UNIT 1
The Clinical Laboratory

UNIT OBJECTIVES

After studying this unit, the student will:

- Discuss the regulation, organization, and function of the clinical laboratory.
- Discuss the qualifications, job functions, and ethical responsibilities of clinical laboratory personnel.
- Identify and define selected abbreviations and acronyms commonly used in the clinical laboratory.
- Identify, define, and use prefixes, suffixes, and stems in selected medical terms.
- Discuss and implement laboratory safety rules that must be followed to guard against biological, chemical, and physical hazards.
- Identify common types of labware and demonstrate their correct uses.
- Discuss and demonstrate safe use of general laboratory equipment.
- Use the metric system to perform measurements and calculations.
- Use laboratory math to prepare simple laboratory reagents.
- Discuss the importance and use of quality assessment programs in the clinical laboratory.
- Use the compound bright-field microscope.
- Perform a capillary puncture.
- Perform a venipuncture.

UNIT OVERVIEW

The clinical laboratory is a place where blood, body fluids, and other biological specimens are tested, analyzed, or evaluated. The observations can be qualitative or quantitative. The tests can be performed manually or using automated analyzers. Precise measurements are made and the results are calculated and interpreted. Because of this, laboratory workers must have the skills necessary to perform a variety of tasks.

Unit 1 is an introduction to the laboratory environment as a workplace and to the profession of clinical laboratory science, also called medical laboratory science. Key concepts and procedures laboratory professionals need to know to work in the laboratory are described in the introductory unit.

The regulation, organization, and function of the clinical laboratory are addressed in Lesson 1-1. Qualifications and job functions of laboratory personnel are reviewed in Lesson 1-2.

As an introduction to the structure of medical terms, Lesson 1-3 gives basic information about medical terminology and abbreviations and acronyms used in the laboratory. As other units are studied, additional vocabulary terms will be introduced and defined.

Two lessons on laboratory safety (Lessons 1-4 and 1-5) are included in Unit 1 because workers must understand and follow all safety procedures and practices before any laboratory exercises can be performed. Every worker in the clinical laboratory must be thoroughly aware of potential hazards in the workplace and must perform tasks in a manner that keeps them, coworkers, and patients safe.

The correct and safe use of general laboratory equipment such as centrifuges, pH meters, autoclaves, and laboratory balances is described in Lesson 1-6. Also explained is the care, use, and cleaning of frequently used labware such as beakers, cylinders, test tubes, and flasks.

Because laboratory analyses use metric units, a brief introduction to the metric system is given in Lesson 1-7. Knowledge of the metric system is required for exercises in other units. Basic laboratory calculations, methods of reagent preparation, and the correct use of pipets are explained in Lesson 1-8.

Principles, methods, and procedures for ensuring the reliability and accuracy of laboratory analyses are presented in Lesson 1-9, Quality Assessment. These quality assessment principles are included in Unit 1 because they must be integrated into all aspects of laboratory operations, from employee training and evaluation to specimen collection and processing, specimen analysis, and interpretation and reporting of results.

The proper care and use of the microscope is included in Unit 1 (Lesson 1-10) because knowledge of its use is required for lessons in the microbiology, hematology, urinalysis, and parasitology units. Lessons 1-11 and 1-12 introduce techniques for collecting capillary and venous blood.

Unit 1 is an introduction to the techniques, rules, and skills needed to perform the exercises in Units 2 through 8. Unit 1 can also be used alone as an introduction to the profession of clinical laboratory science. After Unit 1 has been completed, the remaining units can be studied in order of the instructor’s preference depending on available time, laboratory space, and equipment.

