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The Change of Electrical Resistance of Skeletal Muscle of Frog after Death.

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The Change of Electrical Resistance of Skeletal Muscle of Frog after Death.

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Experiment (A).

1. Introduction.

*Hermann*¹⁾ reported experiments which showed that there is a decrease of electrical resistance of muscle after death. *Galeotti*²⁾ observed first an increase in electrical resistance of dog's muscle on death followed by a decrease. *Crile, Hosmer and Rowland*³⁾ reported that the electrical resistance shows a 2% increase followed by a decrease and they attributed it to the autolysis of cell-membrane. *Hemmingway and Collins*⁴⁾ also observed these facts.

From these results noted above it is evident that there is a decrease of electrical resistance of tissues after death.

In this investigation the change in the electrical resistance of frog's muscle was measured with low frequency alternating current at different intervals after death.

2. Method of Procedure.

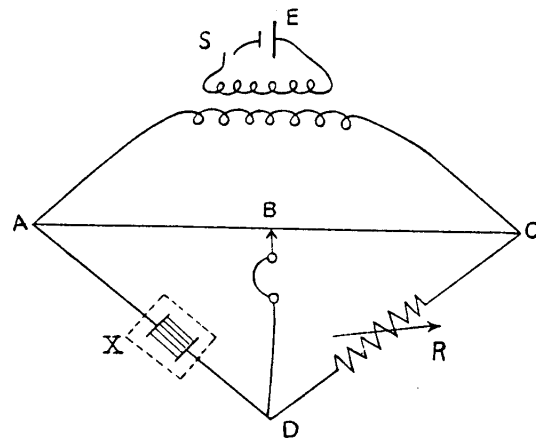
Kohlrausch's method was used of which circuit is shown diagrammatically in Fig. 1.

X, - represents the unknown resistance; R, - a known resistance and AC, - a uniform wire along which a movable contact slides; E, - a 2-volt accumulator which is attached to the primary circuit of an induction coil and the secondary of which is connected to A and C; A telephone headpiece is attached to D and to the sliding contact. The contact is moved along the wire AC until a point B is found where a minimum of sound is heard in the head phone, then by the following formula, the

$$\frac{R}{X} = \frac{BC}{AB} \qquad X = \frac{R \cdot AB}{BC}$$

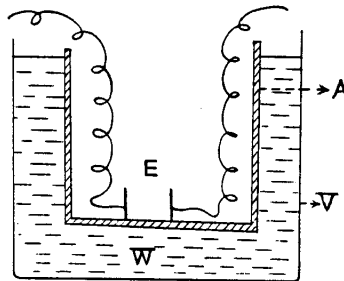
value for X can be calculated since R is known.

Fig. 1.



A thermostat as shown in Fig. 2, was used to hold the material at a constant temperature.

Fig. 2.



A and V are porcelain vessels; W, - water; E, - the electrodes, which were placed in the bottom of the inner porcelain vessel. The electrodes were made of silver plates and were movable along a square woodenpole.

Material used: *M. sartorius* or *M. adductor magnus* taken from living frog and was killed by ammonia vapour. Two ends of the muscle were cut off and a square mass of muscle was used. The material was used within 30 minutes after dissection. The material thus prepared, was placed between the electrodes and the electrical resistance was measured as well as, the length, the weight of the material and the temperature in the vessel noted. As usual, rigor mortis was established within 2-3 hours in muscle and its length was measured carefully with callipers. The specific gravity was measured by *Moll's* method, and found to have an almost constant value of 1.0413. The weight was measured with a chemical balance after rigor mortis was established. The specific electrical resistance can be calculated from these data;

$$\rho = \frac{S.R}{L} \quad S = \frac{W}{G.L} \quad \therefore \rho = \frac{W.R}{L^2.G}$$

