

8.—THE RELATION OF SCIENTIFIC RESEARCH TO ECONOMIC PROBLEMS.

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It would seem quite unnecessary at this period in the history of civilization to plead for the right of science to participate in the discussion of economic problems, or of any problems whatsoever which may concern mankind.

“Natural science is no longer content with the contemplative attitude which sufficed for Newton and Laplace. Science is now concerned with all the personal acts of our existence; she intervenes in all measures of public interest; industry owes to her our immense prosperity; agriculture is regenerated under her fostering care; commerce is forced to take her discoveries into account; the art of war has been transformed by her; politics is bound to admit her into its councils for the government of states. How could it be otherwise? Have not mechanics, physics, chemistry, the natural sciences, become intelligent and necessary agents for the creation of wealth by labor? If comfort is more universal, the life of man more prolonged, wealth better distributed, houses more commodious, furniture and clothing cheaper, the soldier better armed, the finances of the state more prosperous, is it not to the sciences that all this progress is due? Whether we wish it or not, we must needs accept Science as a companion, to possess her or to be possessed by her. If you are ignorant, you are her slave; if you are skilled, she obeys you. The future belongs to Science; unhappy are they who shut their eyes to this truth.”*

We celebrate this year in Chicago the discovery of America, the end of the dark ages, the birth of individual freedom and of popular government. We celebrate at the same time, it seems possible, the beginning of a new epoch. The mediæval renaissance was limited to Europe; ours will embrace all the nations of the earth. It may be that this should be considered the outgrowth and fulfillment of that which marked the end of the middle ages; but whether we are at the beginning of a new movement or the culmination of an old one, the last forty years have undoubtedly witnessed greater changes in the spirit of men's thoughts than the four centuries which had gone before.

* Address of M. Dumas, President of the French Association for the Advancement of Science, at the Fifth Annual Meeting, Clermont-Ferrand, August 18, 1876.

The earlier renaissance gave to man the right and liberty to think and act as he in his own judgment saw fit. The renaissance of to-day is leading men to think, not only with personal freedom, but accurately and rightly. Far be it from me to assert that mankind in general are very much nearer to accurate and just standards of judgment than they were four hundred years ago; but the spirit of to-day favors the untrammelled and searching investigation of every question in which man is concerned, the critical comparison of the results of such investigation, and frank intolerance of all illogical or unsound theory and application. This is the spirit of science, the spirit of unprejudiced search after truth, and this is emphatically the spirit of the thinking men of to-day in every part of the world.

Whatever may be the ultimate and full outcome of the forces now at work, it is certain that a great industrial and economic revolution has already taken place, and that science is fully recognized as the power by which, in future, the material interests of mankind are to be regulated.

Speaking thus of science, it is not my purpose to include solely that body of professional men who are customarily classified as "scientific men." I use the term in a broader sense, with the meaning that every man who applies accurate observation and deduction to the solution of any problem whatsoever is in some degree a man of science.

Science is knowledge, nothing less nor more. It is needless to add the word *exact*, for knowledge which is not exact is not knowledge at all.*

Science aims to be not only exact, but complete, and, when true to itself, never attempts to conceal its own shortcomings.

Scientific methods of work are simply methods based upon accurate knowledge of what is already known and due allowance for the uncertainties of the unknown.

Science implies not only complete and exact knowledge, but accurate methods of thinking based upon it. When there are differences of opinion in regard to the solution of any scientific problem, there is but one way to arrive at the truth: There must be further investigation. This will confirm or set aside the results of previous researches and perhaps bring out new truths as well. Argument is often unscientific. Darwin used little argument in his "Origin of Species"—that wonderful book which has had more influence on the thoughts of the men of this century than any other not religious or ethical. He marshaled his facts in classified ranks, and after a modest suggestion of his own as to what their meaning might be, he left his readers to make deductions for themselves.

Fifty years ago the domain of science was much more restricted than now. Her votaries were few, and there were among them but a limited number of scholars of high ability. Men of energy and ambition found slight inducement to enter this field of activity, for the rewards were manifestly not great, and even opportunities for study and the discovery of truth—the greatest of possible rewards—were almost entirely wanting. Economic science was in a crude state, and the circle of the sciences was limited. The empirical methods of long ago were still very influential in almost every department of study.

