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A Panoramic View of Eighteenth Century

Natural Science in America

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Introduction

One obstacle in looking at the natural science of two centuries ago is almost impossible to overcome. That is the obstacle described by T. S. Kuhn, who showed for any one time in the history of a science that scientific work is carried out either under the umbrella of a "paradigm" or while the paradigm changes.¹ The paradigm is the set of assumptions which the scientist uses in order that he carry out his work. For example, once men thought that the earth is fixed and that the sun and other heavenly bodies move around the fixed earth. This idea or paradigm conditioned them. When eventually it was suggested that certain scientific results, i.e., astronomical observations, could be better explained using another paradigm, the thinkers of the day had great difficulty in giving up the older idea which had shaped their thinking.

Kuhn claims that the history of

natural science is first of all the history of the change of paradigms and secondly the history of what happened during the periods in which each successive paradigm was accepted. The problem that any historian of science has is his inability to remove himself from the paradigm of his own day. There have been paradigm changes in each of the natural sciences since the eighteenth century, and consequently there is a certain artificiality in our recounting and attempting to understand what went on at that time. It is easy to illustrate this point by taking an example from chemistry. We today cannot conceive of a substance which has negative weight. We would say that talking about negative weight is talking nonsense; negative weight does not fit into our picture of the world. That is, the paradigm we use in all the physical sciences, including chemistry—even though we might not be physical scientists—does not permit the concept of negative weight. But the eighteenth cen-

tury chemists did hold that there was substance which could have negative weight, a substance called "phlogiston." By the end of the century they were arguing bitterly as to whether or not this substance existed, and some scientists, Thomas Jefferson among them, refused to change their minds. While we cannot conceive of a world in which substance has negative weight, those scientists could not conceive of a world in which negative weight is impossible. It is clear that this kind of problem, our inability to think eighteenth century scientific thoughts, limits us in our understanding of what happened in natural science in that century.

It would be futile to recount the isolated facts of the history of eighteenth century science in America without first attempting to understand what motivated the eighteenth century man. Let us focus our attention first of all on what happened in earlier years to produce the eighteenth century climate. Michelangelo, symbolic of much that was fine in the arts, died in 1564. He was followed by many other giants in the branches of the arts, but something else began to happen. Galileo was born three days before Michelangelo died. Because of Galileo's work in physics and astronomy, the world was never the same again. Galileo died in 1642, the year the great Isaac Newton was born. Newton built on the work of Galileo and developed a physical picture of the world which became universally accepted in his lifetime and which in some ways (although paradigm change must be taken into account) is the picture we still have. Newton's great work was summarized in his book, Philosophiae Naturalis Principia Mathematica, published in 1687.

Newton's work in physics, such as in the science of motion and in optics, suddenly gave people the idea that everything in the universe is something man can know. Because of Newton's work determinism and scientific optimism were on their merry way. One wonders what the English Enlightenment would have been without the work of Newton. At

any rate, men widely believed that they could not only know but that they could also determine what would happen in the future, much as one can determine what a machine will do. The world was nothing more than a machine; mystery had been removed. God had made a clock and man could determine what made it tick. A couplet of Alexander Pope written many years later said it well: "Nature and Nature's laws lay hid in night. / God said, Let Newton be! and all was light." Today the paradigm in physics is different, but in a restricted way we can still use Newton's laws and it is possible for us to sense what kind of spirit existed in both Europe and America as the eighteenth century began.

Thus it was that in eighteenth century America men were optimistic concerning what work in natural science could do. We think we live at a time in which many people say that scientific activity can solve all our problems. Evidently the optimism of the eighteenth century was more universally held. The sky was the limit. The other side of scientific activity had not yet been seen.

