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THE SPECIFIC RESISTANCE OF BIOLOGICAL MATERIAL—A COMPENDIUM OF DATA FOR THE BIOMEDICAL ENGINEER AND PHYSIOLOGIST*†

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Abstract—The paper traces the history of, and tabulates determinations of the electrical resistivity of blood, other body fluids, cardiac muscle, skeletal muscle, lung, kidney, liver, spleen, pancreas, nervous tissue, fat, bone, and other miscellaneous tissues. Where possible, the conditions of measurement are given.

1. INTRODUCTION

EVER since the discovery of bioelectric events, there has been an interest in the ability of living tissues to conduct current. Those who have measured bioelectric events arising at a distance from the electrodes have speculated on possible alterations produced by intervening tissues. Although the conducting properties of body tissues and fluids permits measurement at an appreciable distance from a bioelectric generator, the voltages measured are considerably reduced. The fact that the tissues between a bioelectric source and the recording electrodes may possess different electrical characteristics gives rise to the possibility that not only may amplitude be reduced but waveform may be altered, as examplified by noticeable differencs in waveform of the EEG when recorded on the scalp and directly on the cortex. These facts have led many investigators to measure the specific resistance of biological material at different frequencies to better evaluate and to provide some theoretical basis for determining to what extent the volume conductor matrix in which the bioelectric generators are embedded can be considered homogeneous and in what manner inhomogeneities may alter and bias the diagnostic information contained in recordings of bioelectric events. While the matter is still unresolved, there has been published a considerable amount of valuable data relative to the conducting properties of tissues. In addition to their ultimate use in resolving the problem just described, such data have immediate value to the biomedical engineer and physiologist. Not only do the data have relevance to a better understanding of the location and orientation of bioelectric generators, they have value in understanding the bases for techniques in which current is sent into the body via electrodes placed on its surface. For example, in the measurement of blood flow by the impedance method (NYBOER, 1959), currents in the microampere range are caused to flow through the head, thorax limbs, digits, ventricular cavities and other organs. Respiration is measured by changes in transthoracic impedance. The contraction of skeletal muscle, and changes in the

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fat and fluid content of tissues can be detected by impedance. A review of these techniques was presented by GEDDES (1964).

Currents in the milliampere range are passed through electrodes in direct contact with living tissue to stimulate nerve, muscle and gland and to produce anesthesia (GEDDES, 1965). In ventricular defibrillation and electroshock therapy, currents in the ampere range are employed. A knowledge of the resistivities of the structures between electrodes used for these purposes would assist in providing an understanding of the current paths.

Irritable tissues are often stimulated by transmission of electrical energy into a small receiver implanted within a subject. For example, in the unanesthetized animal, various parts of the nervous system have been stimulated by the use of a receiver consisting of a single or three orthogonally-mounted secondary pickup coils implanted below the integument. The terminals of the receivers were connected to electrodes affixed to nervous tissue and electrical energy was coupled into the implanted receiver from an external primary coil. In one series of investigations, the external primary was energized by line voltage. Descriptions of these methods have been presented by LOUCKS (1933), FENDER (1936, 1937), CLARK and WARD (1937) and HARRIS (1947). Similar studies using direct current pulses applied to the primary coil have been described by CHAFFEE and LIGHT (1934), LIGHT and CHAFFEE (1934), LOUCKS (1934) and HARRIS (1948). BICKFORD (1965) has even stimulated irritable tissues in the frog and man without the use of an implanted secondary by discharging a large condenser through a primary coil which induced eddy currents in the body tissues. The eddy currents were of sufficient intensity for stimulation of superficial nerves and muscles.

Radio frequency carriers have also been used to transmit energy into the body. Frequencies ranging from 430 kc/s to 300 Mc/s have been used to transmit stimuli to implanted receivers connected to various parts of the nervous system. Descriptions of these applications were presented by NEWMAN (1937), FENDER (1941), GREIG (1944), GENGERELLI (1948, 1950), LAFFERTY (1949), MAURO (1950), VERZEANO (1953) and RIGGLE (1957). Using the same technique the bladder was stimulated by BRADLEY (1962, 1963) and BOYCE (1964). Cardiac pacemakers using the same principle have been described and are now currently in use. An excellent review of these applications has been presented by ROGEL and MAHLER (1965).

Larger amounts of energy have been transmitted into devices within the body which in turn re-transmit energy to a receiver located outside of the body. For example, this technique was used by FARRAR (1960–61) and HAYNES (1960) for continuous measurement of pressure in the gastrointestinal tract surrounding a swallowed pill receiver–transmitter; the device sometimes being called a transponder.

Still higher power levels have been transmitted to energize other implanted devices. For example, RICHWIEN and MILLNER (1966) used this method to maintain the power supply of a cardiac pacemaker. FURMAN *et al.* (1965) described an implanted cardiac pacemaker in which the batteries were recharged by an external radio transmitter. SCHUDER (1961, 1962, 1963) has investigated the problem of transmitting power levels of 50 W through the thoracic wall of a dog; the goal being to develop the capability of energizing an electric motor to activate an artificial heart.

In all of these energy transport investigations, the efficiency is often low because of the loose coupling between the transmitting and receiving coils and the losses in the intervening biological materials. Calculations of the expected efficiency and the amount of heat developed in the tissues depend upon knowledge of the electrical characteristics of the biological materials.

In view of the obvious importance of the electrical properties of tissue to a wide range of physiological studies, as shown by the foregoing examples, the authors have collected together an extensive body of data which describes one of the most important electrical parameters of biological material, its specific resistance. The data appearing in this paper were derived from the survey of a large amount of literature in the English, French and German languages. Not all of the data screened appear in this report. In many of the investigations, there were obvious errors due to electrode polarization impedance. In such instances the figures listed were considerably different from values presented by those who took care to avoid electrode polarization errors. The authors of this paper selected only the data which indicate that electrode polarization impedance errors were minimal. Included with each entry is pertinent information on the details of the measurement technique (temperature, species, electrode arrangement and orientation and type of current, etc.). A considerable variety of current waveforms ranging from d.c., interrupted d.c., inductorium and sinusoidal have been employed. Wherever possible, these data are included. In most instances, the resistivities were measured *in vitro*; in some, the measurements were made *in vivo*.

The changes in resistivity which accompany the death of cells has long been a controversial issue. Galeotti in 1902 was probably the first to note such changes. In freshly excised tissues he observed an intitial increase followed by a considerable decrease in resistivity. However Galeotti did not maintain careful control of temperature. Crile *et al.* (1922), on the other hand, being careful to maintain the temperature constant, measured the resistivity changes which accompany death. They found that the resistivity of all tissues measured was substantially constant during the first hour after removal from the body. The earliest post-mortem changes were found in the liver (½ hr) and in the brain (1 hr) and the latest in skeletal muscle (2 hr). In all cases resistivity was found to decrease with time. This observation fits with the view that after death, cell membranes lose their ability to maintain their insulating properties and ionic gradients.

