SCIENCE

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THE RELATIONS BETWEEN ENGINEERING AND SCIENCE[1]

WE may well approach our subject of the relation between engineering and science by defining these two.

Engineering is the application to man's use of special knowledge of mechanics and of the properties of matter.

Natural science is the correlation of natural phenomena, often combined with their discovery. Emerson says:

> Science is nothing but the finding of analogy, identity in the most remote parts.

This finding of analogy is correlation. But though science has correlation for its essence it also includes discovery. Science thus has two aspects, it correlates the uncorrelated and hence empirically known phenomena, and it discovers new phenomena and correlates them simultaneously. Their correlation is of origin, congenital. Or, if you will not go so far with me, let us agree that engineering is essentially application and science essentially correlation with or without discovery. In this view engineering is not a science but an art with a scientific basis. A man who is an engineer may correlate his own or others' discoveries, as he may walk a mile or pledge a health, but he does it not as an engineer but as simultaneously a natural philosopher.

From this point of view pure science in

[1] Introductory address of the chairman of the Section of Engineering of the American Association for the Advancement of Science given at the meeting held by invitation of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, New York, December 29, 1916.

its relation to engineering seems to-day to be in an intermediate stage of its asymptotic evolution from the state of a follower to that of an absolute dictator. The first reason why this evolution has to follow this general course is that application must needs precede correlation.

Man like the other animals from the very first can survive only as he applies nature's laws to his needs, as he conforms to them, so that he begins applying them inconceivably earlier than he begins to formulate them or even to be capable of formulating them.

The second reason lies in the unfathomable complexity of the laws on which engineering must needs be based.

The engineering of the savage is military. His existence depends on his power to kill his enemies and incidentally his game by means of weapons made from the materials at hand. Of these materials he knows only certain prominent properties irrelated to each other and to the rest of nature. If this knowledge can be said to consist of laws they are only the most minute fragments when compared even with the fragments of laws which we have joined up. They are fragments comminuted to the second degree. The explanation of these fragments the savage has never sought. Yet the laws themselves were as complex when our forefathers were naked as they are to-day. The Bornean or Fiji knows that wood is strong, stone stronger, and iron stronger still, though corruptible by rust. Armed with this and all other knowledge which he has he destroys those who else would destroy him. The survival is not of those who formulate knowledge but of those who best apply it, and so there evolves a race which applies successfully the laws which it may never even think of thinking of.

By and by evolution lifts certain men so far up out of the imperative need of ceaseless viligance lest they be slain by their fellows or by nature as to give them the opportunity to consider their environment, and note the analogies between phenomena which at first seem irrelated. These are the first men of science. Before them the ratio of observed to correlated phenomena was that of a small body to zero, and hence was infinity. With them that ratio fell from infinity to finiteness, but it was still extremely small.

As the accumulation of observed phenomena goes on and with it the organization and elaboration of society, certain men come to excel their fellows sufficiently in their mastery of this knowledge, and in their ingenuity in applying it, to become recognized as a special class, engineers. More slowly the accumulation of observed analogies becomes so great that those who master it become recognized in their turn as a class, the natural philosophers or men of science.

These philosophers address themselves at first to correlating phenomena, which, however familiar, are known as yet only empirically, and thus to explaining that which engineering has long known how to do, has known in part since the days of Assyria, of Homer, and of Kephren. But this is to trail after engineering, to explain its exploits as the minstrel glorifies those of the warrior. By and by science becomes able, through its accumulation of correlations, to point out to the engineer how he may better his service to man. But this is to snatch a share in the leadership, and add it to the continuing labor of correlation.

From this time on science increases continuously the share which it has in the direction of engineering. It is engaged ever more and more in discovering and simultaneously correlating new knowledge, and less and less in the gradually vanishing

work of the correlation of the old empirical knowledge with which alone engineering formerly worked. With the completion of this latter task science might come to be the sole guide of engineering, but for two considerations.

First, as engineering adopts the knowledge which science has correlated it simultaneously unearths new uncorrelated knowledge. Science indeed correlates this in turn, but not instantaneously, so that engineering has always at its hand both that which science has correlated and its own empirical discoveries which science has not yet had time to arrange. As optimists we may well expect that this uncorrelated knowledge will form a gradually decreasing fraction of the whole, but can we expect it ever to vanish completely? Must not science's approach to exclusive leadership be asymptotic?

We begin to get a glimmering of the vastness of the scheme of creation when we remember that every lengthening of man's artificial vision by means of telescope and camera, every new strengthening of telescope, sensitizing of plate, and lengthening of exposure brings a proportional increase in the number of visible suns, telling us that even at that inconceivable distance we have not begun to approach the limit of the discoverable universe. When we turn from telescope to microscope and thence to the inferred constitution of matter, we find with every new refinement of observation and inference a proportional addition of new wonders, a proportional increment in the complexity of natural phenomena. Hence while we may speculate that, as there must be a place where the stars end, so there must be a degree beyond which the subdivision of matter can not go, and a limit to the number of nature's laws, we may well ask whether either that limit or the limit of stellar space will be reached in that little throb in the pulse of the universe which we call the habitable period of this earth. Will man survive long enough to complete the discovery of all laws, so that no uncorrelated phenomena will remain for the engineer to unearth?

The second of the two considerations which tend to postpone the completion of science's leadership is that the beautiful as distinguished from the useful and the good will increase without limit its demands upon the work of the engineer. Though the beautiful itself should in time be capable of complete mathematical analysis, who shall say that that time, now seemingly so inconceivably remote, can arrive during man's earthly stay?

HENRY M. HOWE

OUR PSYCHOLOGICAL ASSOCIATION AND RESEARCH[1]

THE American Psychological Association, like the infants who are among the objects of our study, celebrated its first birthday some months after it was born. We are thus able to hold at the same time our twenty-fifth meeting and mark the completion of nearly twenty-five years of activity. This period covers the working life of most of us and about half the adult life of the science in which we work. Wundt's "Physiologische Psychologie," published in 1874, may be taken to mark the coming of age of the experimental work of Weber, Helmholtz and Fechner. But if psychology as a science was made in Germany, the raw materials were contributed from many nations, many centuries, many sciences; and the leading strings attaching us to Germany were severed at about the time when this association was organized.

[1] Address given on the occasion of the celebration of the twenty-fifth anniversary of the American Psychological Association, New York, December 28, 1916.