honest and true, and they lead us to the Golden Rule. ASAPH HALL.

POPULAR SCIENCE.*

LADIES AND GENTLEMEN: Five years ago I prepared a sketch of an address which I expected to deliver as retiring president of the Iowa Academy of Science. I was not able to deliver the address, however, on account of enforced absence from the Des Moines meeting of the Academy at Christmas time, 1897. It was my intention in that address to speak in terms of commendation of some of the ideas advanced by Professor Woodrow Wilson in his then recent address given on the occasion of the Sesquicentennial celebration of Princeton University. Professor Wilson's recent promotion to the presidency of Princeton University has called his Sesquicentennial address again to our minds, and it seems to me that I may very properly say now what I had intended to say in 1897, especially inasmuch as no one, speaking for science, has expressed any degree of sympathy with President Wilson's point of view. I hope to make my meaning so clear and definite as to render it unnecessary for me to limit or qualify my general expression of sympathy with Professor Wilson; although the words he has used in his Sesquicentennial address are certainly open to an interpretation which no seriously minded man of science could possibly accept.

In order that we may enter upon this subject with some degree of mutual understanding, I think it is necessary to quote President Wilson at some length. He says, "I am much mistaken if the scientific spirit of the age is not doing us a great disservice, working in us a certain great degeneracy. Science has bred in us a spirit of experiment and a contempt for the past, * * *" yet "I have no indictment against what science has done: I have only a warning to utter against the atmosphere which has stolen from our laboratories into lecture rooms and into the general air of the world at large. * * *" Science "has driven mystery out of the universe; it has made malleable stuff out of the hard world and laid it out in its elements upon the table of every class room. Its own masters have known its limitations; they have stopped short at the confines of the physical universe; they have declined to reckon with spirit or with the stuffs of the mind, have eschewed sense and confined themselves to sensation. But their work has been so stupendous that all other men of all other studies have been set staring at their methods, imitating their ways of thought, ogling their results." "Let me say once more, this is not the fault of the scientist, he has done his work with an intelligence and success which cannot be too much admired. It is the work of the noxious and intoxicating gas, which has somehow got into the lungs of the rest of us from out of the crevices of his workshops—a gas it would seem, which forms only in the outer air, and where men do not know the right use of their lungs. * * *" "We have not given science too big a place in our education, but we have made a perilous mistake in giving it too great a preponderance in method over every other branch of study. We must make the humanities human again; we must recall what manner of men we are; must turn back once more to the region of practicable ideals. * * *" "I should fear nothing," says President Wilson, "better than utter destruction from a revolution conceived and led in the scientific spirit."

The chief obstacle to me in my attempt to reach a satisfactory appreciation of President Wilson's point of view lies in his apparently loose and unguarded use

* Address of the Chairman of Section B and Vice-President of the American Association for the Advancement of Science, read at the Washington meeting, December 29, 1902.

of the term 'scientific spirit.' If he means by it that humble spirit of inquiry based upon systematic methods of analysis which are really applicable to the nature of the inquiry, I certainly can not agree with him that it can do any disservice or that it would be anything but a basis of hope as the ruling element in a revolution. I do not believe that President Wilson entertains any such idea. If he means, however, to signify by 'scientific spirit' that widespread and portentous 'neglect of the essential qualities in things,' I most certainly approve his meaning and share his feelings of distress, although I disapprove his mode of expression.

Scientific men are of course not entirely free from this neglect of the essential qualities in things, but I think that the chief neglect lies in the general popular imagination, and I believe that the growth of modern science and the resulting transformations of our material world, have brought upon us an acute and distressing manifestation of it. Inasmuch as I intend to speak to you mainly of the nature and extent of the influence of scientific work on the popular imagination, I may claim to speak on popular science.

We can not discuss intelligently any subordinate manifestation of science until we come to some mutual understanding as to what science itself is; but I must confess that I do not like to go to the extent of defining a thing which, in my own mind at least, is so severely plain and humble. I do not know how you feel, but for my part I am sick of this disgusting din which has been increasing for a hundred years in canting praise of science, a din which I can most easily specify to your perception by saying that my reluctance to define science is chiefly the fear that a pack of popular idiots will rise up with indiscriminate shouting and say—you know, of course, that I have endless choice of ridiculous sayings of influential men in needless and foolish praise of science to quote from! Science does not need praise, nor does work need praise; they both need plain wages. I think it is time to urge a definition of science which will help to purge the popular imagination. Science is the spirit of work. I do not mean the spirit of a man who works, but I do mean simply that science has to do solely with the increasing efficacy of the sweaty labor of this world. I am little disposed to argue what many of you may be inclined to think an undue narrowness in this definition, but I assure you that it is wide enough for me. 'An affected thinker,' says Ruskin, 'who supposes his thinking of any other importance than as it tends to work is about the vainest kind of person that can be found' among busy men.

