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SCIENCE AND SOCIETY

By HAROLD G. MOULTON

PRESIDENT OF THE BROOKINGS INSTITUTION[1]

THIS series of discussions of "Science and Society" may well begin with some quotations selected with a view to placing the problem before us in broad perspective. The first two statements suggest the vast contributions of science in the evolution of society.

Science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring discussions of politics seem to be our guide—empty appearances! What really leads us forward is a few scientific discoveries and their application.[2]

Science as fundamental knowledge has been the greatest factor in freeing our minds from the preconceptions and superstitions handed down to us through the ages. Our mental attitude has been profoundly modified by our knowledge of the processes of evolution. . . . Knowledge not only helps to set us free, but will lead us on to higher things. . . . The applications of scientific knowledge have made possible a standard of living undreamed of a generation ago. . . . Our greatest hope for future well-being and prosperity lies in further applications of science.[3]

While the authors of the two quotations which follow would not deny the vast rôle which science has played in the evolution of society they nevertheless question

[1] Address of the retiring vice-president and chairman of the section on social and economic sciences of the American Association for the Advancement of Science, given at Indianapolis on December 27, 1937. The address was introductory to a series of five conferences on "Science and Society" to be held under the auspices of the American Association for the Advancement of Science. The first conference was held at the Indianapolis meeting.

[2] Louis Pasteur, quoted in Millikan, "Science and the New Civilization," p. 41.

[3] Irving Langmuir, in address on "Chemical Research," at the dedication of the new building of Mellon Institute, 1937.

the ultimate effects of scientific advancement upon civilization.

> The enormous advance gained by the sciences of inanimate matter over those of living things is one of the greatest catastrophes ever suffered by humanity. The environment born of our intelligence and our inventions is adjusted neither to our stature nor to our shape. We are unhappy. We degenerate morally and mentally. The groups and the nations in which industrial civilisation has attained its highest development are precisely those which are becoming weaker. And whose return to barbarism is the most rapid. But they do not realize it. They are without protection against the hostile surroundings that science has built about them.[4]

> Humanity stands to-day in a position of unique peril. An unanswered question is written across the future: Is man to be the master of the civilization he has created, or is he to be its victim? Can he control the forces which he has himself let loose? Will this intricate machinery which he has built up and this vast body of knowledge which he has appropriated be the servant of the race, or will it be a Frankenstein monster that will slay its own maker? In brief, has man the capacity to keep up with his own machines?
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> This is the supreme question before us. All other problems that confront us are merely its corollaries. And the necessity of a right answer is perhaps more immediate than we realize. For science is not standing still. . . . There lies in full view before us a realm of discovery in physical science till now untrodden by mortals even in their dreams.[5]

The fundamental question posed by these statements is whether, as the years pass, science will prove a beneficent power continually advancing the welfare of the people who comprise society, or a social demogorgon. While new technological developments have often been looked upon with apprehension because of the economic readjustments which they bring, it is only within recent years that deep concern has been manifested over the impact of science upon society. The traditional attitude has been that the primary requirement is to encourage in every possible way both scientific discovery and the application of science to productive enterprise. This point of view of course finds expression in the charters of national associations for the advancement of science, as well as in the efforts of universities, industries and governments to promote scientific progress through fostering research. But recently in scientific meetings, as well as in public discussions and private conversations, the question is repeatedly asked: Is not science responsible for many of our existing ills, and does it not, in any case, cast an ominous shadow over the future?

In what concrete ways is science held to be a menace —a threat to the future of civilization? At its door various commentators, reflecting upon the undisciplined progress of the past 100 years, have placed responsibility: for developing an industrial organization of such vast complexity as to baffle human control; for creating an international economic structure in a world of political nationalism; for building implements of warfare which threaten the very extinction of peoples; for so mechanizing work processes as to dull the qualities of human intelligence; for changing the relative rates of population growth in the upper and lower strata of society; for bringing into existence new forms of goods and services in such rapid succession and in such profusion as to make it difficult for slowly changing human beings to assimilate them; for giving us leisure that we do not know how to use; for producing chronic unemployment and the grave social problems which it entails; for building up a capacity for production beyond our powers of consumption; for creating an artificial way of life in place of the old simplicity; and for distorting ethical values and undermining religion and morals.

