HUMAN PHYSIOLOGY

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HUMAN PHYSIOLOGY

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To the memory of

JUAN BAUTISTA SAUBERAN

and to

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in grateful acknowledgment

of their work in support of

scientific research

this book is dedicated

Foreword

WHILE THERE IS no avowed tendency to "nationalism" in science, it is inevitable that any scientist will give more attention and, hence, more apparent importance to what is being done in his own country. Such a tendency has always been known to be responsible for overemphasis on the laboratory from which emanates an author's or editor's own work. This is, perhaps, an unavoidable tendency, inherent in the nature of things, but it is pernicious because it detracts from an essential attribute of science, its universality. The geographic and, to some extent, also the cultural detachment of the great continent to the south of us has yielded an unique fruit in this remarkable treatise on physiology. It is the product of a group of men who not only are fruitful investigators but who, working where science has not hitherto been intensively cultivated, have felt themselves forced to study conscientiously the literature in mammalian physiology produced throughout the world. They have thus the perspective requisite for a balanced account.

The group has furthermore led an ideal intellectual life with daily or at least frequent intercommunication. It has been led by a great individual, Bernardo A. Houssay, whose capacity to break new ground has been adequately acknowledged by a Nobel award. Those who had watched the initiation of Professor Houssay's career and the remarkable School which he had set up in that great capital, Buenos Aires, were not surprised by his brilliant Dunham Lectures at Harvard University some years ago, but it is perhaps safe to say that the Dunham Lectures first introduced this scholar and his pupils to his North American confreres.

The group effort just mentioned has conferred upon this treatise a remarkable unity, a unity otherwise given a treatise only by a single individual, and it is well known that it is no longer possible for an individual to cover the whole field of a given science. Furthermore, the English version of the treatise has been provided by one of its authors, Juan Lewis, and that has itself aided the uniformity and harmony of the book.

While the sections on circulatory physiology, under the able auspices of Orías, and renal physiology, under Braun-Menéndez, could be compared advantageously with any textual treatments of these themes, it is inevitable that the outstanding excellence of this treatise will be considered its treatment of the field of endocrine physiology, a field of enormous present-day importance, in which almost daily advances are being made. All North American colleagues of these Argentine scientists now welcome warmly this signal accomplishment of the group.

HERBERT M. EVANS
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Preface

This book has been written for medical students and for doctors of medicine who wish to study the fundamental principles of modern physiology. It has been written for students who have no knowledge of pathology, but who must acquire the physiological basis necessary for the study of disease and the practice of medicine. A book to be used in medical education cannot be merely a textbook of applied medical physiology; therefore the facts of human physiology have been given preferential, but not exclusive, consideration. Human physiology is better understood in the light of general and comparative physiology, and a living organism is more completely known when there is some knowledge of other species. Many advances in human physiology have originated in studies on isolated cells, on yeasts, and on the lower animals.

Physiology is a science that studies the phenomena occurring in living organisms and endeavors to establish their laws. It is that part of biological science which studies the functions of living organisms in health and disease. The knowledge of physiology is indispensable in medicine because the same general laws apply to normal and to pathologic conditions of life; disease is simply the modification or deviation of normal function and cannot be understood without previous knowledge of the normal state.

Physiology as a science is not dependent on medicine, and as such it should be studied for its own sake, without being limited to its medical, veterinary, or zootechnical applications. Even in a medical school, the study of physiology should not be reduced to problems of human physiology and its medical applications. Undoubtedly, however, human medicine has been the most powerful stimulus for the study of physiology, and even now in several countries it is taught only in medical schools.

An outstanding feature of modern medicine is its physiological foundation. Medicine has a threefold purpose: to preserve health, to prevent disease, and to cure disease. The doctor in the first place must know how to preserve and improve health, which is the normal condition of man's life, whereas illness attacks him only during short periods. The advancement of physiology and experimental medicine has been instrumental in the lengthening of life and in ever greater efficiency in the prevention and treatment of disease.

Physiological discoveries sooner or later always find useful applications in medicine and in hygiene, but they must first become familiar to the medical man. Unfortunately, many years often pass by before these applications enter into current medical practice. A solid grounding in physiology and in the experimental method, from the very beginning of medical education, will do much to remedy this regrettable state of affairs.