My own knowledge of science rests partly on anticipation and partly on a college and university experience more than usually varied, and I am convinced that science is 'primarily concerned with the making of breeches,' although, of course, you know and I know many things not now applicable to that useful, or in some cases it may be useless, business. Perhaps one who is chiefly engaged in technical education is prone to accept that practical view, yet one should not, I think, attempt to escape the evidence of one's experience, the less so, indeed, the more intimately his experience is related to practical affairs, and in any case one should only strive against exaggerated inference and extravagant conclusion.

I trust that the granting of my contention as to the severe and unpretentious homeliness of science may not divest it in your minds of a bloom which you deem essential to your interest in it; but however that may be, an understanding of what I have to say demands that much of you.

I hesitate to accept President Wilson's ideal of the perfect place of learning of which he says: 'Calm Science [is] seated there, recluse, ascetic, like a nun, not knowing that the world passes, not caring, if truth but come in answer to her prayer; and Literature walking within her open doors, in quiet chambers, with men of olden time, and calm voices infinitely sweet,' for I fear that President Wilson assumes that the spirit of science is the same as the spirit of literature which is no less a grievous error than to assume that the spirit of literature is the same as the spirit of science. I can not think of science as 'recluse, ascetic, like a nun'; but unquestionably the true seat of learning is a place apart from the world, hedged about by virtue, intrenched in grace and beauty like a woman's womb, its air pure and wholesome with the breath of faith, and looking to heaven for the confirmation of its hope.

I am inclined to look upon science as a servant and I have no sympathy for that state of mind which is exemplified by two extreme types; the man of alleged general culture who has so far forgotten his manhood as to be lost in vacant, staring wonder at the material results of modern science, but who remains in either lazy or stupid ignorance of the underlying method, and the specialist who sighs for those good old days when one man's mind might compass the entire range of scientific activity. This second type is a man who errs mainly in false humility and I am reminded in this connection of the character of Wagner in Goethe's Faust, second part, who humiliates himself before a creature of his own devising, the Homonculus. I take it to be self-evident that science can never transcend the intellectual grasp of a single man. Of course we must remember that as in case of a large industrial establishment there are many details which cannot be carried forward by the superintendent alone, so in science there are many special details which cannot be carried forward by one person, but if we consider rightly, I think it must appear that these details are essentially not intellectual.

Concerning those whose interest in science is based upon its results, I think you will agree with me that no intelligent interest can be so founded. Everything that appears in the name of science in our newspapers and magazines relates only to results. Have any of you seen in our newspapers or popular magazines any detailed description of the principles and methods used by Marconi in his wireless telegraphy? I think you have not, and yet we know too well that there is not a newspaper reader in the country but imagines he has an idea of wireless telegraphy simply because he has read that Marconi has signaled across the Atlantic Ocean!

I am somewhat intimately connected with the teaching of electrical engineering, more intimately, perhaps, than my chief interests warrant, and I frequently have occasion to speak with non-technical men respecting this subject. There are, indeed, many plain men who keep their senses when they speak of the developments in applied electricity and who talk with some degree of rudimentary intelligence concerning these things, but there are many, very many, more who seem to imagine that the glad comfort with which they ride in a trolley car constitutes an intelligent interest in science and has an intellectual quality!

True interest in science begins when one gets an idea into one's head and sees its firm and unequivocal application to external fact, and the characteristic feature of the study of science is a *determining objective constraint upon the processes of the mind.* I am surprised that this one important feature of science study is never

mentioned in the many estimates that have been made of the value of science study in education, for as a matter of fact that complete definiteness which is usually urged as the characteristic feature of science study is the fundamental condition of every psychological process; you say this or you say that, you go or you do not go; and the psychological processes which play in the study of science do not differ from other psychological processes in this respect, absolutely not at all.

