

November 17, 1892.

Sir JOHN EVANS, K.C.B., Vice-President and Treasurer, in the Chair.

Mr. Frank E. Beddard, Professor C. Le Neve Foster, Dr. Hans Gadow, Mr. Francis Gotch, and Professor T. Jeffery Parker (elected 1888) were admitted into the Society.

A List of the Presents received was laid on the table, and thanks ordered for them.

In pursuance of the Statutes, notice of the ensuing Anniversary Meeting was given from the Chair.

Professor W. G. Adams, Professor Rücker, and Professor W. C. Williamson were by ballot elected Auditors of the Treasurer's accounts on the part of the Society.

The following Papers were read :—

- I. "On the Characters and Behaviour of the Wandering (Migrating) Cells of the Frog, especially in relation to Micro-organisms." By A. A. KANTHACK, M.R.C.P., M.B., and W. B. HARDY, M.A. Communicated by Professor M. FOSTER, Sec. R.S. Received November 1, 1892.

(Abstract.)

The paper deals with the results of an investigation of the structure and functions of the wandering (migrating)* cells of the Frog. Certain preliminary observations on Mammals and Crustacea are also included.

The results may be summarised as follows :—

The histology of the wandering cells of the Frog is almost identical with that of the wandering cells of *Astacus*. The different cells are very clearly marked off from one another when seen alive or when in preparations. Excluding red blood corpuscles and platelets, which stand on a different footing from all the rest, the following forms are found :—

* This appellation is used in preference to such terms as "leucocyte" or "white corpuscle," since it is more inclusive.

VOL. LII.

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Normal.	I. Cells normally free in the blood and in the lymph.	(a) Eosinophile cells; nucleus horse-shoe shaped or lobed; do not ingest particles; are motile unicellular glands.
		(b) Hyaline cells, free from specific granulation; nucleus round with central nucleolus. Phagocytic, <i>i.e.</i> , they possess the power of ingesting and digesting discrete particles.
Abnormal.	II. Cells very few in number and small in normal lymph. Normally present in the lacunar spaces of areolar tissue.	(c) Basophile cells, spherical, with scanty protoplasm when small; angular, rounded or flattened when large; cell substance charged with tiny basophile granules, which give a vivid rose colour with methylene-blue. Large oval or round vesicular nucleus, sometimes containing irregular chromatin mass and filaments.
		Giant cells formed by fusion of hyaline cells, similar to the large phagocytic cell of <i>Astacus</i> .
	III. Large amœboid cells; vacuolate, frequently with ingesta in the vacuoles, multinuclear, very active and phagocytic.	
	IV. Small bodies, either round and quiescent or amœboid.	Nucleated cells budded off from the eosinophile or hyaline cells.
		Non-nucleated bodies produced by breaking up of red corpuscles.

The hyaline cell is less resistant than the eosinophile cell. Rough manipulation causes a rapid bursting up of the cell, thus recalling the hyaline explosive corpuscles of *Astacus*.

We have studied the functions of these cells in relation to their anti-bacillary action (1) by taking samples of lymph from a Frog at varying intervals after the injection of bacilli, &c.; (2) by inoculating hanging drops suspended in moist chambers and kept at different temperatures, the chambers being sufficiently large to afford plenty of oxygen. By the second method we have been able to observe the conflict between cells and bacilli for continuous periods of eight to nine hours. The *same cells and bacilli* have been watched for the whole period.

In the same manner we have also examined the effect of the injection of finely-divided coagulated proteid (boiled white of egg solution), Indian ink, vermilion, egg albumen, and anthrax spores. At first we used curarised Frogs to obtain lymph, and this led to the discovery that curare produces a profound alteration in the wandering cells.

The phenomena of leucocytosis have also been examined, and we find the following:—

1. Corresponding with the three different kinds of wandering cells found in the blood and lymph, three kinds of leucocytosis may be distinguished, each characterised by the relatively greater increase in number of one particular kind of cell. This may be illustrated by citing the effect of the injection of finely-divided coagulated proteid, which produces a great increase in the number of the hyaline (phagocytic) cells without a correspondingly large increase in the numbers of the other wandering cell forms. Eosinophile leucocytosis, that is, increase in the numbers of the eosinophile cells, occurs with wonderful rapidity after injection of anthrax bacilli or other micro-organisms, and it is then followed by a leucocytosis of the hyaline cells.

2. The leucocytosis, or increase in the number of the cells, is largely due to the proliferation of the cells themselves. Thus eosinophile leucocytosis, followed by hyaline leucocytosis, occurs out of the body in a hanging drop of lymph. Also we have witnessed the division of the cells in a hanging drop. The phenomena classed under the head of chemiotaxis are undoubtedly to be partly explained by the very rapid power of proliferation by fission of the wandering cells.