The desire to obtain the benefit of applied science must not make one forget that an exclusive interest in that which is immediately practical ends in a narrow rut of mediocrity. The most useful discoveries in medicine have been the consequence of disinterested research, not directed toward any definite application. Excessive preoccupation with practical results leads to shortsightedness and diminishes the fertility and scope of research and knowledge. There is no pure science; there is only science and its applications, which may be evident immediately or may take some time to develop. It is a common belief that many physiological facts are of only academic interest and have little or no practical value. This serious misconception should be corrected; every method of diagnosis and treatment now in use is the outcome of disinterested scientific research, and no one can say that knowledge that is apparently useless today will not have some application tomorrow that may be of great value.

Medical students can be taught only a small part of all that is known. The choice of what is most formative and useful will best be made by those with a wide knowledge of the science to be taught and with personal experience in its methods and techniques. Such competency can be achieved only after long and arduous work in the laboratory with complete dedication to the task.

A textbook of physiology for medical students and doctors must strike a balance between widely differing requirements. It must expound ideas taken from several sciences applied in physiology; it must explain the general principles of physiology and the functions of the different organs and systems, as well as their correlations; finally, it must integrate information obtained by the clinical and experimental study of altered function. A student can assimilate only a limited amount of knowledge in the time given to physiology in a well-balanced medical curriculum. This requires wise discrimination between the little that can be taught and the far wider field that must be left out. It is far better to have precise knowledge of fundamental principles than vague ideas about a great number of facts.

The facts of human physiology should be used in preference to physiological facts on other species for the illustration of general principles, thus satisfying the need for applied knowledge and at the same time linking it up with medicine and surgery. The tendency to separate them fostered by the inevitable separation between the clinic and the laboratory will thus be counteracted. It will be of great advantage for the education of the future physicians, and for the advancement of medicine and of physiology, if the development of as many contacts as possible is stimulated by the study of problems common to physiology and medicine.

Many problems can be solved only by animal experimentation, and most of the discoveries afterward usefully applied in man were first made by this method. Nevertheless research in human physiology has the advantage that its results can be applied immediately to man and that the subjects can give reasonable and conscious collaboration, which cannot be obtained from animals.

The study of pathologic conditions is also important, because knowledge of disease or altered function is useful for the understanding of normal function. Diseases can be considered as natural experiments, some of which have given valuable information not obtained from laboratory experiments. Clinical physiologists contribute daily to the advancement of physiology, and reciprocally a profound knowledge of physiology is indispensable for the making of original discoveries in clinical medicine and for efficiency in the practice of medicine. In the teaching of physiology, demonstrations in healthy subjects and a variety of clinical cases become more useful every day.

The student should never lose sight of the fact that it is only for didactic reasons that the different systems and organs are considered separately, as if they could be taken apart from the rest of the organism. This separation is completely artificial, as the whole organism is an indivisible anatomic and functional unit.

Physiology is in a constant process of evolution and advancement; a textbook should reflect this active life and not give the impression of a catalogue of completed and unchangeable statements. The reader's interest should be awakened by this progressive evolution, and the wish should be born in him to follow this continuous increase in knowledge and, if possible, to make personal contributions to it.

Science in general, and physiology in particular, can be taught properly only by intense, practical, and individual teaching—a fact recognized in all advanced centers of medical education. A book cannot be a substitute for this kind of teaching; it can be no more than a useful guide. The practical and rational study of physiology develops a scientific attitude of mind; namely, the capacity to find truth and to recognize error, and the habit of rigorous demonstration instead of dogmatic affirmation of imaginative statements that dazzle the simple-minded.

Physiology is nourished by experimental research, which is the permanent search for truth by adequate and precise methods. It is conscientious and continuous searching and researching so as to increase and perfect knowledge. In former times the only precise medical science was that of normal anatomy; later that of pathologic anatomy was added; at a still later date bacteriology was preeminent; today we are in the era of physiology, which has rejuvenated these sciences and given fresh vigor to them and to medicine in general.

In this book, statements will be supported by adequate proof as far as possible, so as to create the habit of critical appreciation. Unfortunately, for reasons of space it is not possible to do this in all cases, but it must be understood that these demonstrations exist and are available in more specialized books or in the original papers quoted in the bibliographic references. The only way of avoiding the intellectual vice of unreasoned acceptance of unsupported statements, when these are presented in an attractive form, is a practical and individual education in the scientific method. For such an education, no textbook can be a substitute.

