

# THE ELECTRIC CAPACITY OF TUMORS OF THE BREAST <sup>1</sup>

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## INTRODUCTION

A suspension of biological cells or a biological tissue when placed in a conductivity cell, behaves as though it were a pure resistance in parallel with a pure capacity. This parallel capacity is the capacity of the specimen of tissue which is measured while the specific capacity is the capacity of a one centimeter cube of the tissue. While the resistance of biological tissues has been studied by many investigators, little attention has been directed to their capacity. During the course of an investigation of the capacities of various biological systems, which is at present in progress in this laboratory, certain facts regarding the capacity of tumors were noted which justified a somewhat extensive study of the practical aspects of this subject. In short, it was found that certain types of malignant tumors have a rather high capacity in comparison with benign tumors or with inactive tissues of the same or similar character. Early in the investigation it was determined that tumors of the breast constituted the most convenient and uncomplicated material for study and while numerous tumors of other tissues have been measured, only those belonging to this group will be reported here. Fifty-eight cases have been admitted to this series, which constitutes an unselected group comprising all the cases of tumors of the breast which have been operated on at the Cleveland Clinic Hospital for a period of about one year, together with sporadic

<sup>1</sup> The work reported in this paper is an extension of the investigations extending over many years, which have been carried out by Dr. G. W. Crile and his associates with the systematic purpose of relating biological changes in tissues to changes in various physical constants of the tissues. It is a pleasure to acknowledge here the active interest which Dr. Crile has taken in this work throughout its entire course.

cases taken at random prior to this time and a few cases, particularly of benign tumors, which were operated on at other hospitals in the city.<sup>2</sup>

#### HISTORICAL NOTE

The capacity values determined in the investigation which is reported in this paper are quantitative measurements of that well known property of tissue which is usually called its *polarization*. It is doubtful, however, whether the latter term should be employed as the phenomenon so designated is not always due to a polarization in the true physical sense of the term. Since Peltier and du Bois-Reymond discovered and described this phenomenon, several investigations of it have been made, principally by means of a direct current. This procedure has serious technical and theoretical objections and it is hardly possible to secure measurements by this method which are of value for the present purpose. Recently a few investigations have been made by means of an alternating current. (Gildemeister (1), Philippson (2, 3), Waterman (4).) We shall not enter here into any especial discussion of the work of earlier investigators since their results are of no special importance for the present problem. A short reference only may be made to Waterman's investigation of the capacity of malignant tumors. He has compared the capacity of human and mouse tumors of several types, especially the malignant growths obtained by painting the skin of mice with tar, with the capacity of various normal tissues (liver, kidney, muscle, spleen and especially the skin of mice) and has found the former markedly lower than the latter. We can confirm this result, at least as regards the majority of the tissues studied; but we cannot agree with his conclusion that this difference is of fundamental importance since we find in our study, which includes practically all the most important types of tumors, that the malignant tumor has a high and not a low capacity as compared with benign tumors of a similar character and also with the normal tissue in which it lies. We must therefore

<sup>2</sup> We desire here to acknowledge the courtesy of Dr. E. C. Cutler, in allowing us to use material of this nature from Lakeside Hospital.

state also that Waterman's own results are not a sufficient basis for his suggestion that capacity measurements be used in the diagnosis of tumors as the practicability of such a method can only be determined by a comparison of malignant and benign tumors. We may add that Waterman's technic is hardly well enough developed to determine with sufficient accuracy the differences in capacity with which we are concerned in this study.

#### THEORETICAL NOTE

The electric capacity of a tissue can theoretically be assumed to be of two different types: (1) The "static capacity" type which is due to the presence of actual condensers consisting of thin films of a relatively high resistance, such as undoubtedly exist in certain tissues in certain locations; and (2) the "polarization" type which is due to a polarization at the interphases in the tissue. A characteristic of the first type of capacity in contrast to the second is that it is independent of the frequency of the alternating current. This contrast makes it possible in any given case to decide which form is present by varying the frequency. According to this test the capacity of the tissues dealt with in this paper is of the second or "polarization" type. As has been reported elsewhere, "static capacity" seems to be the sole form of capacity present in blood (5).

The fact that the capacity of a tissue depends upon the interphases in the tissue suggests that capacity might have considerable biological significance. The capacity of a tissue will depend upon a great number of factors; although we are unable to give any final statements concerning these factors for the tissues studied here, we think that a tentative indication of what these factors are and how they will tend to affect the measurements is not out of place, in order that the reader may obtain an idea of what the interpretation of the results may be (5) (6). With every possible reservation, therefore, the following statements are offered as applying only to the types of tissue studied here. The capacity of a tissue increases with the volume concentration of cells but comparatively slowly when the latter is more than 50 per cent, and it is directly proportional to the

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average diameter of the single cell. The capacity decreases with the amount of differentiation within the cell and decreases as the differential permeability (difference between the permeability of the cell membranes to anions and to cations) increases and as the concentration of the electrolytic ions, which are effective in producing the polarization, decreases.

#### EXPERIMENTAL TECHNIC

##### *A. The Physical Measurements*

*General.*—The tissues are cut into small cylindrical blocks, and placed in a conductivity cell of special design in such a way as to insure the passage of the whole current through the block. The electrodes are set some distance away from the tissue and electrical connection is made by filling the rest of the cell with Ringer-Locke solution. The cell therefore consists of two parts, one the tissue proper, which has a certain intrinsic resistance and capacity, and the other the conducting liquid which has a certain resistance which we shall term the “external resistance.” The electrodes exhibit a certain large series capacity which is due to polarization and is expressible as an equivalent small parallel capacity which with certain other stray capacities, not due to the tissue, we shall term the “zero capacity.”

Measurements of the resistance and of the capacity of the cell as a whole are made simultaneously on a Wheatstone bridge of special design, a substitution method being employed. The measurements here reported have been made at 20,000 cycles per second. After the tissue has been measured, it is removed and a measurement is made on the cell containing only the Ringer-Locke solution; this measurement furnishes the external resistance independent of the temperature; and also shows whether the bridge is in right working order. The zero capacity is determined once for all by a special series of measurements, to be described later, on the cell without tissue. The external resistance and zero capacity being known, the resistance and capacity of the tissue can be calculated. From these and from its dimensions the specific resistance and the specific capacity of the tissue can be obtained.



*The Electrolytic Cell.*—In Figure 1 are shown a photograph and a diagram of the electrolytic cell which has been used in the latter part of the investigation, the cells previously used differing from this one only in small details of construction. This cell is divided into two equal parts, between which a

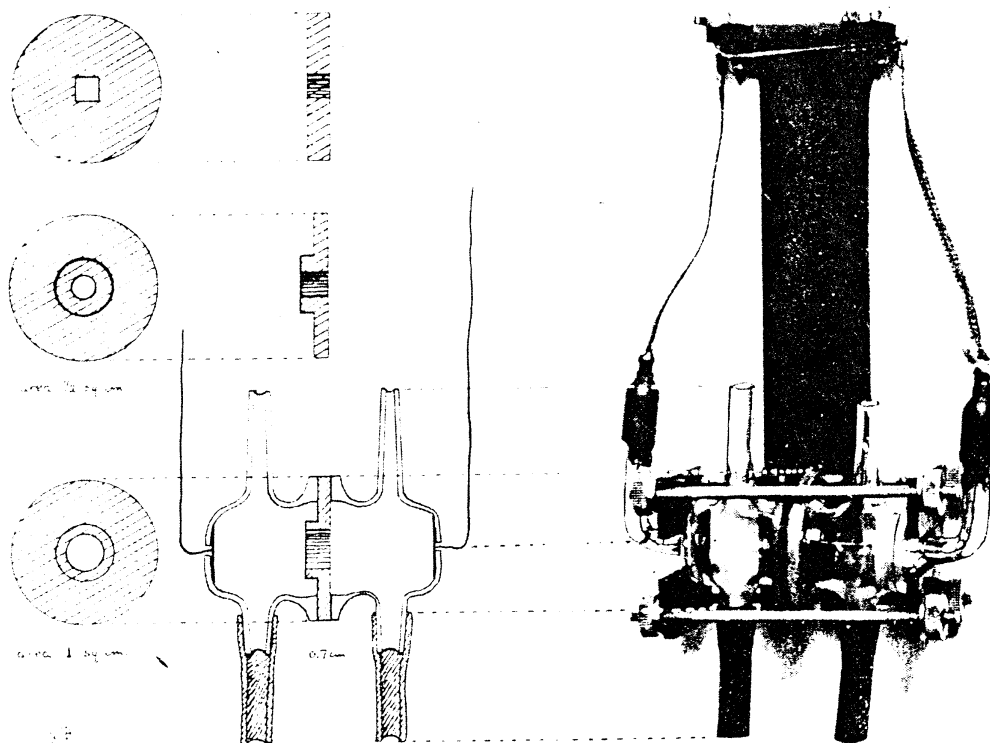


FIG. 1.

circular celluloid diaphragm with a central hole can be placed, a clamping holder enabling the whole to be fastened together to form a single water-tight vessel. The halves are circular in shape and are ground flat on their internal surfaces. In this way the diaphragm can easily be centered. The diaphragms which we have used are shown in the figure. In one of these the central hole is cubical so that the capacity can be estimated in different directions, in the others the hole is cylindrical. Beside these diaphragms, intended for tissues, we use also a series of diaphragms of the same outside diameter but with central holes of different sizes which make it possible to give the cell any desired cell constant, while utilizing the same elec-

trodes. These diaphragms are used to determine the zero capacity, as mentioned above. The electrodes, of platinum foil, are melted into the glass so as to occupy the whole areas of the ends of the cell. Their area is quite large in order to make the series capacity, due to polarization at the electrodes, as large as possible (reducing the parallel capacity due to this cause as much as possible). The electrodes are placed at some distance from the tissue in order that their full area may be utilized; this minimizes also the parallel capacity due to polarization. The electrodes are platinized for the same reason. The particular purpose of the design of this cell and especially of the presence of the solution between the tissue and the electrodes is to make possible the accurate determination and elimination of that part of the measured capacity which is due to polarization at the electrodes.

