FORMS OF BEHAVIOUR OF THE ELECTRICAL RESISTANCE OF THE SKIN RELATED TO CERTAIN PSYCHIATRIC AND ENDOCRINE CONDITIONS.

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This paper is devoted to investigations into the resistance of the skin to a direct current, measured daily in normal and mental subjects. These investigations arose out of special studies in the endocrinology of mental disease, and revealed some correlation between the diurnal resistance and endocrine functioning.

The resistance of the body to the passage of a direct current is not a true resistance, being a complex phenomenon in which ohmic resistance and polarization are concerned. It has usually been referred to by other workers as the DC resistance of the skin, and has been expressed in ohms when measured with the type of apparatus used in this study. With apparatus of this sort, various workers have reported fluctuations. In this paper, although fluctuations are referred to as changes in diurnal resistance, they are in reality an effect, and not in the strict sense a resistance change. It is with the alterations in this effect in a variety of psychiatric and endocrine conditions that this paper is concerned.

An extensive literature on the subject of skin resistance and especially of the psychogalvanic reflex, some of which will be referred to later, now exists ; much of it is so conjectural and contradictory that it is difficult to approach the whole problem without some prejudice. Technical erors in making successive measurements of skin resistance can be large, and method alone may account for discrepancies in results. Non-fluid electrodes pressed to the skin are quite unreliable for comparing day-to-day readings, and electrodes for recording the resistance from small areas of the body exaggerate the importance of polarization in the apparatus and of other technical errors. Some workers have taken readings from individual fingers or even finger tips, regardless of the fact that the skin of the fingers is often the most traumatized part of the body, liable to contain scar tissue and subject to circulatory abnormalities.

These facts were borne in mind in arriving at a technique designed to give uniform conditions and fair accuracy in making many successive measurements on a large series of subjects.

Method.

The apparatus consisted of a Wheatstone bridge and galvanometer circuit, the patient forming the fourth arm of the bridge. The resistance was recorded through the patient's hands by balancing the bridge with alterations in the resistance of the variable arm. The electrodes were circular plates of zinc, 9 in. in diameter, placed in the bottom of glass pots 8 in. deep, containing normal saline ; the saline was changed frequently, and the electrodes and pots were scrubbed at the same time. A reversing switch was incorporated in the leads of the 2-volt accumulator which supplied the current, so that readings with the current flowing in each direction could be made. The saline was kept at room temperature. The resistance was read as soon as the galvanometer needle was steady, care being taken that the current should flow for as short a time as possible, and was recorded as the average of the two readings, thus modifying operational error.

In view of possible psycho-galvanic fluctuations, and the influence of temperature, sweating, and grease on the skin, all subjects washed their hands in soap and tepid water, dried them without rubbing, and sat for at least 15 minutes in a warm room before being examined. The majority of subjects, being patients of the hospital, took a standard diet and led a fairly uniform type of existence. For the examination, the subject sat with the hands immersed in saline up to the level of the carpal joint, establishing contact with the zinc electrodes only through the saline. The examinations were made in a small warm room insulated from noise and distractions. The effect of hand washing was found to be negligible, and it was therefore not enforced in the later measurements.

This apparatus and technique were designedly rather insensitive, and recorded changes of about 2½ per cent.; in general, operational error was probably not greater than 250 ohms. In one subject, three successive hourly readings gave 1,900 ohms exactly, and in steady subjects the diurnal variation for a week or more was sometimes less than 50 ohms per day. For recording values above 10,000 ohms the ratio of the arms of the bridge was altered. If, as seems likely, much of the resistance change is due to changes in E.M.F., the values recorded with arms of unequal ratio may exaggerate the magnitude of the fluctuations above 10,000 ohms (W. Grey Walter, 1942). Most of the records have been studied graphically on a scale that disregards differences of less than 250 ohms. In discussing results little importance will be attached to changes of less than 50 per cent. where the lower reading is 2,000 ohms or less, or 2,000 ohms where the general level is higher. In this way the variations of 20 or 30 per cent. described by various workers as following some experimental measures need not be considered, as they are of a different magnitude from the phenomena now investigated.

Case Material.

With the method described, a number of diurnal measurements were made on a number of subjects of both sexes (mostly mental patients, with some normals, excluding epileptics). It was noticed that in some subjects there was little difference between the daily resistance readings, but in others wide variations were observed.

It was thought at first that the curves of daily variations in different subjects might be compared, but that individual factors such as the size of the hand would forbid any useful comparison between the actual resistance value of one subject and another. This was not so; the majority of one group of female subjects and males of the same group were below a certain level, the average resistance of the males being somewhat lower than that of the females. Much higher resistances were only observed in special cases and under special conditions.

From the first survey, 21 females and 7 males were selected for special and more prolonged study. This material was chosen so as to include examples whose diurnal resistance was steady or showed extreme or moderate fluctuations respectively. It also covered certain endocrinological types as well as normals.

The diurnal resistance was measured in most subjects for more than 90 days, this period being chosen so as to include three menstrual cycles. (Several subjects were absent occasionally for various reasons not connected with the investigations, such as leave from hospital, influenza, etc.). It was then seen that the diurnal resistance behaviour seemed to fall into certain groups, namely: Group I—subjects in whom there was little significant variation; Group II—those in whom there was a moderate and somewhat cyclical variation; and Group III—those in whom the resistance fluctuated irregularly between wider extremes. Fig. 1 shows examples of each group. In resistance-steady subjects, the average daily resistance was in the range 1,200 to 3,500 ohms, approximating to 2,000 in males and 2,500 in females.

The following problems had therefore to be considered: The site of the fluctuations in D.C. resistance, the local or general physiological factors responsible, and whether variations in D.C. resistance could be determined by endocrine activity, or linked with special psychiatric conditions. Experimental measures were devised to throw some light on these questions. Many of them cannot be answered completely, and investigations are still proceeding along certain lines. In view of the many aspects of the subject, it was thought advisable to record these early findings, especially as some of them have not been described before and are not in complete agreement with opinions expressed by others.

The Site of the Fluctuations in D.C. Resistance.

Various workers have suggested that the D.C. resistance is a property of the skin. Lewis and Zotterman (1927), using very small electrodes, have shown that 80 per cent. of the D.C. resistance disappears if the epidermis is shaved off.

MacClendon (1927) and MacClendon and Hemingway (1930) have investigated the impedance, electrical properties of tissues to varying frequencies and changes in the polarization capacity and resistance of the skin. Their work, which bears chiefly on the psycho-galvanic reflex, shows that the skin resistance to a current of very high frequency undergoes little change during the reflex. Although it throws little light on the problem of diurnal variations in D.C. resistance, it suggests that D.C.

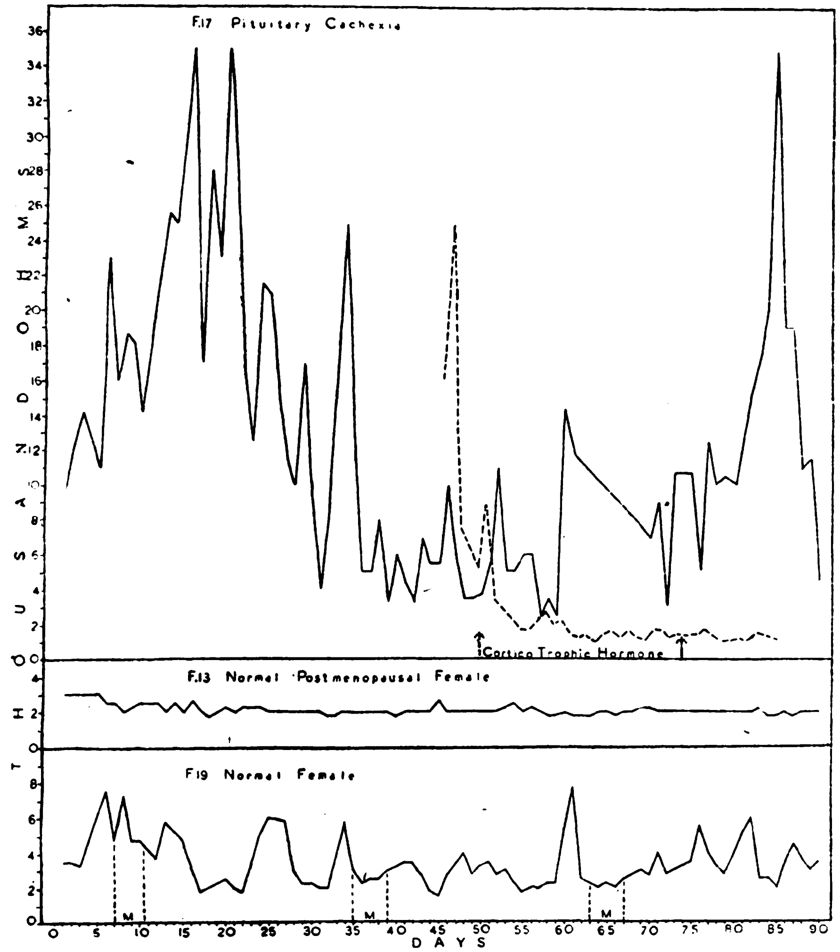

FIG. 1.—The fluctuation in resistance measured daily in a normal female, F. 19, a normal post-menopausal female, F. 13, a case of pituitary cachexia, F. 17 ; illustrating Groups II, I, and III respectively. The dotted line indicates the effect of corticotrophic hormone as shown in Fig. 4 and has been superimposed to demonstrate the scale of resistance changes. In point of time the resistance curve of F. 17 recorded by the dotted line follows some time after day 90. The curve for F. 13 is similar to curves recorded in male subjects, and in non-menstruating females. Menstrual periods indicated by M.

resistance is almost entirely a polarization phenomenon of the skin—a theory confirmed by Gildemeister (1928), who has worked out the relevant physics. If variations in D.C. resistance are due to polarization, they depend upon changes in the skin, as is generally believed.