2. BODY FLUIDS

In the mammalian species, approx. 70 per cent of the body weight is water. Of this amount, 50 per cent is within the cells that constitute the organism and 20 per cent is designated as extracellular water which includes such fluids as blood, the digestive juices, urine, cerebrospinal fluid, lymph, etc. Because all of the body fluids are rich in dissolved salts it is not surprising that their resistivities are relatively low when compared with those of other biological materials.

In Table 1 are shown the resistivity figures for cerebrospinal fluid (CSF), bile, amniotic fluid, urine and various solutions used in physiological studies. These fluids, all rich in electrolytes, are good conductors and have resistivities much lower than those of other biological tissues. Inspection of Table 1 shows that in general there is a reduction in resistivity with an increase in temperature.

3. BLOOD

Table 2 presents the resistivity values for human, canine, bovine, equine, pig, rabbit and turtle blood and plasma. An examination of Table 2 reveals that the resistivities of all the blood specimens are temperature-dependent and resemble other electrolytes in having a negative coefficient, i.e. an increase in temperature lowers the resistivity. This relationship for human blood is shown in Fig. 1.

The resistivity of blood is also dependent on the percentage of red cells (hematocrit). With fewer red cells, the resistivity is lower, confirming the view that cells act as insulating particles at low frequencies. This relationship, shown in Fig. 2, also illustrates that the resistivity is also related to motion. It has been observed frequently that flowing blood exhibits a lower resistance than stationary blood (Molnar *et al.*, 1953; Sigman *et al.*, 1937; Velick, 1940; Coulter, 1949). Figure 2 shows that the reduction in the resistivity of flowing blood is less with fewer cells in the blood. From the data in Table 2, a typical value for the low frequency resistivity of human blood at body temperature and normal hematocrit (40%) is between 148 and 176 Ω-cm. For canine and bovine blood at body temperature and normal hematocrit the low frequency resistivity values are approx. 130 and 138 Ω-cm respectively.

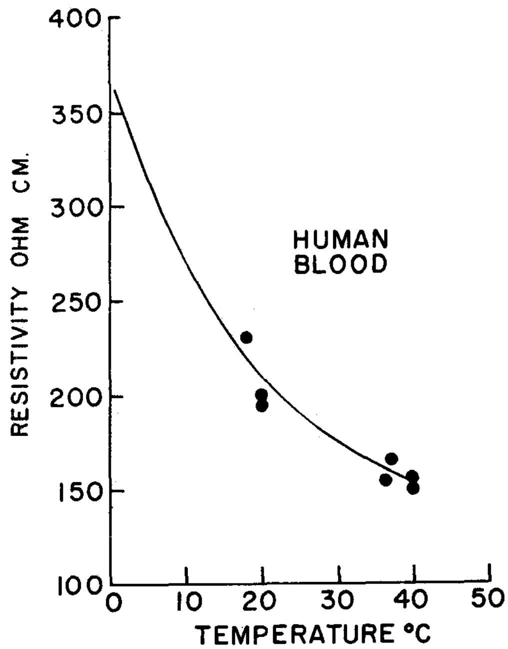

FIG. 1. Resistivity vs. temperature for human blood.

Although there are limited data for plasma resistivity, there is fairly good agreement among the plasma values for the mammalian species. An average low-frequency body-temperature resistivity range for plasma and serum for the human, cow and pig is 66 Ω-cm. Locating this average value derived on Fig. 2, it is seen that the body temperature resistivity values for canine and human blood could easily extrapolate to this zero hematocrit value.

4. CARDIAC MUSCLE

Table 3 lists the resistivity values for cardiac muscle. The values shown for the human are considerably lower than those for other mammalian species. In the dog there is a considerable spread in the values and some degree of temperature-dependence is shown. It is difficult to state a single value for the resistivity of cardiac muscle and the data derived in one investigation (RUSH, 1963) may indicate a reason for the variability. In his study, resistivity was measured parallel and transverse to the direction of the muscle fibers. The two values bear a 2·2:1 relationship to each other. Studies on other types of muscle have produced similar information.

If the techniques used to derive the various resistivity values were valid, then the range of values represents the variations in the different specimens. Although there are insufficient data for the various species, averaging of the more numerous canine data will produce a resistivity figure representative of random orientation of the fibers. The average body-temperature low-frequency resistivity value for randomly-oriented canine cardiac muscle is 750 Ω-cm.

5. SKELETAL MUSCLE

Table 4 lists the values for the resistivity of skeletal muscle in the human, dog, cow, horse, pig, rabbit, guinea pig, frog and turtle. Cursory examination of the table reveals that there is a considerable variability in the values for each species at the same temperature. Part of the variability would appear to be related to the current pathway through the specimen. Skeletal muscle fibers are long and thin, resembling bundles of poorly-conducting tubes filled with electrolytes. It is therefore not surprising that the resistivity measured transverse to the fiber direction is higher than that measured in the direction of the fibers. In those studies which investigated the resistivities along and across muscle fibers, resistivity ratios ranging from 1·8 to 14·4 were observed. Hermann, according to GALEOTTI (1902), observed ratios of transverse to longitudinal resistivities ranging from 4·4 to 9·2 and SAPENGO (1930) reported a ratio of 1·97, clearly demonstrating the anisotropic nature of skeletal muscle. The high values of 14·4 and 11·8 obtained in rabbit and dog muscle may well be accurate, since a four-terminal method was employed (BURGER, 1960–1; RUSH, 1963). Based on the data in Table 4 the average transverse-to-longitudinal ratio of resistivities is 5·26. Bearing in mind the existence of considerable anisotropy, a random-orientation resistivity for skeletal muscle can be derived by averaging the data. The largest number of

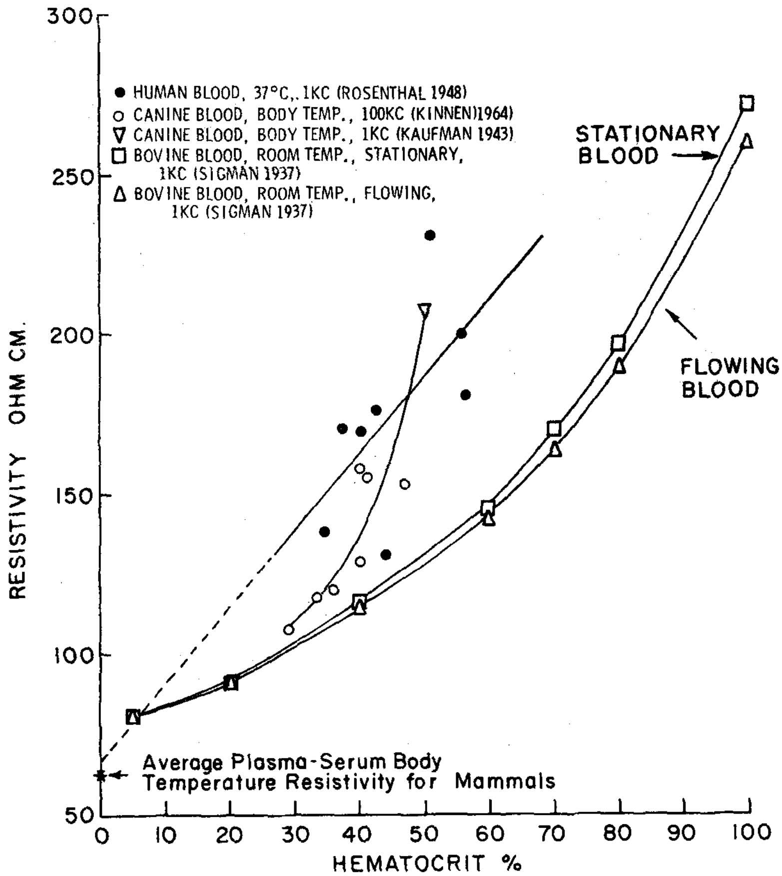

FIG. 2. Resistivity vs. hematocrit.

observations have been on the canine and the average body-temperature low-frequency resistivity value for random orientation is in the vicinity of 950 Ω-cm.