*Temperature.*—The capacity of tissues is sufficiently independent of changes in temperature to make measurements at room temperature precise enough for the present purpose, and most of the measurements here reported have been so made.<sup>3</sup>

*The Wheatstone Bridge.*—The cell constitutes the fourth arm of a Wheatstone bridge of special design, a photograph of which is shown in Figure 2 and the electrical diagram in Figure 3. Two arms of the bridge consist of a Kohlrausch slide wire (Leeds and Northrup) which is used near its middle point; the third arm consists of a General Radio Co. resistance box,  $R_l$ , reading from 0.1 ohm to 1111 ohms or one from one to 11110 ohms. The coils in these boxes are wound by the Ayrton-Perry method and their inductance is rather low. In parallel to this resistance is a decade mica condenser and a variable air condenser,  $C_l$ . The fourth arm, as stated above, contains the electrolytic cell which is in parallel with a decade mica condenser and also with a General Radio precision condenser calibrated by the Bureau of Standards,  $C_r$ . In series with the cell is a second General Radio resistance box,  $R_r$ , identical in design with that on the left side, all of the coils of which have

<sup>3</sup> According to later measurements the change of capacity with temperature is a few per cents per degree.

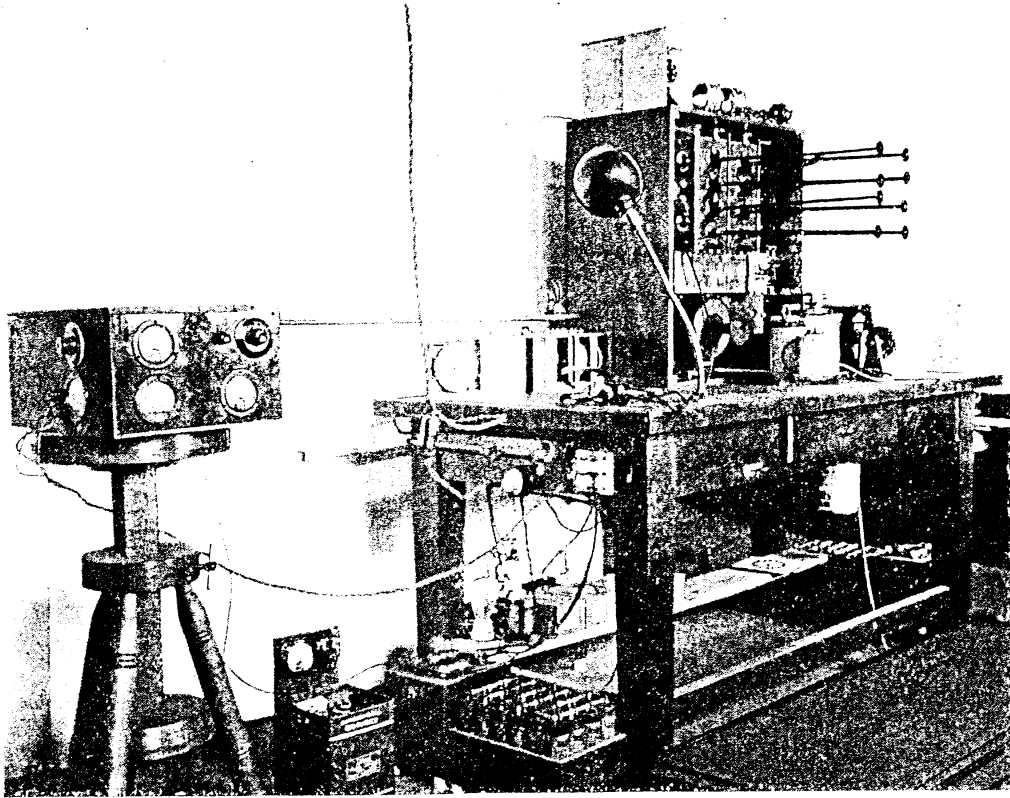


FIG. 2.

been carefully calibrated for inductance. By a switch,  $S$ , the cell can be switched out of the bridge and the leads to it short-circuited.

The current is delivered to the bridge over a loose inductive

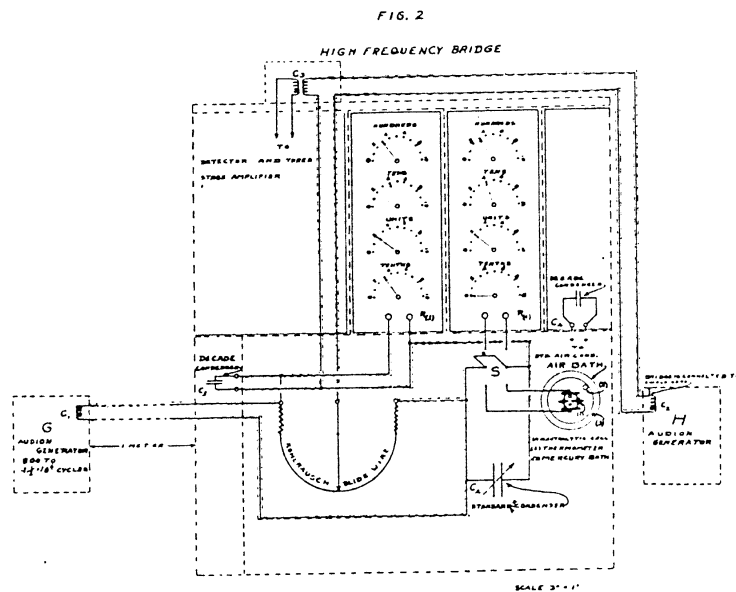


FIG. 3.

coupling,  $c_1$ , by an audion oscillator which is so arranged that by changing the capacity and inductance therein a current the frequency of which varies from 870 cycles to 4,500,000 cycles per second can be delivered. The heterodyne method of detection is employed, a beat note being introduced by a second heterodyne oscillator of identical construction, working through a second very loose inductive coupling,  $c_2$ . By a third loose inductive coupling,  $c_3$ , the potential across the bridging arm is impressed on the grid of a detector tube, three stages of amplification are employed and the beat note is heard in a telephone. All parts of the bridge are carefully shielded, the shield being connected to the bridging arm, but the bridge is not connected to a ground; as, if a ground is employed, X-ray apparatus in the building causes noises in the telephone. The oscillator is placed at about two meters distance from the bridge in order to prevent direct coupling effects. Complete details regarding the construction and theory of this bridge will appear elsewhere.

#### *The Making of a Measurement.*

In Table I are given the various measurements, which must be made, and also the necessary calculation. The making of a measurement consists in the following steps: (1) The right resistance box and the right decade condenser are set at zero, the cell is switched into the bridge and the latter is balanced by varying the left resistance, the left capacity and finally the right precision condenser. (2) The cell is switched out and the bridge is rebalanced, only the resistance box, and the condensers on the *right* side being varied, the left side remaining untouched. The resistance of the cell is the reading of the right resistance box,  $R_c$ , and an uncorrected value for the capacity of the cell,  $C'' - C'$ , is obtained by taking the difference in value of the condensers on the right side in the two balancings of the bridge. (3) The tissue is displaced from the hole in the diaphragm by squeezing a dropper nipple placed on one of the two upper tubes of the cell and the whole measurement is repeated, first, the cell being switched in, by balancing with the left resistance box; and then, (4), the cell being switched out, by balancing

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with the right resistance box as before (reading, right resistance box,  $R_{c-t}$ ). No account is taken of capacity in these last two settings, other than the necessity of making sufficient adjustment to make possible an accurate setting for resistance.

TABLE I  
*Protocol of a Typical Measurement*

Symbol	Quantity	$\mu\mu$ Farads
$C'$	Capacity reading, cell out, right . . . . .	750
$C''$	Capacity reading, cell in, right . . . . .	250
$C' - C''$	Uncorrected capacity of cell . . . . .	500
		Ohms
$R_r$	Resistance reading, cell out, right . . . . . (Resistance of cell)	251.5
$R_{c-t}$	Resistance of cell, tissue displaced . . . . .	221.0
$aR_{c-t} = R_{ext.}$	External resistance of cell . . . . .	143.0
$R_r - R_{ext.} = R_t$	Resistance of tissue . . . . .	108.5
	Inductances	$\mu\mu$ Henries
	100 ohm coils . . . . .	$20 \times 10^4$
	10 ohm coils . . . . .	50
$L_R$	1 ohm coils . . . . .	5
	0.1 ohm coils . . . . .	10
$L_l$	Cell leads (subtracted) . . . . .	41
$L_R - L_l$		$44 \times 10^4$
$(L_R - L_l)/R_r^2 = C_L$		7
$C' - C'' - C_L = C_c$	Capacity of cell . . . . .	493
$C_o$	Zero capacity of cell . . . . .	25
$C_c - C_o$	Capacity derived from tissue capacity . . . . .	468
$(C_c - C_o) \cdot (R_r/R_t)^2 = C_t$	Capacity of tissue . . . . .	2,515
$C_t \cdot l/A = C_s$	Specific capacity of tissue . . . . .	3,520
$a$ = a constant depending on the geometry of the cell.		
$l$ = length of block parallel to current.		
$A$ = area of face of block perpendicular to current.		

From the reading of the right resistance box,  $R_{c-t}$ , we obtain the resistance of the cell filled with the solution used for electrical connection between the tissue and the electrodes at the particular temperature used in making the primary measurement and from this value the resistance external to the tissue can be obtained as shown below.

