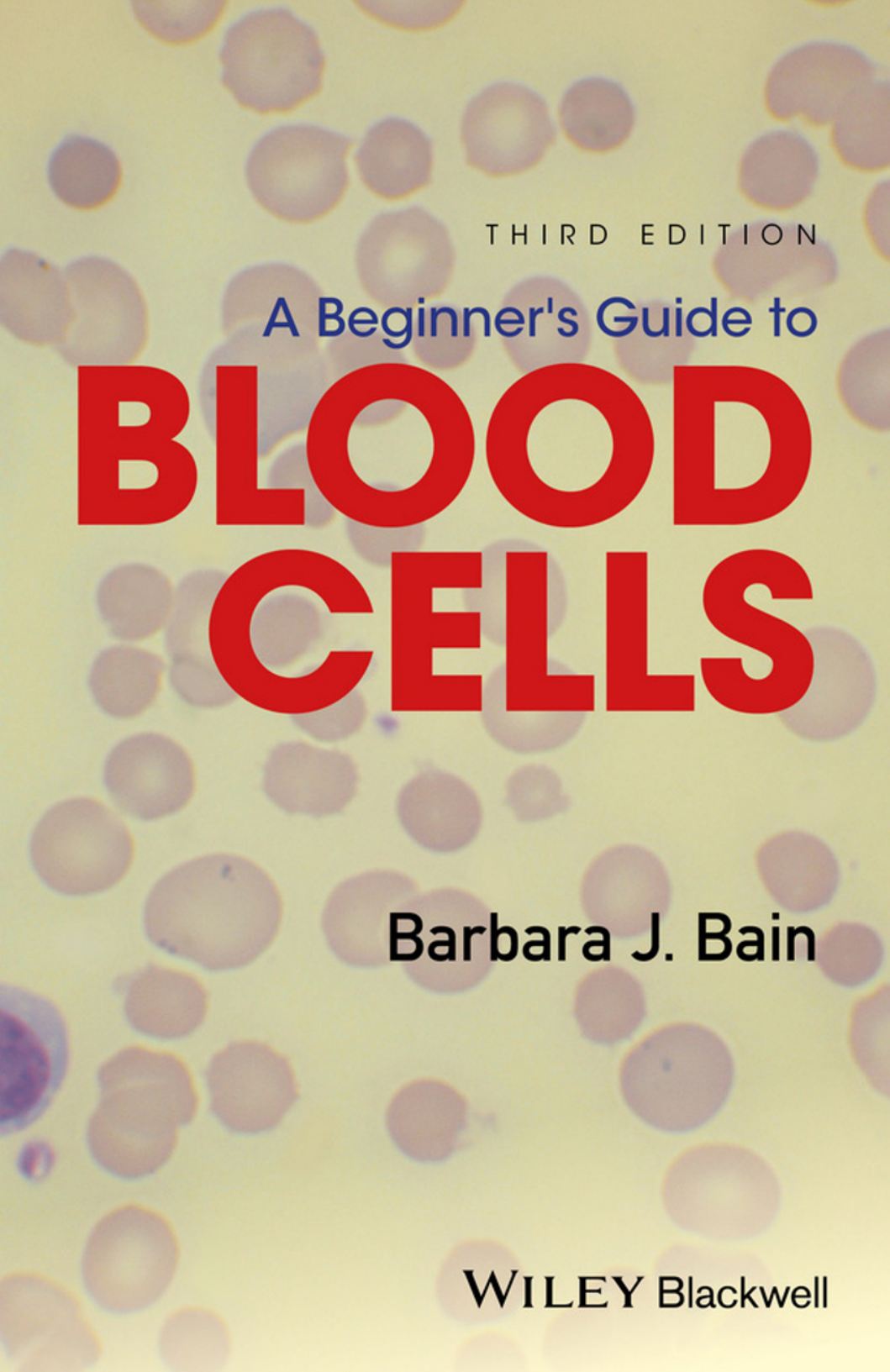
THIRD EDITION
A Beginner's Guide to
BLOOD CELLS
Barbara J. Bain
WILEY Blackwell

A BEGINNER'S GUIDE TO BLOOD CELLS

A Beginner's Guide to Blood Cells

3rd Edition

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Preface

A Beginner's Guide to Blood Cells is an introduction to normal and abnormal blood cells and blood counts for trainees, whether they be trainee laboratory scientists, medical students, trainee haematologists or trainee physicians. It may be seen as complementary to *Blood Cells: a Practical Guide* (5th edition, Wiley-Blackwell, Oxford, 2015), from which the illustrations are largely drawn and which should be consulted for more information and relevant references. *A Beginner's Guide*, unlike *Blood Cells*, does not seek to be comprehensive. It introduces the important basic concepts, sets haematological findings in a clinical context and, in the final chapter, lets the reader test his or her own knowledge. An important new chapter in this edition deals with emergency morphology and will be of particular importance to those working out-of-hours for the first time.