Using 5·26 as the average ratio of transverse to longitudinal resistivity, the transverse and longitudinal resistivity values for canine skeletal muscle are 1600 and 300 Ω-cm. While it may be expected that the resistivity figures for skeletal muscle in other mammals would be similar, the data in Table 4 do not support this assumption.

6. LUNG

Because lung tissue contains considerable amounts of air even when removed from the donor species, the resistivity values might be expected to vary considerably. However, the data in Table 5, with only minor exceptions, show a fairly good agreement for the mammalian species at body temperature and in the low-frequency region. Several investigators have measured lung tissue *in vivo* with different degrees of inflation. In these studies the ratio of the resistivities for maximum inspiration and expiration varied between 1·23–3·41. In the dog, at body temperature and in the low-frequency region, an average resistivity figure (obtained by averaging all of the data) is 1275 Ω-cm. Maximum inspiratory and minimum expiratory values reported by different observers extends from 2170 to 401 Ω-cm. Inspection of the mammalian resistivity values reveals that there is a trend indicative of a negative coefficient of resistivity.

7. KIDNEY

The resistivity values for the kidney of various mammals and the turtle are shown in Table 6. Only a few figures are available for the mammalian species at body temperature and low frequencies. Excluding the values for the human, the average low-frequency values for all of the mammals is 370 Ω-cm at body temperature. Inspection of the low-frequency values presented indicates some tendency toward the existence of a negative temperature coefficient. However the lack of an adequate amount of data precludes further comment.

8. LIVER

The resistivity values for human, dog, cow, pig, rabbit, guinea pig and turtle liver are shown in Table 7. Taking the mammalian species as a whole, in the low-frequency region and at body temperature, there is a considerable lack of agreement among the values. As a group, those in closest agreement are for the canine at body temperature. From the data, an average low-frequency resistivity of 817 Ω-cm (589–1100) can be stated. At room temperature, the 1 Mc/s resistivity value for the human (298) appears to be rather low and that for the guinea pig extremely variable (225–3860) when compared with the other mammals.

9. SPLEEN

Table 8 lists the resistivity values for human, canine, cow, pig and turtle spleen. The canine figures group together fairly well and show a slightly negative temperature coefficient. At the following temperatures, the average low-frequency resistivity figures for canine spleen are: 38°C, 885; 24°C, 1032; 18°C, 1040 and at 12°C, 1187. In the turtle, a cold-blooded animal, the average resistivities are 1820 at 20° C and 1892 at 18° C.

10. PANCREAS

Table 9 lists both low- and high-frequency resistivity values for cow and pig pancreas. Unfortunately, the literature does not provide an adequate number of measurements for comparison. The values listed must, therefore, be used with caution because at audio frequencies there appears to be a positive coefficient of resistivity while in the radio-frequency range the reverse is true.

11. NERVE TISSUE

Table 10 lists the resistivity figures for specimens of the nervous system. As in other tissues in which there are well-defined long fibers, there are notable differences between transverse and longitudinal resistivities. Ratios of transverse to longitudinal resistivities are found to vary between 5·7 and 9·4. In addition remarkable differences in resistivity exist between grey and white matter, that of the latter being many times higher. The average low-frequency body-temperature resistivity for cow–pig, and rabbit brain is 580 Ω-cm. Rabbit cerebellum exhibits an average resistivity of 670 Ω-cm. Average values for rabbit and cat grey and white matter are 284 and 682 respectively, measured at body temperature in the low-frequency region.

12. FAT

The resistivity data for human and canine fat are shown in Table 11. Unfortunately there are no human data for the low-frequency region. The figures that are available indicate a resistivity of 2180 Ω-cm at 1 Mc/s for specimens between body and room temperature and an average resistivity of 2733 Ω-cm at 27°C in the 200–900 Mc/s region with a spread of values extending from 1100–5000 Ω-cm. For canine fat, the average low-frequency resistivity at body temperature is 2880 Ω-cm with a spread of values extending from 1000–5000 Ω-cm. If the data for cow and pig fat are included with that for the dog, the average low-frequency body temperature value for resistivity is 2720 Ω-cm.

13. BONE

Of all of the tissues in the body, the resistivity value for bone is the most variable. This is probably not too surprising, since bone is so varied in composition. For example, the skull consists of two dense, poorly-conducting bony tables separated by a spongy region containing blood, a good conductor. Electrically the skull mimics a leaky capacitor rather than a resistor. Similarly, the long bones are in reality poorly-conducting tubes filled with highly-conducting vascularized marrow, the seat of red cell production. Therefore, the values listed in Table 12 should be taken as indicative of the difficulty in the measurement of the resistivity of bone and, accordingly, are to be used with reservation.

14. MISCELLANEOUS

The high-frequency (200 and 500 Mc/s) resistivity values for parts of the bovine eye are shown in Table 13. The single value for human skin in Table 13 is open to speculation since the specimen measured included subcutaneous fat and the object of the authors study was to study the distribution of heat in diathermy procedures. Additional data will be required before a definite resistivity value can be stated for skin.

15. BODY SEGMENTS

In a few studies, segments of the body have been considered as conductors and values designated as resistivity have been reported. However, caution must be exercised in interpreting the meaning of resistivity as applied to such segments. Implied in the determination of resistivity is the existence of a known current-density distribution between the potential-measuring electrodes. In inhomogeneous conductors, current-density distribution is not uniform and is extremely difficult to specify. Therefore, the resistivity values listed in Table 14 for such biological structures should be used with discretion.

16. DISCUSSION

Although many resistivity measurements appear in the literature, there are many tissues which have not as yet been measured. In addition, many of the values presented by the various workers are not in good agreement, despite care to avoid electrode polarization errors. However, it must be pointed out that most biological structures are composed of cells and hence exhibit different properties in different directions. The range of resistivities presented for the same tissue may reflect this feature of biological material. In addition, excised samples carry along with them various amounts of body fluids and standardization of the technique for inserting such samples into conductivity cells presents its own difficulties and probably widens the range of resistivity values. Moreover, as CRILE (1922) and others have observed, there are seasonal, environmental, age and disease-linked changes as well as those which accompany the physiological function of the various tissues.