Meanwhile, the ambitions of science are not being realized; indeed, there is a deep feeling of frustration. Applications of new knowledge and inventions to productive processes are delayed by restrictive business practices and governmental regulations and especially by great economic dislocations which thwart the profit incentive and at the same time diminish the financial resources required for continuing research.

It is this prevailing confusion and uncertainty with respect to issues of transcendent importance which has suggested to the American Association for the Advancement of Science the need of holding at this juncture a series of conferences, or symposia, in which representatives drawn from various sections of its membership may join in a systematic consideration of science and society.

The Nature of Our Problem

The term *science,* as employed in the foregoing quotations, obviously relates to discoveries in the realm of natural phenomena and their use through the medium of technological developments. However, in the series of discussions which the association is here inaugurating, the problem is to be considered not merely in terms of the impact of the natural sciences upon society. We shall be quite as much interested in the reciprocal effects of economic and political organization upon scientific discoveries and upon the applications of new knowledge to the processes of wealth production. In short, our concern is with the combined and interrelated influence of the development of science and of the evolution of economic, political and social institutions upon economic and social progress.

[4] Alexis Carrel, "Man, the Unknown," (1936), p. 38.

[5] Raymond B. Fosdick, "The Old Savage in the New Civilization," (1928), pp. 21–22.

Moreover, we shall be considering the implications of *science* in a broader setting than natural phenomena merely. The term science is in some ways ambiguous and confusing: to some it merely connotes a field of study—"the natural sciences"; to others it means a particular method of analysis; and again it often suggests a body of exact principles of fixed and unchanging character. What we are really interested in here is the *scientific spirit,* which is an attitude of mind. As William James expressed it: "I have to forge every sentence in the teeth of irreducible and stubborn facts."

The objective, open-minded, scientific outlook need not of course be restricted to consideration of natural phenomena; it may and should pervade all other realms of investigation. Nor is there any single methodology or technique of scientific inquiry. There are as many different methods of observation, experimentation and analysis as there are divisions of science; indeed, within the same field more than one technique may be employed, and even a single research project may require the utilization of a combination of methods. Galileo, Newton, Franklin, Darwin, Pasteur, Edison, Pavlov, Mill and Curie employed widely differing methods of observation and analysis in arriving at their generalizations. They were alike only in the common purpose of deriving their conclusions from facts.

It should also be observed here that the conception of science as a body of exact knowledge, embodying principles and laws of eternal verity, has in recent times undergone profound modification. The human mind, or rather spirit, longs for certainty; and it was the hope that as the proclaimed doctrines of the authoritarian age were overthrown the advance of science would unfold the laws of nature and reveal for our contemplation and satisfaction the ultimate truths of the cosmos. In the eighteenth and nineteenth centuries scientific writers in every field—in economics and law and government as well as in the realm of natural phenomena—sought to systematize and crystallize knowledge in a body of fixed principles.

But it has been found necessary as the years have passed, and especially in the last few decades, to qualify our former generalizations in the light of new knowledge and conceptions and also in the light of organic changes in the phenomena under investigation. This last consideration is of course especially the case in the social fields where institutions and processes have recently been undergoing rapid evolution. Nothing altogether endures; even mathematical analysis has undergone profound modification in the last half century. As summarized by Whitehead:

> The progress of science has now reached a turning point. The stable foundations of physics have broken up. . . . The old foundations of scientific thought are becoming unintelligible. Time, space, matter, material ether, electricity, mechanism, organism, configuration, structure, pattern, function, all require reinterpretation.[6]

A state of flux in scientific thought is disturbing to some minds; to others it only serves to open anew and more widely the avenues of intellectual adventure and to stimulate the quest for yet more knowledge, as well as for greater wisdom in its use. While the present age of disorganization and doubt calls for re-examination of basic tendencies and relationships and a broader orientation of our thinking, it has no place for discouragement with respect to science. On the contrary, the challenge to imaginative and unfettered minds was never so great as now.

Rapid change is commonly viewed with profound concern, even by distinguished students of social trends. We not only fear the unknown road that opens before us, but we distrust the capacities of individuals for adjustment to a changing environment; we envisage the destruction of old ideas with nothing adequate to take their place and we foresee the disintegration of the primary virtues on which our lives have been built.

