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THE RELATIONSHIP BETWEEN THE SLOT EXCITABILITY AND THE EXCITABILITY DUE TO A SINGLE POLE

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The foregoing papers have shown how to determine the spatial distribution of excitability along a frog's nerve due either to a single-pole electrode, or to a slot (which is the equivalent of two single electrodes placed close together). Now these two distributions should be related in a simple manner, for in the previous paper (Rashbass & Rushton, 1949*b*, p. 343) it was deduced from the Superposition Theorem, that the single-pole excitability should be minus the integral of the slot excitability. The purpose of the present paper is to find out how far this theoretical expectation is experimentally true.

METHOD

The single-pole excitability was measured as in the previous paper, but the method of measuring the slot excitability was modified so that the determination could be done without removing the nerve from the jelly cylinder or from the trough in which the single-pole measurement had been made.

The circuit connexions for determining the slot excitability by this method were the same as for plotting the asymmetric tripolar curves (previous paper, p. 345) except that a variable resistance (0–50,000 Ω) was introduced in series with electrode Y (Fig. 2*a*). The convention for signs in plotting was the same as usual, x being positive when electrode X is positive to electrode O. Similarly, with y and electrode Y. Electrodes X and O remained fixed throughout the experiment, at a separation of not more than 1 mm. They constitute the slot.

Fig. 1 shows the potential measured by a probe inside the jelly cylinder when the electrodes were 1 mm. apart. It is seen that the change of potential is limited to a very short region and in fact the curve is almost identical with that obtained with a true slot (Rushton, 1949, Fig. 5).

Electrode Y was applied at various known distances from O, and in each position the following portions of the complete tripolar curve (Fig. 2*b*) were plotted. A, the region where the curve crosses the negative y axis; B, the point where the curve crosses the positive x axis; C, the region where the curve lies farthest to the right. Owing to the asymmetry of the electrode system it was not possible to compare the scales of the two axes by means of any physical measurement. Instead, the thresholds for stimulating through XO and through YO were defined as being equal. By adjusting the variable resistance in series with Y it was possible to represent these thresholds by approximately equal intercepts on the axes. Although theoretically not necessary, this adjustment rendered the records easier to plot and more accurate to analyse.

Theoretical considerations

The extraction of the slot excitability curve from these measurements was based on the following theoretical considerations. So long as the distance YO is not too great, the slope of the curve of Fig. 2*b* varies continuously, except in the third quadrant. Therefore there must be a point C on the polar curve where the tangent is parallel to the y axis (and the value of x there is a maximum). Since at that point the strength of x is independent of y, the slot electrodes

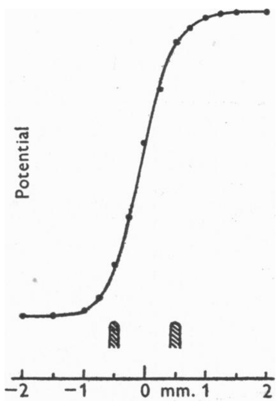

Fig. 1.

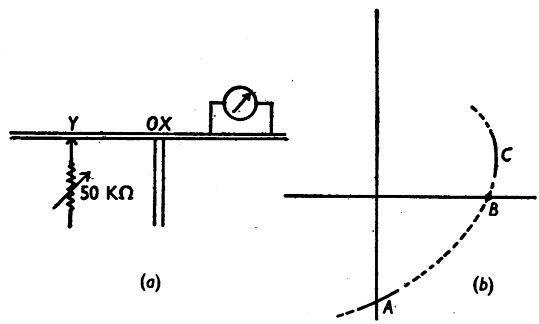

Fig. 2.

Fig. 1. The potential inside an agar jelly cylinder surrounded by two ring electrodes 1 mm. apart.

Fig. 2. (*a*) The electrode system for measuring the slot excitability curve. (*b*) The asymmetric tripolar curve showing the parts actually plotted as continuous lines.

must be stimulating at a point on the nerve where the current through Y is producing zero excitability. Assuming the nerve to be uniform this point will be midway between Y and O. It follows that the abscissa C gives the threshold when the slot excites a distance $\frac{1}{2}XY$ from its centre. Also OB is the threshold when the slot excites at its optimum point. Thus the ratio of the abscissae x_B/x_C will give the ordinate of the slot excitability curve corresponding to abscissa distance $\frac{1}{2}XY$, and scaled so that the maximum ordinate is unity.