The resistivity values presented in the tables in this paper are those derived from gross samples of biological material. In using the values, caution must be exercised and generalizations about small samples should be avoided. When small, closely-spaced electrodes are in contact with small samples of biological material, the nature of the cellular structure will become a factor which cannot be neglected. In addition, when physiologically active structures are between small electrodes, large resistance changes will be observed to accompany the depolarization and repolarization of these tissues when they propagate their action potentials. Under these conditions it is difficult to obtain truly representative resistivity values.

17. CONCLUSION

From the data presented in the tables, a few broad generalizations can be made relative to the conducting properties of biological materials. Among those with the highest conductivity, i.e. the lowest resistivity, are the cell-free fluids, e.g. urine, amniotic fluid, bile, cerebrospinal fluid and plasma. The addition of cells (in the normal percentage) to plasma decreases the low frequency conductivity by a factor of about 2·5.

Less well conducting than blood are liver and spleen tissue. Although brain conducts better, and skeletal muscle less well, on the average than these three tissues, the considerable degree of anisotropy present in skeletal muscle and brain precludes generalization about their conducting properties. Noteworthy however is the fact that grey matter, consisting as it does of a large number of nerve cell bodies, conducts better than white matter, which consists of fiber tracts which have their own anisotropy like skeletal muscle. Among the poorest conductors in the warm-blooded animals are lung, fat and bone.

From the data presented in the tables, two other generalizations appear to be valid. Firstly, biological fluids and nearly all tissues exhibit a negative temperature coefficient of resistivity, i.e. the conductivity increases with increasing temperature. Secondly, in most tissues, with the possible exception of those which exhibit a considerable degree of anisotropy, the resistivity values are not strongly frequency-dependent in the range extending from d.c. to a few hundred kc/s.

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LA RESISTANCE SPECIFIQUE DES TISSUS BIOLOGIQUES—UN TABLEAU DE VALEURS DESTINES AUX PHYSIOLOGISTES ET INGENIEURS BIOMEDICAUX

Sommaire—Cet article présente l'historique et les résultats de l'évaluation de la résistivité électrique du sang et d'autres liquides biologiques, du muscle cardiaque, des muscles du squelette, des poumons, des reins, du foie, de la vesicule biliaire, du pancréas, des tissus nerveux, des vaisseaux, des os et de divers autres tissus. On indique les conditions de mesure lorsque cela est possible.

DER SPEZIFISCHE WIDERSTAND BIOLOGISCHEN MATERIALS—EIN DATENKOMPENDIUM FUR BIOLOGISCH-MEDIZINISCHE TECHNIKER UND PHYSIOLOGEN

Zusammenfassung—In dieser Arbeit wird die historische Entwicklung der Bestimmung des elektrischen Widerstands beschrieben. Tabellierte Daten für den elektrischen Widerstand von Blut, anderen Körperflüssigkeiten, Herzmuskel, Skelettmuskel, Lunge, Niere, Leber, Milz, Pankreas, Nervengewebe, Fett, Knochen und verschiedenen anderen Geweben werden zusammengestellt. Wenn möglich, werden die Meßbedingungen angegeben.

Table 1. *Body fluids*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
C.S.F.						
Human	64·6(64·0–65·2)	1 kc/s–30 kc/s	24·5	Not given	Radvan-Ziemnowicz, 1964	
Cat	65·7(65·5–66·1)	1 kc/s–30 kc/s	24·5	Not given	Radvan-Ziemnowicz, 1964	
Rabbit	55·9 aver. (51–62)	1 kc/s	39	2	Crile, 1922	
Bile						
Cow–pig	60	Audio	37	2	Osswald, 1937	
	78	Audio	20	2	Osswald, 1937	
	59	50 Mc/s	37	2	Osswald, 1937	
	76	50 Mc/s	20	2	Osswald, 1937	
Rabbit	66·2 aver. (61–72)	1 kc/s	39	2	Crile, 1922	
Amniotic fluid						
Sheep	65	1 kc/s	25	2	Unpublished	Measured after 2 days of refrigerated storage
	49	1 kc/s	37·5	2	Unpublished	
Urine						
Cow–pig	30	Audio	37	2	Osswald, 1937	
	39	Audio	20	2	Osswald, 1937	
Physiological solutions						
Saline	72	d.c.	18	4	Burger, 1943	
Saline 0·9%	57 aver. (56–58)	200–900 Mc/s	27	2	Schwan, 1953	
Tyrode	52	Not given	37	?	Freygang, 1955	
Saline 0·9%	70	1 kc/s	20	2	Unpublished by authors	
	50·5	1 kc/s	37·5	2	Unpublished by authors	
3 M KCL	4·28	1 kc/s	20	2	Unpublished by authors	
	3·26	1 kc/s	37·5	2	Unpublished by authors	
	3·85	—	23·5	—	Frank, 1959	
	3·70	—	38	—	Frank, 1959	
Saline 1%	55·5	—	23·5	—	Frank, 1959	
	50·0	—	38	—	Frank, 1959	
Saline 2M	7·14	—	23·5	—	Frank, 1959	
	5·88	—	38	—	Frank, 1959	

Table 2. Blood

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human blood	150	d.c.	40	4	Burger, 1960–61	
	155	20 c/s–5 kc/s	40	4	Burger, 1960–61	
	165 aver. (148–176)	1 kc/s	37	2	Rosenthal, 1948	Normal subjects
	137·8	1 kc/s	37	2	Rosenthal, 1948	34·4% hematocrit
	170·3	1 kc/s	37	2	Rosenthal, 1948	37·2% hematocrit
	169·1	1 kc/s	37	2	Rosenthal, 1948	40·2% hematocrit
	176·0	1 kc/s	37	2	Rosenthal, 1948	42·5% hematocrit
	131·2	1 kc/s	37	2	Rosenthal, 1948	43·9% hematocrit
	230·9	1 kc/s	37	2	Rosenthal, 1948	50·9% hematocrit
	199·8	1 kc/s	37	2	Rosenthal, 1948	55·6% hematocrit
	180·0	1 kc/s	37	2	Rosenthal, 1948	56·4% hematocrit (all calculated values)
	160	d.c.	37	4	Burger, 1943	
	154 aver. (of two methods)	120 kc/s	36·3 aver.	2 and 4	Molnar, 1953	Flowing venous blood
	200	d.c.	20	4	Burger, 1960–61	
	195	20 c/s–5 kc/s	20	4	Burger, 1960–61	
	230	d.c.	18	4	Burger, 1943	
	363	120 kc/s	1·3	2 and 4	Molnar, 1953	Flowing blood
Human plasma	63 aver. (61–67)	1 kc/s	37	2	Rosenthal, 1948	Normal subjects
	100	d.c.	18	4	Burger, 1943	
	70	d.c	Body	4	Burger, 1943	
Dog blood	108	100 kc/s	Body	2	Kinnen, 1964	29% hematocrit
	118	100 kc/s	Body	2	Kinnen, 1964	33% hematocrit
	120	100 kc/s	Body	2	Kinnen, 1964	36% hematocrit
	129 and 158	100 kc/s	Body	2	Kinnen, 1964	40% hematocrit
	155	100 kc/s	Body	2	Kinnen, 1964	41% hematocrit
	153	100 kc/s	Body	2	Kinnen, 1964	47% hematocrit
	156–243	Inductorium	38	2	Galeotti, 1902	Measured within 1 min
	207 aver. (185–230)	1 kc/s	Body	2	Kaufman, 1943	Approx. 50% hematocrit
Dog serum	138 aver. (98–178)	1 kc/s	Body	2	Kaufman, 1943	
Cow blood	145	20 c/s–5 kc/s	38	4	Burger, 1960–61	
	131	d.c.	37	4	Burger, 1960–61	
Cow–pig blood	137 aver. (119–152)	Audio	37	2	Osswald, 1937	
	192 aver.	Audio	20	2	Osswald, 1937	

