BLOOD
PHYSIOLOGY AND CIRCULATION

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CONTENTS

INTRODUCTION 10

CHAPTER 1: THE FLUID OF LIFE 17
Blood 19
Blood Components 21
Plasma 23
Blood Cells 29
Blood Cell Formation 53
Bone Marrow 54
Production of Red Blood Cells 56
Destruction of Red Blood Cells 58

CHAPTER 2: THE DYNAMICS OF BLOOD 61
Circulation 61
Arteries 63
Veins 65
Capillaries 66
Blood Pressure 67
Functions of Blood 68
Respiration 69
Nutrition 71
Excretion 72
Hemostasis 73
Immunity 74
Temperature Regulation 75
Bleeding and Blood Clotting 76
Significance of Hemostasis 76
The Hemostatic Process 79

CHAPTER 3: BLOOD GROUP SYSTEMS 92

Blood Groups 93
Historical Background 93
Blood Typing 96
ABO Blood Group System 97
MNSs Blood Group System 98
P Blood Group System 99
Rh Blood Group System 100
Lutheran Blood Group System 102
Kell Blood Group System 102
Lewis Blood Group System 103
Duffy Blood Group System 104
Kidd Blood Group System 105
Diego Blood Group System 106
Yt Blood Group System 107
Li Blood Group System 108
Xg Blood Group System 109
Dombrock Blood Group System 110
Secretor System 111
Antigens and Antibodies 112
Chemistry of Blood Groups 114
Blood Groups and Genetic Linkage 115
Blood Groups and Population Groups 119

Chapter 4: Blood Analysis and Therapeutic Applications 121

Blood and Disease 121
Laboratory Examination of Blood 122
Blood Analysis 126
Serum and Serum Albumin 126
Plasma 127
Separation of Plasma and Serum 129
Measurable Properties of Blood 129
Blood Cell Count 130
Coagulation Tests 132
Sedimentation and Compatibility Tests 132
Hematocrit 133
Serological Tests 134
Methods of Blood Grouping 135
Identification of Blood Groups 135
Coombs Test 137
Adsorption, Elution, and Triation 138
Inhibition Tests 139
Hemolysis 140
Sources of Antibodies and Antigens 140
Blood Bank 141
Therapeutic Applications 143
Blood Transfusion 143
Organ Transplant 150
Paternity Testing 153
Bone Marrow and Hematopoietic Stem Cells 153
Bone Marrow Transplant 157
Autologous and Alloeneic Transplants 158
Risks of Bone Marrow Transplant 159
Collection of Donor Stem Cells 160

CHAPTER 5: DISEASES OF RED BLOOD CELLS AND HEMOGLOBIN 161
Disorders of Red Blood Cells 161
Anemia 163
Megaloblastic Anemias 165
Pernicious Anemia 169
Normocytic Normochromic Anemias 170
Aplastic Anemia 172
Hypochromic Microcytic Anemias 174
Iron Deficiency Anemia 175
Hemolytic Anemias 177
Hemoglobinopathy 181
Polycythemia 190
Pickwickian Syndrome 192
Porphyria 193
Sulfhemoglobinemia 195
Methemoglobinemia 195

Chapter 6: Diseases of White Blood Cells and Platelets and Disorders of Coagulation 197
Diseases of White Blood Cells 197
Leukocytosis 198
Leukopenia 203
Leukemia 205
Lymphoma 211
Multiple Myeloma 213
Bleeding Disorders 214
Thrombocytopenia 215
Disorders of Platelet Function 217
Vascular Causes of Bleeding Disorders 218
Coagulation Disorders 218
Hemophilia 219
Vitamin K Deficiency 221
Von Willebrand Disease 221
Thrombosis 224

Conclusion 226
Appendix: Tables 227
Glossary 229
Bibliography 232
Index 234
Humans have been fascinated by the intricacies of blood as far back as early Egyptian civilization. Tombs in Egypt depicted bloodletting—a procedure through which blood is intentionally removed from a vein—as a treatment for sick patients. Some ancient Greeks drank the blood of a fallen warrior, believing that by doing so they would gain the dead man’s strength and courage. Misunderstandings persisted for centuries. For instance, medical professionals still erroneously believed that bloodletting was the “cure” for a number of maladies well into the Common Era. It wasn’t until 1628, when British physician William Harvey published his finding on how blood was pumped from the heart throughout the body and then recirculated, that the widespread practice of draining a person’s blood was called into question.

