XI.—BIOLOGICAL ACTION OF THE SALTS CONTAINED IN SEA-WATER FROM THE POINT OF VIEW OF THE MAINTENANCE OF MARINE ANIMALS.*

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Marine animals are organisms of excessive sensibility, and are subject to the varied influences of the element in which they live. The disposition of the fauna of the sea is dependent on the composition of the salt water, the nature and quantity of the gases dissolved, and the temperature, force, and operation of the currents. The succession of species of marine animals in geological strata, little different from each other in the nature of the deposits, shows plainly that influences which appear to us but of slight importance, have governed this succession itself.

I wished to ascertain the influences which the modifications in the nature of the salts dissolved might have on the marine animals, and with this view I entered upon a series of researches for the purpose of establishing a biological parallel between these salts. My experiments have been solely devoted to the molluscs of our shores, especially those which form articles of food for our population.

The sea water contains for every 1,000 grams an average of 35 grams of different salts in solution, among which chloride of sodium appears to exercise the most important influence on animal life. The supposition is doubtless permissible that the other substances are useful to a certain limited extent, and have, apparently at least, no hurtful influence.

* "*Action biologique des sels de l'eau de mer au point de vue de l'entretien des animaux marins.*" From *Bulletin mensuel de la Société nationale d'Acclimatation de France*, 3d series, vol. X, No. 2, February, 1883. Read at the 19th meeting of the learned societies, in 1882, in general session. Translated from the French by Herman Jacobson.

I have prepared eight solutions containing 35 grams per 1,000 of distilled water, of the following substances:

Solution No. 1: Chloride of sodium ..... $\frac{35}{1000}$
No. 2: Chloride of magnesium ..... $\frac{35}{1000}$
No. 3: Sulphate of magnesia ..... $\frac{35}{1000}$
No. 4: Bromide of potassium ..... $\frac{35}{1000}$
No. 5: Ioduret of potassium ..... $\frac{35}{1000}$
No. 6: Chloride of potassium ..... $\frac{35}{1000}$
No. 7: Sulphate of soda ..... $\frac{35}{1000}$
No. 8: Sulphate of potash ..... $\frac{35}{1000}$

Here we have eight solutions, each containing one of these natural elements of the sea-water, in the proportion in which it contains all of them. The sulphate of soda alone does not belong, properly speaking, to sea-water, although its elements are contained in it.

Three other solutions have been prepared, in which all the elements are found united, but in which the quantitative preponderance which in the water of the sea belongs to the sea-salt, is given (1) to chloride of magnesium, (2) to chloride of potassium, (3) to sulphate of magnesia. The following is the composition of these solutions:

Solution No. 9:

Chloride of magnesium	27.00
Chloride of potassium	0.75
Chloride of sodium	3.70
Sulphate of magnesia	2.30
Sulphate of lime	1.50
Bromide of potassium	0.02
Distilled water	1000.00

Solution No. 10:

Chloride of potassium	27.00
Chloride of magnesium	3.70
Chloride of sodium	0.75
Sulphate of magnesia	2.30
Sulphate of lime	1.50
Bromide of potassium	0.02
Distilled water	1000.00

Solution No. 11:

Sulphate of magnesia	27.00
Chloride of magnesium	3.70
Chloride of potassium	0.75
Chloride of sodium	2.30
Sulphate of lime	1.50
Bromide of potassium	0.02
Distilled water	1000.00

Another solution was composed as follows:

Solution No. 12:

Chloride of sodium	8
Chloride of potassium	8
Chloride of magnesium	8
Chloride of calcium	8

Besides these solutions, or means of experimentation, there were also employed:

Solution No. 13: Natural Vichy water (Célestins).
No. 14: Common water (springs at Brest).
No. 15: Natural sea-water (roads of Brest).
No. 16: Atmospheric air.

The Vichy water represented an aqueous element different from the sea-water, but rich in salts of soda. It was also necessary to compare the action of the artificial elements with that of the natural element, the sea-water, and to observe whether mollusks, well enclosed in their shells, could not live for some time in fresh water, or even in the air.

