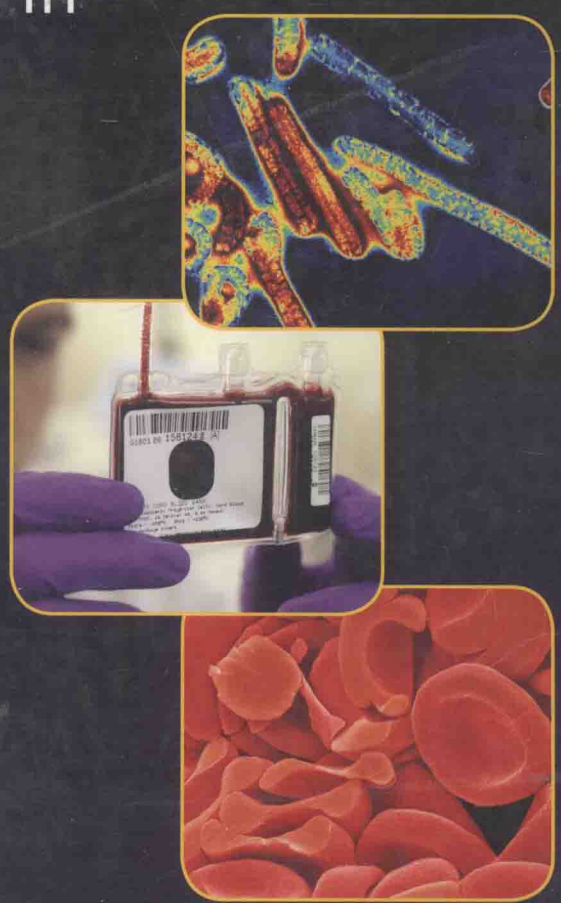
Laboratory Medicine

The Diagnosis of Disease in the Clinical Laboratory



Michael Laposata

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Laboratory Medicine

The Diagnosis of Disease in the Clinical Laboratory

Edited by

Michael Laposata, MD, PhD

Edward and Nancy Fody Professor and
Executive Vice Chair of Pathology
Pathologist-in-Chief
Vanderbilt University Hospital
Professor of Medicine
Vanderbilt University School of Medicine
Nashville, Tennessee

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Laboratory Medicine: The Diagnosis of Disease in the Clinical Laboratory

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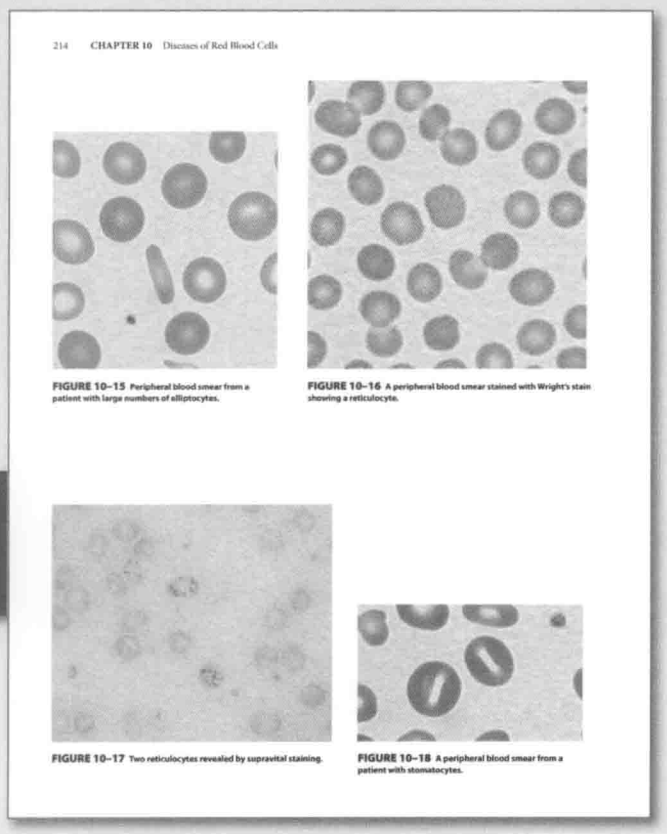
My three wonderful children, Michael, Joe, and Maria, continue to inspire me to think about what I can do to make a difference for someone else. Without their love, this textbook would not have been created.

Key Features of
Laboratory Medicine

A complete full-color guide to selecting the correct laboratory test and accurately interpreting the results—covering the entire field of clinical pathology

- 36 clinical laboratory methods presented in easy-to-understand illustrations which include information on the expense and complexity of the assays
- More than 200 tables and full-color algorithms encapsulate important information and facilitate understanding
- Consistent presentation: chapters begin with a brief description of the disorder followed by a discussion of laboratory diagnosis that includes tables detailing the evaluation of the disorder
- Valuable learning aids in each chapter, including learning objectives, chapter outlines, and a general introduction
- Full-color blood-smear micrographs demonstrate common abnormal morphologies of red blood cells
- Logical systems-based organization parallels most textbooks
- 13-page table of Clinical Laboratory Reference Values showing the conversions between U.S. and SI units for each value

Blood-smear micrographs demonstrate common abnormal morphologies of red blood cells



