CHANGES IN RESISTANCE ACROSS PLANARIANS (*DUGESIA DOROTOCEPHALA*) DURING REGENERATION

Reuben Paul Bell, Jr. and Barbara Shirley

Faculty of Natural Sciences, University of Tulsa, Tulsa, Oklahoma

Electrical resistances across both intact and regenerating planarian worms (*Dugesia dorotocephala*) were measured every other day, during a nineteen-day period. An increase in electrical resistance and a subsequent return to the initial resistance was measured across regenerating worms but no significant change in resistance across control animals occurred. Since structural proteins of cells have been demonstrated to act as semiconductors, change in tissue conductivity concurrent with mitosis suggests that an alteration in the structural proteins of dividing cells might have been responsible for the observed change in cell conductivity.

INTRODUCTION

From a series of observations, Szent-Györgyi (1, 2) and Szent-Györgyi and McLaughlin (3) concluded that the insoluble, or structural, proteins isolated from cells can serve as semiconductors. The purpose of the present study was to determine whether this property of semiconduction by structural proteins could be demonstrated within the normal, functioning cells of an organism. If structural proteins serve this function within cells, it would be expected that conduction through cells would change during mitosis due to the reorganization of cells' structural components. Because planarian worms are capable of rapid regeneration, and because regeneration requires rapid cell divisions, these organisms were selected for study of the effect of mitosis on electrical conductivity of tissue.

MATERIALS AND METHODS

Planarian worms (*Dugesia dorotocephala*) were collected from a shallow spring-fed tributary of the Illinois River in Adair County, Oklahoma, and were maintained in the laboratory according to the method of Behringer (4). Until experimentation was begun, the animals were fed a diet of dried beef liver. No food was administered during the course of the experiment. The worms were confined to stender dishes containing tap water. Each dish was 2 cm deep and had a diameter of 3 cm. Lids were kept on the containers to retard evaporation.

Fourteen planarians comprising a control group were assigned to stender dishes in pairs. Worms in an experimental group were severed transversely at midlength with a scalpel on day one of the experiment and fourteen fragments of these planarians were placed, two per dish, in stender dishes.

Electrical resistance through each planarian, and each fragment of a planarian, was measured every other day, for a period of nineteen days, beginning on the day on which animals in the control group were sectioned. Resistance through each animal was measured with a Simpson 260 Ohmmeter which had been adjusted to zero to compensate for the resistance in the fine steel wires that served as recording electrodes. Prior to each measurement of resistance, water was removed from the dish containing planarian worms or worm fragments. When measuring resistance across each intact planarian, the electrodes were placed against both sides of the worm at midlength and a measurement of resistance across the worm was taken. Resistance through each fragment of a planarian was measured by placing the electrodes on both sides of the fragment near, but not on, the cut surface. Care was taken to avoid piercing the animals with the tips of the electrodes.

Resistances measured in the control group and in the group of regenerating planarians were compared using Student's t-test.

RESULTS

On the first day of the experiment there was no significant difference ($0.4 > p > 0.3$) between the electrical resistance measured across intact planarians and the resistance measured across fragments of planarians that had been transected that day (Table 1). However, by

the third day of the experiment the resistance across the regenerating planarian fragments was significantly greater than the resistance across worms in the control group and remained significantly greater through the fifteenth day of the experiment. Comparisons of resistance measured across control and experimental animals after the fifteenth day revealed no significant difference between the two groups.

By the fifteenth day of the experiment, the regenerating fragments had resumed the shape typical of *Dugesia* but the size of each animal still appeared less than it had been prior to the time the animals were sectioned. However, the ability of the worms to elongate and contract made appraisal of their lengths difficult.

Resistances measured across the intact worms varied little during the experimental period (Table 1).

DISCUSSION

Although conduction through cells such as those of muscle and nerve tissue by means of ion transfer across cell membranes has been examined extensively, the ability of cells or tissues to conduct electrons is not well understood. The work of Szent-Györgyi (1,2) and Szent-Györgyi and McLaughlin (3) has indicated that structural proteins isolated from cells can behave as semiconductors. From the results obtained in the present study, it can be inferred that structural proteins can exhibit this property in some living cells as well. During mitosis there is extensive internal reorganization of cell structure and it was found that, concurrent with changes in cell morphology during mitosis, an increase in electrical resistance occurred across tissues of planarian worms. Since no significant alteration in resistance across intact worms in the control group occurred, the change in resistance across the regenerating planarians was not due to manipulation of the animals during measurement of resistance but was attributed to cellular reorganization during mitosis.

By the end of the experimental period regenerating worms had resumed the shape characteristic of their species and by this time exhibited no significant difference in electrical resistance from control animals. Although it was difficult to determine whether the experimental animals had regained their original length by the end of the test period, the rate of cell division was considered to be reduced by this time.

While the results obtained afford no explanation of the function that may be served by electrical conductivity in the tissues of the species studied, our results suggest that electron transport in tissue is related to the arrangement of structural proteins in cells. Thus, our findings linking these proteins with electrical conductivity *in vivo* are in accord with earlier reports that structural proteins conduct electrons *in vitro* (1,2,3).

ACKNOWLEDGMENT

This investigation was supported in part by University of Tulsa Student Research Grant R-3300-59.

TABLE 1. *Mean electrical resistance through nonregenerating and regenerating planarians* (Dugesia dorotocephala)

Day	Mean resistance ± standard deviation (ohms x 10,000)		Probability
	Nonregenerating planarians N = 14	Regenerating planaraian fragments[a] N = 14	
1	38.57 ± 2.87	37.42 ± 3.45	0.4 > p > 0.3
3	38.71 ± 3.72	47.28 ± 2.89	p < 0.01
5	38.57 ± 2.13	50.42 ± 2.50	p < 0.01
7	38.14 ± 2.53	51.00 ± 2.32	p < 0.01
9	36.71 ± 2.30	50.85 ± 1.70	p < 0.01
11	38.85 ± 1.70	50.57 ± 1.82	p < 0.01
13	38.00 ± 2.35	46.28 ± 2.58	p < 0.01
15	38.85 ± 1.70	41.14 ± 2.90	0.02 > p > 0.01
17	38.71 ± 2.43	38.57 ± 2.27	0.9 > p > 0.8
19	37.14 ± 2.44	37.00 ± 2.18	0.9 > p > 0.8

[a] Regenerating planarians were transected on day 1.

REFERENCES

1. A. SZENT-GYÖRGYI, Nature 148: 157-159 (1941).

2. A. SZENT-GYÖRGYI, Life Science 15: 863-875 (1974).

3. A. SZENT-GYÖRGYI and J. McLAUGHLIN, Proc. Natl. Acad. Sci. U.S. 69: 3510-3511 (1972)

4. M. P. BEHRINGER, *Techniques and Materials in Biology*, McGraw-Hill Book Co., New York, 1973, pp. 51-54.