LESSON 1-1

Introduction to the Clinical Laboratory

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Explain the function of a medical or clinical laboratory.**
- **Discuss the organization of a typical hospital clinical laboratory.**
- **Describe the functions of the different levels of laboratory personnel.**
- **List the major departments of a typical clinical laboratory and name a test that would be performed in each department.**
- **List three examples of nonhospital clinical laboratories and describe the function of each.**
- **Explain how clinical laboratories are regulated.**
- **Explain the relationships between Centers for Medicare and Medicaid Services (CMS), Clinical Laboratory Improvement Amendments of 1988 (CLIA ’88), and clinical laboratories.**
- **Discuss benefits of point-of-care (POC) testing.**
- **Explain how the Health Insurance Portability and Accountability Act (HIPAA) affects the laboratory and laboratory workers.**
- **Discuss the use and value of electronic health records (EHRs).**
- **Describe the purpose and scope of quality assessment programs in the clinical laboratory.**
- **Explain the reason for proficiency testing.**
- **Explain the purpose of laboratory accreditation.**
- **Define the glossary terms.**

GLOSSARY

accessioning / the process by which specimens are logged in, labeled, and assigned a specimen identification code

accreditation / a voluntary process in which an independent agency grants recognition to institutions or programs that meet or exceed established standards of quality

American Association of Blood Banks (AABB) / international association that sets blood bank standards, accredits blood banks, and promotes high standards of performance in the practice of transfusion medicine

anticoagulant / a chemical or substance that prevents blood coagulation

bacteriology / the study of bacteria

blood bank / clinical laboratory department where blood components are tested and stored until needed for transfusion; immunohematology department; transfusion services; also the refrigerated unit used for storing blood components

Centers for Disease Control and Prevention (CDC) / central laboratory for the national public health system

Centers for Medicare and Medicaid Services (CMS) / the agency within the Department of Health and Human Services (DHHS) responsible for implementing CLIA ‘88

Clinical and Laboratory Standards Institute (CLSI) / an international, nonprofit organization that establishes guidelines and standards of best current practice for clinical laboratories; formerly National Committee for Clinical Laboratory Standards (NCCLS)

clinical chemistry / the laboratory section that uses chemical principles to analyze blood and other body fluids

Clinical Laboratory Improvement Amendments of 1988 (CLIA ’88) / a federal act that specifies minimum performance standards for clinical laboratories

coagulation / the process of forming a fibrin clot

College of American Pathologists (CAP) / organization that offers accreditation to clinical laboratories and certification to clinical laboratory personnel

COLA / agency that offers accreditation to physician office laboratories, hospitals, clinics and other healthcare facilities; formerly the Commission on Office Laboratory Accreditation

Department of Health and Human Services (DHHS) / the governmental agency that oversees public healthcare matters; also called HHS

electronic health record (EHR) / comprehensive, portable electronic patient health record

electronic medical record (EMR) / a digital form of a patient chart created in a physician’s office or a hospital where a patient received treatment

epidemiology / the study of the factors that cause disease and determine disease frequency and distribution

Food and Drug Administration (FDA) / the division of the Department of Health and Human Services (DHHS) responsible for protecting the public health by ensuring the safety and efficacy of foods, drugs, biological products, medical devices, and cosmetics

Health Care Financing Administration (HCFA) / see Centers for Medicare and Medicaid Services (CMS)

hematology / the study of blood and the blood-forming tissues

HIPAA / Health Insurance Portability and Accountability Act of 1996

immunohematology / the study of the human blood groups; in the clinical laboratory, often called blood banking or transfusion services

immunology / the branch of medicine encompassing the study of immune processes and immunity

Joint Commission (JC) / an independent agency that accredits hospitals and large healthcare facilities; formerly known as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO)

Laboratory Response Network (LRN) / a nationwide network of public and private laboratories coordinated by Centers for Disease Control and Prevention (CDC) with the ability for rapid response to threats to public health

microbiology / the branch of biology dealing with microbes

mycology / the study of fungi

National Committee for Clinical Laboratory Standards (NCCLS) / see Clinical and Laboratory Standards Institute (CLSI)

pathologist / a physician specially trained in the nature and cause of disease

phlebotomist / a healthcare worker trained in blood collection

physician office laboratory (POL) / small medical laboratory located within a physician office, group practice, or clinic

plasma / the liquid portion of blood in which the blood cells are suspended; the straw-colored liquid remaining after blood cells are removed from anticoagulated blood

point-of-care testing (POCT) / testing outside the traditional laboratory setting; also called bedside testing, off-site testing, near-patient testing, or alternative-site testing

proficiency testing (PT) / a program in which a laboratory's accuracy in performing analyses is evaluated at regular intervals and compared to the performance of similar laboratories

