A Study of the Morphology of the Living Cells of Blood and Bone Marrow in Supravital Films with the Phase Contrast Microscope

II. Blood and Bone Marrow from Various Hematologic Dyscrasias

By G. Adolph Ackerman and Nicholas C. Bellios

The morphologic characterization and identification of the pathologic cell forms of the hemopoietic system have served as the basis for the final diagnosis of many hematologic dyscrasias. For the proper interpretation of the cells observed it is necessary to be acquainted with the minute detail of the normal cell forms and their pathologic deviations. Present methods for the investigation of cellular structure, composition and metabolism emphasize the need of a critical evaluation and understanding of the minute anatomy of the living pathologic cell in relation to the normal cell form. Cellular morphology continues to serve an important function not only in the differential diagnosis of hematologic dyscrasias but also as a guide of the body's response to newer modes of therapy and their subsequent evaluation.

Supravital films examined under phase contrast and bright field microscopes provide an excellent method for the morphologic characterization of the living cells of the blood and bone marrow in the normal and diseased condition. Numerous investigators have described and illustrated many of the morphologic features of the cells of the blood and bone marrow as visualized in phase contrast microscopy. It is the purpose of this investigation to further characterize and illustrate by means of the supravital staining technic used in conjunction with bright field and phase microscopy the salient morphologic features that may be of aid in the identification and evaluation of the living pathologic cell forms. In addition these morphologic features will be summarized into a more general concept of changes observed during the disease manifestations. Previous studies of the cells of the blood and bone marrow will serve as a basis for the comparison of the normal and pathologic cell forms. It is impossible to discuss all of the variations occurring in each disease process adequately; therefore only

From the Department of Anatomy, Ohio State University College of Medicine, Columbus, Ohio.

This investigation was supported in part by a research grant #C-1084(C4) from the National Institutes of Health, Public Health Service.

The authors wish to gratefully acknowledge the help and guidance of Drs. R. A. Knouff, W. J. Frajola and E. R. Hayes. We also wish to thank Drs. C. A. Doun and B. K. Wiseman and the personnel of the Hematology Service, Kinsman Hall for their assistance in obtaining the necessary pathologic material.

Submitted March 8, 1954; accepted for publication August 27, 1955.
the more common variations from the normal pattern will be presented and illustrated at this time.

**Materials and Methods**

Blood and bone marrow specimens were obtained from patients suffering from various blood diseases and examined immediately by the following technic. Fresh moist films were prepared by touching a clean cover slip to a drop of blood or bone marrow and inverting it upon a supravital (neutral red and Janus green) prepared slide.\(^2\) They were then examined with the phase contrast (American Optical Company, Dark M, 97X oil immersion objective) and bright field microscopes. This technic is particularly favored in the study of bone marrow since a small "fragment" may be obtained which is equivalent to a surgical biopsy of the bone marrow. Upon microscopic examination of this "fragment" one may readily observe the predominating cell type as it exists in the bone marrow proper. Furthermore this permits the study of living cells unaltered by fixation and staining. The morphologic identification and cellular differentiation of the hematologic dyscrasias studied were established by Dr. Charles A. Doan or Dr. Bruce K. Wiseman of the Hematology Service, University Hospital, Ohio State University. Observations were made on more than 150 selected untreated cases over a period of 5 years. The cells of the blood and bone marrow were classified according to the polyphyletic doctrine (i.e., myeloblast, myelocyte A, B, C, etc.).\(^3\) Morphologic descriptions were based upon phase microscopy examinations of the cells in supravital films. Coloration (staining) of the cytoplasmic organelles was noted from the supravital films following bright field microscope examination rather than by phase microscopy. The morphologic characteristics of the normal cellular elements of the blood and bone marrow were described in detail in a previous report.\(^4\)

**Results and Discussion**

1. **Leukemias**

An examination of vital films with the bright field and phase contrast microscopes reveals a number of morphologic differences between the cells of the normal blood and bone marrow and comparable cells in leukemia, although the basic morphologic and developmental patterns are quite similar. Leukemic cells exhibit characteristics of immature cells and a number of variations prevail in the

**Plate I**

**Fig. 1.**—Neutrophilic myelocyte A and two band form neutrophils. Peripheral blood-granulocytic leukemia. Supravital and phase microscope. × 1275. Marker represents 10 microns.

