male meiotic phenomena in the male gonads of *D. melanogaster* are strikingly similar to the reduction divisions in known hybrids, whether plants or animals. The abnormalities of the maturation division in this species, so much investigated by too purely experimental means, seem to show beyond any reasonable doubt that it is of hybrid origin. This is the more obvious because meiosis in certain other species of Drosophila to judge from the published descriptions is quite normal. It seems unfortunate that the experimentalists *pur sang* should in the main choose for investigation such freaks as the Boston fern, species of Oenothera and above all *Drosophila melanogaster*. The results of experimental work would apparently be much more permanent and convincing were the subject material less abnormal than in the cases mentioned above.

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HIGH AND LOW FREQUENCY MEASUREMENTS WITH LAMINARIA[1]

An interpretation of the resistance changes in *Laminaria* when bathed in solutions of NaCl, $CaCl_2$, etc., is of importance in the theory of permeability. Several possibilities exist beside alteration of the ionic permeability of the protoplasm.

(1) There may be a change in the specific resistance of the intercellular substance corresponding to its well-known hardening in calcium and the softening in sodium salts. (2) The specific resistance may remain constant while the cross section expands or contracts, as observed by Kotte in the walls of algae. Or (3) a change in the electrical capacitance of the cell surface might alter the effective impedance of the whole system.

None of these interpretations is clearly indicated by measurements taken at one frequency only, so that it seemed desirable to extend the readings made at 1,000 cycles by Osterhout,[1] both to zero frequency and to very high frequencies, in order better to locate the seat of change.

Direct current measurements were made by using magnesium metal ribbons dipping into the sea water of the electrode cups. (The Osterhout apparatus was used for holding the column of *Laminaria* discs. Sea water was kept in the end cups while the discs were bathed in various solutions.) These ribbons acted as reversible electrodes to the magnesium ions, which are present in the sea water in sufficient number to carry small currents without much polarization. They were likewise balanced by another pair of similar electrodes in the adjacent arm of the bridge.

The $CaCl_2$ curves of Osterhout were nicely duplicated with this apparatus and the direct current readings agreed exactly with 1,000 cycle ones taken alternately with the same electrodes. At 40,000 cycles the readings were about 20 per cent. lower, at the highest point, and nearly the same at death.

For very high frequencies a thermocouple ammeter-voltmeter apparatus was employed through the kindness of Dr. Kenneth S. Cole, who made the measurements. Values were obtained at the following frequencies: 6,000, 13,750, 45,500, 115,500, 375,000, 1,090,000, 10,800,000 cycles. Not enough points were obtained to construct good curves, but the essential fact was developed that while the low frequency readings rose and fell during injury, the high frequency readings showed much less change, and at 10^7 cycles the values were nearly constant through the whole run. Whether this constant value is actually that of the dead ohmic resistance must be answered by future research. It is nearly as low, however.

Meanwhile we may conclude from these results that:

(1) There is no change in the specific conductivity of either the inter- or intracellular material during treatment with $CaCl_2$ or NaCl, since the high frequency value remained constant.

(2) The changes in impedance are not due to changes of capacitance since the latter would not affect the direct current readings, which agree entirely with the 1,000 cycle values. What capacitance there is has little effect on the impedance except at much higher frequencies.

(3) Changes in cross section may occur but are not sufficient to explain the results.

We may therefore hold to the interpretation advanced by Osterhout that the observed resistance change is really a change in the permeability of protoplasm to ions. Since the resistance may rise 60 per cent. or more above the normal value in sea-water, it is evident that there must be considerable ionic exchange in the normal state. The reconcilement of this fact to the relatively low permeability of *Valonia* and *Nitella* to ions is a task toward which present experiments are directed.