Provider-Performed Microscopy Procedures (PPMP) / a certificate category under CLIA '88 that permits a laboratory to perform waived tests and also permits specified practitioners to perform on-site microscopy procedures

quality assessment (QA) / in the laboratory, a program that monitors the total testing process with the aim of providing the highest-quality patient care

reference laboratory / an independent regional laboratory that offers routine and specialized testing services to hospitals and physicians

serology / the study of antigens and antibodies in serum using immunological methods; laboratory testing based on the immunological properties of serum

serum / the liquid obtained from blood that has been allowed to clot

standard operating procedure (SOP) / established procedure to be followed for a given operation or in a given situation with the purpose of ensuring that a procedure is always carried out correctly and in the same manner

virology / the study of viruses

waived test / a category of test defined under CLIA '88 as being simple to perform and having an insignificant risk for error

TEACHING AIDS AND RESOURCES

- Examples of hospital and laboratory organizational charts
- Examples of various laboratory requisition forms
- Transparencies or overheads of Figures 1-1 through 1-9
- Transparencies or overheads of Tables 1-1 through 1-5
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction

II. Regulation of Clinical Laboratories
   - A. CLIA '88
   - B. Centers for Medicare and Medicaid Services (CMS)

III. Types of Clinical Laboratories
   - A. Hospital Laboratories
   - B. Nonhospital Clinical Laboratories
     1. Physician office laboratories
     2. Reference laboratories
     3. Government laboratories—federal
        - a. Centers for Disease Control and Prevention
        - b. Consultation
        - c. Education
        - d. Epidemiology
        - e. Laboratory Response Network
     4. Government Laboratories—State
        - a. Specialty tests
        - b. Confirmation of reportable infectious diseases
        - c. Environmental testing

IV. CLIA Certificate Categories
   - A. Certificate of Waiver
   - B. Certificate of Registration
   - C. Certificate of Compliance
   - D. Certificate of Accreditation—Moderate or High-Complexity Tests
   - E. Certificate for Provider-Performed Microscopy Procedures (PPMP)

V. Organization of the Hospital Laboratory
   A. Clinical Laboratory Personnel
      1. Laboratory director
      2. Technical supervisor/laboratory manager
      3. General supervisor/department head
      4. Testing personnel
   B. Departments of the Clinical Laboratory
      1. Hematology
         a. Coagulation
         b. Urinalysis
      2. Clinical Chemistry
      3. Immunology
      4. Blood Bank/Transfusion Services
      5. Microbiology
         a. Bacteriology
         b. Virology
         c. Mycology
         d. Parasitology
      6. Laboratory Support Services
         a. Specimen collection
         b. Accessioning
         c. Specimen sorting and processing
      7. Laboratory information systems
      8. Point-of-care testing (POCT)

VI. Electronic Health Records
   A. Electronic Health Records vs. Electronic Medical Records
   B. Benefits
   C. Concerns

VII. Quality Assessment in the Laboratory
   A. Proficiency Testing
   B. Accreditation

VIII. Privacy Issues
   A. HIPAA
   B. Computers
   C. Confidentiality

IX. Critical Thinking Problem

X. Summary

Critical Thinking Problem and Answer

Timothy is a medical assistant working in a small POL. His laboratory operates under a certificate of waiver. The physician requests a microscopic examination of urine for patient Mary Smith. During Timothy's medical assistant training, he learned to perform microscopic examination of urine, classified by CLIA as a moderate complexity test.

1. What is the appropriate action for Timothy to take?
   a. Tell the physician that it is not possible to have the test performed.
   b. Send the specimen to a laboratory approved for performing moderate- to high-complexity testing.
   c. Perform the test and report the results to the physician.

2. Explain your answer.
   Even though Timothy has been trained to perform the requested test, which is of moderate complexity, the laboratory where he is employed only has permission to perform waived tests. Laboratories with certificates of waiver use reference laboratories to perform tests that are beyond their permitted level.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Interview an employee of a clinical laboratory and report on your interview. Inquire about the laboratory's organization, the types of tests performed, how specimens are received, and how results are recorded and delivered to physicians. Obtain various laboratory test report forms and note the types of tests performed in each department.
3. Tour a hospital laboratory or reference laboratory in your area.
4. Visit a POL and find out the types of tests performed there.