Measurements of the resistance to D.C. and to A.C. of 500, 1,000, 10,000, 15,000 cycles per second were made each morning for more than two weeks, on all patients of the selected series. The results of some of these measurements are seen in Fig. 2.

It was found that at 15,000 and 10,000 cycles per second the skin resistance was identical each day, at 1,000 and 500 cycles per second somewhat higher and nearly equal, and that all the A.C. resistances were within the range of 500 to 1,000 ohms. There was little diurnal variation in the A.C. resistance, never more than 30 per cent., and no correspondence between these A.C. variations and the extremely wide fluctuations noted in some of the D.C. measurements. Diurnal fluctuations in A.C. resistance occurred in patients irrespective of whether the D.C. resistance was steady or variable.

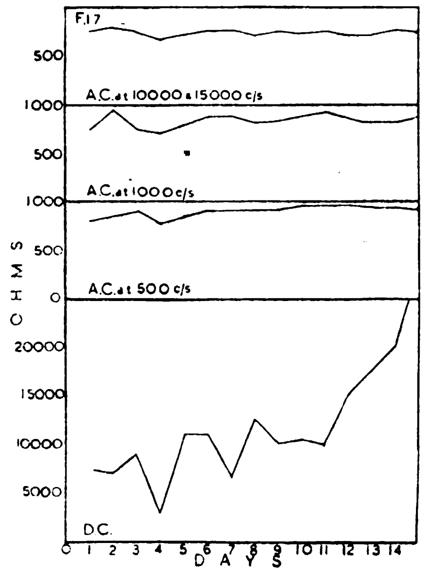

FIG. 2.—Variations in resistance to DC and to AC at 500, 1,000, 10,000, 15,000 c/s, measured daily in F. 17.

The impedance angle (Brazier, 1933) was also measured ; on the whole its diurnal variations were slight and did not correspond with the D.C. changes. (The apparatus used for this special investigation consisted of an oscillator and capacity bridge, kindly lent by Mr. Grey Walter.)

This experiment shows that significant diurnal variations in resistance are confined to measurements with a direct current, and that as polarization effects are not much apparent at frequencies above 1,000 cycles per second, the D.C. resistance variations are largely due to polarization, which is generally held to be a skin phenomenon. The steadiness of the impedance angle, which is considered to be related to the body as a whole, tends to confirm this suggestion. The electrophysical problems will not be discussed further.

It can be stated therefore that the phenomenon under investigation is due to some property of the skin, subject to diurnal variation of different degree and type in different individuals, which for convenience have been recorded and represented graphically as changes in ohmic resistance.

Conditions Responsible for Variations in the D.C. Resistance of the Skin.

Much of the evidence on the nature of D.C. skin resistance is derived from two lines of approach, namely, the physiological changes that accompany or influence the psycho-galvanic reflex, and the use of measures to produce local changes in the skin. It is clear that many factors, such as dampness of skin, sweating, or vasoconstriction, operating singly or together, may have the same effect on the resistance, and antagonistic processes may act at the same time. Much confusion

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is derived from inferring that the physiological accompaniments of the psychogalvanic response are the same factors that control the resistance under non-experimental conditions.

Although many aspects of electrical phenomena of the skin have been reviewed by Landis (1932), it is advisable to refer here to some of the work of others. Féré (1888) described the psychogalvanic response. Vigouroux (1888) thought that the reflex changes in resistance were due to vasomotor activity. Gildemeister (1923) showed that the reflex could be elicited from parts of the entire body surface. Veraguth (1906) concluded that the psychogalvanic response was due to sweating, as devascularization of the limb failed to abolish it—a theory opposed by Aveling and McDowall (1933). Many other workers have tried to prove that the skin resistance and psycho-galvanic response depend upon vasomotor disturbances or sweat secretion.

Aveling and McDowall (1925), working on cats with padded electrodes bandaged to the feet, demonstrated that haemorrhage, the action of histamine, and externally applied cold, produced a fall in resistance; venous engorgement leading to vaso-dilatation caused a rise.

Wells (1928), attaching the electrodes to the fingers of the subjects, confirmed these findings. He stated that acapnia, by lowering the tone of the vasomotor centre, caused a fall of 20 or 30 per cent.; raising the venous pressure to cause vaso-dilatation produced a marked rise.

Densham and Wells (1928), in a series of rather inconclusive experiments, tried to show that fixation of skin vessels by freezing and adrenalin caused a drop in the skin resistance. Darrow (1929) stated that any relationship between vaso-constriction and skin resistance was fortuitous. Wang and Richter (1928) demonstrated a resistance drop on stimulation of the tuber cinereum of the cat, and showed that spontaneous E.M.F. changes in the foot-pads disappeared on section of the sympathetic, while stimulation of the cut end of the sympathetic produced galvanic response.

Carmichael *et al.* (1941) attributed the changes in skin resistance following stimulation to vasomotor disturbances or sweating or both, being the result of activity of the autonomic system. Waller (1919) has recorded that spontaneous changes in the D.C. resistance value of the skin occur throughout the 24 hours, corresponding to the waxing and waning of the temperature. Wells (1928) stated that local heat applied to the skin increased the conductivity and lowered the resistance, local cold having the opposite effect. He thought that any condition tending to reduce body heat caused vaso-constriction with a fall in the resistance, conditions tending to increase body heat having the reverse effect.

The investigations of Richter (1927) showed that the psycho-galvanic reflex was absent on the side of a hemi-sympathetic lesion, and yet obtainable in Gilchrist's case of histologically verified absence of sweat glands. Sympathectomy can cause an increase in the resistance of the skin of the hands. Richter and Levine (1937), Densham and Wells (1927), confirming the findings of Lewis and Zottermann that the greater part of skin resistance lay in the epidermis, were forced to conclude that if, as they thought, changes in the skin resistance are invariably accompanied by corresponding changes in the lumen of vessels of the corium, the changes in the bore of these vessels must influence the epidermis mechanically by causing an increase in the vertical tension and alteration in conductivity. This rather simple explanation can hardly fit all the possibilities, as Strohl (1931) has shown, by building elaborate circuits to illustrate the electrical properties of the skin, eliminating many possible variables that can operate simultaneously. Golla (1922) investigated the psychogalvanic reflex and skin resistance in a large number of normal and neurotic subjects, and found considerable individual variation.

Recent work by Goadby and Goadby (1936), using photographic methods of recording, showed that the current flowing in the psychogalvanic reflex due to the resistance drop and the E.M.F. differed.

Exsanguination abolishes the resistance reaction but leaves the E.M.F. unchanged. Hyperaemia, by heating the limb, reduces the basic resistance but does not alter the skin potential.

To recapitulate, the work of others suggests that there is some change in D.C. skin resistance during the day, perhaps corresponding with the body temperature, and that active sweating or vaso-constriction can produce a fall, vaso-dilatation a rise, of resistance.

Measures to bring about these changes are supposedly followed by corresponding changes in skin resistance; the most consistent experimentally-produced drop is seen in the psychogalvanic reflex, probably through the activity of the autonomic nervous system.

It will be noted that little account has been taken of sex difference and individual variations, normal or abnormal, of the order described here.

It was necessary at the outset to determine to what extent the diurnal resistance depended upon the above-mentioned generally accepted physiological processes. Many of the subjects were therefore submitted to some of the experimental procedures that have been employed to influence the D.C. skin resistance.

Hourly Variations.

Assuming that all subjects showed considerable hour-to-hour variations, it was possible that the wider difference between some morning readings merely indicated that the hourly resistance cycle was not regular, and that all the diurnal changes might be represented in the course of 24 hours. Accordingly, the DC resistance of all subjects in Group III, and some in Groups I and II, was measured hourly for 24 hours. These readings in mental subjects showed that the above possibility is not the case. In some subjects there was a total fluctuation of less than 20 per cent. or less than 400 ohms, in others of 200 per cent. or 6,000 ohms. No subject showed the extremes that were seen in some of the diurnal readings. One subject (F. 16), whose diurnal readings were usually high, ranged between the extremes of 1,400 and 2,500 ohms. Another subject (F. 21), usually steady, remained at about 1,900 ohms, not varying by 10 per cent. throughout the 24 hours. In most subjects the curve for the whole day had certain general features. There was a fairly abrupt fall in the forenoon, a low level maintained until early evening, a more or less steady rise reaching a peak at about 4 a.m., with a fall and rise once more towards later morning. In Group III the morning readings, as might be expected, were considerably different from readings taken at the same time 24 hours previously.

