Electrical Shocking Effect on Larvae of *Balanus*

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(Pl. 1; Text-figs. 1–3; Table 1)

INTRODUCTION

Reaction of a fish to electrical current, up to the present, has been studied by many authors on basic principles[1)2)3)4)5)7)] or on applications[5)6)7)]. And pulse current was found to be the most effective one to cause electrotaxis or electronarcosis. But few have been reported that the same principles had been applied to microscopical animals in sea water[8)].

Observing the animals in a small bath with a microscope, electric potential was applied to the electrodes of a bath. Then the critical voltage gradient in the sea water in a bath to narcotize the cypris larvae of *Balanus* to death at each definite duration of current was obtained and then the potential curve of the stimulative period measured for cypris larvae was determined. This curve was as the curve hitherto reported which was obtained for a fish with pulse current. This study was done as one of the basic study to defend *Balanus* growing on the walls of the sea water course at power stations etc.

MATERIALS AND METHODS

Experimental Animals

Cypris larvae of *Balanus amphitrite albicostatus* were caught by a plankton net from the sea near the laboratory in Fukuyama City, and these samples were put to the experiments within two hours to hold animals vigorous throughout the experiments.

Experimental Shocking Baths and Electrical Equipment.

Experiments were carried out in an insulated box made of glass or bakelite pieces and carbon electrodes, bound together on a glass plate by binding agent called araldite, as shown in Fig. 1. Dimensions of several baths used in these experiments were also indicated in a table attached to Fig. 1.

In this table in Fig. 1, d denotes the distance between two electrodes. In the electric circuit in Fig. 1, primary voltage of the power transformer is changed from 0 to 100 volts by autotransformer not denoted in this figure. Secondary current is rectified by a selenium rectifier and the voltage of direct current up to 2500 volts is supplied to the condenser C_1, C_2. Observing the animal in a bath with a microscope
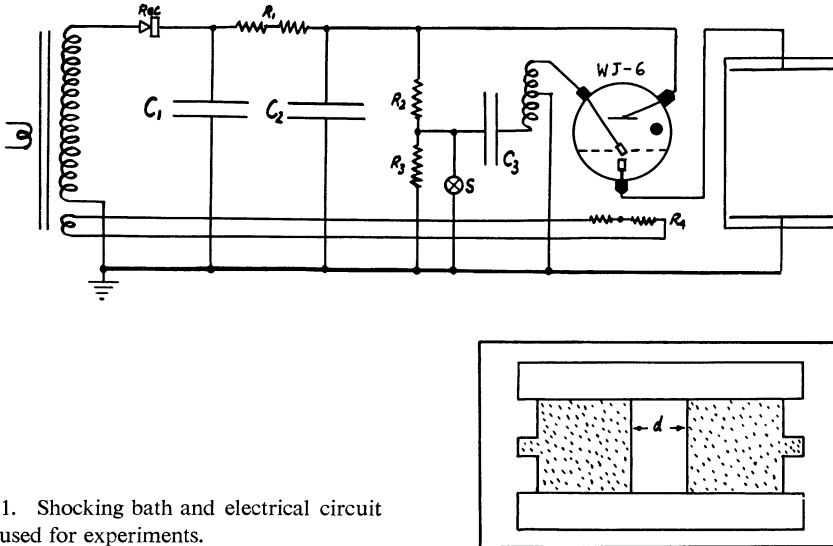
Fig. 1. Shocking bath and electrical circuit
used for experiments.

C_1 : 8μF
C_2 : $2\sim24\mu$F
C_3 : 0.05μF
R_1 : 40KΩ
R_2 : 1MΩ
R_3 : 500KΩ
R_4 : heater, used when temperature of
the tube was lower than 15°C

	No. 1	No. 2	No. 3	No. 4	No. 5
d	1.52^{cm}	1.52^{cm}	2.50^{cm}	3.02^{cm}	4.51^{cm}
width	0.60	2.50	0.60	0.60	1.80
depth	0.80	1.00	0.80	1.10	0.80

