



SCRIBNER'S MAGAZINE

February 1930

VOL. LXXXVII

NO. 2



Alleged Sins of Science

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Is man a victim of science's machine age? Is science building up a world of terror? In this and the next article, two distinguished scientists answer. Dr. Millikan examines the part science plays in the ills of the modern world. Dr. Michael Pupin in "Romance of the Machine" draws an impressive analogy between the cosmic engine and the man-made machines of America.

THE cardinal doctrine in the creed of every man of science is stated in the motto of the University of Chicago, namely, "Crescat Scientia Vita Excolatur"—let knowledge grow, let life be enriched; or equally well in the motto of the California Institute, "The Truth shall make you free." And any effort to suppress or impede the growth of science, which means to the scientist merely the growth of man's understanding of his world, and hence of his ability to live wisely in it, is to him an unpardonable sin, or at least not the work of an understanding mind.

If we are to be asked deliberately to shut our minds to the truth, or to be deterred by fear from searching for it, we might as well, so says the scientist, give up the effort at intelligent living altogether and go back to savagery. Furthermore, the whole history of man's age-long rise from superstition and igno-

rance up to his present estate seems to the scientist to be a practical demonstration of the essential soundness of this view.

So when a couple of years ago the Bishop of Ripon suggested to the meeting of the British Association for the Advancement of Science that it would be well for the world if science could take a ten-year holiday his words did not meet with a chorus of applause from scientists.

But the Bishop's views are not so uncommon, and we scientists have to some extent been responsible for them. The following quotation from a book written by one of the best-informed and most intelligent of living Americans states the case against science thus. I quote from Mr. Raymond Fosdick's recent book entitled, "The Old Savage in the New Civilization."

"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?

"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. In speaking of the scientific revolution I have not been speaking of a phenomenon that was confined to the Nineteenth Century. Rather we are just at the beginning of the revolution. We could not stop it if we would. It is advancing by leaps and bounds, gaining in impetus with each year. It is giving us more machines, faster machines, machines increasingly more intricate and complex. . . .

"Life in the future will be speeded up infinitely beyond the present. Sources of energy will be tapped and harnessed far outrivalling what we have to-day. There lies in full view before us a realm of discovery in physical science till now untrodden by mortals even in their dreams. The pioneers are already upon the road to this promised land. . . . We now know that in atoms of matter there exists a store of energy incomparably more abundant and powerful than any other of which we have thus far obtained control. If once we can liberate this force, what machines we can build! Steam and electricity will be an anachronism at which our children will laugh as we laugh at the hand loom and the spinning wheel. With a pound weight of this radioactive substance we will get as much energy as we now obtain from 150 tons of coal. Or another pound weight can be made to do the work of 150 tons of dynamite.

"One hundred and fifty tons of dynamite—enough to blow a modern city into oblivion—compressed to a pound weight which might be held in the hand! No wonder that a sober-thinking scientist like Professor Frederick Soddy of Oxford University should write: 'I trust this discovery will not be made until it is clearly understood what is involved.' 'And

yet,' he goes on to say, 'it is a discovery that is sooner or later bound to come. Conceivably it might be made to-morrow.'

"One has only to turn the pages back to 1914 to find the grounds for Professor Soddy's uneasiness. All the machines that ingenuity could invent were directed to the single purpose of human destruction. In a hundred laboratories, in a thousand arsenals, factories, and bureaus, physics and chemistry were harnessed to the task of mass death. The gigantic success of the enterprise is shown in the statistics: 10,000,000 known dead soldiers; 3,000,000 presumed dead soldiers; 13,000,000 dead civilians; 20,000,000 wounded; 3,000,000 prisoners; 9,000,000 war orphans; 5,000,000 war widows; 10,000,000 refugees.

"This was the tabulation that our mechanical civilization made possible. This is the result of creating machinery for which we have no method of control. This is the consequence of giving children matches to play with. . . .