**Fig. 2.**—Neutrophilic myelocyte A and two neutrophilic C myelocytes. Peripheral blood-granulocytic leukemia. Supravital and phase microscope. × 1275.

**Fig. 3.**—Two neutrophilic A myelocytes with increased "nucleolar associated chromatin." Peripheral blood-granulocytic leukemia. Supravital and phase microscope. × 1275.

**Fig. 4.**—Neutrophilic myelocyte A and small neutrophilic myelocyte B with irregular cytoplasmic borders and nuclear contour. Bone marrow-granulocytic leukemia. Supravital and phase microscope. × 1275.

**Fig. 5.**—Neutrophilic myelocyte B with large cytochroma surrounded by aggregates of cytoplasmic granules. Note the relative vesicular nucleus, the prominent nucleoli, and "nucleolar associated chromatin." Bone marrow-granulocytic leukemia. Supravital and phase microscope. × 1275.

**Fig. 6.**—Large neutrophilic myelocyte B with cytoplasmic granules which appear slightly larger than those of normal B myelocytes. Peripheral blood-granulocytic leukemia. Supravital and phase microscope. × 1275.
Plate I

See legend, facing page.
### Table 1.—Summary of the Differential Morphologic Characteristics of the Primary Blast Cells
(Supravital Staining and Phase Contrast and Bright Field Microscopes)

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Size</th>
<th>Relative Vesicularity of Nucleus</th>
<th>Number of Nucleoli</th>
<th>Relative Density of Cytoplasm</th>
<th>Color of Granules (Neutral Red)</th>
<th>Mitochondria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myeloblast* (normal)</td>
<td>14-20</td>
<td>++</td>
<td>2-5</td>
<td>++</td>
<td>Deep red</td>
<td>Light blue-green; near cytocentrum; perinuclear</td>
</tr>
<tr>
<td>Myeloblast* (leukemic)</td>
<td>14-20</td>
<td>++++</td>
<td>2-5</td>
<td>+++</td>
<td>Deep red</td>
<td>Light blue-green; near cytocentrum; perinuclear</td>
</tr>
<tr>
<td>Monoblast (leukemic)</td>
<td>14-20</td>
<td>++</td>
<td>2-5</td>
<td>+++</td>
<td>Deep orange-red</td>
<td>Moderate green-blue; distal portion of cytoplasm near cytocentrum</td>
</tr>
<tr>
<td>Lymphoblast (leukemic)</td>
<td>18-20</td>
<td>+</td>
<td>3-5</td>
<td>++</td>
<td>Deep orange-red</td>
<td>Light to moderate green; near cytocentrum</td>
</tr>
<tr>
<td>Early erythroblast (normal)</td>
<td>20-25</td>
<td>+++</td>
<td>5-7</td>
<td>+</td>
<td>Deep orange-red</td>
<td>Light green-blue; near cytocentrum; perinuclear</td>
</tr>
<tr>
<td>Megaloblast† (pernicious anemia)</td>
<td>25-30</td>
<td>+++</td>
<td>4-7</td>
<td>++</td>
<td>Deep orange-red</td>
<td>Light green-blue; near cytocentrum; perinuclear</td>
</tr>
</tbody>
</table>

* Includes the myelocyte A.
† Includes the early erythroblast.

The precise differentiation of the primitive stem cells is most difficult and most essential in the acute leukemias. The stem or blast cells from various leukemias exhibit a structural pattern which readily permit the differentiation between leukemic and normal cells of the same lineage and degree of maturation.