Web Activities

1. Select five analytes from Table 1-2. Find information about the analytes from the CMS or FDA web site. List two brands of test kits that qualify as waived for each of the five analytes.
2. Find web sites of three clinical laboratories. Note the types of information provided on each web site. Look for organizational charts for the laboratories and compare them with what you have learned in this lesson about how laboratories are organized.

REVIEW QUESTIONS AND ANSWERS

1. What is the function of a clinical laboratory?
   Clinical laboratories perform chemical and microscopic tests on body fluids and tissues to aid in diagnosis of diseases.

2. Draw an organizational chart of a typical hospital laboratory.
   See Figure 1-2 in the textbook.

3. Name five major departments found in a hospital laboratory.
   Any 5 of the following are acceptable:
   a. **Chemistry**
   b. **Microbiology**
   c. **Hematology**
   d. **Blood bank**
   e. **Immunology**
   f. **Laboratory support services (Specimen collection and processing)**
   g. **Laboratory information systems**

4. Name two procedures performed in the hematology department.
   Any two of the following are acceptable:
   a. **Blood cell counts**
   b. **Hemoglobin determinations**
   c. **Hematocrit**
   d. **Examinations of blood smears**
   e. **Coagulation tests**

5. Name two tests performed in the chemistry department.
   Any two of the following are acceptable:
   a. **Glucose**
   b. **Electrolytes**
   c. **Cholesterol**
   d. **Enzymes**
   e. **Drug levels**
   f. **Hormone levels**

6. How does the HIPAA affect workers in the laboratory?
   Much communication in laboratories is facilitated by computers. Patient information stored in computers must be password-protected so that only authorized personnel can access information. Computer monitors must be positioned so that visitors, other patients, and other nonauthorized personnel cannot view the screen. All patient information must remain private and confidential and must be shared only with authorized persons to facilitate and improve patient care.

7. Name three benefits of electronic health records.
   Any three of the following are acceptable:
   a. **Better coordination of patient care**
   b. **Improved follow-up after hospitalization**
   c. **Maintain comprehensive information about patient's health in one file**
   d. **Provide a secure way to share patient information**
   e. **Motivate patient to comply with recommendations**

8. List three locations of clinical laboratory facilities other than in hospitals.

   Any three of the following are acceptable:

   a. **Physician offices**
   b. **State and federal government facilities (public health)**
   c. **Universities**
   d. **Research institutions or facilities**
   e. **Reference laboratories**

9. Explain the job functions of the laboratory director, technical supervisor, and department head or general supervisor.

   The laboratory director has ultimate responsibility for all laboratory operations; the director may be a pathologist, a qualified M.D., or a doctoral scientist. The technical supervisor handles the day-to-day operation of the laboratory, sets personnel standards, and supervises employee performance. The department head is responsible for work within a specific department and for training and evaluating employee performance.

10. Who is responsible for creating the laboratory's SOP manual?
    The technical supervisor (or laboratory manager) is responsible for the information and keeping the manual up-to-date.

11. What is contained in the SOP manual?
    It contains the up-to-date instructions for all procedures performed in the laboratory.

12. What is the purpose of CLIA '88?

    CLIA '88 specifies minimum standards for all clinical laboratories. The objective of CLIA '88 is to ensure quality laboratory testing.

13. What federal agency is responsible for implementing CLIA '88?
    CMS (formerly known as HCFA) is responsible for implementing CLIA '88.

14. What are waived tests?
    Waived tests are those that are determined by CDC or FDA to be so simple that there is insignificant risk for error.

15. List the five certificates issued under CLIA '88, and state the activities each certificate permits.

    a. **Certificate of Waiver—permits a laboratory to perform CLIA-waived tests only**
    b. **Registration Certificate—permits the laboratory to (temporarily) conduct moderate- or high-complexity laboratory testing (or both) until the laboratory is determined by survey to be in compliance with CLIA regulations**
    c. **Certificate of Compliance—issued to a laboratory holding a Certificate of Registration after an inspection finds the laboratory to be in compliance with all applicable CLIA regulations**

d. **Certificate of Accreditation—issued to a laboratory that has been accredited by a CMS-approved accrediting organization**

e. **Certificate for PPMP—permits the laboratory to perform waived tests and allows a physician, midlevel practitioner, or dentist to perform microscopy procedures but no other tests of complexity.**

16. What is the advantage of proficiency testing?

    Proficiency testing programs evaluate a laboratory's performance for accuracy and compare it to that of other laboratories. This allows the laboratory to have confidence in testing methods and to identify deficient areas.