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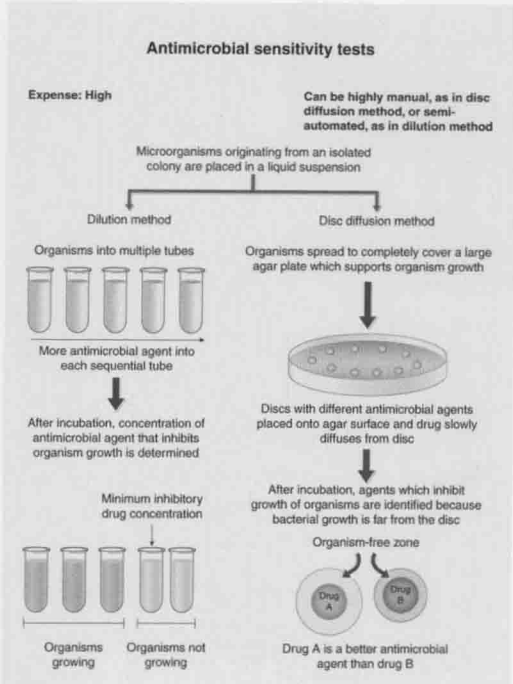

FIGURE 2–10

200 tables and full-color algorithms encapsulate important information

TABLE 5–23 Evaluation for Tuberculosis (TB)

	Pulmonary Tuberculosis	CNS Tuberculosis	Genitourinary Tuberculosis	Disseminated Tuberculosis
Clinical findings	Symptoms range from none to fever with productive cough and dyspnea; hemoptysis indicates presence of advanced disease	Fever, unremitting headache, nausea, and malaise; in the United States, elderly are frequently affected; where TB is common, it primarily affects children aged 1–5 years	Most common site for extrapulmonary TB is the kidney; dysuria, frequency, and hematuria are common; women may present with a chronic pelvic inflammatory process; menstrual irregularities, or sterility; men may present with an enlarging scrotal mass	More likely to occur in HIV-positive individuals; may be present without miliary pattern in chest radiographs; patient may present with fever, weight loss, and anorexia
Tests				
PPD	In the presence of compatible radiologic and clinical findings, a positive PPD in an unvaccinated patient suggests TB	In the presence of compatible radiologic and clinical findings, a positive PPD in an unvaccinated patient suggests TB	In the presence of compatible radiologic and clinical findings, a positive PPD in an unvaccinated patient suggests TB	In the presence of compatible radiologic and clinical findings, a positive PPD in an unvaccinated patient suggests TB
Microscopy	Acid-fast bacilli in sputum smears permit rapid diagnosis; sensitivity is variable, but increases with the number of specimens examined (up to 4)	Acid-fast bacilli in smears of CSF lead to identification of 20% or less of CNS TB cases; sputum samples also should be tested	Both urine and sputum samples should be examined, as a smear from a urine sample may not have detectable acid-fast bacilli	Urine, lymph nodes, liver, bone marrow, and sputum smears have low sensitivity for organism detection
Mycobacterial culture	Culture from sputum specimen on liquid and solid media is the most sensitive method in current use; for pediatric cases, multiple gastric lavage specimens can be used; liquid culture with DNA probe hybridization also enables TB confirmation	Culture of CSF may reveal organisms in CNS TB cases	Urine specimens for mycobacterial culture are positive in 60%–80% of cases, though it is more likely to be positive in men than in women	Culture may be performed using bone marrow, liver, urine, and sputum specimens
Nucleic acid amplification	May be useful for rapid diagnostic confirmation of specimens negative by direct examination	May provide a rapid diagnosis but cannot replace culture	Utility not well defined	Sputum specimens may be used for amplification
Other findings	Pleural fluid, if present, is an exudate (not a transudate) with mononuclear cells	With lumbar puncture, there may be an increased opening pressure and 100–1,000 cells/μL of CSF (mostly mononuclear cells) and elevated CSF protein	In the appropriate clinical setting, TB may be considered if negative routine urine cultures show WBCs in acid urine	Impaired function of infected organs may be noted in routine laboratory tests of those organ systems
Radiology	Chest radiograph may detect adenopathy, effusion, or nodules in HIV-infected patients, the chest radiograph is more likely to be normal	If TB is established in the brain, it may produce a mass, or "tuberculoma," visible by CT scan	40%–75% of cases have a positive chest radiograph; other radiologic studies are not very useful	Chest radiograph may be normal and repeat testing may prove useful; CT scan or MRI may be useful to detect TB in extrapulmonary sites such as the brain or vertebrae
Anatomic pathology	Caseating granulomas may be observed in biopsies of enlarged lymph nodes	Biopsy may be diagnostic	Renal biopsy may be helpful to identify genitourinary lesions	If bronchial washings do not provide diagnosis, granulomas in bone marrow or liver biopsy may be diagnostic

CNS, central nervous system; CSF, cerebrospinal fluid; CT, computed tomography; MRI, magnetic resonance imaging; PPD, purified protein derivative.

CHAPTER

22

The Endocrine System

Michael Laposata, Samir L. Aleryani, and Alison Woodworth

LEARNING OBJECTIVES

1. Learn the physiology and biochemistry of the relevant hormones and other important mediators.
2. Understand the laboratory tests used in the diagnosis of the more commonly encountered disorders.
3. Identify the clinical disorders associated with each of the endocrine glands and the role of specific laboratory tests in their diagnosis.

