ATLAS OF HEMATOLOGY—OSGOOD AN

VO

ATLAS OF HEMATOLOGY

With Three Hundred and Twenty-Five Illustrations and Frontispiece in Color

by

EDWIN E. OSGOOD, M. A., M. D.

ASSISTANT PROFESSOR OF MEDICINE AND HEAD OF EXPERIMENTAL MEDICINE

UNIVERSITY OF OREGON MEDICAL SCHOOL

PORTLAND, OREGON

and

CLARICE M. ASHWORTH

MEDICAL ILLUSTRATOR

UNIVERSITY OF OREGON MEDICAL SCHOOL

PORTLAND, OREGON

SAN FRANCISCO

J. W. STACEY, INC.

236-238 FLOOD BUILDING

PREFACE

This Atlas is written to fill a demand for a book primarily for the clinician, student, and technician rather than for the hematologist. It is also written in response to the requests of many who have seen the illustrations in the Textbook of Laboratory Diagnosis or some of the original drawings of the illustrations in this Atlas when they were exhibited at the Cleveland meeting of the American Medical Association in 1934. Its major theses are first, that accurate diagnosis is prerequisite to good therapy, second, that a systematic hematologic study will aid materially in the diagnosis of almost any disease, whether it be a primary disorder of the blood-forming organs or not, and third, that such an examination is simple enough to be performed by any qualified practitioner of medicine. Its aim is to show the physician and medical student how to plan and interpret this examination and the technician how to perform the laboratory phase of it.

Symptoms and signs are included as aids to diagnosis and guides to planning the hematologic examination, and the principles of prognosis and therapy are outlined to show the practical application of the hematologic study. Tables of cell identification are planned to guide the observer to the identity of a cell under the microscope even though such a cell has never been seen or heard of before. Tables of differential diagnosis are planned to guide the physician from the patient before him to the most probable diagnosis with a minimum expenditure of time. The method of presentation is that which has seemed most satisfactory in teaching graduate students, medical students, and technicians the clinical and laboratory phases of hematology. It incorporates the results of the author's studies of hematologic methods, normal hematologic standards, the differential diagnosis of anemias and leukemias, the technic and diagnostic value of the simple method of obtaining and studying sternal marrow, and many heretofore unpublished observations from cultures of human marrow and blood.

The junior author, C. M. A., is responsible for the drawings and the senior author, E. E. O., is responsible for the selection of the cells to be drawn, for supervision of the drawing and photoengraving, for the text material and for the opinions expressed in the book. Since only the senior author is responsible for the text matter, the singular person has been used throughout the book.

The illustrations have been reproduced to an exact scale corresponding to a magnification of x 2,500 unless otherwise indicated. This magnification permits reproduction of minute cellular detail in the photoengraving process. With the exception of cells **38, 40, 42, 52, 107, 109, 111, 116, 299** and **300,** which were drawn from donated slides, all the drawings were made from Wright's stained smears of oxalated blood or sternal marrow from the author's collection from more than one thousand patients with hematologic disorders or from reticulocyte or peroxidase stains made according to the technics recommended. With each illustration, the source of the material has been given. The illustrations are from the blood or marrow of patients so thoroughly studied that there is little question as to the correctness of the diagnosis and, in many instances, the diagnosis was confirmed by necropsy or biopsy.

It differs from other Atlases in that the major stress is placed on the morphology of the individual cell although microscopic fields are given. The reason for this is that the diagnosis of disease of the blood and blood-forming organs depends, not on a glance in the microscope, but on the ability to identify each cell seen in the blood or marrow. No two microscopic fields, even on the same slide, ever look alike, whereas it is possible to present all of the major variations in the appearances of the cells.

The numbering of the cells in sequence should make it possible for anyone writing articles on hematology to indicate clearly the type of cells in the material described without the expense

of having color plates made for a single article. For example, a person writing on monocytic leukemia could say: "The most frequently observed cells in the blood were similar to cells 34 to 41 in the Osgood and Ashworth Atlas of Hematology."

The problem of nomenclature was a very real one because so many authors have used the same terms for different cells or different terms for the same cells. It was necessary to choose between coining new terms or redefining old terms. The difficulty with using old terms that have several meanings is that anyone using them must indicate whose definition is followed. The coining of an entirely new system of nomenclature was seriously considered but it was finally decided to use new terms only for the erythrocyte and granulocyte series and to utilize as far as possible terms in current use, selecting those which seemed most descriptive and defining them as clearly as possible. It is hoped that differential cell counts using this book as a guide will agree within the limits of error of the method no matter by whom they are made. When new terms are used, the old term most nearly equivalent is given in parentheses so that usage may decide which term is preferable for use in subsequent editions. To aid the student in interpreting hematologic literature, the other English terms used for the same cell type are given in table 2 and the German and French equivalents are given with the major discussion.