Continued opposite

Table 2. Blood—continued

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Cow blood	190	d.c.	20	4	Burger, 1960–61	
	180	20 c/s–5 kc/s	20	4	Burger, 1960–61	
	169·6 aver. (164·5–174)	1 kc/s	Room	2	Sigman, 1937	Stationary 70% cells
	164 aver. (159–168)	1 kc/s	Room	2	Sigman, 1937	Flowing at 15 cm/sec—70% cells
	271·75	1 kc/s	Room	2	Sigman, 1937	100% cells stationary
	249·75	1 kc/s	Room	2	Sigman, 1937	100% cells flowing—15 cm/sec
	116·15	1 kc/s	Room	2	Sigman, 1937	40% cells stationary
	114·65	1 kc/s	Room	2	Sigman, 1937	40% cells flowing—15 cm/sec
	80·75	1 kc/s	Room	2	Sigman, 1937	5% cells stationary
	80·75	1 kc/s	Room	2	Sigman, 1937	5% cells flowing—15cm/sec
	196·5 aver.	1 kc/s	Room	2	Sigman, 1937	80% hematocrit—stationary
	189·25 aver.	1 kc/s	Room	2	Sigman, 1937	80% hematocrit flowing—15 cm/sec
	145·4 aver.	1 kc/s	Room	2	Sigman, 1937	60% hematocrit—stationary
	142·25 aver.	1 kc/s	Room	2	Sigman, 1937	60% hematocrit flowing—15 cm/sec
	91·5 aver.	1 kc/s	Room	2	Sigman, 1937	20% hematocrit—stationary
	91·35 aver.	1 kc/s	Room	2	Sigman, 1937	20% hematocrit flowing—15 cm/sec
Cow–pig blood	91 aver.	25–100 Mc/s	37	2	Osswald, 1937	
	133 aver.	25–100 Mc/s	20	2	Osswald, 1937	
	99 aver.	25–100 Mc/s	37	2	Osswald, 1937	
Cow blood	89 aver. (80–96)	200–900 Mc/s	27	2	Schwan, 1953	
Cow plasma	65	20 c/s–5 kc/s	40	4	Burger, 1960–61	
Cow–pig serum	62·5	Audio	37	2	Osswald, 1937	
	83	Audio	20	2	Osswald, 1937	
Cow plasma	90	20 c/s–5 kc/s	20	4	Burger, 1960–61	
Calf serum	89·4	87 kc/s–4·52 Mc/s	21·6	2	Fricke, 1926	
Cow–pig serum	62·5	25–100 Mc/s	37	2	Osswald, 1937	
	83	25–100 Mc/s	20	2	Osswald, 1937	
Horse red cells	3890	1 kc/s	25	2	Philipson, 1920	Centrifuged and packed
	840	400 kc/s	25	2	Philipson, 1920	Centrifuged and packed
	410	1 Mc/s	25	2	Philipson, 1920	Centrifuged and packed
	285	2 Mc/s	25	2	Philipson, 1920	Centrifuged and packed
	232	3·5 Mc/s	25	2	Philipson, 1920	Centrifuged and packed
Rabbit blood	128 (117–136)	1 kc/s	39	2	Crile, 1922	
	129–176	Inductorium	39	2	Galeotti, 1902	
Turtle serum	120	Inductorium	16	2	Galeotti, 1902	
	110	Inductorium	20	2	Galeotti, 1902	
	103 aver.	Inductorium	24	2	Galeotti, 1902	
	91 aver.	Inductorium	30	2	Galeotti, 1902	
	78 aver.	Inductorium	38	2	Galeotti, 1902	

Table 3. *Cardiac muscle*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Human	106 aver. (83–130)	200–900 Mc/s	27	2	Schwan, 1953	Autopsy material (aver. values)
	132	1 Mc/s	Near room temp.	2	Hemingway, 1932	2–3 hr after death
Dog	563	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Transverse to fibers
	252	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Parallel to fibers
	965 aver.	10 c/s	Body	2	Schwan, 1956–57	Anesthetized animal
	1250	10 c/s	Body	2	Schwan, 1955	Anesthetized animal
	925	100 c/s	Body	2	Schwan, 1956–57	Anesthetized animal
	1150	100 c/s	Body	2	Schwan, 1955	Anesthetized animal
	215 aver. (207–224)	1 kc/s	Body	2	Kaufman, 1943	Anesthetized animal
	875 aver. (750–1000)	1 kc/s	Body	2	Schwan, 1956	Anesthetized animal
	825 aver. (700–950)	1 kc/s	Body	2	Schwan, 1955	Anesthetized animal
	845	1 kc/s	Body	2	Schwan, 1956–57	Anesthetized animal
	600	10 kc/s	Body	2	Schwan, 1956–57	Anesthetized animal
	825 aver. (700–950)	10 kc/s	Body	2	Schwan, 1955	Anesthetized animal
	456	100 kc/s	Approx. Body	2	Kinnen, 1964	Left ventricle
	1235	Inductorium	38	2	Galeotti, 1902	Freshly extirpated
Dog–adult	1346	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
	1170 aver.	Inductorium	18	2	Galeotti, 1902	Freshly extirpated
Dog	1368	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
	1380	Inductorium	12	2	Galeotti, 1902	Freshly extirpated
Dog peri-cardium	419 aver. (405 and 434)	1 kc/s	Body	2	Kaufman, 1943	Anesthetized animal
Rabbit	900 aver. (855–952)	1 kc/s	39	2	Crile, 1922	Author reports variability
	1252 aver.	Inductorium	18	2	Galeotti, 1902	Author reports variability
Turtle	1490, 1540	Inductorium	18	2	Galeotti, 1902	Freshly extirpated