17. How do laboratories become accredited?

    A facility desiring accreditation invites the accrediting agency to inspect its facility and evaluate its performance to determine if established standards are being met.

18. Define accessioning, accreditation, American Association of Blood Banks (AABB), anticoagulant, bacteriology, blood bank, Centers for Disease Control and Prevention (CDC), Centers for Medicare and Medicaid Services (CMS), Clinical and Laboratory Standards Institute (CLSI), clinical chemistry, Clinical Laboratory Improvement Amendments of 1988 (CLIA '88), coagulation, College of American Pathologists (CAP), COLA, Department of Health and Human Services (DHHS), electronic health record (HER), electronic medical record (EMR), epidemiology, Food and Drug Administration (FDA), Health Care Financing Administration (HCFA), hematology, HIPAA, immunohematology, immunology, Joint Commission (JC), Laboratory Response Network (LRN), microbiology, mycology, National Committee for Clinical Laboratory Standards (NCCLS), parasitology, pathologist, phlebotomist, physician office laboratory (POL), plasma, point-of-care testing (POCT), proficiency testing, Provider-Performed Microscopy Procedure (PPMP), quality assessment, reference laboratory, serology, serum, standard operating procedure (SOP), virology, and waived test.

    See Glossary.

LESSON 1-2

The Clinical Laboratory Professional

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Give a brief history of medical technology.**
- **List five personal qualities that are desirable in a clinical laboratory professional.**
- **Describe the educational requirements for medical laboratory scientists and technicians.**
- **Explain the functions of accrediting agencies and credentialing agencies.**
- **Discuss the relationship between the laboratory professional and the patient.**
- **Explain the laboratory professional's responsibility in relation to patient privacy.**
- **Explain the purpose and benefits of professional societies.**
- **Discuss the importance of ethical conduct by laboratory professionals.**
- **Name five areas of employment for clinical laboratory professionals other than in hospital laboratories.**
- **Define the glossary terms.**

GLOSSARY

American Association of Medical Assistants (AAMA) / professional society and credentialing agency for medical assistants

American Medical Technologists (AMT) / professional society and credentialing agency for several categories of medical laboratory personnel

American Society for Clinical Laboratory Science (ASCLS) / professional society for medical/clinical laboratory personnel

American Society for Clinical Pathology (ASCP) / professional society for medical/clinical laboratory personnel and allied health personnel

American Society of Phlebotomy Technicians (ASPT) / professional society and credentialing agency for phlebotomists, as well as credentialing agency for specialty areas such as point-of-care technician

ASCP Board of Certification (ASCP BOC) / a separate body within the ASCP organizational structure, formed in 2009 by merging NCA with the ASCP BOR and providing certification for medical laboratory personnel

clinical laboratory science / the health profession concerned with performing laboratory analyses used in diagnosing and treating disease, as well as in maintaining good health; synonymous with medical laboratory science and medical (laboratory) technology

clinical laboratory scientist (CLS) / the NCA term for a professional who has a baccalaureate degree from an accredited college or university, has completed clinical training in an accredited clinical/medical laboratory science program, and has passed a national certifying examination; also called medical laboratory scientist (MLS) or medical technologist (MT)

clinical laboratory technician (CLT) / the NCA term for a professional who has completed a minimum of 2 years of specific training in an accredited clinical/medical laboratory technician program and has passed a national certifying examination; also called medical laboratory technician (MLT)