The only correspondence with the temperature—and this appears to be unimportant—was that the highest reading in the early morning sometimes synchronized with the lowest temperature. Probably the changes in the hourly curve are related to activity of the autonomic nervous system, and diminished control of temperature regulation with vaso-dilatation of skin vessels during later sleep accounts for the higher readings in the early morning hours. Degrees of sensitivity of the autonomic system possibly explain to a great extent the different behaviour of the hourly DC skin resistance between individuals. It may be concluded, therefore, that the wider range of diurnal variations in this series is not represented in measurements taken in the course of the day, and therefore not solely dependent on the hourly fluctuation of temperature and the associated vaso-motor and normal metabolic processes. The statement of Waller (1919) *et al.* that body temperature can be correlated with DC skin resistance found no confirmation in this series of measurements.

DC Resistance in Pyrexia.

Two women in the fifth decade with early syphilitic disease of the brain were treated with induced malaria. Their diurnal resistance was measured on several occasions and found to range between 2,000 and 6,000 ohms. Measurements were also made hourly during 24 hours, when the temperature was not abnormally elevated, and also at half-hourly intervals as the temperature was rising and falling during the course of malarial rigors. The physiological events during the malarial rigor are probably as follows: Constriction of superficial vessels reducing heat loss, rise of body temperature with continued constriction of skin vessels, then relaxation of cutaneous vessels, fall of temperature, and—when the paralysis of sweat glands has passed off—sweating (Wright, 1940). It might have been reasonable to expect the skin resistance to remain low during the period of vaso-constriction, high during vaso-dilatation, and somewhat lower when the sweating had occurred.

The behaviour of the skin resistance was not the same for each malarial rigor. The ranges attained were not extreme and did not correspond with the temperature.

Sometimes the resistance rose steadily just before, during, and after the rigor, until the temperature had reached its peak, remained raised while the temperature was falling, and at the onset of sweating fell quickly. Fig. 3 illustrates resistance changes during one malarial rigor in one subject. Exactly similar curves of resistance variation were not obtained for other rigors in the same subject, nor for pyrexial attacks in the second subject.

The ranges of DC resistance observed during the extremes of malarial rigors were not often markedly outside the range for a normal day in the same subject.

This experiment suggests that extreme changes in body temperature, with associated vasomotor activity and sweating, can influence the DC resistance of the skin to a limited extent only. It indicates that there are other determining factors which may be of equal or greater importance. Keutmann *et al.* (1939), investigating the electrolyte balance and water loss through the skin in artificial fever, have found that after several pyrexial attacks, up to 22 per cent. of the extra-cellular water present at the beginning of treatment might be lost. Water lost in this way may be responsible for the lack of any consistent correspondence between the temperature and resistance curves.

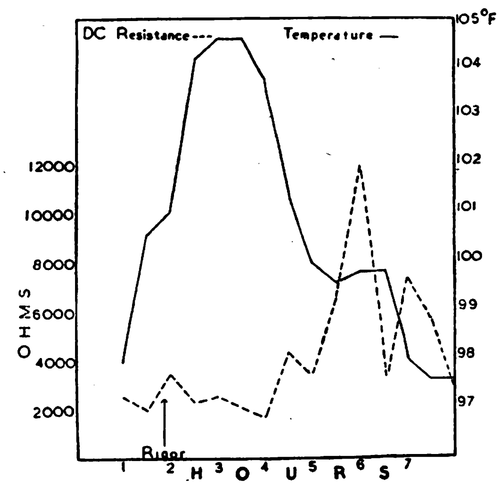

FIG. 3.—Variations in DC resistance during rise and fall of temperature in a malarial attack, measured ½-hourly. Resistance ...... Temperature ———

The Effect of Sweating.

Sweating was induced experimentally on the subjects and the author, by injection of pilocarpine ⅛ gr. The resistance was measured at 10 minutes' intervals for an hour. Corrections for the psycho-galvanic response to the needle prick were made individually in all injection experiments. Some small drop in resistance was observed in all subjects. The maximum was 700 ohms—15 per cent., the average being about 10 per cent. One subject (the author), after violent and repeated exercise, was immersed in a hot bath at 105° F. for 20 minutes to induce sweating; the resistance was measured, and found to have fallen from 3,400 to 1,600. The effect of sweating was probably offset somewhat by peripheral vaso-dilatation. After plunging into a cold bath to inhibit sweating, the resistance rose to 3,200.

On another occasion active sweating was induced by the hot bath and exercise in the same subject, the resistance then being 2,400. Sweating was inhibited by drinking three pints of cold water. Vaso-dilatation still continued. The resistance was found to have risen to 3,000 ohms.

Measurements were made on the author and another male before and after exposure to dry heat in a Turkish bath for 45 minutes. The temperatures in the various rooms were 180°, 220°, 250°. Profuse sweating was induced and in each case the resistance had fallen by about 50 per cent. After "cooling off" when

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sweating had ceased the resistance had risen to a little less than the original figure. The actual figures were :

Before	2,800	2,500
Immediately after	1,400	1,300
After cooling	2,600	2,400

In these experiments the effect of sweating was compensated to some extent by vaso-dilatation. They show, however, that under fairly extreme experimental conditions, the skin resistance in active sweating was reduced by only 50 per cent. of 3,400 ohms, and that inhibition of sweating led to an increase of no more than 25 to 50 per cent.

Atropine, gr. $\frac{1}{50}$, injected to inhibit sweating, showed no consistent results, perhaps due to its vaso-dilating property. In some subjects there was an unimportant rise or fall, in others there was no change.

Effect of Vaso-constriction.

Injection of pitressin 10 pressor units had no constant result. In the majority of subjects, during the first half-hour after injection the resistance dropped, but the drop exceeded 20 per cent. in one case only, the fall being from 5,200 to 1,800 ohms. In all subjects the resistance rose in the second half-hour.

In a male subject (the author), injection of 20 pressor units produced severe blanching of the skin with marked vaso-constriction confirmed by the skin microscope. It was followed by a fall of skin resistance from 2,500 to 2,000 in the first half-hour ; the resistance had risen to 2,700 ohms by the end of the second half-hour.

Intake of two litres of water did not effect any further change.

The Epileptic Fit.

The nature of vasomotor changes during and following an electrically-induced epileptic fit are not established with certainty. During the convulsion there is a rise in blood pressure and sometimes blanching of the skin. At some moment, following the clonic stage, sudden flushing of the skin usually occurs and precedes the return of active movements. The vasomotor disturbances are probably severe.

Skin resistance measurements were made on a number of non-epileptic patients just before the electrical induction of a fit, immediately clonic movements had ceased, and then almost continuously until active movement appeared. In general the results were the same. The first reading after the clonic stage was about 25 per cent. less than the original resistance, and was later increased by upward of 15 per cent. when flushing of the skin had occurred and active movements begun to appear.

Typical results : Before, 2,100 ; after, 1,600 ; later, 1,800.

Acapnia.

Acapnia pushed to the limit of co-operation possible in a number of patients had little effect. In the best normal subject it produced a fall in resistance of about 20 per cent. This agrees with the finding of Wells (1928).

Raynaud's Disease.

Measurements were made in one subject during and after an attack of Raynaud's disease involving the right hand. The attack was severe and rather typical, in which the fingers and hand were pale, cold, and " dead." The resistance read at intervals in the course of three days until the hand was normal again lay between 2,000 and 3,000 ohms, being 2,600 ohms at the height of the attack. These figures were within the customary range for this subject.

Local Heat and Cold.

Warming or cooling the hands by hot air or by immersion in hot or cold saline was without significant effect on the resistance level. In some subjects there was a slight rise or slight fall independent of the temperature. Here, once again, pure experimental conditions were impossible to obtain, vaso-dilatation being sometimes complicated by sweating.

State of Peripheral Vessels at Time of Measurement.

The peripheral vessels of some subjects were inspected by the skin microscope on several occasions both before and after measuring the resistance.

Although vascular adjustments could have taken place between the times of inspection and measuring, and the vascular reaction to the normal saline cannot be estimated, it is significant that no correlation between the state of the vessels and the diurnal resistance could be found. In F. 16 marked vaso-dilatation was observed when the resistance was 1,800 ohms; in F. 17 (subject to great changes) vaso-constriction was observed with resistances of 1,800 and 11,000 ohms.

Psycho-galvanic Reflex.

The psycho-galvanic reflex was studied several times in each subject with the apparatus described. The stimuli were: Pin-prick, pinching of skin of neck, threat of inflicting pain, pistol shot, and the noise of a bucket unexpectedly dropped behind the subject.