* It was one thing to be optimistic. It was another thing to get the job done. For the most part, America simply was not the place where scientific work could best be carried out. In Europe, there was an intellectual heritage whose fruits were evident in the great universities and libraries of the day. There were rich patrons of the sciences and those interested in scientific work could talk with each other. In the first part of the eighteenth century in America there was no such heritage; patrons were almost unknown; and because only a few were engaged in scientific work, it was not easy to have the benefit of face-to-face communication with others. Late in the century Boston and Philadelphia became centers of what activity there was, but for most of the century personal communication, so invaluable in this kind of work, was mostly by letter and at no time did the Americans have the advantage of being close to the great

minds of European science. Of course, many of the educated Americans who did scientific work did receive their education in Europe.

The factors mentioned, coupled with the fact that prior to 1735 there was little intercolonial transportation, meant that the first third of the century saw almost no scientific achievement and that our account can begin with what was going on in the 1730's.

Natural Science in the Middle Third of the Eighteenth Century

If we had no prior knowledge concerning which of the natural sciences first became important in America, we still might be able to guess correctly which science achieved that position.² In the early days there was widespread interest in natural history in America. The reasons are obvious. Because of the Enlightenment, Europeans, Americans, and many others wanted to know much more about what was in the world; the world was now something which could be investigated and having been investigated could serve man. As more and more was found out about the living things of the New World; it was realized that here were fantastic numbers of living things which were not known to

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Europeans. The desire for knowledge of the natural history of America could hardly be satisfied. As early as the first part of the seventeenth century Shakespeare said (in *The Tempest*), “When they will not give a doit to relieve a lame beggar, they

will lay out ten to see a dead Indian.” Wild rumors spread easily in a world curious to know more about this strange place, America. In Constantinople a book was published showing a picture of the American wakwak tree, a tree which bore women.

Thus, Americans could carry out a considerable amount of scientific work in natural history because they lived just where they could best investigate. They had the advantage of position. In England, France, The Netherlands, and other European countries it was common for the wealthy or royalty to maintain large, formal gardens and consequently exotic American plants were much in demand. In the gardens of one English nobleman there were ten thousand American plants. The demand for these plants was so great that stealing from these large gardens became a problem. Paradoxically, the English parliament decided that this crime was to be punished by sending the perpetrators to America. Thus, there were wealthy Europeans who acted as patrons for Americans in their work in natural history. Plants were collected, seeds were preserved and distributed, knowledge was codified, and articles and books on the natural history of the various parts of the colonies were written largely because of the interest Europeans had in such matters.

The leading American naturalist of the colonial period was John Bartram, whose work began in the 1740's and continued for several decades. Bartram, a nurseryman whose farm was near the Schuylkill River in Pennsylvania, roamed the colonies collecting seeds and information. He recorded what he found in his journal. Europeans codified what he recorded; he was content not to be involved with the theoretical side of his work.

There were many others. A leader among them was Cadwalleder Colden. Colden, educated in Scotland and England, was considerably more sophisticated than Bartram. Bartram did not (or could not) classify his discoveries according to the Linnaen system, the system still used today

which was devised by the great eighteenth century Swedish biologist, Carl Linneaus. Colden, however, not only made extensive discoveries but also used this system so well that Linneaus called him "Summus Perfectus" among scientists. It tells us quite a bit about American science of the colonial period when we realize that we must continually ascertain what Europeans thought of American developments before we can evaluate those developments.

Evidently worthwhile scientific work could be carried out by those, like Bartram, who did not have extensive formal education. But such education always is the key to sustained successes in science. Among those scientifically inclined, it was the physicians of the eighteenth century who received the best education. This education was received in Europe, quite often in Scotland. Much of the scientific work carried out in America was the work of physicians, and so, in this way also, Europe affected the course of American scientific development.