Commission on Accreditation of Allied Health Education Programs (CAAHEP) / agency that accredits educational programs for allied health personnel; formerly CAHEA

ethics / a system of conduct or behavior; rules of professional conduct

Health Insurance Portability and Accountability Act (HIPAA) / 1996 Act of Congress, a part of which guarantees protection of privacy of an individual's health information

medical laboratory science / the health profession concerned with performing laboratory analyses used in diagnosing and treating disease, as well as in maintaining good health; synonymous with clinical laboratory science and medical (laboratory) technology

medical laboratory scientist (MLS) / a professional who has a baccalaureate degree from an accredited college or university, has completed clinical training in an accredited medical laboratory science program, and has passed a national certifying examination; synonymous with medical technologist (MT) or NCA certified clinical laboratory scientist (CLS)

medical laboratory technician (MLT) / a professional who has completed a minimum of 2 years of specific training in an accredited medical laboratory technician program and has passed a national certifying examination; synonymous with NCA certified clinical laboratory technician (CLT)

medical technologist (MT) / a term gradually being replaced but referring to the professions of medical laboratory scientist (MLS) or clinical laboratory scientist (CLS)

medical technology / synonymous for clinical laboratory science and medical laboratory science

National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) / agency that accredits educational programs for clinical laboratory personnel

National Credentialing Agency for Laboratory Personnel (NCA) / a credentialing agency for clinical laboratory personnel that merged with the ASCP Board of Registry (BOR) in 2009 to form the ASCP Board of Certification (BOC)

National Phlebotomy Association (NPA) / professional society and credentialing agency for phlebotomists

TEACHING AIDS AND RESOURCES

- Career Information Fact Sheet and Interview Fact Sheet
- Clinical/Medical Laboratory Science journals
- Information about medical laboratory professions from professional societies
- Information about educational programs in clinical/medical laboratory science
- Guest speaker: laboratory professional from a local hospital or other laboratory
- Transparencies or overheads of Figures 1-10 and 1-11
- Transparencies or overheads of Tables 1-6 through 1-9
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
   A. Medical Technology
   B. Medical Laboratory Science
   C. Clinical Laboratory Science
II. History of Medical Technology
   A. Early Medical Laboratories
      1. Late nineteenth century
      2. Primitive
   B. Modern Medical Laboratories
      1. Growth in laboratories after World War I
      2. Need for formal education and identification of trained personnel
      3. Rapid changes in technology after World War II
   C. The Clinical Laboratory in the Twenty-First Century
      1. Emphases on wellness, geriatrics, home health care, and hospice
      2. State-of-art technology
      3. Rapid, portable testing
      4. ASCP Board of Certification (BOC)—change in certification categories
III. Role of the Laboratory Professional
IV. Certification Requirements for Laboratory Personnel
   A. Educational Programs and Accrediting Agencies
   B. Educational Requirements
      1. Medical Laboratory Scientist
      2. Medical Laboratory Technician
   C. Areas of specialization

D. Credentialing and certification
E. Licensing of Laboratory Professionals

V. Other Allied Health Personnel in the Clinical Laboratory
A. Phlebotomist / Phlebotomy Technician
B. Certified Medical Assistant / Registered Medical Assistant
C. Physician Office Laboratory Technician
D. Clinical Laboratory Assistant
E. Diagnostic Molecular Scientist
F. Point-of-Care Technician
G. Other Personnel Performing Testing
1. Paramedics
2. Nursing staff

VI. Ethics and Professionalism
A. Ethics and the Clinical Laboratory Professional
1. Maintain high standards of practice
2. Duty to patients, profession, colleagues, and society
3. Maintain honesty, integrity, and reliability
4. Maintain respect for patients, the profession, and other healthcare professions
B. Qualities Desirable in Laboratory Professionals
C. Patient Privacy/Confidentiality
D. Interactions Between Laboratory Personnel and Patients
E. Professional Organizations
F. Employment Opportunities

VII. Case Study

VIII. Summary

Case Study and Answer

Rob works in the laboratory at Bay Regional Hospital. Each work day before he begins his duties in the laboratory, he helps collect blood from hospital patients. On one occasion, the patient on his collection list was his friend Louis, who had been admitted to the hospital through the emergency department the night before. Rob collected blood from Louis for several laboratory tests and chatted with him briefly before returning to the laboratory.

After Rob got home that evening, he received a call from Susan asking for information about their mutual acquaintance Louis, who she heard was in the hospital. Susan said she had called the hospital but they would not release information about Louis and would not even confirm that he was a patient in the hospital. Susan asked Rob if he knew if Louis was hospitalized and if so, why.