CHAPTER OUTLINE

Valuable learning aids are included in each chapter

Authors

Yash Pal Agrawal, MD, PhD
Associate Professor of Clinical Pathology and Laboratory Medicine, Weill Cornell Medical College; Director, Central Laboratory; Director, Point of Care Testing Services, Department of Pathology and Laboratory Medicine, New York Presbyterian Hospital, New York, New York

Samir L. Aleryani, PhD
Instructor of Pathology, Medical Director, Laboratory Support Services, Department of Pathology, Vanderbilt University Medical Center, Nashville, Tennessee

Fred S. Apple, PhD
Medical Director, Clinical Laboratories, Hennepin County Medical Center; Professor, Laboratory Medicine and Pathology, University of Minnesota School of Medicine, Minneapolis, Minnesota

Sheila Dawling, PhD, CChem, FRSC
Associate Professor of Pathology, Vanderbilt University School of Medicine; Director, Toxicology/TDM Laboratory; Associate Director, Clinical Chemistry, Vanderbilt University Medical Center, Nashville, Tennessee

D. Robert Dufour, MD, FCAP, FACB
Consultant, Pathology and Hepatology, Veterans Affairs Medical Center; Emeritus Professor of Pathology, The George Washington University Medical Center, Washington, District of Columbia

Karin E. Finberg, MD, PhD
Medical Instructor in Pathology, Department of Pathology, Duke University Medical Center, Durham, North Carolina

Jacqueline J. Haas, MD
Staff Pathologist, Clinical Pathology Associates; Laboratory Medical Director, St. David's Medical Center, Austin, Texas

Michael Laposata, MD, PhD
Edward and Nancy Fody Professor and Executive Vice Chair of Pathology, Pathologist-in-Chief, Vanderbilt University Hospital; Professor of Medicine, Vanderbilt University School of Medicine, Nashville, Tennessee

Daniel D. Mais, MD
Medical Director for Hematopathology, St. Joseph Mercy Hospital and Warde Medical Laboratory, Ann Arbor, Michigan

Stacy E.F. Melanson, MD, PhD
Associate Medical Director, Clinical Chemistry, Brigham and Women's Hospital; Assistant Professor, Harvard Medical School, Boston, Massachusetts

Mandakolathur R. Murali, MD
Director, Clinical Immunology Laboratory, Massachusetts General Hospital; Assistant Professor, Harvard Medical School, Boston, Massachusetts

Fritz F. Parl, MD, PhD
Professor of Pathology, Director of Clinical Chemistry, Vanderbilt University Medical Center, Nashville, Tennessee

Daniel E. Sabath, MD, PhD
Associate Professor, Department of Laboratory Medicine; Adjunct Associate Professor, Department of Medicine (Medical Genetics), University of Washington School of Medicine; Head, Hematology Division, Department of Laboratory Medicine; Director, Clinical Laboratory Services, Seattle Cancer Care Alliance, Seattle, Washington

Susan L. Saidman, PhD
Director, Histocompatibility Laboratory, Massachusetts General Hospital; Associate Professor, Harvard Medical School, Boston, Massachusetts

Eric D. Spitzer, MD, PhD
Associate Professor of Pathology and Molecular Genetics and Microbiology, Chief of Clinical Microbiology, Stony Brook University Medical Center, Stony Brook, New York

Paul Steele, MD
Medical Director, Clinical Laboratories, Cincinnati Children's Hospital Medical Center; Clinical Associate Professor, Department of Pathology and Laboratory Medicine, University of Cincinnati, Cincinnati, Ohio

Christopher P. Stowell, MD, PhD
Director, Blood Transfusion Service, Massachusetts General Hospital; Assistant Professor, Harvard Medical School, Boston, Massachusetts

Elizabeth M. Van Cott, MD
Director, Coagulation Laboratory; Medical Director, Core Laboratory, Massachusetts General Hospital; Associate Professor, Harvard Medical School, Boston, Massachusetts

William E. Winter, MD
Professor, Department of Pathology, Immunology, and Laboratory Medicine, University of Florida College of Medicine, Gainesville, Florida

Alison Woodworth, PhD
Assistant Professor of Pathology, Director, Esoteric Chemistry, Vanderbilt University Medical Center, Nashville, Tennessee

Preface

Everyone accepts that a physician caring for a patient cannot accurately interpret biopsy specimens and complex imaging studies. The roles of the anatomic pathologist and the radiologist as diagnostic physicians are well accepted and regarded as necessary for patient safety. Currently, most hospitals in the United States do not have a pathologist capable of interpreting the wide array of laboratory test results and guiding a clinical laboratory assessment to completion.

This means that, to care effectively for patients, the practicing physician today must have a working knowledge of his or her own about appropriate test selection and result interpretation, in an era when new tests are appearing every week. The tests appearing now are increasingly expensive and scientifically complex, particularly because so much of the new diagnostic testing relates to genetic variations. Before the 1980s, the number of clinical laboratory tests was so small that most physicians had no difficulty selecting the correct tests and interpreting the test results. However, the last 3 decades, and especially the last 10 years, have witnessed a dramatic increase in the number of clinical laboratory tests. Many physicians caring for patients today openly admit that they do not know which clinical laboratory tests to select or how to interpret the test results in a growing percentage of their cases.

