quent in the southeast quadrant of a depression. Professor Waldo ("Elementary Meteorology," p. 221) says:

> In the eastern and northern parts of the United States the area of maximum rainfall lies southeast of the center of the cyclone, and usually at a distance of about 300 miles from it; but the distance varies greatly in individual instances.

In New England, however, the rainfall seems to be heaviest in the northeast quadrant of a cyclone, the precipitation accompanying a "northeaster," in which the center of the depression remains south of the observer during its eastward movement, is usually heavier than that of a storm whose center passes down the St. Lawrence Valley. Dr. Shaw ("Forecasting Weather," p. 206) seems to be of the opinion that the precipitation is most abundant, or at least is most frequent, in the "left front of the depression." In the latest discussion of the problem, Mr. F. J. Wardale (*Symonds's Meteorological Magazine,* February, 1912, p. 8) concludes that when a depression crosses England the bulk of the rain falls in subsidiary eddies on its northern side, the region of heaviest precipitation as the storm advances being "a broken band parallel to or gradually diverging from the central track on its left side." He believes that these eddies, too shallow to be evidenced on the meteorological charts, have a counter-clockwise orbital movement around their primary, at the same time sharing its forward movement. These eddies, in which the heavier downpours occur, pass quickly over and hence give slight precipitation to a place south of the storm track, for there they are accelerated by the general forward movement. For a place to the north of the center, the orbital velocity of the secondary is subtracted from the general forward movement, consequently the eddy passes slowly and in some cases might remain stationary, resulting in prolonged and therefore heavy rain. These eddies, he believes, are formed at intervals during the progress of the cyclone, thus accounting for the patchiness of the band of high rainfall. Mr. Wardale's suggestions are well worth the serious consideration of forecasters, since unnoticed secondaries and trough-like isobars have often resulted in heavy precipitation when fair weather was expected. His conclusions agree closely with those previously reached by Mr. W. G. Reed in a study of the cyclonic distribution of rainfall in the United States (*Monthly Weather Review,* October, 1911, p. 1609).

NEW BOOKS

AMONG the books which have recently appeared are: (1) "Meteorology," by W. I. Milham. New York, The Macmillan Co. 8vo. 549 pp. $4.50 net. (2) "Weather Signs and How to Read Them, for Use at Sea," by W. Allingham. Glasgow, J. Brown & Son. 117 pp. 2s. net. (3) "The Sun," by C. G. Abbot. New York, D. Appleton & Co. 448 pp. (4) "Über die Helligkeit des Himmels in der Nahe der Sonne," by H. Diercks. Kiel, Lüdtke & Martens. 48 pp. (5) "Über die Gesetze der Wärmestrahlung," by W. Wien. Leipzig, J. A. Barth. 21 pp. 1 Mark. Among the books soon to appear are: (1) "The Meteorology of the Globe," by W. N. Shaw. (2) "Clouds," by C. T. R. Wilson. (3) "Structure of the Atmosphere," by C. J. P. Cave. (4) "Weather-science," by G. F. K. Lempfert. (5) "Radiation," by P. Phillips. Professor R. DeC. Ward has begun the preparation of a "Climatology of the United States."

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May 1, 1912

SPECIAL ARTICLES

THE ORIGIN OF ERYTHROCYTES BY A PROCESS OF CONSTRICTION OR BUDDING

IT is gradually becoming apparent that in the solution of some of the more intricate morphological problems, involving phenomena of development and histogenesis, recourse will be necessary, in part at least, to data other than those obtained from fixed and stained preparations alone. Sabin, '05, in a discussion of evidence from fixed histological material bearing on certain questions regarding lymph-

ocytes and lymph glands has well expressed this conviction in the conclusion that "we must await some new method of attacking the problem." The recent development in the technique of tissue culture, with the striking results obtained by Harrison, Burrows, Lewis, Loeb and others, leads one to expect that similar methods may yield important data concerning the complicated problem of the life history and genetic relationship of the various types of blood cells. With this hope a study of the behavior of blood corpuscles in plasma cultures was begun somewhat over a year ago. Some of the results regarding the red blood cells appear of sufficient importance to justify a preliminary statement.

The present observations relate to the origin of the erythrocytes or non-nucleated red blood corpuscles and bear directly upon the long-standing question of the elimination of the nucleus. The description will be confined to certain results reached in a study of the blood of the pig embryo. Stating the method briefly, the erythroblasts of the embryonic blood were taken at various stages of differentiation and observed in hanging-drop cultures, employing the technique devised by Harrison and Burrows, with such modifications as appeared essential for the present purpose. Biased by the prevalent view that the nucleus of the erythroblast subsequently disappears, either by disintegration or by extrusion, it was hoped that it might be possible to observe the process directly in the living cell. It can be readily appreciated then with what surprise it was discovered that erythrocytes may arise in a manner fundamentally different from either of the above alternatives.