Students do not always have sufficient training in the basic sciences of biology, physics, and chemistry. In other cases, their knowledge has been forgotten. It is therefore sometimes necessary to recall certain facts that ought to be familiar. Other indispensable information in anatomy, histology, embryology, biochemistry, and biophysics is omitted because it is considered as known or can be easily found in the appropriate textbooks. A few subjects of great importance are treated somewhat summarily, *e.g.*, nutrition and growth in childhood, and pregnancy and parturition. In the course of medical studies, these will be discussed in greater detail in pediatrics, obstetrics, etc. Certain information considered of secondary or mainly clinical interest, or debatable questions, or the description of methods, is included in smaller print. At the foot of the page reference is made to a few classic papers and to others of recent date that describe work of importance. At the end of each chapter there is a short list of books and papers which will help those who wish to make a deeper study of the subject in question.

Information included in this book has been obtained from sources in all countries and languages, and although sometimes the work done by the authors' group is given in greater detail, an effort has been made to keep this within reasonable bounds. The authors have been engaged for many years exclusively in teaching and research, and although they give their personal views and experience of the different problems, they have tried to render a balanced account covering the whole field of physiology. The book has been written in difficult circumstances, which have caused some otherwise avoidable defects. Also it is not easy to choose wisely and to present adequate knowledge in a field that is constantly developing over an ever wider area, extending to several allied sciences, and in which information must be kept up to date.

This book was written originally to satisfy the need of South American students. Later, French, Portuguese, and English editions were published. The authors have revised the text of each new edition; they have made many corrections, some of the chapters have been almost completely rewritten, and every effort has been made to keep the book up to date.

The authors will be grateful for constructive criticism and suggestions that may help to improve the book and make it a more efficient stimulus and guide for students, thus fulfilling the purpose with which it was written.

BERNARDO A. HOUSSAY

STANDARD UNITS

Mass: The unit is the gram (gram mass, gm.); 1 gm. is the mass of 1 ml. of water at 4°C.; it is the one-thousandth part of the international standard kilogram, made of platinum and iridium, which is kept in Paris.

Time: The unit is the second (sec.); 1 sec. is the sixtieth part of 1 min., which is the sixtieth part of 1 hr.; 1 hr. is the twenty-fourth part of the average solar day; *i.e.*, the average duration of the days in the solar year (86,400 sec.).

Length: The unit is the centimeter (cm.); 1 cm. is the hundredth part of the standard meter, which is the distance between two lines on a platinum bar kept in Paris; it is approximately one ten-millionth part of a quadrant of a meridian of the earth.

Velocity: The unit is the centimeter per second (cm./sec.).

Acceleration: The unit is the centimeter per second per second (cm./sec.^{2}).

Force: The CGS[1] unit is the dyne; 1 dyne is the force that, acting on a mass of 1 gm. for 1 sec., imparts to it a velocity of 1 cm./sec., *i.e.*, causes an acceleration of 1 cm./sec.^{2} The unit of gravity is the gram weight; 1 gram weight is the force with which the earth attracts 1 gram mass. It is equal to 981 (980.665) dynes and imparts to 1 gram mass an acceleration of 981 cm./sec.^{2} It varies in different places.

Work: The CGS unit is the erg; 1 erg is the force of 1 dyne acting through a distance of 1 cm.; *i.e.*, 1 erg = 1 dyne $\times$ 1 cm. = 23.8 $\times$ 10^{-9} cal. = 10.19 $\times$ 10^{-4} gm.-cm. One joule = 10^7 ergs = 0.23885 cal. The gravitational unit is the gram-centimeter; 1 gm.-cm. = 981 ergs = 23.43 $\times$ 10^{-6} cal., *i.e.*, 23.43 microcalories. The kilogram-meter (kg.-m.) is the most commonly used unit; it is the amount of work spent in raising a mass of 1 kg. to a height of 1 m. It is equal to 9.81 joules.

Power: The CGS unit is the erg per second. One watt = 10^7 ergs/sec. = 1 joule per second. One kilowatt (kw.) = 10^3 watts = 10^{10} ergs/sec. The gravitational unit is the gram-centimeter per second. The metric horsepower is 75 kg.-m./sec. = 0.736 kw. The English horsepower (hp.) is 550 foot-pounds per second = 0.746 kw.

Heat: The unit is the calorie (cal.) or small calorie; 1 cal. is the amount of heat required to raise the temperature of 1 gm. of distilled water 1 degree centigrade (from 14.5 to 15.5°C.); it is equivalent to 4.185 $\times$ 10^{-7} erg = 0.4266 kg.-m. = 4.185 joules. One kilogram-calorie (kg.-cal.) or large calorie (Cal.) is 1,000 cal. = 426.6 kg.-m. = 4,1868 joules.

