XVI. "Protoplasmic Movements and their Relation to Oxygen Pressure." By JAMES CLARK. Communicated by Professor VINES, F.R.S. Received June 19, 1889.

(Abstract.)

That the presence of free oxygen is one of the essential conditions of protoplasmic movements has long been recognised. Further than this however the subject has not hitherto been investigated.

The following are the results of a long series of experiments made to ascertain the minimum pressure of oxygen necessary to restore the streaming, amœboid and ciliary movements of protoplasm after they have come to rest in the absence of that gas. The object experimented upon was in each case placed in a hanging drop of water and exposed to an indifferent gas such as hydrogen or nitrogen, or else put into connexion with the exhausted receiver of an air-pump. In the former case when the observed movement had ceased a current of indifferent gas containing a definite percentage of oxygen was passed over the object; in the latter a small quantity of air was admitted and the pressure registered. By varying in successive experiments the percentage of oxygen mixed with the diluent gas, and the quantity of air admitted into the air-pump, the minimum pressure of oxygen necessary to restore movement could be ascertained by both methods, so that one could act as a check upon the other.

In this way the minimum for the streaming movement in the plasmodia of Myxomycetes, and in the cells of hairs, of parenchyma, of xylem, phloëm and cambium was found to vary from 1 mm. to over 3 mm. It was lowest for the plasmodia of Myxomycetes, the minimum for *Chondrioderma difforme* being 1 mm., and for *Didymium farinaceum* 1·2 mm. Except with very old plasmodia the results obtained even with unfavourable specimens rarely exceeded 2 mm. With the vegetable cell the variation was much more extensive. In such a favourable object as the root hairs of *Trianea bogotensis* a minimum of 1·2 mm. was occasionally obtained, whereas for the partly cuticularised leaf hairs of *Urtica americana* it sometimes exceeded 3 mm. With the cells of the parenchyma the experimental difficulties were usually very great, and for those of the xylem, phloëm, and cambium still more so. With the former the minimum found for each plant usually lay between 2 mm. and 3 mm., and was sometimes even less. With the latter, cells of all three were found which gave similar results but these were rare, as death of the cell contents usually arrested the experiment. It seems probable however that if variation due to experimental difficulties and the resistance of the cell wall to the passage of oxygen could be eliminated, the minima

for the various tissues of different plants would not vary any more among themselves than do the actual results obtained for naked plasmodia.

The age of the cell or plasmodium and the conditions under which it has been developed to some extent influence the minimum oxygen pressure necessary to restore movement.

The time taken by the protoplasm to recover its streaming movement is too short to be measured in cases where the conditions are favourable, as in young hairs and in slender threads of plasmodia, but increases with cuticularisation of the cell wall, the age of the cell, and the length of time between the cessation of movement and the introduction of the necessary oxygen supply.

Very slight irritation of the plasmodia during the experiment causes them to contract towards definite centres where the protoplasm assumes a more or less spherical condition.

Temporary deprivation of oxygen in a cell showing circulation induces a simplification in the arrangement of the protoplasmic strands. In the leaf cells of Elodea for example the circulation may occasionally pass over into rotation.

After the streaming in plasmodia has been restored by the introduction of the necessary oxygen pressure it ceases again in a very short time. The movement in fact can be maintained only by constant small additions to the oxygen pressure. This is not caused by the consumption of the oxygen in the immediate neighbourhood.

Amœboid movements continue in an atmosphere of hydrogen for some time after the streaming has ceased.

After ciliary movement is arrested in any healthy infusorian by the absence of oxygen the organism soon begins to disintegrate. The introduction of an oxygen pressure of about 1 mm. is sufficient to arrest disintegration and restore ciliary movement, provided the breaking up has not proceeded too far.

The growth of the plant and the streaming of protoplasm in the active cells thereof appear to be parallel phenomena, streaming, or at least the power of very rapidly assuming the streaming movements, being possessed by the parenchyma and probably the phloëm of plants so long as they continue to grow in an atmosphere of hydrogen. Inability on the part of the protoplasm to continue its movements seems to be always associated with total cessation of growth.