The resistance drop could not be expressed as a percentage, as it varied somewhat with the stimulus, nor was the response to the same stimulus of the same magnitude on different occasions. The maximum response is only obtained if the skin is warm and the peripheral vessels dilated (Carmichael *et al.*, 1941). The range of resistance drop was between 80 and 500 ohms, the relative drop being most marked when the initial resistance was low rather than high. It is of passing interest that the pistol shot had the smallest psycho-galvanic effect, perhaps because all the subjects were well habituated to gunfire and explosions.

Conclusions.

Variations in the DC skin resistance have been attributed by most workers to activity of the autonomic nervous system influencing sweating or producing vasomotor changes. Variation due to these causes can be produced experimentally and are usually no greater than 50 per cent., often no more than a few hundred ohms. Experiments have shown that these slight changes occurred physiologically in all subjects, but that they represent only the slight fluctuation in the "resistance-steady" cases, and are of a different order from the wider ranges described in some groups, where variations of several hundred per cent. were noted. Spontaneous variations were greater than any that occurred in extreme disturbances caused by malarial pyrexia, the dry heat bath or electrically-induced epileptic fits. Other processes must therefore be sought to account for the wider ranges.

Other Circumstances Influencing DC Skin Resistance.

It has been shown that there is a considerable loss of water through the skin apart from the activity of sweat glands, which can amount to 600–700 gm. per 24 hours (Schwenkenbacher, 1925), and forms the greater part of the insensible perspiration. The epidermis appears to act as a semi-permeable membrane, water leaving the skin as a vapour. Water lost in this way can preserve the heat balance between moderate extremes of temperature in congenital absence of sweat glands. Insensible perspiration is most profuse where the epidermis is thick and exposed to the air, as in the hands and feet (Kuno, 1934). If the epidermis provides the bulk of the resistance of the skin to a direct current, alterations in its water content might reasonably be expected to lead to great changes in the resistance.

Dehydration of the body was attempted on the author by fasting and withholding fluids for 24 hours. This period was preceded by exercise, hot baths, and repeated saline purgation. The skin resistance was measured hourly for 24 hours. The result was rather inconclusive and the hourly resistances were only slightly higher than usual in this or other male subjects; this was not surprising, as without prolonging these measures only a moderate dehydration could be expected. During the absorption of 2 litres of water, drunk immediately at the end of the water-free period, there was no significant change.

A further attempt to alter the water content of the epidermis was made in the following experiment: After reading the resistance in normal saline, the subject immersed the hands for five minutes in saturated salt solution, in order to attract water from the tissue spaces through the epidermis. The excess salt solution was washed off in normal saline and the resistance read again. The hands were then

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washed in water and after five minutes the resistance read once more; this cycle was repeated. It was found in every case that a considerable reduction in resistance followed immersion in saturated solution of salt, greatest when the original resistance was high. In every case the resistance fell to below 2,000 ohms. In some subjects the resistance rose to its first figure after washing, and fell again after immersion again in the saturated solution. A similar experiment was performed on a normal male and female subject, the whole body and limbs up to the neck, instead of the hands alone, being immersed in saturated salt solution at 99° F. Immersion was maintained for half an hour, followed later by immersion in plain water under similar conditions. The results were:

Female:	Before, 2,600.	After salt bath, 1,600.
		After water bath, 2,500.
Male:	Before, 2,500.	After salt bath, 1,800.
		After water bath, 2,600.

It seems probable that a concentration of water in the epidermis can be effected temporarily by movement of water from within towards a strong solution outside, or, under certain conditions, vice versa. Fluid might be retained in the skin by substances whose molecular structure gives them an affinity for water. If the epidermis already contains much water and the resistance is low, little further experimental reduction can be expected.

Although these experiments are inconclusive, it may be tentatively suggested that while vaso-constriction and sweating, vaso-dilatation and hydrosis are responsible for moderate changes in the skin resistance and for the psycho-galvanic phenomenon, the wider variations observed in some subjects are due to the retention or otherwise of water in the epidermis, the thickness of the epidermis possibly determining the individual basic resistance. This would account for the usually lower resistance of males, in whom the skin of the hands is often thick. The basic resistance does not seem to depend to any extent on the size of the hands, although —other things being equal—the larger the area of the skin in contact with the electrodes the lower the resistance. The volume of the hands of all subjects was measured and found not to correspond with the resistance. A female subject with almost the smallest hands had the lowest average resistance, while the male with the largest hands had consistently the lowest (F. 9, M. 5).

Group I. *Resistance: Steady.*

Case number.	Sex and age.	Psychiatric diagnosis.	Endocrine state.	Vaginal smears.	Resistance range (ohms).	Daily fluctuations.
M. 1	M. 65	Delusional	—	—	1,550–3,000	Slight.
M. 2	M. 50	Depression	—	—	1,600–2,800	,,
M. 3	M. 20	Schizophrenic in remission	—	—	1,400–2,000	,,
M. 4	M. 73	Early senile dementia	—	—	1,550–2,500	,,
M. 5	M. 36	Post-traumatic aphasia	—	—	1,000–1,500	,,
M. 6	M. 19	Early schizophrenia	—	—	1,300–2,000	,,
F. 1	F. 19	Catatonic schizophrenic	Amenorrhoea	R. II	1,650–2,900	,,
F. 2	F. 20	Catatonic schizophrenia in remission	Oligomenorrhoea	R. II	1,550–3,000	,,
F. 4	F. 18	Simple depression	Amenorrhoea	R. III	1,700–2,500	,,
F. 6	F. 24	Hysteria	,,	R. II	1,700–2,600	,,
F. 8	F. 29	Schizophrenia	Irregular menses	R. III	2,050–3,000	,,
F. 9	F. 46	Recurrent depression	Oligomenorrhoea; hyperthyroid	R. II	1,300–2,100	,,
F. 10	F. 52	Melancholia in remission	Post-climacteric	R. I	1,950–2,300	,,
F. 11	F. 50	Recurrent depression in remission	,,	R. I	2,000–3,000	,,
F. 12	F. 54	Melancholia	,,	R. II	2,100–3,200	,,
F. 13	F. 60	Delusional	,,	R. I	1,750–2,500	,,
F. 21	F. 55	Normal	,,	—	2,400–3,000	,,

Group II. *Resistance : Moderate Regular Variations.*

Case number.	Sex and age.	Psychiatric diagnosis.	Endocrine state.	Vaginal smears.	Resistance range (ohms).	Daily fluctuations.
F. 3	F. 21	Schizophrenia in remission	Amenorrhoea. Later menstruated	R. IV	2,050–4,900	Slight at first; after menses moderate
F. 5	F. 19	Simple depression	Normal menses	R. IV	2,400–5,000	Moderate
F. 19	F. 18	Normal	Normal	—	1,500–7,000	,,
F. 20	F. 19	,,	Normal ?	—	1,900–4,500	,,

Group III. *Resistance: Irregular Variations of Wide Range.*

Case number.	Sex and age.	Psychiatric diagnosis.	Endocrine state.	Vaginal smears.	Resistance range (ohms).	Daily fluctuations.
F. 7	F. 32	Hyperthyrotic catatonia	Amenorrhoea	R. III	1,900–10,000	Wide.
F. 14	F. 72	Recurrent melancholia	?	—	1,800–9,000	,,
F. 15	F. 52	Involutional melancholia	Hypo-pituitarism	R. II, ? III	1,800–10,400	,,
F. 16	F. 51	Ditto	Acromegaly	R. II, ? III	1,800–15,000	,,
F. 17	F. 42	Depression	Pituitary cachexia	R. II	1,100–35,000	,,
F. 18	F. 55	Involutional melancholia	Virilism; post-climacteric	R. I	2,000–12,500	,,
M. 7	M. 33	—	Pituitary eunuch	—	2,200–5,000	Up to 100%

Notes.—Vaginal smears : R. I indicates complete oestrogen deficiency ; R. II severe ; R. III moderate or slight ; R. IV normal smear. The figures quoted for the range of diurnal resistance are the extremes recorded at any time. "Slight" fluctuation indicates that irrespective of the extremes the day-to-day change was slight ; thus in F. 1, F. 2 and F. 13 the diurnal reading was usually 1,800 to 2,000 ohms, sometimes varying by not more than 50 for a week.

This suggestion that concentration of fluid in the epidermis determines to a large extent the DC resistance value agrees with the finding that 80 per cent. of the resistance of the skin is located in the epidermis.

Psychiatric Relationships.

As mentioned before, subjects could be classified according to the resistance behaviour, namely, whether diurnal resistance was steady or fluctuated moderately or widely. Males had, on the whole, a lower resistance than females and fluctuated little. The majority of the subjects being mental patients, it was possible to classify mental conditions and look for correlations between them and the type of resistance behaviour. The accompanying table indicates the nature and characteristics of the case material. It requires little comment. There is no significant correspondence.