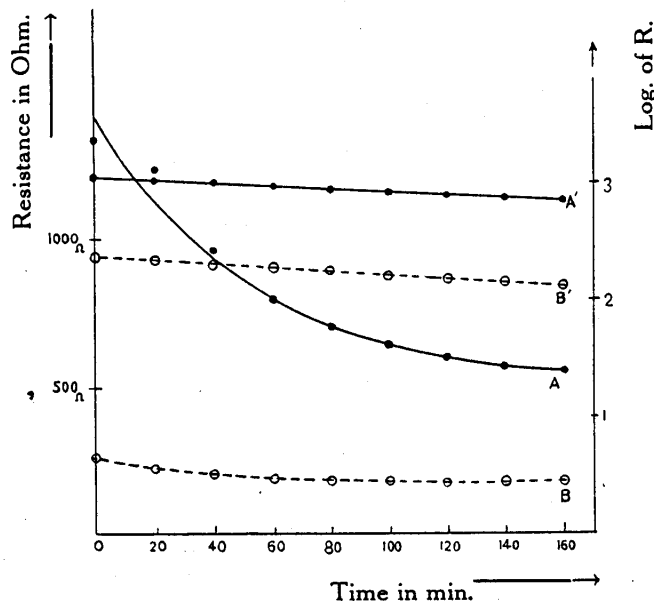
ρ = specific resistance, L = length, W = weight, S = area of section,
 R = resistance measured, G = specific gravity.

The frequency of the oscillator was 400 d.v. per second. The measurements were continued until rigor mortis had plainly set in in the muscle. The experiment continued for 2-3 hours.

3. Results and Discussions.

A typical graph of the electrical resistance of frog's muscle is given in Fig. 3. It decreases rapidly at first and then more slowly later, tending to approach a constant lower value in comparison to the initial resistance. The same changes were observed in the other examples.

Fig. 3.



In Fig. 3, A represents the resistance in ohms in transverse direction; A' = its log.; B = the resistance in ohms in longitudinal direction, and B' = its log..

It is noteworthy that the electrical resistance and its change in the transverse direction to the muscle fibre is much more pronounced than in the longitudinal direction. This was discussed in a former paper (No. 5).

Plotting the electrical resistance of the muscle against time on the rectangular coordinate system, resulted in a logarithmic curve.

If we assume the electrical resistance of muscle is inversely proportional to the concentration of electrolytes in the muscle, it will show the increase of the concentration of electrolytes in muscle in

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the course of time after death. The cause of the increase of electrolytes after death remains to be questioned.

The graph of electrical resistance indicates that the order of the chemical reaction is a unit, i.e. a monomolecular reaction.

Accordingly the constant of this chemical reaction was culculated after the following formula as usual:

$$K = \frac{1}{t} \log. \frac{a}{a-x}$$

K = The velocity constant of the chemical reaction.

t = The time in minutes from the beginning of the experiment to the moment when the measurement took place.

a = The initial electrical resistance.

x = The decrease of the electrical resistance in the time t.

In the following tables,

- (A) 'Transverse' indicates that the electrical resistance was measured in a transverse direction to the muscle fibre.
 (B) 'Longitudinal' indicates that the electrical resistance was measured in a longitudinal direction to the muscle fibre:

Table 1.
(A) Transverse.

t	a - x	log (a - x)	$\log \frac{a}{a-x}$	$\frac{1}{t} \log \frac{a}{a-x} = K$
0	1093	3.073	—	—
20	1008	3.042	0.031	0.0020
40	983	2.991	0.082	0.0020
60	874	2.941	0.132	0.0022
80	824	2.916	0.157	0.0019
100	719	2.857	0.216	0.0022
120	698	2.842	0.231	0.0019
140	638	2.802	0.271	0.0019
160	528	2.725	0.348	0.0021
Temp. = 17.5°C				Km. = 0.0020

(B) Longitudinal.

t	a - x	log (a - x)	$\log \frac{a}{a-x}$	$\frac{1}{t} \log \frac{a}{a-x} = K$
0	305	2.480	—	—
20	294	2.468	0.012	0.0006
40	287	2.456	0.024	0.0006
60	283	2.451	0.029	0.0005
90	266	2.426	0.054	0.0006
110	249	2.398	0.084	0.0007
130	242	2.382	0.098	0.0007
150	241	2.380	0.100	0.0006
Temp. = 17.5°C				Km. = 0.0006