* "Knowledge," says Cardinal Newman, "is called by the name of Science or Philosophy, when it is acted upon, informed, or impregnated by reason."

To-day all has changed. Science has ceased to be a pursuit and has become a mode of thought, and is an essential factor of learning in every department thereof, liberal or useful. The philologist, the historian, the social and political economist, and the jurist employ scientific methods. Every intelligent man uses them in the consideration of every serious question.

There are differences of degree in the manner in which individual men are scientific. Scientific research involves four processes: (1) observation; (2) the record of the results of observation; (3) the classification and assimilation of these results; (4) their interpretation, both for immediate use and as a guide for subsequent inquiry.

While facts may be observed effectively by any intelligent man, and may be recorded by any person who has been educated to use instruments of precision and to write, it is only the scholar who can classify these records, assimilate them, and incorporate them with the stores of knowledge already in existence, while the man who makes successful interpretations must be to some extent a philosopher.

I had intended to illustrate my meaning here by citing some instances of the relative importance of these various processes in the consideration of an economic problem, but I am disposed to believe that an illustration of a different character will serve my purpose better, and I quote from Bishop Latimer, in the last sermon which he preached before Edward VI, of England, in 1530:

Here, now [said he]; I remember an argument of Master More's, which he bringeth in a book, that he made against Bilney; and here, by the way, I will tell you a merry toy. Master More was once sent into Kent to try (if it might be) what was the cause of the Goodwin sands and the shelf that stopped up Sandwich-haven. Thither cometh Master More, and calleth all the country before him, such as were thought men of experience, and men that could of likelihood best certify him of the matter concerning the stopping of Sandwich-haven. Among others came in one before him, an old man with a white head, and one that was thought to be little less than an hundred years old. When Master More saw this aged man he thought it expedient to hear him say his mind in this matter (for, being so old a man, it was likely he knew most of any man in that presence and company); so Master More called this old-aged man unto him, and said: "Father," said he, "tell me if ye can, what is the cause of the great arising of the sands and shelves here about this haven, the which stop it up, and no ships can arrive here? Ye are the eldest man that I can espy in this company, so that if any man can tell any cause of it, ye of likelihood can say most to it, or, at leastwise, more than any man here assembled." "Yea, forsooth, good master quoth this old man, for I am well-nigh an hundred years old, and no man here in this company any thing near unto mine age." "Well, then," quod Master More, "how say you to this matter? What think you to be the cause of these shelves and sands that stop up Sandwich-haven?" "Forsooth, sir," quoth he, "I am an old man. I think Tenterden steeple is the cause of Goodwin sands: for I am old man quoth he, and I may remember the building of Tenterden steeple, and I may remember when there was no steeple at all there. And before that Tenterden steeple was in building there was no manner of speaking of any flats or sands that stopt up the haven; and, therefore, I think that Tenterden steeple is the cause of the destroying and decay of Sandwich-haven."

Here is an example of thought which is faulty in all its processes—imperfect observation, substitution of memory for written records, absolute inability to classify and assimilate, and deductions absolutely without relation to the foundations on which they are supposed to rest. Had he lived at the present day this rustic philosopher would have wrongly described himself as a *practical man*. He would have been in error, for nothing is less practical than ignorance and poor thinking.

The most serious obstacle to economic progress is the attitude of a certain class of men who, seemingly proud of their own limitations in knowledge and training, boast

that they are the *practical* men, and therefore best qualified to deal with all material matters. These men are unworthy of the name which they assume. They are our heritage of years gone by. In the familiar language of the day they are "back numbers."

The man truly practical is he who knows the boundaries of his own knowledge.

With exact and full knowledge, the treatment of economic questions is simple and easy. The American farmer understands how to raise a full crop of corn or tobacco on rich soil, and if his soil needs strengthening, or his foes and rivals in the animal or vegetable kingdom become too strong, he may summon experts in agricultural science who know just how to relieve him from his foes.