All subjects were co-operative and did not represent extreme forms of their mental illnesses. It will be noted that the greatest irregularity occurred in four cases that could be described as involutional melancholia, and one unusual form of catatonia. Case 14 was examined daily for four weeks. Her mental state appeared to be normal. The diurnal reading fluctuated above 3,500 ohms. She became acutely depressed coincidentally to the day with a fall of resistance to 1,800 ohms. For the next fortnight the resistance remained below 2,500 ohms. The patient became extremely agitated and unco-operative, and died subsequently of bronchopneumonia.

The diurnal resistance was "steady" in most patients of the schizophrenic group where menses were not normal. This will be discussed in a subsequent section.

Richter (1928) and Syz and Kinder (1931) studied the diurnal resistance in mental illness. Their patients were not all examined daily. They have reported a high resistance in catatonic states, low in paranoia, and a higher reading than normal in depressions. Richter (1928), using paste electrodes, found that the diurnal resistance of normal subjects remained fairly steady. Odegaard (1930) reported decreased activity in dementia praecox. Westburg and Syz (1929), with rather unsystematic investigations, found decreased resistance in various mental types. More recent contributions have been made by Bingel (1940) and Barnett (1939). Barnett reported that, though impedance curves do not correspond with the clinical state, in some cases the impedance value is decreased in agitation, increased in retarded depression. He suggests that the low impedance in some mental cases is due to thinning of the epidermis from failure of growth hormone.

None of the reports of these workers differentiate between the sexes. Their statements find no confirmation in the results noted above, but viewed with these results they show that the skin resistance behaviour in normal and mental subjects is neither uniform nor identical in all individuals, and that no true correspondence between skin resistance and mental illness can be expected with the present system of psychiatric classification.

Endocrinological Relationships.

There seemed to be some correspondence between the diurnal resistance behaviour and endocrine activity. This was suggested by the groups into which the subjects fell.

(1) Inactivity or steadiness in diurnal reading was noted in male subjects, in young females who menstruated infrequently or not at all, and in post-menopausal subjects without special climacteric symptoms or evidences of endocrine dysbalance.

(2) Moderate cyclical activity was observed in the two subjects who menstruated normally, and to a less extent in two others.

(3) Most of the higher resistance readings and irregular fluctuations of greater amplitude occurred in four cases with menopausal disturbances, in one special type of hyperthyroidism, and in one case of agitated depression who died while investigations were still incomplete.

The table shows the distribution of resistance behaviour amongst the endocrine types.

It has been shown that the more extreme variations of resistance could not be produced experimentally, nor did they seem to be the result of simple or obvious physiological processes, and it has been suggested that they are an expression of endocrine activity. This possibility was examined by investigating certain endocrine functions in some of the patients, and by endeavouring to bring about endocrinological changes while the electrical resistance was under observation.

Menstruation.

When all the results were expressed graphically, the most outstanding and prominent finding was the flatness of the curves of males and of all the female subjects who did not menstruate, apart from those of Group III, where fluctuations were extreme. The diurnal variations of Group I were in many cases less than 50 ohms and could probably be accounted for by normal autonomic activity.

Thorn, Nelson and Thorn (1938) investigated the excretion of electrolytes and oedema connected with the menses. They showed that there is sodium retention at the inter- and pre-menstrual phases, but increased excretion at menstruation. Injection of various sex hormones produced sodium retention ; the most potent of this series was oestradiol.

The evidence is that fluctuation of the retention-excretion of sodium through the month parallels the production of oestrogenic hormone in the normal female, and in many cases may cause water retention sufficient to produce oedema of tissues. This increase of extra-cellular water may account for the moderate cyclical resistance behaviour of Group II. Absence of this rhythm, as probably occurs in males and in females with inactive ovarian function, may be associated with the flat curve of steady diurnal resistance of Group I. It is likely that different degrees of cyclical variation of resistance correspond to individual degrees of sodium retention. The curve of F. 19 illustrated may therefore be representative of only one section of normal women. The small number of normal women investigated precludes definite conclusions.

Greenhill and Freed (1940) *et al.* have treated cases of pre-menstrual oedema with ammonium chloride and salt-free diet. They report the prevention or restriction of oedema in a high proportion of such cases. Their method was tried empirically on a small series of resistance-steady males. Six were chosen and their resistance behaviour was studied for two weeks. A salt-free diet and ammonium chloride, gr. 30 *t.d.s.*, for one week was enforced. Total quantities of urine excreted were measured daily. There was no significant increase in skin resistance during this period and no increase in urinary output that could not be explained by increased intake. This experiment was conducted on " steady " males because of the impossibility of assessing the responsibility of the measures in any effect produced in fluctuating cases.

Lack of resistance activity was a constant and striking feature of all young cases with amenorrhoea and oligomenorrhoea. In young subjects much resistance activity was never observed unless menstruation was normal. In F. 3 the diurnal resistance was low and steady until a menstrual period unexpectedly occurred, the first for 12 months. Thereafter, the range of diurnal variation was wider and the average resistance about 50 per cent. above previous figures. The curve resembled more that of a normal subject.

Great difficulty was experienced in finding normal (non-mental) young female subjects whose resistance could be measured daily for three months. Several failed to complete the course, or were so irregular in attendance that their results cannot fairly be recorded. Only two were available for continuous observation. Of these, one showed moderate cyclic variation up to 400 per cent., the other slight cyclic variation up to 250 per cent. From these figures and from the other scattered results, there appear to be different degrees of the moderate fluctuations classified as Group 2, none of which occurred in the " steady " Group I.

Nevertheless, the association of normal menstruation with diurnal change was not very conclusive, for the range of resistance was moderate and in some subjects not markedly outside the hourly range for a full day. On the other hand, some males and young cases of amenorrhoea showed very little change from hour to hour as well as from day to day. This might suggest that the activity of Group II is specifically related to menstruation, or that there is relative insensitivity of the autonomic nervous system, reflected by the steady diurnal resistance ; the experiments described and the evidence seem to indicate that the former is more probable.

Vaginal Smears.

The control of menstruation and the factors responsible for amenorrhoea are still uncertain, but the vaginal smear is regarded as a reliable index of oestrogenic activity. Vaginal smears of all subjects were taken and classified according to the method of Papanicolaou and Shore (1934), modified by Geist and Salmon (1939). Smears indicated four degrees of oestrogenic function. The table shows that marked lack of oestrogenic activity was always associated with inactivity of skin resistance, and normal oestrogenic function with moderate cyclical resistance behaviour ; incomplete degrees of oestrogenic deficiency occurred in cases with a wide range of irregular variation.

These coincidences suggest further that production of oestrogenic hormone or the mechanism that controls it has a bearing on skin resistance.

Oestrogenic Hormones and Skin Resistance.

The excretion of oestrin during the whole menstrual cycle has been studied by Smith and Smith (1936). Their figures show a minimum excretion of oestrin just before and just after the onset of menstruation, with a maximum excretion between the 10th and 23rd days. The diurnal resistance of one normal subject examined for three months, expressed graphically, formed a roughly similar curve. This curve is probably modified to some extent by vasomotor changes.

The local effect of oestrin upon the skin resistance was tested as follows: Two resistance-steady subjects, F. 6 and F. 13, aged 24 and 60 respectively, were treated with a cream containing 50,000 units of oestrin (menformon) per dose, rubbed into the skin of the hands and fingers twice daily for one week. In each subject a slight drop of resistance was noted for the first three days, and the resistance then rose to about 25 per cent. above its early figure. One week after the cessation of treatment the resistance had fallen to about the usual level.

Two female patients, F. 10 and F. 11, and two males, M. 5 and M. 6, were injected daily with 50,000 units of oestrin (menformon) for one week. In all four the effect on the resistance was unimportant.

These experiments indicate that even large doses of oestrin applied locally to the skin of the hands of resistance steady subjects do not effect any great change, and that excessive administration by injection into males and post-menopausal females of Group I is similarly ineffective.

Pituitary Function as Related to Skin Resistance.

Evidence of complex endocrine disturbance was found in all the females of Group III and in the one male in whom diurnal resistance was highest and fluctuated the most. These cases were:

M. 7: A pituitary eunuch, aged 33, with an extensive tumour involving the pituitary, confirmed recently at autopsy. Thyroid and adrenals, as well as testes, were abnormally small. The histological investigation is in progress.

F. 16: A case of menopausal acromegaly with long jaw, and bony changes confirmed by X-ray.

F. 15: The thyroid was impalpable, ovarian function depressed, there was considerable loss of weight, and the appearance was that of excessive age for her years.

F. 18: The thyroid was impalpable, the skin was dry, there was severe loss of weight, and since the menopause an enormous overgrowth of hair on face and chin, with certain other signs of virilism.

F. 7: A schizophrenic with hyperthyroidism and amenorrhoea, an example of an uncommon syndrome that has been described as hyperthyrotic catatonia (Hemphill, 1942).

F. 17: A case of pituitary cachexia. There were various gastro-intestinal disturbances, general weakness, depression, and a dry skin. Emaciation was extreme.