Dimensions of shocking baths used

operated by hands, switch S was closed by foot at a moment when the specimens
came to the center of the bath and swimmed parallel or perpendicular to the electric
current.   When the switch S is closed, the charge of C_3 discharges through the pri-
mary coil in the ignition transformer.   Then the ignition transformer ignites dis-
charge tube WJ-6.   Discharge of this tube close the discharging circuit of C_2 and
the potential of C_2 measured beforehand was applied to the electrodes of the bath.
The time of duration of this discharge is treated as "half value time" t (=0.37 C.
R) as hitherto done at the electrical shocking on a fish[4)6)], where R is the resistance
of the discharging circuit of C_2 and it is considered as that of the water in the bath
neglecting other small resistances in the discharging circuit.   The shocking bath was
filled with sea water containing animals and the electric resistance R between two
electrodes in the sea water bath was chosen a definite value by changing the volume
of water in the bath measured by Kohlrausch bridge just before the electrical shock-
ing.   In these experiments of electrical shocking, the value of t was given for the
first time, capacitor C was then chosen from 2 to 24μ F, the value of R is decided
at last to obtain the given value t (=0.37·C·R) as described above.   By the surface
tension of water, sections of water in the bath are not uniform and then the electrical
field in the water should not be strictly uniform.   But in these experiments voltage
gradients were obtained by dividing the input voltage by distance d separating the

electrodes.   Electrical potential was applied to the electrodes only when the speci-
mens were swimming in the center of the shocking bath.

DETERMINATION OF CRITICAL VOLTAGE GRADIENTS

The critical voltage gradient was defined as the minimum voltage gradient in
the water of the bath which narcotizes a cypris larva of *Balanus* about 0.57 mm in
length to death.   Observing a cypris larva swimming in the center of the bath par-
allel or perpendicular to the direction of the electrical current with a microscope,
switch S was closed as described above and the minimum voltage gradients to cause
serious narcosis showing the deformation of the body of a cypris larva as shown in
Plate 1 (b) and Fig. 3 (d) were obtained.   Almost all the cypris larvae showed such
reactions within about thirty minutes after an electrical shock when higher volt-
age gradients than the critical values were applied at 28°C.   And these animals
showed such reactions as shown in Plate 1 (b) and Fig. 3 (d) within about thirty
minutes after a shock did not revive after two days.   Then these reactions as
shown in plate 1 (b) or Fig. 3 (d) are treated simply as a reaction of death.   Such
animals reacted only a few stages as shown in Fig. 3 (b) and (c) at the voltage gra-
dient lower than the critical one within about thirty minutes did not react the last
stage as shown in Fig. 3 (d) or in Plate 1 (b), and they were recovered till next day.
These animals showed incomplete reactions of death for electrical shocking moved
about in the sea water of a glass dish next day, but deformed parts of the body remain-
ed as before. Values of minimum voltage gradients obtained to cause narcosis to death
for the *half value time t* were about the same values in spite of the direction of the
body of swimming cypris larvae were same or opposite to the electric current or
perpendicular to the current in so far as the cypris larvae were in the swimming
condition, stretching out its appendages.   But when the animal was confined in its
carapace as shown in Plate 1 (a), about 100 volts/cm was added to each critical
value of the voltage gradient obtained in these experiments for each value of t.

RESULTS

Critical voltage gradients for the *half value time t* were obtained as shown in
Table 1.   In Table 1, the values of t are denoted in milliseconds calculated from
$t = 0.37 \ C. \ R$, where C is the capacity of C_2 in Fig. 1, and R is the resistance of the
water in the bath determined by the method described above.

In Table 1, each value of V is the arithmetical mean of some values observed
at the same value of t.   From these values of V and t, potential curve of the stimu-
lative period was obtained as shown in Fig. 2.   This curve is a rectangular hyperbo-
la.   Then from the values of V and $\dfrac{1}{t}$, regression analysis was done and the equa-
tion of the regression line is

Table 1.   Minimum voltage gradients obtained to narcotize a larva of *Balanus*
to death at 28°C for the *half value time t* of the discharging current.