As the distance OY is increased the shape of the polar curve changes, and eventually the slope becomes discontinuous where the point of excitation jumps from near the slot to near Y. Under these circumstances the nerve is never stimulated midway between O and Y and the above method becomes inapplicable. However, it is certainly valid for determining the slot excitability curve from the origin up to the maximum ordinate. To plot the curve for distances greater than this, use is made of portion A of the tripolar curve (Fig. 2*b*).

On the negative y axis the nerve is stimulated at or near Y (Fig. 2*a*) and the cotangent of the angle which curve A makes with that axis is proportional to the ordinate of the slot excitability curve at the point where excitation is occurring, as has been shown in a previous paper (Rashbass & Rushton, 1949*a*). Now the site of excitation is exactly at Y only when the distance OY is great. For shorter distances it is displaced into the extrapolar region and its exact location can be found by sliding the single-pole excitability curve on itself as has been shown previously (Rashbass & Rushton, 1949*b*, Fig. 3). When Y is very close to O the excitation site practically coincides with the optimum of the slot excitability curve. As Y moves away, the site also moves out to a known extent, and finally coincides with Y. Clearly then, by measuring the cotangents for each position of Y, the slot excitability curve may be found for all distances greater than the optimum.

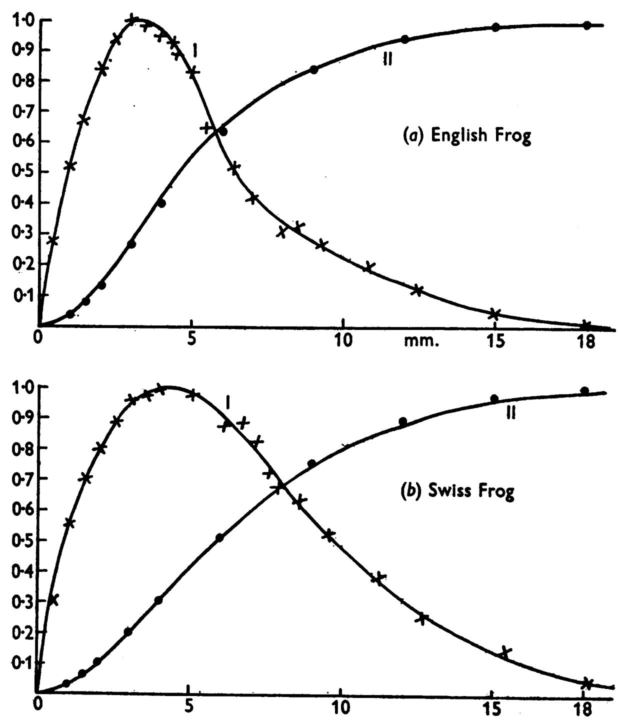

Fig. 3. I is the slot excitability curve drawn freehand through the experimental points (crosses). II is the integral of I, and the dots are the symmetrical tripolar excitabilities. All the curves are scaled to the same maximum ordinate. (*a*) Small English frog; (*b*) large Swiss frog.

By combining these two analyses, therefore, the slot excitability curve can be obtained in its entirety, and the method is not only rather accurate, but also admits of exact comparison with the single-pole excitability curve.

RESULTS

Figs. 3(*a*) and (*b*) show results obtained from the sciatic nerves of English and Swiss frogs respectively (*Rana temporaria*). The slot excitability results are shown by crosses, and curve I has been drawn freehand through them. Curve II is its calculated integral scaled to a maximum value unity. The experimental points on the symmetrical tripolar curve which is the single-pole excitability curve inverted (dots) are also scaled to a maximum of unity.

The good agreement between curve II and the dots substantiates the expectation that the slot excitability is minus the differential of the single-pole excitability.

SUMMARY

1. A method is described for determining the slot excitability curve in the same apparatus as the single-pole excitability curve.

2. The spatial distribution of excitability about a slot is shown to be minus the differential of the spatial distribution of excitability about a single pole.

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