Perhaps the best corrective to the perennial concern over "ominous current developments" is to be found in historical comparison. Hence I set side by side a 1937 quotation relating to modern developments in the field of locomotion and one written in 1673 pointing out the baleful effects upon humankind of the coming of the stage coach. Due allowance will of course be made for the presumably deliberate effort of the writers in both cases to gain through exaggeration an increased attention to what they regard as developments of serious human import.

> The once erectly striding biped abandons human locomotion and whizzes through the landscape, crouched over wheels and levers worked by his still prehensile hands, and his flat, vestigial feet, no less useful for this purpose than those of his Simian ancestors.[7]

> Travelling in these Coaches can neither prove advantagious to Men's Health or Business: For, what advantage is it to men's Health, to be called out of their Beds into these Coaches, an hour before day in the morning, to be hurried in them from place to place till one hour, two, or three within night; insomuch that after sitting all day in the Summer time stifled with heat, and choked with dust; or the Winter time starving and freezing with the cold, or choked with filthy Fogs, they are often brought into their Inns by Torchlight, when it is too late to sit up to get a Supper; and next morning they are forced into the Coach so early, that they can get no Breakfast. What addition is this to men's Health or Business, to ride all day with strangers, oftimes sick, ancient, diseased Persons or

[6] "Science and the Modern World," p. 24.

[7] Earnest A. Hooton, in address to the American Society of Mechanical Engineers, December, 1937.

Young Children crying. . . . Is it for a Mans Health to travel with tired Jades. . . . .

For passage to London being so easie, Gentlemen come to London oftner than they need, and their Ladies either with them, or having the Conveniences of these Coaches, quickly follow them. And when they are there they must be in the Mode, have all the new Fashions, buy all their Cloaths there and go to Plays, Balls and Treats, where they get such a habit of Jollity, and a love to Gayety and Pleasure, that nothing afterwards in the Countrey will serve them.[8]

All this is presented, I hasten to add, not for the purpose of suggesting that present-day fears are altogether groundless. My purpose is merely to place current problems before us in historical perspective and in a setting which may suggest grounds for hope. In concluding this introductory statement, it may be well to recall that although former civilizations have declined it is not of record that such disintegration was the result of too much science. Perhaps the way forward lies in a great extension of the scientific spirit.

Scientific Foundations of the Modern Social System

The system of free enterprise under which the vast economic expansion of the past 100 years or so has occurred has often been extolled. But there is little realization of the part played by science in laying the foundations of this system. Again, while the influence upon man's productive power of the application of scientific discoveries to industry has repeatedly been emphasized, comparatively little has been said about the reciprocal importance of social institutions in promoting scientific advancement. A brief recapitulation of the mutual interactions of scientific and social developments over the past few centuries may thus prove a useful background against which to project our thinking with respect to the present and the future.

In the Middle Ages, to go no further back, men's thoughts were largely determined by higher authority. They were not supposed to question *why,* but only to *believe.* Similarly, under the economic organization known as the Feudal System men's productive activities were directed from above with the individual possessing virtually no freedom of choice. Even after feudalism disintegrated in the fifteenth and sixteenth centuries, a centralized control of economic life was continued under the city states and the emerging national governments which followed. Even under the so-called mercantilist system of the eighteenth century business enterprise remained so hedged about by governmental controls that little opportunity was afforded for the exercise of individual initiative. It appears clearly to have been the influence of the great scientific discoveries of the seventeenth century which in due course provided the philosophical foundations for the system of free private enterprise.

The key to the great transition from regulated to free enterprise was found in the conception of *"nature's laws"* with which the physical scientists were concerned. What about the human being? Was he not a part of the natural order of things and if so could he possibly realize his potentialities if his life were circumscribed by man-made restrictions which curbed his free-born spirit? The writings of Blackstone, Rousseau, Adam Smith and others who formulated the principles of the common law, the laws of economics, the principles of government and the science of sociology are permeated with the conception of natural law. And Jefferson, it may also be recalled, prefaced the Declaration of Independence with an all-embracing reference to the separate and equal station to which the laws of nature and of nature's God entitle us. These men, drawing their inspiration from the great scientific discoveries of the preceding century sought to apply the new-found knowledge and conceptions to social organization—to invent legal, economic and political institutions in harmony with the universe of nature. The three remarkable events of the years 1775–76—the application of the steam engine to industry, the publication of Adam Smith's "Wealth of Nations," and the writing of the American Declaration of Independence—were not mere coincidence.