All photographs, except those showing malaria parasites, are of blood films stained by May–Grünwald–Giemsa (MGG) stain and the majority, one exception being that showing microfilariae, have been taken at the same magnification so that they can be readily compared with each other.

I should like to thank Sally Gordon and Abbas Hashim Abdulsalam for their critical review of this edition.

Barbara J. Bain
2017

Abbreviations

DNA	deoxyribonucleic acid
FBC	full blood count
fl	femtolitre
G6PD	glucose-6-phosphate dehydrogenase
Hb	haemoglobin concentration
Hct	haematocrit
HDW	haemoglobin distribution width
HPLC	high-performance liquid chromatography
MCH	mean cell haemoglobin
MCHC	mean cell haemoglobin concentration
MCV	mean cell volume
MGG	May–Grünwald–Giemsa
NRBC	nucleated red blood cell
PCV	packed cell volume
pg	picogram
RBC	red blood cell count
RDW	red cell distribution width
RNA	ribonucleic acid
WBC	white blood cell count

Other abbreviations that are used only occasionally are explained when first used in a chapter.

CHAPTER 1

The Blood Film and Count

Blood

Blood is a life-sustaining fluid that circulates through the heart and blood vessels. It carries oxygen and nutrients to the tissues and waste products to the lungs, liver and kidneys, where they can be removed from the body. Usually when blood is removed from the body it forms a solid blood clot. However, if clotting is prevented by mixing with an anticoagulant, the blood separates, under the influence of gravity, into three layers (Fig. 1.1). The bottom layer is deep red in colour and is composed of red cells. The top layer is clear and pale yellow. It is called plasma and is composed of various salts and proteins dissolved in water. In between is a narrow layer called the buffy coat because of its buff or yellowish white colour. The buffy coat is composed mainly of cells of a variety of types, collectively known as white cells. In addition there are small cellular fragments, called platelets, which have a role in blood clotting.

The blood film

Although we can judge the proportions of red cells and white cells in a tube of sedimented blood, we get far more information if the blood is carefully mixed and a thin layer is spread on a glass

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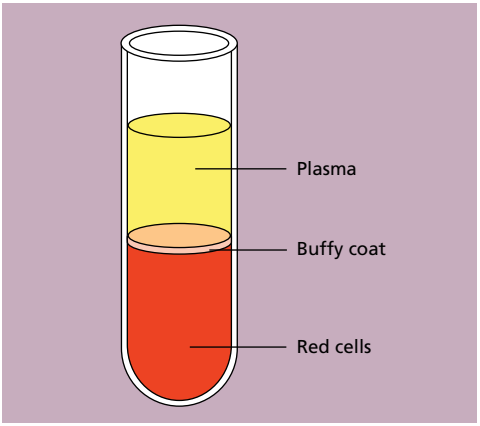

Fig. 1.1 Diagram of a tube of anticoagulated blood that has been allowed to sediment, showing the separation of blood into red cells, a buffy coat (white cells and platelets) and plasma.

slide to form a blood film. The blood cells are then preserved by exposure to the alcohol methanol, a process known as fixation. The fixed film of blood is stained with a mixture of several dyes so that the individual cells can be recognized when they are examined with a microscope. After staining, the colour of red cells is enhanced and the white cells and platelets, which would otherwise be transparent and colourless, have acquired a variety of colours that allow their detailed structure to be recognized. One of the commonest mixtures of dyes used to stain blood cells is the May–Grünwald–Giemsa (MGG) stain, named after its inventors. All the photographs in this book are of MGG-stained blood films.

Red cells

The most numerous cells in a blood film are the red cells, also known as erythrocytes. Normal red cells are disc-shaped but are thinner in the centre (Fig. 1.2). As a consequence, on a stained blood film, they have a circular outline and a paler central area (Fig. 1.3). Red cells owe their pinkish-brown colour to the presence of a complex protein, haemoglobin, which is their major constituent. Enhancement of their colour in a stained film is

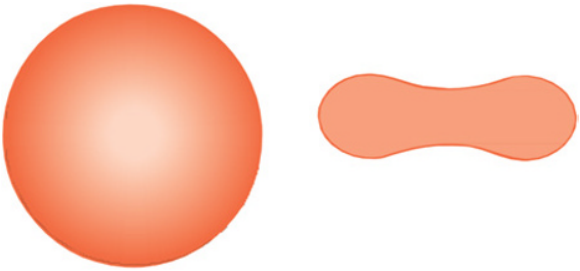

Fig. 1.2 A diagram of a red cell viewed from above and in cross-section.

