light and power industry, and so to a time when Edison was but little known outside of his own field, makes it clear that within that field he was even then recognized as master.

If one were writing a complete biographical appraisal of Edison and his works, pages could easily be filled with descriptions of the tremendous array of things which he produced and patented, and of the wide range of his interests. In so short a note even as the present one there is great temptation to expand the list to include a few more items, notably his work in the motion picture art. Some of this work is but little inferior to that which seems to me to constitute Edison's principal unassailable claim to fame.

The amazing variety of the things which Edison did and the fact that he seldom made contact with any art without contributing something to its advance lead one to speculate on what might have happened to the development of some of these arts had Edison concentrated his attention on them during the years of his greatest productivity.

In closing this brief appraisement of the engineering side of a man for whom I had the most sincere regard, I can not refrain from voicing a bit of regret that during his evening years his name should have been so frequently associated with inconsequential things or with personal idiosyncrasies, with which we are all amply provided. While these associations subtracted nothing from the judgment of men who knew Edison's real worth, they did unquestionably portray a great man in a somewhat false and belittling light to vast numbers of a younger generation.

EDISON AS A SCIENTIST

By Dr. ROBERT ANDREWS MILLIKAN

DIRECTOR OF THE NORMAN BRIDGE LABORATORY OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY

I AM asked to say something about the scientific qualities and achievements of Mr. Edison. But from my point of view the scientific influence of any man is so interwoven with his character, with his mode of thought, with his outlook on life as reflected in his acts, his words and his daily walk among his fellows that I prefer to let what I say about Mr. Edison's science grow out of a somewhat broader consideration of the qualities which made him the commanding figure that he was and that, as I think, he always will be.

I should like to raise first one very fundamental question. Is it merely an accident, a coincidence, that the two greatest scientists of the nineteenth century, the two who, the world over, would be first named as the most significant creators of the age of electricity with all that it has meant to the world, namely Michael Faraday and James Clerk Maxwell, were also great souls, possessors in peculiar measure of the virtues which in all times and all places have been regarded by mankind as the most fundamental, namely, modesty, simplicity, straightforwardness, objectiveness, industry, honesty, human sympathy, altruism, reverence and a keen sense of social responsibility. These qualities arise, I think, from one great all-inclusive quality, namely, balanced but penetrating and objective judgment, *i.e.*, from a correct understanding of relations between phenomena, social as well as physical, including that of one's own position in the scheme of things: and this quality, this perception is precisely what gives the great scientist his insight and his effectiveness. Smart rogues, clever scoundrels, gifted egotists, exist, no doubt; but do they do the things that live? I suspect not often. Certainly history is replete with the names of great scientists who have also been great souls—Copernicus, Leonardo da Vinci, Newton, Kepler, Faraday, Helmholtz, Pasteur, Maxwell, Kelvin, Lorentz, Einstein. What a galaxy of greatness not merely as scientists but as men!

Had Edison their quality and was this the reason of his greatness? I did not know him intimately, but I saw enough of him to be sure that I saw some of their virtues. He had not the educational background of most of them, and might therefore have been expected to be somewhat wanting in their breadth of vision, but the very exceptional minds—the really great—do not need the schools, for they appreciate what educational opportunity means, and have the capacity to become educated without the aid of the schools. This quality—the *sine qua non* for a scientist—namely, the appreciation of one's own ignorance and limitations coupled with the eternal urge to learn, and the will and power to follow that urge—I myself had the opportunity to see in Edison.

During the war when we were both engaged in Washington I spent an evening or two with him. He was then, at the age of seventy and more, reading some of the newer books that were then appearing in the field of pure science, and asking intelligent questions about them, too. His ears were gone, but there had been no crystallizing of his mind, such as occurs with some of us before we are born; with others, especially with so-called men of action, before we are forty; and with most of us, even with those who have learned to combine the art of knowing with

the power of doing, by the time we are seventy. That Edison above all men retained his essential modesty, simplicity, intellectual honesty and willingness to learn, in spite of the disease to which it was his misfortune to be exposed in early life and continuously thereafter, is, I think, the best proof that we have of his real greatness. I refer of course to the disease which attacks and almost always lays low football heroes, movie stars, presidents and kings—the disease of publicity and adulation.