The health care system has presumed that the ordering physician knows precisely which coagulation factor test to order when the PTT is prolonged or which serologic tests should be ordered when the antinuclear antibody test is strongly positive and speckled. Unfortunately, this assumption is incorrect. These 2 simple examples are extremely common occurrences in clinical practice. Because there is so much to know and because there is so little teaching of laboratory medicine and clinical pathology in medical school, most physicians today are forced to make guesses about appropriate diagnostic tests and their clinical significance. To consider the impact of molecular testing on the complexity of test selection, a diagnosis of cystic fibrosis not long ago was associated with a single test for sweat chloride. Now there are more than 1,300 mutations described for the cystic fibrosis gene, many of which can be identified by genetic testing in the clinical laboratory, and the information has clinical importance because there are differences in prognosis and treatment among the mutations. A single test with a single clinical meaning has changed into something of enormous size and complexity. A physician whose knowledge about testing for cystic fibrosis goes beyond the sweat chloride test is more clinically successful, to the great benefit of the patient.

There is now increased recognition of a major patient safety problem related to physicians selecting incorrect tests and misinterpreting test results. As a physician with a specialty practice in coagulation disorders (in addition to being a clinical pathologist), who has been receiving referrals for more than a decade, I have seen cases in which fathers were charged with child abuse because a well-intentioned physician misinterpreted the test results for bleeding in a child; a case in which a pregnancy was unhappily terminated as a result of a misinterpretation of a test result for protein S; inappropriate decisions about anticoagulation therapy because of a poor understanding of the laboratory tests that predict thrombotic risk; and many more cases involving severe harm to the patient.

Consider what is taught to medical students in the preclinical years about myocardial infarction. Given the current sensitivity regarding patient safety, it is surprising that virtually every medical school pathology course teaches the cardiac histopathology associated with a myocardial infarction, while instruction about the appropriate use and result interpretation for circulating markers of cardiac ischemia, such as troponin, varies widely in quantity and quality among medical schools. In some medical schools, there is only passing attention in the preclinical years to most of the diagnostic tests in the clinical laboratory. From the perspective of the patient with chest pain, a physician is most valuable if he or she has knowledge about the troponin level and can confidently use this test result to identify cardiac ischemia and separate it from other causes of chest pain. Nevertheless, in many medical schools, probably in most medical schools, much more attention is directed toward instruction on the histopathology of the infarct.

I believe that a major reason why laboratory medicine and clinical pathology have been overlooked in the teaching of medical students in the preclinical years is the absence of a single comprehensive textbook, written at the medical student level, that approximately parallels the topics in anatomic pathology. Such a textbook is also greatly needed in medical school because there are areas of diagnostic pathology, such as toxicology and coagulation, where there is little anatomic pathology and much clinical pathology. Commonly encountered topics such as drug testing may or may not be taught in a pathology course if there is little emphasis on clinical pathology. It is my greatest hope that this textbook will spur the development of systematic teaching of laboratory medicine and clinical pathology in the preclinical years of medical school and will lead to a better balance of teaching time between clinical pathology and anatomic pathology. It is empowering to the practicing physician, and protective of the patient, for medical students in the preclinical years, and beyond, to learn appropriate test selection and test result interpretation.

Michael Laposata
Nashville, Tennessee

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Clinical Laboratory Reference Values

The conventional units in this table are the ones most commonly used in the United States. Outside the United States, SI units are the predominant nomenclature for laboratory test results. The base units in the SI system related to laboratory testing that are found in this table include the mole (amount of substance), meter (length), kilogram (mass), second (time), and Celsius (temperature).

Reference ranges vary depending on the instrument and the reagents used to perform the test. Therefore, the reference ranges shown in this table are only close approximations to the reference ranges found in an individual clinical laboratory. It is also important to understand that reference ranges can be significantly affected by age and sex.

Conversion factors are provided in the table to allow the reader to convert conventional units to SI units and vice versa. The conversion of the conventional unit to SI unit requires a multiplication with the conversion factor, and conversion of the SI unit to the conventional unit requires division by the conversion factor.

The sample fluid is sometimes highly restrictive. For example, coagulation tests must be performed using plasma samples and serum samples are unacceptable. For other compounds, plasma samples and serum samples may both be acceptable. However, there may be differences, often minor, in the results obtained using plasma versus serum. Potassium is 1 such compound in which reference ranges may be different for plasma and serum. There is a significant movement away from the use of serum in favor of plasma. The principal reason for this is that extra time is required for samples to clot so that serum may be generated. A sample collected into a tube with anticoagulant results in the generation of plasma rather than serum after the tube is centrifuged. The clotting step is omitted when plasma samples are prepared, and therefore the turnaround time for the performance of the test is shortened. In some circumstances, whole blood is used for analysis, but the number of tests performed using whole blood is very limited. Urine and other body fluids, such as pleural fluid and cerebrospinal fluid, are also used for testing. Some of the entries in the table are associated with a fluid other than plasma, serum, or whole blood.