In the physical sciences Americans did not have the advantage of position. Instead, they had the disadvantage of position. Normally, chemists and physicists cannot work alone: they need the intellectual undergirding and stimulation found in universities and other kinds of research centers. Thus, when a Benjamin Franklin appeared on the scene in the eighteenth century, his conclusions and discoveries in physics amazed men in many countries. The thinking eighteenth century man was convinced that the nature of things could be discovered and comprehended, and that as a result of such comprehension useful things could be invented. Franklin satisfied such a man on all counts. He did theoretical work in electricity and he invented using his theoretical work as a basis. In 1751 there was published a collection of Franklin's letters, Experiments and Observations in Electricity. He postulated the positive-negative nature of electricity and suggested that it is a fluid. With his insights, it was possible for him to be the first to describe the lightning

rod. The response was tremendous. Franklin, the "simple American," took the world by storm. Thanks and congratulations poured in from the King of France and a host of lesser personages. Franklin was the first American recognized as a leading scientist of the world.

Most of those who were active in the physical sciences could be active only in subjects which did not have so much dependence on what had been learned earlier and was being taught in the universities of Europe. Although observational astronomy was even then a very ancient science, Americans had the advantage of position (since, of course, certain observations could be made only in America) and they used this advantage. In particular, there were planetary transits of the sun in 1753, 1761, and 1769 which could be observed (among other places) in America. The observations were desired for the purpose of calculating the all-important astronomical unit, the earth-sun distance. (The American contribution to the study of these transits belongs to the discussion of the last third of the century, and so the remaining discussion of astronomy is deferred until the next section.)

An illustration of the difficulty which Americans encountered in the physical sciences in this period is given by the rather pathetic story of the last years of the life of Cadwallader Colden, the great naturalist. Colden thought that he was a seminal thinker in physics and that his ideas started where those of Newton stopped. Colden thought he had discovered the cause of gravitation. Some responses to Colden's work indicated his conclusions were absurd; others, who did not want to hurt him, said they withheld judgment. Bartram was puzzled and was quoted as saying that Colden's ideas were too much to consider until after harvest. It is apparent that Colden never truly understood either Newton or those who criticized Colden. He spent his last years revising his theories, never realizing that revision was not the answer.

How did American scientists com-

municate with each other? We assume today that scientific communication requires the existence of scientific societies and journals. In the middle third of the eighteenth century there were no scientific journals published in America, although a few persons belonged to the Royal Society, which did publish a journal. It was quite common to publish one's scientific results in newspapers; evidently scientific work was much closer to the comprehension of the average man than it is today. Often results were communicated in private letters. As for societies, a medical society started around 1736 lasted for at least eight years. In 1743 Bartram and Franklin were instrumental in starting the American Philosophical Society. Politicians and others who did not carry out scientific work contributed much of the membership and consequently the society was dead by 1747. Not for many years was there a viable scientific society.

The schools which existed did not contribute significantly to the scientific developments of the day. Harvard was the most prominent school; others were Yale, College of Philadelphia, King's College, College of Rhode Island, College of New Jersey, and William and Mary. Eventually, of course, American science became very important and some of these schools played a prominent role in that development. But that story does not belong to the eighteenth century.

Natural Science from 1765 to 1780

Americans continued to be very optimistic about what studying the world could do for them, even though the results of their studies were minimal. Franklin's homilies reflected what men thought was accomplished by hard work, and it was fitting that he was one person who was successful in going all the way from the theoretical to the practical. Throughout this period Franklin was a leading scientist and in the later part of the period he was revered as an elder statesman of science.

The work of physicians became more

important in this period. Laws regulating the practice of medicine, including examinations for those who wished to practice, were introduced. Many local medical societies were started. In 1773 Virginia opened the first hospital devoted exclusively to mental patients. The first American medical school was that of the University of Pennsylvania in Philadelphia; in 1768, the year of its first graduating class, there were forty students in that school. Benjamin Rush, considered to be one of the leading American chemists of the early period, taught in this school and, having been trained in Edinburgh, said that he hoped that the new medical school would help Philadelphia become the "Edinburgh of America." New York City saw its medical school produce its first graduates in 1769.

Thus, serious medical work began in the colonies just as American patriotism was becoming as intense as it had ever been in the colonial period. Medical men were enthusiastic about what an American approach to medicine could mean. Was it possible, it was asked, to reorganize what had been learned in Europe, and thereby bring the science of medicine higher than it had ever been? As in so many matters, American patriotic optimism was far greater than was justified for that day. It is true that some of those dreams eventually were realized, but it is also true that the prophets of the 1770's and 1780's did not live to see the changes which they predicted, changes which did not come about for several generations.