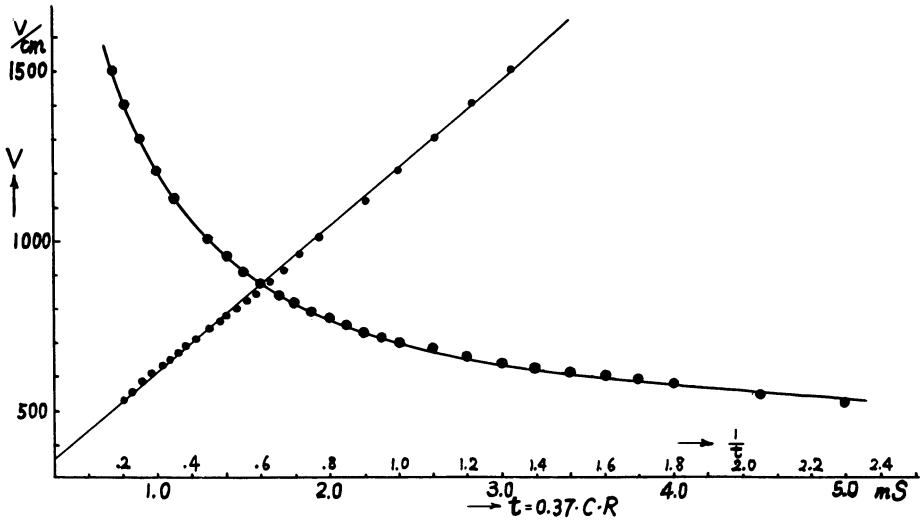| t (mS)	$\frac{1}{t}$	V (volts/cm)	t (mS)	$\frac{1}{t}$	V (volts/cm)
0.75	1.33	1500	2.20	0.46	730
0.82	1.22	1400	2.30	0.43	710
0.90	1.11	1300	2.40	0.42	700
1.00	1.00	1200	2.60	0.38	680
1.10	0.91	1120	2.80	0.36	660
1.30	0.77	1000	3.00	0.33	640
1.40	0.71	950	3.20	0.31	630
1.50	0.67	900	3.40	0.29	615
1.60	0.63	870	3.60	0.28	600
1.70	0.59	830	3.80	0.26	590
1.80	0.56	810	4.00	0.25	580
1.90	0.53	785	4.50	0.22	545
2.00	0.50	770	5.00	0.20	520
2.10	0.48	750			

Fig. 2.   Potential curve of the stimulative period and regression line, measured for cypris larvae of *Balanus*. Temperature and specific resistance of sea water in the bath: 28°C, 21.5 Ω-cm.

$$V = 354.4 + \frac{847.7}{t},\qquad(1)$$

where t is denoted in milliseconds and its reciprocals are put on the horizontal axis instead of t in Fig. 2; V is the potential gradient denoted in volts/cm.

In Fig. 2, straight line denotes the equation (1) and the marks●(big and small), denote respectively the arithmetical means of observed values of V.
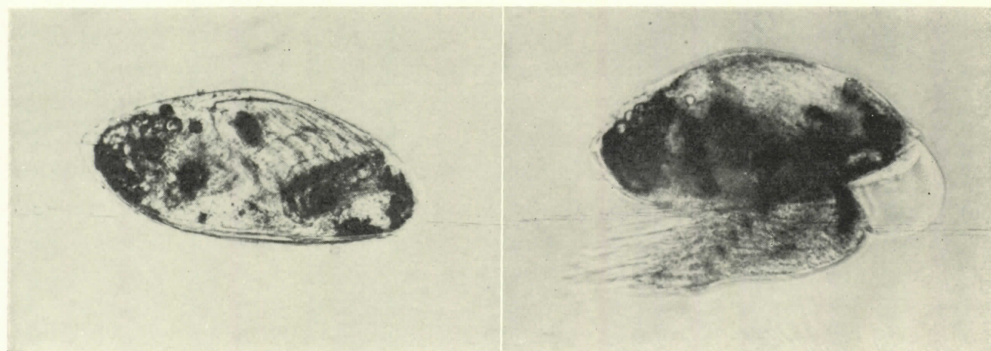
(a) normal   (b) deformed after an electrical shock (dead)
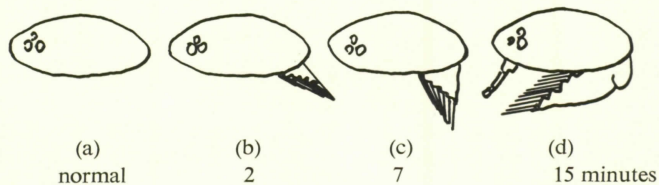
Plate I   Cypris larvae of Balanus ($\times 80$)

| (a) | (b) | (c) | (d) |
| normal | 2 | 7 | 15 minutes |

Fig. 3.   Deformed figures of cypris larvae of *balanus* shocked by pulse current at a crytical
voltage gradient.   The time denotes the total sum in minutes to react to each stage of
narcosis as usual.