The references which are all given at the end of the book have been chosen with the objectives of familiarizing the reader with the names of those who are doing outstanding work, the most important recent articles in each field, and the sources where material given in the text may be supplemented and amplified. In addition, the major articles expressing views differing from those of the author are given so that the student may read both sides of the question. References are given chiefly to recent articles because the older literature will be found critically analyzed in the general references and can be readily located in the bibliographies of the articles cited.

The authors wish to acknowledge their indebtedness to Mrs. Mable W. Osgood, the wife of the senior author, and to Dorothy Madge Ellis for much help in the preparation of the manuscript; to the Hicks-Chatten Engraving Company of Portland, Oregon, for their patience and skill in doing the photoengraving; and to The Arcady Press, Portland, Oregon, for the excellence of the printing and format of this volume. In addition, the authors wish to thank Doctor A. G. Foord of Pasadena (**40-42**), Doctor W. M. Fowler of Iowa City (**38**), and Doctor W. A. Groat of Syracuse (**52, 107, 109, 111, 116**) for donating slides and for permission to reproduce drawings from these slides in this volume.

Edwin E. Osgood
Clarice M. Ashworth

July, 1937.

TABLE OF CONTENTS

CHAPTER IX

CHAPTER X

CHAPTER XI

CHAPTER XII

LIST OF TABLES

CHAPTER I

GENERAL PRINCIPLES OF HEMATOLOGIC DIAGNOSIS

This Atlas is designed to aid the physician and medical student in making accurate hematologic diagnoses and to enable any one to learn to identify correctly the cells of the blood and bone marrow. Chapters I-X tell how to determine from examination of the patient and of the smears of the blood and marrow what conditions must be considered in the differential diagnosis. Chapters XI-XVII show how to analyze this differential diagnosis into a definite diagnosis and give a brief description of the characteristic features and therapy of each disease. Throughout this book, stress has been placed on the practical diagnostic and prognostic rather than on the theoretical aspects of hematology.

USE OF THE ATLAS

Chapter I. To use the Atlas most efficiently, one should become thoroughly familiar with the contents of this first chapter since it outlines the method of using the book. It gives the important points to be obtained in the history, physical examination, and laboratory study of patients thought to have disorders of the blood or blood-forming organs and indicates by chapter number where to find a detailed description of these conditions. One section discusses the problem of nomenclature and gives a table of equivalents for the terms used in this Atlas. The section on cell identification in this chapter is the most important part of the book. It explains the use of a series of tables which should enable any one to identify any cell encountered in a satisfactory preparation. The final section with the frontispiece and its legend outlines briefly the various theories of the histogenesis of the cells of the blood.

Chapters II-X. These chapters picture and describe in detail the cells of the blood and sternal marrow. *For convenience of reference, each cell and its accompanying description is numbered in sequence in bold face type and all numbers given in bold face type in this Atlas refer to these cells and their descriptions.* To avoid repetition, a general discussion of each cell type precedes the comment on the individual cells. This general discussion explains the method of identifying this cell type and of differentiating it from cells resembling it, and gives the normal occurrence and the diagnostic significance of the presence or any change in the incidence of this cell type in blood or marrow. The number of the cell having the most typical morphology for this type is given. The other cells of the type show the variations less frequently encountered. The specific comment on each cell gives the size of the cell in micra, the source from which it was obtained, and any deviations from the typical description of the cell type.

It is evident, therefore, that in looking up any number, one should always read the general discussion of this cell type before the specific comment. For example, if one is looking up a reference to **40**, one should read first the general discussion in chapter III under the main heading PROMONOCYTES **34-41** and then the discussion headed by the number **40**.

The cell types are arranged in order from the most immature to the most mature. This is the actual order of development of these cells. Since the more mature types are the ones most commonly seen in the blood, if one wishes to study the cells by proceeding from the better known to the less well known, one should start with the last cell type in the chapter and read about the cells in reverse order. For example, in chapter II, one could read first the discussion of the LYMPHOCYTES, **17-30**, then of the PROLYMPHOCYTES, **6-16**, and finally of the LYMPHOBLASTS, **1-5**.

Since there is no logical order for the sequence of chapters II-X, it makes no real difference in what order they are read.

Chapters XI-XVII. These chapters discuss the general principles of diagnosis of the major groups of hematologic disorders and give tables of differential diagnosis and a concise description of the characteristic hematology of each disease.

