

form to it? If there were no dispute about the nature of greatness, this might probably prove the most convenient plan. It would be like a rule of grammar adduced to decide whether a phrase is good English or not. Nor would the circumstance that the definition could not be as explicit and determinate as a rule of grammar constitute a serious difficulty. Unfortunately, however, among the few writers who have seriously studied the question, the most extreme differences prevail as to the nature of great men. Some hold that they are fashioned of the most ordinary clay, and that only their rearing and environment, conjoined with fortunate opportunities, make them what they are. The heaviest weight, intellectually, among these writers maintains, on the other hand, that circumstances are as powerless to suppress the great man as they would be to subject a human being to a nation of dogs. But it was only the blundering Malvolio who got the notion that some are born great; the sentence of the astute Maria was: "Some are become great, some achieve greatness, and some have greatness thrust upon em." Amid this difference of opinion, any definition of greatness would be like a disputed rule of grammar. Just as a rule of grammar does not render an expression bad English, but only generalises the fact that good writers do not use it, so, in order to establish a definition of greatness, it would be necessary to begin by ascertaining what men were, and what men were not, great; and, that having been done, the rule might as well have been dispensed with. My opinion will, I fear, be set down by some intellectual men as foolishness, though it has not been lightly formed, nor without long years of experimentation,—that the way to judge of whether a man was great or not is to put aside all analysis, to contemplate attentively his life and works, and then to look into one's heart and estimate the impression one finds to have been made. This is the way in which one

THE CENTURY'S GREAT MEN IN SCIENCE

By C. S. PEIRCE

HOW shall we determine that men are great? Who, for instance, shall we say, are the great men of science? The men who have made the great and fruitful discoveries? Such discoveries in the nineteenth century have mostly been made independently by two or more persons. Darwin and Wallace simultaneously put forth the hypothesis of natural selection. Clausius, Rankine, and Sadi-Carnot, perhaps Kelvin, worked out the mechanical theory of heat. Krönig, Clausius, Joule, Herapath, Waterston, and Daniel Bernouilli independently suggested the kinetical theory of gases. I do not know how many minds besides Robert Mayer, Colding, Joule, and Helmholtz hit upon the doctrine of the conservation of energy. Faraday and Joseph Henry brought magnetoelectricity to light. The pack of writers who were on the warm scent of the periodic law of the chemical elements approached two hundred when the discovery itself, a most difficult inference, was partly achieved by Lothar Meyer, wholly by Mendeléef. When great discoveries were thus in the air, shall that brain necessarily be deemed great upon which they happened earliest to condense, or the man supereminent who, by the unmeaning rule of priority of publication, gets the credit in brief statements? No, this method of estimation, natural as it is to make success the standard of measure, will not do.

Shall we, then, by a logical analysis draw up an abstract definition of greatness, and call those men great who con-

would decide whether a mountain were sublime or not. The great man is the impressive personality; and the question whether he is great is a question of impression.

The subject admits of much interesting discussion, but the pertinent point here is to confess that the judgments herein expressed have been formed in this way; and if I make general remarks about the great men of the century, these are not deductions from any preconceived principles, but are simply inductions from such pure æsthetic estimations. Although I call them æsthetic, and, no doubt, the "subjective," or personal, factor in them is considerable (but it is, indeed, quite impossible to determine how far they are "objective," that is, representative of the ultimate judgment of posterity), yet I think I am warranted in saying that I have ascertained that a large majority of the educated Americans of the present day would, if thoroughly trained in the practice of this delicate method of pure æsthetic estimation, reach judgments about great men which, if based on the same information, would show a degree of concordance that would surprise most people not a little.

The glory of the nineteenth century has been its science; and its scientific great men are those whom I mean here to consider. Their distinctive characteristic throughout the century, and more and more so in each succeeding generation, has been devotion to the pursuit of truth for truth's sake. In this century we have not heard a Franklin asking, "What signifies a philosophy which does not apply itself to some use?"—a remark that could be paralleled by utterances of Laplace, of Rumford, of Buffon, and of many another well-qualified spokesman of eighteenth-century science. It was in the early dawn of the nineteenth that Gauss (or was it Dirichlet?) gave as the reason of his passion for the Theory of Numbers that "it is a pure virgin that never has been, and never can be, prostituted to any practical application

whatsoever." It was my inestimable privilege to have felt as a boy the warmth of the steadily burning enthusiasm of the scientific generation of Darwin, most of the leaders of which at home I knew intimately, and some very well in almost every country of Europe. I particularise that generation without having any reason to suspect that that flame has since burned dimmer or less purely, but simply because if a word belonged to one's mother tongue, one may be supposed to know unerringly the meaning the teachers of one's boyhood attached to it.