	Specimen	Traditional Reference Interval	Traditional Units	Conversion Factor, Multiply →, ← Divide	SI Reference Interval	SI Units
Acetaminophen (therapeutic)	Serum, plasma	10–30	µg/mL	6.62	70–200	µmol/L
Acetoacetic acid	Serum, plasma	<1	mg/dL	0.098	<0.1	mmol/L
Acetone	Serum, plasma	<2.0	mg/dL	0.172	<0.34	mmol/L
Acetylcholinesterase	Red blood cells	30–40	U/g of Hb	0.0645	2.13–2.63	MU/mol of Hb
Activated partial thromboplastin time (APTT)	Whole blood	25–40	seconds	1	25–40	Seconds
Adenosine deaminase[a]	Serum	11.5–25.0	U/L	0.017	0.20–0.43	µKat/L
Adrenocorticotropic hormone (ACTH) (see corticotropin)						
Alanine[b]	Serum	1.87–5.89	mg/dL	112.2	210–661	µmol/L
Alanine amino-transferase (ALT, SGPT)[b]	Serum	10–40	U/L	1	10–40	U/L
Albumin[b]	Serum	3.5–5.0	g/dL	10	35–50	g/L
Alcohol (see ethanol, isopropanol, methanol)						
Alcohol dehydrogenase[a]	Serum	<2.8	U/L	0.017	<0.05	µKat/L
Aldolase[a, b]	Serum	1.0–7.5	U/L	0.017	0.02–0.13	µKat/L
Aldosterone[b]	Serum, plasma	7–30	ng/dL	0.0277	0.19–0.83	nmol/L
Aldosterone	Urine	3–20	µg/24 hours	2.77	8–55	nmol/day
Alkaline phosphatase[b]	Serum	50–120	U/L	1	50–120	U/L
Alprazolam (therapeutic)	Serum, plasma	10–50	ng/mL	3.24	32–162	nmol/L
Aluminum	Serum	0–6	ng/mL	37.06	0.0–222.4	nmol/L
Amikacin (therapeutic, peak)	Serum, plasma	20–30	µg/mL	1.71	34–52	µmol/L
Amino acid fractionation						
Alanine[b]	Serum	1.87–5.89	mg/dL	112.2	210–661	µmol/L
α-Aminobutyric acid[b]	Plasma	0.08–0.36	mg/dL	97	8–35	µmol/L
Arginine[b]	Plasma	0.37–2.40	mg/dL	57.4	21–138	µmol/L
Asparagine[b]	Plasma	0.40–0.91	mg/dL	75.7	30–69	µmol/L
Aspartic acid[b]	Plasma	<0.3	mg/dL	75.1	<25	µmol/L
Citrulline[b]	Plasma	0.2–1.0	mg/dL	57.1	12–55	µmol/L
Cystine[b]	Plasma	0.40–1.40	mg/dL	83.3	33–117	µmol/L
Glutamic acid[b]	Plasma	0.2–2.8	mg/dL	67.97	15–190	µmol/L
Glutamine[b]	Plasma	6.1–10.2	mg/dL	68.42	420–700	µmol/L
Glycine[b]	Plasma	0.9–4.2	mg/dL	133.3	120–560	µmol/L
Histidine[b]	Plasma	0.5–1.7	mg/dL	64.5	32–110	µmol/L
Hydroxyproline[b]	Plasma	<0.55	mg/dL	76.3	<42	µmol/L
Isoleucine[b]	Plasma	0.5–1.3	mg/dL	76.24	40–100	µmol/L
Leucine[b]	Plasma	1.0–2.3	mg/dL	76.3	75–175	µmol/L
Lysine[b]	Plasma	1.2–3.5	mg/dL	68.5	80–240	µmol/L
Methionine[b]	Plasma	0.1–0.6	mg/dL	67.1	6–40	µmol/L
Ornithine[b]	Plasma	0.4–1.4	mg/dL	75.8	30–106	µmol/L
Phenylalanine[b]	Plasma	0.6–1.5	mg/dL	60.5	35–90	µmol/L
Proline[b]	Plasma	1.2–3.9	mg/dL	86.9	104–340	µmol/L
Serine[b]	Plasma	0.7–2.0	mg/dL	95.2	65–193	µmol/L
Taurine[b]	Plasma	0.3–2.1	mg/dL	80	24–168	µmol/L
Threonine[b]	Plasma	0.9–2.5	mg/dL	84	75–210	µmol/L
Tryptophan[b]	Plasma	0.5–1.5	mg/dL	48.97	25–73	µmol/L
Tyrosine[b]	Plasma	0.4–1.6	mg/dL	55.19	20–90	µmol/L
Valine[b]	Plasma	1.7–3.7	mg/dL	85.5	145–315	µmol/L
α-Aminobutyric acid[b]	Plasma	0.08–0.36	mg/dL	97	8–35	µmol/L
Amiodarone (therapeutic)	Serum, plasma	0.5–2.5	µg/mL	1.55	0.8–3.9	µmol/L

The sample type listed under Specimen in this table shows the reference interval for that specimen type. Thus, if the specimen for a test is listed as serum, the reference interval shown is for serum specimens. For many tests listed with serum as the specimen type, plasma is also acceptable, often with a similar reference interval.