Let me illustrate this objective character of science study by an example which happens also to illustrate an error which I suppose many of you entertain. What is the definition of the mass of a body? The careless and imaginative definition which is usually given is that 'the mass of a body is the quantity of matter the body contains.' I suppose that definition satisfies many of you, but it does not satisfy me. All our notions of length and angle take their rise in and are fixed or defined by those fundamental geometric operations of congruence. The real definition of mass is no less a physical operation, the verbal definition is the briefest possible specification of this operation and it can be nothing else, the result of this operation on a given body is an invariant number, and by a feat of the imagination we conceive this invariant number to be a measure of the quantity of matter the body contains. Ask a farmer's boy how he would define or set the boundaries to a cow pasture, explaining to him that you seek real practical information, and I think he could only answer, by building a fence around it! Most of our definitions in physics which apply to sensible things are necessarily applied to ideally simplified conditions which can not be feasibly realized as actual operations, all for the sake of simplicity and directness of statement, and the consequence is, I think, that many of us lose sight of the fact that these definitions are in reality operations.

I sometimes think that no popular scientific writings should be tolerated which do not introduce the reader to some appreciation of the exacting requirements of successful work. Some of Jules Verne's stories, for example, are peculiarly faulty in this respect, and these stories, and many others like them, are largely responsible, in my opinion, for the widespread fancied interest in science on the part of those who really care only for its immediate results. Most persons are fascinated by Jules Verne's care-less trip to the moon and by the easy improvidence of his ten thousand leagues under the sea.

A short time ago I had occasion to review a little book in the pages of SCIENCE, and I found therein an opportunity to briefly state what in my mind is a more serious perversion of science than that which is presented by those whose fancied interest in it is based on its results, and who, poor fools, invest in Keeley motors and sea gold companies because, forsooth, the desired result is so clearly evident. Surely one can not hold the 'scientific spirit' accountable for 'great degeneracies' like these. The book in question purports to treat of the atomic theory, it is prefaced by an introduction by a professor in the University of Chicago, and it deserves a place in DeMorgan's 'Budget of Paradoxes.' I mentioned in my review, to begin with, a list of headings to serve to indicate to the general reader the present scope of the atomic theory; the atomic theory of gases, the theory of crystal structure, the molecular theory of elasticity, the electro-atomic theory of radiation, the corpuscular theory of the electric discharge and of the electric current, stereo-chemistry, and the like, and I expressed it as my conviction that neither the author nor

his introducer knew even a little of these things.

When I take up a book like the one under consideration I am always impelled to ask myself the question, What are atoms? although in studying ordinary books on physical science the question never forcibly occurs to me. In so far as we have anything really to do with atoms, I believe they are mere logical constructions. Bacon long ago listed in his quaint way the things which seemed to him most needful for the advancement of learning. Among other things he mentioned 'A New Engine, or a help to the mind corresponding to tools for the hand,' and I think that the greatest achievement of the nineteenth century in the physical sciences is the realization of Bacon's idea in a great body of useful theory. Helmholtz says: 'It is a great advantage for the sure understanding of abstractions if one seeks to make of them the most concrete possible pictures, even when the doing so brings in many an assumption that is not exactly necessary.' Just how much of this useful theory is to become the common property of all men it is impossible to say. For the theory is by no means fixed and may not be for a century to come, and no one but the most determined specialist can be expected to appropriate and use the more complex theories which depend upon the keenest mechanical sense, the sharpest algebraic faculty, the strongest geometrical imagination, and the most devoted study; but there is a great and growing body of simple conception and theory which can and does represent to the understanding a vast array of fact.

This New Engine, as Bacon calls it, is a necessity to every man in so far as its state of perfection and the limited opportunity for education permits, and on these two conditions no one need fear any serious clogging of men's minds by it. Many scientists do not, however, fully realize, I think, that the great majority of men do not have and should not have any interest, or at least they should not expend their energies, in those border regions of science where uncertainty and obscurity necessarily and prevailingly obtain. The failure of a specialist to realize the remoteness of his work from legitimate popular interest often results in his endeavor to capture the popular imagination by sensational announcements of which we see only too many examples. The fact is that specialization in science requires a degree of renunciation and to the extent that this requirement is not met by scientists they do a disservice to their fellow men. I believe indeed that no man can do honest and effective work as a specialist and fail to meet this fundamental requirement; and the disservice that accrues when he attempts to evade it is illustrated most distressingly by that would-be electro-scientist who has recently telegraphed to Mars!

