, ends the play with its supreme gift for destruction, revealing its true character as a destroyer just when the curtain falls on the shattering ruin of civilization itself. By the law of the drama, the main character must see his predicament, he must struggle to avert the disaster, but he is swept along to the inevitable end by forces he can not control, even though he may have originated them.

Since the tragedy has not yet occurred, except in token form, physics may yet have a choice as to what it is going to do in the time remaining. Historically it is faced with a decreasing supply of energy, a diminishing amount of substance, and the demands of an increasing number of people. It had great success in expanding the booming world of abnormal conditions. What will physics do now with a contracting world that is getting back to the normal prefrontier stage? It has known how to act on the false assumption of the infinite and unlimited. How will it respond to the unrelenting facts of the finite?

I have no doubt that the applied physicists will unfold many new devices, for they still have some time. I am sure that people will continue to say with wistful hopefulness that the physicists will open new frontiers and continue to work their old magic. They, along with their fellow scientists, will indeed be men of magic if they open anything comparable in magnitude or influence to what they, and all of us, had in the Great Frontier.