When, on the other hand, knowledge in regard to an economic problem is inexact or incomplete, it is in the province of scientific research to determine exactly what is to be done. All the facts, or supposed facts, must be brought together, weighed, analyzed, and classified. Prejudices, traditions, and false opinions must be eliminated, and a true estimate must be made of the facts which remain. A map must be drawn showing how much of the field of knowledge has been traversed and how much is unknown—a map corresponding to that of North America at the beginning of the century, which our exploring parties had when they set forth to discover the sources of the Mississippi and the western limits of the continent. Then, aided by all necessary appliances for exact investigation and guided by the most logical methods of deductive reasoning, a series of researches must be begun which shall continue until a full understanding has been reached, not only of the subject itself, but of its relation to the kindred problems which touch it upon every side.

This is the province of modern science in the discussion of economic questions.

The arts and industries of man are separated naturally into two classes. The primary or exploitative industries are those by which the fruits and resources of the earth are gathered. The secondary, the elaborative or manufacturing industries, are those based upon the primary industries, from which and through which they obtain the materials which they elaborate.

The primary industries stand between man and the bounties of Mother Earth. Without their agency he is like Tantalus of old, and not one drop or morsel can he have to supply his simplest needs.

The primary or exploitative industries are arranged in three groups: *Agriculture*, *Mining*, and *Fishery*—the exploitation of the products of the earth's surface, the products of the interior of the earth, the products of the waters.

In each of these fields of activity there should be fuller knowledge in certain definite directions:

- (1) In determining the character and extent of the sources of supply.
- (2) In discovering the least expensive and least wasteful mode of bringing the harvest to the consumer or the manufacturer.
- (3) In the case of agriculture and fisheries, in preventing destruction of the sources, either by protective restriction or by artificial replenishment.

Of the three the fisheries are most in need of scientific aid. The mines are always under the control of individuals, whose personal interest forces them to be prudent. Agriculture is based upon individual proprietorship, and the improvident and careless farmer or stock-breeder at once feels the results of his own shortcomings. In the fisheries, however, individual wants are lost sight of in individual rivalries, and although the preservation of aquatic animals is a matter of national importance, reckless men with engines for wholesale capture may entirely exterminate the inhabi-

tants of a lake or a river, and almost depopulate the waters of a coast. This may be done without the knowledge of the public, and indeed before the fishermen themselves recognize the consequence of their own improvidence.

The only parallel to this is in the destruction of the forests, in which individual owners may cause national disaster. The lumberman, however, is checked in his work of destruction to a greater degree than the fisherman, for his operations, being visible to all, are more subject to control by public opinion.

It appears, then, that one of the most potent of all motives—self-interest—affects two classes of industries in directions which are diametrically opposite. For agriculture and the mines it is conservative, while for the fisheries it is essentially destructive.

The secondary or elaborative industries—those by which the products of the primary industries are elaborated to supply the manifold necessities of modern civilization—have also need of scientific direction and the application of the most improved methods known in chemistry, physics, and mechanics.

Through the agency of the arts and handicrafts man is supplied with clothing, shelter, amusement, and intellectual occupation, and the great system of accessories and refinements with which these are associated in civilized life. In the conduct of the secondary industries, however, private interest is sufficiently potent to force the men in control to utilize the latest results of scientific discovery, and is strictly conservative.

The importance of securing the aid of science for the solution of economic problems has for the last fifty years been very generally recognized in this country. No better proof can be found than the liberality with which the Congress of the United States, in such matters usually the embodiment of the will of the thoughtful majority, has provided for scientific aid for all the great industries.

In these days of progressive democracy, governments are working more and more for the benefit of the people at large. The founders of our Republic never ceased to insist that the safety of a free government must depend upon the enlightenment and intelligence of its citizens. They understood, also, that its industrial and economic welfare requires the application of enlightened knowledge to the administration of every industry. The whole public record of Washington, Jefferson, Franklin, and their associates bears witness to this.

The mediation of government seems, in a Republic like ours at least, to be essential in order to secure, for the benefit of the people at large, the immediate advantages of the results of new scientific discoveries, which would otherwise be appropriated, for the most part, for the personal profit of limited classes.

