fied research is involved. Finally, even if the submission of sworn statements were to be reduced in this manner to a kind of empty ritual, it would nevertheless be a ritual in which many a young man, already idealistically dedicated in his own eyes to the service of his countrymen, would participate only with a certain sense of humiliation and a corresponding feeling of resentment; and I could not bring myself to continue a remote but identifiable association with the compulsion to participate. On this last point I recall with clarity the feelings I experienced when required to take the so-called Teacher's Oath some years ago in Massachusetts, an oath which I could and did take with a perfectly clear conscience and without reservations.

You will understand, I am sure, that this letter, being an expression of conscientious beliefs and not a discussion of mere practical arrangements, is a communication which I do not feel bound to hold private.

MARSHALL H. STONE

The University of Chicago

Method for Supplying a Laboratory with Warm Sea Water in Winter

One of the handicaps faced by the biologist working in northern waters is the long winter period when the water temperature is too low for active functioning of many invertebrates. In our case this period, when the water temperature in Long Island Sound is 5.0° C or less, may extend from four to almost five months. In severe winters a temperature of −1.5° C is often recorded (LOOSANOFF, V. L., *Ecology,* 1937, 18, 506). Under such conditions many forms are hibernating, while others are less active than at higher temperatures.

During the last five years we tried to overcome this difficulty by artificially increasing the temperature of sea water used in our experiments. The first attempts, which consisted in maintaining a high temperature in the experimental aquaria by means of electric heaters, were rather promising because they showed that oysters kept under such conditions could be induced to develop ripe eggs and spermatozoa even in the middle of winter (LOOSANOFF, V. L., *Science,* 1945, 102, 124). However, since the use of electric heaters was rather expensive, and because there were certain objections to keeping metal heaters and experimental animals in the same water, we did not consider the method entirely satisfactory and continued to seek a better one.

The principle of our present method is rather simple. Cold sea water is passed through a coiled lead pipe, which is immersed in a large tank filled with warm fresh water. The temperature of this water is maintained at the desired level by a gas flame regulated by a pilot light thermostat (Fig. 1, A). The temperature of sea water in the lead pipe leaving the tank is regulated by an electric thermostat, the bulb of which is attached to the pipe itself. This thermostat is also connected to the magnetic gas valve (Fig. 1, B) of the gas burner. If the temperature of outgoing warm sea water in the lead pipe decreases below a certain minimum, the thermostat sends a signal to the magnetic gas valve, which increases the gas flame. To prevent the stratification of warmer water in the upper part of the tank, a strong stream of air bubbles is continuously passed through the tank. In general, the system is simple and can be installed by a person familiar with installation of domestic hot water heaters. Ours was installed by our laboratory mechanic, Joseph Lucash.

The advantages of having warm running sea water in a laboratory are numerous, the most obvious being the possibility of conducting throughout or almost throughout the year many experiments which formerly had to be confined to the relatively short summer period. For example, by subjecting adult clams, *Venus mercenaria,* to gradually increasing temperatures during January, we induced them to spawn in February and March and grew their larvae to metamorphosis. For several years oysters were conditioned in the same way, and recently my colleague, Harry C. Davis, was successful in obtaining heavy sets of oysters in the middle of winter. No doubt similar success can be achieved with other forms which normally are inactive in winter.

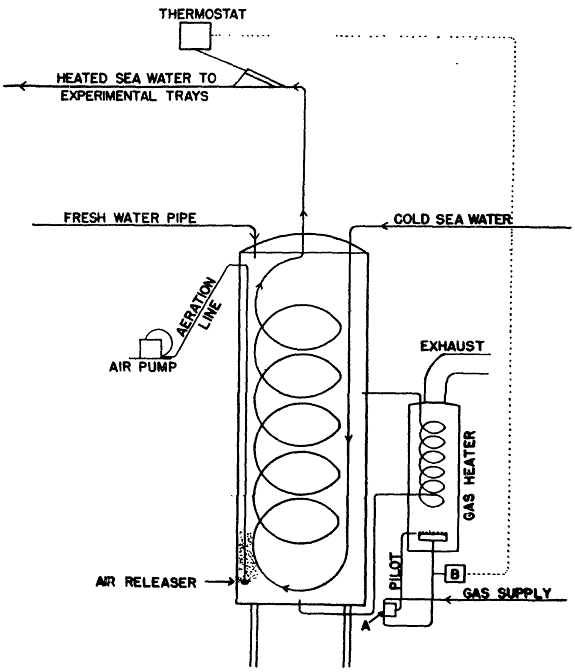

FIG. 1. Diagram showing method of raising temperature of cold sea water.

By keeping the animals during the cold period at desired temperatures, laboratories can be assured of a sufficient supply of biological material, which is ordinarily unavailable in winter. For instance, we already know on the basis of our experience that embryological studies on eggs of some lamellibranchs can now be continued on almost a year-round basis. Thus, at least in this respect, we can hope to accomplish as much in one year now as could be done formerly in three or four.