**Plate II**

Fig. 7.—Two neutrophilic B myelocytes. The cell on the right exhibits an irregular cytoplasmic border and slightly more hyperchromatic nucleus and less cytoplasm than the classical morphologic pattern of the B myelocytes. Peripheral blood–granulocytic leukemia. Supravital and phase microscope. × 1275.

Fig. 8.—Neutrophilic myelocyte B with irregular cytoplasmic and nuclear contour and a prominent cytocentrum surrounded by aggregates of cytoplasmic granules. Peripheral blood–granulocytic leukemia. Supravital and phase microscope. × 1275.

Fig. 9.—A typical neutrophilic myelocyte B similar to those seen in figures 7 and 8. Peripheral blood–granulocytic leukemia. Supravital and phase microscope. × 1275.

Fig. 10.—Two neutrophilic C myelocytes with lobulated nuclei. Peripheral blood–granulocytic leukemia. Supravital and phase microscope. × 1275.

Fig. 11.—Three hand form neutrophils, a late myelocyte B and a metamyelocyte. Peripheral blood–granulocytic leukemia. Supravital and phase microscope. × 1275.

Fig. 12.—Three neutrophilic B myelocytes with thickened nuclear membranes and clumping of the cytoplasmic granules. Near the center of the field is a neutrophilic myelocyte A with a thick nuclear membrane and prominent nucleolus; also an atypical normoblast at edge of field. Toxic bone marrow etiology unknown. Supravital and phase microscope. × 1275.
Plate II

See legend, facing page.
may be most easily differentiated and identified from one another by examining them in the living condition with the aid of the supravital staining and the phase contrast and bright field microscopes. The more fundamental characteristics necessary for the morphologic recognition of the primary types of blast cells are summarized in table 1.

In general all leukemic cells are larger, with a relatively larger, more vesicular nucleus, a thin nuclear membrane and usually have a greater number of nucleoli. The relatively larger size of the nucleoli and "nucleolar associated chromatin" in the leukemic cells is correlated with the increase in nucleolar basophilia, i.e., increase in cellular density as directly related to basophilic staining in fixed film preparations. Furthermore the density of the cytoplasm is also greater which is reflected by the more basophilic staining of the cytoplasm. The cyto-centrum is usually larger in leukemic cells particularly during the growing phase as the cells increase in size and elaborate cytoplasmic granules. The cytoplasmic organelles in most instances do not appear to differ qualitatively from those seen in the normal cells of a corresponding developmental stage. The number of mitochondria is increased in the younger forms of leukemic cells greater than that observed in normal cells, and decreases as the cell matures. Frequently an increased ameboid activity as well as an irregular cytoplasmic contour is observed in leukemic cells especially in the more mature forms.

The general morphologic features enumerated above which characterize leukemic cells in vital films are best seen in the cells of acute and chronic monomyelotic leukemia, (Figs. 25–34). In addition to the previously mentioned characteristics, these cells are generally more immature than those commonly observed in other forms of leukemia.

Specifically, leukemic cells of granulocytic leukemia (figs. 1–11, 13–15) present several additional morphologic features which differ from the normal develop-

**Plate III**

**Fig. 13.**—Eosinophilic myelocyte B exhibiting a reniform nucleus and smaller cytoplasmic granules than are seen in normal eosinophilic myelocytes. Peripheral blood-granulocytic leukemia. Supravital and phase microscope. X 1275.

**Fig. 14.**—Basophilic myelocyte A and B. Note the smaller size of the basophilic B myelocyte and the ring contour of the nucleus. Bone marrow-granulocytic leukemia with terminal basophil proliferation. Supravital and phase microscope. X 1275.

**Fig. 15.**—Basophilic A myelocyte with large basophil granules near cyto-centrum. A neutrophil is also shown. Bone marrow–granulocytic leukemia. Supravital and phase microscope. X 1275.