There seems to be no known method of inoculating human beings against that disease. Only the really great, apparently the extraordinarily great, are immune. One can set it up as a well-nigh universal law that "human nature can not stand too much corn," and but few men in our American history have had so much of it as did Edison. Did it go to his head, as it has done in the case of so many others who have been *almost* great? I could see no indication of it. The fact that his name became probably the best-known one in the United States, that commercial electrical companies from one end of the country to the other adopted it as their trademark, as a guarantee of their quality, that sycophants and exploiters swarmed about him—all this apparently left him practically untouched.

Nor was this merely the impression which he made upon me, one individual scientist. I well remember when Professor Fabry, of Paris, the head of the allied scientific mission sent to the United States by the Allied European Governments during the war, came back from a visit with Edison and said, "Simple, direct, intelligent, unspoiled—a very much greater man than I expected to find in view of the way his name has been exploited and the kind of influences with which he has been surrounded." So much for the fundamental qualities which make true greatness in a scientist.

As to his actual accomplishment in science. It is customary to make a rough-and-ready distinction between pure science and applied science, and it is indeed possible to set up definitions which bring out the difference as applied to a given time and place, but in the ultimate analysis all increase in knowledge is directed toward one single end, namely, the increase in human satisfactions. When one talks about pursuing knowledge for its own sake he is only asserting his belief that it is important to stretch the mind of man, to feed his intellect and his soul as well as his body. At one time and place, for example in time of famine, the latter, *i.e.,* the material need, may be the all-important one; at another time and place, for example, in a time in which the capacity for producing material things is superabundant, the former, *i.e.,* the spiritual need, may be a vastly more crying one. In the United States the period into which Mr. Edison was born was one which called loudly for the increase in material facilities. It was a new and a largely undeveloped country calling violently for transportation, for communications, for the means to make one man's labor produce the maximum of goods. Edison heard that call, saw that need, and bent his matchless energies and capacities to meet it. Our country through our patent laws had striven to stimulate our people in just that direction. Hence with his gifts and his background it was practically inevitable that his contributions to human progress should have found their outlet almost entirely through the patent office.

Had he been born to-day when, through the applicatoin of science, mankind in the United States can produce more food that it can eat, more clothes than it can wear, more buildings than it can occupy, I venture to estimate that he would have seen, as you and I see so clearly now, that the satisfactions that come from the stretching of the human mind, through the growth and the dissemination of knowledge, and through the giving of leisure for the acquiring of the knowledge of how to live more wholesomely, more inspiringly as a race than we live now, has pushed itself to the front as the greatest of our present human needs. New occasions have indeed taught new duties. Having fed his body, man's next great need is to feed his intellect, his heart and his soul. In a word, the relative importance of pure science and applied science in the United States has undergone a change since Edison was born and that for two reasons, first, because all applied science grows out of pure science, and if the springs that feed the river dry up presently there will be no river left; and second, because having learned how to feed and clothe the body the *art* of living, which comes from the growth and spread of knowledge, is now our greatest need. "Crescat scientia, vita excolatur"—"Let knowledge grow that life may be enriched."

Thus far I have said nothing about Mr. Edison's specific scientific accomplishment as distinct from his engineering and industrial contributions. There were, however, two of them. The so-called Edison effect was discovered in 1883 and patented in 1884. It underlies in a way the whole vacuum tube art with all that it has since been found to mean for the life of the race, but nothing came of it then because neither he nor any one at that time understood it, or had the time, or the urge so conspicuously displayed by Faraday, to stop and find out what it meant; *i.e.,* why nature worked that way. The credit for finding out goes in this case to Edison's scientific successors two decades later.