*Calculation of a Measurement*

1. *Correction for Inductance.*<sup>4</sup>—It is well known that the presence of a small inductance of  $L$  micro-micro-henries in a resistance of  $R$  ohms may be neutralized by adding a capacity of  $L/R^2$  micro-micro-farads in parallel to the resistance. We have in separate experiments determined the effective inductance of each coil in the right resistance box (that is, the value which any such coil has in connection with the foregoing coils of the decade). The total inductance of the box,  $L_R$ , is the sum of all these inductances which are in use. We have similarly determined the value of the inductance of the cell leads,  $L_l$ . The reading for capacity in the first measurement,  $C''$ , is greater by  $L_l/R_r^2$  than it would be if  $L_l$  did not exist and similarly  $C'$  is greater by  $L_R/R_r^2$ ; their difference is accordingly greater by  $(L_R - L_l)/R_r^2$  than it would be if no inductances existed and this is therefore subtracted from  $C'' - C'$ ; value obtained  $C_c$ .

2. *Correction for the Zero Capacity.*—On account of polarization capacity the electrodes of the cell possess a certain large series capacity which is equivalent to a small parallel capacity. The cell possesses a certain capacity which is inversely proportional to the cell constant, and is known as the static capacity of the cell. Finally a difference exists between the capacities which neutralize the static couplings of the electrolytic cell and of the resistance box with respect to the rest of the bridge. The sum total of these capacities and possibly others, which we term the "zero capacity," is dependent on the resistance exhibited by the cell. Accordingly by the use of the other diaphragms, mentioned above, in place of the diaphragm used to hold the tissue, we have once for all determined the capacity of the cell, as outlined above, for the whole series of resistances which may be encountered and have plotted a curve for the zero capacity, thus defined, against resistance. From this curve the zero capacity may be found for any value of the resistance which may be encountered; this capacity is subtracted from the gross

<sup>4</sup>This correction is usually too small for its consideration to be necessary in capacity measurements for the diagnosis of tumors.



value of the capacity of the cell,  $C_c$ , the difference being that portion of the capacity of the cell which is derived from the capacity of the tissue,  $C_c - C_o$ .

3. *The Determination of the Resistance of the Tissue.*—The resistance of the tissue is determined by means of the value obtained for the resistance of the cell with the tissue displaced,  $R_{c-t}$ . This resistance bears a constant ratio,  $1/a$ , to the external resistance of the cell,  $R_{ext.}$ , which is independent of the temperature or of the solution used, and is dependent only on the geometrical form of the cell;  $a$  being determined once and for all as shown below,  $R_{ext.}$  is found from the equation:

$$R_{ext.} = a \cdot R_{c-t};$$

and the resistance of the tissue,  $R_t$ , is obtained by subtracting  $R_{ext.}$  from the resistance of the cell,  $R_c$ .

The ratio,  $a$ , of  $R_{ext.}$  to  $R_{c-t}$ , is determined in the following way: The cell is set up with two identical tissue diaphragms, and is filled with any liquid; the resistance is then measured; one diaphragm is removed, the resistance is again measured and the second resistance is subtracted from the first, the difference, divided by the second resistance giving the value of  $a$ .<sup>5</sup>

4. *Derivation of the Tissue Capacity from  $C_c - C_o$ .*—The quantity  $C_c - C_o$ , while wholly derived from the capacity of the tissue, is in parallel to the whole of the resistance  $R_r$ , while the capacity of the tissue is in parallel only to the resistance of the tissue. Now if two capacities are so placed the one,  $C$ , in parallel with the whole of a resistance,  $R$ , the other,  $C_1$ , in parallel to a portion,  $R_1$ , of an equal resistance,  $C/C_1$  must be equal to  $(R_1/R)^2$ , in order that the two systems be electrically equivalent. It should be noted that  $C\omega R$  and  $C_1\omega R_1$  ( $\omega$  indicates

<sup>5</sup> The external resistance, theoretically, is not entirely independent of the resistance of the tissue, inasmuch as the course of the current lines within the tissue is strictly parallel, the deviation depending on the value of the tissue resistance. It can be shown theoretically, and we have determined experimentally, that this deviation is so small that it may be disregarded for the accuracy desired in the present work; therefore the described method of determining the external resistance is sufficiently precise.



angular frequency) are both always less than  $l$ . We know therefore that the capacity of the tissue  $C_t$ , is equal to  $(C_c - C_o) \cdot (R_r/R_t)^2$ .

5. *Derivation of the Specific Capacity of the Tissue.*—The capacity of a homogeneous substance in which the capacity, as in tissues, is the resultant of small elements of capacity evenly distributed through the substance, varies with the dimensions of the substance in the same way as does its electrical conductivity. We may therefore define the specific parallel capacity of a substance, as the capacity of a cube of the substance, 1 cm. in dimensions, this magnitude having meaning only in so far as the substance is homogeneous, and can thus determine the value of its specific capacity from the capacity of a block of any regular form. Accordingly we have the specific capacity equal to  $C_t \cdot l/A$ , where  $l$  is the length of the block measured, parallel to the current flow and  $A$  is the area of the face, perpendicular thereto.

### B. The Handling of Tissues

*Preservation.*—Tissues should be in as fresh a condition as possible. The chief practical precaution to be taken, especially in the case of small specimens, is to prevent them from drying. They should not be preserved in salt solution or in Ringer-Locke solution, although they may be kept in a tightly closed jar, inside of which has been placed a piece of damp gauze or cotton. If any appreciable time is to elapse before measurement, they should be preserved as nearly as possible at  $0^\circ\text{C}$ . but *they must never be frozen*.

*Change with Time.*—Under these precautions all tissues show a small decrease in capacity per day, measurements continuing to be valuable for several days. In tumors of very rapid growth and high malignancy which show marked central degeneration the capacity may at first decrease rapidly from an original very high value, this decrease amounting to as much as 40 per cent or more in the first hour or two, but after this first decrease the value is still high enough to be of diagnostic value, and remains as stable as in the case of other tumors.

*Selection of Blocks for Measurement.*—In the case of tumors, the blocks of tissue should be selected from the edge of the growth, especially when the growth is large, as the central area, if degenerated, may show any value down to zero, depending on the extent of the degeneration. As a rule secondary nodules and metastases show higher values than the original growth. Radiated tumors will usually show decreased values if the radiation has been effective. It is our practice to cut the whole tumor into slices about 1 cm. thick and, proper points having been selected, to bore through the slice with a circular steel cutter, which is preferably made a little larger than the hole in the diaphragm. The cutter should be sharp and in particular the taper of the edge should be long. The core is then placed in the hole of the tissue diaphragm and its ends are sliced off with a knife. The diaphragm is placed in the cell and the cell is filled as described above.

### *C. Application of the Measurements to Pathological Material*

*General.*—As before stated, the material used in the measurements reported here consists of tumors of the breast and the adjacent normal tissues which have been brought to the biophysics laboratory from the operating room. The anaesthetic (perhaps of some importance) has been nitrous oxide and oxygen in practically all cases. After measurement, the blocks of tissue have been fixed and examined histologically. In addition to this histological study, a rather full study has been made of the clinical records in each case, and whenever sufficient time has elapsed to make it worth while, the case has been followed up. A report concerning the final fate of these cases will be made later, the present report being only in the nature of a preliminary communication in this regard, pending the development of the ultimate facts.

*Precision and Reproducibility of Measurements.*—The precision of measurement with the bridge used in this study is quite beyond that necessary for the practical purposes outlined in this paper—the error being one per cent or less. The method used to obtain a block of tissue is quite precise both as regards

face area and length and different blocks usually agree in weight to one per cent or better. Variations due to the lack of homogeneity of the tissue are of course far larger than this. It goes without saying that in the ideal case the block of tissue must consist purely of the type of tissue in which we are interested, as to the extent to which this ideal condition is approximated will the capacity measurement for the tissue have value. If doubt on this point exists, if the malignant growth is invading the neighboring tissue, for example, smaller blocks must be cut until the specific capacity remains constant. In such a case it may also be well to use the cubical hole and measure the capacity in different directions. If the practical limit of size has been reached, and directional effects still persist, an average of the value in three dimensions will give an approximation of the true value.

*Distribution of Capacity within a Tumor and External to It.*—The central and older portion of a tumor as a rule shows less capacity than the actively growing edge. Metastases in lymph nodes nearly always show higher values than the original tumor, and as a rule they also show very much higher resistance, probably due to the fact that the growing tumor is confined within the lymph node capsule and the cells are pressed more closely together. The progressive variation of the capacity of a tumor from the part which is mainly or wholly neoplastic, to that which is mainly or wholly normal is most important from a theoretical standpoint. The interesting point is that as one proceeds outward from the wholly neoplastic tissue the rate of decrease in the capacity is far from correspondent to the rate of decrease in the number of cells which can positively be identified as tumor cells provided that they are infiltrating diffusely through the tissue. If, as seems certain, the capacity of a tissue is a phenomenon referable to the individual cells of the tissue, and if the number of tumor cells is in reality as small in these locations as it seems to be, the conclusion is inescapable that something has changed the supposedly normal tissue cells in such a way as to increase their capacity—the something being either the presence of the tumor cells or of

'something' proceeding from them. It is interesting to note, however, that if the tumor cells are confined, as for example when they are growing within a lymphatic, we may find no observable influence of the tumor cell on the capacity of the normal tissue.

