tracting cells can be grown not only from the pieces of hearts of young embryos, but from the heart muscle of a fourteen-day chick embryo.

These experiments, therefore, give direct evidence for the myogenic theory of the heart beat.

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ON MOLECULAR COHESION. A PRELIMINARY STATEMENT

There is much uncertainty both about the laws and nature of molecular cohesion. The attraction has been supposed to vary inversely with the square, the fourth, fifth, seventh, or even the ninth power of the distance between molecular centers; and whether cohesion is of the nature of magnetic, electric, or gravitational attraction, or whether it is of a kind of its own, is uncertain. Its relation to gravitation, on the one side, and to atomic affinity, on the other, is unknown.

1. *The Derivation of the Value a/V^2 in Van der Waals's Equation.*—The value of a/V^2 in Van der Waals's equation represents molecular cohesion. If each molecule has a mass of cohesion, M, and if the molecules attract each other inversely as the fourth power of the distance, as Sutherland suggests, then the attraction between two molecules is $M^2K/v^{4/3}$, v being the volume of one molecule. If there are $1/v^{2/3}$ molecules in a surface of one sq. cm. of a gas or liquid, the pressure per sq. cm. will be M^2K/v^2. If each molecule attracts only its neighbors, owing to the fact that the cohesion does not penetrate matter, then the internal pressure will be the same as the attraction of each double layer of molecules and instead of M^2K/v^2 we may multiply numerator and denominator by N^2, where N is the number of molecules in the volume V. This makes N^2M^2K/V^2, which is the value a/V^2 of Van der Waals's equation. It has the advantage over the usual form, a/V^2, in that the various constituents of "a" appear at once.

2. *The Latent Heat of Vaporization.*—Mills discovered the empirical relationship that the internal latent heat of vaporization divided by the difference of the cube roots of the densities of the liquid and vapor was a constant, except near the critical temperature. His equation was: $L - E_e = K(d^{1/3} - D^{1/3})$. He assumed that the internal latent heat of vaporization, or $L - E_e$, where L is the total latent heat and E_e that part of it consumed in doing external work, represented only the energy consumed in separating the molecules. He was struck by the resemblance of this equation, when transformed into $L - E_e = K'(1/v^{1/3} - 1/V^{1/3})$, to that of Helmholtz representing the heat given out from the sun on contraction from the radius CR to the radius R, or $3M^2K(1/R - 1/CR)/5$. The latter equation is derived by the gravitational law. Mills, therefore, concluded that the attraction of molecules must also follow the gravitational law and vary inversely as the square of the distance. The error in Mills's reasoning is the assumption that $L - E_e$ represents only the work of overcoming molecular cohesion. It represents not only this but also the heat consumed by the expansion of the molecules from their volume in the liquid to their volume in the vapor, for the molecules certainly expand on passing from the liquid to the vapor. If the heat thus consumed by molecular expansion is E_m, then since the difference in molecular cohesive energy in the vapor and liquid is $N^2M^2K(1/v - 1/V)$, $L - E_e = N^2M^2K(1/v - 1/V) - E_m$. Near the critical temperature E_m becomes nearly zero, and at the critical temperature this goes into the form $L - E_c = N^2M^2K(1/v - 1/V)$. Since the heat rendered latent by the expansion of the molecules increases as we go downward from the critical temperature, the value $L - E_e$ must become constantly greater than $N^2M^2K(1/v - 1/V)$, by the amount E_m. This is found to be the case. For example in methyl propionate $(L - E_e)/(d - D)$ has the following values in absolute units taking gram mol quantities:

Temperature	$(L-E)/(d-D)$	N^2M^2K/Wt
100°	3.417×10^{11}	
200°	3.030	

250°	2.598	
256°	2.396	
257°.4 (critical)		2.353×10^{11}

The fact that Mills's equation gives a constant is, then, rather evidence against the hypothesis that the attraction is inversely as the square of the distance, instead of in favor of that hypothesis. The real representation of the gain in molecular potential energy on passing from the liquid to the vapor is more probably, as Sutherland and others have shown, the expression $N^2M^2K/(1/v-1/V)$, and not $K(1/v^{1/3}-V^{1/3})$. The former expression is in harmony with the conclusion that the attraction is inversely as the fourth power of the distance.

3. *The Radius of Action of the Molecules.*—The most recent calculations of the radius of action of molecules make it about 1.2 to 2×10^{-7} cm., or about two molecule diameters in the liquid state. As means of measurement have improved, the radius has shrunk. The distance between the centers of ether molecules in the liquid state at 20° is about 6×10^{-8} cm. Einstein and Sutherland have computed that the radius of action is proportional to, and very nearly equal to, the distance apart of the molecular centers. Kleeman has computed it as a little less than a molecular diameter. The only interpretation of Einstein's result is that the molecules attract only their immediate neighbors and hence, as Mills suggested, molecular cohesion does not penetrate matter. This makes it possible for the cohesion to vary inversely as the fourth power of the distance; since, if the cohesion penetrated matter like gravitation and the attraction was inversely as the fourth power, the cohesional mass is so enormously greater than the gravitational mass that the cohesional attractions of two masses would, when the masses were near, greatly surpass their gravitational attractions.