In an earlier paper Hemphill and Reiss (1940) showed that post-menopausal mental types could be classified according to prevailing glandular disturbances, and suggested that malfunction of the anterior pituitary might be responsible. Cases F. 15, F. 16, F. 17 and F. 18 are such involutional types, with a pituitary origin. Hormone analyses were made in cases F. 15, 16, 17, 18, and 7; the results may be tabulated as follows:

Hormone Analyses

The excretion of gonadotrophic, thyrotrophic, and corticotrophic hormones was estimated in the total urine passed during 48 hours.

	Gonadotrophic.	Thyrotrophic.	Corticotrophic.
	International units.	Units according to Heyl and Laqueur (1935).	Sudanophobic units according to Reiss (1936).
F. 15	*Nil*	*Nil*	*Nil*
F. 16	>3 <6 (subnormal)	>7< 12 (raised)	>4< 8 (normal)
F. 17	*Nil*	*Nil*	*Nil*
F. 7	>6 <12 (normal)	1–2 (normal ?)	*Nil*
F. 18	8 (normal)	?	*Nil*

These figures show that in F. 15 and F. 17 there was an extreme depression of pituitary function with urinary excretion of the three hormones comparable to that of the hypophysectomized animal; these were the two cases of clinical pituitary cachexia. In F. 7, an atypical form of hyperthyroidism, there was a severe deficiency of corticotrophic hormone output.

The analyses were performed by bio-assay, similar methods being utilized for all subjects. They were made after 90 days of preliminary observation, and at this time the resistances of F. 15, F. 17 and F. 18 were fluctuating irregularly, while those of F. 16 were fairly and F. 7 completely steady.

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Corticotrophic Hormone

In cases F. 15 and F. 17, there was no urinary excretion of corticotrophic hormone, and lack of this hormone appeared to be a major factor in the clinical picture. As a considerable amount of pure corticotrophic hormone was available, it was possible to study the electrical resistance behaviour while these patients were undergoing treatment.

Each patient received 24 daily injections of 40 units of standardized hormone. The accompanying diagram shows the effect of treatment. In each case there was a marked drop in the resistance, which in case F. 17 reached the lowest level attained by any female during the whole period of research. This low level was

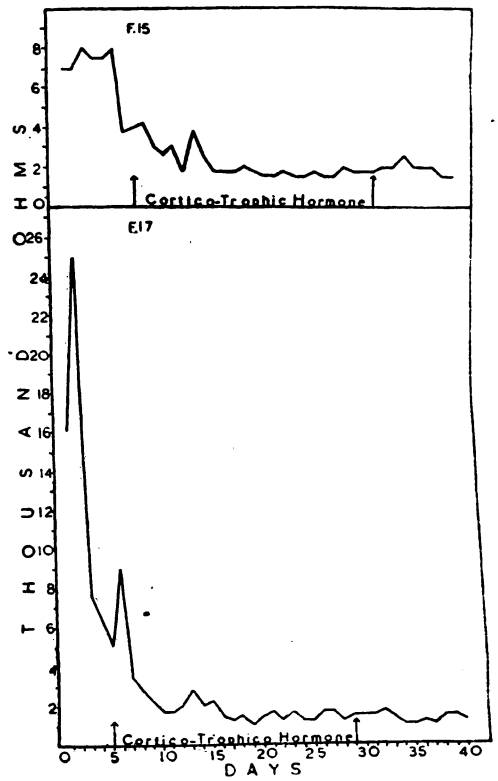

Fig. 4.—Effect of corticotrophic hormone on resistance of F. 15 and F. 17.

maintained on both subjects during a month of investigation following the cessation of treatment. The result was extremely striking, as F. 17 had shown the widest fluctuation in resistance before treatment, having attained levels of over 30,000 ohms. Corticotrophic hormone, 40 units, injected daily for seven days in two "steady" control subjects produced no significant resistance change. The physical state of each patient showed some improvement, but there was little gain in weight until after the second week of treatment; F. 17 then gained 10 lb. in a fortnight. F. 15 has since been discharged from hospital. Therapeutic aspects of this case will be recorded in another paper. The change in resistance preceded any noticeable alteration in physical or mental state. There was some rather significant increase in water intake and output after the second day of treatment.

Oestrin in Acromegaly.

On the assumption that high dosage of oestrin might inhibit anterior pituitary activity, F. 16 was treated with daily injections of oestrin (menformon), 50,000 units for 14 days. In this case the resistance fell to the average level observed in normal post-climacteric subjects. It must be pointed out that prior to treatment this subject had shown a tendency to more stable resistance behaviour, but during the last 20 days of investigation the diurnal resistance reading was more constant than in any previous corresponding period. F. 16 was treated and examined concurrently with F. 10 and F. 11, the two steady controls who were injected with oestrin for a shorter period of time. The diurnal resistance curves of all three were rather similar.

Skin Resistance and Thyroid Function.

It has been stated by Vigouroux (1888), and afterwards confirmed by Golla (1922), that a low skin resistance is common in hyperthyroidism. Golla was able to demonstrate a marked reduction in skin resistance following administration of thyroid extract. Lueg and Grassheim (1929), Wohl (1933) found some association between the skin resistance and thyroid function ; but the findings of the former were inconstant in adipose subjects. They have claimed that measurement of polarization capacity might prove a more accurate estimation of thyroid function than basal metabolic rate. In F. 9, with exophthalmic goitre and menopausal amenorrhoea, the diurnal resistance was one of the lowest and the steadiest of the whole female series. F. 7, on the other hand, exhibiting thyrotoxicosis and catatonia, showed an entirely different resistance behaviour. Up to the present it has not been possible, for wartime reasons, to investigate the relationships between thyroid function and skin resistance.

Discussion.

These investigations have shown that the resistance of the skin varies from day to day, little in certain individuals, moderately in some, and irregularly and between wide extremes in others.

Sweating, body temperature, and vasomotor changes are usually assumed to control skin resistance. It was shown by a number of experiments that these processes, even if carried to extremes, did not account for the wider ranges of variation, and that other factors are responsible.

Some earlier experiments have been repeated on this case material, and results of these, as well as of other experiments, have been recorded in detail. They form largely negative evidence which indicates that theories on the supposed physiology of skin resistance are incomplete or incorrect. The classification of resistance behaviour, described here for the first time, shows why this is so, and why neglect of individual and type differences invalidates much that has been recorded previously.

Almost the entire resistance of the skin is provided by the epidermis, and can perhaps be reduced by increasing its water content. Although not proved conclusively, it seems feasible that a high skin resistance is associated with a relatively water-free epidermis, and a low resistance with a more water-saturated condition of the outer skin in the same subject. While sweating can exert only a moderate influence, water saturation and alteration in the sodium balance would explain all the degrees of a very wide range of resistance.

The resistance-steady subjects were males, and females—young or old—in whom the menstrual function was deranged or inactive.

There was a moderate diurnal variation in resistance of a roughly cyclical form in some subjects, exclusively those whose menstruation was normal. Moderate resistance variations occurred in one young woman—formerly resistance-steady—when menstruation had returned spontaneously after 12 months' amenorrhoea. These facts suggest that oestrogenic activity corresponds in some way with skin resistance.

In this connection the work of Zuckermann (1939) is of great interest. He has shown that swelling of the sexual skin of the pig-tailed monkey, which is due to accumulation of water in the skin, can be produced by large doses of oestrin injected daily in the post-ovulative phase. He considered that this effect was due to some water-retaining property of oestradiol, and could be attained also by using corticosterone. Zuckermann (1935) had already shown that injection of oestrin in denervated species produced sexual skin swelling, and concluded that the phenomenon was the result of local action of the hormone and not of a central neural discharge.

The possibility that the behaviour of the electrical resistance of the skin in normal young women is akin to this water-retention observed in monkeys, and an index of the production of oestrin, is attractive, especially as it may be a demonstration of an archaic physiological function important in the animal, but no more than inconvenient in the human.

Water retention at certain phases in the menstrual cycle has been suggested by the clinical observation that some women experience tightness of clothing or even local oedema before menstruation. Okey and Stewart (1933) found in about 50 per cent. normal women a gain of weight during the inter- and pre-menstrual phases, with a loss at the onset of menstruation. Similar cases were reported by Thomas (1933), Sweeting (1934), and others, oedema being sometimes noticed to coincide with the maximum weight increase. Changes of this sort were noticed by all the normal women examined, but in no case so marked as to cause much discomfort.

Okey and Boden (1927) found various fluctuations in blood cholesterol, which was low just before and during menstruation. Kaufmann (1928) showed that these rhythmic variations in blood cholesterol did not occur when ovarian activity was disturbed.

Oestrin applied locally in some subjects failed to bring about more than a slight and unimportant drop in resistance. This was not surprising, for in all cases investigated in this way, the basic resistance was low and therefore no further large drop in resistance could be expected if the water content of the epidermis was already high. Operational error, sweating, and local vasomotor action may account for a higher percentage of the resistance change when the initial resistance is low.

