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## GSR and Polarization Capacity of the Skin

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# GSR and Polarization Capacity of the Skin[1]

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## Abstract

By applying a square voltage pulse across GSR electrodes and observing the voltage waveform across a small series resistance, the conductivity of skin may be seen to decrease by some 80 percent during the first 300 microseconds to its steady-state or DC value. At the end of the applied voltage pulse, a polarization voltage may be observed across the skin, equal to about 80 percent of the applied voltage and opposite in polarity. During the GSR, this polarization voltage decreases with a corresponding increase in steady-state conductance, whereas the initial peak conductance does not change. This suggests that the GSR involves a change in polarization capacity of some structure(s) in the epidermis.

## Problem

When a voltage is applied across skin, the current flowing through the tissue falls exponentially to about one-fifth of its initial peak value during the first 100 to 300 microseconds, as illustrated in Fig. 1. When the applied voltage is removed, a back e.m.f. or polarization voltage may be observed across the cutaneous membrane, equal to perhaps four-fifths of the external voltage previously applied.

This behavior may be explained thus: The unpolarized cutaneous membrane has a certain minimum ohmic resistance determined by the size and density of its pores and by the size and concentration of ionic charge carriers. But the cutaneous membrane adsorbs anions which become fixed negative charges in or near the pores of the membrane (Sollner, 1955). The "counter ions" of these fixed wall charges, small cations paired to the fixed anions by electrostatic attraction, have some freedom of movement through the pores of the membrane in either direction. An external voltage applied across the membrane causes these counter ions to move through the pores in the direction of the negative pole until backward attraction toward the fixed wall charges prevents further movement, producing an ionic double-layer which acts as a battery in a series-oppositition to the applied voltage. Therefore, during the 100 to 300 microseconds required for this ionic reorientation to take place, current through the membrane falls from the maximum value, equal to the applied voltage, E, divided by the ohmic component of membrane resistance, $R_{min}$, to a minimum or steady state (DC) value which is well enough approximated by subtracting the back e.m.f. of polarization from the applied voltage and dividing this residual effective voltage by the membrane resistance, $R_{min}$.

When the GSR is measured as a transitory decrease in impedance of the skin to an alternating current, this impedance GSR gradually disappears as the frequency of the applied AC rises above about 10,000 cps. This was observed by McClendon and Hemingway in 1930 and again by Forbes and Landis in 1935 and interpreted by these authors to indicate that the GSR consists of a momentary decrease in the polarization capacity of the tissue, having the effect of increasing the residual potential across the tissue and thus decreasing the apparent resistance. If one accepts the polarization hypothesis, then one expects that the limiting value of the AC impedance of the skin as frequency increases will be the ohmic resistance, $R_{min}$; hence, on this hypothesis, the failure to observe the GSR at high frequencies is a fairly compelling proof that the GSR does <u>not</u> involve a change in ohmic resistance, e.g., that the GSR is not a mere increase in the number of current paths due to increased sweat gland activity, nor an increase in the permiability of some interposed membrane.

However, the polarization hypothesis has not been universally accepted and, in particular, some authors attribute to the skin a considerable literal capacitance, similar to the capacitance across the cell membrane, and regard the decrease in skin impedance with increasing frequency as primarily due to the change in capacitative reactance. If that were the case, then the GSR might indeed be a decrease in ohmic resistance which simply cannot be observed at high frequencies due to the much larger shunting effect of skin capacitance.

The present experiment tests the polarization hypothesis in a more analytic fashion by observing the change in current through the skin during the application of a square pulse of (constant) voltage across the skin.

## Method

Three zinc electrodes (Lykken, 1959) on the palmar surface of the distal phalanges of three fingers of one hand were connected together to serve as the active electrode, giving a total area of about 2 $cm^2$. The reference was another zinc electrode over a drilled site on the forearm (Schackel, 1959). The electrolyte was a 0.07 molar solution of $ZnSO_4$ in a neutral ointment cream (Unibase). The subject was wired in series with a 1000 ohm signal resister and a 100 ohm stimulus resister. The latter was connected across the cutput of an AEL 104A stimulator set to provide a 15 mSec, 0.5 volt square pulse once very 100 mSec. One channel of a Tektronix 502 dual-beam oscilloscope monitored the stimulus voltage across the subject while the second channel was connected across the 1000 ohm signal resister to read the current through the tissue. The total series resistance being small relative to the resistance of the subject, the voltage waveform across the skin remained square and constant in spite of momentary or gradual changes in skin impedance.

The current waveform shown on the left in Fig. 2 was obtained while the subject was at rest just before stimulation to produce GSR. The waveform on the right was obtained about five seconds after stimulation, during the GSR. It may be seen that the effect of the GSR is to increase the steady-state or DC level of current flow and to decrease the back e.m.f. of polarization, measured by the negative-going spike on the right of each current waveform. The positive-going spike on the left of each waveform does not appear to change.

## Discussion

The experiment indicates that the size of the back e.m.f. produced by the tissue decreases during the GSR (from about 60 mV to 54 mV in this instance), giving the appearance of a decrease in apparent resistance (from about 30 K-ohms to 21 K-ohms in this instance). If there is any change in the ohmic component of resistance, as measured by the positive-going spike, it is too small relative to the change in back e.m.f. to be detectable by this method; therefore, changes in resistance of the tissue on either side of the membrane or in the ohmic resistance of the membrane itself are apparently much less important than the change in polarization capacity of the membrane in producing the GSR.

The cause of this change in polarization capacity is obscure. According to the model outlined above, polarization capacity of a membrane is a function of the membrane's ability to adsorb some species of ion, thus anchoring one end of some quantity of ionic dipoles the density of which, per unit area of membrane, will dtermine the maximum polarization voltage of which the membrane is capable. If the externally applied field is too strong, the fixed ions may be torn from the membrane, lowering its polarization capacity and thus decreasing its apparent electrical resistance. It would appear that the sudomotor impulse produces the GSR by somehow reducing momentarily the ion-adsorbing characteristics of the amphoteric protein lining of the sweat duct walls.

## References

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## Figure Legends

Fig. 1. Oscilloscope trace of current through the skin when a 0.5 volt square voltage pulse of 1.0 mSec duration is impressed across the tissue. Horizontal time axis is 0.5 mSec per large division, vertical current axis is 10 microamps per large division. Initial or ohmic resistance is about 10 K-ohms, steady-state or DC resistance is about 50 K-ohms and the back e.m.f. of polarization (producing the terminal, negative current spike) is about 40 mV.

Fig. 2. Current waveforms through the skin before (left) and during (right) a GSR. Voltage applied was a 0.5 volt, 15 mSec square pulse. Ohmic resistance (measured by dividing initial current spike into 0.5 volts applied) is about 7 K-ohms both before and during GSR. Steady-state or DC resistance (measured by dividing steady-state current into 0.5 volts applied) is about 30 K-ohms before and about 21 K-ohms during the GSR. Back e.m.f. of polariaation (measured by length of negative current spike, appearing after termination of applied voltage square-wave) is about 60 mV before and 54 mV during the GSR.