Table 4. Skeletal muscle

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human	245	d.c.	37	4	Burger, 1960–61	Longitudinal
	240	100–1000 c/s	37	4	Burger, 1960–61	Longitudinal
	675	100–1000 c/s	37	4	Burger, 1960–61	Transverse
	110	1 Mc/s	Freshly excised	2	Hemingway, 1932	Between body and room temp.
	100 aver. (81–120)	200–900 Mc/s	27	2	Schwan, 1953	Autopsy material
Dog	965	10 c/s	Body	2	Schwan, 1956–57	Anesthetized
	1150 aver. (800–1500)	10 c/s	Body	2	Schwan, 1955	Anesthetized
	1075 aver. (850–1400)	100 c/s	Body	2	Schwan, 1955	Anesthetized
	880	100 c/s	Body	2	Schwan, 1956–57	Anesthetized
	1000 aver. (700–1300)	1 kc/s	Body	2	Schwan, 1955	Anesthetized
	643 aver. (575–711)	1 kc/s	Body	2	Kaufman, 1943	Anesthetized
	830	1 kc/s	Body	2	Schwan, 1956–57	Anesthetized
	875 aver. (750–1000)	1 kc/s	Body	2	Schwan, 1956	Anesthetized
	760	10 kc/s	Body	2	Schwan, 1956–57	Anesthetized
	900 aver. (600–1200)	10 kc/s	Body	2	Schwan, 1955	Anesthetized
	1885	d.c. pulses—0·1 sec	Body	4	Rush, 1963	Anesth. spinal transverse
	2300	d.c. pulses—0·1 sec	Body	4	Rush, 1963	Anesth. spinal transverse
	205	d.c. pulses—0·1 sec	Body	4	Rush, 1963	Anesth. spinal longitudinal
	150	d.c. pulses—0·1 sec	Body	4	Rush, 1963	Anesth. spinal longitudinal
	1040	Inductorium	38	2	Galeotti, 1902	Tongue longitudinal cut
	490	Inductorium	38	2	Galeotti, 1902	Tongue freshly extirpated
Dog–adult	472	Inductorium	24	2	Galeotti, 1902	Tongue
Dog–newborn	834	Inductorium	24	2	Galeotti, 1902	Tongue
Dog	1280	Inductorium	24	2	Galeotti, 1902	Transverse current
	408	Inductorium	24	2	Galeotti, 1902	Longitudinal current
	395	100 kc/s	Room ?	2	Kinnen, 1964	Excised semitendinous
Dog–adult	485 aver.	Inductorium	18	2	Galeotti, 1902	Tongue
	984	Inductorium	18	2	Galeotti, 1902	Transverse current
	470	Inductorium	12	2	Galeotti, 1902	Tongue freshly extirpated
Dog	408	Inductorium	12	2	Galeotti, 1902	Longitudinal current
Dog–adult	1072	Inductorium	12	2	Galeotti, 1902	Transverse current
Cow and Horse	1000	20 c/s–10 kc/s	33	2	Burger, 1960–61	Random orientation
	300	20 c/s–5 kc/s	33	4	Burger, 1960–61	Longitudinal
	700	20 c/s–5 kc/s	33	4	Burger, 1960–61	Transverse
	550	20 c/s–5 kc/s	33	4	Burger, 1960–61	Random orientation
Cow–pig	1000	Audio	37	2	Osswald, 1937	Average values
	1110	Audio	20	2	Osswald, 1937	Average values
	124	50 Mc/s	37	2	Osswald, 1937	
	170	50 Mc/s	20	2	Osswald, 1937	

Continued overleaf

Table 4. Skeletal muscle—continued

Substance	Resistivity (Ω cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Rabbit	1800	20 c/s–1 kc/s	37	4	Burger, 1960–61	Transverse
	1750	20 c/s–1 kc/s	37	4	Burger, 1960–61	Random orientation
	125	20 c/s–1 kc/s	37	4	Burger, 1960–61	Longitudinal
	169 aver. (134–290)	1 kc/s	39	2	Crile, 1922	
	1243	Inductorium	18	2	Galeotti, 1902	Transverse current
	548	Inductorium	12	2	Galeotti, 1902	Longitudinal current
	1720	Inductorium	12	2	Galeotti, 1902	Transverse current
Guinea pig	1840	1 kc/s	25	2	Philipson, 1920	
	1130	10 kc/s	25	2	Philipson, 1920	
	725	20 kc/s	25	2	Philipson, 1920	
	595	50 kc/s	25	2	Philipson, 1920	
	435	100 kc/s	25	2	Philipson, 1920	
	310	200 kc/s	25	2	Philipson, 1920	
	183	600 kc/s	25	2	Philipson, 1920	
	158	1 Mc/s	25	2	Philipson, 1920	
	145	2·5 Mc/s	25	2	Philipson, 1920	
	1280	Inductorium	24	2	Galeotti, 1902	Transverse current
Frog	1535	1 kc/s	25	2	Philipson, 1920	
	418	10 kc/s	25	2	Philipson, 1920	
	250	100 kc/s	25	2	Philipson, 1920	
	172	600 kc/s	25	2	Philipson, 1920	
	165	1 Mc/s	25	2	Philipson, 1920	
	167	2·5 Mc/s	25	2	Philipson, 1920	
	4530 and 4690	Inductorium	20	2	Galeotti, 1902	Gastroc. strongly contracted
	2640 aver. and 4110 aver.	Inductorium	18	2	Galeotti, 1902	Transverse current
	3950	Inductorium	18	2	Galeotti, 1902	Thigh—strongly contracted
	2150	Inductorium	17	2	Galeotti, 1902	Thigh—strongly contracted
	2560	Inductorium	16	2	Galeotti, 1902	Thigh—strongly contracted
Turtle	1350 aver.	Inductorium	18	2	Galeotti, 1902	Transverse current
	740 aver.	Inductorium	18	2	Galeotti, 1902	Longitudinal current

Table 5. Lung

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Human	161 aver. (137–190)	200–900 Mc/s	27	2	Schwan, 1953	Autopsy material
Dog	2390	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Peak inflation—anesth. animal
	1950	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Max. deflation—anesth. animal
	2170	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Average—anesth. animal
	1120	10 c/s	Body	2	Schwan, 1956–57	Anesthetized animal
	900–1600	10 c/s	Body	2	Schwan, 1955	Anesthetized animal
	1090	100 c/s	Body	2	Schwan, 1956–57	Anesthetized animal
	800–1500	100 c/s	Body	2	Schwan, 1955	Anesthetized animal
	1100	10 c/s–100 kc/s	Body	2	Schwan, 1965	Anesthetized animal
	744–766	1 kc/s	Body	2	Kaufman, 1943	End inspiration anesth. animal
	1227–1367	1 kc/s	Body	2	Kaufman, 1943	Super inflation—anesth.
	401	1 kc/s	Body	2	Kaufman, 1943	Deflation—anesthetized
	800–1300	1 kc/s	Body	2	Schwan, 1955	Anesthetized animal
	1040	1 kc/s	Body	2	Schwan, 1956–57	Anesthetized animal
	750–1000	1 kc/s	Body	2	Schwan, 1956	Anesthetized animal
	950	10 kc/s	Body	2	Schwan, 1956–57	Anesthetized animal
	800–1200	10 kc/s	Body	2	Schwan, 1955	Anesthetized animal
	1530	100 kc/s	Body	2	Kinnen, 1964	Full inspiration
	1345–2100	100 kc/s	Body	2	Kinnen, 1964	Mid inspiration
	1220	100 kc/s	Body	2	Kinnen, 1964	Complete expiration
	1720	Inductorium	24	2	Galeotti, 1902	5 min after extirpation
Dog–adult	1636 aver.	Inductorium	18	2	Galeotti, 1902	
Dog	1840	Inductorium	12	2	Galeotti, 1902	
Dog–adult	1739	Inductorium	12	2	Galeotti, 1902	
Cow–pig	1250 aver.	Audio	37	2	Osswald, 1937	
	345 aver.	50 Mc/s	37	2	Osswald, 1937	
	500 aver.	50 Mc/s	20	2	Osswald, 1937	
Rabbit	1770 aver. (1410–1970)	1 kc/s	39	2	Crile, 1922	
	1864 aver.	Inductorium	18	2	Galeotti, 1902	
	2180 aver.	Inductorium	12	2	Galeotti, 1902	

