slower reactions, slower coördinated movements, less sensitiveness to stimulation and an increase in pulse rate. The memory and word reactions, as in the earlier results, were improved after the alcohol.

Some attention should be given to the fact that in Period 6, and to a less extent in Period 5, in Sections I and II of the table, the signs are in the majority of cases the opposite of those in Periods 2 and 3 for similar measurements. This means a superior performance and is in contrast to the earlier condition of general depression. There are some indications in the data previously published that this facilitation following the alcohol depression may not be a peculiarity of Subject VI, but a characteristic phenomenon of the alcohol effect.

[1] Dodge and Benedict, Psychological effects of alcohol, *Carnegie Inst. Washington, Pub.* 232, 1915; these PROCEEDINGS, 1, 605 (1915).

[2] For family and personal history see Dodge and Benedict, op. cit., p. 277.

[3] Rivers, *The influence of alcohol and other drugs on fatigue*, London, 1908.

THE INFLUENCE OF THE MARGINAL SENSE ORGANS ON METABOLIC ACTIVITY IN CASSIOPEA XAMACHANA BIGELOW

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The results of my earlier studies[1] have shown a marked influence of the marginal sense-organs on the rate of regeneration in *Cassiopea*, when halves of the same specimen are used for comparison. Further experiments on regeneration have confirmed these results, and have shown that when two halves of any medusa disk are subjected to the same operation the amount of regeneration from the two halves is identical in extent within the limits of error of measurement employed

Since the influence of the sense-organs on the rate of regenerations is most marked in the earlier stages of any experiment, several series of disks were (1) separated into halves, and (2) the sense-organs were then removed at different intervals of time after the first operation as shown in the following table:

TABLE 1

Series No.	*First operation Disk cut into 2 half disks*	*Second operation S. O. removed from one-half disk*	*Result*
1	9.45 a.m. July 22	7.00 a.m. July 23	Half with S. O. fastest
2	8.00 a.m. July 24	7.00 p.m. July 24	Half with S. O. fastest
3	7.15 a.m. July 25	8.00 a.m. July 26	Reg. equal
4	8.00 a.m. July 25	4.00 p.m. July 25	Half with S. O. fastest
5	7.00 a.m. July 26	8.00 a.m. July 27	Reg. equal

When the sense-organs were removed from one half disk in less than 24 hours regeneration occurs just as if they had been removed at the time of the first operation. After about 26 hours, however, the removal of the sense-organs from one of the half disks had no apparent influence on the rate of regeneration, which was the same from both halves of any disk.

Influence of marginal sense-organs on loss of weight in starving.— Mayer[2] found that when Cassiopea was starved in sea water from which all food organisms had been removed by careful filtration, the loss of weight could be expressed mathematically by the formula $y = W\ (1-a)^x$, in which W = the original weight, x the number of days of starvation and a a constant, the 'coefficient of negative metabolism.' The value of a in the equation above differs in experiments involving varying conditions as regards light and darkness, presence or absence of regeneration, etc., but in all cases the formula gives a very close approximation to the observed loss of weight.

In my experiments the two halves of a series of disks were compared after they had been subjected to operations which made possible the comparison of the halves of the disks upon one of which the sense-organs remained, while these were removed from the other half disk (active and inactive series); second, the comparison of half disks on one of which the sense-organs remained, while the other, from which all sense-organs were removed, had its muscles activated by a circuit wave of contraction maintained in an endless labyrinth of subumbrella tissue (active and activated series); third, half disks from which all sense-organs were removed, while one of them was activated by a circuit wave of contraction (activated and inactive series).

TABLE 2

	Loss of weight in active and inactive half disks		*Loss of weight in active and activated half disks*		*Loss of weight of activated and inactive half disks*	
Days after operation	*Weight of half with sense-organs*	*Weight of half without S. O.*	*Weight of half with sense-organs*	*Weight of activated half*	*Weight of activated half*	*Weight of half without S. O.*
0	100.00	100.00	100.00	100.00	100.00	100.00
1	75.34	81.81	76.29	79.41	79.47	81.97
2	66.72	71.27	67.18	70.58	70.63	71.84
3	58.54	64.09	59.76	61.99	62.03	63.91
4	55.27	55.41	55.88	57.18	57.21	57.23

In every instance the results follow closely those obtained when the regeneration was used as the standard of comparison. The results of the entire series of experiments are shown in the following tables, in which the original weight of each series of disks is taken as 100 so that the results read as percentages of the original weight.

