J. Mar. biol. Ass. U.K. (1954) 33, 173–175
Printed in Great Britain

EFFECT OF EXTERNAL MILIEU ON LUMINESCENCE IN *CHAETOPTERUS*

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In a previous paper some effects of anisosmotic and unbalanced salt solutions on the luminescent responses of *Chaetopterus variopedatus* have been described (Nicol, 1952). Similar experiments have been carried out on polynoid elytra, and the results are described elsewhere in this Journal, together with a brief review of the relevant scientific literature (Nicol, 1954*b*). The present experiments were undertaken to investigate the effects of single salts in physiological concentrations, balanced by the addition of some inert substance, and to explain the possible mechanism of stimulation by hypo-osmotic solutions.

The experiments were simple. Whole specimens of *Chaetopterus*, or isolated anterior regions, were placed in the solutions to be tested. Salts (NaCl, KCl, $CaCl_2$, $MgCl_2$), sucrose and choline chloride were made up in solutions osmotically equivalent to normal sea water. Alkalinity of salt solutions was raised to pH 8·2.

Results were as follows:

Choline Cl	No luminescent response
Sucrose	Faint light appeared slowly
NaCl 81 + choline Cl 19	Faint brief light
KCl 2 + choline Cl 98	Faint brief light
$CaCl_2$ 3 + choline Cl 97	Little faint light, especially when container agitated
NaCl 81 + sucrose 19	Luminescent response
KCl 2 + sucrose 98	Luminescent response
$CaCl_2$ 3 + sucrose 97	Luminescence fairly bright
$MgCl_2$ 15 + sucrose 85	No light
NaCl 81 + fresh water 19	Luminescent response
KCl 2 + fresh water 98	Faint, brief light
$CaCl_2$ 3 + fresh water 97	Luminescent response
$MgCl_2$ 15 + fresh water 85	Luminescent response

Specimens were anaesthetized for half an hour in 0·2% chloretone or 0·5% cocaine (made up in sea water). They were then transferred to sucrose containing the same quantity of anaesthetic. A feeble luminescent response resulted.

These results confirm those obtained in earlier experiments, namely that solutions of the single salts NaCl and KCl are excitatory and evoke

luminescence; $CaCl_2$ raises irritability, resulting in faint light, especially if the preparation is subjected to gentle mechanical stimulation. In addition, the results show that these three salts produce their effects not only when acting in excess, but also when, balanced with choline chloride, they occur in normal physiological amounts.

Contrary to the effect of choline chloride, which appears to be physiologically inert so far as the luminescent response is concerned, sucrose evokes a faint luminescent response which is not blocked by anaesthesia with chloretone or cocaine, but which does not appear in the presence of $MgCl_2$.

As previously noted, hypo-osmotic sea water (25%) evokes luminescence, and luminescence appears in solutions of each of the four ions, Na, K, Ca and Mg, in physiological concentration plus fresh water. It is noteworthy that neither Ca nor Mg, in physiological quantity, block hypo-osmotic excitatory stimulation.

In an investigation of the viability of various marine animals in diluted sea water, Pearse (1928) found that *Chaetopterus* would tolerate 50% sea water for long periods. A previous study has shown that luminescence does not appear until the sea water is diluted 50% or more (Nicol, 1952). This is the physiological limit of the species, and the harmful effects of dilutions greater than 50% are not offset by $CaCl_2$ and $MgCl_2$ in physiological quantities.

In any system consisting of excitable tissue dependent upon a properly balanced ionic environment for stability, any radical alteration in the concentrations or proportions of the external ions will produce great changes in excitability, and depolarization of external boundaries. Changing the external milieu could affect either the nervous system or the luminescent cells. Evidence has recently been adduced to show that the latter possess a contractile mechanism for discharging the luminescent secretion. The excitatory effect of Na and K on excitable tissues is well known, and these two ions probably act on both the photogenic cells and nervous system of *Chaetopterus*. The responses which they induce are by no means as bright or as long-lasting as those evoked by strong electrical stimulation, probably owing to initial localized depolarization, followed by loss of excitability as this process becomes complete. The increased irritability produced by Ca has been reported for other invertebrate groups, and may be linked with Mg-lack (Robertson, 1941; Nicol, 1954*a*, *b*).

As in the vertebrate preparation, choline chloride appears to be inert; any possible blocking action such as it exerts on the neuro-muscular junction has not been ascertained. Sucrose, on the other hand, has a weak stimulatory effect in isosmotic concentration. Sucrose, therefore, is osmotically but not ionically inert. Its stimulatory effect on the luminescent response is not abolished by prolonged nervous anaesthesia, and it probably acts directly on the photogenic cells apart from any effect on the nervous system. The ionic unbalance produced by the introduction of isosmotic sucrose produces some

degree of depolarization owing to ionic shifts, and results in excitation and luminescence. The same effect is probably responsible for the luminescence appearing in diluted sea water or fresh water.

In a recent paper Bonhomme (1953) gives a histological picture of luminescent secretion in *Polycirrus* rather similar to that in *Chaetopterus*. The course of secretion is presented as opening of the cell, hydrolysis of secretory granules, and expulsion of photogenic material, possibly as the result of swelling or changed osmotic relations. The possibility that cytolysis or raised intracellular pressure resulting from imbibition of water may be responsible for the luminescence of *Chaetopterus* in dilute media has been considered, and seems most unlikely in view of the faint and transitory light produced, compared with the brighter response which can be evoked by electrical stimulation, and with the amount of photogenic material present. Dilute sea water and fresh water probably exert a transitory depolarizing effect on the excitable tissues, which rapidly lose irritability. A similar explanation is probably applicable to the many instances of luminescence in marine animals evoked by application of fresh water.

Summary

The effects of hypo-osmotic solutions, and of isosmotic solutions of choline chloride, sucrose, NaCl, KCl, $CaCl_2$ and $MgCl_2$ on the luminescent response of *Chaetopterus variopedatus* are reported. Choline chloride, as an inert substance, can be used in conjunction with each of the other salts to test the effects of the latter in physiological quantities. Sodium and potassium excite in physiological concentrations; calcium raises irritability. Sucrose produces a weak luminescent response, which is not blocked by nervous anaesthetics (cocaine, choloretone). Changes in the ionic environment induce localized depolarization, followed by complete depolarization and loss of irritability of both nervous and photogenic tissue. This explanation will probably account for most instances of luminescence evoked by ionically abnormal media.

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