It is manifest that all cannot be left to the universities and colleges. Their self-imposed and evidently proper limitations forbid. Indeed there are many wise men who maintain that these limitations should be increased. These insist that the sole duty of a university should be to *teach* universal knowledge. The *increase* of knowledge is, in their opinion, the proper function of an academy of sciences.

Now, academies of sciences exactly corresponding to those of the Old World do not exist on this twin continent of Republics. Such academies remind one of the lordly salmon, of which it was once said that it could only survive in rivers which were under the shadow of a throne. This was before the days of public fish-culture. Academies are associated with forms of society in which aristocratic ideals prevail. Membership is limited, and is a mark of personal distinction. Successful discoveries are rewarded by decorations and titles of honor, by governmental subsidy, even more

effective than grants in direct aid of research, and there are liberal appropriations of money as well. Our own academies of science are no less honorable and efficient, but they receive neither money nor recognition from the Government, and though, as in the case of the National Academy of Sciences, often responding to calls for gratuitous advice, are never used by the nation as public agencies for the *increase* of knowledge.

The real analogues under our Government of the European academies of sciences are the scientific bureaus, whose officers are the salaried agents of the nation.

A scientific investigator, working in his own laboratory, directs his studies in the channels most agreeable to himself. If not influenced by the need of money-getting, he will, as a rule, pursue some branch of *pure science*, for the love of knowledge or in the hope of fame. In the college and university laboratories the tendency is always to seek for the discovery of principles rather than to make economic applications of those already familiar—to the pursuit of knowledge for its own sake.

Universities do not often encourage or even tolerate studies in applied science, for the reason that these are not so well calculated to direct the minds of their students to the highest intellectual ideals. It is well that this is so; for our universities by their work in pure science have rendered possible almost all which has been done in economic science, and have done far more for the material advancement of the world than they could have done with more practical ends immediately in view.

The attitude of a government when it subsidizes scientific workers is always more or less sordid, and as unlike as possible to what we desire to believe to be the spirit of science itself, as it is cultivated in the universities. We should be grateful, nevertheless, for evidences of liberality wherever they are manifested, and supremely thankful that our law-makers rarely object to allowing work of a scientific character to be done when there is reason to hope that it may ultimately serve as a foundation for economic applications.

A very wholesome condition is manifest in the confidence which is shown in the scientific bureaus, both by the heads of the Government and by the people. Questions of politics have never been considered in the selection of the scientific officers of the Government so far as the National Government is concerned, and the advice of the universities and the scientific men has always been sought and regarded. I speak from the observations of twenty years' residence in the National Capital. Once selected, these officers are held responsible solely for the results of their work, and have only been criticised in the rare instances where, after long waiting, adequate results have seemed to be lacking.

The confidence of the people is quite as remarkable, and to this may be ascribed much of our national industrial welfare. When perplexities arise in any industrial enterprise, through lack of knowledge or experience, it rarely happens that the aid of science is not invoked, and in the case of the primary industries at least it is usually a Federal or State scientific bureau which is the agency selected.

I read not long ago an editorial in the London *Athenaeum* in which it was said that there is not a department of the British Government to which a citizen had a right to apply for information upon a scientific question. This seems hard to believe, for I cannot think of any scientific subject regarding which a letter, if addressed to the scientific bureaus in Washington, would not receive a full and practical reply. It is estimated that not less than 30,000 such letters are received each year. The Smithsonian Institution and National Museum alone receive about 10,000, and the

proportion of these from the new States and Territories, which have not yet developed institutions of learning of their own, is the largest. An intelligent question from a farmer on the frontier receives as much attention as a communication from a royal academy of sciences, and often takes more time for the preparation of the reply.

One source of this public confidence is the fullness of the annual reports of the several bureaus and the extent of the editions for general distribution. These reports contain not only the results of the year's work, but appendices which illustrate the methods of work, and then, taking the reader into confidence, show him the manner in which conclusions are reached. It would be a national misfortune if the protests of specialists and book-dealers were to result in reducing the editions of these reports. The 500,000 reports annually sent out from the Department of Agriculture are none too many, and the waste of an inconsiderable percentage of them is of no moment when the enlightening effect of the whole is properly estimated.