Table 2.
(A) Transverse.

t	a - x	log (a - x)	$\log \frac{a}{a - x}$	$\frac{1}{t} \log \frac{a}{a - x} = K$
0	2085	3.319	—	—
20	1885	3.273	0.046	0.0022
40	1700	3.230	0.087	0.0022
100	1318	3.119	0.200	0.0020
160	883	2.943	0.376	0.0022
220	710	2.850	0.469	0.0021
280	425	2.628	0.691	0.0022
Temp. = 20°C				Km. = 0.0021

(B) Longitudinal.

t	a - x	log (a - x)	$\log \frac{a}{a - x}$	$\frac{1}{t} \log \frac{a}{a - x} = K$
0	286	2.440	—	—
20	257	2.409	0.031	0.0015
40	230	2.361	0.079	0.0015
80	205	2.311	0.129	0.0016
100	184	2.262	0.178	0.0017
120	178	2.250	0.190	0.0016
140	170	2.230	0.210	0.0016
160	167	2.223	0.217	0.0015
Temp. = 20°C				Km. = 0.0016

Table 3.
(A) Transverse.

t	a - x	log (a - x)	$\log \frac{a}{a - x}$	$\frac{1}{t} \log \frac{a}{a - x} = K$
0	980	2.991	—	—
30	885	2.946	0.045	0.0015
50	781	2.893	0.098	0.0014
70	678	2.832	0.159	0.0015
90	674	2.828	0.163	0.0016
110	662	2.821	0.170	0.0018
130	620	2.792	0.162	0.0016
150	572	2.757	0.234	0.0016
170	498	2.698	0.293	0.0016
190	490	2.690	0.301	0.0015
Temp. = 17°C				Km. = 0.0016

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(B) Longitudinal.

t	a - x	log (a - x)	$\log \frac{a}{a-x}$	$\frac{1}{t} \log \frac{a}{a-x} = K$
0	222	2.346	—	—
20	214	2.330	0.016	0.0008
40	206	2.313	0.033	0.0008
60	194	2.287	0.059	0.0009
80	190	2.272	0.068	0.0008
100	180	2.255	0.091	0.0009
120	172	2.233	0.113	0.0009
Temp. = 17°C				Km. = 0.00086

Table 4.

(A) Transverse.

t	a - x	log (a - x)	$\log \frac{a}{a-x}$	$\frac{1}{t} \log \frac{a}{a-x} = K$
0	1217	3.086	—	—
20	1168	3.066	0.020	0.0015
50	1027	3.011	0.075	0.0014
80	937	2.971	0.115	0.0018
110	760	2.880	0.206	0.0016
170	612	2.786	0.300	0.0017
200	534	2.728	0.358	0.0015
230	485	2.683	0.393	0.0015
Temp. = 21°C				Km. = 0.0016

(B) Longitudinal.

t	a - x	log (a - x)	$\log \frac{a}{a-x}$	$\frac{1}{t} \log \frac{a}{a-x} = K$
0	220	2.341	—	—
20	210	2.321	0.020	0.0010
40	201	2.305	0.036	0.0009
60	189	2.278	0.063	0.0011
80	178	2.260	0.081	0.0010
100	166	2.220	0.101	0.0010
120	164	2.215	0.126	0.0010
140	160	2.202	0.139	0.0009
Temp. = 16°C				Km. = 0.0010

Table 5.
(A) Transverse.

t	a - x	log (a - x)	$\log \frac{a}{a - x}$	$\frac{1}{t} \log \frac{a}{a - x} = K$
0	258	2.411	—	—
20	246	2.390	0.021	0.0010
40	235	2.371	0.041	0.0010
60	220	2.341	0.070	0.0011
80	215	2.331	0.081	0.0010
100	210	2.321	0.090	0.0009
120	209	2.319	0.092	0.0007
140	184	2.262	0.149	0.0010