The word *science* was one often in those men's mouths, and I am quite sure they did not mean by it "systematised knowledge," as former ages had defined it, nor anything set down in a book, but, on the contrary, a mode of life; not knowledge, but the devoted, well-considered life-pursuit of knowledge; devotion to Truth—not "devotion to truth as one sees it," for that is no devotion to truth at all, but only to party—no, far from that, devotion to the truth that the man is not yet able to see but is striving to obtain. The word was thus, from the etymological point of view, already a misnomer. And so it remains with the scientists of to-day. What they meant, and still mean, by "science" ought, etymologically, to be called *philosophy*. But during the nineteenth century it was only a metaphysical professor of a now obsolescent type, as I hope, who could sit in his academic chair, puffed up with his "systematised knowledge,"—no true philosopher, but a mere philodoxer. For a snapshot at the nineteenth-century man of science, one may take Sir Humphry Davy, willing, as early as 1818, seriously to investigate the liquefaction of the blood of St. Januarius; or John Tyndall, with scientific ingenuousness proposing that prayer-test to which no clerical Elijah has yet been found with the faith and good faith to respond; or William Crookes, devoting years of his magnificent powers to examining the supposed evidences of the direct

action of mind upon matter, in the face of the world's scorn. Contrast these instances with the refusal of Laplace and Biot, in the closing years of the previous century, to accept the evidence that stones fall from heaven (evidence proving that they do so daily), simply because their prepossessions were the other way. One of the geologist brothers De Luc declared that he would not believe such a thing though he saw it with his own eyes; and a scientifically given English ecclesiastic, who happened to be sojourning in Siena when a shower of aërolites was dashed in broad daylight into an open square of that town, wrote home that having seen the stones he had found the testimony of eye-witnesses so unimpeachable, and so trustworthy that—that he accepted the fact, you will say? by no means—that *he knew not what to think!* Such was the *bon sens* that guided the eighteenth century, —a pretty phrase for ineradicable prejudice.

To this self-effacement before the grandeur of reason and truth is traceable the greatness of nineteenth-century science, most obviously in mathematics. In the minds of eighteenth-century mathematicians their science existed for the sake of its applications. Forgetfulness of this was in their eyes reprehensible, immoral. The question was, What would a given piece of mathematics do? They liked smooth-running and elegant machinery —there was economy in that; but they were not sedulous that it should have symmetry; idle admiration of its beauty they hardly approved. If it was excessively complicated and intricate, that was regarded rather as a feature to be proud of than as a blemish. Were the complete revolution that the nineteenth century wrought upon the ideal of mathematics not notorious, one could soon convince himself of it by looking over almost any modern treatise — say, Salmon on *Higher Plane Curves*. That volume, for example, would be found replete with theorems hardly any of which hold good for any curves

that could really exist. Realisable curves have hardly been studied at all, for the reason that they do not yield a beautiful theory such as is now exacted. Modern mathematics is highly artistic. A simple theme is chosen, some conception pretty and charming in itself. Then it is shown that by simply holding this idea up to one's eye and looking through it, a whole forest that before seemed a thick and tangled jungle of bushes and briars is seen to be in reality an orderly garden. The word *generalisation* really cannot be fully understood without studying modern mathematics; nor can the beauty of generalisation be in any other way so well appreciated. There is here no need of throwing out "extreme cases." Far from that, it is precisely in the extreme cases that the power and beauty of the magic eyeglass is most apparent and most marvellous. Let me take back the word "magic," though; for the reasonableness of it is just its crowning charm. I must not be led away from my point to expatiate upon the repositiveness of the new mathematics, upon how it relieves us of that tiresome imp, Man, and from the most importunate and unsatisfactory of the race, one's self. Suffice it to say that it is so reasonable, so simple, so easy to read, when the right view has once been attained, that the student may easily forget what arduous labours were expended in constructing the first convenient pathway to that lofty summit; what mastery over intricacies, far beyond that of the eighteenth-century master. "It must not be supposed," said C. G. J. Jacobi, one of the simplifying pioneers, "that it is to a gift of nature that I owe such mathematical power as I possess. No, it has come by hard work, hard work. Not mere industry, but brain-splitting thinking—hard work; hard work that has often endangered my health." Such reflections enable us to perceive that if modern mathematics is great, so also were the men who made it great.

