combining individuals into a multi-individual organization, a social organism surely new in the history of the world. This biological trend and process is constructing a social organism the cohesion of which depends mainly on a property developed so specifically in man as to be, broadly speaking, his alone, namely, a mind actuated by instincts but instrumented with reason. Man, often Nature's rebel, as Sir Ray Lankester has luminously said, can, viewing this great supra-individual process, shape his courses conformably with it even as an individual, feeling that in this case to rebel would be to sink lower rather than to continue his own evolution upward.

C. S. SHERRINGTON

CAN WASTE OF MENTAL EFFORT BE AVOIDED

ONE of the most startling phenomena in the history of science and invention is the lack of economy of mental effort. As a rule the great discoveries in science have not been made once, but have been repeated several times. It is as though engineers had built several Panama canals when only one was needed, thereby producing financial waste. At the recent death of Alexander Graham Bell the daily press reminds us that he invented the telephone. But he was not the only one who accomplished this. On the very day that Bell patented his telephone, Elisha Gray applied for a patent for an instrument of similar kind. At an earlier date Phillip Reis sent a speaking machine to the emperor of Russia. The same is true in the invention of the telegraph. No historian of science can give Samuel Morse exclusive credit. Before him, Joseph Henry at Albany, by the attraction of an electromagnet, produced audible signals at a distance. Gauss and Weber sent messages by an electromagnetic device over wires connecting the Observatory and Physical Cabinet at Göttingen. The mental effort of inventing the telegraph and telephone was made, not once, but several times.

These are only two of the numerous illustrations which might be given of duplication in applied science. In pure science the situation is even worse. Waste of effort through repetition occurred in the discovery of the laws of gases, Ohm's law in electricity, the principle of the conservation of energy, logarithms, determinants, J. W. Gibb's equilibrium of chemical systems and Mendel's law. The full accounts of reproduction of scientific discovery and invention would fill a large book. The waste of gray matter has resembled the prodigality of the pine-tree which produces millions of pollen particles for every new plant that is actually started.

It may be argued that the waste occurs only in the records of centuries which are passed, that the number of scientific journals has now increased so greatly that scientific results can be published promptly. As a matter of fact, the greater number of journals has not brought effective relief. The danger of unnecessary repetition is still with us. Not only is the army of scientific workers tremendously augmented, so that even now the editorial desks are overloaded with able manuscripts and publication is not so prompt as some suppose, but the long list of scientific journals has greatly augmented the labor on the part of any one worker to ascertain what new results have been reached in his particular field of activity. Paradoxical as it may seem, the publications themselves, by their great mass, clog the worker's efforts to find what he desires.

It is still true that investigators are frequently unacquainted with results already reached by others. And so it frequently happens that the best brains are exercised to the utmost in discovering things already discovered by others. Creative genius is rare. There are in a generation few cubic decimeters of brains in a nation, capable of materially advancing science, and yet history shows that in the past a large part of these precious cubic decimeters of gray matter has been expended upon needless repetition.

Is it not possible to improve on the present wasteful methods of conducting research? There is indeed need of persistence in the endeavor that

> No subtle, bright and novel thought
> In this wide world shall come to naught;
> No germ of purest ray serene
> Shall scintillate by us unseen.

Can the pathfinders of the intellect conduct their inquiries as if organized in a team for a relay race, each individual carrying the torch of light from the point reached by his predecessor? Such a procedure would prevent repetition. But unfortunately the problem before us is too complex to admit of such simple solution. The impracticability of the relay plan is evident from the consideration that when A has announced some startling novelty, not only B, but also C, D and E may take up the further pursuit of the subject. And it is indeed well that it should be so, for not every B, C, D and E may be fortunate to travel in the right direction and reach desired results. The probability of further penetration into the unknown is increased when several able minds are at work simultaneously, rather than one alone. Moreover, several workers may expect to obtain a greater volume of new knowledge. Under these circumstances some duplication is quite certain and can not be avoided. But when a goal has been reached by one or more men, there should be an effective system of distribution of this knowledge that will stop all unnecessary intellectual endeavor.

In the prevention of waste the capitalist can play a leading rôle. A serious difficulty encountered in the United States at the present time is the lack of funds for prompt publication. In mathematics, for example, no new books in advanced fields have been issued in this country in recent years. Several manuscripts are awaiting publication. Moreover, the American periodicals devoted to research articles are financially unable to print articles except after long delay. Terminal stations for the distribution of scientific products are greatly congested. Moreover, there is a crying need for efficient and prompt bibliography and abstracts of scientific output. It is here that the sympathetic capitalist can contribute to the advancement of science almost as much as he could, were he himself one of the foremost research workers. He can contribute to a very essential phase of scientific progress, namely, the prompt distribution of new knowledge and the prevention of avoidable waste of effort. Essential agencies in the dissemination of knowledge are abstracts and bibliographies. Except in chemistry and medicine, the United States has been derelict in the discharge of its share of obligation in this regard. The Great War has disarranged what was being accomplished in Europe and the present international situation is much worse than that of eight years ago.

The need of the hour is not only adequate funds for printing, but also new, more instantaneous and effective methods of distribution. Some advance is desired which will accomplish for the twentieth century what the invention of printing achieved for the fifteenth century and photography for the nineteenth century. Scientific discovery should take up as one of its problems its own more efficient progress. Science should bend its efforts to devise new plans to accelerate its own rate of advancement. Is it not possible for progress to be made on the compound interest or the snowball mode of accretion? The printing press will not be superseded, but it should be supplemented by new agencies. The possibilities of the radiophone seem almost unlimited. It can be made to do what it is not yet doing. When John Smith has a new result, it lies theoretically within his power to transmit it instantaneously to his co-workers all over the world. And if such were done, the largest part of the waste of mental effort could be avoided. At present this method lends itself more readily to some fields of science than to others. As yet, it is difficult to see how the "radio" could be effectively used in diffusing advanced mathematics that is expressed, perhaps, in the notation of differential equations or in the Peano symbolism. "Radio" appeals, not to the eye, but to the ear. Moreover, it transmits a message that is not permanent, but vanishes as quick as wink. But, probably even in abstruse mathematics, modes of quick and permanent communication by wireless telegraphy will be found to lie within the range of practicability.

The instantaneous distribution of intelligence in the form of a permanent record will remove all avoidable waste of scientific effort.

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