*Influence of the Outside Liquid.*—When blocks of the size usually measured in this study are rapidly measured, the influence of the outside liquid on the capacity values is sufficiently small to be negligible. Ringer-Locke solution has been chosen as a standard in order to decrease variation from this cause as much as possible, and it has in fact proved to be fairly satisfactory, even when an extended series of measurements, occupying some hours, has been made on the same block of tissue. That it is by no means perfect, however, is shown by comparing the rate of variation of the capacity of tissues kept in Ringer-Locke solution with the variation when they are preserved in a moist chamber. The changes in capacity which are observed when the solution in contact with them is varied, especially as regards solutions containing calcium, are of great interest theoretically, but their consideration is outside the limits of this paper.<sup>6</sup>

### *The Diagnostic Value of Tissue Capacity*

*General.*—It was fully expected, when this investigation was undertaken, that while measurements of this sort, carried out on a large number of neoplastic and normal tissues might, when taken in the mass, give results of interest, on the other hand the measurements in individual cases would have little significance on account of the variations due to variations in the local constitution of the tissue. It has been a constant surprise to find that this has not been the case: *The capacity of malignant tumors of the breast is so consistently larger than that of normal tissues in the same location or of benign tumors as to make its estimation in any individual case clearly of diagnostic value.* This statement is true with the proviso that comparisons be made in patients of about the same age for we find—a point of great theoretical interest—that there is a very pronounced



<sup>6</sup> See Waterman, loc. cit.

connection between the capacity of the tissues here studied and the age of the patient, the capacity decreasing with age.

The relationship between the variables of capacity, malignancy and age in our series has been plotted in Figure 4, in

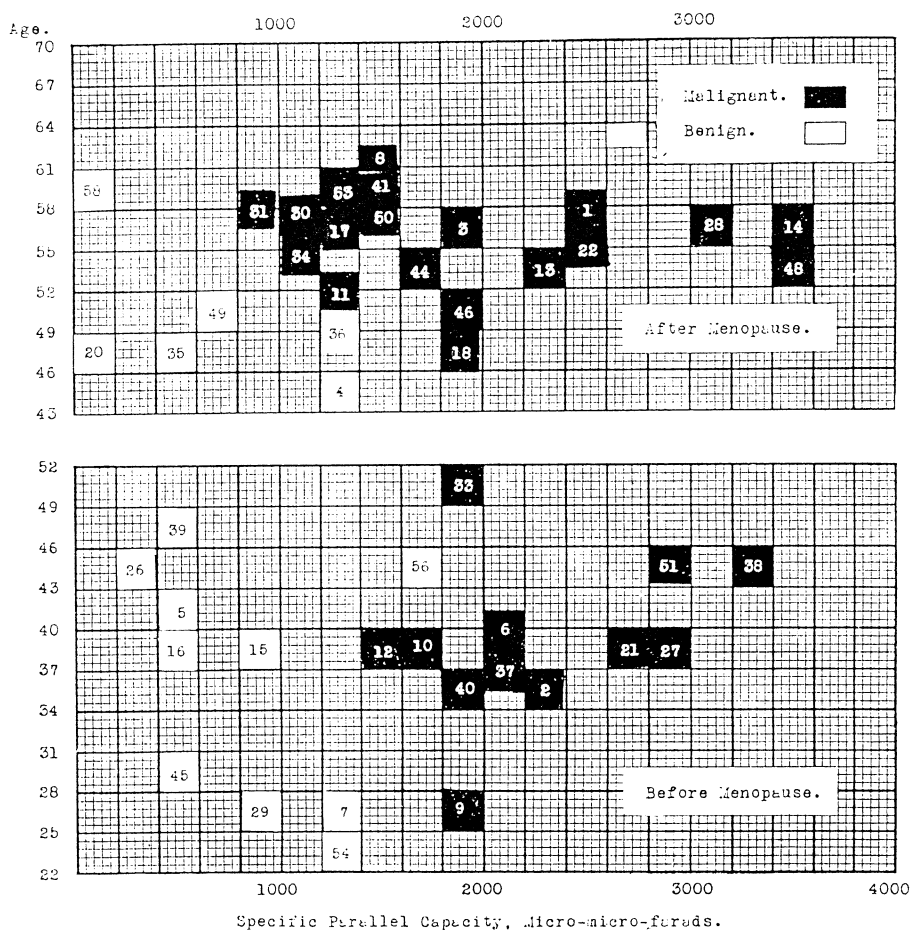


FIG. 4.

Although this point is still uncertain, our present data indicates that the function of menstruation may have some influence on the capacity values. We have accordingly plotted the cases separately according to whether or not the menopause has occurred.

which black squares indicate malignant tumors, and the white benign tumors.<sup>7</sup> The numbers in the squares refer to the num-

<sup>7</sup> The criteria for malignancy used in this study are closely similar to those used by Greenough and Simmons, see Greenough (7). The classification of breast tumors which has been followed is that of Warren (8; 9).

bers of the cases in the case list in which the more important clinical and pathological data are given. Whenever, as is usually the case, more than one block from a given tumor was measured, the largest value for the capacity was chosen; for a few typical cases all such measurements are given in the case list. In each case, the measurements have been checked by the microscopical examination of longitudinal sections of the block measured, and usually also by cross sections, cut parallel to the face of the block.

It will be seen that there is a very satisfactory separation between the tumors classified as malignant and those which are benign. How clear the separation actually is can only be decided when more material is accumulated and when the records of the patients are completed. The most pronounced interference with the clear separation is due to the two benign cases, Nos. 36 and 56. In one of these cases, No. 36, that of a papillary cyst adenoma, the decision as to the benign or malignant character is more difficult than in any other of the benign tumors measured. The other breast of this patient had been removed a year previously for the same condition. The threatening character of these tumors is well established, and this tumor in particular shows numerous histological evidences of a tendency to malignant degeneration. Certain elements in the history and pathological findings in No. 56 indicate that this tumor was of a more or less threatening character. Tumors had existed in both the breasts for many years, and, as stated above, had once before been removed. An aunt had died of cancer of the breast. These tumors were always painful during menstruation. They were removed by local excision and gross examination showed them to be fibro-adenomata, the hospital pathologist stating that they had no capsule. In Figure 5 are given the gross appearance of this tumor, a low power photomicrograph of the section longitudinally through the center of the cylinder measured, and a high power photomicrograph. The tumor is evidently a periductal fibroma of the intercanalicular type in which the fibrous tissue has become extensively hyalinized, sometimes to the point of complete cell

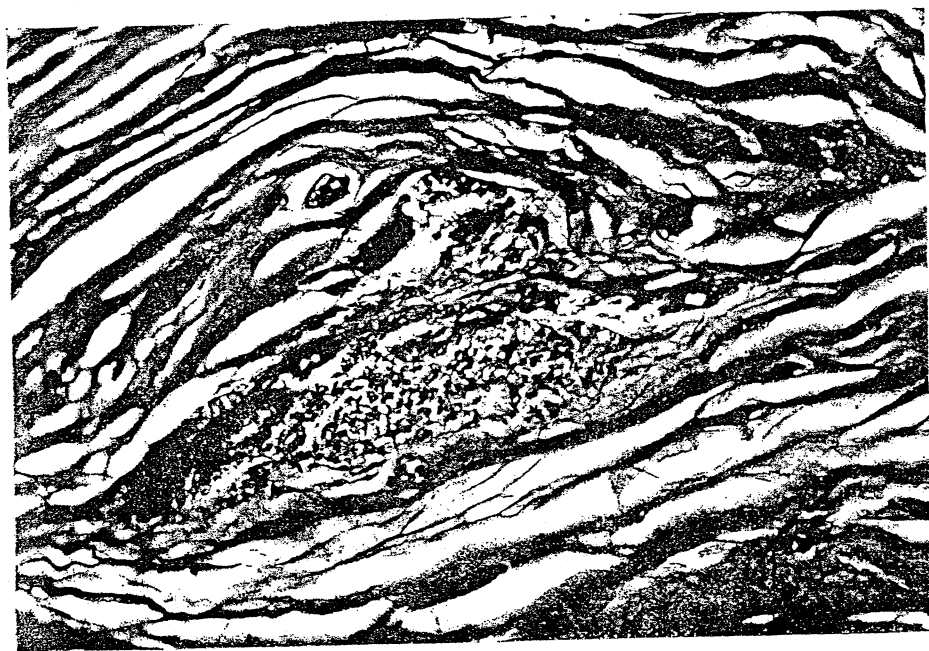
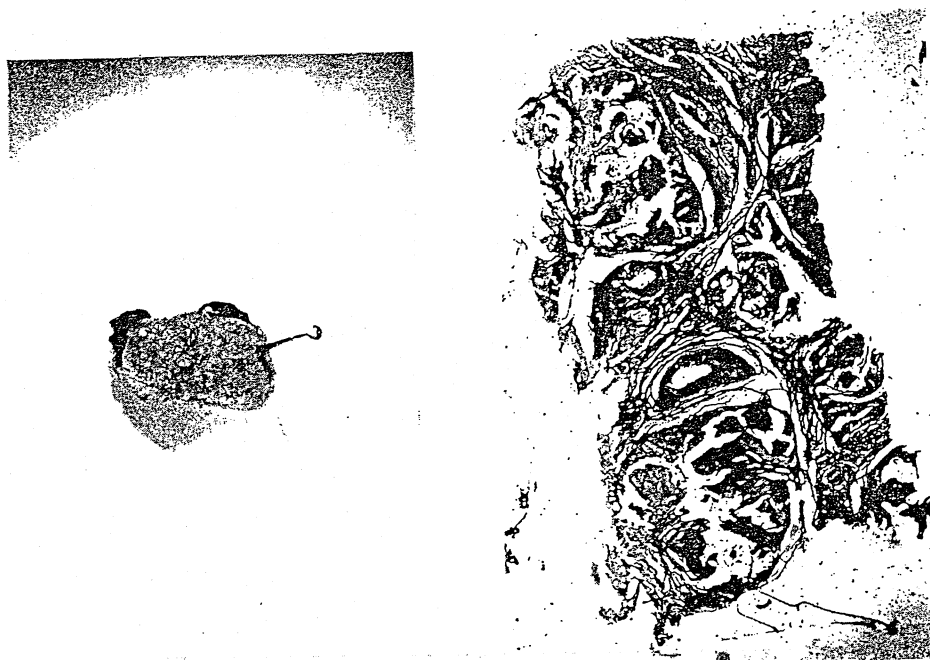


FIG. 5.


destruction. At some points the epithelium shows a certain tendency to proliferate but taking the case as a whole there is little or no histological evidence of a tendency to malignancy, with the possible exception of such appearances as are shown in the high power field.