The immediate consequence of the writings of the social philosophers of the eighteenth century was the establishment of the system of free business enterprise which characterized the nineteenth century. First, innumerable laws which restricted the freedom and initiative of the individual were repealed. Second, industry and trade were relieved from a multitude of hampering regulations. Third, national boundaries came largely to be ignored through the removal of barriers and restrictions against the free international movement of trade and currency and against the migration of people from country to country. There was born the conception of a world society, in which men should be free not only to develop their individual capacities to the utmost but also to live in whatever spot on the globe they desired and to conduct their business operations without reference to any national boundaries.

This system of free enterprise not only gave direct encouragement to the application of scientific discoveries to the production of wealth, but the expanding scope of business organization made it possible to utilize such discoveries with great effectiveness. In turn, the growth of wealth provided the means essen-

[8] Excerpt from "The Grand Concern of England," 1673. Quoted in Sir Josiah Stamp, "The Science of Social Adjustment."

tial to the systematic conduct of large-scale scientific research. Thus through action and interaction science and social organization have made possible—for good or for ill—the highly productive but complex and baffling civilization of our time.

THE DISMAL SCIENCE

The economic principles that were formulated by early nineteenth century economists were so somber in their implications that economics was long referred to as the dismal science. This phrase did not arise, as many have assumed, out of the difficulty or dreariness inherent in economic analysis; it reflected merely the drab outlook for humankind on a planet characterized by the niggardliness of nature. As a setting for the discussion of the great contributions of science to the processes of wealth production during the course of the last century, it will perhaps be useful to summarize very briefly the fundamental conclusions reached with respect to human progress by the earlier writers on political economy.

These scholars concluded that the economic condition of the masses of the people at any given period and the degree of economic progress that might occur with the passage of time were controlled or limited by three fundamental factors: (1) the land or other resources provided by nature; (2) the accumulation of capital, that is, tools, machinery, factories, etc.; and (3) the labor supply. Two of these factors were regarded, so far as expansion was concerned, as subject to severe limitations, while the third—the labor supply—was subject to a very rapid rate of growth which tended to defeat, so far as standards of living were concerned, whatever gains might come from the improvement in the other factors.

While new agricultural areas might be opened to settlement and new mineral, forest or aquatic resources might be discovered, there were clearly ultimate limits to these resources. Moreover, the fundamentally important land resources were very definitely limited from the point of view of quality. The most fertile areas were in the main those first utilized and, as population grew, resort would have to be had to poorer and poorer land. While improved methods of land utilization might serve to increase productivity, such increase was subject to the law of diminishing returns.

The supply of capital was limited by factors of a different type. In brief, its increase involved a choice between the *immediate* satisfactions that might be realized by devoting all our energy to the production of consumer goods and the larger satisfactions that might *ultimately* be realized if some of our resources were currently devoted to the production of capital goods in order to increase our future productive capacity. The growth of capital thus depended upon the ability and the willingness of individuals to make current sacrifices for the sake of future gains. Inasmuch as the great majority of human beings possessed the most meager standards of living, and were moreover regarded as lacking in foresight, it did not appear likely that capital would be created at a rapid rate. Moreover, if capital should perchance for a time be increased with exceptional rapidity its use in conjunction with limited natural resources would inevitably result in a decrease in its marginal productivity. Hence its interest yield would decline, thus checking the tendency to further accumulation.

The labor supply, on the other hand, was subject to no such limitations. On the contrary, as a result of natural instincts, it tended inevitably to increase out of all proportion to the other factors of production. Hence population growth would necessitate a continuous resorting to poorer resources, thereby tending to reduce living standards to the minimum of subsistence. While war and pestilence might serve at times to improve the balance among the factors of production, there appeared little hope for progressively rising standards of living—unless perchance "prudential restraint" might eventually serve to control the birth rate.

It was the geometric rate of population growth as compared with the arithmetic rate of growth of the other factors which not only gave to the science of economics its awesome appellation, but also foreshadowed a grim future for the human race. Moreover, the conditions of life in China, India and other old civilizations afforded striking illustration of the permanent tendency for population growth to exceed that of other resources; indeed, the very redundancy of the labor supply served as an effective deterrent to technological developments which might economize human labor.