The government of the United States does nothing for our manufacturing interests, save to collect their statistics, protect them against foreign competition, and gather information about foreign markets through the consular system and the Bureau of American Republics. It has however provided for the primary industries—agriculture, mining, and fisheries—with great liberality and with an amount of intelligence which is even more noteworthy.

The interests of agriculture are attended to by a bureau which, after a consistent and wholesome growth of three decades, has attained to the rank of a Department, and which receives for the current year an appropriation of three millions of dollars. The plan of this Department is to place at the disposal of the farmer all the results of the sciences, and when necessary to apply them for his benefit, as is done in the Weather Bureau. It makes new discoveries and shows how old ones shall be applied, and it publishes information broadcast throughout the land. In further prosecution of its plans the government aids each State government in maintaining a local center of investigation and education, appropriating for this purpose about seven hundred thousand dollars for the current year, which is supplemented by an equal or greater annual expenditure on the part of the several State governments.

For the benefit of the mines we have the Geological Survey, the history of which extends over a period of nearly twenty-five years, during which it has made a consistent and healthy growth. Its work is of the utmost importance, not only to the mining industries but to agriculture as well—an importance which will be much greater in the years to come, when the surface supplies shall have become depleted. In this work, too, the general government is seconded by the State governments, many of which have local agencies of their own. With comparatively few exceptions, all the scientific geologists of the country are engaged in the official surveys, either of the government or of the States.

Ten years ago, in a paper upon "The Status of the U. S. Fish Commission in 1883," I took occasion to quote the opinions of scientific experts in all parts of the world, in criticism and commendation of the manner in which the problems of fish-culture were treated, as illustrated at the International Fisheries Exhibition in London. The displays of the United States in Berlin in 1880, and in London in 1883, resulted in a complete change of public policy throughout Europe; for on those occasions the world saw demonstrated the essential distinction between private and public fish-culture. Private fish-culture is, like poultry-raising, a field for individual effort with private

capital, for purposes of personal gain. Public fish-culture has to do with the preservation and renovation of the great source of public supply—a field to be compassed in part by the States, but in its broader developments only properly covered by national or international enterprise.

Public fish-culture, as now known, in Europe, Asia, Australia, and America is actually the result of the liberal policy of the Government of the United States in securing, for the national good, scientific talent of a very high order.

The problems of fisheries and fish-culture require, more particularly than those in any other field, the skill and experience of trained scientific investigators.

The miner and the agriculturist have to do with phenomena which are visible and tangible. The culture of terrestrial plants and animals is comparatively simple, because they are affected by changes in climate and temperature which we ourselves feel and appreciate. The fisherman and the fish-culturist, on the other hand, have to do with living organisms, whose presence and movements are uncertain and often seemingly mysterious, and which exist under conditions which he can understand only after they have been interpreted for him by science.

The study of these difficult problems has drawn to it many great naturalists, among them such men as Duhamel du Monceau, Agassiz, Vogt, Huxley, Quatrefages, Coste, Von Siebold, and Baird, and the greatest of these was Baird.

I wish I could properly eulogize the wise, the judicious, the practical plan of work which was devised by our first National Commissioner of Fisheries, when he entered upon his duties in 1871; then the results, as partly reviewed by himself in the last year of his life, in his paper on "The Sea Fisheries of North America," posthumously published, or in his later reports to Congress, and also in the volumes on "The Fishery Industries of the United States," in which the members of his staff endeavored to summarize the knowledge which had been developed under his direction. Time will not permit me to do this, and it is unnecessary, for the results are familiar to you all.

I should be glad, also, to take up the achievements of the National Commission during the past five years and to point out how success has been achieved in all lines of work previously decided upon, while new paths have been laid out in the light of new results which have been attained.

After all, what more can be said than that it is living up to the high ideals of its founder, the illustrious Baird, and that it has never failed to meet the constantly increasing demands upon its resources, whether in the field of science or in that of practice, and that it is one of the best examples of the way in which science may be utilized in behalf of a great industry.