THE EXAMINATION OF PATIENTS WITH HEMATOLOGIC DISORDERS

The history. Any patient who complains of weakness, pallor, hemorrhages from the mucous membranes or under the skin, sore throat, swollen gums, recurrent attacks of jaundice, ataxia, paresthesias, or enlargement in the region of the superficial lymph nodes should have a thorough hematologic examination.

Weakness, pallor, and shortness of breath are general symptoms of anemia (chapter XI) but may occur in many other diseases. Hemorrhage from the mucous membranes or petechiae necessitates consideration of the hemorrhagic diseases (chapter XIV). Sore throat or stomatitis may be the first symptom of agranulocytosis, infectious mononucleosis (chapter XV), aplastic anemia (chapter XI), or acute leukemias (chapter XII). Enlargement of the lymph nodes may occur in Hodgkin's disease, lymphosarcoma (chapter XIII), or leukemias (chapter XII). Ataxia or paresthesias are often early symptons in combined system disease which is usually associated with pernicious anemia (chapter XI).

The patient should be asked specifically as to whether any drugs are being taken or treatment given. If so, further questions should be asked to ascertain whether aminopyrine, dinitrophenol (chapter XV), benzol, lead, acetanilid, radio-active substances, or roentgen rays may be an etiologic factor in the patient's illness (chapter XI).

The family history should include a definite statement as to whether any relative is known to have had an illness similar in character to the patient's illness or whether any relative had a tendency to excessive hemorrhage or recurrent jaundice. In a male patient with hemorrhagic tendencies a history of a hemorrhagic tendency in the mother's uncles or brothers is especially suggestive of hemophilia (chapter XIV). Recurrent attacks of jaundice in a patient or in the patient's relatives, especially if the first attacks occur before 20 years of age, strongly suggest a diagnosis of hemolytic icterus (chapter XIII).

Any of these findings in the history indicates a thorough physical examination with special attention directed to the hematopoietic system and a careful laboratory study.

The physical examination. The color of the skin, mucous membranes, and palms of the hands should be observed. The presence of prolonged, unexplained fever, or intermittent fever with chills should be noted. The size of the cervical, axillary, epitrochlear, and inguinal lymph nodes should be recorded on a scale of one to four plus. The description of the lymph nodes should include the consistency, the degree of sensitivity to pressure and the amount of fixation to each other or to adjacent tissue. Any lesions of the oral or pharyngeal mucous membranes or a sore or smooth, atrophic tongue should be described. The distribution, depth in the skin, and extent of any petechiae, ecchymoses, or skin lesions should be noted. Tenderness over the sternum should be tested for by firm pressure. The size of the spleen and liver should be investigated by palpation and percussion. The size as determined by palpation should be given on a scale of one to four plus, and the size by percussion in centimeters. For the spleen, measure the distance from the intersection of the posterior axillary line and the upper level of splenic dullness, diagonally along the intercostal space, to the point anteriorly where splenic dullness is replaced by tympany from gas in the bowel or stomach. For the liver, measure the distance along the mid-clavicular line from the upper border of liver dullness which is determined by heavy percussion

to the lower border as determined by light percussion. If the spleen or liver is palpable, the description should include the consistency, the shape, and the characteristics of the surface and edge of the organ.

The muscle sense should be determined in the fingers and toes and vibration sense should be tested over the malleoli and tibiae with a tuning fork with a frequency of 64 or 128 vibrations per second to detect evidence of dorsal column involvement. The Babinski and tendon reflexes should be tested to determine the function of the pyramidal tracts.

Pallor of the skin and mucous membranes suggests anemia (chapter XI) but may be due to edema as in nephrosis, to a thick skin as in myxedema, or to contracted peripheral capillaries as in persons who spend much time indoors. The color of the palms of the hands (Duke) is a more reliable criterion than the color of the skin elsewhere. Only an accurate red blood cell count and hemoglobin estimation will tell with certainty, however, whether or not the patient is anemic. A deep red color in the face and mucous membranes with engorgement of the veins is suggestive of polycythemia (chapter XI).

Jaundice in any person, if diseases of the liver or biliary tract can be excluded, is suggestive of an increased rate of hemoglobin destruction such as occurs in internal hemorrhage, malaria, pernicious anemia, and sickle cell anemia (chapter XI). Jaundice in a person under 25 years of age is especially suggestive of familial hemolytic icterus (chapter XIII).

Prolonged, unexplained fever may be due to Hodgkin's disease, lymphosarcoma (chapter XIII), leukemia (chapter XII), subacute bacterial endocarditis, tuberculosis, or undulant fever (chapter XVI). Intermittent fever with chills may be due to malaria (chapter XVII), pyelitis, liver abscess, or thrombophlebitis (chapter XVI).