"This, then, is the problem: science will not wait for men to catch up. It does not hold itself responsible for the morals or capacities of its human employers. It gives us a fire engine with which to throw water to extinguish a fire; if we want to use the engine to throw kerosene on the fire, that is our lookout. The engine is adapted to both purposes. With the same hand, science gives us X-rays and machine guns, modern surgery and high explosives, anæsthetics and poison gas. In brief, science has multiplied man's physical powers ten thousand fold and in like ratio has increased his capacity both for construction and destruction. How is that capacity to be used in the future? How can we hold in check the increasing physical power of disruptive influences? Have we spiritual assets enough to counterbalance the new forces? How can we breed a greater average intelligence? Can education run fast enough, not only to overcome the lead which science has obtained, but to keep abreast in the race? Can the old savage be trusted with the new civilization which he has created?

"These are ugly questions. They are hurled as a challenge at our generation, and upon their answers the future depends."

Now perhaps the alleged sins of science have never been stated more tellingly than in the foregoing, and I would

like to ask you to allow me to bring Science herself to the witness stand and ask her what she has to say for herself.

She replies very quietly that there are both statements and implications in the foregoing that need further consideration. First, that, following her conviction that the only matter of supreme importance is to find out the facts, since we have to live with them anyway, she has kept steadily at work since Mr. Soddy raised the hobgoblin of dangerous quantities of available subatomic energies and has brought to light good evidence that this particular hobgoblin—like most of the bugaboos that crowd in on the mind of ignorance—was a myth; that it was exceedingly fortunate that Mr. Soddy's fears did not at the time he uttered them induce a terrified humanity, like a frightened child paralyzed by its fear in the dark, to stop its efforts to get more light, for the worst disasters have always come from panic born of ignorance; that she (Science) regards it as her chief function to deter men from over-hasty conclusions, though she does not always succeed, even with her devotees; that her influence, nevertheless, is always to constrain men to replace panicky, emotional acting by reflective, informed, rational acting. The great world explosions, including the World War, have been mental, not physical. She would ask you then to withhold your judgment until all the available evidence is in.

Now the new evidence born of further scientific study is to the effect that it is highly improbable that there is any appreciable amount of available subatomic energy for man to tap; in other words, that henceforth men like the Bishop of Ripon who are living in fear lest some bad boy among the scientists may some day touch off the fuse and

blow this comfortable earth of ours to star dust may go home and henceforth sleep in peace with the consciousness that the Creator has put some fool-proof elements into his handiwork and that man is powerless to do it any titanic physical damage anyway.

This may relieve the Bishop of Ripon, but it will disappoint men like Lord Birkenhead, who have been hypnotized rather than scared by the prospect of tapping enormous new sources of subatomic energy and who have been revelling in the prospect of some day lying in bed, pressing a button, and calling for two atoms' worth of massage. These men will be obliged to give up their idle Utopian dream and console themselves with the reflection that the chief joy of life after all comes from the striving and the overcoming, that there is much more satisfaction in smashing a resistant atom, as man will doubtless do, than in lying on one's back and watching it explode.

One may become blue or happy then, according to his temperament, over the fact that it is now highly improbable that we on the earth shall ever get any appreciable amounts of energy from any other source than the sun, whence we have always obtained our energy, directly or indirectly, in the past, but at any rate that is the indication to which we must adjust ourselves, and it serves at least to remove from the account of Science one sin with which she had been charged.

But that is only the first of the sins charged against her. What about the horrible indictment as to the twenty-six million people actually killed in the World War? The answer is twofold. First, the implication was that Science had a good deal of responsibility for that war—an erroneous implication I think, since war has been the chief business of

all the glorious civilizations of the past when there was no science, and with every advance in science I think it becomes less and less so. Indeed, primitive man's chief tools were probably arrowheads and tomahawk and his chief industry making and using them. When the age of bronze replaced the age of stone a multitude of new peaceful arts were born. Copper smiths, silver smiths, gold smiths appeared who developed a wonderful decorative art for use on urns, on vases, on table ware, on personal ornaments, on sarcophagi, on friezes, on monuments—witness the amazing perfection of these arts revealed in Tutankhamen's tomb—and these arts reduced the relative importance of the successor of the arrowhead and tomahawk maker, for these peaceful arts turned men's minds and energies and interests away from war, toward peace.