Table 6. Kidney

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Human	126	1 Mc/s	Near room	2	Hemingway, 1932	2–3 hr after death
	94 aver. (81–104)	200–900 Mc/s	27	2	Schwan, 1953	Autopsy material
Cow–pig	111	Audio	37	2	Osswald, 1937	
	119	50–100 Mc/s	37	2	Osswald, 1937	
	143	Audio	20	2	Osswald, 1937	
	147	50–100 Mc/s	20	2	Osswald, 1937	
	204	25 Mc/s	20	2	Osswald, 1937	
Dog	272	Inductorium	38	2	Galeotti, 1902	3 min after extirpation
	600	100 kc/s	Body	2	Kinnen, 1964	
Dog–newborn	380	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
Dog–adult	241	Inductorium	18	2	Galeotti, 1902	
Dog–adult	252	Inductorium	12	2	Galeotti, 1902	
Dog–newborn	410	Inductorium	12	2	Galeotti, 1902	
Dog–newborn	376	Inductorium	12	2	Galeotti, 1902	Freshly extirpated
Guinea pig	449	Inductorium	38	2	Galeotti, 1902	Freshly extirpated
	424	Inductorium	38	2	Galeotti, 1902	Freshly extirpated
	396 aver.	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
	702	Inductorium	18	2	Galeotti, 1902	
Rabbit	391	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
	454 aver.	Inductorium	18	2	Galeotti, 1902	
	685 aver.	Inductorium	12	2	Galeotti, 1902	
Turtle	1065–1143	Inductorium	38 ?	2	Galeotti, 1902	Living tissue
	1175	Inductorium	38 ?	2	Galeotti, 1902	After extirpation
	1038–1048	Inductorium	20	2	Galeotti, 1902	Living tissue
	1925	Inductorium	20	2	Galeotti, 1902	After extirpation
	757	Inductorium	18	2	Galeotti, 1902	Freshly extirpated
	1014–1043	Inductorium	18	2	Galeotti, 1902	Freshly extirpated

Table 7. Liver

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human	298	1 Mc/s	Near room	2	Hemingway, 1932	2–3 hr after death
	128 aver. (92–170)	200–900 Mc/s	27	2	Schwan, 1953	Autopsy material
Cow–pig	833 aver.	Audio	37	2	Osswald, 1937	
	192 aver.	25 Mc/s	37	2	Osswald, 1937	
	182 aver.	50 Mc/s	37	2	Osswald, 1937	
	164 aver.	100 Mc/s	37	2	Osswald, 1937	
	667 aver.	Audio	20	2	Osswald, 1937	
	250 aver.	25 Mc/s	20	2	Osswald, 1937	
	213 aver.	50 Mc/s	20	2	Osswald, 1937	
	200	100 Mc/s	20	2	Osswald, 1937	
Dog	700	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Anesthetized
	1100 aver. (1000–1200)	10 c/s	Body	2	Schwan, 1955	Anesthetized
	840	10 c/s	Body	2	Schwan, 1956–57	Anesthetized
	800	100 c/s	Body	2	Schwan, 1956–57	Anesthetized
	925 aver. (850–1000)	100 c/s	Body	2	Schwan, 1955	Anesthetized
	900	10 c/s–100 kc/s	Body	2	Schwan, 1965	
	900 aver. (800–1000)	1 kc/s	Body	2	Schwan, 1955	Anesthetized
	765	1 kc/s	Body	2	Schwan, 1956–57	Anesthetized
	875 aver. (750–1000)	1 kc/s	Body	2	Schwan, 1956	Anesthetized
	589 aver. (506–672)	1 kc/s	Body	2	Kaufman, 1943	Anesthetized
	685	10 kc/s	Body	2	Schwan, 1956–57	Anesthetized
	775 aver. (700–850)	10 kc/s	Body	2	Schwan, 1955	Anesthetized
	600 aver. (300–900)	100 kc/s	Body	2	Kinnen, 1964	Anesthetized
	1070	Inductorium	38	2	Galeotti, 1902	3 min after extirpation
Dog–newborn	3220	Inductorium	24	2	Galeotti, 1902	
Dog–adult	1010 aver.	Inductorium	18	2	Galeotti, 1902	
Dog	1460 aver.	Inductorium	12	2	Galeotti, 1902	
Dog–newborn	2530 aver.	Inductorium	12	2	Galeotti, 1902	
Dog–newborn	1447	Inductorium	12	2	Galeotti, 1902	
Rabbit	1235 aver. (990–1639)	1 kc/s	39	2	Crile, 1922	Freshly extirpated
	1100 aver. 1885, 3730 aver.	Inductorium	18	2	Galeotti, 1902	
Guinea pig	3700	Inductorium	38	2	Galeotti, 1902	
	3710	Inductorium	38	2	Galeotti, 1902	Freshly extirpated
	2380	1 kc/s	25	2	Philipson, 1920	
	464	200 kc/s	25	2	Philipson, 1920	
	317	800 kc/s	25	2	Philipson, 1920	
	260	2 Mc/s	25	2	Philipson, 1920	
	225	3·5 Mc/s	25	2	Philipson, 1920	
	3860	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
	1335	Inductorium	18	2	Galeotti, 1902	
Turtle	2750 and 2825	Inductorium	38	2	Galeotti, 1902	Living tissue
	2830–2980	Inductorium	20	2	Galeotti, 1902	Living tissue
	2890 and 3065	Inductorium	18	2	Galeotti, 1902	Living tissue
	1556 aver.–2970 aver.	Inductorium	18	2	Galeotti, 1902	Living tissue