A generalized enlargement of the lymph nodes suggests Hodgkin's disease, lymphosarcoma (chapter XIII), leukemia (chapter XII), or infectious mononucleosis (chapter XV), but may occur in syphilis or, rarely, in tuberculosis.

A gangrenous stomatitis or a pharyngitis, especially if covered by a dirty white membrane, is characteristically present in any condition in which the neutrophils are markedly decreased in the blood but may occur in infectious mononucleosis (chapter XV).

Marked swelling of the gums occurs more commonly in monocytic than in any other form of leukemia but should always suggest the possibility of an acute leukemia (chapter XII).

Hemorrhages (chapter XIV) from the mucous membranes or into the skin occurring in either sex without obvious trauma suggest thrombopenic purpura which may be of the idiopathic type or a part of the syndrome of leukemias, aplastic anemia, or poisoning with benzol or radio-active substances. Hemorrhages dating from early life, in a male, which are brought on by slight trauma suggest hemophilia. Scurvy must be considered in infants or in adults on an inadequate diet.

Tenderness over the sternum is often present in leukemia (chapter XII) and may be present in multiple myeloma or bone metastases of malignant tumors (chapter XI). Absence of this sign does not exclude these diagnoses.

Enlargement of the spleen and liver, associated with enlargement of the lymph nodes (chapter XIII) suggests leukemia, Hodgkin's disease, or lymphosarcoma. Enlargement of the spleen with or without enlargement of the liver but not associated with enlargement of the lymph nodes suggests, if the enlargement is very great, Gaucher's disease, Banti's disease, kala azar, xanthomatosis, Niemann-Pick's disease, or hemolytic icterus (chapter XIII). A slight or moderate enlargement sometimes occurs in these conditions and may occur in pernicious anemia, cirrhosis of the liver, malaria, sickle cell anemia (chapter XI), infectious mononucleosis (chapter XV), or subacute bacterial endocarditis (chapter XVI). In any of these conditions the spleen may be enlarged without enlargement of the liver, and in portal thrombosis the spleen is uniformly enlarged without enlargement of the liver.

TABLE 1. NORMAL HEMATOLOGIC STANDARDS*

	No.	Age	Sex	Average	Range, 95 per cent
Erythrocyte count	215	4–13	M & F	5.0	4.20–5.80
	259	14–30	M	5.4	4.60–6.20
	152	14–30	F	4.8	4.20–5.40
Hemoglobin, per cent	215	4–13	M & F	85.0	70.0–100.0
	259	14–30	M	115.0	100.0–130.0
	152	14–30	F	100.0	85.0–115.0
Hemoglobin, grams	215	4–13	M & F	12.0	10.0–14.0
	259	14–30	M	15.8	14.0–18.0
	152	14–30	F	13.8	11.5–16.0
Hemoglobin coefficient	215	4–13	M & F	12.0	10.2–13.8
	259	14–30	M	14.7	12.8–16.8
	152	14–30	F	14.3	12.5–16.0
Cell volume	215	4–13	M & F	36.0	31.0–41.0
	46	14–17	F	36.0	31.0–41.0
	63	14–19	M	41.0	36.0–45.0
	106	18–30	F	41.0	36.0–45.0
	153	20–30	M	45.0	40.0–50.0
Volume coefficient	304	4–17	M & F	36.0	31.0–41.0
	173	18–30	M	41.0	35.0–45.0
	106	18–30	F	43.0	38.0–47.0
Color index	626	4–30	M & F	1.00	0.85–1.15
Volume index	583	4–30	M & F	1.00	0.85–1.15
Saturation Index	583	4–30	M & F	1.00	0.90–1.10
Reticulocytes	476	4–30	M & F	1.50	0.50–3.00
Leukocyte count	86	4– 7	M & F	10,400	6,000–15,000
	242	8–18	M & F	8,300	4,500–13,500
	269	19–30	M & F	7,400	4,500–11,500
Neutrophil lobocytes (Segmented neutrophils)	241	4–14	M & F	38.0	18.0–58.0
	120	15–19	M & F	48.0	25.0–75.0
	236	20–30	M & F	54.0	33.0–78.0
Neutrophil rhabdocytes (Neutrophil staff cells)	219	4–13	M & F	3.0	0.0–10.0
	378	14–30	M & F	0.8	0.0– 5.0
Lymphocytes	241	4–14	M & F	48.0	21.0–71.0
	120	15–19	M & F	42.0	22.0–62.0
	236	20–30	M & F	38.0	18.0–65.0
Monocytes	219	4–13	M & F	3.0	0.5– 7.0
	378	14–30	M & F	4.0	0.0– 9.0
Eosinophil lobocytes (Segmented eosinophils)	219	4–13	M & F	2.8	0.0– 8.0
	378	14–30	M & F	1.9	0.0– 6.0
Basophil lobocytes (Segmented basophils)	597	4–30	M & F	0.5	0.0– 2.0
Disintegrating cells	219	4–13	M & F	5.0	0.0–10.0
	378	14–30	M & F	3.5	0.0– 7.0
Sedimentation rate,					
15 minutes	853	4–30	M & F	.....	0.0– 5.0
45 minutes	853	4–30	M & F	.....	1.0–30.0

