SCIENCE

VOL. 101 FRIDAY, MARCH 2, 1945 No. 2618

SCIENCE: A Weekly Journal, since 1900 the official organ of the American Association for the Advancement of Science. Published by the American Association for the Advancement of Science every Friday at Lancaster, Pennsylvania.

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Communications relative to articles offered for publication should be addressed to Editors of Science, The Science Press, Lancaster, Pa.

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Annual subscription, $6.00 Single copies, 15 cents

SCIENCE AND OUR NATION'S FUTURE[1]

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THE nation is now calling for all its scientific strength. On the battlefields of Europe and the Orient and on the seven seas new weapons are turning the tide of battle. On both sides of the conflict determined men fight with courage and skill. If we are to win a decisive victory we must have weapons not only greater in quantity but superior in quality. Superior quality requires skilled labor and great industries with knowledge of the best techniques. It requires ingenious inventors with fertile imaginations. But basic to all is required the science that makes possible the new inventions.

When the war is won the task of maintaining a strong leadership in science will still be with us. After the hates and injustices that the war has brought, the safety of the United States in a postwar world will demand eternal vigilance. But not even vigilance is enough. If we are in earnest in striving for a peace with freedom to work for the best we know, there is only one course for us to follow. This course is to maintain with the nations friendly to us such strength that we shall not be challenged while we seek to build a world in which war will be considered as a disaster rather than as the only hope for the improvement of a people's lot.

How shall we maintain order while this peace-loving world is being built? Only by keeping ourselves strong and working for friendly relations with our neighbors.

It will require a long time thus to make the world forget war. If we are to retain our leadership it will be only through superiority in those things that make a modern nation great. Foremost among those things is science.

[1] Address during the New York Philharmonic Symphony-United States Rubber Company broadcast, January 14, 1945.

Have you ever paused to consider why the Occident has, during the past two or three centuries, come to dominate the world? You may remember that at the time of Marco Polo under the great Khan of China there flourished a civilization more powerful and more refined than Europe could boast. Somehow there arose in the West the ardent desire to know. Henry of Portugal and Columbus of Genoa, following Polo's example, went out to explore the world. Leonardo and Francis Bacon and Galileo sought to learn the hidden nature of things that they might enlarge the bounds of human empire. Newton and Lavoisier, Franklin and Faraday, Henry and Helmholtz—these great men of science opened up a vast new world. They gave to Europe and America the steam power and the firearms that meant military might. They made possible the machines of industry which supplied the means of living to greatly increased populations.

It is only very recently that the United States has taken a leading place in searching out nature's secrets. We were busy carving a nation out of the wilderness.

While Europe was refining her science, we were applying our knowledge to the every-day jobs of making agricultural machinery, electric lights and transcontinental railroads. We found these things worthwhile because they enabled more people to live better. During the last war we learned, however, that in spite of our great industrial strength, our European allies and enemies were ahead of us in devising new weapons. We found them leading us in almost all branches of fundamental science. When the war was over, our soldiers returned with a determination to learn the science that had shown itself of such value. The great educational foundations established fellowships to encourage scientific study and research. The universities rapidly built up their departments of science. By the time the second great war came we had become respected the world over for our work in science. In medicine and chemistry and physics and astronomy we trained thousands of capable young men and developed many recognized leaders. In the present war we are proud of what our men of science are doing. We have taken our full part beside our great allies in the scientific as well as the industrial aspects of this great struggle. Our enemies, both Germany and Japan, had years of head-start on us in developing machines of war. Some of these developments, such as the long range bombs, are only now beginning to be effective. Yet with our control of the submarine menace, our precise techniques of radio-location and our airplane developments, the score is perhaps turning in our favor.

The international competition for leadership in science, though on a friendly basis, is nevertheless intense. I recall in 1927 commenting to the director of Germany's great National Institute of Physics and Chemistry with regard to the high quality of his scientific instruments. Though Germany was complaining then of her poverty, in our country no universities or government laboratories could afford such equipment. The reason, said Dr. Paschen, was not far to seek. The Reichstag was determined to give all possible support to German science. They no longer had any Kaiser, nor any army. In what could they take pride? "Their men of science," they said. "Let's make of them the best in the world."

This was the spirit that has enabled our enemy to match step by step the combined technical developments of ourselves and our allies. It is true that when the Nazis came into power, the study of fundamental science was greatly curtailed and even the technical schools fell to roughly 25 per cent. of their full enrolment as they were building up their armies just before 1939. Yet this did not go as far toward destroying their scientific strength as we have gone in weakening our own science in this war. Just as the war began, the Germans came to realize the danger to their future because of their failure to train enough scientific and technical men. They set aside an increased group of young men best qualified for science and barred them from entering the armed forces.