METHOD OF EXPERIMENTATION.—The above solutions were poured into porcelain capsules, placed in the light at an average temperature of 12°. Every two days the evaporated water was replaced by distilled water, so as to keep the solutions in the same state of concentration. Every day these solutions were strongly aërated and shaken, with the view of maintaining conditions analogous to those of sea-water. Mollusks recently caught were placed at the bottom of the capsules at a distance of 20 centimeters from the surface of the liquid.

SUBJECTS OF EXPERIMENTATION.—A very small number of species have been subjected to these physiological experiments.* They are:

The reticulated venus-shell (*Venus reticulata*).
The common mussel (*Mytilus edulis*).
The *palourde* (*Venus decussata*).
The common periwinkle (*Littorina vulgaris*).
The *buccin* of the British Channel (*Tritonium undatum*).

By reason of their different organization these mollusks have given very different results. The bivalves, mussels and venuses, which can shut themselves up between their valves, have as a general rule showed greater resistance than the opercular spiral-shelled mollusks, periwinkles and buccins. Of these the periwinkles, whose operculum can close entirely, prudently retired into the remotest coils of the spiral, and were thus better protected than the buccins, whose opening does not shut tightly, and into which the water can easily enter by the canal at the mouth of the shell.

The bivalves, which can resist external influences, whilst inclosed between their valves, do not by any means act in the same manner. In

* Oysters, subjected to the same experiments, have shown great variableness of impressions, and have generally succumbed very rapidly in the different solutions.

artificial elements the mussel resists less than the venuses; and among these latter the reticulated venus or *clovisse* shows less resistance than the palourde (*Venus decussata*), which exhibits a remarkable degree of resistance. In the solution of sulphate of magnesia, for instance, the mussel succumbed after ten days, the reticulated venus-shell after fifteen, whilst the palourde was still alive after sixty days. These proportions were very nearly maintained in the other solutions relatively to the duration of life in these mediums.

Below is given the result of these experiments as regards the palourdes (*Venus decussata*). Five specimens of this kind were on the 10th January, 1882, placed, under the same conditions, in each of the different solutions mentioned above. The same care was bestowed on all of them, and they were properly aërated every day. At the same time a certain number of these mollusks were placed, near to the former, in vessels containing natural sea-water.

January 10. Experiments commenced with the palourdes.
25. They succumbed in the ioduret of potassium.
February 10. They succumbed in the chloride of potassium.
15. They succumbed in the air.
18. They succumbed in the sulphate of potassium.
18. They succumbed in the common water.
20. They succumbed in the solution No. 10.
20. They succumbed in the bromide of potassium.
20. They succumbed in the chloride of magnesium.
25. They succumbed in the Vichy water.
22. They succumbed in the chloride of sodium.
22. They succumbed in the solution No. 12.
24. They succumbed in the solution No. 9.
March 10. They succumbed in the sulphate of magnesia.
10. They succumbed in the solution No. 11.
15. Some palourdes are still living in the sulphate of soda.
15. The palourdes placed in the sea-water are alive.

OBSERVATIONS ON THESE FACTS.—It appears from these experiments that, in spite of the possibility of shutting themselves up between their valves, the venuses yield to the action of the surrounding mediums, since their power of resistance is not equal.

Salts of potash seem much less favorable than the salts of magnesia, and especially than salts of soda. Life ceased first in the ioduret, the bromide, the chloride, and the sulphate of potassium, and in solution No. 10, the prevailing element of which is chloride of potassium.

The salts of soda and magnesia still maintained life when the animals had succumbed in the salts of potash. Solution No. 9, for instance, the principal element of which is chloride of magnesium, preserved its inhabitants alive much longer, and the same applies to the sulphate of magnesia alone and in solution No. 11.

The resistance of the palourdes in the Vichy water shows the favor-

able action of salts of soda on the preservation of life in marine animals; for forty days the palourdes lived in this mineral water!

It was in the sulphate of magnesia and the sulphate of soda that life was sustained longest, the latter excelling the former. On the 12th March I tasted some of the *Venus decussata* which had been kept in sulphate of soda for sixty days, and found their flavor excellent and without any trace of a bitter flavor. This observation might prove useful in alimentary economy, as the palourde is a highly prized shell-fish, and sulphate of soda can be bought cheap.