In the activated and inactive series as well as in the series composed of activated and inactive half disks the visible activity, i.e., muscular contraction was much greater in those members of each series in the tissues of which the circuit wave of contraction was maintained. When compared with half disks under the control of the sense-organs, the rate of pulsation of the activated disks was from 3.5 times as great at the beginning of any experiment to 10 times as great at the end of the first day. During this interval the rate of the half disks with the sense-organs fell to scarcely more than half the original rate while, on the contrary, the rate of the activated half disk always increased.

Simultaneous kineograph records of the pulsations of the two halves of the same disk, one with its sense organs and the other activated by a circuit wave of contraction, were made to measure the amount of muscular work done by each half under the given experimental conditions. In all these determinations it was found that the amplitude of the contraction as recorded on the drum depended upon the character of the operation that had been performed upon the half disk. When the active half remained with its subumbrella muscles undisturbed, the resulting contraction was more extensive than that of the activated mate. When, however, the same operation had been made upon each of the two halves of a disk, from one of which the sense organs were removed, the amplitudes were equal for each half, so that the rate of pulsation is apparently a true measure of the work done.

The comparison of the loss of weight shown by activated and active, as well as by the activated and inactive pairs of half-disks, shows very clearly, just as when regeneration is used as the basis for comparison, that muscular activity is a relatively unimportant factor in determining the metabolic activity of *Cassiopea*.

Influence of marginal sense-organs on total metabolism.—To measure the total metabolism of half disks of *Cassiopea* under the several operative conditions involved in the regeneration and starvation experiments, specimens prepared in the manner previously described for these experiments were placed in closed jars containing known volumes of fresh sea water, and after different intervals of time the amount of CO_2 given off was determined for each specimen. In making these determinations, the records were kept in terms of increased hydrogen ion concentration, the values of which were later determined by adding known volumes of CO_2 to a volume of fresh sea water equal in amount to that contained by the jars used in the experiments with the medusa disks. In many of the experiments the disks were kept in the closed jars until one member of a pair had ceased to pulsate, because of the narcotizing effects of the CO_2, so that it was possible to obtain a

measure of the CO_2 concentration necessary to bring about narcosis. In nearly all instances the activated half disk was the first to succumb, and when it had stopped it did not again pulsate until once more stimulated by an induction shock. The active half disks showed more resistance to CO_2, and when removed from the jars in which they had ceased to pulsate and put into fresh sea water would start pulsating again within one or two minutes, even when they had been inactive for several hours.

When the closed jars, in which the medusae were kept for these experiments, were allowed to remain in the light, the disks would continue to pulsate for several days as the CO_2 would be in part used up by the symbiotic algae which are very abundant in the tissues of *Cassiopea*.

The results of a typical experiment are shown in table 5, in which the half disk with sense-organs is designated "*a*" and the activated half disk "*b*."

TABLE 3

No. of Specimens	Weight in grams	Pulsation Rate 1.45 p.m.	4.40 p.m.	7.30 p.m.	H· Concentration
1 a	22.8	44	62	18	7.80
1 b	23.0	128	136	120	7.90
2 a	30.0	36	34	22	8.00
2 b	30.5	88	86	98	8.00
3 a	39.0	44	36	8	7.90
3 b	41.0	130	158	126	7.90
4 a	28.00	56	22	25	7.90
4 b	29.00	96	106	Out	8.00
5 a	29.25	84	32	32	7.90
5 b	28.75	116	120	132	7.90

The hydrogen ion concentration of the sea water determined at the beginning of the experiment was PH. 8.10 (8×10^{-9}) so that the change brought about in its reaction on account of the activity of the several half disks was from 0.1 to 0.3 of the PH. unit. Using the same volume (1200 cc.) of fresh sea water, it was found that the addition of the 5 cc. of CO_2 would usually bring about a change of 0.2 in the PH. reading, so that each half disk had apparently given off approximately that volume of CO_2, in the 8 hours during which they were in the jars. When the specimens were left for a longer time in the jars the amount of CO_2 given off became proportionately less as time went on as the disks became more thoroughly narcotized, so that when the hydrogen ion concentration of the water had become 7.8 the disks had ceased pulsating. If left for some hours in this water, the nervous system became incapable of transmitting impulses and finally the sense-organs were rendered inactive.

[1] Cary, L. R., these PROCEEDINGS, 1, No. 12; *J. Exper. Zoöl.*, 21, No. 1.

[2] Mayer, A. G., *Publ. Carnegie Inst. Washington*, No. 183.