And this has been the consequence I think of practically every advance in science and its applications since that time. Let him whose eyes have recently been focussed on the increased effectiveness of tools of destruction and whose fears have been aroused lest the savage in man may use these tools to destroy the race lift up his head and look all around him. I think that such a survey will show conclusively that every scientific advance finds ten times as many new, peaceful, constructive uses as it finds destructive ones. Explosives and fertilizers are basically the same, and even explosives as such meet a dozen peaceful needs to one warlike one. The duPont Company is known as a powder concern, but that is a well-nigh negligible part of its business. Public thinking is misled merely by the fact that a horror makes better news than a wheat crop. One man blown painlessly to atoms gets more news space than a thousand men in the

agonies of starvation or dying by inches from disease. Steel does indeed make bayonets, but it also makes ploughshares and railroads and automobiles and sewing machines and threshers, and a thousand other things whose uses constitute the strongest existing diverter of human energies from the destructive to the peaceful arts.

In my judgment war is now in process of being abolished chiefly by this relentless advance of science, its most powerful enemy. It has existed in spite of religion, and in spite of philosophy, and in spite of social ethics, and in spite of humanitarianism and the Golden Rule, since the days of the caveman because, in accordance with the evolutionary philosophy of modern science, and simply because, *it has had survival value*. It will disappear like the dinosaur when, and only when, the conditions which have given it its survival value have disappeared, and those conditions are disappearing now primarily because of the changes in world conditions being brought about by the growth of modern science.

I am with Mr. Fosdick in every effort to arouse more fully the social sense, the conscience, and the morals of mankind, in every effort to develop a new machinery like a world court and a League of Nations to assist in bringing about better international and social relations. If I differ with him at all, and I am not sure that I do, it is only in my estimate of the *relative effectiveness* of the different available agencies. He seems to fear too active experimenting in physics and its applications, but not in sociology, for when he is dealing with the latter field he says, "We need not fear that we shall progress too fast. The overwhelming danger is that we shall not be able to progress fast enough."

My own reason for exactly reversing this emphasis is very precisely stated by him in the following words: "But social science to-day is still lacking in the fundamental groundwork of knowledge. It is still too largely based upon inspiration rather than upon facts." My own position stated in one sentence is that all progress comes from knowledge, and I am enthusiastically for everything that increases knowledge, whatever be the field, sociology or physics, and for acting upon that knowledge when found. But it is as unsound to talk about the danger of too much knowledge in physics as in sociology.

For look farther at what is actually happening, at what kind of effort is to-day yielding the largest social returns. Without aiming directly at doing so, modern science and its applications have within the past fifty years actually produced the most profound and beneficial social changes that the world has ever seen. They have raised the average working man's wage in terms of actual buying power about fifty per cent in forty years, and that along with a twenty per cent decrease in his working hours. That is not everything, but it is the necessary first step, the indispensable foundation upon which all other kinds of building must rest. Also, according to recent "Carnegie" studies modern science and its applications have actually resulted in increasing the amount of reading done by the average man in Middle Town more than three hundred per cent, and this applies, too, to magazines like the *Atlantic Monthly* as well as to other grades of reading matter. Also, they have given the average man through the radio and the "movie" the opportunity for education and entertainment (partly abused, no doubt, but partly utilized; and in any case opportunity is a *sine qua*

non to progress)—opportunity such as the common man never had before.