A career in which one could come into sympathetic touch with great numbers of men would be very satisfactory to most of us, no doubt, but the career of the scientific specialist is not such, and I can not refrain from stating it as my conviction that a sufficiently guarded appropriation of, say, ten per cent. of the income of the Carnegie endowment for furthering the personal intercourse of scientific specialists would be productive of greater results by far than could possibly be effected by the expenditure of the remaining ninety per cent. in any other way whatever. I say this more particularly from the point of view of the western man.

I think, with President Wilson that scientists have, as a rule, recognized the limitations of their work, and I certainly think, also, that other men err in attribu-

ting to science too great an extensity and in failing to reach any just appreciation of the intensity of science. Every one should know that a specialist's idea of a thing, such as a gas, an electric current, or a beam of light, comes very near to being a working model of the thing. The elements out of which such models are made are purely notional, and although the specialist habitually speaks of them in objective terms for the sake of concreteness and clearness, it is of the utmost importance that the thought be chiefly directed to the physical facts which are represented and not to the models themselves. 'Our method,' says Bacon, 'is continually to dwell among things soberly, without abstracting or setting the mind farther from them than makes their images meet,' and 'The capital precept for the whole undertaking is that the eye of the mind be never taken off from things themselves, but receive their images as they truly are, and God forbid that we should ever offer the dreams of fancy for a model of the world.'

There is a tendency among reflecting men to confuse the boundaries between our logical constructions and the objective realms which they represent to the understanding. Münsterberg thinks that this is the gravest danger of our time. I do not fully agree with this, but I do agree with President Wilson in seeing in this confusion of boundaries the effects of a noxious gas which has somehow got into the lungs of other men from out of the crevices of our workshops, a gas, it would seem, which forms only in the outer air and where men do not know the right use of their lungs.

This confusion of boundaries is, to my mind, a new species of idolatry. The old idolatry is the worship of form, and this new idolatry is that contemplation of our logical constructions which despises objective constraint. Now, I can not see that we as scientists are in any degree responsible for this disservice, this working of a great degeneracy among men, but as individuals I think most of us are guilty of more or less frequent and flagrant lapses of that submission to objective constraint which is the very essence of moral quality in scientific work.

An amusing collection of instances of this new idolatry, which we all know is not so very new after all, is given by DeMorgan in his 'Budget of Paradoxes.' There are many more of these paradoxes, to use DeMorgan's word for those unconstrained flights of the scientific imagination, in the mathematical and physical sciences than in biology. The explanation of this fact is, I think, that the logical structures of those sciences are to a great extent concrete in character so that even strong minds may lose sight of the boundaries between the realms of the mind and the realms of objective reality. The wide difference between the logical structures of physics and of biology may be further illustrated if I mention that I have long been impressed with the fact that the most satisfactory specialist to talk with is the biologist. His knowledge is not represented to his understanding by a mathematical-mechanical system of conceptions, but it approaches art in its close association with external form. Conversation with a physicist is, however, very like looking into the mechanism of a Mergenthaler type-casting machine, with the machine out of sight, a thing which is feasible enough among designers and builders, but scarcely a satisfactory basis for the flow of thought when one party in the conversation happens to be unfamiliar with and perhaps not interested in the mechanism in question.

Having so far expressed a degree of sym-

pathy with President Wilson in the distress which some of the results of science, direct or indirect, have given him, I wish to say that giving the words of his sesquicentennial address their most sinister interpretation a modern man would infer that President Wilson is inclined to turn back to the hope of a revival of classical and cloistered erudition as the chief end of learning. Now, I think that many of us feel that science itself is threatened by just this sort of thing in its own field. Many of us in fact know so much of the partial knowledges that have been reached during the century that we are deterred from effective work. 'We advise all men,' says Bacon, ' to think of the true ends of knowledge, and that they endeavor not after it for curiosity, contention, or the sake of despising others, nor yet for profit, reputation, power, or any such inferior consideration, but solely for the occasions and uses of life.'

Above all I believe it to be in general a perverting thing to use the elements and results of science as a basis of metaphysical speculation. 'I believe,' with Ruskin, 'that Metaphysicians and Philosophers are, on the whole, the greatest troubles the world has got to deal with; and that, while a tyrant or bad man is of some use in teaching people submission or indignation, and a thoroughly idle man is only harmful in setting an idle example, and communicating to other lazy people his own lazy misunderstandings, busy metaphysicians are always entangling good and active people and weaving cobwebs among the finest wheels of the world's business; and are as much as possible by all prudent persons to be brushed aside like spiders.'