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THE ABSOLUTE ZERO OF INTERNAL ENERGY AND ENTROPY, AND THE CORRESPONDING INERTNESS OF MATTER

The controllable internal energy and entropy of a substance or mixture, which varies with the volume v and absolute temperature T, the writer has shown

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[1] Osterhout, W. J. V., "Injury, Recovery and Death, in Relation to Conductivity and Permeability," Philadelphia and London, 1922.

to be zero according to thermodynamics when the substance is at $T=0$ under its vapor pressure, which is zero, and that besides the adiabatic of zero entropy corresponds to $T=0$ (*J. Phys. Chem.* 31, 747, 937 (1927)). In the deduction the theorem (deduced thermodynamically) was used that the specific heat is a positive quantity. A simple proof of this theorem which depends only on our fundamental notions of heat is given in a letter by the writer in the March number of the *Philosophical Magazine,* and the deduction of the above results is thus rendered simpler and more straightforward. Experimental evidence of the truth of these results is afforded mainly by the important investigations of G. N. Lewis and his associates on the third law of thermodynamics, which is included in these results.

The above zero corresponds to minimum values of the quantities involved, and hence by the help of the axiomatic notion that the minimum does not involve discontinuities, a number of differential properties were deduced by the writer (*J. Phys. Chem.,* 31, 747; 937, 1559 (1927)). It may be pointed out that the same notion is tacitly involved in Gibbs' investigation of phase equilibrium. One of the properties deduced is that the first differential coefficient of the internal energy with respect to the temperature, or the specific heat, is zero at $T=0$. This corresponds to Nernst's theorem, and hence all the experimental evidence of this theorem is also evidence of the soundness of the deduction of the foregoing results. Another important result is that the differential coefficient of the specific heat is zero. This is sustained by the experiments of Kammerlingh Onnes on the specific heat at low temperatures, and the theoretical investigations of Einstein and Debye on the connection between specific heat and quanta. We may therefore regard the above results as fairly well established theoretically and experimentally; further experiments would be most desirable in the case of mixtures.

A set of the differential properties obtained express that the first and second differential coefficient with respect to the temperature of the internal energy, pressure and volume of a condensed substance at $T=0$ initially under its vapor pressure, are each zero corresponding to the volume or pressure being kept constant, or to the substance being kept under its vapor pressure. Some of these results will be shown in a subsequent paper to hold for other states at $T=0$. Thus the properties of the specific heat mentioned also hold for a substance in the vaporous state at $T=0$. Matter thus possesses *a remarkable inertness to temperature changes at $T=0$.* This suggests that *at $T=0$ an atom differs considerably in nature from that it has at higher temperatures,* this difference being no doubt associated with *a change in electronic configuration.*

This is further suggested by the remarkable properties deduced by the writer (May number of *J. Frank. Inst.*) that at $T=0$ the internal heat of evaporation L is zero, and that a substance in the gaseous state at $T=0$ possesses an abnormally large specific heat which may amount to thousands of calories per gram. These results may be explained by supposing that during evaporation an atom undergoes a change in electronic configuration which gives rise to a decrease in internal energy equal to the work done against the atomic forces of attraction over repulsion, and that on heating the vapor an approximately equal increase in internal energy takes place, and a corresponding reversal of the change in electronic configuration. That a substance may become unstable and explode near $T=0$ (*J. Phys. Chem.,* 31, 1669, (1927)) indicates the possibility of electronic rearrangements taking place which give rise to large atomic forces of repulsion.

Another proof that $L=0$ at $T=0$ may be given here, and that there is an associated abnormally large specific heat of the vapor. On multiplying the well-known thermodynamical equation

$$\left(\frac{\partial U}{\partial v}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_v - p$$

by ∂v, where U denotes the internal energy and p the pressure, and integrating, it may be written

$$L = T\frac{\partial}{\partial T}\int p.\,\partial v - \int p.\,\partial v$$

But $\int p.\,\partial v = \sum MRT$, where M is a constant, and hence the right hand side is zero when $T=0$. This result combined with an equation obtained by a simple thermodynamical cycle (May number *J. Frank. Inst.*) gives

$$C_\infty - C = \frac{L_m}{T_m}$$

where L_m is a finite value of the internal heat of evaporation at the temperature T_m near $T=0$, and C_∞ and C are the *average* specific heats of the vapor and condensed substance respectively over the range T_m. Thus C_∞ has a value of the order of 10 or 100 cals, and is one of the abnormal specific heat effects associated with a vapor close to $T=0$. It is not unlikely that C may occasionally have an abnormally large value close to $T=0$, but at present its existence has not been proved thermodynamically nor found experimentally.

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