No. 9 is a case which from the history and pathological findings would be classified with Nos. 36 and 56 as a borderline tumor but nevertheless it is definitely malignant. The patient was a young woman showing the definite, though early development of an adenocarcinoma in a small tumor which had remained stationary for three years. A local excision of the tumor was made as there was no suspicion of its malignant character which was first suspected from the capacity findings; a complete operation was performed later. This is the only case in this series in which such an error in diagnosis occurred.

In judging the value of capacities which fall in the borderline of the chart, the occurrence of diffuse cellular necrosis is of importance because of its important influence upon the capacity of the tumor. Massive necrosis, as elsewhere stated, may be accompanied with complete disappearance of the capacity and it is to be fully expected that diffuse necrosis will cause the capacity to diminish. We note especially that a tumor which has been radiated prior to operation will have a low capacity even though the radiation is insufficient to cause a serious amount of cellular necrosis. Nos. 10 and 11 of the cases with border-line capacity values (see also No. 46 in the case list) illustrate these points. In No. 11 especially, a radiated cancer of great malignancy in which general metastasis and death occurred early, there was so much necrosis in the blocks of tissue studied as to raise the question whether it should not have been omitted from the chart entirely.

As would be expected, capacity not only allows a separation of malignant and benign tumors, but there appears to be a general relation of the capacity to the type of tumor. A comparison of the capacities with the data given in the case list tends to show that for any age (1) those tumors which have the lowest capacity are of the very slow growing types



such as the pure fibromata. From this stage in fairly direct relation to increasing capacities we find (2) tumors in which the epithelial elements have become more pronounced; (3) tumors in which irregularity of structure increases progressively until the clinical border line between benign and malignant tumors is reached; (4) tumors which are definitely malignant; and finally, with the highest capacities, (5) tumors which are most cellular, irregular, invasive, and rapid in growth. Of course there are various exceptions to this scheme, as would be expected considering the fundamental difference in the two methods involved. The most serious of these is No. 12, being of especial importance because, as to its capacity value, it is in a border-line position.<sup>8</sup> Metastases occurred early in this tumor; it appeared to be growing rapidly both from its size and from the occurrence of numerous mitotic figures and it must be considered to be of considerable malignancy. 

Closer correlation between capacity values and types of tumor must be reserved for the future. We may here only say that of the different factors which make up the clinical term malignancy, capacity seems to bear a rather close relationship to the growth power of the tumor. This is illustrated by the following three cases, which are also introduced in order to show the histological appearance of some tumors with very high capacity. Figures 6, 7, and 8 show the histological appearance of sections from these cases, Nos. 28, 38, and 48 respectively. Nos. 28 and 38 are fairly similar histologically. Each consists of tissue which is practically entirely composed of neoplastic epithelial cells. In both cases the cells are large, of considerable, though not extreme variability in form and size and many cells show a mitotic division. There seems to be very little intercellular substance. The histological appearance in No. 48 is very different. This is a malignant degeneration in a tumor of 

<sup>8</sup> Unfortunately the measurements of some of the most important of the border-line cases were made in the earlier stage of our research, when the technic was in process of development and several sorts of error, which are no longer possible, may have affected these earlier findings. As a matter of fact we have reason to believe from the resistance figures that the capacity figures for No. 12 and also for Nos. 9, 10, and 11 are all somewhat low.

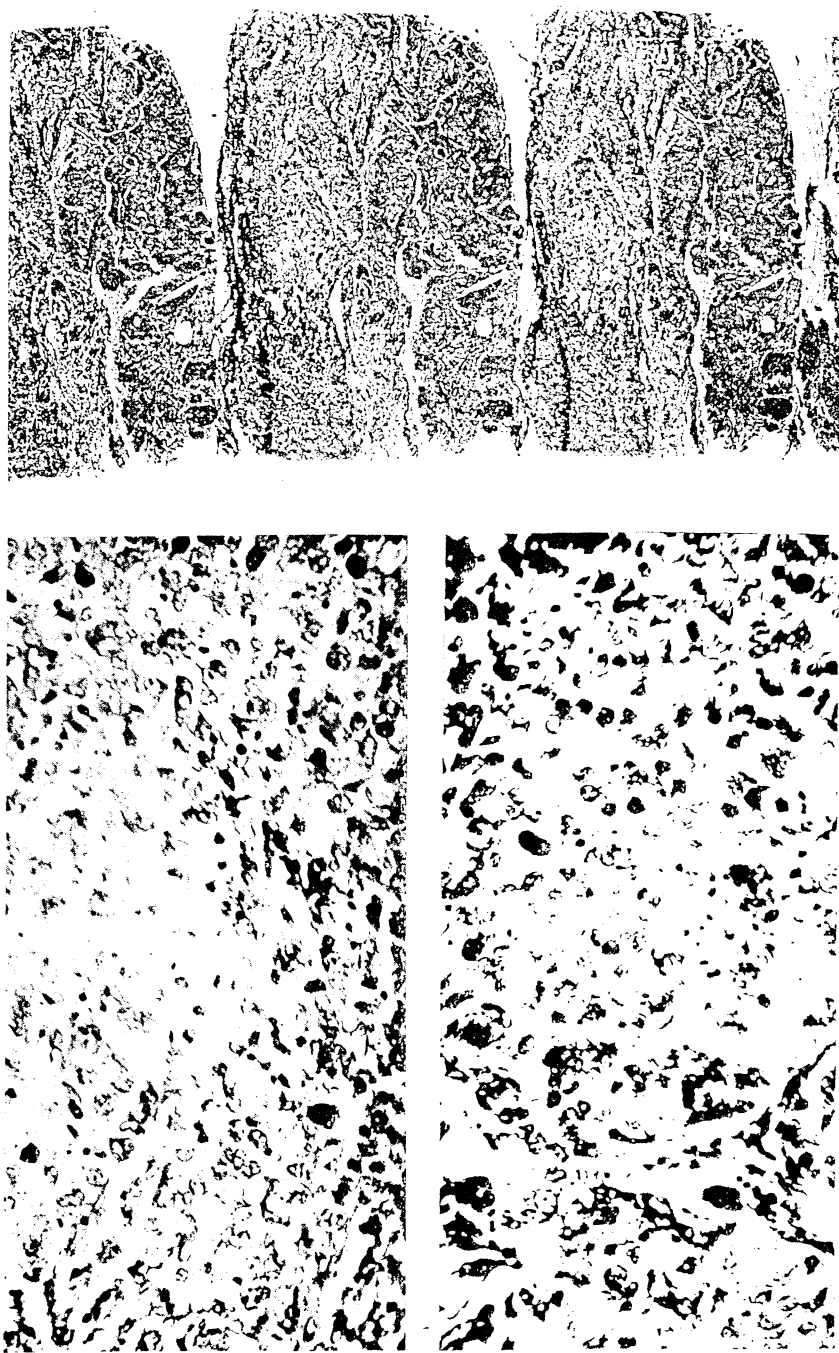


FIG. 6.

very long standing. The histological picture shows the development of large acini into which projects an irregular papilliform epithelium, with an abundant basal capillary blood supply. It is noted that the rate of growth and the capacity values in these three tumors agree closely, although the histological character of two of them is so entirely different from that of the third.