The behaviour of the cells towards micro-organisms differs according to the nature of the latter. In this abstract we will confine ourselves to the conflict with *Bacillus anthracis*.

The Frog at ordinary temperatures is absolutely immune against anthrax. When lymph is treated with anthrax bacilli the following phenomena are seen, and may be grouped as successive stages:—

Stage I.—The eosinophile cells are strongly attracted to the anthrax. They apply themselves to the chains of bacilli. When contact is absolutely or nearly effected their cell substance shows the following phenomena:—

1. It is profoundly stimulated, and exhibits quick streaming movements. Ordinarily the eosinophile cell is very sluggish.

2. The eosinophile spherules are discharged: those nearest the bacillus fading and dissolving first.

3. If the eosinophile cells are present in sufficient numbers to match the anthrax, in other words, if they are unharmed by the bacilli, they bud off daughter cells, which are at first free from granules. These creep a short way from the point of conflict, and in a short time spherules appear at one end. Later, these daughter cells seek the same or another focus of conflict. Several eosinophile cells will, towards the close of Stage I, and when their numbers have increased, be massed round one chain, and they ultimately fuse, though the endosarc, with its granules, remains distinct. In this way an eosinophile plasmodium is formed, though the fusion is con-

fined to the more mobile peripheral cell substance. Whether the eosinophile cells or the bacilli win the fight depends largely on their relative numbers. The bacillus is only injured near the eosinophile cell; there the contents become rapidly curdled and irregular in appearance, and may be completely dissolved (it should be noted that Leber has shown that pus dissolves copper, and even platinum, and Kanthack has shown that the pus cell is the eosinophile cell). If the bacillary chains are in great number, then there may not be eosinophile cells enough to attack them all, although the eosinophile cell will extend itself to most attenuated lengths in order to be able to attack as great a length of chain as possible. Even where the chain is not directly attacked, the near presence of eosinophile cells profoundly arrests its development.

If the cells win they early recharge themselves with spherules; *but these are no longer eosinophile—they are amphophile*; that is, they stain with both eosine and methylene-blue, and rather more readily with the latter.

During the later portion of Stage I the eosinophile cells are aggregating and fusing round the chains of bacilli.

This fusion, and the later and more complete fusion of the hyaline cells is a kind of conjugation, the cells ultimately separating.

During Stage I the hyaline cells, *the phagocytes*, remain quiescent, and *are not attracted towards the bacilli*, though *they may take up indifferent matter such as Indian ink*. In the neighbourhood of a healthy bacillus they appear to be paralysed.

Stage II.—Hyaline cells have now increased in numbers, and come to the eosinophile cell masses surrounding a bacillus and *fuse with them*. The eosinophile cells probably lie extended along a chain; the hyaline cells work with one object, namely, to draw the long-drawn-out mass into a ball. To this end a hyaline cell will attach itself by a broad attachment, and then, by means of long filiform pseudopodia stretched towards more distant parts, it will bend the chain up into a close U, rolling the eosinophile cells round itself, and fusing superficially with them. The superficial fusion of eosinophile cells with the hyaline cell produces violent streaming movements. Other hyaline cells come and fuse with the now lobate spherical and opaque mass. The impact of each successive cell acts as a stimulus, causing streaming and pseudopodial movements, which fade away, to be re-awakened by the arrival of a fresh cell.

We have now a lobed mass, curiously opaque, and—to take one particular instance—formed by the fusion of seven eosinophile cells and four hyaline cells. Three eosinophile cells originally attacked the chain. (It will be noted that we retain the term eosinophile cells, though the second formed spherules are at first amphophile.) This fusion may persist for one to two hours.

Stage III.—The cells of the mass commence to regain their individuality and slowly separate. The separation is in two very distinct stages, and when the individual cells are again to be seen the mass is found to consist of a central giant hyaline plasmodium, formed by the very complete fusion of the four hyaline cells, and enclosed by a crust of eosinophile cells. The first stage in the dissolution of the mass is the separation and wandering away of the eosinophile cells, fully charged with the second set of spherules, which have now become truly eosinophile. A very curious appearance is presented as they shred themselves off the central hyaline mass. This plasmodium or giant cell is now seen to be an amœboid body, with several food vacuoles containing ingesta in the form of the remnants of the chain of bacilli. It pushes out on one side long filiform pseudopodia, which resemble those of the Heliozoa in their sluggish, streaming movements, while from the other side project short round pseudopodia.

The hanging drop contains, at this stage, multitudes of these phagocytic plasmodia, with free eosinophile cells and free hyaline and rose-staining cells.

Stage IV.—This is the second stage of the disintegration of the cell masses. The food vacuoles of the plasmodium close up, and the whole structure becomes lobed, taking on the appearance of a heap of hyaline cells, which subsequently separate into the original four cells.