During the first half day (circumstances necessitated beginning the cultures in the afternoon) the erythroblasts manifest a variety of cytoplasmic activities, not inadequately described as amœboid in character. Numerous pseudopodia-like projections of various types are present. The greater number are in the form of tapering points or slender, elongated processes, varying from one to several in a given erythroblast. In a smaller number of cases the cytoplasm extends out in blunt, rounded, somewhat bud-like projections. These processes manifest constant quivering and oscillating movements. Other erythroblasts, spherical in form, are more or less quiescent. During the second day, of the above types of processes, the blunt bud-like form has become much more predominant. In other respects the cells appear as on the preceding day. These bud-like processes may involve one third or even more than one half of the cytoplasm of the cells. A striking feature is that not only are the buds completely filled with hemoglobin, but in many cases practically the entire hemoglobin content of the erythroblast has become segregated in the bud, leaving a more or less clear and hemoglobin-free cytoplasmic area surrounding the nucleus. If observations are begun upon the cell at this stage, the bud will be found in a state of amœboid activity manifested in changes in the contour varying from slight modifications to elongated projections. If the cell is at the height of its activity an astonishing thing may now occur: a constriction becomes evident and within a few minutes or even seconds this constriction is completed and the hemoglobin-containing bud is liberated from the cell. Typically this liberated bud corresponds in size and appearance with the adjacent erythrocytes; it may assume a bi-concave disc shape, and in one instance it was possible to continue the observations sufficiently to follow the final transformation of the liberated bud beyond this disc shape to a typical cup-shaped form. In each case control specimens of the blood originally employed for the cultures were fixed in formalin vapor and stained. Budding erythroblasts were also successfully fixed and stained and were found to correspond both in their cytoplasmic and nuclear characteristics with the control specimen. Erythroblasts were maintained in normal condition in several experiments for three or more days. Budding activities were continuous throughout this time, and under favorable conditions ten or more cells in various stages of active budding could be counted in a given field of the microscope.

When these remarkable activities were first observed it seemed incredible that we were witnessing a normal mode of erythrocyte formation. The experiments were consequently repeated many times, subjected to various tests, and the results analyzed in the light of all the criticism that could be brought to bear upon the subject. Temperature, media, evaporation, staining reaction and degenerative changes have been carefully considered. It is a pleasure to state that Professor R. J. Terry and Mr. C. H. Danforth, of the anatomical department, have also carefully followed these erythroblast activities and have kindly subjected the results to valuable criticism. In brief, after careful study the conclusion seems unavoidable that we are here confronted with a *normal mode of formation of mammalian erythrocytes by a process of budding and constriction from the parent erythroblast.* It is interesting that this result is in accord with the discarded theory of Malassez (1882), on the origin of erythrocytes from bone marrow cells by budding, while at the same time the investigations were made and the conclusions drawn entirely independent of any previous knowledge of his work.

In addition to the formation of typical erythrocytes, another type of activity consists in the production of either very small buds or slender, elongated, rod-like processes which may ultimately segment into a varying number of subdivisions about one third or one fourth the size of the average erythrocyte. These correspond very closely in size and form to blood platelets. As for the amount of cytoplasm remaining with the nucleus, after the constriction off of an erythrocyte, it may vary from a small rim about the nucleus to a quantity occasionally even larger than the erythrocyte to which the parent cell has given rise. No conclusive evidence of a migration of the nucleus from the cell has as yet been obtained. However, in the case of the smaller erythroblasts the constriction may take place so close to the nucleus that it may present the appearance of nuclear extrusion, and it is readily conceivable that in some cases the constriction may be such as to leave behind a practically cytoplasmic-free nucleus and thus account for the free erythrocytic nuclei occasionally found in the blood. That the fundamental process here described is one of cytoplasmic constriction rather than of nuclear extrusion is still further demonstrated by the fact that occasionally a single large erythroblast was observed to give rise to even two buds, both of which became detached from the parent cell.

Granting that we are justified in the above conclusion, various questions naturally present themselves; among others the behavior of the erythroblasts in different media; the factors involved in the formation of hemoglobin and its separation from the erythroblast; the subsequent assumption by the liberated globule of a disc or cup-shaped form; the fate of the nucleated remainder of the erythroblast, and the possible relationship between lymphocytes and erythroblasts. Investigation bearing on these problems is under way. The present preliminary statement will be followed as soon as possible with a full description of technique, detailed data, and figures upon which these conclusions are based.

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ON THE APPEARANCE OF ALBINO MUTANTS IN LITTERS OF THE COMMON NORWAY RAT, MUS NORVEGICUS

AFTER several failures to breed the Norway rats in cages, we have finally succeeded in raising them in captivity by means of an improvement in the cages and diet, as well as in general treatment.

This successful experiment was begun more than two years ago and we are just getting the litters which belong to the third generation born in captivity. It may be added that in all cases the brothers and sisters of the same litters were mated as I wished to determine the combined effects of close inbreeding and captivity.