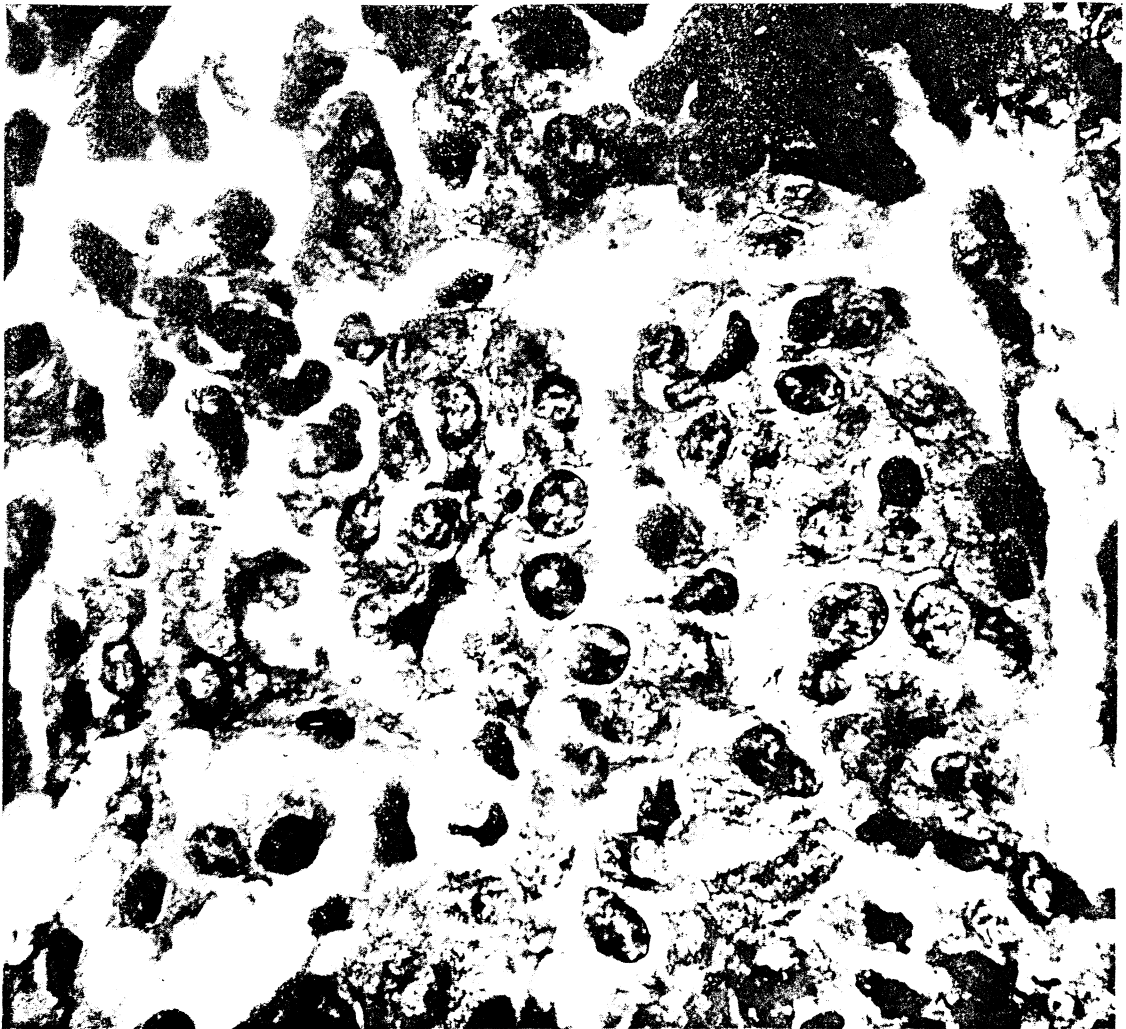


FIG. 7.

Three cases, Nos. 23, 42, and 52, which appear in the case list, are omitted from this chart for technical reasons. They illustrate, however, certain aspects of the investigation which

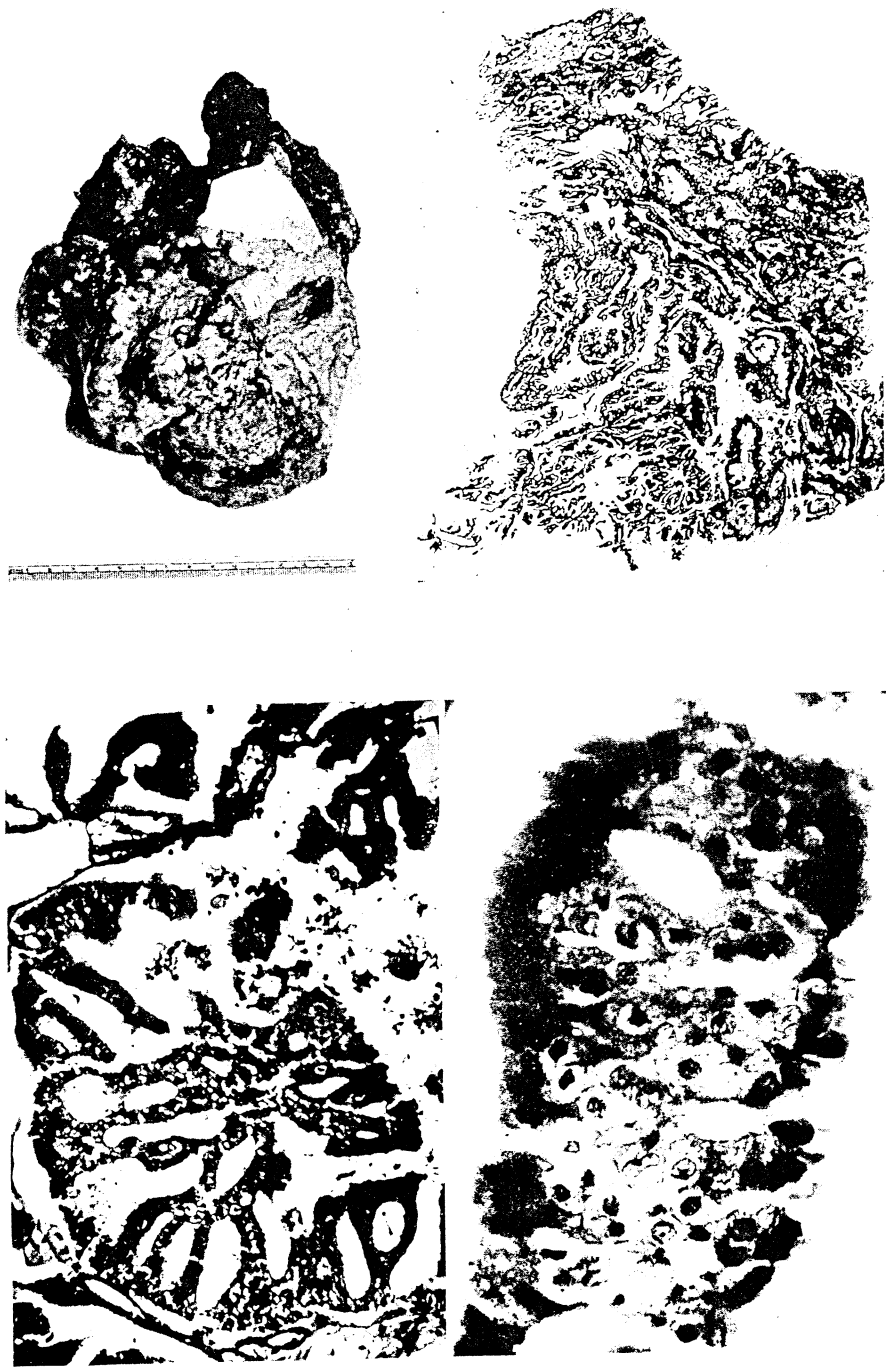


FIG. 8.

are of importance. As may be seen by reference to the case list, No. 23 is a malignant tumor in which the amount of degeneration of the neoplastic elements was extreme in the location studied. The tissue was selected for measurement in the authors' absence by a relatively untrained assistant and does not represent a fair sample of the viable tumor in that particular case. No. 42 is a supernumerary breast, removed in the third month of the first pregnancy. Histologically, this in many ways resembles a simple adenoma. The history, shape and location of the tumor, and presence of structures which indicate a rudimentary nipple and ducts, establishes the classification as a breast in process of physiological lactation hypertrophy. The rate of growth in this case, however, is comparable with that of the most rapidly growing malignant tumors of this series. No. 52, a very small fibroma, was by error placed in formalin for a short time. The gross appearance of the center of the growth did not indicate that fixation had occurred and it was accordingly measured. The findings were so out of line with many other tumors of this type as to make it most probable that the fixative had produced changes.

*Applicability of Capacity Measurements to Problems of Diagnosis.*—The possible theoretical applications of this method we believe are manifold. As for its possible practical use we do not feel that it will necessarily replace or render unnecessary any present standard procedure in the examination of pathological material. We do think however that important added information may conceivably be gained by this method. The great advantage of the procedure is the ease and speed with which results may be obtained. As has been shown the final decision as to benignancy or malignancy when all clinical and pathological evidence is at hand may be predicted in over ninety per cent of the cases, in less time than is required for a rapid microscopical examination of a frozen section, that is, as far at least as tumors of the breast are concerned. It may be stated, however, that while this paper is primarily concerned with the measurements of breast tumors, many measurements of tumors in other locations have convinced us that the method

is just as applicable in a wider field as it is in the limited field which we have considered here.

Future applications of the method may include the rapid searching of large masses of tissue for small concealed centers of malignancy and in certain important cases measurements may be made directly on the patient.

SUMMARY OF HISTORIES OF CASES OF BREAST TUMORS  
OF WHICH THE CAPACITY MEASUREMENTS  
ARE GIVEN IN FIG. 4

*Case 1.* Age, 55 years, married.

Tumor, size of hickory nut, hard and firm, with heavy masses of irregular epithelial cells; many mitotic figures.

Pathological diagnosis: Scirrhus carcinoma; carcinoma simplex.

Duration not stated

Postoperative history: Some evidence of recurrence 15 months after operation.

Scirrhus.....	Capacity 2,560	Resistance 336
Normal gland.....	" 320	" 162

*Case 2.* Age, 36 years, married.

Tumor; hard, fixed, aberrant lobules of irregular cells, infiltrating and invading; normal breast shows low-grade inflammatory change.

Pathological diagnosis: Adenocarcinoma; chronic mastitis.

Duration: Over one year, during which time it enlarged noticeably.

Postoperative history: No recurrence (?) 15 months after operation.

Adenocarcinoma.....	Capacity 2,280	Resistance 269
Mastitis.....	" 1,065	" 116

*Case 3.* Age, 55 years, married.

Tumor,  $1\frac{1}{2}$  cms. in diameter with secondary nodule of same size but more cellular in character than the primary growth.

Pathological diagnosis: The growth varied from the simplex type in the primary nodule to the medullary type in the secondary.

Duration: Not stated.

Postoperative history: No recurrence 15 months after operation.

Primary nodule.....	Capacity 1,625	Resistance 154
Secondary nodule.....	" 1,950	" 244
Normal gland.....	" 386	" 198

*Case 4.* Age, 44 years, married.

Tumor, freely movable, 2 cms. in diameter, with numerous smaller nodules; microscopic examination revealed numerous small cysts and few lobules showing round cell infiltration.

Pathological diagnosis: Chronic cystic mastitis.

Duration: Not stated.

Postoperative history: Had not been heard from 15 months after operation.

Capacity 1,265      Resistance 95

*Case 5.* Age, 41 years, married.

Tumor; a cyst 3 cms. in diameter in conjunction with a small grayish translucent tumor which microscopically is an intracanalicular adenofibroma. The block measured showed no ducts.