To-day, as every one realizes, the situation is profoundly different from that which was contemplated by the observers of the early nineteenth century. In a large part of the world the standards of living have been enormously increased and the dire results of the laws formulated by our economic forefathers appear somehow to have been avoided. Instead of a conception of all controlling scarcity, we are troubled with conceptions of abundance; indeed, before the eyes of many is the specter of super-abundance. We have, moreover, been utilizing the powers of government to restrict further technological advancement—through fear of the economic and social consequences.

THE SCOPE OF THESE CONFERENCES

The first task in this series of conferences is to make an appraisal of the factors which have been responsible for the great changes which have come in the last century, with particular attention to the rôle of science

in these developments. Hence the series of papers given in this first conference are grouped around the general theme "Fundamental Resources as Affected by Science."

The first two papers are concerned with agricultural and mineral resources. In each case the primary purpose is to show the ways in which the applications of science have served to amplify, increase or otherwise modify or utilize these basic natural resources. Other papers are focussed on the growth of capital, the development of business organization and the utilization of power, which has revolutionized the processes of production during the past century. Finally, we survey the changes that have occurred with respect to the labor factor—indicating the economic significance of changing rates of population growth and the improving utilization of our human resources.

The organization of the five succeeding conferences is still in a tentative state, and it is hoped we may receive many suggestions for improvement. However, in order to provide a basis for suggestions we present herewith a brief statement designed to indicate the character of the conferences which we have in mind.

To the second conference we have given the general title "Science and the Future." Whereas the first conference was concerned mainly with reviewing the developments of science in relation to society over the course of the past century or so, the second conference will be chiefly devoted to indicating what may be expected in the way of future applications of science in the service of society. For this appraisal of the range of potentialities which science holds for the future we must of course look to representatives of such fundamental sciences as physics, chemistry and biology, and also of applied engineering.

As a foundation for this forward look, we shall in the first session take stock of the present. The first paper will deal with "World Standards of Living," with a view to indicating as precisely as possible just how far we have progressed in the direction of "reasonable" or "satisfactory" conditions of life, and the general magnitude of the production problem still before us. Another paper will survey the situation with respect to "World Natural Resources" at the present time. For the second session we plan two major papers to which we have given the titles "Physics and the Future" and "Chemistry and the Future." In each case we should like to have as realistic a picture as it is possible to give in the light of present knowledge of what these sciences hold in store for the future. The third session, devoted to the "Biological Sciences and the Future" would undertake a similar ask. The discussions, however, should not include the direct relationship of biology to the development of man himself, for this aspect of the problem is reserved to the fifth conference. The final session of the present conference we have entitled "The Future Applications of Science," the central purpose being to indicate the character of the engineering and business problems involved in applying the results of scientific knowledge to production.

To the third conference we have given the general title "The Economic System in Relation to Scientific Progress." Inasmuch as the practical benefits of scientific discoveries can be realized only through their applications in industry, an efficiently functioning economic system is obviously of fundamental importance. Traditionally, it has been assumed that the process of applying the results of scientific discoveries to human welfare is more or less automatic. New scientific discoveries lead to inventions of improved instruments of production which in due course are utilized by industry in increasing the efficiency of production. Increasing efficiency simply means producing more with the same effort—in consequence of which standards of living are raised. In fact, however, the process is one of great complexity, having its setting in a structure of pecuniary costs, prices and profits, and distributing its fruits in the form of money income which must be exchanged for the goods and services desired.

The introductory paper, entitled "Free Enterprise and Scientific Development," should reveal the ways in which the modern economic system has promoted the growth of large-scale business organization and stimulated the development of science and its applications to the productive process. It should also explain how the price and profit mechanism is supposed to operate and must operate if the results of scientific discoveries are to be utilized promptly. The second paper should discuss the handicaps and impediments to the successful operation of the existing mechanisms as the economic system has increased in size and complexity. Another paper should be devoted to the significance of the monetary and credit system by means of which modern large-scale business enterprise is conducted. Inasmuch as recurring business depressions periodically retard the applications of science to productive enterprise, there must of course be discussion of the so-called business cycle. It is hoped that a joint consideration of this problem by natural scientists, industrial engineers and economists may shed new light on this baffling phenomenon. A final session in this conference might well be devoted to what may be called "The Scientific Approach in Economics." Scholars working in the field of the social sciences like to believe that they are scientific in their outlook and methodology; but our brethren in the field of the natural sciences not infrequently express skepticism on this point. It seems desirable, therefore, that serious con-

sideration should be given to the methodology employed in economic investigations and to the potential contributions which natural scientists might make to economic analysis.