*As modified from Osgood, E. E.: Textbook of Laboratory Diagnosis. Ed. 2, p. 179. P. Blakiston's Son and Company, Philadelphia, 1935.

The laboratory examination. This is most important but cannot be intelligently planned until the history and physical examination have been completed. Every patient examined should have a routine hematologic examination, consisting of a red and white blood cell count, hemoglobin estimation, differential cell count, and a sedimentation rate determination. The reason for doing such an examination in every patient is that it frequently gives information when there is nothing in the history or physical examination to suggest a disturbance of the hematopoietic system. The normal values for the routine hematologic examination are given in table 1.

If the red cell count or hemoglobin are significantly above the normal limits given for the patient's age and sex group, polycythemia (chapter XI) is present and the Congo red test for the total blood volume may be necessary.

If the red cell count or hemoglobin estimation or both are below normal limits for the patient's age and sex group, the patient has anemia (chapter XI) and the color, volume, and saturation indexes should be determined to establish the type of anemia. The stained smear should be examined for nucleated red cells, polychromatophilia, and basophilic stippling, and a reticulocyte count should be done to determine the rate of erythrocyte formation. The icterus index of the blood serum and urobilinogen in the urine should be determined to permit an estimate of the rate of red cell destruction. The stools should be examined for blood and parasites and the gastric contents studied for evidences of tumor, ulcer, or pernicious anemia.

If the total leukocyte count is above 50,000, it is almost certain that the patient has leukemia (chapter XII) but such counts may rarely occur after acute hemorrhage or in whooping cough.

A total leukocyte count between 11,500 and 50,000 is usually due to infection, acidosis, pain, severe muscular activity, etc. (chapter XVI), but is compatible with a diagnosis of leukemia (chapter XII), Hodgkin's disease, lymphosarcoma (chapter XIII), or polycythemia rubra vera (chapter XI) if the other evidence supports such a diagnosis. A normal leukocyte count does not exclude leukemia or any of the other causes of an increased leukocyte count.

If the total leukocyte count is under 4,500, agranulocytosis (chapter XV), aleukemic leukemia (chapter XII), aplastic anemia, pernicious anemia (chapter XI), Banti's disease, thrombosis of the portal vein (chapter XIII), typhoid fever, and influenza (chapter XVI) must be considered and a careful study of the marrow obtained by sternal puncture is indicated unless the diagnosis is readily established from the history, physical examination, or study of the blood.

An increase in the sedimentation rate indicates organic disease, usually infection, malignant tumor, or internal hemorrhage. It is also increased in pregnacy. Its chief value is in following the course of an illness and in detecting disease which has not been recognized from the routine history and physical examination.

Examination of the stained smear and the differential cell count are the most important parts of the routine hematologic examination but since most of the book is devoted to the technic and interpretation of these examinations, the discussion will be deferred.

In patients who have a history of hemorrhage from the mucous membranes or into the skin, a platelet count, a Rumpel-Leede test of capillary fragility, a Lee and White coagulation time, and a determination of the bleeding time and clot retraction are indicated. The differential value of these tests is discussed in chapter XIV.

In Negroes, especially if anemia is present a moist cover slip preparation should be examined for the development of sickle cells (chapter XI).

Whenever hemolytic icterus (chapter XIII) is suspected because of recurrent jaundice, enlargement of the spleen, a high reticulocyte count, or microcytosis in the blood smear, an erythrocyte fragility test should be done. If pernicious anemia (chapter XI) is suspected, the stomach contents after histamine stimulation should be examined for free hydrochloric acid which is nearly always absent.

Splenic puncture is indicated in all patients with an enlarged spleen (chapter XIII) in which the diagnosis has not been established by methods previously mentioned.

