from Eq. 7, 0.00197 cal/deg. If the solute is a polymer, with $v_1 = 100$ ml and $v_2 = 10^3 v_1$, Eq. 9 gives 0.39 cal/deg. With $T = 298°K$, the values of $RT \ln(f_1°/f_1)$ are 0.024 lit atm and 4.7 lit atm, and the osmotic pressures, by Eq. 1, are 0.24 and 47 atm, respectively, an enormous difference.

But most solutions are far from ideal, by reason not only of unequal molar volumes but of unequal intermolecular forces: van der Waals, dipole, hydrogen bonding, acid-base, and ionic. These introduce not only changes in configuration, disorder, and therefore entropy but also changes in heat content. No longer can one assume that the entropy of mixing will be correctly predicted by the foregoing equations or that the heat of mixing will be zero. It is worth mentioning, however, that the heat term in Eq. 12 is a quadratic function of the concentration of the solute and, hence, disappears in the limit. For a solution, in which thermal agitation suffices to give random mixing, this term is given approximately by the expression,

$$\overline{H}_1 - H_1° = v_1 \phi_2^2 (\delta_2 - \delta_1)^2,$$

where the δ's are "solubility parameters" expressing the intermolecular forces of solute and solvent. To deal with all these factors is far beyond the scope of so limited a treatment as this, which is intended only to remove some of the mystery that often beclouds the subject and to warn against the drawing of too simple inferences from deviations that may be encountered from the primitive equation, $\Pi = c_2 RT$. The emphasis upon the role of entropy in modern solution theory is in striking contrast to its neglect during the period when the theory was based upon osmotic pressure. In Nernst's *Theoretische Chemie,* there is but one reference to entropy. It is in small type and consists of an argument for not using it! Today, no physical or natural scientist can afford to be utterly ignorant of entropy.

References

1. For derivations, see J. H. Hildebrand and R. L. Scott, *Solubility of Nonelectrolytes* (Reinhold, New York, 1950).
2. For references and detailed discussion, see reference 1, Chapters VI and XX; also J. H. Hildebrand *J. Chem. Phys.* 15, 225 (1947).

The European Oyster in American Waters

V. L. Loosanoff

U.S. Fish and Wildlife Service, Milford, Connecticut

THE common European oyster, *Ostrea edulis* L., which occurs along the Atlantic Coast of Europe from Norway to Spain, in the British Isles, and the western part of the Mediterranean, may propagate at a somewhat lower temperature than our native oyster, *Crassostrea virginica* Gmelin. We thought, therefore, that the European oyster might be introduced into this country (*1*) to occupy eventually a definite ecologic niche in areas where the water is too cold for the successful propagation of our native oyster but is still sufficiently warm to be within the propagating temperature range of *O. edulis*. Among such areas are certain bodies of water along the shoreline of Maine and some well-protected bays and harbors of our Pacific Coast states.

The oysters were shipped to us from the Oosterschelde, Holland, by P. Korringa late in September 1949 and were placed in Milford Harbor on 11 October. The shipment consisted of approximately 9000 oysters representing 3 year-classes, that is, the 1947, 1948, and 1949 sets. Because of the long trip approximately 13 percent died soon after arrival, the mortality being heaviest among the youngest year-class.

The oysters were intended chiefly for studies to determine whether they would survive and propagate under the ecologic conditions to which they would be subjected in this country. Simultaneously with these studies, observations were also made on the seasonal gonadal changes of the oysters kept in different localities, their rate of growth, artificial propagation, and several other aspects of their biology.

Some of the oysters were left in Milford Harbor, but the others were transplanted to four localities of Maine, including Boothbay Harbor. The oysters grew well in all regions. Their mortality in Milford did not exceed, in general, that of the native oyster living in the same environment. Each winter since their arrival from Europe the oysters have lived under a layer of ice, at least for some time. In Milford Harbor, an estuary strongly affected by river discharge, the oysters were subjected, especially in the spring, to prolonged periods of low salinity but, nevertheless, survived, a fact indicating that they possess good tolerance in this respect.

The European oysters were noticeably affected if the turbidity of the water, whether caused by silt or high concentrations of microorganisms, was relatively high. We even witnessed cases of abortion of embryos and immature larvae by gravid females that had been exposed to a dense concentration of dinoflagellates belonging to the genera *Prorocentrum* and *Gymnodinium.* The larvae were expelled in pseudofeces imbedded in mucus along with masses of dinoflagellates. The abortion was usually complete, removing all larvae from the mantle cavity where they are normally carried by the mother oyster. This observation suggests that such a natural phenomenon as the "red tide" may often be responsible for the complete extermination of embryos and larvae of larviparous species of bivalves.