Pathological diagnosis: Pure adenofibroma.

Duration: Not stated.

Postoperative history: No recurrence 15 months after operation.

Capacity 460      Resistance 179

*Case 6.* Age, 42 years, unmarried.

Tumor: Irregular hard tumor, 3 cms. in diameter with axillary involvement very hard.

Pathological diagnosis: Duct carcinoma.

Duration: 6 months.

Postoperative history: No recurrence 15 months after operation.

Block 1.....	Capacity 1,670	Resistance 232
" [2.....	" 2,020	" 225

*Case 7.* Age, 27 years, married.

Tumor: 2½ cms. in diameter.

Pathological diagnosis: Intracanalicular adenofibroma showing some aspects of incipient malignancy.

Duration: 6 months; 1 cm. in diameter when first noticed.

Postoperative history: No recurrence 14 months after operation.

Block 1.....	Capacity 1,300	Resistance 168
“ 2.....	“ 1,150	“ 180

*Case 8.* Age, 60 years, married.

Tumor;  $2\frac{1}{2}$  cms. in diameter.

Pathological diagnosis: Carcinoma simplex; scirrhus carcinoma.

Duration: One year; no increase in size noticed.

Postoperative history: No recurrence 4 months after operation.

Carcinoma (in part).....	Capacity 1,020	Resistance 267
“ (mostly).....	“ 1,530	“ 296
Normal gland.....	“ 116	“ 120

*Case 9.* Age, 27 years, married.

Tumor,  $2\frac{1}{2}$  cms. in diameter, freely movable.

Pathological diagnosis: Adenocarcinoma.

Duration: 3 years.

Capacity 1,920      Resistance 356

*Case 10.* Age, 37 years, married.

Tumor:  $3\frac{1}{2}$  cms. in diameter, very firm, freely movable.

Pathological diagnosis: Carcinoma simplex—large size of cells and their tendency to necrosis especially noticeable.

Duration: 2 months.

Postoperative history: No recurrence 14 months after operation.

Capacity 1,760      Resistance 317

*Case 11.* Age, 49 years, married.

Tumor; very large with axillary and supraclavicular metastases.

Intensive radiation resulted in such diminution of the tumor and metastases that it was deemed operable.

Pathological diagnosis: Medullary carcinoma which had suffered cell changes seen in radiated carcinoma; a few nuclei were preserved but no mitoses were seen.

Duration: 5 months.

Postoperative history: Early recurrence followed by death within a few months.

Infiltrating border of tumor.....	Capacity 1,290	Resistance 91
Tumor-block 1.....	“ 1,137	“ 108
“ “ 2.....	“ 1,029	“ 94



*Case 12.* Age, 39 years, married.

Tumor,  $3\frac{1}{2}$  cms. in diameter with axillary metastasis.

Pathological diagnosis: Medullary carcinoma.

Duration: 12 months; when first seen was size of dime; showed volume increase of 36 per cent per month.

Tumor.....	Capacity 1,289	Resistance 213
Metastasis.....	" 1,475	" 712
Normal gland.....	" 314	" 159

*Case 13.* Age, 53 years married.

Tumor: Inoperable carcinoma.

Pathological diagnosis: Medullary carcinoma.

Duration: 3 years.

Capacity 2,400      Resistance 170

*Case 14.* Age, 55 years, married.

Tumor: Axillary and probably distant metastases.

Pathological diagnosis: Scirrhus carcinoma; mitoses not seen.

Duration: Lump present since injury 8 years earlier; second injury 3 years previous. Gradual increase in size during past year.

Capacity 3,460      Resistance 191

*Case 15.* Age, 38 years, married

Tumor: Two small masses in right breast.

Pathological diagnosis: Fibroadenoma.

Duration: Discovered during course of general examination.

Section 1.....	Capacity 932	Resistance 131
" 2.....	" 510	" 110

*Case 16.* Age, 38 years, unmarried.

Tumor: Multiple small tumors in both breasts.

Pathological diagnosis: Fibroadenoma.

Duration: Discovered during general examination.

Postoperative history: No recurrence (?) 12 months after operation.

Capacity 490      Resistance 121

*Case 17.* Age, 56 years, married.

Tumor: Large axillary and supraclavicular gland; considered inoperable but radiation resulted in decreased size and operation was performed.

Pathological diagnosis.

Duration: 21 months; small tumor first noticed was incised by self.

Postoperative history: No recurrence 11 months after operation.

Capacity 1,240      Resistance 136

*Case 18.* Age, 47 years, unmarried.

Tumor: Size of pigeon's egg, with axillary involvement.

Pathological diagnosis: Scirrhus carcinoma.

Duration: Nine years with discharge from nipple for 15 years which became bloody in character 9 months before operation, later ceasing altogether.

Capacity 1,835      Resistance 146

*Case 19.* Age, 66 years, married.

Tumor: Extensive with axillary and distant metastases.

Moderate X-ray therapy did not decrease size.

Pathological diagnosis: Scirrhus carcinoma, infiltrating markedly at border.

Duration: Not stated.

Block from border of tumor.....	Capacity	515	Resistance	160
Block from center of tumor.....	"	630	"	104

*Case 20.* Age, 46 years, married.

Tumor: 3 x 2 cms. in diameter.

Pathological diagnosis: Chronic productive mastitis.

Duration: Lump noticed six years previously, several years after previous operation.

Capacity 129      Resistance 112

*Case 21.* Age, 38 years, married.

Tumor: 8 x 3 cms. in size with extensive axillary involvement.

Pathological diagnosis: Carcinoma simplex.

Duration: 8 months.

Postoperative history: Distant extensive metastases 6 months after operation.

Block from tumor.....	Capacity	2,660	Resistance	160
" " fat.....	"	113	"	802

*Case 22.* Age, 56 years, married.

Tumor: 2-3 cms. in diameter with bandlike extensions and extensive axillary metastases.

Pathological diagnosis: Paget's disease of the nipple, epidermoid elements not apparent.

Duration: Eczematous condition about nipple for 6 years; at examination 9 months before operation, lump about

size of dime was discovered below nipple. Operation was at first refused and radium treatment was given with resultant clearing up of skin condition.

Capacity 2,500      Resistance 188

*Case 23.* Age, 50 years, married.

Tumor: Size of orange with large central fluctuant area and inflammatory skin reaction; consists of large cyst for most part surrounded by very thick, hard, fibrous walls.

Pathological diagnosis: Scirrhus carcinoma with complete degeneration of epithelial elements and axillary involvement.

Duration: Not stated.

Capacity 532      Resistance 194

*Case 24.* Age, 60 years, married.

Tumor: 8 x 8 cms.

Pathological diagnosis: Carcinoma simplex with marked degeneration of epithelial elements.

Duration: 9 months; moderate deep X-ray therapy received before operation.

Capacity 980      Resistance 184

*Case 25.* Age, 63 years, married.

Tumor: 8 x 7 x 4 cms. with axillary involvement; fibrous with central degeneration.

Pathological diagnosis: Infiltrating scirrhus carcinoma.

Duration: 9 months.

Capacity 463      Resistance 230

*Case 26.* Age, 43 years, unmarried.

Tumor: 1 cm. in diameter, smooth, movable and painless.

Pathological diagnosis: Chronic cystic mastitis, with a great deal of fibrosis.

Duration: Three days.

Postoperative history: Since operation 6 months ago, a similar tumor has been removed from other breast.

Capacity 220      Resistance 105

*Case 27.* Age, 39 years, married.

Tumor: Size of walnut; developed from aberrant breast tissue in axilla. Glands not involved.

Pathological diagnosis: Carcinoma simplex, with many mitoses and a pronounced proliferative reaction in the stroma.

Duration: 6 months.

Tumor.....	Capacity 2,860	Resistance 559
Normal gland.....	" 583	" 218

*Case 28.* Age, 57 years, married.

Tumor: 3 cm. in diameter with involvement of axillary gland.

Pathological diagnosis: Carcinoma medullare, largely epithelial with a large number of mitoses.

Duration: 3 months.

Capacity 3,160      Resistance 715

*Case 29.* Age, 27 years, married.

Tumor: Small and freely movable made up for the most part of youthful connective tissue containing many glands and ducts, the latter showing proliferation of basement membrane.

Pathological diagnosis: Fibroadenoma.

Duration: Not stated.

Capacity 980      Resistance 142

*Case 30.* Age, 57 years, married.

Tumor: 10 x 10 x 5 cms. with extensive axillary involvement.

Pathological diagnosis: Carcinoma simplex; mitoses rare.

Duration: "Long duration."

Capacity 1,200      Resistance 505

*Case 31.* Age, 60 years, married.

Tumor: Very large, with axillary involvement.

Pathological diagnosis: Carcinoma simplex; diffuse extension with marked inflammatory reaction; mitoses rare.

Duration: "Long duration."

Capacity 925      Resistance 401

*Case 32.* Age, 66 years, married.

Tumor: 3 cms. in diameter, hard and adherent with axillary involvement and distant metastases.

Pathological diagnosis: Scirrhus carcinoma.

Duration: 6 months.

Capacity 809      Resistance 192

*Case 33.* Age, 49 years, unmarried.

Tumor: Small and round, 2 cms. in diameter. Made up for the most part of connective tissue showing diffuse growth.

Pathological diagnosis: Carcinoma simplex.

Duration: 5 months.

Capacity 1,939      Resistance 271

*Case 34.* Age, 55 years, married.

Tumor: Small recurrence in scar from large tumor which had been removed 13 months ago after an existence of about one year. Consisted of infiltrating cords and large cells in a considerable amount of fibrous tissue.

Pathological diagnosis: Carcinoma simplex.

Block 1..... Capacity 1,202

" 2..... " 1,067

(Diaphragm with cubic hole used)

*Case 35.* Age, 47 years, unmarried.