One continually hears complaints that our machine age, with its mass production, has ruined the life of the common man, that it has deadened and routinized labor and taken away the joy of craftsmanship. These protests are natural, because the man who is taken through a modern factory and does not look beneath the surface of things will easily gain such an impression. A very superficial glance at the Ford factory, for example, would seem to justify the worst charges that are made against our machine age, but to the man who is capable of seeing beyond his nose it is a very different picture that unfolds itself. This man sees not merely the 8,400 cars turned out each day by routine labor in the summer of 1929 by the Ford plant, but he looks beyond to see what these cars are doing to the life of the common man. He sees, in the first place, that these eight thousand cars are driven by roughly as many persons, and he realizes that driving a car in crowded streets is in itself a highly skilled occupation, which develops in large measure the qualities of sobriety, alertness, and intelligence. He contrasts the bleary-eyed, ruby-nosed old soak who thirty years ago sat on the driver's seat of the average cab in London or New York with the highly skilled chauffeur of to-day, alert, self-respecting, sober, intelligent, and well dressed. The change is striking and the improvement enormous.

Secondly, he sees that every one of those 8,400 cars turned out in one day has to be taken care of and repaired by an intelligent garage mechanic and "trouble man," a man who must understand the intricate mechanism of an automobile from top to bottom and from one end to the other, who must be able

to find the difficulty no matter where it appears, and, more than that, who must know how to right it. No such requirement of expert knowledge, no such variety of stimulating activity, was ever the lot of any middle-age artisan, and no such demand for intelligence was ever made before upon so large a fraction of the population as is now made by our mechanical age.

Thirdly, he sees that all these 8,400 Ford cars turned out per day must be serviced by thousands of wide-awake, courteous, attractive service-station men—men who have taught the world as it has never been taught before that the maximum of success is definitely related to the maximum of cheerfully rendered service to one's fellows. He sees that back of these service station men are the refineries, with their expert staffs of chemists and physicists, and that back of these are the geologists and the seismologists and the radio engineers of the producing company, and so on without end.

As I read history the machine age taken in its entirety has actually freed, educated, and inspired mankind, rather than enslaved it! Even the few routine men who feed the machines in Mr. Ford's factory are less routinized and have shorter hours than the dumb agricultural drudge who hoed potatoes for twelve hours a day through all the history of the world before the machine age appeared.

But the far-seeing man will see even deeper than that. It is science and its applications that, through the Ford car and its like, have given to the average man and his family the opportunity for the broadening influences of travel, an opportunity that he is utilizing amazingly, too. It is science and its applications that, through the wonderful develop-

ment of the art of communications, and through incredible stimulation and acceleration of trade and commerce, have knit the whole world together into a unity that makes war an anachronism. Much more important than treaties, I think, in abolishing war as an instrument of national policy is the growing recognition of the fact, taught in no uncertain language from 1914 to 1918, that in our modern scientific civilization war is no longer well adapted to the attainment of national ends. Let no man henceforth ever make the error of assuming that modern science made the last war. Rather was that war, let us hope, the last titanic struggle of militarism to escape the extinction foredoomed for it in a world motivated by modern science. The World War was surely not a sin of science.

Again, can science escape the responsibility for those twenty-six million lives lost during that war? That is a matter of opinion. Granted only that these people could all have got to the fighting line, which, mind you, was of wholly unprecedented length, I am not sure that, with only ancient man's weapons, the sword, the shield, and the spear, given the world's war issues to fight about, the thirteen million who died in battle might not have been even more; and without modern medical science the thirteen million civilian deaths would almost certainly have been augmented.

But that is after all not particularly important. The significant fact is one brought out by Mr. Fosdick himself when he says, "Stop the machines and half the people in the world would perish in a month." That is not an overestimate. Modern science undoubtedly made it possible for more than twice as many people to live comfortably in Eu-

rope before the war as could otherwise have done so. Robert Fulton predicted in about the year 1800 A. D. that the time would come when England, then thought densely populated, would hold 10,000,000 souls. To-day she has five times that number. It was but a small fraction of these people, people who owed their very existence to science, who had been created by science, that lost their lives in the war. Had preceding generations abolished or slowed up science, more than this number would have died more miserably, *i. e.*, with greater suffering, for disease with science is bad enough, while without science it is hell.

Now the balance of this whole account shows scarcely a sin to be credited to science. Looked at in the large, I do not think there can be the slightest question that the only hope this world has of maintaining in the future a suitable balance between population and the food supply is found in science. That, in the last analysis, is mankind's greatest problem. Its solution alone, and there are the best of reasons for believing that in the long run it can be solved, is sufficient to warrant the fullest stimulation of both the biological and physical science that can in any way be brought about.