Continued next page—

	Specimen	Traditional Reference Interval	Traditional Units	Conversion Factor, Multiply →, ← Divide	SI Reference Interval	SI Units
δ-Aminolevulinic acid	Urine	1.0–7.0	mg/24 hours	7.626	8–53	μmol/day
Amitriptyline (therapeutic)	Serum, plasma	80–250	ng/mL	3.61	289–903	nmol/L
Ammonia (as NH_3)[b]	Plasma	19–60	μg/dL	0.587	11–35	μmol/L
Amobarbital (therapeutic)	Serum	1–5	μg/mL	4.42	4–22	μmol/L
Amoxapine (therapeutic)	Plasma	200–600	ng/mL	1	200–600	μg/L
Amylase[a,b]	Serum	27–130	U/L	0.017	0.46–2.21	μKat/L
Androstenedione,[b] male	Serum	75–205	ng/dL	0.0349	2.6–7.2	nmol/L
Androstenedione,[b] female	Serum	85–275	ng/dL	0.0349	3.0–9.6	nmol/L
Angiotensin I	Plasma	<25	pg/mL	1	<25	ng/L
Angiotensin II	Plasma	10–60	pg/mL	1	10–60	ng/L
Angiotensin-converting enzyme (ACE)[a,b]	Serum	8–52	U/L	0.017	0.14–0.88	μKat/L
Anion gap (Na^+)–(Cl^- + HCO_3^-)	Serum, plasma	8–16	mEq/L	1	8–16	nmol/L
Antidiuretic hormone (ADH, vasopressin) (varies with osmolality: 285–290 mOsm/kg)	Plasma	1–5	pg/mL	0.926	0.9–4.6	pmol/L
α2-Antiplasmin	Plasma	80–130	%	0.01	0.8–1.3	Fraction of 1.0
Antithrombin III	Plasma	21–30	mg/dL	10	210–300	mg/L
Antithrombin III activity	Plasma	80–130	%	0.01	0.8–1.3	Fraction of 1.0
α1-Antitrypsin	Serum	126–226	mg/dL	0.01	1.26–2.26	g/L
Apolipoprotein A[b]						
Male	Serum	80–151	mg/dL	0.01	0.8–1.5	g/L
Female	Serum	80–170	mg/dL	0.01	0.8–1.7	g/L
Apolipoprotein B[b]						
Male	Serum, plasma	50–123	mg/dL	0.01	0.5–1.2	g/L
Female	Serum, plasma	25–120	mg/dL	0.01	0.25–1.20	g/L
Arginine[b]	Plasma	0.37–2.40	mg/dL	57.4	21–138	μmol/L
Arsenic (As)	Whole blood	<23	μg/L	0.0133	<0.31	μmol/L
Arsenic (As), acute poisoning	Whole blood	600–9300	μg/L	0.0133	7.9–123.7	μmol/L
Ascorbate, ascorbic acid (see vitamin C)						
Asparagine[b]	Plasma	0.40–0.91	mg/dL	75.7	30–69	μmol/L
Aspartate amino transferase (AST, SGOT)[a,b]	Serum	20–48	U/L	0.017	0.34–0.82	μKat/L
Aspartic acid[b]	Plasma	<0.3	mg/dL	75.1	<25	μmol/L
Atrial natriuretic hormone	Plasma	20–77	pg/mL	1	20–77	ng/L
Barbiturates (see individual drugs; pentobarbital, phenobarbital, thiopental)						
Basophils (see complete blood count, white blood cell count)						
Benzodiazepines (see individual drugs; alprazolam, chlordiazepoxide, diazepam, lorazepam)						
Bicarbonate	Plasma	21–28	mEq/L	1	21–28	mmol/L
Bile acids (total)	Serum	0.3–2.3	μg/mL	2.448	0.73–5.63	μmol/L
Bilirubin						
Total[b]	Serum	0.3–1.2	mg/dL	17.1	2–18	μmol/L
Direct (conjugated)	Serum	<0.2	mg/dL	17.1	<3.4	μmol/L