The science next in abstractness after mathematics is logic. The contributions of the eighteenth century to this subject were enormous. In pure logic, the doctrine of chances, which has been the logical guide of the exact sciences and is now illuminating the pathway of the theory of evolution, and is destined to still higher uses, received at the hands of Jacob Bernoulli and of Laplace developments of the first importance. In the theory of cognition, Berkeley and Kant laid solid foundations; their personal greatness is incontestable. This is hardly true of Hume. In the nineteenth century, Boole created a method of miraculous fruitfulness, which aided in the development of the logic of relatives, and threw great light on the doctrine of probability, and threw upon the theory and rules of inductive reasoning. De Morgan added an entirely new kind of syllogism, and brought the logic of relatives into existence, which revolutionises general conceptions of reasoning. The works of Comte, Whewell, J. S. Mill, Jevons, and others upon the philosophy of inductive science were less successful or fruitful. In the more metaphysical part of logic, the philosophy of Hegel, though it cannot be accepted on the whole, was the work of a great man. In metaphysics and general cosmology, the attitude of the century has been expectant. Herbert Spencer has been proclaimed as a sort of scientific Messiah by a group of followers more ardent than philosophic, which does not seem to be gathering strength.

At the head of the physical sciences stands nomological physics. Dr. Thomas Young was here the earliest great man of the century, whose intellect illuminated every corner to which it was directed, taking the first difficult steps in the decipherment of the hieroglyphics, originating the doctrine of colour-mixtures, propounding the correct theory of light and illuminative everywhere. It gives a realising sense of the century's progress that

this great man in its early years should have opined that experimentation in general had then been pushed about far enough. On that occasion, it was not his usual logic, but the eighteenth-century watchword "*bon sens*," that was his guide, with the sort of result it is continually turning out when used beyond its proper sphere of every-day practical affairs. The advance of years with their experience has led physicists to expend more and vastly more effort upon extreme precision, against every protest of good sense. What has come of it? Marconi's wireless telegraphy, for one thing. For it was the precision with which the velocity of light on the one hand, and the ratio of static and dynamical constants of electricity on the other, had been determined that proved to Maxwell that the vibrating medium of light was the substance of electricity, a theory that his great follower Hertz applied to making giant light-waves less affected by obstructions than even those of sound. I dare say sapient "good sense" pooh-poohs those wonderful new substances, helium and the rest, that seem the connecting link between ordinary matter and the ether. So it would be useless to point out that their discovery was entirely due to Lord Rayleigh's fastidiousness in the determination of the density of nitrogen. But it has to be noted as a characteristic of the great physicists of the nineteenth century that their reverence for every feature of the phenomenon, however minute, has been in thorough disaccord with the older "good sense." The greatest advances in physics during the century were made by several men at once. Certain ideas would come somehow to be in the air; and by the time they had crystallised for a student here and there, he would hesitate to announce as original conceptions what he had reason to suppose many men shared, while he knew that the larger body would not be yet ready to accept them. Under those circumstances, priority of publication can signify

nothing except haste. Yet, when we come to apply the method of pure æsthetic estimation to the different thinkers who first brought out the mechanical theory of heat, the kinetical theory of gases, and the doctrine of the conservation of energy, we find, to our surprise, not that they were none of them great, but that a remarkable crop of great men made its appearance to work out those problems, a fact only explicable by the forest-tree theory. I mean by that, the theory that such an enormous majority of men capable of developing into greatness are kept down by extraneous circumstances, like trees in a forest, that wherever there is room for them they are sure to appear.

Of all men of the century Faraday had the greatest power of drawing ideas straight out of his experiments and making his physical apparatus do his thinking, so that experimentation and inference were not two proceedings, but one. To understand what this means, read *Researches on Electricity*. His genius was thus higher than that of Helmholtz, who fitted a phenomenon with an appropriate conception out of his store, as one might fit a bottle with a stopper. The most wonderful capacity for "catching on" to the ideas of nature when these were of a complicated kind was shown by Mendeléef in making out the periodic law of the chemical elements, as one might make out the meaning of a pantomime, from data so fragmentary—and in some cases erroneous—that the interpretation involved the correction of sundry facts, corrections since confirmed, as well as the prediction of the very peculiar properties of the unknown gallium, scandium, germanium, which were soon afterward actually met with. Minute examination of all his utterances convinces one that Mendeléef's mental processes in this unparalleled induction were largely subconscious and; as such, indicate an absorption of the man's whole being in his devotion to the reason in facts.