In the fourth conference we turn from the field of private enterprise to discuss "Government in Relation to Scientific Progress." The introductory paper should survey the changing rôle of government in economic enterprise from the Middle Ages to the present time. It should outline the manifold ways in which government to-day attempts to assist, regulate or participate in economic activities. A second session would undertake a critical appraisal of the patent system, by means of which government seeks to encourage and reward invention. Attention must be given to the bearing both of present laws and of business policies on the utilization of inventions. An underlying concept of democracy is that all its members are entitled to the fruits of new knowledge, which should be permitted and encouraged to flow quickly through the channels of productive enterprise in the service of society. Are there factors and tendencies which impede this process and, if so, by what means may the situation be remedied?

The continuous expansion of the functions of government in recent times has involved a vast increase in public indebtedness in nearly every country in the world. Some government enterprises yield revenues adequate to cover their costs, while others are not self-supporting. Our discussions should include an appraisal of these developments, with the central purpose of determining the growth of tax requirements in relation to the growth of the taxable income of nations. Unbalanced fiscal systems increase the burdens of taxation, lessen the funds available for the advance of science and technology, and also ultimately undermine the stability of both fiscal and monetary systems, which in turn impedes business enterprise and retards economic progress. If we are to continue the forward road to higher standards of living we must obviously preserve the financial and credit foundations.

We must also give consideration to the scientific approach in government. In what ways does our political organization promote and in what ways does it impede the scientific outlook with respect to problems which vitally concern the welfare of the people? What changes in organization and in procedures might be suggested with a view to facilitating the development of the scientific point of view with respect to governmental issues? Similarly, our attention must be given to the future rôle of government in fostering scientific research. Must we, as many apparently believe, henceforth look increasingly to government to provide financial support for, and also to give stimulus and direction to, scientific research? Or, as others apparently believe, must we continue to rely primarily upon endowed institutions and industrial organizations as the best means of preserving freedom and flexibility in the conduct of research? Is there a middle ground or a division of labor with respect to this great problem; and, if so, what are the principles or conditions necessary to effective cooperation? This would seem to be one of the fundamental issues to which this association should give attention if it is to advance science.

Since our ultimate goal is the development of the individuals who compose society, we make "Science and Human Beings" the theme of our final conference —to be held two years from this date. Are the changes in modes of life and in human attitudes which have been, or may be, wrought by scientific discoveries and their applications to productive processes beyond our frail human powers of effective assimilation? What of the alleged advantages accruing as a result of our escape from unremitting toil and the acquisition of leisure in which to study and improve the mind, to contemplate the beauties of nature, to enjoy and profit from broader human associations?

We do not need, or wish, oratorical effusion on this primary issue of contemporary civilization. What is required is a pooling of our scientific resources in studying the effects of science upon human beings. To this end we need the cooperation of the medical scientists, of biologists and geneticists, of psychologists and psychiatrists, of sociologists and philosophers, and also of those who devote their lives directly to the service of individuals through educational institutions, the churches and welfare and character-building and life-adjustment agencies. Our purpose is to take stock of current tendencies by bringing to bear upon them as wide a range of scientific knowledge and human experience as is possible. We express the hope that this conference may be the forerunner of others to be held under the auspices of this association for the purpose of clarifying, and perhaps gradually solving, some of the problems which now confuse—but challenge—our thinking.

OBITUARY

WILLIAM HENRY PICKERING
1858–1938

WILLIAM H. PICKERING was born in Boston on February 15, 1858. After graduating from the Massachusetts Institute of Technology in 1879, he was instructor in physics there until about 1883, when he became engaged in astronomical research at the Harvard Observatory, where his brother, Edward C. Pickering, nearly twelve years his senior, had been appointed director.