It is a fact worthy of remark that it was only in the solutions of sulphate of soda and sulphate of magnesia that green algæ commenced to make their appearance at the end of sixty days. The conditions favorable to marine animal life are then apt to develop vegetable life. There is nothing surprising in this parallelism, but it receives from the present circumstance a curious confirmation. One singularity appears: the solution of chloride of sodium (impure marine salt) did not sustain life as long as the solutions of salt of magnesia and sulphate of soda, and yet salt is an essential element of the sea-water. This proves that the mollusks are adapted, not to pure salt, but to that peculiar mixture which constitutes the natural sea-water; and that the secondary elements, as regards their quantity, play an important part. This gives us reason to suppose that the accidental modifications of the water of the sea during the different geological periods must have had a great deal to do with the extinction of various species.

The venus remained closed in most of the solutions, the nature of which they doubtless learned to know by opening their valves a very little. Meanwhile they occasionally put their siphons outside the shell, for instance in the sulphate of magnesia and in the sulphate of soda. In the solution of chloride of sodium and in the sea-water they had their siphons out nearly all the time.

The palourdes can live for more than a month in the air in a cool place. For about twenty days they remain shut; later they open their valves and protrude their siphons. At the least touch they draw them in and close their valves. Then comes the moment when the striped muscles which bring the valves together have no longer the strength to do this, although the smooth muscles which retain them will still do so, when one closes the valves. In all the solutions in which these mollusks have lived these same phenomena could be observed.

The weakening of the muscles showed itself first in the striped part of the adductors, which draw the valves together, and later in the smooth part of the same muscles, which held the valves artificially closed for a constantly decreasing period.*

The *Venus reticulata*, or clovisses, showed the same phenomena; the order of extinction of vitality in the different solutions was the same;

*See *De l'énergie et de la structure musculaire chez les mollusques acéphales.* [On the energy and muscular structure of the acephala.] By J. B. Baillière, Paris.

but these mollusks did not live as long as the preceding ones. They succumbed a month after they had been placed in the solutions, first in the salts of potash, then in the salts of magnesia, and finally in the salts of soda.

The periwinkles resisted longer than the bivalves, and showed less repugnance to sulphate of soda, in which they lived forty days.

The great buccin succumbs much quicker, as it cannot close its shell hermetrically like the periwinkles. At the end of twenty-four days it died in most of the solutions employed, especially in the salts of potash. Its life was prolonged forty-eight hours in solution No. 12, in the sulphate of magnesia, and in the sulphate of soda, but soon came to an end.

During all the time these experiments were going on, from January 10 to March 15, the palourdes and the periwinkles lived in the sea-water of the laboratory, the *Venus reticulata* and the mussels not quite so long, and the buccins only a few days.

It is a very important fact, to which we direct special attention, that the salts which constitute the sea-water and the different solutions which we employed gave to the water the faculty of dissolving variable quantities of atmospheric air. We proved by direct experiments that the solutions of salts of soda retain more air when agitated by it than the solutions of salts of potash. This would, therefore, prove that the poisonous character of the salts mentioned in our experiments is caused in part by the circumstance that they do not let their solutions become sufficiently aërated; their action produced asphyxia. This explains why the sulphate of potash and the sulphate of soda, neutral salts to which the mollusks are by no means adapted, act so differently upon them, the salts of potash killing them quickly and the salts of soda preserving them for some time.

From these experiments the following conclusions have been reached:

1. The saline elements of the sea-water act very differently on mollusks.

2. Every modification in the composition of the sea-water finally becomes fatal to the life of these animals.

3. Their greater or less resistance depends on their organization. Bivalves resist better than spiral shells, and in these two groups the results vary according to the different species.

4. Salts of potash are less favorable to the life of mollusks than salts of magnesia; and salts of magnesia are less favorable than salts of soda.

5. Outside of the salts dissolved in sea-water the sulphate of soda seems to possess a well-established preserving neutrality.

6. The death of the bivalves is caused by a general weakening of the muscles.

7. As the muscles can no longer either draw together or open the valves, the animal is exposed to the unfavorable or poisonous action of the element.