A proper and thorough understanding of blood’s function took thousands of years to develop. Throughout the 20th century and into the 21st, methods of examining, storing, and using blood were improved in order to more effectively fight disease and save lives. Indeed, the understanding of how blood works in the body has come a long way, as elucidated in this volume. Readers will discover virtually everything science has learned about blood, from its basic properties to its circulation through the body to its malfunction in disease.

Blood has numerous functions in a healthy body. One of its primary tasks is to deliver oxygen and nutrients to the body’s cells. Blood also distributes warmth to those regions that need it the most, wards off disease, and helps to filter harmful waste products such as carbon dioxide out of the body.

The various components of blood each play a role. In humans, blood cells are produced by stem cells in the bone marrow. Once these cells develop, they are released into
the bloodstream. Red blood cells deliver hemoglobin, which is the iron-bearing protein that makes the transportation of oxygen possible. Hemoglobin also gives human blood, and that of many other animals, its red colour. Certain creatures have different oxygen-carrying pigments, such as hemocyanin or chlorocruorin. When oxygenated, these pigments turn blood various colours; for example, blood is blue when the copper-rich hemocyanin is present, and it is green when chlorocruorin is present. The existence of different types of blood pigments explains why crustaceans such as lobsters have blue blood.

Also known as erythrocytes, red blood cells make up about 45 percent of blood. The liquid portion of the blood, plasma, makes up about 54 percent of blood’s content. Although 90 percent water, plasma contains elements that are essential for sustaining health and life, including critical proteins. The remaining 1 percent of blood’s composition is made up of white blood cells (leukocytes) and platelets (thrombocytes). White blood cells help protect the body from infections and disease by destroying the agents that cause illness. White blood cells are further categorized as lymphocytes, which help the body’s immunity, and phagocytic cells (both granulocytes and monocytes), which ingest and break down microorganisms and foreign particles. The tiny fragments called platelets are important in the formation of blood clots (coagulation).

The average adult has about 5 quarts (4 to 5 litres) of blood coursing through his or her body, working in conjunction with organs to control concentrations of various elements necessary to keeping a person healthy. The lungs deliver oxygen, for example, and the kidneys take away extra water and waste. The liver performs several functions together with blood, including the removal of toxins, the manufacture of blood-clotting agents, and the destruction of old red blood cells. (The average red blood cell can
survive as many as 120 days.) The liver also stores sugars, which are converted into glycogen. When the body needs energy, the glycogen is converted back to glucose and is released into the bloodstream.

The body depends on the circulatory system for blood to carry out its functions. The heart is the engine that keeps the bloodstream flowing, carrying blood away from the heart in arteries and transporting it back through veins.

Two veins, the inferior vena cava and the superior vena cava, allow blood to enter the heart’s right chamber, while the aorta pumps blood out from the left chamber. Each beat of the heart involves both muscular relaxation, to let blood in, and muscular contraction, to push blood out. The average human heart beats about 60 to 80 times per minute, but it slows during sleep and beats faster during exercise.

Arteries transport blood away from the heart. First they feed into smaller vessels called arterioles and then into even tinier capillaries, which transport the blood to the body’s tissues. The network of capillaries—each of which is smaller in diameter than a human hair and just large enough for red blood cells to pass through in single file—is extensive. The capillaries also connect to small veins called venules, which connect to veins for the blood’s journey back to the heart.

The force that blood flow exerts against the walls of blood vessels is called blood pressure, and it is, in every sense, a true life force. Among the standard tests medical professionals perform to gauge a person’s health is the measurement of his or her blood pressure. Two types of readings are taken: systolic, which is the force as the heart pumps blood out to the tissues, and diastolic, which is the pressure as the heart relaxes. Doctors give the measurement with a number indicating systolic pressure on top and diastolic pressure on the bottom. According to the
American Heart Association, a healthy blood pressure for an adult age 20 years or older is less than 120/80. High blood pressure, which is called hypertension, can be a warning sign of developing heart disease, kidney disease, hardening of the arteries, and stroke. Proper diet and regular exercise can help keep blood pressure at healthy levels.

