

MOLECULAR ORIENTATION IN LIVING MATTER.

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Living matter offers many examples of what appears to be action exerted at a distance. I am not attempting to renew the discussion of the classical problem of physics because the action at a distance which I have in mind is not exerted through vacuous space but through matter, and its peculiarity lies in the fact that the intervening matter seems to act in a purely passive way.

The example which has been present in my mind for more decades than I feel happy in contemplating is furnished by the neuro-muscular system. The muscle fibres are controlled by the nervous system with respect to three things: (1) those contractions which move the several parts of the body, (2) their elastic properties which maintain the several parts of the body in their normal posture and (3) the production of heat by the muscles of warm blooded animals in which the skeletal muscles are the chief thermogenic tissues. Of these the second is commonly called by physiologists muscular tone.

The agent, the middle man that is, between a particular cell in the central nervous system and the group of muscle fibres which it controls, is a delicate fibril no more than say 4μ in diameter which consists mainly of protein, and which is enclosed in an insulating sheath of fatty matter. The way this agent acts in controlling the contraction of the muscle fibres is well known. Waves of short length, called nervous impulses, pass down the fibril to discharge some of the stored energy of the muscle fibres, the muscle fibre being an internal combustion engine. Each nervous impulse viewed in one aspect is a wave of molecular displacement involving chemical change, and in another aspect a wave of electrical displacement. The mode of action of the nerve fibre, however, in the other two cases is, so far as I am aware, completely unknown. It is of course possible that muscular tone and

heat production also are controlled by nervous impulses which have not hitherto been detected by reason, for example, of their short period. It is also possible, however, that the nerve fibrils act in some purely static way and, should they do so, it would be an example of what I mean by action at a distance in living matter. A simple physical analogy would be a row of bricks on end on an inclined plane supported at the bottom and supporting some weight at the top of the row. There a certain structure transmits stresses which are in equilibrium so long as the structure remains intact.

Let us consider other instances. The nerve fibril itself furnishes one. It is an outgrowth from a nerve cell which has in its interior a little bladder of fluid called the nucleus. The nerve cell may be perhaps 50μ across. The filament may be a metre, or metres in length. If the filament be cut that part which is separated from the parent cell dies and breaks up. That part remaining in contact with the parent cell not only persists but grows. In similar cases which have been analyzed experimentally the influence which upholds structure and also that capacity for reproducing a particular molecular architecture in space which is called growth, is found to reside in the nucleus. This kind of action at a distance can also be detected in those plates of cells called epithelia, in embryos, in colonial polyps, and elsewhere. I used to wonder whether there was anything similar to this in the world of non-living matter. In a ridiculously humble way I think there is, though its existence has tended to be obscured by the amount of attention which has been rightly paid to monomolecular films.

An interface between two phases is the seat of forces of great magnitude directed along the normal and tangent to the face. These force fields orientate the molecules on either side of the interface, the effect on any individual molecule being greater or less according to the extent to which the equipotential surfaces of the molecule deviate in shape from spheres drawn about the centre of mass. That fact is, of course, familiar to everybody nowadays but to the question how far and to what extent is the orientation transmitted from molecule to molecule into the substances of the phases on either side of the interface no simple answer is forthcoming. Mathematically I believe the orienting influence of an interface to be transmitted to infinity; actually, however, a limit will be fixed by the heat motions, since the righting

action of the interface must be supposed to diminish along the normal until it is so far upset by the heat motions as to be sensibly non-existent. I have in mind, of course, fluid states of matter in the interior of which the disposal of the molecules is random.

The greater the eccentricity of the force fields about the molecules, that is the greater their polarity, the thicker will be the orientated layer; also the higher the temperature the thinner will be the layer.

Is there any direct experimental evidence as to whether these orientated layers are a few or possibly very many molecules in depth? I think there is direct and unequivocal evidence that the layer may be at least of the order of a thousand molecules in thickness. The simplest experiment is the following. A weighted cylinder with a plane face is placed on a plate, both faces being clean, and fluid is allowed to be drawn in by capillary attraction with the result that the weighted cylinder is lifted, the work being done against considerable pressure. Every molecule which is drawn in must be under the influence of the attraction field of the solids. The temperature is then lowered until the lubricant is frozen. If the cylinder be now broken away the layer between the faces is found to be of sensible thickness easily visible to the naked eye. One has, then, a layer whose depth must be measured by the thousand molecules and of which no part is beyond the influence of the solid faces. Two physical properties of the layer are open to measurement, its tensile strength when the cylinder is pulled or broken away, and its friction when the cylinder is moved tangentially. In both cases the numerical values depend as much upon the chemical nature of the solids as upon the chemical nature of the lubricant. In both cases too the numerical results are extraordinary in one particular. So far as the measurements have gone at present the following is found both for adhesion and for friction. Let both cylinder and plate be of the same material, say material *A*, and let *a* be the value of either friction or adhesion; and let the value be *b* when cylinder and plate are made of material *B*. Now let cylinder *A* be placed on plate *B* or *vice versa*. The value now always is $\frac{a + b}{2}$.

This is a humble example of transmission to place beside the colossal examples furnished by living matter, but when for years one has contemplated a scientific problem towards the explanation of which nothing could be advanced even the slightest clue is welcome.