tons and electrons, which exist in ordinary solutions only at extremely minute concentrations, but which still attain equilibrium with the rest of the system rapidly. Another very important equilibrium involves water, the most abundant component of biological systems, which appears able to go from one part of the body to another so rapidly that minute changes in its chemical potential are important. The activity of water in our blood is only about half a per cent. less than in pure water and only about two thousandths of a per cent. less than in its ultrafiltrate. Yet the balance in a biological system appears to depend upon a small fraction of the latter difference, which corresponds to the effect of a pressure of twenty-five millimeters of mercury. Even the simplest system of interest to the biological chemist is a very complicated one for accurate thinking. To improve over the ideal solution treatment developed by van't Hoff and Donnan, it is necessary to keep very clear the distinction between activity coefficients and osmotic coefficient and not to forget which variables are being maintained constant. This is also one of the cases in which second approximations partially cancel each other so that the first approximation is much better than a treatment which uses the second approximation in one part but the first in another.

The distributions of many other substances throughout the body make some of the most interesting and probably the most important problems of biological chemistry. Not all can have the same chemical potential throughout, but the first step in the study must be the determination of how far the actual distribution varies from the equilibrium distribution because of impermeability, slow permeability or other cause. The rest of the problem will require knowledge outside of thermodynamics, although there will be no violation of thermodynamic laws. For two examples, it would be very valuable to know how closely two changes of state must be coupled so that a decrease in free energy in one may compensate for an increase in free energy in the other, and also what concentration gradients are produced by a temperature gradient which is maintained constant in spite of flow of heat.

The details of a review of this kind are essentially personal and subjective. The examples are mostly taken from protein chemistry, partly because I believe it important, but largely because I am less ignorant of protein chemistry than of the other branches of biological chemistry. I have called attention to those applications of thermodynamics which I believe need more careful scrutiny and to another application of which my opinion is much higher than those of most physical chemists. Yet it would be unfortunate if this question should become one of my authority against that of my colleagues. The most important part of my contribution is impersonal and objective. It is the reminder that each new application can and must be thoroughly tested without regard to the name associated with it.

THE TRAINING OF BIOLOGISTS[1]

By Professor PAUL WEISS

THE UNIVERSITY OF CHICAGO

A FEW comments to introduce our topic may seem appropriate. Why this conference on the Training of Biologists? Well, simply because by shaping future biologists, we shape the future of biology. And there seem to be some grounds for concern. The question is: Can we profitably consider the many ramifications of a *training program* in biology without having a unified concept of *Biology* itself? There is our cardinal issue: What *is* biology, and what would we want it to be like? If we accord to biology the dignity of an integrated, consistent and coherent science, rather than view it merely—if you pardon the irreverent figure of speech—as a holding company embracing numerous separate and independent enterprises, then a clear understanding about the substance, aims and limits of this science would help to establish a sort of central beacon with regard to which we could orient ourselves, when dealing with subordinate issues. Then, anybody's problem becomes everybody's concern, and the common ground for this meeting of representatives of diverse interests is satisfactorily circumscribed.

Our meeting seems timely, or even overdue, in view of world events. In this world crisis, science finds itself confronted with mounting short-range demands and an altered long-range outlook. All around we hear it being predicted, that after this crisis has come to pass—in fact, if it is to be overcome for good—this world can never be the same again; and that, if the change is to be for the better, the critical, disciplined, fact- and relation-conscious mind of the scientist will have to be accorded a major share in the improvement.

[1] Address by the Chairman of the Conference on the Training of Biologists, held in connection with the Fiftieth Anniversary Celebration of The University of Chicago on September 18–20. A full report of the proceedings of the conference will be published at a later date. Aid by the Carnegie Corporation of New York is gratefully acknowledged.

If experience and reason are to gain the ascendancy over emotion and superstition in the conduct of human affairs, man will have to know more about man, and then live up to his knowledge. Since for much of this knowledge he will have to call on biology, it becomes our responsibility to provide a generation of biologists fit to answer the call.

Only partly will their fitness depend on biological competence. Unless they are also made conscious of their obligation to society, they will, I am afraid, be at a loss to justify their subsidized existence to a society asking uncomfortable questions. As the support of science will become incumbent on increasingly broader strata of society, for reasons of which you are aware, more and more such questions will be asked. And the biologist will have to be convincing in showing cause why what he is doing should not be discontinued as a publicly supported enterprise. The research man must prove that his work is more than a glorified hobby, the teacher that he is more than a slow-motion rendition of a text; the practicing biologist being the only one who will be taken for granted because of the plausibility of his utilitarian value.

Now, it is somewhat alarming to have to think of the possibility that in some future attempts might be made to set up an authoritarian agency to sit in judgment, and exert control, over what a scientist should or should not do or teach. Science would choke in such an atmosphere. But it is just as alarming to think of what would happen if the coming generation were left with the illusion that society will continue to stand for the random movements of unoriented and confused minds, privileged to receive public support for their playful exertions, good or no good, just because the story goes that a blind hen, too, occasionally finds a grain. Presumably, an economically minded society would withdraw its support from what it considers a bad investment, and science would be starved. It is up to us to avert both these dangers of either thus choking or starving our science.

We can do this, I submit, by waking up our students to the realization that their privilege of carrying on science as a public trust carries responsibilities. Heighten their sense of responsibility, and they will all by themselves check and recheck their conduct and activities by the standards of scientific and social ethics of which they will have been made conscious; and they will give a good account of themselves under any enlightened scrutiny. But keep on leaving them in the dark, and the whole structure of science will suffer.