So far in my search for the sins of science I have failed to find her guiltiness of the charges brought against her, but there is one to me very regrettable tendency in modern life for which science is probably to some extent at least responsible. I refer to the craze for the new regardless of the true, to the demand for change for the sake of change without reference to the consequences, to the present-day wide-spread worship of the bizarre, to the cheap extravagance and sensationalism that surround us, as evi-

denced by our newspapers, our magazines, our novels, our drama, our art in most of its forms, our advertising, even our education.

These are, I suppose, inevitable, though I hope transient, accompaniments of the stupendous *rate of change* that modern science and its applications have forced on modern life. The spirit of change has been caught *where its basis has been wanting*. In this particular our generation stands unique in all history, and it is difficult to see how the future can have any other period of such rapid change in store.

In the way he conducted his daily life, my grandfather is undoubtedly more remote from me than he was from the earliest man mentioned in recorded history. In the last analysis this change is primarily due to the introduction of the power machine as a substitute for animal muscle, for this includes everything that has come to this generation through the steam-engine, the dynamo, the automobile, the airplane, the telephone, and the radio. Add to this the change in mode of thought due to the new host of discoveries, primarily in physics and biology, and it is no wonder that our age has become infected, or better drunk, with the spirit of change. *In many fields no past time has known and no future time can know* so sudden and so complete a transformation, for the whole gamut of possibilities has been run through by our single generation. In woman's dress, for example, the limits are obviously zero and infinity, and whatever there is in between that has not been tried since 1900, isn't likely to be tried very soon, nor would it represent a very large change if it were, so that whatever zest and joy there be in something brand new and radically different in this domain has been tasted to

the full by this generation, and will never be tasted in such completeness again.

In physics and its applications these changes have been made by men who were fully conversant with the past, men who knew the difference between perpetual-motion cranks and real discoverers, men who knew that the fully verified laws of the past must remain the laws of the future for the whole range of phenomena for which their correctness had been tested; in a word, men who knew that Einstein would have to contain the whole of Newton, *i. e.*, be merely a refinement of, and supplement to, Newton or else that his work would be wrong. But unfortunately many of the other fields in which the spirit of change is rife have no such criteria for past or present truth as physics possesses and no such group of well-trained, capable, and historically informed minds working in them, so that in these fields we cannot be certain whether the changes represent progress or retrogression. In such cases, however, the counsel of the wisest heads of the past is the only possible guide for the present.

Be that as it may, I suppose that the present spirit of revolt, of change for the sake of change, the present effort for the new at all costs, the bizarre, the extravagant, the sensational is in part an inevitable reflex of the rapid changes taking place in our times because of the rapid growth of science. When I go into an exhibition of the so-called secessionists in art in Germany I feel certain that I am in a madhouse, or when I read the literature poured forth by what Mr. Stuart Sherman called the emetic school of modern American writers, I dislike to admit that these modern excrescences of our civilization are a part of the sins of

science, but I suspect the spirit of change which we have started has been partially responsible for them.

Yet I am not greatly disturbed even by these. The world will become sick of the emetic school in time. The actual method by which science makes its changes is becoming better understood. The demand for the saner popular books upon it is continually increasing. The remedy is in part at least in understanding it better.

As soon as the public learns, as it is slowly learning, that science, universally recognized as the basis of our civilization, knows no such thing as change for the sake of change, as soon as the public learns that the method of science is not to discard the past, but always to build upon it, to incorporate the great bulk of it into the framework of the present, as soon as it learns that in science truth once discovered always remains truth, in a word that evolution, growth, not revolution, is its method it will I hope begin to banish its present craze for the sensational, for the new regardless of the true, and thereby atone for one of the sins into which the very rapid growth of science may have tempted it.