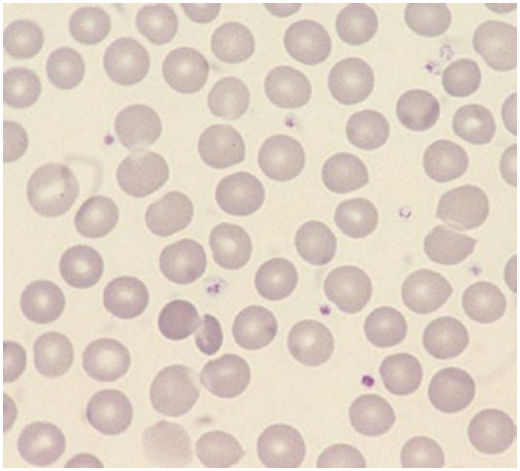

Fig. 1.3 Normal red cells (erythrocytes) showing little variation in size and shape, an approximately round outline and a small area of central pallor in some of the cells. The small structures containing lilac-staining granules between the red cells are platelets.

because haemoglobin takes up eosin, one of the dyes of the MGG stain. In the body it is haemoglobin of the red cells that, in the lungs, combines with oxygen from inspired air and transports it to tissues where it is needed for the metabolic processes supplying the energy needs of the body. Mature red cells in humans (although not in some other species) differ from most body cells in that they do not have a nucleus. Red cells are produced in the bone marrow and usually lose their nuclei when they are released into the blood stream.

White cells

In healthy people there are at least five types of white cell, or leucocyte, in the circulating blood. Unlike red cells, white cells have retained their nuclei. The cell is therefore made up of a nucleus and cytoplasm. The cytoplasm is the site of protein synthesis and other cellular functions. The nucleus is composed of chromatin, which is mainly deoxyribonucleic acid (DNA), carrying genetic messages. Genetic messages are transmitted from the nucleus to the cytoplasm by ribonucleic acid (RNA).

White cells are divided into granulocytes (also known as polymorphonuclear leucocytes) and mononuclear cells. There are three types of granulocyte and two types of mononuclear cell (Fig. 1.4). The names are not very logical but they have been in use for a long time and are generally accepted. Granulocytes are so named because their cytoplasm contains prominent granules. However, monocytes also have granules and so do some lymphocytes. The term 'granulocyte' should not be used as a synonym for neutrophil. The term polymorphonuclear leucocyte refers to the very variable nuclear shape that is typical of granulocytes. The term mononuclear cell means that the cell has only a single nucleus. However, this is true of granulocytes, as well as of the cells conventionally referred to as mononuclear. The functions of the various leucocytes are summarized in Table 1.1.

Neutrophils

Neutrophils (Fig. 1.5) have a nucleus that stains purple and is divided into two to five segments or lobes. The lobes are separated by a thin strand or filament of nuclear material. The nuclear chromatin is heterogeneous with some clumping. The cytoplasm of neutrophils is very pale pink and is packed with fine lilac-staining granules. The visible granules are actually the primary or azurophilic granules, the secondary or specific granules being invisible by light microscopy but conveying the pink tinge to the cytoplasm. The term 'neutrophilic' indicates that at this stage of maturation the primary granules owe their colour to uptake of both the acidic and the basic components of the stain.

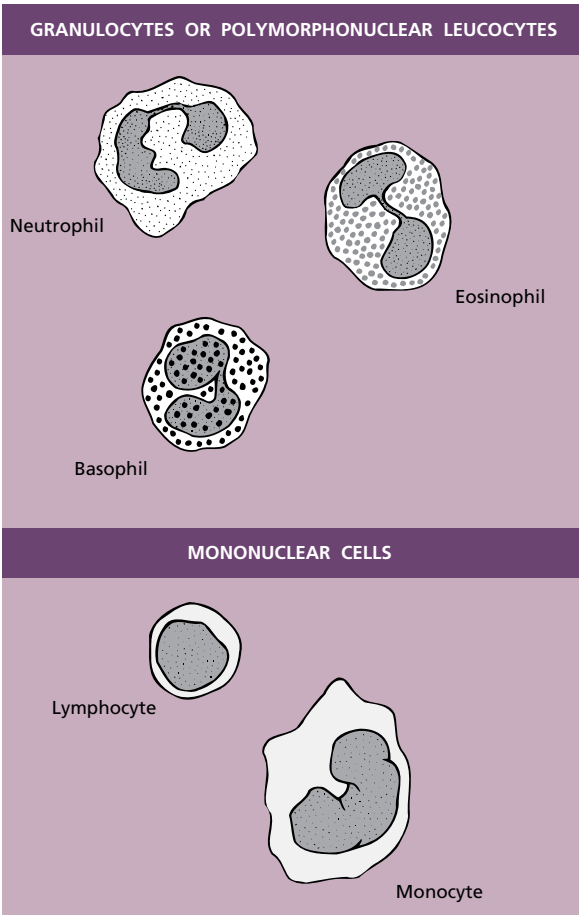

Fig. 1.4 A diagram showing how white cells are classified.