Continued next page—

	Specimen	Traditional Reference Interval	Traditional Units	Conversion Factor, Multiply →, ← Divide	SI Reference Interval	SI Units
Biotin	Whole blood, serum	200–500	pg/mL	0.0041	0.82–2.05	nmol/L
Bismuth	Whole blood	1–12	µg/L	4.785	4.8–57.4	nmol/L
Blood gases						
P_{CO_2}	Arterial blood	35–45	mmHg	1	35–45	mmHg
pH	Arterial blood	7.35–7.45	—	1	7.35–7.45	—
P_{O_2}	Arterial blood	80–100	mmHg	1	80–100	mmHg
Blood urea nitrogen (BUN, see urea nitrogen)						
C1 esterase inhibitor	Serum	12–30	mg/dL	0.01	0.12–0.30	g/L
C3 complement[b]	Serum	1200–1500	µg/mL	0.001	1.2–1.5	g/L
C4 complement[b]	Serum	350–600	µg/mL	0.001	0.35–0.60	g/L
Cadmium (nonsmoker)	Whole blood	0.3–1.2	µg/L	8.897	2.7–10.7	nmol/L
Caffeine (therapeutic, infants)	Serum, plasma	8–20	µg/mL	5.15	41–103	µmol/L
Calciferol (see vitamin D)						
Calcitonin	Serum, plasma	<19	pg/mL	1	<19	ng/L
Calcium, ionized	Serum	4.60–5.08	mg/dL	0.25	1.15–1.27	mmol/L
Calcium, total	Serum	8.2–10.2	mg/dL	0.25	2.05–2.55	mmol/L
Calcium, normal diet	Urine	<250	mg/24 hours	0.025	<6.2	mmol/day
Carbamazepine (therapeutic)	Serum, plasma	8–12	µg/mL	4.23	34–51	µmol/L
Carbon dioxide	Serum, plasma, venous blood	22–28	mEq/L	1	22–28	mmol/L
Carboxyhemoglobin (carbon monoxide), as fraction of hemoglobin saturation						
Nonsmoker	Whole blood	<2.0	%	0.01	<0.02	Fraction of 1.0
Toxic	Whole blood	>20	%	0.01	>0.2	Fraction of 1.0
β-Carotene	Serum	10–85	µg/dL	0.0186	0.2–1.6	µmol/L
Catecholamines, total (see norepinephrine)						
Ceruloplasmin[b]	Serum	20–40	mg/dL	10	200–400	mg/L
Chloramphenicol (therapeutic)	Serum	10–25	µg/mL	3.1	31–77	µmol/L
Chlordiazepoxide (therapeutic)	Serum, plasma	0.7–1.0	µg/mL	3.34	2.3–3.3	µmol/L
Chloride	Serum, plasma	96–106	mEq/L	1	96–106	mmol/L
Chloride	CSF	118–132	mEq/L	1	118–132	mmol/L
Chlorpromazine (therapeutic, adult)	Plasma	50–300	ng/mL	3.14	157–942	nmol/L
Chlorpromazine (therapeutic, child)	Plasma	40–80	ng/mL	3.14	126–251	nmol/L
Chlorpropamide (therapeutic)	Plasma	75–250	mg/L	3.61	270–900	µmol/L
Cholesterol, high-density lipoproteins (HDL)						
Male	Plasma	35–65	mg/dL	0.02586	0.91–1.68	mmol/L
Female	Plasma	35–80	mg/dL	0.02586	0.91–2.07	mmol/L
Cholesterol, low-density lipoproteins (LDL)[b]	Plasma	60–130	mg/dL	0.02586	1.55–3.37	mmol/L
Cholesterol (total), adult						
Desirable	Serum	<200	mg/dL	0.02586	<5.17	mmol/L
Borderline high	Serum	200–239	mg/dL	0.02586	5.17–6.18	mmol/L
High	Serum	>240	mg/dL	0.02586	>6.21	mmol/L

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	Specimen	Traditional Reference Interval	Traditional Units	Conversion Factor, Multiply →, ← Divide	SI Reference Interval	SI Units
Cholesterol (total), children						
Desirable	Serum	<170	mg/dL	0.02586	4.40	mmol/L
Borderline high	Serum	170–199	mg/dL	0.02586	4.40–5.15	mmol/L
High	Serum	>200	mg/dL	0.02586	>5.18	mmol/L
Cholesterol esters (as percent of total cholesterol)	Plasma	60–75	%	0.01	0.60–0.75	Fraction of 1.0
Chromium	Whole blood	0.7–28.0	µg/L	19.2	13.4–538.6	nmol/L
Citrate	Serum	1.2–3.0	mg/dL	52.05	60–160	µmol/L
Citrulline[b]	Plasma	0.2–1.0	mg/dL	57.1	12–55	µmol/L
Clonazepam (therapeutic)	Serum	15–60	ng/mL	3.17	48–190	nmol/L
Coagulation factor I (fibrinogen)	Plasma	150–400	mg/dL	0.01	1.5–4.0	g/L
Coagulation factor II (prothrombin)	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor V	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor VII	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor VIII	Plasma	50–200	%	0.01	0.50–2.00	Fraction of 1.0
Coagulation factor IX	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor X	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor XI	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Coagulation factor XII	Plasma	60–140	%	0.01	0.60–1.40	Fraction of 1.0
Cobalt	Serum	4.0–10.0	µg/L	16.97	67.9–169.7	nmol/L
Codeine (therapeutic)	Serum	10–100	ng/mL	3.34	33–334	nmol/L
Complete blood count (CBC)						
Hematocrit[b]						
Male	Whole blood	41–50	%	0.01	0.41–0.50	Fraction of 1.0
Female	Whole blood	35–45	%	0.01	0.35–0.45	Fraction of 1.0
Hemoglobin (mass concentration)[b]						
Male	Whole blood	13.5–17.5	g/dL	10	135–175	g/L
Female	Whole blood	12.0–15.5	g/dL	10	120–155	g/L
Hemoglobin (substance concentration, Hb [Fe])						
Male	Whole blood	13.6–17.2	g/dL	0.6206	8.44–10.65	mmol/L
Female	Whole blood	12.0–15.0	g/dL	0.6206	7.45–9.30	mmol/L
Mean corpuscular hemoglobin (MCH), mass concentration[b]	Whole blood	27–33	pg/cell	1	27–33	pg/cell
Mean corpuscular hemoglobin (MCH), substance concentration, Hb [Fe]	Whole blood	27–33	pg/cell	0.06206	1.70–2.05	fmol
Mean corpuscular hemoglobin concentration (MCHC), mass concentration	Whole Blood	33–37	g Hb/dL	10	330–370	g Hb/L
Mean corpuscular hemoglobin concentration (MCHC), substance concentration, Hb [Fe]	Whole Blood	33–37	g Hb/dL	0.6206	20–23	mmol/L
Mean cell volume (MCV)[b]	Whole Blood	80–100	μm^3	1	80–100	fl
Platelet count	Whole blood	150–450	$10^3\ \mu L^{-1}$	1	150–450	$10^9\ L^{-1}$
Red blood cell count						
Female	Whole blood	3.9–5.5	$10^6\ \mu L^{-1}$	1	3.9–5.5	$10^{12}\ L^{-1}$
Male	Whole blood	4.6–6.0	$10^6\ \mu L^{-1}$	1	4.6–6.0	$10^{12}\ L^{-1}$
Reticulocyte count[b]	Whole blood	25–75	$10^3\ \mu L^{-1}$	1	25–75	$10^9\ L^{-1}$
Reticulocyte count[b] (fraction)	Whole blood	0.5–1.5	% of RBCs	0.01	0.005–0.015	Fraction of RBCs
White blood cell count[b]	Whole blood	4.5–11.0	$10^3\ \mu L^{-1}$	1	4.5–11.0	$10^9\ L^{-1}$