But there is another side even to this admitted sin which will appeal to those of us who want to speed up social change, to those who feel that many of our laws and customs have actually become outgrown, that they were developed for, and were adapted to, the old civilization, not to the new. In many, many instances this view is undoubtedly correct, but here the sin just now admitted becomes a virtue. That the spirit of change is in the air obviously helps rather than hinders in the case of these needed social readjustments. The whole question however is, "Do we know enough yet to make any particular

change?" The answer is sometimes yes and sometimes no.

In the latter case the new knowledge that is still needed is just as likely to come from further physical experimenting as from further social studies. The whole history of science shows that it is impossible to predict beforehand where a new bit of knowledge is going to fit in. The amazing thing about that history is the extraordinary rapidity with which each new advance in one domain actually finds its application in another. Physical knowledge *is* social knowledge! Let us not then hold back anywhere in the search for knowledge. *Crescat Scientia, Vita Excolatur.*

There is one other sin that is charged against science concerning which I wish to say a word, namely the alleged sin of exalting the material at the expense of the spiritual.

If this means providing food and clothing and wholesome living conditions for millions upon millions of people who would otherwise die of starvation or otherwise drag out such miserable lives that their only recourse would be to dream of another life free from the miseries of this, then science must plead guilty.

The rise of science has undoubtedly filled mankind with a new vision of, a new hope for, and a new effort toward a better human existence than the world has known in the past. If this is exalting the material over the spiritual then she must again plead guilty.

The rise of science has undoubtedly shifted somewhat the relative emphasis of our thinking from individual-soul salvation to race salvation. If this is exalting the material, then she is again guilty.

But, as I myself use words, the foregoing facts do not mean the subordination

of the spiritual to the material. I myself think that the aforesaid changes represent an increase rather than a decrease in what I call "spiritual values," *i. e.*, an increase in the essential spirit of the great teacher which was epitomized in the Golden Rule. The essence of Christianity is to be found, I think, in the altruistic teaching and living which Jesus felt to be his chief mission to spread on earth. I have no reason to think that this spirit is on the wane. Even the membership in the Christian churches, which are the chief stimulants of it, is increasing, and a civilization built upon modern science unquestionably demands its further increase. For as society becomes more and more complex civilization cannot endure at all save as the individual learns in ever increasing measure to subordinate his own appetites and impulses to the common good, to the group life wherever the two come into conflict. In other words, the development of the sense of social responsibility which, broadly speaking, is merely the spirit of the Golden Rule, or slightly differently stated, the stimulation of the "consciences, the ideals and the aspirations of mankind," must be done in ever increasing measure in a civilization which is growing more and more complex and interrelated under the influence of modern science.

So much for the practical side of the question. There is also a philosophic side. Science is sometimes charged with inducing a materialistic philosophy. But if there is anything which the growth of modern physics should have taught it is that such dogmatic assertiveness about the whole of what there is or is not in the universe as was represented by nineteenth-century materialism is unscientific and unsound. The physicist has had the bottom knocked out of his generali-

zations so completely that he has learned with Job the folly of "multiplying words without knowledge" as did all those who once asserted that the universe was to be interpreted in terms of hard round soulless atoms and their motions. The Oxford biologist John Scott Haldane has recently written "materialism, once a scientific theory, is now the fatalistic creed of thousands, but materialism is nothing better than a superstition on the same level as belief in witches and devils."

The best possible cure for materialism is the following chapter from the recent history of physics. A hundred years ago, physics consisted of six distinct, sharply separated departments: Mechanics, Molecular Physics, Heat, Sound, Light, Electricity. The first partition between these compartments to be broken completely down was that between heat and molecular physics, when about 1850 heat was found to be not a substance, as had been supposed, but simply molecular motion. The next discovery was that radiant heat and light were not different categories of phenomena but essentially the same phenomenon, that they were both ether waves identical save for wave length. The next great discovery, made by Maxwell and Hertz, was that electric wave phenomena are indistinguishable from light and heat save for wave length, and all these phenomena of radiant heat, light and electric waves then became fused under the general heading "ether-physics," still sharply separated from matter-physics and also from current electricity.

The next partition to go was that between current electricity and matter-physics, when electric currents were found to be the motions of electrons. But one partition then remained, that between ether-physics and matter-physics.