There were renewed efforts to form an American scientific society. In 1767-8 both the American Society and the American Philosophical Society were started. (The latter claimed to be the continuation of the old American Philosophical Society.) They vied for leadership and competed for members. Both were based in Philadelphia. Their (somewhat inflated) combined membership was 273 when they made peace and joined to form a single society, to be called the "American Philosophical Society, Held at Philadelphia, for

Promoting Useful Knowledge." If we compare that number with the population of the colonies and make a similar comparison between scientific society membership and population for present-day America, we find that on a percentage basis at least fifteen times as many people now belong to scientific societies as did then. This comparison tells us the same thing which we learn by making other comparisons, that is, activity in the natural sciences was not very important in the lives of eighteenth century Americans.

The main purpose of the Society was to publish scientific results. The first issue of the Transactions of the American Philosophical Society, published in 1771, consisted largely of papers describing American observations of the 1769 Venus transit. The issue was the occasion of worldwide acclaim and it is generally considered to be the best pre-Revolutionary scientific enterprise of Americans. This development did not insure that American science was now on the way to success. After all, the second issue of the Transactions did not appear until 1786, and it was considered not to be as good as the first.

Partly because Americans had the advantage of position enabling them to make certain observations, the study of astronomy in eighteenth century America was more successful than the study of any other physical science. At least three reasons contributing to the interest in astronomy can be identified. First, America tended to produce men who not only worked with their hands but who also became adept at building new things. The best example of such a person was David Rittenhouse, the clockmaker who also could build one of the finest telescopes of the day. He also built orreries, instruments which could display the relative positions of the planets for the next 5000 years. Interest in the orrery suggests the second reason the eighteenth century American wanted to know more about astronomy. The motions of the stars and the planets are predictable and regular, just as the man of the Enlightenment

would expect. The universe was thought to be an orderly, divine machine. Why shouldn't man be able to imitate God and build an instrument which imitated the motions of the heavenly bodies?

The third reason astronomy was important reflects the practical interests of the colonists. Astronomical observations could aid surveying and navigation, both extremely important activities in a nation that was being settled and becoming a seafaring nation. For example, the services of two English astronomers, Charles Mason and Jeremiah Dixon, were used to draw part of the boundary between Maryland and Pennsylvania, the boundary which when extended westward became so important in a later period of American history, when the Mason-Dixon line divided North and South.

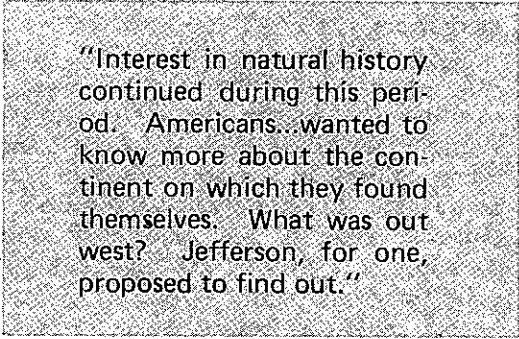
Three times in the late colonial period planets, as viewed from America, crossed the sun. These transits were visible in certain other parts of the earth also, but because they were visible in America there was among Americans particular interest in making observations which might become important contributions to the science of astronomy. It is possible from observation of a transit to determine the fundamental astronomical unit of length, the distance from the earth to the sun. The time at which the planet begins to cross the sun's disc, the time it leaves the disc, the time elapsed, and the exact place on the surface of the earth that the measurements are made can all be measured. It is possible to make these measurements at more than one place on the surface of the earth and to compare such measurements. Not all of these measurements are necessary to determine the earth-sun distance: the desired distance can be obtained by using different combinations of these measurements. There was a Mercury transit in 1753, a Venus transit in 1761, and another Venus transit in 1769. The first two served to interest people in the question: the science was not developed enough for many observations to be made; also, the 1761 transit

was not visible in settled areas. Another reason for interest in the 1769 transit was that there would not be another transit until 1874, and it was assumed that the value of the earth-sun distance would be a much-desired quantity in the intervening years.

