VARIATIONS IN THE POLARIZATION CAPACITY AND RESISTANCE OF THE SKIN*

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The name 'psychogalvanic reflex' was given by Veraguth (1907) to certain electrical changes in the skin, although it had been noticed previously and had been studied by a number of investigators. Tarchanoff (1890) measured the bioelectric current of the skin but Fere (1888) and most workers have measured the electric resistance. In the opinion of the authors these two phenomena depend upon the same variables in the cells. Bio-electric currents and electric conductivity of cells in general both depend on certain variables in the cell surface and, although the chemistry of the process is not known, interesting electrical measurements on conductivity have been made by Fricke, Cole and others. It has been shown by experiments of Höber, Philippson, Fricke, McClendon, and others, that ions are free to move in the interior of the cell. With all possible assumptions of dielectric constant, it has been shown by Fricke and others that the impermeable layer is very thin on the surface of some resting cells; in fact, it is not greater in thickness than the length of a fatty-acid molecule.

It is a question whether the whole skin is involved in the 'psychogalvanic reflex' or only the sweat-glands. The blood vessels have very little to do with the apparent resistance change of the psychogalvanic reflex. The blood corpuscles are highly resistant but the blood plasma is of such low resistance that the whole blood has only moderate resistance. It is necessary to have a layer of cells packed so closely that very few ions can pass between them in order to have a

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very highly resistant structure, like the skin. The resistant layer is
the Malpighian layer which extends over the surface of the dermis and
is reflected inward to form the sweat-glands. According to Ebbecke
the general Malpighian layer can be stimulated only by local irritants
and not through these sympathetic nerves, so that (by exclusion)
the sweat-glands must be the seat of the “psychogalvanic phenomena.”
It has been shown by Leva that the ‘‘psychogalvanic reflex’’ is dis-

\[ \text{TABLE 1} \]

\textit{Change in Polarization Capacity and Resistance (C and r) of the Skin of the Fingers}
While the Ohmic Resistance of the Fingers Remained Constant at 900
Ohms

<table>
<thead>
<tr>
<th>Time in minutes</th>
<th>C (\mu F)</th>
<th>r (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0348</td>
<td>9,900</td>
</tr>
<tr>
<td>1</td>
<td>0.0350</td>
<td>9,900</td>
</tr>
<tr>
<td>2</td>
<td>0.0348</td>
<td>9,900</td>
</tr>
<tr>
<td>3</td>
<td>0.0348</td>
<td>9,950</td>
</tr>
<tr>
<td>4</td>
<td>0.0349</td>
<td>10,000</td>
</tr>
<tr>
<td>5</td>
<td>0.0352</td>
<td>10,000</td>
</tr>
<tr>
<td>6</td>
<td>0.0345</td>
<td>10,000</td>
</tr>
<tr>
<td>7</td>
<td>0.0340</td>
<td>10,000</td>
</tr>
<tr>
<td>7.5</td>
<td>stimulus applied</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0349</td>
<td>10,000</td>
</tr>
<tr>
<td>9</td>
<td>0.0355</td>
<td>8,750</td>
</tr>
<tr>
<td>10</td>
<td>0.0357</td>
<td>8,850</td>
</tr>
<tr>
<td>11</td>
<td>0.0356</td>
<td>8,950</td>
</tr>
<tr>
<td>12</td>
<td>0.0356</td>
<td>9,100</td>
</tr>
<tr>
<td>13</td>
<td>0.0355</td>
<td>9,150</td>
</tr>
<tr>
<td>14</td>
<td>0.0352</td>
<td>9,200</td>
</tr>
<tr>
<td>15</td>
<td>0.0352</td>
<td>9,200</td>
</tr>
</tbody>
</table>

tributed in different parts of the skin in a manner similar to the
sweat-glands (Figs. 1 and 2).

Gildemeister (1913) demonstrated that the psychogalvanic reflex
is due rather to a decrease in the counter electromotive force of polar-
ization than to a decrease in the true “ohmic” resistance of the skin.
In a later paper (Gildemeister (1922)) he gave the relation between
this counter electromotive force and the corresponding polarization
capacity.

In order to measure true ohmic resistances and polarization capaci-
ties, we have built a Wheatstone bridge of equal ratio arms which, we believe, is superior to any bridge previously used for high-frequency electric currents. When a high-frequency electric current is passed through the cell the plasma membrane offers very little impedance to the current. More than 99 per cent of the impedance is the true ohmic resistance of the cell interior.
Fig. 3. Graph showing the variation in the current with an applied potential of 6 volts across the fingers, which are coated over in one case with vaseline and in another case with collodion. During a 10 minute period vaseline shows a very high resistance, that is to say, allows only 4 micro-amperes of current to pass.

Fig. 4. Circuit diagram showing the electrodes with the fingers immersed in them. (In the drawing the electrode vessels are made much too small for the fingers.) The electrodes are connected on the one end to a direct current circuit, including a galvanometer (indicated by the circle with the arrow) and the choke coil (indicated by the spiral) for preventing a high-frequency current from entering the direct current circuit. The electrodes are also connected to the high-frequency Wheatstone bridge operated with a high-frequency current through a 1 microfarad condenser to prevent the direct current from entering the high-frequency circuit.
The marking off of a constant area of the skin had been done by Densham and Wells by painting with collodion. Our results show (see Fig. 3) that this is a very poor method and probably accounts for the erroneous conclusions of Densham and Wells that the change in impedance is due to stretching following vaso-constriction. Collodion is permeable to the electric current, as shown by the measurements plotted in Fig. 3, and its resistance is changed by stretching. Stretching not only changes its thickness but tends to lift it up from the skin or cracks it. The addition of castor oil (added to make collodion pliable) does not abolish these changes. Densham and Wells assume that stretching the skin changes its resistance but this change is evidently due to stretching the collodion and not the skin since we found that if vaseline is used to mark out the area of the skin, these effects disappear.

Experiments.—Two fingers of the same hand, except the terminal joints, are coated with vaseline and immersed in separate electrode vessels, shown in Fig. 4. The 1 per cent NaCl solution in the electrode vessels is kept at approximately constant temperature. The electrode vessels are connected with the bridge. The arrangement shown in Fig. 4 was used for simultaneous measurements of the apparent direct-current-resistance and the resistance to an alternating current of a million cycles. The average of the results shows that when the apparent resistance to direct current changed 13.7 per cent during the reflex, the resistance to a million cycle current changed 0.93 per cent. For practical purposes then, we may assume that the high-frequency resistance does not change during the reflex. The d.c. apparatus is then removed, the electrodes remaining connected to the bridge and measurements made in quick succession by means of the high-frequency current and then by a current of 1000 cycles per second. By means of the high-frequency current the “ohmic” resistance of the body R is determined and its value in the balancing arm of the bridge then fixed, and after substituting a 1000 cycle current a resistance r and parallel capacity C are connected in series with R and the bridge balanced again. In one case for example, R was 900 ohms and C and r remained almost constant for 8 minutes. After 7½ minutes a stimulus was applied to the other hand by means of an induction coil. After a half minute latent period there was a very sudden drop in r from 10,000 ohms to 8800 ohms. At the same time there was an apparent increase in C from about 0.035 microfarad (µF) to 0.0357 microfarad.

Repetitions of these experiments on a number of persons gave similar results.
Polarization Capacity and Resistance of Skin

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