Quite recently this too is gone, and matter and ether waves are fused together in Einstein's equation and ether and matter become indistinguishable terms. Electrons are now both particles and waves, and light waves are also corpuscles. What does it all mean? Simply that there is an interrelatedness, a unity, a oneness about the whole of nature, and yet still an amazing mystery. Is it at all likely in the light of that history that we can long maintain air-tight compartments separating ether (or matter, whichever you will) from life and mind?

Now another finding of modern physics! With astonishing rapidity within the past twenty years man has extended his vision. He has looked inside the atom, a body one-millionth the diameter of a pin head, and found an infinitely small nucleus one-ten-thousandth the diameter of the atom and arranged about it as many as 92 electrons (in uranium) each playing its appropriate rôle in a symmetrical, co-ordinated atomic system. He has then looked inside that nucleus and counted in uranium exactly 238 positives and 146 negatives, and he has found that the atom changes to something else if any one of these positives or negatives drops out. He has watched the interplay of radiation upon these electrons, both within the nucleus and out of it, and found everywhere amazing orderliness and system. He has learned the rules of nature's game in producing the extraordinarily complicated spectrum of a substance like iron, for example, and it is, in Sommerfeld's phrase, unbelievable *zauberei* (magic) that these complicated rules never fail to predict exactly the observed results. Again, man has turned his microscope upon the living cell and found it even more complex than the

atom, with many parts each performing its function necessary to the life of the whole, and again he has turned his great telescopes upon the spiral nebulae a million light years away and there also found system and order.

After all that, is there any one who still talks about the materialism of science? Rather does the scientist join with the psalmist of thousands of years ago in reverently proclaiming "the Heavens declare the glory of God and the Firmament sheweth his handiwork." The God of Science is the spirit of rational order and of orderly development, *the integrating factor in the world of atoms and of ether and of ideas and of duties and of intelligence*. Materialism is surely not a sin of modern science.

I have thus found Science "not guilty" of most of the specific counts raised against her. But after this defense I am ready to go back to the quotation from Mr. Fosdick and join him in raising precisely the question he there asks. For in the last analysis that question is merely whether for any reason whatever, scientific or non-scientific, mankind, or more specifically this particular generation of Americans has the moral qualities that make it safe to trust it with the immensely increased knowledge and the correspondingly increased power which has come into its possession. I join him in throwing out that question as a challenge to our generation, for there can be no doubt that our generation has been getting hold of the sources of knowledge and of power at a rate such as no generation of the past has ever known, and so far at least as mechanical power is concerned such as no generation of the future is likely to know.

I am not in general disturbed by expanding knowledge or increasing power, but I begin to be disturbed when this

comes coincidentally with a decrease in the sense of moral values. If these two occur together, whether they bear any relationship or not, there is real cause for alarm.

There are certain disturbing indications in America just now of such a coincidence. I will mention but two of them: the one is the obvious effort at the deflation of idealism, the ridiculing of the existence of such a thing as a sense of duty or of social responsibility, not, thank God, by scientists; but rather by a group of American writers which is apparently trying to create something brand new in morals; and the second is the apparently increasing lawlessness just now characteristic of American life. When we have now, and have had for twenty years, *i. e.*, for a time long antedating the advent of prohibition, sixteen times the number of murders per thousand of population that is found in England there is some reason for alarm. Where individuals in sufficiently large numbers are willing to destroy the basis of confidence in themselves by refusing to be governed by the rules which they themselves, with the aid of their recognized and duly established and agreed upon machinery, have set up, then obviously the foundations of civilization are being completely undermined. If that spirit coexists with the destructive possibilities brought forth by modern science the danger is very great. The remedy, however, is obviously not to try to hold back the wheels of scientific progress, but rather to use every available energy, religious, social, educational, as individuals, as groups, and as a nation, to stay the spread of the spirit of selfishness, lawlessness, and disintegration. That, I take it, is essentially the challenge of Mr. Fosdick's book, and in that challenge I am quite ready to join with him.