**Fig. 16.**—"Sarcomatous" transformation in the cells from a patient diagnosed several months earlier as granulocytic leukemia (figs. 5, 6, 13, 15). Note the large nucleoli, relative small amount of cytoplasm containing multiple translucent lipid droplets in the sarcoma cells. Peripheral blood–acute exacerbation of granulocytic leukemia ("Myelosarcoma"). Supravital and phase microscope. X 1275.

**Fig. 17.**—Leukemic lymphocytes with hyperchromatic nucleus resulting from an increase in the number of nucleoli and the "nucleolar associated chromatin." The small rim of cytoplasm tends to accentuate the slight increase in cytoplasmic organelles. Peripheral blood–chronic lymphocytic leukemia. Supravital and phase microscope. X 1275.

**Fig. 18.**—Same as figure 17 showing a lymphoblast with large irregular nucleoli and moderately hyperchromatic nucleus. Peripheral blood–chronic lymphocytic leukemia. Supravital and phase microscope. X 1275.
Plate III

See legend, facing page.
MORPHOLOGY OF LIVING BLOOD CELLS. II

mental pattern. These abnormalities appear to indicate an alteration in the formation and development of the cytoplasmic granules. During the early myelocyte stage neutrophils and basophils exhibit larger granules whereas the granules of the eosinophils are slightly smaller and less refractile than those observed in the respective normal cells. In addition the cytoplasmic granules tend to aggregate near the cytocentrum during the rapid growth phase of the neutrophilic B myelocyte. Mature neutrophils exhibit an increased ameboid activity and frequently a deficiency of cytoplasmic granules. Neutrophils tend to form a lobed nuclear contour, during the late B and early C myelocyte stage. Basophils, in most instances, develop a crescentic or ringed formed nucleus during the final stage of maturation and have a more irregular cytoplasmic contour than is observed in normal basophils. Adult eosinophils observed in leukemias do not differ significantly in their morphology from the normal cell form.

Lymphocytes in chronic lymphocytic leukemia (figs. 17, 19) are usually rather small and possess a denser clumped chromatin pattern. The hyperchromatic appearance of the nucleus is dependent upon the increase in the number of nucleoli and in the “nucleolar associated chromatin.” The number of mitochondria and cytoplasmic granules as well as degree of cytoplasmic basophilia is greater in the leukemic than in normal mature lymphocytes. Thus the morphologic characteristics of the leukemic lymphocytes correspond with the generalized description of the leukemic cells which has been presented.

These morphologic variations in the normal pattern ascribed to leukemic cells correspond in general to the structural characteristics of the erythroid elements seen in pernicious anemia. Such variations in morphology are quantitative rather than qualitative in nature and may suggest that, like pernicious anemia, the leukemias represent a maturation arrest in specific cell lineages and reflect an impairment in cellular metabolism. Metabolic alterations may arise from de-

---

PLATE IV

Fig. 19.—Lymphoblast with prominent nucleoli and “nucleolar associated chromatin” and a more vesicular nucleus than is seen in the lymphoblast in figure 18. Several small leukemic lymphocytes are also illustrated. Peripheral blood-chronic lymphocytic leukemia. Supravital and phase microscope. X 1275.

Fig. 20.—Lymphosarcoma cells exhibiting marked pleomorphism. Several lipid refractile bodies are present in the cytoplasm of a number of these cells. In this photomicrograph these bodies appear as a small black particle surrounded by a clear halo. Bone marrow—lymphosarcoma. Supravital and phase microscope. X 1275.

Fig. 21.—Lymphosarcoma cell with extremely vesicular nucleus and thin rim of cytoplasm. No refractile bodies are seen. Peripheral blood-lymphosarcoma. Supravital and phase microscope. X 1275.

Fig. 22.—Lymphosarcoma cell containing one highly refractile lipid droplet near the cytocentrum. Peripheral blood-lymphosarcoma. X 1275.

Fig. 23.—Intermediate size Rieder lymphocyte with a markedly indented nucleus and an increased number of cytoplasmic organelles. The cytoplasm is homogeneous, moderately dense and opaque. Peripheral blood-infectious mononucleosis. Supravital and phase microscope. X 1275.