Temperature: The unit is the degree centigrade (°C.); 1 degree centigrade is the one-hundredth part of the difference in the temperature of melting ice and water boiling at a pressure of 760 mm. Hg. Zero in the centigrade scale corresponds to 273° (273.15°) in the scale of absolute temperature (T or K).

Mole is the molecular weight of a substance in grams = 6.02 $\times$ 10^{23} molecules (Avogadro's number). One millimole = 10^{-3} gram molecular weight. One micromole = 10^{-6} gram molecular weight.

Molar solution contains 1 mole or the molecular weight of the solute in grams in 1 liter of solution. It exerts an osmotic pressure of 22.4 atmospheres at 0°C., and its freezing point is —1.86°C. if the solute is not dissociated.

[1] Centimeter-gram-second, or metric, system of measurement.

ABBREVIATIONS AND SYMBOLS FOR STANDARD UNITS

Prefixes: micro = 10^{-6}, *i.e.*, one-millionth
milli = 10^{-3}, *i.e.*, one-thousandth
centi = 10^{-2}, *i.e.*, one-hundredth
deci = 10^{-1}, *i.e.*, one-tenth
kilo = 10^{3}, *i.e.*, one thousand
mega = 10^{6}, *i.e.*, one million

kilometer	km.
meter	m.
decimeter	dm.
centimeter	cm.
millimeter	mm.
micron (10^{-3} mm.)	μ
millimicron (10^{-6} mm.)	mμ
micromicron (10^{-9} mm.)	$\mu\mu$
Ångstrom unit (10^{-7} mm., 100$\mu\mu$)	A
square meter	sq. m.
square centimeter	sq. cm.
degree (angle)	°
minute (angle)	′
second (angle)	″
hour	hr.
minute (time)	min.
second (time)	sec.
millisecond (0.001 sec.)	σ or msec.
microsecond (0.001 msec.)	μsec
kilogram-meter	kg.-m.
kilogram	kg.
gram	gm.
decigram	dg.
centigram	cg.
milligram	mg.
microgram (10^{-3} mg.)	γ or μg
liter	liter or l.
centiliter	cl.
milliliter (1,000,027 cc.)	ml.
cubic meter	cu. m.
cubic decimeter	cu. dm.
cubic centimeter	cc.
calorie	cal.
Calorie or kilogram-calorie	Cal. or kg.-cal.
degree Celsius (centigrade)	°C.
degree Fahrenheit	°F.
ampere	amp.
volt	volt or v.
millivolt (10^{-3} volt)	mv.
microvolt (10^{-6} volt)	μv.
cycles per second	c.p.s.
revolutions per minute	rev./min.

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SECTION ONE

The Internal Environment and the Blood

CHAPTER 1

The Internal Environment and the Blood

THE INTERNAL ENVIRONMENT

The body fluids. Water constitutes about two-thirds of the body of an adult man. It can be said that the organism is made up of water in which micellae, molecules, and ions are dispersed. The physical and chemical reactions of colloidal and true solutions are therefore of fundamental importance in living organisms.

The body fluids are distributed in three compartments. One is within the cells, the *intracellular fluid;* the other two, outside the cells and forming the *extracellular fluid*, are the *interstitial fluid* and the *blood plasma*. Between these last two compartments the exchange of diffusible substances is easy and continuous, so they have a very similar content of water and salts.

Fluid blood is made up of a liquid, the blood plasma, in which cells (erythrocytes, leukocytes, and platelets) and minute particles (hemokonia or chylomicrons) are suspended. When blood coagulates, it first becomes solid and then a fluid oozes out, which is called the serum.

The internal environment. Multicellular organisms are surrounded by an external environment—air or water—but their cells live in a fluid environment which Claude Bernard in 1878 named the "*milieu intérieur*" (internal environment). This *milieu* is formed by the extracellular fluids, *i.e.*, by (*a*) the interstitial or tissue fluids, which bathe the cells and circulate slowly; (*b*) the lymph contained in the lymphatic vessels, which goes from the tissues to the blood; (*c*) the blood plasma, which circulates rapidly. The cerebrospinal fluid, the aqueous humor of the eye, and the fluid in the pleural and peritoneal cavities, the joints, and the synovial sheaths are particular forms of interstitial fluid.