The greatest loss of sodium occurs in adrenal cortical failure, so that adrenalectomized animals can be used for assaying the relative sodium-retaining potency of various hormones (Thorn, Nelson and Thorn (1938)). Great loss of sodium is associated with great alteration in water balance. The highest resistances and the greatest fluctuations were observed in patients in whom there was no assayable excretion of corticotrophic hormone in 48 hours' urine, and therefore presumably adrenal cortical atrophy and failure of production of adrenal cortical hormone, comparable with that of a hypophysectomized animal. The findings strongly support the suggestion that the DC skin resistance is determined to a great extent by extra-cellular water and alteration in water balance.

Injected corticotrophic hormone in F. 15 and F. 17 almost immediately produced a drop of skin resistance to a low level, at which it was maintained even after the hormone had been withheld, the curve being similar to that of normal post-menopausal females of Group I. The action of this hormone should have been to stimulate the adrenal cortex in the production of its hormones, but whether the resistance drop could be attributed to the action of the corticotrophic hormone itself or to hormones liberated by the adrenal cortex could not be ascertained. The latter possibility is more likely true, for cortin injected into normals has been found to produce retention of sodium up to ten hours only ; repeated injections produced a refractory state in some subjects (Haufmann *et al.*, 1938). That corticotrophic hormone produces its effect by essential physiological rather than pharmacological action is suggested by the sustained result in F. 15 and F. 17, and its ineffectiveness in two controls. In F. 15 and F. 17 malfunction of the anterior pituitary was shown, there being no excretion of thyrotrophic, corticotrophic, or gonadotrophic hormones. These two cases, therefore, appear to be extreme examples of menopausal disturbance, in which the water balance is affected by altered production of various steroid hormones, and the resistance behaviour exceptional.

The vaginal smears of four of the five in Group III showed some evidence of oestrogenic activity. This would suggest that the menopause had not as yet resulted in a state of sex-hormone equilibrium.

Corticotrophic hormone was excreted normally by F. 16. In this case the urinary examination was carried out after three months' preliminary investigation of the skin resistance, and by this time the resistance behaviour had become " steady " as in Group I, and remained so subsequently. It seems likely that the irregularities in normal pituitary function, believed to occur sometimes in the early menopause, with increased production of certain fractions for a time until a physiological balance is restored, would account for high resistance and erratic behaviour preceding the more normal flat curve as noted in F. 16. The injections of oestrin may have assisted in establishing a normal endocrine balance.

Although the production of substances with water-retaining properties may account for a moderate rise and fall in skin resistance, the very high resistances may be due to a general dehydration of the body, such as is seen in hypofunction of the pituitary or hypothalamic lesions.

Polyuria did not occur in any of the cases, but as in F. 15 and F. 17 the anterior pituitary seemed to be almost functionless, a true diabetes insipidus was not to be expected (Cameron, 1940). In F. 15 and F. 17 water intake and output were very low and there was no thirst.

Accurate measurements of water consumption and output are not easily obtained in mental patients, and it is not possible to attach value to any of the results obtained.

Fluctuations in electrical potential have been described as associated with menstruation and ovulation. Rogers (1938) demonstrated cyclic variations in potential between the pubis and vagina of rats during the oestral cycle, which disappeared if the ovaries were removed. Large doses of theelin restored the flat "castrate" curve to the normal oestral one. Whether this curve parallels changes in the vaginal mucosa is not clear.

Burr *et al.* (1935), Rock *et al.* (1937), using special apparatus, have shown differences of potential between cervix and anterior abdominal wall in humans and rabbits at or about the time of ovulation, confirmed in one case by laparotomy. Measuring between finger tips Barton (1940) recorded differences of potential which she believed coincided with ovulation. Sufficient is not known of the electrophysical and physiological factors operating to bring her figures into line with those recorded in this paper.

Little light has been thrown on possible psychiatric relationships of skin resistance. The young subjects with disturbed menstruation were for the most part suffering from schizophrenia and the glandular dysfunctions were principally accompanied by melancholic types of illness. One subject, who unfortunately died, is of interest, in that a high and fluctuating resistance was recorded during the first weeks of investigation, at a time when the mental state appeared to be perfectly normal. The resistance fell abruptly to 1,800 ohms coincidentally to the day with the recurrence of severe agitated depression. No factors to account for this attack of depression in a woman who had been apparently perfectly well for years could be found. She was the only post-menopausal subject without evidence of glandular abnormality in whom the resistance showed such irregular behaviour. This behaviour possibly indicated some prodromal activity preceding the mental relapse.

Incomplete though the results of these investigations are, it is possible to construct a hypothesis which includes the relevant facts. The skin resistance is maintained at an average value by its thickness and the presence of water in the epidermis. Minor and transitory variations follow activity of the autonomic nervous system. Alterations in the water balance through excretion or retention of sodium and in the production of steroid hormones with water-retaining properties are reflected by changes in the skin resistance, and such changes are seen in some normally menstruating women. Severe pituitary failure or dysfunction, as seen in its extreme form in pituitary cachexia, leads to an erratic production of relevant hormones and to high and fluctuating skin resistances, absence of corticotrophic hormone with adrenal cortical failure causing the greatest variations. After the menopause, a state of pituitary and glandular equilibrium may be established, and if so skin resistance behaviour becomes quiescent, resembling that of the male. This hypothesis is no more than a framework upon which to hang the new facts arrived at in the course of this investigation ; its ultimate value depends upon the results of the many paths of research that it suggests. It is possible that the technique described may be of diagnostic value in investigating adrenal cortical failure.

Epilepsy.

Epileptics were designedly excluded from the earlier part of the work. It was therefore decided to investigate their resistance behaviour, especially in view of the supposed relationship between fits and water metabolism in some epileptics.

A representative group of 18 male epileptics was chosen. Their ages varied between 22 and 65. The group included patients who had many or infrequent fits, and who had major, minor, or psychic attacks.

Using the same technique as before, and employing four of the original series of males as controls of known resistance behaviour, diurnal measurements were made for 72 days. The incidence of fits was noted and plotted against the resistance curve.

It was found that in some cases there was a rather wider range of variation than in the controls. In the majority the fluctuations were unimportant, and no consistent correlation existed between fits and the resistance behaviour. In two cases (E. S—, E. S. T—) resistances of over 10,000 ohms were recorded on one or more occasions, and in one subject (E. P—) high and irregular fluctuations, comparable with Group III described before, were seen. In this case, as the graph shows, the majority of fits occurred when the resistance was low or falling. The time interval

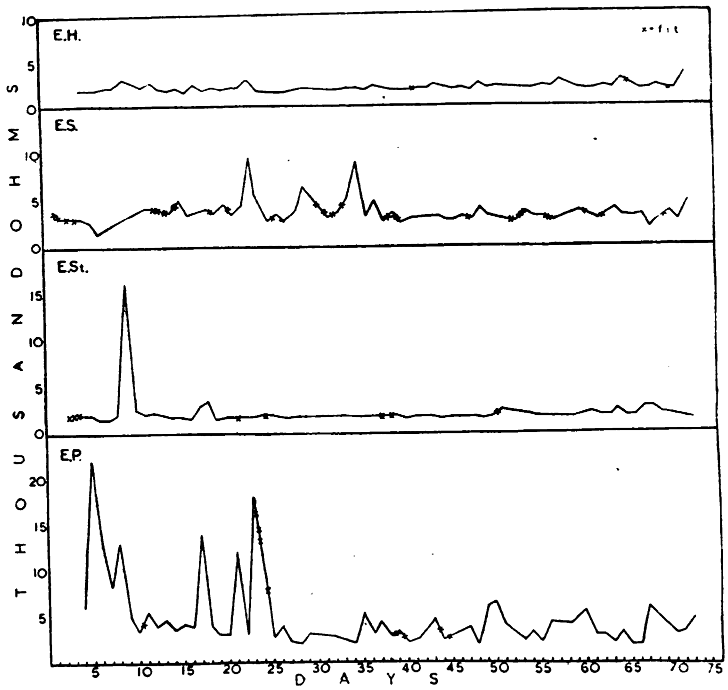

FIG. 5.—Diurnal resistance in four epileptics, E. H—, E. S—, E. S. T—, E. P—. Fits indicated by X.

between fits and resistance recording was anything up to 24 hours, and this alone vitiated accurate comparisons.

If the autonomic disturbances resulting from the electrically-induced epileptic fit are similar to those of the spontaneous major convulsion, they are slight, as determined earlier, and therefore do not modify these resistance curves to any considerable extent.

All patients were taking anti-epileptic drugs, which may have suppressed fits and masked their real incidence. Electro-encephalograms of all patients were examined by Mr. Grey Walter. They showed no features that could be classified with the type of resistance behaviour.

Water Metabolism.

The morning fasting weight and the total urinary output are a very approximate indication of changes in water balance, but the accuracy of these measurements is almost impossible to guarantee in mental subjects. Nevertheless, ten of the patients, including E. P—, E. S—, E. S. T—and E. H—, were weighed daily and the total urine passed measured for 28 days. The results justify no conclusions.