Fig. 24.—Large size Rieder lymphocyte with indented nucleus and increased number of cytoplasmic granules and mitochondria. Peripheral blood-infectious mononucleosis. Supravital and phase microscope. X 1275.
Plate IV

See legend, facing page.
Plate V

Figs. 25-30.—Monoblasts exhibiting a moderate variation in size and a large number of mitochondria localizing in the distal portion of the cytoplasm and to a lesser degree near the cytocentrum. Cytoplasmic granules tend to localize near the cytocentrum. Monoblast in upper corner of figure 26 contains an Auer body. Peripheral blood-monoeytic leukemia. Supravital and phase microscope. X 1275.
Plate VI

Figs. 31–34.—Young monocytes exhibiting several small nucleoli, many cytoplasmic organelles and an irregular cytoplasmic contour. A monoblast is also shown (fig. 31). Peripheral blood–monocytic leukemia. Figs. 35–36.—“Sarcomatous” transformation in the cells from a case of acute monocytic leukemia. These cells exhibit an extremely vesicular nucleus, a thin rim of cytoplasm, and a moderate number of mitochondria, which tend to localize in the distal cytoplasm. Peripheral blood–acute monocytic leukemia (“monosarcoma”). Supravital and phase microscope. × 1275.
ficiencies in substances necessary to promote proper growth and development of specific cell strains, i.e., erythroid elements in pernicious anemia. The extent of the deficiency of metabolites may be reflected in the relative degree of cellular maturation of the leukemic cells.

Variations in the size of the granules in developing leukemic granulocytes, the formation of the granular aggregates in neutrophilic myelocytes, the occasional formation of Auer bodies in leukemic monocytes and neutrophilic myelocytes, and the rare occurrence of cytoplasmic crystalloids in myeloma cells provide further morphologic evidence of impaired cellular metabolism in leukemia.

Certain changes may occur in various types of hemopoietic cells including those of the lymphocytic (figs. 20–22), monocytic (figs. 35–36), and granulocytic (fig. 16) series which have been considered to represent “sarcomatous alterations.” “Sarcomatous alterations” are considered to occur in hemopoietic cells that appear morphologically to represent irreversible changes in the metabolic pattern of the cell rather than the reversible maturation arrest of the leukemic cells. These cells differ by possessing a more vesicular nucleus with larger, denser and more refractile nucleoli and by having a small rim of cytoplasm which often contains a variable number of highly refractile, non-staining, lipid droplets. The presence of these highly refractile cytoplasmic inclusions definitely establishes the identity of the cell as a “sarcoma cell,” however, their presence is not always essential for identification of this cell type. These “sarcoma cells” also have a relatively high mitotic index when compared with the normal, acute and chronic leukemic cells.15

These morphologic observations and interpretations are in agreement with those of other authors,15–18 in regards to the status of the lymphosarcoma cell observed in the peripheral blood of lymphosarcoma patients (leukosarcoma). Metabolic studies15 have helped corroborate the morphologic interpretation of an irreversible metabolic alteration occurring in the lymphosarcoma cells. The higher mitotic rate described above and also reported by other investigators15 further substantiates the concept that these cells are neoplastic in nature as compared to hyperplasia in leukemia. Several authors have used the term “lympho-

PLATE VII

Fig. 37.—Megaloblast exhibiting large prominent nucleoli, increased “nucleolar associated chromatin,” and deeply basophilic cytoplasm. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.

Fig. 38.—Early erythroblast. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.

Fig. 39.—Late erythroblast with relatively vesicular nucleus and prominent nucleoli and “nucleolar associated chromatin.” Cytoplasmic organelles tend to localize near the cytocentrum and nuclear membrane. An elongate reticulum cell is also shown. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.

Fig. 40.—Two late erythroblasts, three normoblasts and a small lymphocyte. Note the formation of mitochondria into ring forms possibly as a result of cellular degeneration. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.