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	Specimen	Traditional Reference Interval	Traditional Units	Conversion Factor, Multiply →, ← Divide	SI Reference Interval	SI Units
(Continue complete blood count, white blood cell count)						
Differential count[b] (absolute)						
Neutrophils	Whole blood	1800–7800	μL^{-1}	1	1.8–7.8	$10^9 L^{-1}$
Bands	Whole blood	0–700	μL^{-1}	1	0.00–0.70	$10^9 L^{-1}$
Lymphocytes	Whole blood	1000–4800	μL^{-1}	1	1.0–4.8	$10^9 L^{-1}$
Monocytes	Whole blood	0–800	μL^{-1}	1	0.00–0.80	$10^9 L^{-1}$
Eosinophils	Whole blood	0–450	μL^{-1}	1	0.00–0.45	$10^9 L^{-1}$
Basophils	Whole blood	0–200	μL^{-1}	1	0.00–0.20	$10^9 L^{-1}$
Differential count[b] (number fraction)						
Neutrophils	Whole blood	56	%	0.01	0.56	Fraction of 1.0
Bands	Whole blood	3	%	0.01	0.03	Fraction of 1.0
Lymphocytes	Whole blood	34	%	0.01	0.34	Fraction of 1.0
Monocytes	Whole blood	4	%	0.01	0.04	Fraction of 1.0
Eosinophils	Whole blood	2.7	%	0.01	0.027	Fraction of 1.0
Basophils	Whole blood	0.3	%	0.01	0.003	Fraction of 1.0
Copper[b]	Serum	70–140	µg/dL	0.1574	11.0–22.0	µmol/L
Coproporphyrin	Urine	<200	µg/24 hours	1.527	<300	nmol/day
Corticotropin[b]	Plasma	<120	pg/mL	0.22	<26	pmol/L
Cortisol, total[b]						
Fasting, 8 a.m. to noon	Plasma	5–25	µg/dL	27.6	138–690	nmol/L
Noon to 8 p.m.	Plasma	5–15	µg/dL	27.6	138–414	nmol/L
8 p.m. to 8 a.m.	Plasma	0–10	µg/dL	27.6	0–276	nmol/L
Cortisol, free[b]	Urine	30–100	µg/24 hours	2.759	80–280	nmol/day
Cotinine (smoker)	Plasma	16–145	ng/mL	5.68	91–823	nmol/L
C peptide	Serum	0.5–2.5	ng/mL	0.333	0.17–0.83	nmol/L
Creatine, male	Serum	0.2–0.7	mg/dL	76.3	15.3–53.3	µmol/L
Creatine, female	Serum	0.3–0.9	mg/dL	76.3	22.9–68.6	µmol/L
Creatine kinase (CK)[a]	Serum	50–200	U/L	0.017	0.85–3.40	µKat/L
Creatine kinase-MB fraction	Serum	<6	%	0.01	<0.06	Fraction of 1.0
Creatinine[b]	Serum, plasma	0.6–1.2	mg/dL	88.4	53–106	µmol/L
Creatinine	Urine	1–2	g/24 hours	8.84	8.8–17.7	mmol/day
Creatinine clearance	Serum, urine	75–125	mL/min	0.01667	1.24–2.08	mL/second
Cyanide (toxic)	Whole blood	>1.0	µg/mL	38.4	>38.4	µmol/L
Cyanocobalamin (see vitamin B_{12})						
Cyclic adenosine monophosphate (cAMP)	Plasma	4.6–8.6	ng/mL	3.04	14–26	nmol/L
Cyclosporine (toxic)	Whole blood	>400	ng/mL	0.832	>333	nmol/L
Cystine[b]	Plasma	0.40–1.40	mg/dL	83.3	33–117	µmol/L
D-dimer	Plasma	Negative (<500)	ng/mL	1	Negative (<500)	ng/mL
Dehydroepiandrosterone (DHEA) (unconjugated, male)[b]	Plasma, serum	180–1250	ng/dL	0.0347	6.2–43.3	nmol/L
Dehydroepiandrosterone sulfate (DHEA-S) (male)[b]	Plasma, serum	10–619	µg/dL	0.027	0.3–16.7	µmol/L
Desipramine (therapeutic)	Plasma, serum	50–200	ng/mL	3.75	170–700	nmol/L
Diazepam (therapeutic)	Plasma, serum	100–1000	ng/mL	0.00351	0.35–3.51	µmol/L
Digoxin (therapeutic)	Plasma	0.5–2.0	ng/mL	1.281	0.6–2.6	nmol/L

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