While these stages are in progress the rose-colouring cells are increasing in size and number. They are at first small and spherical, with not very abundant cell substance. Later they become large, angular, and sometimes vacuolate, and their cell substance becomes completely filled with basophile, rose-staining granules.

The activities of the rose-staining cells are, we believe, directed towards the removal of foreign noxious substance in solution in the plasma. We find that if the bacterial poisons accumulate beyond a certain point they paralyse the eosinophile cells, and destroy the hyaline cells. This is prevented, in part at any rate, by the action of the rose-staining cells. We correlate the increase in the granulation of these cells, or, in other words, the increase in the amount of rose-staining substance, with the removal of the bacterial products.

The conflict thus consists of, *first*, the maiming of the bacilli by the eosinophile cells; *secondly*, the removal of the remains of the bacilli by means of the ingestive and digestive activity of the hyaline cells; and, *thirdly*, the removal of dissolved foreign substances by the rose-staining cells. We do not propose to deal at present with the further processes of repair.

Action of Urari.

It induces extensive leucocytosis.

Stage I.—After three hours lymph drawn is found to contain hyaline and *amphophile* cells, the latter in great abundance.

By treating a hanging drop with urari and methylene-blue, we were able to watch the granules of the eosinophile cells slowly undergo a slight decrease in size and stain with the methylene-blue. The granules of the normal cell never stain with methylene-blue.

Stage II, 12 hours.—Repair in progress; numerous large cells present charged with ingesta.

Stage III.—The normal eosinophile cell re-appears. Frogs completely recover from urari in a day or two.

Action of Heat.

Frogs are rendered susceptible to anthrax by being warmed. We therefore inoculated hanging drops and watched them on the warm stage.

We found that the first attack of the eosinophile cells was commenced before the temperature had risen, but never carried out, the cells becoming completely paralysed, and showing no movement for five hours. Therefore there was no phagocytosis, *for this can only follow the eosinophile attack.*

Morphology and Comparative Physiology of these Wandering Cell Elements.

We are now able to point to three animal forms, the Frog and Lamprey, types of a complex and highly developed group, and *Astacus*, a complex member of a group containing animals of widely divergent complexity. In all these different forms of wandering cells occur. These we may class as—

Granular eosinophile.	Found free in the body fluids.
Non-granular hyaline.	„ „ „
Rose-reacting cell, granular.	Wandering cell which is found in the body fluids, but which also inhabits the spaces of connective tissues, though it is not by any means identical with the connective-tissue cell.

Of these diverse forms we see the archetype in the granular, protective, digestive, absorptive, and constructive (for it contributes to form the fat tissue and scar tissue) blood cell of the primitive animal *Daphnia*, and the granulation of this primitive cell is amphophile and rose-staining, as is also the granulation of the ectoderm of *Daphnia*.

The physiological differentiation we can trace when we see that the eosinophile cell has accentuated the glandular and protective character of the primitive cell; while in its attack by direct contact brought about by pseudopodial activity we see the remnant of the direct pseudopodial and ingestive attack of the primitive cell.

The hyaline cell, or permanently free phagocyte, represents the specialisation of the direct pseudopodial ingestive activity of the primitive cell.

While, lastly, the absorptive powers of the primitive cell are represented by the rose-staining cell of the more differentiated animal forms.

II. "Stability and Instability of Viscous Liquids." By A. B. BASSET, M.A., F.R.S. Received October 10, 1892.

(Abstract.)

The principal object of this paper is to endeavour to obtain a theoretical explanation of the instability of viscous liquids, which was experimentally studied by Professor Osborne Reynolds.*

The experiment, which perhaps most strikingly illustrates this branch of hydrodynamics, consisted in causing water to flow from a cistern through a long circular tube, and by means of suitable appliances a fine stream of coloured liquid was made to flow down the centre of the tube along with the water. When the velocity was sufficiently small, the coloured stream showed no tendency to mix with the water; but when the velocity was increased, it was found that as soon as it had attained a certain critical value, the coloured stream broke off at a certain point of the tube and began to mix with the water, thus showing that the motion was unstable. It was also found that as the velocity was still further increased the point at which instability commenced gradually moved up the tube towards the end at which the water was flowing in.

Professor Reynolds concluded that the critical velocity W was determined by the equation

$$W a \rho / \mu < n,$$

where a is the radius of the tube, ρ the density, and μ the viscosity of the liquid, and n a number; but the results of this paper show that this formula is incomplete, inasmuch as it does not take any account of the friction of the liquid against the sides of the tube.

In the first place, if the surface friction is supposed to be zero, so that perfect slipping takes place, the motion is stable for all veloci-

* 'Phil. Trans.,' 1883, p. 935.