A supravital study, using the technic of Sabin, is of value in research study of any marrow or blood and is often of diagnostic assistance in differentiating monocytes from other cell types. It is especially valuable in proving that cells are still living in marrow cultures. However, in the author's opinion, any cell which can be identified in a supravital preparation can be identified in a good Wright's stain, using the system of cell identification given here.

The interpretation of the differential cell count of blood and marrow is discussed in detail in a subsequent section of this chapter and in chapters II-X. The technics of sternal puncture, reticulocyte staining, and peroxidase staining are given in the appendix. Detailed directions for the technic and interpretation of the other tests mentioned in this section will be found in the author's Textbook of Laboratory Diagnosis and will not be repeated here.

NOMENCLATURE

Much of the confusion in hematologic literature is due to the terminology. Authors have used terms without defining them sufficiently clearly so that others can be certain to use them in the same way, and many terms have been coined to describe the same cell type. Actually cells undergo continuous changes in the process of maturation and it is possible to divide them into a few stages (just as people may be divided into children or adults) or into a great many stages (newborn infants, preschool or school age, adolescents, etc.). Any classification is arbitrary but some subdivision is necessary. The most practical classification should have the fewest subdivisions compatible with diagnostic and descriptive accuracy, and the terminology should be descriptive and clearly defined.

These ideals have been kept in mind in choosing the nomenclature for this Atlas. In order to aid in comparing the terms used here with those used in hematologic literature, table 2 is appended. Rather than coin an entirely new nomenclature, the terms in current use which seemed most accurately descriptive have been selected as the preferred terms and have been redefined with such definite criteria that it is hoped that any one using these criteria will classify the same cell in the same way. In the case of the erythrocyte and granulocyte (myeloid) series, however, a new nomenclature has been introduced, but in this edition the old term most nearly equivalent to the new term is given in parentheses.

It seemed necessary to introduce a new nomenclature for the erythrocyte and granulocyte (myeloid) series because of the disagreement in the definitions and the inappropriateness of the terms in current use. To make certain that they were understood as intended, any one using the old terms would have to define them each time they were used. The term *normoblast* exemplifies the inappropriateness of the old terms. It is a combination of a Latin and Greek root which should mean a normal stem cell since the termination *blast* is ordinarily employed only for the most immature cell of a series. The cell, however, is neither a stem cell nor a normal cell of the blood.

The derivation of the new terms for the erythrocyte series is from the Greek word meaning *nucleated*. It would have been a little more logical to include the syllables *erythro* between the karyo and the final syllable, thus making karyoerythroblast, prokaryoerythrocyte, etc., but this makes the names unduly long and it seemed better to omit these syllables and have it understood that these are cells of the erythrocyte series.

The old term *myeloid series* means marrow-like cells. This is a misnomer because they are cells forming an integral part of the marrow. Furthermore, this does not differentiate them from cells of the monocyte, plasmacyte, or erythrocyte series which are also found normally in the marrow. On the other hand, the term *granulocyte series* has come into current use for all cells of this group and seems much more logical. The letters S and A after the progranulocytes