This is not advocating indoctrination, but merely a better and more explicit exposition before the student of the philosophic, historical, methodological and cultural foundations of his science, than he is commonly offered. He ought to learn not only how to do things, but also how to rate the results of his doings, so that he may intelligently chart his course, ever on guard against the blind alleys of wasteful monomaniac pursuits. He should learn what his science is all about, how it has grown and how it might be made to grow even better, and what he might contribute to that end. He must learn to plan his activities in teaching and research so that they will furnish useful contributions to the organic growth of integrated knowledge, rather than mere punchcards in an enormous filing system.

So long as science was a pioneering adventure of only a few treks into vast terra incognita, there could be unlimited freedom of movement. With science becoming more and more a proposition of mass team work, some sort of traffic control becomes necessary, and we would rather see this come about through the self-control of drivers properly instructed in their responsibilities than by the equivalent of police enforcement. If we unfold before the students the whole plan of that campaign for the conquest of nature that is science, rather than simply teach them how to handle the weapons in that campaign, we shall enable the better ones to pick all by themselves strategic positions of greatest promise of advancement to science, and the less gifted ones, at least, to do with greater understanding what they are called upon to do.

Now, here I feel lies our first duty. If we are to give the student insight into the plan of this campaign that is science, we must first know the plan ourselves. But do we have one? Are we agreed on how best to serve the progress of biology, is there unity behind our purpose and consensus on procedure? To answer these questions is well within the province of this meeting. Unless we succeed in answering them to our mutual satisfaction, we shall have to keep temporizing with the various partial issues of our educational program, which it would be so infinitely easier to deal with as part and parcel of a single broad fundamental policy. It will have to be our task, therefore, to see whether we can agree on certain common programmatic principles.

Let us take an example: the rating, in both teaching and research, of *facts,* as against *principles.* Or, as I would prefer to state the issue: information *vs.* knowledge. This issue has been amply argued with much verbiage, some wisdom and little consequence. Some of us undoubtedly have strong convictions in the matter, and we shall differ in our views. We may or may not be able to reconcile them. But at any rate, the eventual turn of the argument will necessarily influence all such matters of policy as, for instance, whether students should be made to dissect more specimens or more concepts.

The way I see it, the relation between factual data and knowledge is the same as that between food and a growing organism. Like food, so-called pure facts must be digested, resorbed and assimilated in order to become knowledge; and unless they are, they become wastes. Already the hoard of unconsumed facts has become so enormous that to point—by way of alibi—to their possible utility in some future, sounds no longer convincing; if ever their time should come, they will long have become obsolete, if not altogether forgotten. This applies to unrelated facts of research as well as to unrelated data in teaching.

Now, the question is obviously not whether we should teach facts and techniques *or* principles and concepts, but rather what proportion of the student's time and energies we should allocate to the ingestion of facts on the one hand, and their digestion on the other, given a certain educational aim and a definite time limit for its attainment. It seems that, instead of letting these proportions be decided by individual preferences, institutional traditions, technical expediency and sheer accident, we might find some more pertinent formula of apportionment.

It will be the same with most of our other problems: Proportions and not volume will be the main issue. It would be idle to indulge in dreams of what volume of knowledge we, preoccupied as we are with our individual fields of specialization, would like to communicate to our students, if we had not to compete for their time, interest, endurance and resorptive capacity. The volume of instruction will always be limited by the hard reality of restricted facilities and human nature. But even though its volume may have to vary widely, the proportions of any program may be preserved without distortion. It is on these proportions, on the harmony of the educational program, that we should insist. This implies that in apportioning subject matters, attention will have to be paid not only to their factual content, but likewise to their potential value in developing those faculties which transform a student of biology into a biologist. Any carefully conceived program will have to strike a sound balance between attention to detail and generalization; between observation and experiment; analytical acumen and broad perspective; intellectual mastery and manual craftsmanship; mental stability and critical acumen; respect for tradition and courage to break it when necessary for progress; and so on. It should be easier to find our way through this maze of concrete problems with a central objective in view as our directive, than if we continued to drift apart along our various lines of specialization. Gathered here, therefore, as we are from those various lines, we may attempt to reweave a solid fabric of general biology out of the dangerously separating threads of departmentalization.

If, after these five sessions, we shall part with some clarification of purpose as guide for future action, this is all the reward we may duly expect to come from this venture. If, in addition, our collective opinion should turn out to point a way as to how to translate our conclusions into concrete action, so much the better.

ANNIVERSARY ADDRESS OF THE PRESIDENT OF THE ROYAL SOCIETY[1]

By Sir HENRY DALE

DIRECTOR OF THE NATIONAL INSTITUTE FOR MEDICAL RESEARCH

As we come to the end of another year we can see, as yet, no prospect for science of escape from urgent preoccupation with the means of waging war. On the contrary, with the Union of Soviet Russia now locked in a supreme struggle for its own existence and the world's freedom, and with the United States of America rapidly directing its tremendous scientific and technical potential to the support of the same great cause, the diversion of science from its normal uses and objectives has spread right round the world. Yet even this grim necessity has brought with it some measure of compensation, in drawing closer the bonds of friendship, between the men of science in the countries thus united in a common purpose. We in Britain received a tremendous encouragement in the early months of this year, from the visit of President Conant and his associates to establish here, in London, an office for the maintenance of regular and intimate cooperation, between the war researches of our American colleagues and those which are here in hand. More recently, and in spite of all difficulties of communication, the sense of a common peril and a common determination is bringing us into a new and growing intimacy of collaboration with our colleagues of Soviet Russia. The organization of the science of the British Empire for war has brought to London already a number of distinguished colleagues from the Overseas Dominions, and we have heard of others who are on the way. It has been a particular pleasure to gather them here, in the house of the Royal Society, and to invite them

[1] Concluding part of the address given at Burlington House, London, on November 11, 1941.