Observations on living individuals and histologic studies of preserved samples showed that the oysters kept in Milford Harbor and in Maine developed normal gonads, spawned, and released larvae. In Milford Harbor larvae-bearing oysters were found from the beginning of July until the end of August. In Boothbay Harbor, where the summer is shorter and the temperature lower, the larvae-producing season is probably correspondingly shorter.

Regardless of the relatively small number of adult oysters planted in Boothbay Harbor, which even at the beginning of the observations was only about 3000 individuals, approximately 50 young oysters originating from the imported parents were found attached to rocks, shells, sticks, and so forth, on the bank approximately 1/4 mi from the parents. The young oysters were found confined to the +1- to −3-ft tidal level. Judging by their sizes and other characteristics, this group consisted of individuals of three different year-classes, namely, those that set in 1950, 1951, and 1952. In the fall of 1953 the smallest oyster measured was 10.0 mm, but the largest was already 88.0 mm. The finding of so many young, thriving oysters indicates conclusively that European oysters may become successfully established in our waters.

Good growth was also shown by the adult oysters that came from Holland. For example, the largest oyster among the oldest, 1947, year-class, upon arrival here in 1949 measured slightly more than 90.0 mm. In the fall of 1953 some oysters of the same group already exceeded 120.0 mm in size.

Using our methods for ripening mollusks and for inducing their spawning out of season (*2*), we obtained larvae of *O. edulis* throughout the greater portion of the year. Swarms of larvae were released in the laboratory from the beginning of February until the end of the normal spawning season. The larvae were grown through metamorphosis in hatching jars, and in large outdoor tanks with a capacity of several thousand gallons (*3*). Many of these young oysters were later shipped to other places, including the shellfish laboratory of the State of Washington. According to C. E. Lindsay, director of that laboratory, some of this set, which was shipped there in 1951 and planted in North Bay, had reached 77.0 mm in length by August 1954.

Thus our observations have shown that *O. edulis* may survive, grow, and propagate in New England waters and that the young oysters, reared at Milford and sent to Washington, grow well there. They suggest that the introduction of this oyster in certain areas of the United States, and possibly Canada, may eventually lead to the establishment of a new and prosperous shellfish industry.

In introducing a foreign species it should be emphasized that certain precautions should be exercised. First, it should be considered whether the newcomer will engage in biological competition with some of the useful local forms and, perhaps, even displace them from their established niche. A well-known case of such biological competition is the struggle between the highly prized European oyster, *Ostrea edulis,* and the Portuguese oyster, *Crassostrea angulata* Lamarck, which until the middle of the 19th century was confined to the Mediterranean and not found on the Atlantic Coast of France. However, since gaining foothold in the new environment, the Portuguese oyster has rapidly spread throughout a large part of the area formerly occupied only by *O. edulis,* being sometimes responsible for the complete disappearance of the latter in some sections of the coast. The victory of the Portuguese oyster over the native one was ascribed to several factors, of which the chief were that the Portuguese oyster is more prolific, grows faster, and in feeding pumps more water than *O. edulis* (*4*), thus often depriving the European oyster of living space and food.

Another well-known example of an introduced competitor is the small gastropod, *Crepidula fornicata* L., commonly called "slipper-shell" or "quarter-decker" which, in the 1880's, was unintentionally carried along with shipments of American oysters to England, and later extended its range into the coastal waters of western Europe. In both places it quickly multiplied to such an extent that it smothered not only oyster set grown on special tile collectors but occasionally even the beds consisting of adult oysters. The same pest was also introduced to our Pacific Coast where it quickly became a dangerous competitor of the native oyster, *Ostrea lurida* Carpenter.

It is even more important to be certain that, together with the introduced species, we are not bringing along some of the ecologically associated forms which in the new environment may become either serious predators of native commercial species or cause other problems, for example, heavy fouling. An example of the former was the introduction of the American oyster drill, *Urosalpinx cinerea* Say, to our Pacific Coast and to England, and the Japanese drill, *Tritonalia japonica* Dunker, to the oyster beds of our Pacific Northwest. In both places the drills rapidly multiplied and soon began causing heavy losses among the native, as well as the introduced oysters.

A good representative of the second group, one that may cause serious fouling, is the Australian barnacle, *Elminius modestus* Darwin, which recently gained entrance to the waters of Europe and is creating serious difficulties there, being a dominant sedentary organism in the intertidal zone (*5*).