From the equation (1), the minimum voltage gradient known as rheobasis is
354.4 volts/cm, and the condition of minimum energy to cause narcosis to a cypris
larva of *Balanus* to death is calculated from $\dfrac{V^2}{R} \cdot t$ and equation (1) or read from the
curve in Fig. 2.   These conditions of minimum energy are equall to the effective
period of $t=2.39$ mS and double rheobasis of 709 volts/cm at 28°C.

DISCUSSION

A curve and a line obtained in Fig. 2 denoting the relation between the mini-
mum voltage gradients and the "*half value time*" of discharging current to cause
narcosis to death to larvae of *Balanus* were similar in shape to a curve and a line
resulted from electrotaxis or electronarcosis measured for fish.   But the values of
minimum voltage gradients to cause the effective narcosis to put the cypris larvae to
death are very great, because the body length of a larva is very short.   In this method
of electrical shocking, the amount of the energy of electric current to put larvae
to death in sea water running in a watercourse seems to become very serious.   Then
it seems somewhat effective to apply the electrical shock to the wall of the water-
course, not in the running water, soon after the larvae of *Balanus* attached on the
wall.

SUMMARY

Relation between the critical voltage gradients and the time of duration of the current generally known as "*half value time*" to cause a larva to death was studied.

And a potential curve and a regression line representing the relation between the minimum voltage gradients to cause a cypris larva of *Balanus* to death and stimulative periods were obtained. These results obtained for microscopic animals were similar to the results obtained by many authors for a fish except that the values of the critical voltage gradients were greater in the former.

REFERENCES

1) Weiss, M. G. 1901. La loi de l'excitation électrique des nerfs. C. R. Soc. Biol., **53**: 466–468.

2) Kreutzer, C. 1950. Die physiologischen Grundlagen der Elektrofischerei im Meer. Archiv f. Fischereiw., **2**, No. 1/2: 10–14.

3) Haier, U. 1954. Die elektrotechnischen Grundlagen der Elektrofischerei im Meer. ibid., **5**, No. 3/4: 132–144.

4) Halsband, E. Die Beziehung zwischen Reizintensität und Zeitdauer des Einzelimpulses bei elektrischer Durchströmung von Fischen. ibid., **6**: 45–53, 1955; **7**: 74–81, 1956.

5) Meyer-Waarden, P. F. 1956. Über den elektrischen Scheucheffekt und seine Verwendung in Fischerei und Wasserbaw. ibid., **7**: 192–209.

6) Meyer-Waarden, P. F. 1957. Electrical fishing. FAO Fisheries Study, No. 7.

7) Kuroki, T. 1955. Electrical fishing (in Japanese). Gihōdo, Tokyo.

8) Takesita, I. & Miyake, S., et al. 1959. Test of electrical shock on larvae of *Mytilus* and *Ostrea* (in Japanese). Occasional Reports of Generalized Studies of Kyushu Electrical Company, Ltd.

フジツボ幼生に対する電撃の効果

竹　下　伊　佐　雄

　海水中の付着生物を除く研究の一つとして，フジツボ幼生（シプリス）に電撃を加え麻痺致死させる方法を実験した．水槽中の魚に電撃を加えた場合の魚の反応については従来多くの研究結果が報告されている．しかし顕微鏡的小動物に対する電撃効果については殆んど報告されていない．
　フジツボ幼生に対し蓄電器放電による電撃を加えるとき限界電界値以上の場合は麻痺による異常な変形が起りその特異な変形をしたものは2日後にも尚生き返るものがなく死と判定できたので，此の変形をもって麻痺による致死と簡単に取扱うこととしてその麻痺を引起す最低電界値と通電時間との関係を明らかにした．此の結果双曲線を得たので通電時間の逆数を用いて同じ関係を直線関係に改め，回帰直線を求めた．此の結果は水槽中の魚に同種の電撃を加えて得られた感電或は麻痺の最低電界値と通電時間との関係と全く同種のものであることが明らかとなった．フジツボ幼生は体長が短かいため麻痺致死の最低電界値は異常に高くこのままの方法を大量の海水に用いて幼生を死滅させるには莫大な電力量を必要とする．フジツボ幼生の付着を電撃によって防ぐには幼生付着直後の壁に電撃を適用するのが一つの有利な方法と思われる。