Fig. 41.—Normoblasts and a late myelocyte B. Note the rather large size of the normoblasts as compared with the normal condition. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.

Fig. 42.—Three large normoblasts and a megaloblast. Bone marrow—pernicious anemia. Supravital and phase microscope. × 1275.
Plate VII

See legend, facing page.
blastic leukemia" to differentiate this variant from the chronic lymphatic leukemia.

Although a considerable degree of variation exists in the morphology of leukemic blast cells, it is believed that the "sarcomatous alterations" are definitive enough and sufficiently characteristic to readily permit the differentiation between "sarcoma cells" and leukemic blast cells. That this observation is not a subjective phenomenon is illustrated by the demonstration in the same oil immersion field cells adjacent to each other with both normal characteristics and "sarcomatous alterations." Whether the disease process is classified as "myelosarcoma" or acute granulocytic leukemia, is secondary to the postulate that in "myelosarcoma" an identifiable cell possessing the previously described morphologic characteristics is present in the blood and/or the bone marrow and conveys with its presence the process of neoplasia occurring within the individual and the prognosis that is attached thereto. This is also true of "monosarcoma" or acute monocytic leukemia. It is unfortunate that the terms acute lymphatic leukemia and leukosarcoma have become almost synonymous since basically they represent separate disease entities with separate morphologically identifiable cells characteristic to each entity. Other investigators\textsuperscript{1, 19} have expressed similar views. Thus, in review, "sarcoma cells" exhibit characteristics of very primitive cells but fail to exhibit any signs of maturation during any phase of the disease process. It is again emphasized that the morphologic characteristics of the "sarcoma cells" are best observed in living cells on supravital preparations with bright field and phase contrast microscopy.

Morphologic changes suggestive of leukemia may be observed in plasma cells from multiple myeloma (figs. 55, 56) or plasma cell leukemia.

Several additional types of cells seen in the blood and bone marrow from several diseases are illustrated but will not be further discussed. These include the atypical lymphocytes of infectious mononucleosis (figs. 23, 24), the "L.E." cell of lupus erythematosus (figs. 57, 58), the characteristic cell of Gaucher's disease (fig. 59) and developing granulocytes of "toxic marrow" (fig. 12).

Plate VIII

Fig. 43.—Early erythroblast with large dense nucleoli and "nucleolar associated chromatin" and a normoblast. Note the slight tendency for the early erythroblast to have a more thickened appearance than similar cells in pernicious anemia or in the normal condition. Bone marrow—congenital hemolytic anemia. \( \times \) 1275.

Fig. 44.—Two late erythroblasts with thick nuclear membrane and a smaller and more spherical appearance than normal cells. Bone marrow—congenital hemolytic anemia. Supravital and phase microscope. \( \times \) 1275.

Fig. 45.—Several small, rather spherical normoblasts. Bone marrow—congenital hemolytic anemia. Supravital and phase microscope. \( \times \) 1275.

Fig. 46.—Several normoblasts, a late erythroblast, and an endothelial cell near the center of the field. Bone marrow—congenital hemolytic anemia. Supravital and phase microscope. \( \times \) 1275.

Fig. 47.—Clasmatocyte with ingested normoblast. Several normoblasts are present in the field. Bone marrow—congenital hemolytic anemia. Supravital and phase microscope. \( \times \) 1275.

Fig. 48. Clasmatocyte with ingested nucleus and cellular debris. Bone marrow—congenital hemolytic anemia. Supravital and phase microscope. \( \times \) 1275.
Plate VIII

See legend, facing page.
II. Anemias

In the bone marrow in pernicious anemia, the developing erythroid elements, megaloblast and early erythroblast in particular, is increased. These cells (figs. 37–42) differ from the morphologic pattern of normal cells in that they are larger, possess a larger nucleus, larger nucleoli, and have an increased amount of "nucleolar associated chromatin" and cytoplasmic basophilia. Although hemoglobin production does not appear to be impaired it is partially obscured by the increased cytoplasmic basophilia especially in the more immature forms. The morphology of these cells returns to normal shortly after the initiation of folic acid and vitamin B₁₂ therapy.

