BRINE AND BRINE ORGANISMS

George J. Peirce

Within the limits of the State of California the natural waters range in hardness from the softness and purity of rain and melting snow to hardness such that one can drive upon them in automobiles. In the high granitic regions of the Sierra Nevada, the water in streams and springs is so pure that one can use it, in case of necessity, in the batteries of one's automobile. In the southeastern corner of the State, Searles Lake, in San Bernardino County, is a solid mass of salt, dry only at the immediate surface. Between these two extremes are the connecting links. In addition, there are natural waters so charged with poisonous material that they can be drunk only as a step to death, and so hot that only a very few organisms are able to survive in them.

The salt waters are of two origins, marine and land. Along the shore of San Francisco Bay, and on various other flat parts of the coast line, one finds salt works where common salt is made by crystallization from the sea water, concentrated by natural evaporation. Along the eastern foot of the Sierra Nevada is a chain of desert basins, the survivors of the great prehistoric Lake Lahonton. The lowest of these, Death Valley, is in the main waterless. The others contain lakes of varying size and consistency, at different altitudes above sea level.

Both in the brines originating from sea water, and in the brines of inland origin, one finds algae and bacteria living under fatal conditions. The structure and behavior of these unicellular organisms, and the extraordinary conditions under which they live, have interested me for years. One speaks of the conditions which make life possible, and conditions beyond these are considered fatal. Nevertheless, we find plants living at fatal temperatures, in fatal concentrations, and in solutions of fatal compositions. The physiologist naturally asks: What makes this possible? Is it a matter of permeability or impermeability; of contents, in which ordinary reactions do not take place; of mechanical resistances as extraordinary as any of the other features of these remarkable cells? Yet these cells are very similar in shape, size, and general appearance to the cells of algae and bacteria living under more usual conditions. The algae and bacteria in these brines are unicellular; but there are animals—crustaceans and insects—which are multicellular and these have a very considerable degree of development, both anatomically and physiologically.

One associates with algae the power of combining CO^2 and H^2O to form sugar and starch. The green, brown, red and bluegreen algae all do this in ordinary waters; but in saturated brine, from which common salt is crystallized in commercial quantities, there is no carbon dioxide. From carbonates and bicarbonates, therefore, these

Madroño, vol. 1, pp. 171-178, June 20, 1928.

unicellular and motile algae must be able to secure all the carbon they need. Thus the long and historical struggle, finally won by Liebig, the chemist, and Sachs, the plant physiologist, who thought they showed that all the carbon of the usual green plant comes from the carbon dioxide of the air, has proved to have been unnecessary and its conclusion to a certain extent erroneous. As a result of the study of concentrated brines and of sea water, one comes to realize the reason for the extraordinary density of population between the tide marks, namely that there the carbonates and bicarbonates and carbon dioxide are sufficient to maintain a great population.

One associates oxygen with breathing and respiration. At the edge of the sea between the tide marks on rocky shores the waves, beaten by contact with rocks and cliffs, enclose and dissolve much oxygen; but the concentrated brines of marine and inland origin contain insufficient amounts.

The bacteria of decay in the brines are able to attack only, or at least mainly, the lifeless remains of other brine organisms; but it must be admitted that a considerable number of these destructive bacteria are able to break down proteins and other complex compounds originating in meats and in some other organisms living on the land. This may be a part of the explanation of the "embalmed beef" of evil reputation in the Spanish American War, and possibly of scurvy, among both adults and children. But, on the other hand, there are bacteria living in these brines which are independent of other organisms for the carbon and other indispensable elements of their food. If they are able to absorb enough energy from the light, they effect such rearrangements of carbon and other elements as result in the production of very considerable amounts of organic matter. Thus, old brines contain deposits of organic matter manufactured by the autotropic bacteria living in them. Some of these autotropic bacteria produce a magnificent Tyrean purple color, others produce different shades of red; but all of these pigments permit the passage of red rays, at the same time absorbing others which the bacterial cells use in the manufacture of food and fuel for themselves.