Temp. = 16°C

Km. = 0.0009

(B) Longitudinal.

t	a - x	log (a - x)	$\log \frac{a}{a - x}$	$\frac{1}{t} \log \frac{a}{a - x} = K$
0	2041	3.315	—	—
20	1591	3.204	0.111	0.0055
40	1290	3.146	0.169	0.0041
60	920	2.962	0.353	0.0058
80	915	2.960	0.355	0.0044
100	818	2.911	0.404	0.0040
120	772	2.891	0.424	0.0035
140	513	2.711	0.604	0.0043
160	466	2.669	1.046	0.0048

Temp. = 21°C

Km. = 0.0046

From these results it may be stated that the concentration of the electrolytes in the frog's muscle after death increases according to the monomolecular reaction. The nature of this electrolyte was investigated further and will be reported in Experiment (B.).

Experiment (B). Experiment with Monoiodacetic Acid.

1. Introduction:

As above mentioned, the change in the electrical resistance after death agrees very well with the hypothesis of the monomolecular reaction which indicates that this change is due to autolysis of

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glycogen to lactic acid. *Lundsgaard*⁶⁾ discovered that this chemical change can be stopped by monojodacetic acid. Therefore the author attempted to arrest the gradual decrease of the electrical resistance of the frog's muscle after death by treating with monojodacetic acid.

2. Method of Procedure:

Exactly the same method as in the first experiment was employed.

Material used: The frog's muscle, soon after dissection was immersed in 10000× monojodacetic acid in Ringer and killed by deprivation of oxygen e.g. by the bubbling of H_2 gas into Ringer. The time from dissection to measurement was about one hour.

3. Results and Discussion:

Fig. 4.

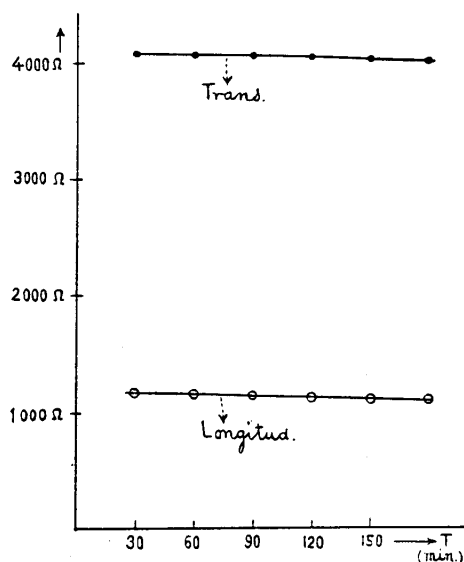


Table 6.

Time Direction	0 min.	60 min.	120 min.
Trans.	4140	4135	4130
Trans.	4100	4050	4010
Trans.	2600	2550	2500
Longitud.	740	740	735
Longitud.	800	740	730
Longitud.	1000	960	925

As Fig. 4 and Table 6 show the change in the electrical resistance of the frog's muscle treated with 0.1 % monojodacetic acid solution is nearly constant over a period of two hours. But the change is not totally checked probably owing to the incomplete imbibition of the solution into the muscle. From these data it may be said that the electrical resistance of the frog's muscle is for the most part due to the autolysis of glycogen to lactic acid. The quicker decrement of the resistance of dead muscle in equal interval of time in transverse direction than in the longitudinal, may be explained by the assumption of the impairment of the semipermeability of the membrane of muscle fibre with the lapse of time.

Conclusions:

- 1) The electrical resistance of the frog's muscle after death decreases logarithmically.
- 2) This change is much more pronounced in a transverse direction to the muscle fibre than in the longitudinal direction.
- 3) Assuming the decrease of electrical resistance of muscle after death is to be due to the liberation of electrolyte, it seems that this change proceeds as a monomolecular reaction.
- 4) This fact gives strong support to the assumption that the decrease of electrical resistance of muscle after death is due to the liberation of lactic acid from glycogen in it.

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