The developing erythrocytic cells of hereditary spherocytosis (figs. 43–48) tend to be slightly smaller and more spherical than normal cells at the same stage of maturation. The nuclear membrane is thicker and the nucleus is slightly more hyperchromatic in these cells. Spherocytosis is evident early in the development of the erythroid elements and becomes more pronounced as the cell matures. Although the number of nucleated erythroid cells is greatly increased during the hemolytic crisis there does not appear to be an increase in the relative number of young forms.

All stages of megakaryocyte development are increased in the bone marrow in idiopathic thrombocytopenic purpura (figs. 49–54). The immediately apparent left shift of megakaryocytes observed is due primarily to the hyperplastic condition of the marrow for this specific formed element. On differential counts it has been observed that the predominating cell is the adult platelet producing megakaryocyte. The characteristics of the normal adult platelet producing megakaryocyte have been previously described. Numerous adult megakaryocytes fully granular but not producing platelets are also present. They are either "resting" megakaryocytes or megakaryocytes in one of the stages of the maturative cycle prior to proliferation of platelets. Since the mar

Plate IX

Fig. 49.—Megakaryocytoblast with large lobed nucleus containing several large irregular nucleoli. The cytoplasm is scant and slightly irregular with a moderate number of mitochondria and cytoplasmic granules. Bone marrow—idiopathic thrombocytopenic purpura. × 1275.

Fig. 50.—Megakaryocyte with banded nucleus and plentiful cytoplasm containing many cytoplasmic granules and mitochondria. The darker granules have been stained with neutral red. Note the irregular cytoplasmic border which appears agranular. The cytoplasm at the upper edge of the photograph shows a fragmentation of clear cytoplasmic buds. Bone marrow—idiopathic thrombocytopenic purpura. × 700.

Fig. 51.—Megakaryocyte with rather well-defined cytoplasmic borders and small amount of agranular cytoplasmic budding. Bone marrow—idiopathic thrombocytopenic purpura. × 700.

Fig. 52.—Megakaryocyte with vacuolated cytoplasm with irregular cytoplasmic borders and a portion of the peripheral cytoplasm which is agranular. Bone marrow—idiopathic thrombocytopenic purpura. × 700.

Fig. 53.—Megakaryocyte with multiple large vacuoles (degeneration). Bone marrow—idiopathic thrombocytopenic purpura. × 700.

Fig. 54.—Megakaryocyte 48 hours postsplenectomy with fragmentation of granular portions of cytoplasm and also a small amount of fragmentation of agranular buds. Bone marrow—idiopathic thrombocytopenic purpura. × 570.
Plate IX

See legend, facing page.
row is hyperplastic for megakaryocytes at this time this particular cell form (i.e., "resting" megakaryocyte) is present in greater numbers than it is present in normal marrows. However differential counts reveal the same percentage of cells present. Young immature megakaryocytes, containing a full compliment of cytoplasmic granules and a few slightly agranular megakaryocytes are also observed with an occasional megakaryoblast. A few of the cells having an agranular peripheral zone of cytoplasm tend to form protoplasmic buds morphologically dissimilar to platelets (fig. 54) lacking the typical granulomere and hyalomere. Following splenectomy the cytoplasmic granularity of all the megakaryocytes is increased. Increased fragmentation and production of platelets and platelet masses are observed concomitantly with a decrease of young megakaryocytes and an increase, in the number of mature cells. The total number of megakaryocytes and the rate of platelet production gradually decreases to within normal limits following this period of hyperactivity. The mature platelet producing megakaryocytes and the younger forms observed before and after splenectomy appear to be morphologically equivalent to those cells observed in normal marrows.