Owens Lake, the salt lake next north of Searles Lake, was covered when I visited it with a soft crust, through which one broke as one walked, leaving footprints red in color. They offered an astonishing contrast to the snow-whiteness of the soft crust and the brilliant blue of the desert sky, the most extraordinary combination of the three colors of the American flag which I have ever seen. Other red-forming bacteria living in marine brines are caught on and in the crystals of salt employed in preserving cod fish and, under favorable conditions, convert the salt cod fish into a striking red mass, the disagreeable taste and smell of which makes them unsaleable rather than unpalatable or injurious. Pure cultures of these red bacteria have been grown, and sterilized salt cod fish infected with them turn red in the cultures. A preservative may therefore carry its antidote with it, and the commercial caption "Sterilized Salt" is not as foolish as it sounds. The carrying of coals to Newcastle is not always unjustified.

North of these two lakes and at somewhat higher altitudes, at the foot of one of the passes leading to Yosemite Valley at its western end, is Mono Lake, famed for its saltness; but which has not yet been accessible to me at the best time to visit it, namely, at the end of the dry season or immediately before the snows and rains of winter begin. Still farther north in the Carson and adjacent valleys one finds a great variety of springs, hot, mineral, poisonous, with larger and smaller accumulations of water and contents; and, within convenient distance, three large lakes with fresh water entering at one end, but the waters at the opposite end at least brackish, if not pronouncedly saline.

In the country adjacent to Fallon, Nevada, are various salt accumulations, dry or still wet. Many of these take the form which the geologists call playas. One of these, Soda Lake, is covered with a crust, barely strong enough to support a man of average weight. Except for involuntary breaking through, such as one might experience on a pond not yet frozen hard enough for safe skating, one must use a pick of some sort to get through the crust. When one does so one penetrates a mass of white salt, with large and glittering crystals on the underside, bathed in a liquor of astonishingly brilliant red color, approaching crimson in its blueness but still possessing enough of the red to deserve the name of Tyrean or royal purple.

Pyramid and Winnemucca lakes, dividing the surplus waters of the Truckee River not used for irrigation, are great inland seas, miles long and slowly shrinking,—their islands, the homes and breeding places of pelicans; their waters, extraordinarily interesting to the student of fish, especially for their trout, living and breeding in the half of the lakes below a certain concentration, and avoiding the further stretches removed from the stream which supplies fresh water. This stream, the Truckee River, is the outlet of one of the most magnificent bodies of fresh water in the world. Surrounded by high peaks, snow-clad for a good part of the year, once covered with a heavy growth of forest, years ago cut off to supply timbering for the mines of the Comstock lode, Lake Tahoe is intensely blue or wonderfully green, according to the bottom. Passing out through the control gates into the Truckee River, its water becomes one of the famous fly fishing streams of the world and farther down gives its power to various manufacturing and electrical establishments. It is distributed over what would otherwise be desert areas, which are thereby made correspondingly productive, and the residue goes to Pyramid and Winnemucca Lakes, past an extensive Indian Reservation. Both in the waters of these lakes and along the shore the vegetation shows the character of the water,—near the intake, carrying only a small load of dissolved salts and, at the opposite end, forming a spray which on drying whitens the shores. Somewhat farther south is a very similar lake set in the desert, its blue waters presenting an extraordinary contrast to the high and otherwise waterless sandy plain, bounded by mountains to the west and extending almost indefinitely eastward. Here also one sees the pelicans with their striking white plumage; but except one drive for a long distance and risk missing the infrequent train, one cannot reach the end where the waters are truly saline.

Still farther north, in northeastern California and eastern Oregon, more of these salty lakes are known; but I have not seen them yet.