TABLE 2. NOMENCLATURE

Name of series	Recommended name	Names which have been applied to the same cell
Lymphocyte	Lymphoblast	Myeloblast[1], hemocytoblast[2], lymphoidocyte[3], stem cell, lymphocyte[4, 5]
	Prolymphocyte	Large lymphocyte[6], pathologic large lymphocyte[6], atypical leukocytoid lymphocyte[7], monocyte[5]
	Lymphocyte	Small, medium, or large lymphocyte, normal lymphocyte, small, medium or large mononuclear
Monocyte	Monoblast	Myeloblast[1], hemocytoblast[2], lymphoidocyte,[3] lymphocyte[4, 5], stem cell, immature monocyte
	Promonocyte	Premonocyte[7], hemohistioblast[2], immature monocyte
	Monocyte	Large mononuclear[8], transitional[9], clasmatocyte[9], endothelial leukocyte[4], histiocyte[10], resting wandering cell[4]
Granulocyte (Myeloid)	Granuloblast	Myeloblast[1, 6], hemocytoblast[2], lymphoidocyte[3], lymphocyte[4, 5], stem cell
	Progranulocyte S*	Promyelocyte I[6], myelocyte A[9], myelocyte, non-filament[11], class I[12]
	Progranulocyte A	Promyelocyte II[6], leukoblast[1], basophil myelocyte[13], myeloblast[5], premyelocyte[9]
	Granulocyte	Myelocyte[6], myelocyte B[9], non-filament[11], class I[12]
	Metagranulocyte *	Metamyelocyte[6], juvenile[14], myelocyte C[9], non-filament[11], class I[12]
	Rhabdocyte	Staff cell[6], stab cell[14], band cell[15], non-filament[11], class I[12], rod nuclear[16], polymorphonuclear
	Lobocyte	Segmented neutrophil[6], polymorphonuclear, filamented[11], class II, III, IV or V[12]
Plasmacyte	Plasmablast	Myeloblast[1], hemocytoblast[2], lymphoidocyte[3], lymphocyte[4, 5], stem cell, lymphoblastic plasma cell[5]
	Proplasmacyte	Türk cell[6], Türk irritation form, lymphoblastic or myeloblastic plasma cell[1, 4]
	Plasmacyte	Plasma cell[6], Unna's plasma cell, Marschalko plasma cell, plasmacytoid lymphocyte[1, 3]
Erythrocyte	Karyoblast	Megaloblast[6], myeloblast[1], hemocytoblast[2], lymphoidocyte[3], lymphocyte[4, 5], stem cell promegaloblast[1], basophilic normoblast[1], primitive erythroblast[9]
	Prokaryocyte	Erythroblast, megaloblast[6], orthochromatic normoblast[1], basophilic normoblast[1], polychromatophilic normoblast[1], macronormoblast[15], macroblast[15]
	Karyocyte	Normoblast[6], pronormoblast[1], macronormoblast[15], erythroblast, polychromatophilic normoblast[1]
	Metakaryocyte	Normoblast[6]
	Reticulocyte	
	Akaryocyte	Erythrocyte, red blood cell, erythroplastid, normocyte[16]
Thrombocyte	Megalokaryoblast	Megakaryoblast
	Promegalokaryocyte	Promegakaryocyte
	Megalokaryocyte	Megakaryocyte
	Platelet	Thrombocyte, thromboplastid
	Disintegrated cell	Senile cells, smudge, basket cell, smear cell, degenerated cell

*Any basophil from the progranulocyte to the lobocyte is sometimes referred to as a *mast cell*.

1. H. Downey and K. Kato; 2. A. Ferrata; 3. A. Pappenheim; 4. A. A. Maximow and W. Bloom; 5. An error in classification; 6. E. E. Osgood; 7. P. W. Clough; 8. An obsolete term; 9. R. Cunningham, F. Sabin, and C. Doan; 10. Common term for monocytes when found in tissues; 11. D. L. Farley, H. St. Clair, and J. A. Reisinger; 12. W. E. Cooke and E. Ponder; 13. An error due to interpretation of azurophil granules as basophil granules; 14. V. Schilling; 15. A. Piney; 16. R. B. H. Gradwohl.

(promyelocytes) have been substituted for the I and II to avoid a suggestion of sequence. S applies to cells which have *s*pecific granulation, i.e., neutrophil, eosinophil, or basophil, and A applies to cells which have *a*zurophil granulation or are *a*granular. The terms *rhabdocyte* and *lobocyte* should really be *rhabdogranulocyte* and *lobogranulocyte* but these seemed unduly cumbersome. The derivation of the term *rhabdocyte* is from the Greek word meaning "curved rod, stick, or wand" which well describes the shape of the nuclei of these cells. The term *lobocyte* is from the Greek word meaning "lobed" and should also suggest the typical lobed or segmented character of the nuclei of these cells much better than the cumbersome old term *polymorphonuclear*. The use of these terms avoids the confusion arising from the use by some of the term *polymorphonuclear* to include the rhabdocytes (staff cells).

The definitions of the terms used here will be found in the general discussions in chapters II-IX and may also be deduced from tables 3-7. For convenience, the German and French equivalents are also given with the description of the cell types in chapters II-IX. It should be noted that in this Atlas the author has changed some of the nomenclature and definitions he used in the first and second editions of his Textbook of Laboratory Diagnosis.

It must always be kept clearly in mind that the confusion is in the terminology and not in the cells. The cells as pictured in this Atlas were drawn from actual examples and every detail of their morphology has been preserved. The slides and mechanical stage numbers for each cell are filed so that the original cells may be shown to any one who wishes to compare them with the drawings.

CELL IDENTIFICATION

The first essential to accurate identification of the cells of the blood or marrow is a satisfactory smear and stain.

Making the smear. To obtain a good smear, place a small drop of blood or sternal marrow one-half inch from the end of a *clean* slide. Place this slide on a firm surface. Select a second slide having a smooth edge free from nicks and, holding it at an angle of about 60° to the first slide, draw it back until it just touches the blood. Then let the drop of blood follow the second slide as it is moved across the first one with a smooth, even motion. The drop of blood should be of such size that the smear runs completely out before reaching the end, and the thickness of the smear should be regulated by the rate of movement of the smearing slide—the slower the motion the thinner will be the smear, and vice versa. A good smear should have a smooth, even surface, free from ridges or waves, and under the microscope the red cells at the thinner end should not touch one another.

