SPECIAL ARTICLES

AMŒBOID MOVEMENT, TISSUE FORMATION AND CONSISTENCY OF PROTOPLASM[1]

1. IN 1901 we found through testing by direct means the consistency of the protoplasm that in the blood cells of *Limulus* amœboid movement depends primarily upon alternating changes in the consistency of the protoplasm, a phase of liquefaction being followed by a phase of hardening. There may be added to these changes in consistency changes in surface tension.[1] Subsequently we showed in experiments in which we likewise tested the consistency of the cells directly that the consistency varies under different conditions, that these variations correspond not only to the pseudopodial activity, but also to the agglutinability of the blood cells and to the formation of tissue like structures from previously isolated cells,[2, 3] that these changes due to stimulation explained the stereotropism of tissue cells,[2, 4] that they played a part in the processes of inflammation,[1, 2] phagocytosis,[4] and thrombosis.[5, 6, 7, 8] More recent observations in 1919 showed that it is possible to vary greatly the character of the amœboid movements and that the changes in the amœboid movements correspond to the changes in the consistency of the protoplasm; these observations suggested that the taking up of fluid from the surrounding fluid on the part of the cells is an important factor in these processes.[9] We furthermore showed that certain phenomena of wound healing can be imitated in this experimental amœbocyte-tissue and that the formation of giant cells which takes place in sensitive cells in contact with a foreign body represents an application of the same principle.[9] Here we have to assume that the process of liquefaction may proceed so far that two cells may flow together. We also pointed out that variations in the hydrogen ion content of the cells under the influence of stimulation might explain these changes.

2. A continuation of these experiments in Woods Hole last summer showed that in the blood cells of *Limulus* it is possible to produce graded variations in the character of the pseudopods and amœboid movements through graded changes in the osmotic pressure in the surrounding medium. Again we find correspondence between the consistency of the protoplasm and the character of the pseudopods and amœboid movement. A particularly great fluidity of the protoplasm could be produced through the use of a slightly hypotonic solution of KCl. In this case the change in consistency became so marked that it affected not only the ectoplasmic layer of the cell, but extended to the whole of the granuloplasm. There is reason to assume that these changes are associated with the taking up of fluid from the surrounding medium. Under those conditions a very peculiar phenomenon which we described previously, a circus movement of the whole cell exoplasm as well as of the granuloplasm, can be produced regularly. These movements, however, take place only if the temperature of the surrounding fluid is sufficiently high. It does not occur in cells kept at a temperature of 10°.

3. Exposure of the blood cells to a temperature of approximately 40°–42° for a short period of time produces in the periphery of

[1] From the Department of Comparative Pathology, Washington University, and from the Marine Biological Laboratory, Woods Holl.

[1] Leo Loeb, *Jour. Med. Research*, 1902, VII., 145.

[3] Leo Loeb, *Biological Bulletin*, 1903, IV., 301.

[2] Leo Loeb, *Virchow's Archiv.*, 1903, CLXXIII., 35.

[4] Leo Loeb, *Anatomical Record*, 1912, VI.

[5] Leo Loeb, *Virchow's Archiv*, 1905, CLXXXV., 160.

[6] Leo Loeb, *Hofmeister's Beitraege z. Chem. Physiol. u. Pathol.*, 1904, V., 191.

[7] Leo Loeb, *Pflueger's Archiv*, 1910, CXXXI., 465.

[8] Leo Loeb, *Biochem. Zeitschrift*, 1910, XXIV, 478.

[9] Leo Loeb, "The movements of the Amœbocytes and the experimental production of amœbocyte (cellfibrin) tissue," Washington University Studies, Scientific Series, 1920, Volume VIII., 3. (Here a general discussion of the subject is given.)

the blood cells the appearance of multiple drops into which the granuloplasm moves subsequently as it does into typical pseudopods. Transition can be observed between these drops and the typical pseudopods.

It is also possible to produce experimentally in the amœbocytes structures which very closely resemble ova in which maturation membranes have formed. Jacques Loeb has formerly shown that this formation depends upon a proces of cytolysis. In the blood cells these structures appear under conditions in which the cell has taken up fluid from the surrounding medium and the consistency of the protoplasm resembles that of a liquid. All kinds of transition between these structures, drop pseudopods and the typical tongue-like pseudopods can be found. These and other observations very strongly suggest that the formation of pseudopodia, the appearance of drops at the surface of the cells and the formation of fertilization membranes are related phenomena and that the latter two conditions represent extremes in a process which, when acting in medium intensity, leads to the formation of the typical pseudopodia.

4. Through changes in the consistency of the protoplasm in the blood cells of *Limulus* it is possible to imitate the structures corresponding to different tissues. Especially did we obtain in certain cases through an increase in the consistency of the cells tissues which resembled those composed of ganglia and glia cells. It may thus be possible to obtain indications as to some of the conditions which induce the cells of different tissues to assume different forms.

Leo Loeb

Washington University

The Relative Numbers of Twins and Triplets[1]

It may be of interest to call attention to a simple relation between the number of human twin and triplet births. The relation was noticed a number of years ago and I supposed it had been recorded, but a search has failed to reveal any published statement.

If $1/n$ is the proportion of twin births to all births in a large population during any period, then the proportion of triplet births during the same period is very near to $1/n^2$. The agreement of the data is often startling. Thus in 13,360,557 births in Prussia during the years 1826–1849 as recorded by Veit[2] the number of twin births is one in 89.1 and the number of triplet births one in $(88.9)^2$. In 1,339,975 births in the United States registration area in 1917[3] the number of twin births is one in 93.1 and the number of triplet births one in $(93.0)^2$.

From the statistical relations it would appear that triplets are produced by the coincidence of two independent processes occurring with equal frequencies. One of these processes by itself gives rise to twins. This relation would apply to any mode of origin of multiple births or to different combinations of them provided that each followed the rule.

The principle might be applied to the two chief explanations of multiple births as follows:

1. *Multiple Ovulation.*—Normally a single ovum is discharged from the ovaries. There is some coordinating mechanism which prevents the ripening of other ova at the same time. Suppose that as a result of a purely intrinsic factor, once in n times an ovum appears which fails to respond to this mechanism. The chance that two such extra ova will appear at the same time is once in n squared. Obviously this presupposes that the failure to respond is due to independent processes in the two ova. To put the case more concretely, suppose that the approach to maturation of an ovum is accompanied by an internal secretion which acts upon other ova and keeps them from completing the process at the same time. The overwhelming major-

[1] Contribution from the Zoological Laboratory of the University of Illinois, No. 172.

[2] Veit, G., 1855, *Monatsschrift für Geburtskunde und Frauenkrankheiten*, 6: 127.

[3] Birth statistics for the birth registration area of the United States, 1917, U. S. Bureau of the Census, Washington, 1919.