Water metabolism was investigated carefully in their patients by Greville, Jones and Hughes (1940), who tried to account for all sources of intake and output as well as insensible water loss. They found that either retention or loss of water may precede fits, and a disturbance in water balance is not a constant finding in all cases. They have reviewed recent literature.

Corticotrophic hormone was estimated in 48 hours' urine of E. S—, E. S. T—, E. H—, E. P—, and results were as follows (sudanophobic units):

E. H— .	1 >< 3 (reduced).	E. S. T— .	2 >< 5 (normal).
E. S— . .	1 (reduced).	E. P— . .	0

Excretion of androgens in 24 hours was determined in these four patients. The figures were:

E. H—: 8·2 mgm. per 24 hrs.	E.S.T—: 10·1 mgm. per 24 hrs.
E. S—: 11·6 ,, ,,	E. P—: 6·8 ,, ,,

In view of the present interest in androgen excretion in adrenal insufficiency, it is worth recording that the lowest figure, 6·8, which is rather subnormal, occurred in case E. P—, the epileptic in whom there was no assayable excretion of corticotrophic hormone in 48 hours' urine.

The curves of E. H—, E. S—, E. S. T— and E. P— are shown in Fig. 1. That of E. P—, in whom there was no excretion of corticotrophic hormone, resembles those of Group III. It is notable, too, that the excretion of corticotrophic hormone in E. S— and E. S. T— was markedly subnormal. None of these patients had any physical symptoms suggestive of adrenal or special glandular insufficiency.

The results of these investigations are suggestive, but the case material was too small to justify conclusions. It may be significant and not merely coincidence that reduction or absence of corticotrophic hormone output was associated with resistance values not seen in other males, whether epileptic or not, and behaviour comparable with Group III. If, as has been suggested before, this behaviour is related to a disturbance of water balance of endocrine origin, there may be epileptics in whom a similar disturbance linked to pituitary function is an operational factor.

Summary.

The diurnal resistance of the skin in males, and in non-menstruating females, young or old, varies little; in some normal young females, moderately; and in post-menopausal glandular and especially pituitary disturbances, irregularly between wide extremes. These have been described as Groups I, II and III respectively.

The variations are a property of the skin and do not occur if measurements are made with a rapidly alternating current.

The wide variations are not the result of sweat glands or vasomotor activity, but probably depend upon the content of extra-cellular water and electrolyte balance, which may be controlled by oestrogenic and adrenal cortical hormones and other steroid hormones with water-retaining properties.

Oestrin locally applied to the skin effected no significant drop in resistance in steady subjects. The fluctuations in resistance in a normal woman can perhaps be correlated with the water balance. The highest resistance and widest fluctuations were associated with no excretion of corticotrophic hormone in the urine. Treatment of two cases with corticotrophic hormone restored the skin resistance to a low level, at which it remained steady.

Experiments in the physiology of skin resistance have been made and described, and it has been shown that in high fever the skin resistance does not correspond with the temperature, nor does it vary much in the epileptic fit, nor during an attack of Raynaud's disease.

The results obtained and problems arising therefrom have been discussed.

Epilepsy.—High resistances and wide fluctuations were noted in three cases of a group of 18 epileptics. In two of these the corticotrophic hormone output was reduced; in the third it was completely absent. It has been suggested that further investigation on these lines may show an endocrine factor in some forms of epilepsy.

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Bibliography.

Aveling, F., and McDowall, R. J. (1925), *J. Physiol.*, **60**, 316.
Barnett, A. (1939), *Proc. Soc. Exper. Biol. and Med.*, **40**, 697, and **42**, 839.
Barton, D. S. (1940), *Yale J. Med. and Biol.*, **12**, 335.
Bingel, A. (1940), *Ztschr. f. d. ges. Neurol. u. Psychiat.*, **170**, 404.
Burr, H. G., Hill, R. T., and Allen (1935), *Proc. Soc. Exper. Biol., N.Y.*, **33**, 109.
Cameron, G. (1940), *Recent Advances in Endocrinology*, p. 338. London: Churchill.
Carmichael, E. A., Honeymon, W. M., Kolb, L. C., and Stewart, W. K. (1941), *J. Physiol.*, **99**, 329.
Darrow, C. W. (1929), *Amer. J. Physiol.*, **88**, 219.
Densham, H. B. A., and Wells, W. M. (1927), *Quart. J. Exp. Physiol.*, **18**, 283.
Féré, C. (1888), *C. R. Soc. Biol., Paris*, **5**, 217.
Geist, S. N., and Salmon, C. J. (1939), *Am. J. Obst. and Gyn.*, **38**, 392.
Gildemeister, M. (1923), *Pfl. Arch. ges. Physiol.*, **200**, 262.
Goadby, K., and Goadby, H. (1936), *J. Physiol.*, **86**, 11.
Golla, F. L. (1922), *Lancet*, **2**, 215.
Greenhill, G. P., and Freed, S. C. (1940), *Endocrin.*, **26**, 529.
Greville G. D., Jones, T. S. G and Hughes, W. F. G. (1940) *J. Ment. Sci.*, **86**, 195.
Grossheim and Lueg, quoted by Landis.
Hartman, F. A., Lewis, L. A., and Toby, C. G. (1938), *Endocrinol.*, **22**, 207.
Hemphill, R. E., and Reiss, M. (1940), *J. Ment. Sci.*, **86**, 365, 1065.
Hemphill, R. E. (1942), *Ibid.*, **88**, 1.
Heyl, T. G., and Laquer, E. (1935), *Arch. intern. de Pharmacodynam. et therap.*, **49**, 338.
Kaufmann, G. (1928), *Arch. f. Gynäk.*, **134**, 603.
Keutmann, Bassett and Warren (1939), *J. Clin. Invest.*, **18**, 239.
Kuno, Y. (1934), *The Physiology of Human Perspiration*, p. 48. London: J. & A. Churchill.
Landis, C. (1932), *Psychol. Bull.*, **26**, 693.
Lewis, T., and Zottermann, Y. (1927), *J. Physiol.*, **62**, 280.
Lueg, W., and Grassheim, K. (1929), *Ztschr. f. klin. Med.*, **110**, 531, 539.
MacClendon, J. F. (1927), *Amer. J. Physiol.*, **82**, 525.
Idem and Hemingway, A. (1930), *J. Gen. Physiol.*, **13**, 621; (1930) *Amer. J. Physiol.*, **94**, 77.
MacDowall, R. J. S. (1933), *Quart. J. Ex. Physiol.*, **23**, 277.
Odegaard, O. (1930), *Acta psychiatr. et neur.*, **5**, 55–105.
Okey, R., and Boden, R. (1927), *J. Biol. Chem.*, **72**, 261.
Okey, R., and Stewart, D. (1933), *ibid.*, **99**, 717.
Papanicolaou, G. N., and Shore, F. (1934), *Proc. Soc. Exp. Biol. and Med.*, **32**, 1, 585.
Prideaux, E. (1920), *Brain*, **43**, 50.
Richter, C. P. (1927), *ibid.*, **50**, 215.
Idem (1928), *Arch. Neurol. and Psychiat.*, **19**, 488–508.
Idem and Levine, F. (1937), *ibid.*, **38**, 756.
Rock, J., Reboul, J., and Wiggers, H. C. (1937), *New Eng. J. Med.*, **217**, 654.
Rogers, A. (1938), *Endocrinol.*, **22**, 35; *Amer. J. Physiol.*, **121**, 565.
Schwenkenbacher, A. (1925), *Klin. Wschr.*, **48**, 202.
Smith, G. Van S., and Smith, D. W(1936), *New Eng. J. Med.*, **215**, 908.
Strohl, A. (1931), *J. de radiol. et d'electrol.*, **15**, 426, 537.
Sweeney, A. (1934), *J.A.M.A.*, **103**, 234
Syz, H. C., and Kinder, F. (1928), *Arch. Neurol. and Psychiat.*, **19**, 1026.
Thomas, J. (1933), *J.A.M.A.*, **101**, 1126.
Thorn, G. W., Nelson, K. R., and Thorn, D. W. (1938), *Endocrin.*, **22**, 155.
Veraguth, O. (1906), *Z. Psychol.*, **42**, 162.
Vigouroux, R. (1888), *C. R. Soc. Biol., Paris*, **5**, 138.
Waller (1919), *Proc. Roy. Soc.* B, **91**, 32.
Walter, W. G. (1942), personal communication.
Wang, R., and Richter, C. (1928), *Chinese Journ. Physiol.*, **1**, 279.
Wells, W. M. (1928), *Quart. Journ. Exp. Physiol.*, **18**, 33.
Westburg, E. M., and Syz, H. C. (1929), *Arch. Neurol. and Psychiat.*, **22**, 719.
Wohl, M. G. (1933), *Endocrin.*, **17**, 299.
Wright, S. (1940), *Applied Physiology*. London: Oxford University Press.
Zuckermann, S. (1935), *Proc. Roy. Soc.*, B, **118**, 22.
Idem (1939), *J. Endocrinol.*, **1**, 147.