Tumor: Rather large and nodular, clinically diagnosed malignant.

Pathological diagnosis: Chronic cystic mastitis.

Duration: One month.

Capacity 623 Resistance 141

*Case 36.* Age, 50 years, married.

Tumor: Clinically diagnosed as a duct papilloma; operated one year ago for similar condition in opposite breast.

Pathological diagnosis: Chronic cystic mastitis; many points suggest incipient malignancy; duct epithelium papilliform in many places.

Duration: Not stated.

Capacity 1,265 Resistance 161

*Case 37.* Age, 40 years, married.

Tumor: 5 x 5 x 2 cms. with axillary involvement.

Pathological diagnosis: Varied in different parts of growth from carcinoma simplex to scirrhus carcinoma; considerable degeneration in a few small areas, but for the most part the cells were viable; few mitoses.

Duration: 3½ years.

Carcinoma simplex..... Capacity 2,060 Resistance

" scirrhus..... " 810 ?

*Case 38.* Age, 45 years, married.

Tumor: Size of goose egg.

Pathological diagnosis: Medullary carcinoma; complete central degeneration; numerous mitoses, amitotic.

Duration: Not stated.

(a) Central degenerating

portion..... Capacity 314 Resistance 82

(b) Edge of tumor..... " 3,265 " 371

Same block after 1½

hours..... " 2,180 " 163

(c) Edge of tumor infil- trating (farther out)	"	2,170	"	188
(d) Edge of tumor infil- trating (still farther out).....	"	2,230	"	227
(e) Normal gland.....	"	236, 291	"	428, 324

*Case 39.* Age, 46 years, married.

Tumor: Large and indefinite; breast tissue diffusely thickened.

Pathological diagnosis: Chronic diffuse mastitis.

Duration: 3 weeks.

Block 1.....	Capacity	500	Resistance	111
" 2 (containing some fatty tissue).....	"	274	"	155

*Case 40.* Age, 36 years, married.

Tumor: 10 x 10 x 5 cms. with axillary and other metastases. Received extensive radiation several months ago.

Pathological diagnosis: Adenocarcinoma, very fibrous and with considerable degeneration. Mitoses fairly numerous.

Duration: 4 years.

Tumor.....	Capacity	1,942	Resistance	276
Normal gland.....	"	113	"	379

*Case 41.* Age, 60 years, married.

Tumor: Small consisting of one hard fibrous portion and one very cellular portion, the latter showing recent infarct like degenerative processes.

Duration: 6 months; when first noticed was size of a pea gradually developing into two nodules. (Recent injury.)

Infarcted portion.....	Capacity	1,107	Resistance	254
Scirrhous ".....	"	1,578	"	205

*Case 42.* Age, 26 years, married, pregnant 3 months.

Tumor: Large oblate spheroid tumor in axilla, flattened on under surface, with a well marked capsule and a fibrous cord proceeding from the upper central portion.

Pathological diagnosis: Appears like a simple adenoma but is believed to be a pregnant supernumerary breast.

Duration: Long duration; began to enlarge very rapidly two months before.

Capacity 2,550      Resistance 190

*Case 43.* Age, 63 years, married.

Tumor: Size of walnut, hard, with axillary involvement.

Pathological diagnosis: Dense fibrous tissue containing a few compressed cords of almost completely degenerated necplastic cells. No mitoses seen.

Duration:  $1\frac{1}{2}$  years.

Capacity 750      Resistance 172

*Case 44.* Age, 54 years, married.

Tumor: 8 x 8 x 2 cms. extensive and ill defined with a marked central degeneration; consisted of several small cysts and galactoceles, and small, firm areas about the size of a pea which appeared carcinomatous.

Pathological diagnosis: Chronic cystic mastitis with neoplastic growth along the lymphatics; small areas, carcinoma simplex.

Duration: Not stated.

(a) Dense fibrous tissue with carcinoma.....	Capacity	140	Resistance	228
(b) Dense fibrous tissue with carcinoma.....	"	180	"	151
(c) Carcinoma simplex—some epithelial growth.....	"	1,060	"	211
(d) Carcinoma simplex—nearly all epithelial growth.....	"	1,760	"	233

*Case 45.* Age, 30 years, married.

Tumor: 3 x 2 x 2 cms. small, irregular, elastic. Cut surface was white mottled with a yellowish material which appeared somewhat mucinous.

Pathological diagnosis: Intracanalicular adenofibroma.

Duration: 8 months.

(a) Partly tumor.....	Capacity	303	Resistance	85
(b) Wholly tumor.....	"	545	"	93
(c) Normal gland.....	"	107	"	95

*Case 46.* Age, 50 years, married.

Tumor: Large, sloughing cancer with axillary and distant metastases and skin nodules. Radiation with Roentgen rays made palliative removal possible one month later; a large nodule was found beneath the pectoralis minor.

Pathological diagnosis: Carcinoma simplex, mainly, but varying in type.

Duration: One year.

(a) Main growth—depth 1.0 cm...	Capacity 1,161	Resistance 314
(b) Deep nodule, 3.2 cm.....	" 1,765	" 353
(c) Skin nodule, 0.5 cm.....	" 1,235	" 382
(d) Skin nodule, 0.5 cm.....	" 1,217	" 386
(e) Deep nodule, 4.5 cm.....	" 1,272	" 219
(f) Deep nodule, 4.1 cm.....	" 1,897	" 251

Case 47. Age, 60 years, married.

Tumor: 5 x 5 x 1 cms. in diameter, hard.

Pathological diagnosis: Dense scirrhou carcinoma; no mitoses seen.

Duration: One month.

(a) Block 1, containing fat and area of necrosis.....	Capacity 837	Resistance 204
(b) Block 2.....	" 1,028	" 208
(c) " 3, contains fat.....	" 964	" 173

Case 48. Age, 54 years, unmarried.

Tumor: 7 x 5 x 5 cms. in diameter.

Pathological diagnosis: Malignant degeneration of a papillary cyst-adenoma with still somewhat feeble invasive powers.

Duration: Many years; rapid increase in size began 6 months before.

Block 1.....	Capacity 3,460	Resistance 201
" 2.....	" 2,560	" 284
(After 24 hours)		

Case 49.

Pathological diagnosis: Adeno-fibroma.

Duration: 18 months; benign tumor removed from other breast 18 months ago.

Capacity 735      Resistance 195

Case 50. Age, 58 years, married.

Tumor: 4 cms. in diameter; skin shows marked dimpling.

Pathological diagnosis: Scirrhou carcinoma.

Duration: 3 weeks; tumor removed from other breast 18 years ago.

Capacity 1,505      Resistance 272

Case 51. Age, 43 years, married.

Tumor: 6 x 3 cms.; one end very cellular, other rather fibrous.

Pathological diagnosis: First portion, carcinoma simplex with abundant mitoses; second portion mostly stroma in



which are a few cords of neoplastic cells which show marked degenerative changes, but with an abundant proliferative reaction in the stroma.

Block 1. (cellular).....	Capacity 2,875	Resistance 238
“ 2. (fibrous).....	“ 1,188	“ 126

*Case 52.* Age, 35 years, married.

Tumor:  $1\frac{1}{2}$  cms. in diameter.

Pathological diagnosis: Intracanalicular myxoma.

Duration: 15 months; benign tumors removed from each breast 12 years ago.

Capacity 2,166      Resistance 183

*Case 53.* Age, 60 years, unmarried.

Tumor: 2 cms. in diameter, hard.

Pathological diagnosis: Carcinoma simplex.

Duration: 8 months.

Capacity 1,322      Resistance 231

*Case 54.* Age, 24 years, married.

Tumor:

Pathological diagnosis: Large duct papilloma extending from nipple, 4 to 5 cms. downward.

Duration: Occasional discharge from nipple for nine years; lump noticed for 2 years.

Capacity 1,320      Resistance 184

*Case 55.* Age, 66 years, married.

Tumor: 8 x 5 x 5 cms. in diameter with axillary involvement.

Pathological diagnosis: Carcinoma medullare, rapidly growing but with considerable necrosis.

Duration: 7 months; lump appeared after injury.

Capacity 1,618      Resistance 207

56

76

## REFERENCES

1. GILDEMEISTER, M.: Ueber elektrischen Widerstand, Kapazität und Polarisation der Haut. Pflügers Arch. ges. Physiol., 1919, clxxvi, 84-101.
2. PHILIPPSON, M.: Sur la résistance électrique des cellules et des tissus. Compt. rend. Soc. de biol., 1920, lxxxiii, 1399-1402.
3. PHILIPPSON, M.: Les lois de la résistance électrique des tissus vivants. Bull. de la Classe des sciences, Acad. Roy. de Belg., 1921, No. 6, 387-403.
4. WATERMAN, N.: Physikalisch-chemische Untersuchungen über das Karzinom. Biochem Ztschr., 1922, cxxxiii, 535-597.
5. FRICKE, H.: The electric capacity of suspensions with special reference to blood. Jour. Gen. Physiol., 1925 (in press).

6. FRICKE, H., AND MORSE, S.: The electric resistance and capacity of blood for frequencies between 800 and  $4\frac{1}{2}$  million cycles. Jour. Gen. Physiol., 1925 (in press).
7. GREENOUGH, R. B.: Carcinoma of breast at the Massachusetts General Hospital, 1918, 1919, 1920. Southern M. J., 1925, xviii, 187-192.
8. WARREN, J. C.: The new classification of benign tumors of the breast with an illustrative case. Boston M. & S. J., 1906, clv, 566-568.
9. WARREN, J. C.: The surgeon and the pathologist; a plea for reciprocity as illustrated by the consideration of the classification and treatment of benign tumors of the breast. J. A. M. A., 1905, xlv, 149-165.