In the most concentrated brines of inland origin one does not find the curious Artemias (crustaceans) which are present in Great Salt Lake and in the salterns on the shores of San Francisco Bay and apparently in similar situations elsewhere. Nor does one find the same species of algae or bacteria. There are no bluegreen algae in the concentrated brines of the San Francisco Bay region. Whether they are present in Great Salt Lake or not I do not know. There are no green algae in the crust of Searles Lake, but at about a centimeter and one-half below the surface of Searles Lake one comes to a layer first of yellow then of pale, bluish green cells which change to green at the bottom. A stratum in which bluegreen algae occupy the zone of optimum illumination, and in which the supply of water is still sufficient to meet this need, one must imagine a solution saturated with the salt which makes up the major part of the deposit which it wets and in which it is contained, carrying also other salts as long as the concentration permits. These liquors, containing potassium, magnesium, sodium and, in smaller proportions, boron and many other elements, constitute solutions of extraordinary physical and chemical properties, of such osmotic pressure that one must conceive the little organisms inhabiting them as being either freely permeable to these salts or else of such mechanical strength that they can resist almost any pressure. It is perfectly evident too that the resistance of these organisms and solutions to temperature is most unusual. Manifestly, the concentrated solutions will freeze only at temperatures far below the freezing point of pure water; but they will absorb from the sun still more heat than pure water, and consequently on a summer day may have a temperature much higher than that of ordinary water similarly situated. Thus, I have found the water in the salterns of the commercial salt works on San Francisco Bay surprisingly warm to the hand; and while the thermometer indicates a temperature quite below that which would be injurious, nevertheless it is far higher than the usual optimum for algae. They must, therefore, be able to resist these high mid-day temperatures of summer and, on the high cold plateau at the western foot of the Sierras, the bitter temperatures of mid-winter. One must realize too that these algae and bacteria must either adjust themselves with extraordinary rapidity to a great change in the concentration of the water when rain falls or melted snow flows upon them in one of these salt accumulations or die; that the mortality in the concentrated brine is enormous, as indicated by the observations which I have made on the salterns in San Francisco Bay, for when the rains come the fresh water, falling on the surface of the much heavier brines, stays on the surface, unless the winds interfere, until a gradual diffusion brings about a distribution of the added waters. Death does not seem to result from bursting, as one might expect, but from distension, which produces mechanical injuries to the structure of a living cell from which it cannot recover. What is actually accomplished by the pulling apart of the solid constituents of the colloidal complex which we call living protoplasm, no one can yet tell. But we can imagine or even set up mechanical models and on these observe the result of such changes as are effected by differences in the amounts of water supplied to and contained within the cells.

The above sketch of what we have learned by the studies of brines and their contents, by a group of men interested in them at Stanford, leads us to hope that the continued investigation of the organisms living in extraordinary environments will throw considerable light upon the actual conditions of life and the physical and chemical conditions prevailing in living organisms.

Stanford University,
December 9, 1927.

THE BOTANICAL EXPLORERS OF CALIFORNIA.—II.

Willis Linn Jepson

Joseph Whipple Congdon

The lower Santa Rosa Valley in the year 1880 presented a rather different aspect from that of the present day. The level plain, stretching northerly from the marshy tule-inhabited shores of San Pablo Bay, was filled with fields of wheat and barley, diversified here and there by wild bits of land where the native flora still persisted rankly and made fine botanizing. In the spring and summer days of that year, a botanist, earning a livelihood as a lawyer in the neighboring village of Petaluma, searched the fields and hillslopes for interesting plants. One day, July 1, 1880, his eager gaze discovered a gray plant in the grassy formation which he knew belonged to the Borage family but seemed unusual. The specimens which he gathered came eventually into the hands of Professor Edward Lee Greene who named the plant as new, Allocarya vestita, in the botanical journal Erythea (3:125,—1895). It was the first of a long series of interesting discoveries to be made by Joseph W. Congdon, who continued to explore California for a life-time. His career had many points of interest and we now set down what is known of it.

Joseph Whipple Congdon, whose father was of Quaker stock, was born in Pomfret, Connecticut, April 12, 1834. He entered Brown University and graduated at the head of his class in 1855. After leaving college he turned to teaching as a stepping stone to law, was admitted to the bar in Providence, Rhode Island, in 1860, and practiced there until 1879. In 1878 and 1879 he was a member of the Rhode Island House of Representatives. He came to California in 1880, taught school for a short time as so many young