Most of those who made observations did not understand how the earth-sun distance could be calculated from the observational data. Consequently, not all observers made the right combination of measurements listed above. But some good work was done (the best telescopes were made by David Rittenhouse and John Winthrop of Harvard) and in all there are 22 known sets of American results. Several of these found their way into the Transactions of the Royal Society and were published in the first issue of the Transactions of the American Philosophical Society in 1771. The best observations of all, which yielded an earth-sun distance of 93 million miles, close to the presently-accepted value, were made in other parts of the world. Nevertheless, American national pride was involved and this scientific effort without doubt gave impetus to a more general interest in science.

Other developments in the physical sciences were mostly related to practical matters. Since surveying and navigation were important, there was interest in finding a general law which would predict for any place how many degrees the compass needle deviates from pointing true north. Of course, there is no such law (such a law would be analogous to a law which would give, according to the position on the map, the heights of mountains, or the shape of a coastline, etc.) but that did not prevent a law from being "discovered." Weather and climate were considered important and so instruments to measure temperature, pressure, humidity, and wind direction and speed were built. The interest in electricity always was closely related to an interest in practical things in both Europe and America. It was even reported during this period that at least one person was cured

of disease by means of lightning. The physical sciences have never flourished where there was not at the same time serious work in mathematics, and so something of the state of affairs in colonial America is revealed by the absence of a mathematics community. As for work in chemistry, another physical science, all that can be said is that chemical work in the modern sense was only beginning in the eighteenth century and, in fact, it



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can be maintained that no modern developments were possible until Lavoisier put the use of the chemical balance on a firm basis in the last part of the century. None of those early key developments took place in America, although Joseph Priestley, whose work in England led to Lavoisier's conclusions, did live in Pennsylvania for a while. The first chemical society in America—concerned chiefly with minerals—dates from 1789. Today one of the largest scientific societies in the world is the American Chemical Society; it is significant for our study that in 1976 the American Chemical Society is celebrating its centennial, not its bicentennial.

Interest in natural history continued during this period. Americans were now not so much serving the interests of Europeans; rather, they simply wanted to know more about the continent on which they found themselves. What was out west? Jefferson, for one, proposed to find out. In the 1780's Jefferson, while he was in Paris, contacted John Ledyard, an explorer, and together they planned that Ledyard

would go from eastern Europe to Siberia and then to what is now the western coast of the United States. Then he would travel overland to the east coast. The plan did not succeed (Ledyard was sent by the Russian police back to where he came from when he was in Siberia within 500 miles of the Pacific) but it does indicate the trend of American thought. Americans believed that there were vast natural resources to the west of the settled region in the east and they wanted to learn more.

The Revolutionary War was responsible for some disruptions in the work of scientists in America, and yet certain disruptions we might expect did not occur. Some colleges were closed down for part of the War. Scientists who were American patriots, such as the astronomer John Winthrop at Harvard (who died in 1779), could work only with difficulty. Rittenhouse, always an active person, quit scientific work for most of the war in favor of activity in the Council of Safety and serving in the state assembly of Pennsylvania. But what is surprising is the ease with which American scientists could communicate not only with foreign scientists in general but with British scientists in particular. It was considered that scientific work was not to be associated with national loyalties. Franklin himself, from his station in Paris, served as a link whereby British and American scientists could contact each other. Probably the attitude which produced this situation was due not so much to lofty ideas about the nature of scientific work, but rather to the unimportance of scientific work in the war effort.