In females a proportion of the neutrophils have a very small lobe, known as a 'drumstick', protruding from the nucleus (Fig. 1.6). It represents the inactive X-chromosome of the cell.

Neutrophils are produced in the bone marrow. They spend 6–10 hours in the blood stream before moving from capillaries into tissues, where they have a life-span of 1–2 days. The major function of neutrophils is as tissue phagocytes. They move preferentially to sites of infection or inflammation where they ingest, kill and break down bacteria. The process of moving to sites of

Table 1.1 The functions of leucocytes.

Cell	Major function	
Neutrophil	Is attracted to sites of infection by a process known as chemotaxis; ingests microorganisms (a process known as phagocytosis) and destroys them	
Eosinophil	The same functions as the neutrophil; in addition, helps control parasitic infections; has a role in allergic responses	
Basophil	Has a role in immediate hypersensitivity reactions, allergic and inflammatory responses and in the control of parasitic infections	
Lymphocyte	Mediates immune responses	B lymphocyte matures into a plasma cell, which secretes antibodies (humoral immunity) T lymphocyte attacks cells bearing foreign antigens and antibody-coated cells; can help or suppress B cells (part of cell-mediated immunity) Natural killer lymphocyte (NK cell) attacks foreign cells and tumour cells (part of cell-mediated immunity)
Monocyte	Phagocytoses and kills microorganisms including mycobacteria and fungi, phagocytoses cells or organisms that have bound immunoglobulin or complement, and phagocytoses dead and damaged cells; presents antigen to cells of the immune system; migrates to tissues where it differentiates to become a long-lived phagocytic and antigen-presenting cell known as a macrophage	

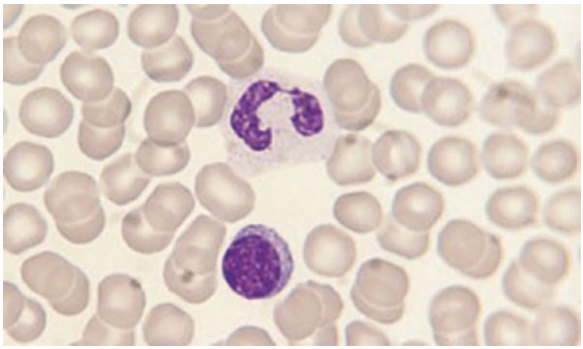

Fig. 1.5 A normal neutrophil with a bilobed nucleus and cytoplasm containing delicate lilac-staining granules. The other nucleated cell is a small lymphocyte.

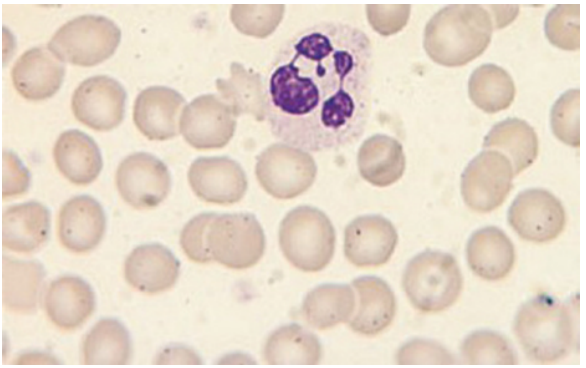

Fig. 1.6 A normal neutrophil from a female showing a nucleus with four lobes and a 'drumstick'.

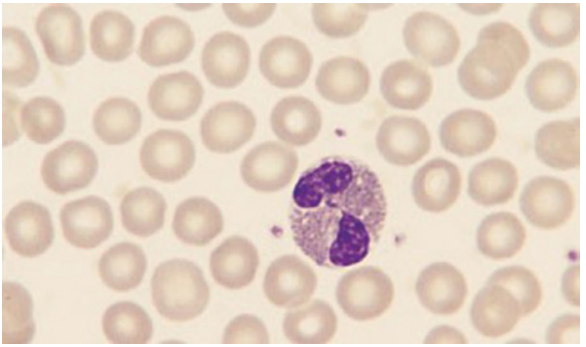

Fig. 1.7 A normal bilobed eosinophil. The granules are reddish-orange and pack the cytoplasm.

infection or inflammation, in response to activated complement components and chemical signals released by a variety of cells, is known as chemotaxis. The process of ingesting bacteria is known as phagocytosis.

Eosinophils

Eosinophils (Fig. 1.7) have a nucleus that is usually bilobed and pale blue cytoplasm, which is packed with large refractile, orange-red granules. The granules are referred to as eosinophilic because they take up the acidic dye eosin. Eosinophils are produced in the bone marrow and circulate in the blood stream