Thus, in principle, the introduction of a new species, whether plant or animal, should always be considered as a potentially dangerous undertaking because of the possibility of bringing along undesirable forms which, in a new environment, could rapidly become pests of major significance, just as the Japanese beetle has become in this country. We think, therefore, that the safest way to build up a population of foreign oysters or other useful bivalves, would be to import a small number of adults, which upon arrival should be kept under such conditions that undesirable forms, incidentally brought along with them, would not gain entrance to the native waters. Later, by using the modern methods of lamellibranch culture (*6*), the spawn of these adults could be used for rearing, under rigidly controlled laboratory conditions, a sufficient number of pest-free individuals for the establishment of initial spawning beds.

References and Notes

1. I wish to express thanks to my colleagues at Milford Laboratory for cooperating with me in many phases of these studies, to the members of the Fish and Wildlife Service at Boothbay Harbor and of the State of Maine Sea and Shore Fisheries who made numerous observations on the oysters planted in Maine, and to C. E. Lindsay of the State of Washington for informing me of the fate of the seed oysters which we shipped there.
2. V. L. Loosanoff and H. C. Davis, *Biol. Bull.* **98**, 60 (1950).
3. V. L. Loosanoff, *Anat. Record* **111**, 126 (1951).
4. P. S. Galtsoff, *U.S. Bur. Fisheries, Fish. Circ. No. 12*, 1 (1932).
5. E. W. Knight Jones, *Nature* **161**, 201 (1948).
6. V. L. Loosanoff, *Am. Scientist* **42**, 607 (1954).

News and Notes

Solar Energy and Wind Power

The Government of India organized a symposium on *Wind Power and Solar Energy* in New Delhi, India, 22–26 Oct. The UNESCO Committee on Arid Zone Research joined with India in sponsoring this conference, the purpose of which was to study the possibilities of using wind power and solar energy, particularly in arid regions.

The 28 scientists from 20 different nations included physicists, engineers, chemists, meteorologists, and botanists, each offering his experience and specialized techniques in an attempt to provide more power and more comforts for people who live in areas where fuels for mechanical power are limited or nonexistent. The difficulty with using sunlight is the low intensity of energy and the large area that has to be covered with any energy-receiving material.

Solar heaters for cooking, house heating, and operating engines were described in detail. Several solar cookers that gave heat equivalent to 350 watts were demonstrated at the National Institute of Physics of India. The parabolic mirrors were about 3 ft in diameter. Another type, developed by L. Gardner of New Delhi, consisted of many small flat mirrors attached to wooden arms with parabolic edges, arranged in such a way that each arm is adjusted at frequent intervals, to focus the sunlight onto a vessel of boiling water. The solar cookers were regarded as important because, if they can be made cheaply enough, they can be used in rural houses instead of the stoves that now burn cow dung or shrubs and grass. The dung should be used for fertilizer and the vegetation should be used to protect the soil against erosion. The present selling price of the solar cooker in India is $14, but this is too high and it was generally agreed that solar cookers would have to be sold for $5 or less in order to be widely accepted. Thin mirrorized plastics in parabolic shapes were suggested in place of the metallic reflectors.

In heating houses with solar energy the problem is simplified by the fact that high temperatures are not needed and no focusing device is required. The heat can be stored in hot water tanks, in beds of small rocks, or in chemicals such as hydrated salts. A large expansion in the number of solar-heated houses is expected in the colder climates and here again valuable trees, shrubs, and grass can be conserved if cheap solar heating equipment can be developed. The problem is to find a way of collecting and storing the sun's heat with a minimum of invested capital. Thin plastics offer promise as a cheap material.

House cooling and refrigeration are also important. V. A. Baum of the U.S.S.R described a refrigerating machine in which a solar engine produced 250 kg of ice per day.

The solar distillation of salt water was reviewed; it seems likely that distillation can be economical in areas where fresh water is at a high premium. Here again, the new hope lies in using thin plastic tubes of large area. Extensive tests will be carried out in several different laboratories to test the length of life of plastic materials under operating conditions in bright sunlight. It was pointed out that there are several areas in Asia and Africa where the solar distillation of sea water and brackish water from wells would be of great help. It was emphasized in one specific case that 2000 gal/day are needed for a fish cannery on the eastern coast of Africa and that this water is now brought long distances by ship. Production of this amount of water by solar distillation could be started soon.

Perhaps the greatest emphasis of the conference was placed on solar engines. Most of the work described involved the use of large parabolic mirrors focusing the light onto water boilers. K. N. Mathur and F. Khanna of the Indian National Institute of Physics demonstrated several different models. V. A. Baum of U.S.S.R. described large installations that generate steam for engines up to 7 atm and he gave plans for still larger installations. Several additional applications of solar energy were shown by Baum with the help of motion pictures.

Steam engines with flat plate collectors instead of parabolic mirrors were discussed and a type of gas engine was mentioned in which the gas could be alternately expanded and contracted by intermittent exposure to sunlight.

Three papers were devoted to meteorology and the recording and interpretation of solar data. Particu-