4. *Computation of the Cohesive Mass, M.*—Since the value "b" of Van der Waals's equation is not constant, but varies both with the volume and temperature, it is impossible to compute M^2K from the deviation from constancy of the pressure-volume product of a gas. M^2K may, however, be computed from the surface tension, as follows: S is the tension along a line one cm. in length and the depth of the surface film, or $fv^{1/3}$. Then $S/v^{1/3}$ is the surface tension per sq. cm. across the surface film, if the latter is one molecule deep, as it probably is at absolute zero, for which temperature the final computation is made. If this act through the space of a molecule, we have $Sv^{2/3}$, the molecular surface tension energy. According to Eötvös this is equal to $3.015\times10^{-16}(T_c-T-6)$, using absolute units and the volume of one molecule, and assuming that the number of molecules in a c.c. of gas under standard conditions is 2.77×10^{19}. This value, $Sv^{2/3}$, must be a function of the difference in molecular cohesive energy in the liquid and vapor, or $M^2K/v-M^2K/V=fSv^{2/3}$. At low temperatures M^2K/V drops out and at absolute zero $M^2K/v_0=fSv^{2/3}=3.015\times10^{-16}(T_c-6)f$. To find "$f$" I had recourse to Thomas Young's formula: $S=rK/3=rM^2K/3v^2$; r being the radius of action and equal to $v^{1/3}$ at absolute zero. Maxwell and Lord Rayleigh have a different coefficient from Young's, *i. e.*, 3/20 instead of 1/3. I could not decide which of these was right, but Maxwell's gives a value for the internal pressure requiring an impossible value for "b," if substituted in Van der Waals's equation, so that Young's seems to be right, unless I have made an error somewhere. We have then $S=M^2K/3v^{5/3}$; and $Sv^{2/3}=M^2K/3v_0$. Therefore $M^2K=9.045\times10^{-16}(T_c-6)$. If this value for M^2K is substituted in Van der Waals's equation using the critical data for pentane, ether, isopentane and benzene, "b"$_c$ is found to have very nearly the uniform value in all of $V_c/2.07$. Van der Waals found, by computing "a" from the coefficient of compressibility, that b_c was $V_c/2.03$; so the two results agree very well. The value obtained from the surface tension is, therefore, tolerably correct. The value of M^2K has been computed for a large number of substances from the critical temperature, pressure and volume, and from the surface tension; and the results are throughout in close agreement.

Having thus found M^2K, the volume "b" of the molecules in the liquid and vapor of pentane at 180° was computed. In the vapor it was 140.3 c.c., and in the liquid 124.24 c.c. for gram molecular quantities. The volume of the molecules in the vapor is, therefore, certainly larger than in the liquid.

4. *The Nature of Cohesive Mass. Relation between Cohesion and Gravitation and the Number of Valences. A Method of Determining the Valence of Compounds.—The very interesting relationship has been discovered that the value M^2K, the factor proportional to the square of the cohesive mass of a molecule, is equal to the constant* 2.97×10^{-37} *multiplied into the two thirds power of the product of the molecular weight and the number of valences in the molecule.* This relationship holds in such a variety of substances that it seems universally true. It gives a valuable means of computing valences, when the critical data are known. Van der Waals's constant "a" can then be computed very exactly for non-associating substances when the valence is known by the formula: $a = 2.97 \times 10^{-37}(\text{Wt. Val.})^{2/3}N^2$. The value is given in absolute units. N is the number of molecules in the volume taken.

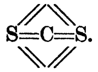
TABLE I

Substance	Mol. Wt.	Valences	$M^2K/(\text{Wt} \times \text{Val})^{2/3}$
Methyl formate	60	16	2.94×10^{-37}
Pentane	72	32	3.00
Iso-pentane	72	32	2.92
Ether	74	28	2.92
Benzene	78	30	2.93
Hexamethylene	84	36	2.92
Hexane	86	38	3.04
Ethyl acetate	88	28	2.95
Propyl acetate	102	34	2.97
Ethyl propionate	102	34	2.95
Octane	114	50	3.14
Diisobutyl	114	50	2.98
Carbon tetrachloride	153.8	16	3.03
Stannum tetrachlor.	260.8	16	2.89
(Methyl alcohol	32	10	4.634)
Helium	4	1	2.90
Hydrogen	2	2	3.07
Oxygen	32	2	2.88
Argon	39.9	1	3.10

The short table illustrates the constancy of c, the quotient, when the factor M^2K, computed in the manner just mentioned from the surface tension, is divided by the two thirds power of the product of the molecular weight and the number of valences per molecule.