The work of the State fish commissions also deserves high praise. Some of the States have but a small interest in fish-culture and have not organized the work on a large scale, and some States have done less than they should have done, but taking them together the aggregate of good work is very considerable and well worthy of mention not only in the field of scientific inquiry, but still more so in respect to judicious application of the results of science. The way in which the State commissioners have coöperated with each other and with the National Commission in every department of fishery economics is a noteworthy example of the manner in which the States may work together for mutual good.

The most significant tribute to the American methods is the constant attention which they receive from the rest of the world. Within the past ten years I have seen

a constant stream of special commissioners from England, Scotland, and Ireland, from Norway and Sweden, from Germany and Austria, from France and Italy, Russia, Finland, and Siberia, from Australia, New Zealand, and Japan, coming as agents of their own Governments, and devoting months and sometimes even years to the study of the methods employed by the Nation and the States, and on their return embodying these results in official reports which are full of praise and approval.

In the application of scientific research to the problems of the fisheries and fish-culture, the duty of the United States in the future appears to be very manifest. The National and State Commissions must be strengthened and encouraged to carry out to the fullest extent all legitimate lines of investigation. Their work will not be ended until the following results shall have been accomplished:

First. There should be a complete physical and biological survey of every hydrographic basin and every mile of coast upon the continent. The survey of the coast begun by the United States Fish Commission in its first year is still being carried on with admirable results, and too much cannot be said in praise of the thorough system of exploration of the various river-basins established by the present Commissioner.

Second. We should attain to an understanding of life-histories (including the embryology) of all aquatic animals of economic value, and of the animals and plants with which they are associated, which may be directly or indirectly beneficial or injurious. This work, too, has been carried rapidly forward by the Federal and State commissions and by many of our colleges, and, although much remains to be done, the mass of information accumulated and assimilated within the past twenty years has been one of the most important factors in bringing about recent advances in fishery economics.

Third. There should be an understanding of all physical and biological problems involved in the practical work of artificial culture. Here, too, there has already been an advance of great magnitude, especially in America; and the forms of apparatus for fish breeding and transportation, devised in this country under the eye of experts in the various mechanical sciences and with the advice of the biologists, have replaced almost without exception those in use twenty years ago.

Fourth. The results of past scientific inquiry should be made effective by framing a consistent code of Federal and State laws for the protection and preservation of the sources of fishery supply. It is doubtful whether such a code exists in any part of the world, and it may be that the time has not yet come for framing it, but I should regard the adoption of a wise and effective law and its successful application as a supreme test of the wisdom of our public men and their scientific advisers.

Fifth. All depleted waters should be repopulated with fishes in their former abundance, or in even greater plenty than at the time of the discovery of America, and unproductive waters must be thoroughly stocked.

Sixth. A school should be established for training fishermen, fishery administrators, and fish-culturists, and (with the coöperation of the universities) of biological investigators. Such a school might be established in the great laboratory building erected by Professor Baird at Woods Holl. Here, at slight expense, might be maintained one of the principal biological establishments and the greatest fishery school in the world. Norway and Sweden, Japan and Germany, have schools for fishermen. England, France, and Holland maintain biological laboratories; and these and almost every nation in Europe contribute to the support of the great International Zoölogical Station at Naples. Why should not our Government, with the coöperation of the

States, maintain a great central establishment of this kind, to do for the fisheries and the sciences upon which they depend what agriculture and agricultural science have had done for them by means of the forty-nine agricultural experiment stations and the almost equal number of agricultural colleges with which they are connected?

Seventh. We should create a national association, after the model of the *Deutscher Fischerei Verein*, in which fishermen, fish-culturists, legislators, social economists, and philanthropists may work together to develop enlightened public opinion and to promote the interests of the nation and of mankind in this department of human activity.

If all these ends shall be attained for the fisheries, and the work of the Government for agriculture, forestry, and the mines shall be carried to equally abundant and beneficent results, we may then feel a just pride in the ability of our Republic to make its public institutions serve the economic interests of the people.