The blood is the part of the *milieu intérieur* that circulates rapidly within a closed system of vessels. An outstanding feature of the blood is the constancy of its chemical composition and physical properties, thus assuring constant conditions for the functioning of the cells. The blood is being continuously renewed by incoming and outgoing cells and substances; nevertheless the variations in its composition fluctuate within a narrow margin and are rapidly corrected. The functions of the organism are regulated so as to maintain the stability of the internal environment, a physiological fact of great importance which Claude Bernard first pointed out and called the "fixity of the *milieu intérieur*." The concept was developed by Cannon, who coined the term "homeostasis" to signify those steady states maintained by coordinated complex physiologic reactions.

Therefore, on the one hand the blood assures constant conditions to the cells, and on the other the organism maintains the chemical, physical, and morphologic constancy of the blood. According to Claude Bernard, the fixity of the internal environment is the necessary condition for the free and independent life of higher organisms.

THE BLOOD

Blood consists of a fluid in which there are free cells—the red cells, or erythrocytes; the white cells, or leukocytes; and the platelets. It is also a dispersion of micellae, molecules, and ions in water, and therefore has the properties of colloidal and true solutions.

The relative volumes of erythrocytes and plasma. The volume of cells in 100 cc. of blood[1] is determined by centrifuging (usually at 3,000 rev./min. for 30 min.) blood in which clotting is prevented,[2] until two successive readings give a constant figure. Wintrobe's hematocrit[3] is used for this purpose (Fig. 1), but any well-calibrated tube will do. The erythro-

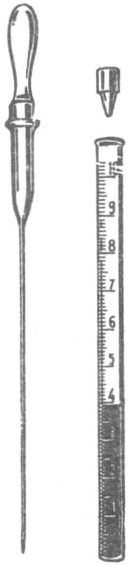

FIG. 1. Wintrobe's hematocrit, with pipet and cover.

cytes are packed at the bottom of the tube; above them there is a 1- to 2-mm. layer of white cells, and above these the plasma. This method of measuring the erythrocyte concentration is less open to error than the red cell count (number of erythrocytes in 1 cu. mm. of blood), and for this reason is now in common clinical use. Human blood has about 45 per cent erythrocytes.

The figures given by the hematocrit are subject to considerable error, according to recent studies,[4] because: (*a*) centrifugation does not separate all the plasma from the erythrocytes, so the cell volume appears to be greater than it really is; (*b*) the plasma-cell ratio in arterial and venous blood, in which it is usually determined, is not the same as in the capillaries, where there is relatively more plasma. By means of methods that use radioactive iron to "label" the erythrocytes (see Chap. 2), it has been shown that the true total amount of red cells in the body is only 70 to 75 per cent of the amount given by the hematocrit.

Functions of the blood. The most important functions of the blood are

1. *Respiration.* It carries oxygen from the lungs to the tissues, and the excess CO_2 from the tissues to the lungs.
2. *Nutrition.* It carries foodstuffs absorbed from the intestine or produced within the body to the cells, which use or store them.
3. *Excretion.* It carries the waste products of cellular metabolism to the excretory organs, where they are eliminated.
4. *Immunity.* It transports leukocytes, antibodies, and other protective substances.
5. *Humoral correlation.* It carries nutritive and hormonal secretions from one organ to another; these secretions regulate the functions of the organism.
6. *Water balance of the body.* Water is continuously passing from one to another of the three compartments previously mentioned and thence to the excretory organs.
7. *Temperature regulation.* In this the blood plays a part in several ways: (*a*) because of the high specific heat of water, the body fluids can store a great quantity of heat; (*b*) the blood circulating rapidly distributes this heat and tends to keep an even temperature throughout the body; (*c*) blood carries heat to the body surface, where the heat is eliminated by irradiation and evaporation; (*d*) blood supplies the water for cutaneous and pulmonary evaporation.
8. *Regulation of the osmotic pressure.*
9. *Regulation of the acid-base equilibrium.*
10. *Regulation of ionic equilibrium* between cations and anions; between monovalent cations (Na^+, K^+) and bivalent cations (Ca^{++}, Mg^{++}); between electrolytes and proteins.
11. *Regulation of the blood pressure* by changes in the blood volume.

Thus these functions of the blood serve to maintain the constancy of the internal environment and of the fundamental physical and chemical equilibriums such as temperature, osmotic pressure, and ionic and acid-base

[1] Also called the "packed-cell volume," the "plasma-cell ratio," the "percentage of red cells," or the "concentration of erythrocytes."

[2] Heparin (see Chap. 8) is used for this purpose; also Wintrobe's dry salt mixture: 4 mg. of potassium oxalate and 6 mg. of ammonium oxalate for 5 cc. of blood.