Natural Science in the Post-Revolutionary Period

The successful conclusion of the Revolution convinced Americans more than ever before that faith could be put in scientific activity. Free men could examine the book of nature. Even during the war John Warren predicted optimistically that the arts and sciences would flourish

in the United States, that the United States would become the most powerful empire in history, and (incredibly) that the population of the United States by the year 2000 would be 1.5 billion. In a July 4, 1787 oration Joel Barlow said, "The present is an age of philosophy, and America, the empire of reason. Here neither the pageantry of courts nor the glooms of superstition have dazzled or beclouded the mind." Noah Webster put it only slightly differently: "Next to the sacred writings those books which teach us the principles of science and lay the basis on which all our future improvements must be built, best deserve the patronage of the public." It was even believed that the regularity of the universe, now seen because men were following Newton in physics, meant that there should also be a scientific basis for governmental laws, state constitutions, etc.

This optimism was not based on what was actually happening. The total number of scientists continued to be small. There still were no great libraries and centers of scientific work. Scientific society efforts were feeble. The best that can be said of this period is that there was a slow improvement, and that after many decades passed the stream that had been a small trickle grew into a mighty river.

Developments in the physical sciences came very slowly partially because of a false optimism. There had been many successes in natural history primarily because one could observe new plants and animals indigenous to the New World. Consequently, many persons felt that all that is necessary in the physical sciences is "just do the experiment" or "just look at nature." Apparently it was not well enough understood how important it is that a physical scientist (or anyone else in a basic science) be a part of a scientific community and that he can only be a part of that community after he has undergone intense training for many years.

The leaders in the physical sciences were still Rittenhouse and Franklin. Franklin was widely acclaimed for his earlier

successes, but most of his time was taken up with work outside the natural sciences. Rittenhouse produced at a steady rate, studying magnetism and optics while he continued building astronomical equipment and making astronomical observations. On the other hand, there was no shortage of scientific quackery. Interest in why the compass did not point in the same direction in different places continued, and so John Churchman developed a theory which was spectacular if it was anything. He postulated the existence of two earth satellites, one over each of the two poles, with a period of 463 years for the northern satellite. Scientists scoffed at him. He tried to improve his theory, saying that the satellites might be rolling over the earth's surface, or possibly on the inside of the earth. Unfortunately, some non-scientists were taken in by the theory. James Madison proposed to the First Congress that an expedition be sent to Baffin Bay to investigate the satellite question. The proposal was rejected not because the theory was scientifically unsound, but rather because it would cost too much and the project's results would not be useful enough.

An emphasis on technology, as contrasted with basic science, an emphasis which dominated American work in science and technology up to World War II, existed as early as the last decades of the eighteenth century. For example, after the first manned balloon flight took place in France in 1783 there was an intense interest in balloons in America. Perhaps a hot air balloon constructed at Yale in 1785 caught the spirit of the times. Surely it would be successful, for there were displayed on the balloon the figure of an angel, an American flag, and a motto in seven languages. Franklin predicted that the day might come when a nation would have as many as 5000 balloons, each manned by two soldiers, and that consequently war might be prevented.

Is there significance for later generations in what happened in the natural sciences in eighteenth century America?

Perhaps what was said and done does not have quite the same relation to later history as did other sequences of events in eighteenth century America. Suppose that the American experiment would have ended at the end of the eighteenth century. What contributions of the short-lived American nation would have lived? Surely a good case could be made for the idea that certain political documents, some literature, and some other cultural contributions could have long outlasted that nation. But it is doubtful that much of the product of the eighteenth century activity in natural science would have lived. What is important about American eighteenth century natural scientific activity is the attitude that fostered its growth, such as it was. Through natural scientific activity wonders were to be performed and man was to be celebrated. Activity in natural science in America in the eighteenth century achieved neither of these goals very well, and everyone who predicted success at that time died without seeing evidence that his prediction was correct. But that prediction did come true, in a way, however, not anticipated by most of those who thought of such things in the eighteenth century. Activity in the natural sciences did eventually increase fantastically, and developments not even comprehensible by eighteenth century man became commonplace. But the attempt to use scientific developments to celebrate man instead dehumanized him. There were good things about the scientific optimism of the eighteenth century, but the end result of placing faith in man rather than God is before our eyes.

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