Another advantage of a continuous supply of warm sea water in winter is that it is so easy to maintain streams of different temperatures by mixing warm and cold water in different proportions. We use streams of about 5.0, 10.0, 15.0, 20.0, 25.0, 30.0, and even 35.0° C.

Water of such temperatures, or any other temperatures within this range, can be prepared by having constant level jars of cold and warm water and by regulating the flow from these jars into a mixing chamber where the desired temperature is attained. From the mixing chamber the water will flow into the trays or aquaria containing the experimental animals. Because the temperature of our cold water is very uniform, adjustments are seldom necessary to compensate for fluctuations.

Having running water of different temperatures offers an opportunity to experiment simultaneously with groups of organisms kept at such temperatures. For example, we used our facilities for observations on growth of adult oysters at temperatures of 10.0, 15.0, 20.0, 25.0, and 30.0° C; on development of eggs and growth of larvae of different mollusks; in studies of some phases of physiology of oysters and clams, such as gonad development and spawning; and in many other experiments.

VICTOR L. LOOSANOFF
Fish and Wildlife Service, Milford, Connecticut

Toxicity and the Chemical Properties of Ions[1]

The mechanism of the toxic action of drugs has long been a controversial subject. Attempts at an elucidation of the problem include correlations between toxicity and molecular properties. The older physiologists and medical men are, in the main, opposed to any such correlation; the younger biochemists are for it. The more conservative investigators have much negative evidence to support their view, for usually when a drug is administered no one has the slightest idea what happens thereafter, other than the end result. Those who believe in an association between the physiological effect and molecular pattern of a poison have little evidence but much confidence to support their view—a view which they regard as the intelligent one, for, to what else can toxicity be due?

A study of the poisonous action of inorganic salts on slime molds should simplify matters, for the ion of a metal has a far less intricate structure than, for example, a molecule of cocaine, and a primitive form of life is devoid of the complexities of higher organisms.

The slime molds are Myxomycetes to the botanists, who regard them as plants, and Mycetozoa to the zoologists, who think these molds are animals. To medical men, slime molds are just protoplasm, far removed from the intricacies of the human body and therefore having little bearing on medical physiology. But perhaps the difference between the protoplasm of lowly organisms and that of higher forms of life is not always as great as imagined. Lacking the differentiations which tissues present, the protoplasm of a slime mold reveals correlations which are obscured in highly complex organisms. Furthermore, the visible effect of a toxic agent on a slime mold may be directly observed through the microscope.

The degree of toxicity of a poison acting on a slime mold is determined by a number of pathological changes which occur in the protoplasm; among them are the periods of time necessary to kill, to stop protoplasmic flow, and to produce injury. The degree and kind of injury are also significant criteria; among these are gelation, solation, syneresis, blistering, surface rupture, and general disorganization.

Results of studies on the poisonous actions of anesthetic agents, drugs, and metallic salts on protoplasm were reported at an Army Symposium in June 1948.[2] The discussion there, and later elsewhere, led to numerous comments and criticisms, both adverse and constructive. They are repeated here in the belief that they will prove of interest not only to toxicologists, biologists, and medical research workers, but to chemists as well, for they deal as much with the physical chemistry of solution as with toxicity.

I had found a correlation between the anesthetic effects of CO_2 and N_2O and their isosteric properties (*Science*, 1948, **107**, 15). The correlation was questioned because, so it was said, the protoplasm is not in contact with the gas, CO_2, but with carbonic acid. This is an old problem, and has long since been answered by both biologists and chemists. Of the several kinds of molecules and ions which CO_2 in water may present, it can be experimentally shown, by a process of elimination, that only the CO_2 molecule is responsible for anesthetic and other toxic effects. There are several ingenious experiments in physiology which demonstrate, by taste and color indicators, that an *acid* condition is established *within* living tissue when an *alkaline* solution is added outside, due to the rapid entrance of CO_2 as such. Few substances enter a cell as freely and as rapidly as does carbon dioxide, and it enters primarily as the CO_2 molecule.

The evidence from the physical-chemical side is of the same sort. H. B. Bull (*Physical biochemistry*, New York City: John Wiley, 1943) states that "at equilibrium, the amount of dissolved CO_2 is about 1000 times the amount of hydrated CO_2, i.e., of carbonic acid." This means that instead of having no free CO_2, there is some 99 percent of it when CO_2 is dissolved in water. The correlation between the isosteric and the anesthetic properties of the gas must, therefore, fall, if it is to fall, on other grounds.

A further criticism, directed against physical-chemical interpretations of the toxicity of metallic salts, involved the validity of the assumption that the metal ions are present as free ions. That hydrates and complexes are formed in solution is, of course, well known. Salts such as those of Al and Zn are particularly bothersome from

[1] A number of chemists have contributed to these comments, some of them unknown to me, speaking in group discussions. Rather than attempt to select those whose comments should be acknowledged, I shall express my indebtedness to all collectively, and disclaim for myself any credit for the more fertile suggestions. I need only add that the physiological work on the toxicity of salts reported here was done in my laboratory by myself and my assistant, whose presence I owe to the Sloan-Kettering Institute for Cancer Research.

[2] Army Chemical Center, Edgewood Arsenal, Maryland.