The second scientific accomplishment is enough by itself to make any man immortal, for to Edison alone

belongs the credit of conceiving, and showing how mortal man may speak with his living voice directly to all the generations that follow after him. Could we to-day but hear Socrates and Marcus Aurelius and Shakespeare and Newton and Franklin and Goethe and Faraday and Maxwell, as our children and our children's children through the long ages will be able to hear their counter-parts of to-day and of all the times yet to come, would we not build another Promethean legend around that deed akin to that of stealing fire from heaven and bringing it down to men. That man has lived and worked and walked on earth with us in our generation. Thomas A. Edison is his name.

EDISON'S LABORATORY IN WAR TIME

By Dr. KARL T. COMPTON

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DR. JEWETT and Dr. Millikan have discussed the importance to science of some of Mr. Edison's inventions and investigations. My own talk will, like Mr. Edgar's, be based on a personal contact with Mr. Edison and his laboratory, and through it I wish to give additional details to the picture of Edison as a workman and as a scientist.

Immediately following the declaration of war in 1917 Mr. Edison telephoned President Hibben, of Princeton, requesting him to send to his laboratory four scientists as volunteer war workers. I went with three of my colleagues from the department of physics and remained for the months required to bring to a conclusion the problem which was set for me by Mr. Edison.

All through the war the newspapers published frequent stories of Edison's war activities and of the secrecy in which they were carried out. One story which I remember described experiments carried on in the dead of night on the top of a mountain with armed guards posted all around the base. Whether these stories are true or not I do not know, but I do know that Edison's research laboratory was actively at work and that contact with this work gave me a vivid picture of Edison and his methods.

Immediately upon meeting Mr. Edison and barely taking time to say "how do you do," he took out his pencil and began to describe a problem which had been put up to him by the Naval Consulting Board—the problem of increasing the efficiency of the driving mechanism of a torpedo so that a larger amount of explosive could be stored in it without changing its range or size. He gave me a very brief history of the development of the present torpedo, told me the conditions which an improved torpedo would have to satisfy, and told me to come back to see him when I had a solution.

In about three weeks I reported to him that I had found three fuels which seemed to offer possibilities. He disposed of these solutions in three sentences: "Fuel A can only be obtained in Germany. Fuel B has been tried but discarded because of the danger of explosions. Fuel C, which included wood alcohol, is no good because the sailors drink the d— stuff."

So I went back for another couple of weeks and returned with a fourth solution. Mr. Edison took the papers, looked over the calculations, muttering the while to himself, and then said, "When I don't understand work like this I get two men to work at it independently. If they agree, maybe it is all right; if they don't agree, I get a third man. Go up into room — and see whether you agree with a young fellow from Columbia University whom I put to work on the same problem."

On interviewing this Columbia scientist I found that we agreed entirely as to method but disagreed radically as to conclusions. Whereas I had found very few fuels possibly superior to those which the Navy was using, he had found that almost every fuel was superior. On looking over his work, however, I found that he had based all calculations on a formula for alcohol, C_{12} H_{22} O_{11}, which is sugar. In other words, he had been actually finding out what fuels would be better than sugar for driving the Navy's torpedoes. When I asked him where in the world he had got that formula for alcohol he said, "You see, I am a mathematician and not a chemist so I went to the library," and with that he showed me an ancient book on chemistry, in which C_{12} H_{22} O_{11} was actually given as the formula for alcohol.

Following this conference, Mr. Edison arranged for me a visit to one of the naval torpedo stations, where the calculations were checked by the torpedo engineer and the work was left in the hands of the Navy, with what results I do not know.

A second investigation illustrated Mr. Edison's great fertility and imagination. There had been numerous demands for the development of a supersensitive microphone for detecting enemy operations by night or under the ground or beneath the sea. According to Mr. Edison the ordinary carbon granule microphone had too high a resistance, and he wanted to try metal granules, "But," he said, "metal granules