**Summary**

The cells of the blood and bone marrow from various blood dyscrasias have been studied in the living state and compared with normal cells of the same lineage by means of vital films and phase contrast and bright field microscopes.

The precise morphology of the cells of the blood and bone marrow in a normal and diseased condition is most accurately obtained by an examination of the cells in a living condition. Such studies are possible with supravital staining and the phase contrast microscope. Since cellular structure and function are interdependent an alteration in one is necessarily reflected in the other. Further insight into the chemical structure and composition of cells of the blood and bone marrow in normal and diseased conditions may be obtained from cytochemical investigations. However, it is essential that cytochemical localization of substances within the cell must have its foundation in the morphology of the intact living cell.

**PLATE X**

Fig. 55.—Plasmacytoblast with relative vesicular nucleus, several nucleoli and a prominent cytozentrum surrounded by cytoplasmic granules, vacuoles and elongate mitochondria. Bone marrow—plasma cell myeloma. Supravital and phase microscope. $\times$ 1275.

Fig. 56.—Plasma cell with extensive cytoplasmic containing numerous mitochondria and granules. The nucleus is relatively vesicular and contains a prominent dense nucleolus. Bone marrow—plasma cell myeloma. Supravital and phase microscope. $\times$ 1275.

Fig. 57.—"L.E." cell from the bone marrow of a patient with lupus erythematosus. The material within the cytoplasm of the cell is opaque homogeneous and fails to stain with neutral red. Bone marrow—lupus erythematosus. $\times$ 1275.

Fig. 58.—Large "L.E."' cell containing a large amount of the opaque nuclear material although it varies slightly in density. Cytoplasmic granules are superimposed over this material. Bone marrow—lupus erythematosus. $\times$ 1275.

Fig. 59.—Gaucher cell with markedly fibrillar and slightly granular cytoplasm and a small oval nucleus. Bone marrow—Gaucher's disease. $\times$ 1275.

Fig. 60.—Reticulum cell sarcoma cells containing an oval moderately granular chromatin pattern, small irregular nucleoli and a number of mitochondria, granules and lipid droplets within their cytoplasm. Lymph node scraping—reticulum cell sarcoma. $\times$ 1275.
See legend, facing page.

Plate X
MORPHOLOGY OF LIVING BLOOD CELLS. II

SUMMARIO IN INTERLINGUA

Le cellulas de sanguine e medulla ossee in varie dyscrasias sanguinee esseva studiate in stato vive e comparate con normal cellulas del mesme lineage per medio de frottis vital e microscopios a contrasto de phases e a campo luminose.

Le exacte morphologia del cellulas de sanguine e medulla ossee in condition normal e morbose es obtenibile melio per un examine del cellulas in stato vive. Tal studios es possibile per medio de coloration supravital e le microscopio a contrasto de phases. Proque le structura e le function del cellulas es interdependente, un alteration del un se reflecte necessarmente in le altere. Un clarification additional del structura e composition chimic del cellulas de sanguine e medulla ossee in stato normal e morbose es obtenibile per investigationes cytochimic.

Sed il es del prime urgentia que le localisation cytochimic de varie substantias intra le cellula es basate super le morphologia del intacte cellula vive.

REFERENCES

A Study of the Morphology of the Living Cells of Blood and Bone Marrow in Supravital Films with the Phase Contrast Microscope: II. Blood and Bone Marrow from Various Hematologic Dyscrasias

G. ADOLPH ACKERMAN and NICHOLAS C. BELLIOS

Updated information and services can be found at:
http://www.bloodjournal.org/content/10/12/1183.full.html

Articles on similar topics can be found in the following Blood collections

Information about reproducing this article in parts or in its entirety may be found online at:
http://www.bloodjournal.org/site/misc/rights.xhtml#repub_requests

Information about ordering reprints may be found online at:
http://www.bloodjournal.org/site/misc/rights.xhtml#reprints

Information about subscriptions and ASH membership may be found online at:
http://www.bloodjournal.org/site/subscriptions/index.xhtml