Table 8. Spleen

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Human	256	1 Mc/s	Near room	2	Hemingway, 1932	2–3 hr after death
Dog	885	Inductorium	38	2	Galeotti, 1902	Freshly extirpated
	1053	Inductorium	24	2	Galeotti, 1902	Freshly extirpated
Dog–adult	1010 aver.	Inductorium	24	2	Galeotti, 1902	
	1040 aver.	Inductorium	18	2	Galeotti, 1902	
	1196 aver.	Inductorium	12	2	Galeotti, 1902	
Dog	1178	Inductorium	12	2	Galeotti, 1902	Freshly extirpated
Cow–pig	715 aver.	Audio	37	2	Osswald, 1937	
	137 aver.	50 Mc/s	37	2	Osswald, 1937	
	120 aver.	100 Mc/s	37	2	Osswald, 1937	
	833	Audio	20	2	Osswald, 1937	
	175	25 Mc/s	20	2	Osswald, 1937	
	156	50 Mc/s	20	2	Osswald, 1937	
	147	100 Mc/s	20	2	Osswald, 1937	
Turtle	1520–1767	Inductorium	38	2	Galeotti, 1902	Living tissue
	1770–1870	Inductorium	20	2	Galeotti, 1902	Living tissue
	1840–1945	Inductorium	18	2	Galeotti, 1902	Living tissue

Table 9. Pancreas

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Elec-trodes	Reference	Remarks
Cow–pig	770 aver.	Audio	37	2	Osswald, 1937	
	185 aver.	25–100 Mc/s	37	2	Osswald, 1937	
	625 aver.	Audio	20	2	Osswald, 1937	
	250 aver.	25–100 Mc/s	20	2	Osswald, 1937	

Table 10. *Nerve tissue*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Brain						
Cow–pig	588 aver.	Audio	37	2	Osswald, 1937	
	222	25 Mc/s	37	2	Osswald, 1937	
	196 aver.	50 Mc/s	37	2	Osswald, 1937	
	185 aver.	100 Mc/s	37	2	Osswald, 1937	
	910 aver.	Audio	20	2	Osswald, 1937	
	322 aver.	25 Mc/s	20	2	Osswald, 1937	
	244 aver.	50 Mc/s	20	2	Osswald, 1937	
	232 aver.	100 Mc/s	20	2	Osswald, 1937	
Rabbit cerebrum	570 aver. (521–725)	1 kc/s	39	2	Crile, 1922	
Rabbit cerebellum	730 aver. (610–855)	1 kc/s	39	2	Crile, 1922	
Cat—internal capsule	800 aver.	20 c/s–20 kc/s	Body	3	Nicholson, 1965	Transverse to fibers—anesthet.
	85 aver.	20 c/s–20 kc/s	Body	3	Nicholson, 1965	Along fibers—anesthetized
Rabbit cortex	321	5 c/s	Body	4	Ranck, 1963	Anesthetized
	230	5 kc/s	Body	4	Ranck, 1963	Anesthetized
	208 $\pm$ 6	1 kc/s	Body	3	Van Harreveld, 1963	Anesthetized animal
Rabbit white matter	957 (approx.)	1 kc/s	Body	3	Van Harreveld, 1963	Anesthetized animal
Rabbit cerebellum	662–794	1 kc/s	39	2	Crile, 1922	
Rabbit cerebrum	505–621	1 kc/s	39	2	Crile, 1922	
Rabbit spinal cord	576 aver. (386–863)	1 kc/s	39	2	Crile, 1922	
Rabbit cerebral (gray)	438 aver.	1 kc/s	39	2	Crile, 1922	
Rabbit cerebral (white)	746 aver.	1 kc/s	39	2	Crile, 1922	
Cat cortex	222 $\pm$ 9	Square pulses 0·3–0·7 m sec	37	4	Freygang, 1955	Anesthetized animal
Cat white matter	344 (approx.)	0·3–0·7 m sec	37	4	Freygang, 1955	
Cat—spinal cord	138–212	5–10 c/s	Body	4	Ranck, 1965	Longitudinal
	1211	5–10 c/s	Body	4	Ranck, 1965	Transverse

Table 11. *Fat*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human	2180	1 Mc/s	Freshly excised	2	Hemingway, 1932	Between body and room temp.
	1500–5000	200 Mc/s	27	2	Schwan, 1953	Autopsy material
	1300–4000	400 Mc/s	27	2	Schwan, 1953	Autopsy material
	1100–3500	900 Mc/s	27	2	Schwan, 1953	Autopsy material
Dog	1500–3000	10 c/s–100 kc/s	Body	2	Schwan, 1965	
	2500	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Anesthetized animals
	2006 aver. (1808–2205)	1 kc/s	Body	2	Kaufman, 1943	Anesthetized animals
	1000–3000	100 kc/s	Body	2	Kinnen, 1964	
	1500–5000	1 kc/s	Body	2	Schwan, 1956–57	Anesthetized
	3000 aver. (1500–5000)	1 kc/s	Body	2	Schwan, 1956	Anesthetized
Cow–pig	2500 aver.	Audio	37	2	Osswald, 1937	
	2000 aver.	25–100 Mc/s	37	2	Osswald, 1937	
	3850 aver.	Audio	20	2	Osswald, 1937	
	2780 aver.	25–100 Mc/s	20	2	Osswald, 1937	

Table 12. *Bone*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human (thorax)	16,000	Low	Not given	Not given	Lepeschkin, 1951	(ECG spectrum)
Human	1800	1 Mc/s	Freshly excised	2	Hemingway, 1932	Between body and room temperature
Cow–pig	4550 aver.	Audio	37	2	Osswald, 1937	
	3700 aver.	25–100 Mc/s	37	2	Osswald, 1937	
	6250 aver.	Audio	20	2	Osswald, 1937	
	5000 aver.	25–100 Mc/s	20	2	Osswald, 1937	

Table 13. *Miscellaneous*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Eye						
Bovine cortical	198 and 131	300 kc/s and 200 Mc/s	32	2	Pauly, 1964	
Bovine intermediate	285 and 210	500 kc/s and 200 Mc/s	32	2	Pauly, 1964	
Bovine central	530 and 340	500 kc/s and 200 Mc/s	32	2	Pauly, 1964	
Skin						
Human	289	1 Mc/s	Freshly excised	2	Hemingway, 1932	Between body and room temperature

Table 14. *Body segments*

Substance	Resistivity (Ω-cm)	Frequency	Temp. (°C)	Electrodes	Reference	Remarks
Human						
Arm	160	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Corrected for bone and fat
Forearm	470	d.c.	Body	4	Burger, 1943	Transverse
	230	d.c.	Body	4	Burger, 1943	Longitudinal
	330	d.c.	Body	4	Burger, 1943	Geometric mean
Fingers and Hand	280	d.c.	Body	4	Burger, 1943	
Finger	235	d.c.	Body	4	Burger, 1943	Current along finger
Neck	280	d.c.	Body	4	Burger, 1943	
Trunk	415	d.c.	Body	4	Burger, 1943	Along axis of body
Head	840	d.c.	Body	4	Burger, 1943	Trans-temporal
Head (Scalp)	230	d.c.	Body	4	Burger, 1943	Closely spaced electrodes
Thorax	455	d.c.	Body	4	Burger, 1943	Maximum inspiration
	375	d.c.	Body	4	Burger, 1943	Maximum expiration
	463	d.c. pulses 0·1 sec	Body	4	Rush, 1963	
Dog						
Thorax	445	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Intact thorax
	281	d.c. pulses 0·1 sec	Body	4	Rush, 1963	Shell-less heart and lungs