At least until perhaps very recently these students have been continuing their training for careers in science and technology. The result is that the German war industries and research organizations have an indefinitely continuing supply of fully trained men.

Our national policy with regard to the training of scientific men has been precisely the reverse. We have gambled on a short war. Science professors and students alike have left the universities. All their effort is concentrated on devising and developing new and improved weapons. Because we were caught unprepared for a war in which scientific developments have become so vital, this has seemed to be the only possible procedure. Yet now practically no students over 18, except a few 4-F's, are studying science.

If the war could have been completed within a year or two this policy would have been a good one. The idea is that every one puts all that he has into the fight now, and gets it over with, and then all return as promptly as conditions permit, to resume their normal tasks. But the war in Europe has already been going for over six years, and our three years of intense effort have not shown us clear evidence of an early victory. If the war should continue for as long as it has already been fought, our present policy of no advanced scientific and technical training will spell national disaster.

It takes at least six years for a capable eighteen-year-old to train himself for effective scientific research. Even if we should start now to resume such

training, it will thus be at least six years before a normal supply of young professionals will again be available to our laboratories. Can we afford to wait any longer?

This is a situation of national concern which needs to be carefully watched lest when the war is won we may find that we have gained a Pyrrhic victory, having lost so much of our technical strength that we shall be unable to carry on the great task of world leadership which we now see before us.

It remains for those who follow me on this program during the next weeks to explain how the growth of science will bring to us life of greater human value. Increased cooperation and concern for each other's welfare, greater attention to education for everybody, fresh consideration of the goals of living worthy of our great new powers, such human developments are sure consequences of the emphasis that science places on specialized skills and on coordinated effort in learning and using knowledge. But more of this later.

What I want to bring to you to-day is the fact that greatly increased emphasis on science is a "must" for our nation's safety and future welfare. If a wise course is followed with regard to training and in other support of science, our nation is in favorable position to lead the world in the scientific age that lies ahead.

THE CONCEPT OF INTEGRATIVE LEVELS AND BIOLOGY[1]

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THE concept of integrative levels of organization is a general description of the evolution of matter through successive and higher orders of complexity and integration. It views the development of matter, from the cosmological changes resulting in the formation of the earth to the social changes in society, as continuous because it is never-ending, and as discontinuous because it passes through a series of different levels of organization—physical, chemical, biological and sociological.

In the continual evolution of matter, new levels of complexity are superimposed on the individual units by the organization and integration of these units into a single system. What were wholes on one level become parts on a higher one. Each level of organization possesses unique properties of structure and behavior which, though dependent on the properties of the constituent elements, appear only when these elements are combined in the new system. Knowledge of the laws of the lower level is necessary for a full understanding of the higher level; yet the unique properties of phenomena at the higher level can not be predicted, *a priori,* from the laws of the lower level. The laws describing the *unique* properties of each level are qualitatively distinct, and their discovery requires methods of research and analysis appropriate to the particular level. These laws express the new organizing relationships, *i.e.,* the reciprocal relationships of elementary units to each other and to the unit system as a whole.

The concept of integrative levels recognizes as equally essential for the purpose of scientific analysis both the isolation of parts of a whole and their integration into the structure of the whole. It neither reduces phenomena of a higher level to those of a lower one, as in mechanism, nor describes the higher level in vague non-material terms which are but substitutes for understanding, as in vitalism. Unlike other "holistic" theories, it never leaves the firm ground of material reality. Integration does not imply, as Lillie has recently maintained, "special vital factors"[2] or "something of the mental or psychic."[3] Both parts and wholes are material entities, and integration results from the interaction of the parts, as a consequence of their properties. The concept points the need to study the organizational interrelationships of parts and whole. This full recognition of both units and whole leads to a more adequate understanding of the whole.

The different levels of matter, while distinct, are not completely delimited from each other. No boundary in nature is fixed and no category air-tight. "Mesoforms" are found at the transition point of one level of organization to the next. Between the highest level of organization of non-living, the crystal, and the lowest level of unicellular organisms are protein paracrystals, the viruses, with some of the internal structure and behavior of living substance. Between the single-cell organism and the multicellular organism are the colonial organisms. Yet the absence of rigid demarcation between two levels does not make the difference between them any less clear or fundamental. Mesoforms, "the more clearly we understand them, will all the more clearly serve to bring out the essentially new elements of (the) higher order."[4]

There is both continuity and discontinuity in the evolution of the universe; and consideration of one

[1] Contribution No. 62.

[2] Ralph S. Lillie, *The American Naturalist,* 72: 414, 1938.

[3] Ralph S. Lillie, *Philosophy of Science,* 7: 327, 1940.

[4] Joseph Needham, *The Modern Quarterly* (London) 1: 30: 1938.