Blood volume is just as important to healthy body function as blood pressure. The body’s self-defence measure against blood loss is hemostasis, a coagulation mechanism that forms a clot when blood vessels are damaged. When blood leaks from a vessel, cells release chemicals that give the platelets a sticky quality, which allows them to bond together and clot. Simultaneously, threads called fibrin are generated, which help trap more blood cells. A scab on a scraped knee is the handiwork of the blood’s hemostasis mechanism. Vitamin K (from the Danish word *koagulation*) is required for the synthesis of several blood-clotting factors.

In a case when serious blood loss occurs, doctors have the option of performing a transfusion. The procedure of transferring blood from one person to another, which is called a blood transfusion, may be required to treat extensive hemorrhaging, burns, or trauma; to increase the number and concentration of red blood cells in persons with anemia; and to treat shock. Transfusion was made much safer in 1901, when American biologist Karl Landsteiner first identified blood by groups—A, B, AB, or O. Blood is typed according to the presence or absence of proteins called antigens on red cells. Blood group O, the most common in the world and known as the universal blood type, lacks A or B antigens.

Blood is also commonly identified by an antigen called the Rhesus (Rh) factor. In blood shorthand, presence of Rh is noted with a + (positive sign), and its absence is marked with a − (negative sign). For a successful transfusion, it is
preferable to use a patient’s exact blood type. Failing that, a compatible blood type needs to be found, but not all blood types are compatible. For example, a person who has type A blood can receive only types A and O blood because O is the universal blood type and can be transfused to people with other types of blood.

There are additional blood group systems, named for the presence or absence of certain, often rare, antigens. These systems include the P, MNSs, Kidd, Kell, Diego, Lutheran, Duffy, and Lewis systems. A Coombs test can help detect these antigens.

Doctors can use blood samples, often referred to as “blood work,” to diagnose their patients. One of the most common blood tests, the complete blood count (CBC) test, is a broad screening exam that can detect disorders. Blood testing can also be used to diagnose allergies, autoimmune diseases, cancer, diabetes, gastrointestinal problems, kidney disease, and liver disease, as well as many other conditions.

Disease can also be contained within blood itself. There are disorders that affect red cells, compromising the blood’s ability to deliver oxygen to bodily tissue and organs. The most common of these is anemia, which is a condition caused by there being too few or a low volume of red cells in a person’s blood composition. Hemoglobin abnormalities are responsible for illnesses such as sickle cell anemia, where red cells exhibit a sickle-shaped deformity, and thalassemia, which is a group of blood disorders marked by hemoglobin deficiency.

Diseases of the white blood cells typically result in immune system suppression, making the body more susceptible to the negative effects of infections. Abnormalities in size, shape, and number of white blood cells are indicative of infections ranging from the relatively innocuous mononucleosis to life-threatening diseases such as leukemia.
Because bone marrow produces white blood cells, bone marrow transplants have been used to treat specific immune deficiency and hematological disorders.

Problems with coagulation define another category of blood disease. Bleeding disorders, which may be either inherited or acquired, are conditions that cause excessive or spontaneous bleeding in response to minor injury. The most readily recognizable of these diseases is hemophilia.

The American Red Cross reports that every two seconds someone in the United States is in need of blood. Blood from donors is essential to replace the blood lost in a patient who is undergoing a major operation, such as an organ transplant, that may involve copious blood loss. Through the 1940s, blood banks rapidly developed throughout the United States as the means to take blood from donors, and the ability to store blood improved. Blood can now be stored for up to 49 days with refrigeration and the addition of special preservatives. Advanced methods allow for the “fractioning” of blood when needed, separating the distinct components for specific treatments. For instance, chronic anemia can be treated with packed red blood, and white blood cells can be used to treat those who have a low white blood cell count and are battling infection. Platelets may be used for bleeding when there is a platelet deficiency. Because blood is capable of carrying disease, all donated blood is tested for HIV (human immunodeficiency virus), hepatitis B and C, and other infectious agents.

The human heart pumps a vast amount of precious blood each day—on average, nearly 600 pints per hour. Through this volume’s provocative exploration of blood’s properties and components, how it maintains the body, how it provides indication of disease and health, and how it can save lives, one can certainly understand why blood is called the fluid of life.