[3] WINTROBE, M. M., "Clinical Hematology," 3d ed., Lea & Febiger, Philadelphia, 1951.

[4] HAHN, P. F., *et al.*, *J. Exper. Med.*, **75**, 221, 1942; GIBSON, J. G., *et al.*, *J. Clin. Investigation*, **25**, 616 and 848, 1946; MENEELY *et al.*, *Am. J. Physiol.*, **148**, 531, 1947.

equilibriums; also to regulate organic functions and to correlate the different parts of the body. The blood is one of the principal means by which the organism behaves as a functional unit.

The constancy of the blood. The blood has the same composition in all the arteries, while venous blood can differ in different parts of the body, because it is modified by the activity of each organ. Arterial blood should therefore be examined in preference to venous blood when one wishes to know the average blood composition.

The remarkable constancy of the composition of the blood, within a narrow margin of transitory variations, is the result of a dynamic equilibrium between continuously changing factors. This equilibrium is maintained by (*a*) the rapidity with which substances leave the blood when they are in excess, or enter the blood when they fall below the normal concentration; (*b*) certain mechanisms within the blood itself, such as those which neutralize base and acid; (*c*) the activity of the tissues and organs.

The excess of a chemical substance or of blood cells is controlled by the following mechanisms: (*a*) passage into the interstitial fluid, if the substance is diffusible; (*b*) storage or fixation in certain cells; (*c*) destruction or transformation; (*d*) elimination. Excess or waste products are eliminated by the lungs (gases, water), the kidneys (water, salts, waste products, foreign substances), the intestine (water, salts, etc.), and the skin (water, salts, etc.).

When, on the contrary, one of the normal constituents of the blood diminishes, the following reactions of the organism serve to replace it: (*a*) the tissues give up substances kept in storage, such as water, salts, CO_2; (*b*) certain organs produce the necessary substances, such as glucose, proteins, and other nutritive components of the blood; (*c*) the blood cells (erythrocytes and leukocytes) are also replaced by the hemopoietic tissues.

Salt solutions, when injected into the blood, rapidly leave it; they pass into the interstitial fluid and later are eliminated by the kidneys. Colloidal particles, on the other hand, pass very slowly, or do not pass at all, through the endothelium of the blood capillaries, according to the size of the micellae and the permeability of the membrane. These particles remain for a long time in the circulation. They disappear gradually, as they are picked up by the reticuloendothelial cells, the function of which is to capture foreign particles entering the blood stream, such as bacteria and parasites. The cells digest the foreign bodies, which are then gradually eliminated.

Changes in the number of erythrocytes are compensated within a few days or weeks. The loss of red blood cells caused by hemorrhage stimulates a greater production of these cells. On the contrary, the excess of erythrocytes produced by blood transfusion is corrected by a greater destruction.

Physical Properties

Color. Arterial oxygenated blood is scarlet. The less oxygenated venous blood is dark red, almost black, in reflected light, and purple-red in transmitted light. The scarlet color is that of oxyhemoglobin; the dark red is that of hemoglobin, or of methemoglobin and other hemoglobin derivates in abnormal cases. Seen in the veins through the skin, blood has a blue color.

Blood plasma and serum are usually transparent, but they can be cloudy or opalescent, or even have a milky aspect. This appearance is due to fine submicroscopic particles of fat (hemokonia, chylomicrons). Fatty emulsion is prominent in plasma after the digestive absorption of fats; also in cases of hyperlipemia (increase in blood fat), such as occurs in diabetes, or after injecting an extract of the anterior lobe of the hypophysis.

Blood plasma and serum have a more or less intense yellow tinge, due mainly to bilirubin. The pink or red color sometimes seen in normal plasma is due to faulty technique in collecting the blood; it is given by the hemoglobin set free by the destruction of a few red blood cells Sometimes properly prepared plasma has a red tinge because there is an abnormal destruction of erythrocytes in the circulating blood and in consequence hemoglobin is set free (hemoglobinemia).

Opacity. Blood is normally opaque, because the erythrocytes reflect light. When the erythrocytes are dissolved (hemolysis) blood becomes transparent (laked blood).

Specific gravity. The specific gravity of erythrocytes is 1.097 (1.090 to 1.100) greater than that of plasma, which is 1.027 (1.023 to 1.032), therefore when blood is prevented from coagulating and remains standing, the erythrocytes fall to the bottom (erythrosedimenta-