There is, of course, a legitimate sphere of scientific speculation of a certain kind, but the purely suggestive and highly tentative efforts in this line should not be confused with the more substantial work of science, and this is precisely what happens in the popular imagination. The majority of men do not appreciate the difference between a discussion of the motion of stars in the line of sight based upon spectroscopic measurements and a discussion of the habitation of Mars based on nothing at all! Idle speculation is the last infirmity of strong minds, but it is certainly the first infirmity of weak ones, and popular science is, I think, primarily speculation.

The extent to which some of our elementary text-books in physics indulge in weak phases of speculation is very surprising to me for in this connection it is absolutely out of place and entirely misleading. What do you think, for example, of the following quotation from Maxwell as a help to clear up an inadequate definition of energy in a secondary school book in physics? "We are acquainted with matter only as that which may have energy imparted to it from other matter, and which may in its turn communicate its energy to other matter. Energy, on the other hand, we know only as that which in all natural phenomena is continually passing from one portion of matter to another." What do you think of the following from an elementary English text-book? "The fundamental property of matter, which distinguishes it from the only other real thing in the universe, is inertia. * * * We are now in a position to give one or two provisional definitions of matter—provisional because we cannot yet say, possibly may never be able to say, what matter really is. It may be defined in terms of any of its distinctive characteristics. We may say that matter is that which possesses inertia, or again since we have no knowledge of energy except in association with matter, we may assert that matter is the Vehicle of Energy." I

wonder if any of you really doubt that every notion in physics, definite or indefinite, is associated with and derived from a physical operation, and that absolutely the only way to teach physics to young men is to direct their attention to that marvelous series of determining operations which bring to light those one-to-one-correspondences which constitute the abstract facts of physical science. If you do, I am bound to say I do not think much of your knowledge or teaching of physics. I think that the sickliest notion of physics, even if a student gets it, is that it is 'the science of masses, molecules and the ether.' And I think that the healthiest notion, even if a student does not wholly get it, is that physics is the science of the ways of taking hold of bodies and pushing them!

W. S. FRANKLIN.

*INCOMPLETE OBSERVATIONS.**

IN scientific literature many observations are recorded which, from the experimental proof offered, have been generally recognized as true, but which may be classed as *incomplete*, owing to the fact that the methods of investigation employed destroyed conditions that were later found to exist, or that subsequent discoveries modified the conclusions reached at the time of the original investigation.

As an illustration of this proposition the theories of alcoholic fermentation may be cited. The members of Section C will readily recall the long and bitter controversy which was waged between the two great masters, Liebig and Pasteur, and their respective adherents as to the true cause of this phenomenon.

It is interesting at this time, in the light of recent observations, to compare the two opposing theories.

According to Liebig alcoholic fermentation is caused by the decomposition of complicated nitrogenous bodies designated by him as putrescible material, and the molecular disturbance thereby produced is imparted to the fermenticible substance, sugar, and breaks it up into simpler bodies, alcohol and carbon dioxide.

The vitalistic theory, revived by Pasteur and brought to general recognition by his masterly and convincing experiments, teaches that alcoholic fermentation takes place only in the presence of a living micro-organism known as the yeast plant, and that the phenomenon of fermentation is intimately connected with the life process of this organism. The most convincing proof in support of the vitalistic theory was furnished by Pasteur in his methods of preventing fermentation and allied phenomena by simply heating perishable bodies to a temperature high enough to kill the living germs. In the case of acetic acid fermentation he showed that a temperature of 60° was sufficient to destroy the vinegar plant. At this temperature, he argued, the nitrogenous bodies, which Liebig claimed as the actual ferments, would remain intact. In spite of this, however, he showed that further fermentation was completely arrested so long as living germs were excluded.

Although the work of Pasteur was of the greatest importance to science and humanity, and his experimental evidence for the establishment of the vitalistic theory of fermentation was of the highest order, yet to the minds of many it was never entirely clear that the rival theory was completely overthrown. For a long time, however, the vitalistic theory had clear sailing. But the observations which led to its adoption remained incomplete until a few years

*Address of the Chairman of Section C and Vice-President of the American Association for the Advancement of Science, read at the Washington meeting, December 29, 1902.