It will be seen from this table that the substances of which the valence is not doubtful, and of which the critical data have been so carefully determined by Young, give a constant value of c. Associating substances, like methyl alcohol, give a quotient higher than the average. A higher mean molecular weight and valence number must obviously be taken for these substances. The high figure for argon may indicate that at the temperature at which its density was determined, there was a slight association, a few two-atom molecules being present. If this is the case, 39.9 would be probably a mean molecular weight. If the theoretical value of 2.97 be supposed to be correct instead of 3.10, it would be necessary for the mean valence number to be 1.06; and from this the atomic weight of 37.5 instead of 39.9 would be computed. The critical data of krypton do not fall in line with the formula; and xenon, if the critical data are right, must be taken as bivalent. In all the argon group, the valence must be taken at least as unity. These substances can not be considered as having zero valence, as that would make the value of c infinite, unless the cohesive mass was zero also. But that this is not zero is shown by the fact that the gases can be liquefied. The critical temperature of helium was taken as 7° Abs. instead of 5° as given by Onnes, and 8° as suggested by Dewar. Hydrogen gives a constant close to 2.94, if Sarrau's critical data are taken, but not when those of Olszewski are used. Oxygen is taken with a valence of 2 instead of 4. Even with this assumption it is only by using the recent determinations of density made by Mathias and Onnes that a value near to 2.97 can be obtained. These matters will be discussed in the complete paper. It is possible that the coefficients for the computation of M^2K should be different in these simple gases.

One of the most interesting results is that all organic chlorine compounds, with one or two possible exceptions, have trivalent chlorine. The formulas of such compounds will need revision to take account of this fact. Methyl chloride, if free valences do not exist, would need to be written: $H_2C{=}ClH$, which would show at once why it dissociates so easily into hydrochloric acid and methylene. Fluorine is monovalent in fluorine compounds; the other halogens have not been computed. Sulfur is generally hexavalent, but in sulfur dioxide it is quadrivalent. It is hexavalent in carbon bisulphide. The formula might be:



The fact that chlorine is trivalent in its organic compounds confirms Drude's and Pascal's deductions from a study of the refractivity, normal dispersion, and molecular magnetic susceptibility of these compounds. Pascal found fluorine to be monovalent, chlorine to be polyvalent.

The fact that the cohesion is thus determined in part by the number of the valences, and that a relationship, long ago foretold by Laplace, is thus shown to exist between molecular cohesion and refraction and dispersion of light is of great interest. The formula $M^2K = c(\text{Wt. Val})^{2/3}$ shows, on the electronic theory, that the electrons of the atoms and those of the valences differ, and that they can not be summed. Hence the cohesion is proportional to their product, not to their sum. This conception was the starting point of Drude's reasoning concerning the influence of valence on refraction and dispersion. The general result of the establishment of this relationship between valence and cohesion, between gravitational mass and cohesional mass, between cohesion and light refraction, and between cohesion and diamagnetic properties is, on the whole, to lend support to Sutherland's view that molecular cohesion is of a magnetic nature. The fourth power law may possibly bear this out, as he urged. The relation of intramolecular cohesion, or chemical affinity, and intermolecular cohesion is also seen to be a very close one; and the latter is apparently dependent upon the former.

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May 18, 1912

SOCIETIES AND ACADEMIES

THE NEW YORK ACADEMY OF SCIENCES

SECTION OF BIOLOGY

AT the regular meeting of the Section of Biology, held at the College of the City of New York, March 11, 1912, Chairman Frederic A. Lucas presiding, the following papers were read:

The Number and Kinds of Bacteria in City Dust: C.-E. A. WINSLOW and I. S. KLIGLER.

The authors presented the results of the examination of about 170 samples of dust from streets, schools, houses and public buildings in New York. The total numbers of bacteria found varied from 150,000 per gram to 145,000,000, averaging from 3,000,000 to 5,000,000 from the indoor dusts and 49,000,000 from the street dust. Spores made up usually less than one tenth of the total. The count obtained at body temperature was about half that at room temperature, averaging from 2,000,000 to 3,000,000 per gram in the indoor dusts and 22,000,000 in the street dusts. *B. coli* was usually present; in the street dust an average of 51,000 per gram was found and in two samples over 100,000, while none showed less than 100. The indoor dust, on the other hand, showed an average of between 1,000 and 2,000. Acid-forming streptococci, such as are characteristic of the mouth, were present to the extent of over 1,000 per gram in three fourths of the street samples and one half of the indoor samples. The average for the street samples was about 40,000 per gram; for the indoor samples about 20,000 per gram. The large proportion of these organisms, particularly in the indoor dusts, appears to be significant of buccal pollution.

The Aerial Transmission of Disease: C. V. CHAPIN.

The diffusion of contagion through the room or out of doors only was considered, not droplet infection, which does not take place beyond a meter. Bacteriological evidence was not discussed, though the quantititative work of Winslow on sewer air and spray infection was referred to, a work which he is now extending to dust. Epidemiological study and experiment have been rapidly narrowing the list of alleged air-borne diseases. We now