A great naturalist, as well as I can make out, is a man whose capacious skull allows of his being on the alert to a hundred different things at once, this same alertness being connected with a power of seeing the relations between different complicated sets of phenomena when they are presented in their entirety. The eighteenth century had its Linnæus, whose greatness even I can detect as I turn over his pages; its Huber, discovering through others' eyes what others could not discern with their own; its Goethe, its Haller, its Hunter; and, mixed with practical greatness, its Pinel and its Jenner. Then there was Lavater, who showed how pure æsthetic estimation might be turned to the discovery of truth,—a man depreciated because logicians and philodoxers can so much more easily detect his weakness than discern his strength. The nineteenth century, with its great thinker Darwin, its Pasteur (great in chemistry as well as in biology, a man who impressed me personally, and impresses me in his works as much as any but two or three of the century), its Lamarroll, Weissmann, Cuvier, Agassiz, von Baer, Bichat, Johannes Müller, Robert Brown, and I know not whom besides, has certainly garnered a magnificent harvest of great men from this field.

Those sciences which study individual objects and seek to explain them upon physical principles—astronomy, geology, etc. (corresponding to history and biography on the psychical side)—demand the greatest assemblage of different powers. Those who pursue them have first to be mathematicians, physicists, chemists, naturalists, all at once, and, after that, astronomers or geologists in addition. It is almost beyond human power. In the eighteenth century, A. G. Werner broke ground in geology, William Herschel, Kant, and Laplace did great things in astronomy. In the nineteenth century, geology was first really made a science, and among its great men one recalls at once Lyell, Agassiz, Kelvin. This country

has become its home. In astronomy, too, this country has been eminent, especially in the new astronomy which has afforded the needed scope for greatness, instead of the narrow rut that Bessel and Argelander had left behind them. Thus it happens that we have a magnificent group of great astronomers living among us to-day. We stand too close to them to take in their true proportions, but it is certain that the names of Chandler, Langley, Newcomb, Pickering, and several others are indelibly inscribed upon the heavens. In England it is only this year that Sir Norman Lockyer has brought the extraordinary research, to which his life has been devoted, to completion, so far as such work can be said to be capable of completion. It is an attribute of its greatness that it is endless.

When we compare all the men I have glanced at, with a view to eliciting a common trait somewhat distinctive of the nineteenth century, we cannot but see that science has been animated by a new spirit, till the very word has become a misnomer. It is the man of science, eager to have his every opinion regenerated, his every idea rationalised, by drinking at the fountain of fact and devoting all the energies of his life to the cult of Truth, not as he understands it, but as he does not yet understand it, that ought properly to be called a philosopher. To an earlier age knowledge was power—merely that and nothing more; to us it is life and the *summum bonum*. Emancipation from the bonds of self, of one's own prepossessions, importunately sought at the hands of that rational power before which all must ultimately bow,—this is the characteristic that distinguishes all the great figures of nineteenth-century science from those of former periods.

THE CENTURY'S ADVANCE IN ASTRONOMICAL SCIENCE

BY SIMON NEWCOMB

ONE hundred years ago Sir William Herschel, then in the zenith of his fame, was interesting the learned world by his wonderful discoveries. With his great reflectors he made a step forward in the size and power of the telescope greater than any before or since. Although his greatest and best instrument would be considered extremely imperfect at the present time, those which it superseded were hardly more than what we should now call spyglasses. Herschel was so far the greatest figure of the time in astronomical science, and his work so overshadowed that of his contemporaries on the Continent that the work of everyone else at the time seems unimportant in comparison. Yet not only were great successors of Herschel coming on the stage, but important additions to our knowledge of the heavens were being made outside of England. William Herschel's son John was a lad of eight years. In France, Arago, a boy of fourteen, was fitting himself for the *École Polytechnique*. At Paris, Lalande, the leading astronomer of France, was actively preparing a catalogue of the fainter stars with an instrument which would now be consigned to the junkshop. But it was the first attempt that had ever been made to determine accurately the positions of the many thousand telescopic stars invisible to the naked eye, and in consequence the *Histoire Céleste* is still one of the classics of the astronomical