Staining. To obtain a good stain it is essential that the absolute methyl alcohol used for dissolving the Wright's stain should be kept tightly stoppered at all times and be absolutely anhydrous. The Wright's stain, after it is made up by shaking 0.1 gm. of the stain with 20.0 c.c. of methyl alcohol, should be kept in a tightly stoppered bottle and filtered at least once a week into a small bottle for current use. This bottle should be kept tightly stoppered.

To stain the smear, cover with Wright's stain for one to two minutes and then add an equal volume of a buffer phosphate solution* having a pH of 6.4, prepared by dissolving 6.63 gms. of monopotassium phosphate and 2.56 gms. of anhydrous di-sodium phosphate in one liter of distilled water, adding about 1.0 c.c. of chloroform. The use of this phosphate solution instead of distilled water is very important if really good stains are to be secured.

When each new lot of stain is made up, test the time of exposure to the buffer phosphate by staining a series of slides, varying the time after mixing the phosphate and stain by one minute

*These solutions and the solutions or standards for any of the methods recommended in this Atlas or in the author's Textbook of Laboratory Diagnosis may be purchased already prepared from the Shaw Supply Company, Portland, Oregon.

intervals from one to ten minutes and note which time gives the best results with this particular stain. As a rule, smears made from sternal marrow should have about double the time after addition of the buffer phosphate that is required for smears made from blood. At the end of the staining time, holding the slide horizontally to avoid pouring off the stain, wash it with a brisk stream of running tap water for at least thirty seconds. Then stand it on edge until dry.

A good stain should show no precipitate or debris between the cells. The red cells should stain an orange-buff similar to the cytoplasm of **206**, the neutrophil granules should stain a shade of lilac (**68-85**), and monocyte granules should be clearly visible (**37-51**). If the colors in the cells are to appear as illustrated in this Atlas, northern daylight or a light source with a blue daylight filter should be used. Some microscopic lamps give a yellow light which is unsatisfactory for correct evaluation of color.

Examination of stained smears. When examining the slide, cover its surface with cedar oil or mineral oil and survey it first under high power or, better, with an 8 mm. objective and 10 x eye piece (magnification x 200) for its general features. Locate an area in which the individual cells do not touch each other for examination with the oil immersion lens. This is important because in thick areas where red cells touch each other, the cells are so distorted that even expert hematologists may be unable to identify them. If for any reason the cells are too scarce for counting, do not attempt to make a thicker smear but centrifugate the blood, draw off the excess plasma, remix, and make a thin smear. If the red cell count is high but the white cell count is low, centrifugate and draw off the buffy coat along with a little plasma and a little of the red cell layer, mix, and make a thin smear.

System for cell identification. The following system has been developed to permit any one to identify any cell encountered in a properly stained preparation. It is based on answering a series of simple questions, suggested by the headings of tables 3-7, just as are the systems used in qualitative chemical analysis. The first question is, *does the cell contain neutrophil, eosinophil, basophil, or azurophil granules?* Neutrophil granules are small, uniform in size, uncountably numerous, and stain a shade of lilac (**68-86**). Eosinophil granules are large, round, uniform in size, and stain orange-red with pale centers (**93-106**). An occasional eosinophil granule stains blue (**94**) in good stains; all may stain blue in poor stains. Basophil granules vary in size from small to large in the same cell, are fewer in number than neutrophil or eosinophil granules, and stain a bluish-red entirely different from the color of the nucleus (**107-117**). Azurophil granules (all cell numbers in table 6) stain exactly the same color as the nucleus of the cell in which they are found but may be darker or paler and vary in number from a very few to many. They may be grouped or diffusely scattered through the cytoplasm.

Having learned to recognize the granules, determine what kind of granule the cell under consideration contains and look up further identification in the tables as listed below.

Granules	See table
Neutrophil	3
Eosinophil	4
Basophil	5
Azurophil	6
No granules	7

If neutrophil, eosinophil, or basophil granules are present (tables 3-5), the next question to ask is, *does the nucleus contain nucleoli?* These are blue staining, structureless areas within the nucleus. If it does, and the nucleus is round or oval, the cell is the progranulocyte S (promyelocyte I) corresponding to the type of granule. If nucleoli are absent, the next question to ask is, *what is the shape of the nucleus?* According to the shape of the nucleus, the name of the cell is given in table 3, 4, or 5.