1. How should Rob respond to Susan?

   Even though Rob, Louis, and Susan are mutual friends, Rob should not reveal medical information about Louis, because the hospital was not releasing information.

2. What are his obligations?

   Rob's first obligation is to protect patient information, unless the patient gives specific permission for it to be revealed.

3. What are his options?

   Rob could contact Louis and ask permission to tell Susan that Louis is hospitalized.

4. Role-play the conversation between Rob and Susan or Rob and Louis

   Have students discuss options for handling this situation.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Use the Interview Fact Sheet and interview a clinical laboratory professional. Be sure to consider the following areas: job functions, relationship with coworkers and patients, advantages and disadvantages of job, satisfactions, dissatisfactions, salary, and opportunities for advancement. Describe the benefits of talking to the laboratory professional in person rather than reading the information in a book.

Web Activities

1. Visit the web sites of three agencies or professional societies listed in Tables 1-6 and 1-9. List the programs they certify and the educational requirements of each program.
2. Search the Internet to find a school in your state (or nearby state) that offers training for clinical laboratory scientists. Find out what required courses are listed in the curriculum.
3. Complete a Career Information Fact Sheet for the careers of medical laboratory technician and medical laboratory scientist. Use this text, other available texts, and the Internet to gather your information. For each career include educational training, estimated cost of the program, nature of the job, advantages and disadvantages, employment opportunities, and salary range.
4. Use the Internet to find sources of current topics related to the clinical laboratory, such as online journals or newsletters. Request an email subscription to some of the free ones.

REVIEW QUESTIONS AND ANSWERS

1. What is clinical laboratory science? What other term is used for this field?

   Clinical laboratory science is the health profession concerned with performing laboratory analyses used in the diagnosis and treatment of disease and in the maintenance of health. It is also called medical laboratory science or medical technology.

2. Describe the beginnings of medical technology.

   Until the improvement of the microscope in the seventeenth century, physicians relied mostly on crude observations, such as observations of urine. The first medical laboratories for clinical testing were established in the late nineteenth century, and the number of laboratories began to grow rapidly after World War I. During this time, schools to train workers were established. Since World War II, laboratory techniques have become increasingly complex. The growth of emerging technologies has allowed rapid changes in clinical laboratory science.

3. Name five personal qualities desirable in clinical laboratory personnel.

   Any five of the following are acceptable:

   a. Manual dexterity

   b. Good intellect

   c. Aptitude for biological sciences

   d. Good eyesight

   e. Physical stamina

   f. Ability to perform accurate, precise manipulations and calculations

   g. Ability to work well and communicate well with others

   h. Honesty and integrity

4. What are the educational requirements for medical laboratory scientists? For medical laboratory technicians?

   A bachelor's degree and 1 year of clinical training are required for medical laboratory scientists; 2 years of postsecondary training, including clinical experience, are required for medical laboratory technicians.

5. What is the purpose of accrediting agencies?

   Accrediting agencies such as CAAHEP and NAACLS establish standards for certain health professions and ensure that educational institutions provide courses that meet national standards for students enrolled in allied health programs.

6. What are the functions of credentialing agencies?

   Credentialing agencies are independent organizations that administer examinations to graduates of health profession programs to ensure they have gained sufficient knowledge to work in their chosen field.

7. List five places of employment for laboratory professionals other than in hospitals.

   Any five of the following are acceptable:

   a. Public health

   b. Reference laboratories

   c. Military

   d. Research

e. Education

f. Physician offices

g. Pharmaceutics

h. Veterinary medicine

i. Sales, technical service, or product development for medical suppliers

8. Explain the importance of ethical standards in the practice of medical laboratory science.

   Ethical behavior is required of all health care professionals, including laboratory employees. They must be committed to maintaining standards of excellence in their work and safeguarding the dignity and privacy of patients.

9. Explain the laboratory professional's obligation to the patient.

   The laboratory professional must perform analyses carefully and accurately. He or she must be courteous and considerate of all patients and maintain confidentiality concerning patient information.

10. How do laboratory professionals become certified?

    They become certified by passing an examination administered by a certifying agency.

11. What is the value of professional societies to the laboratory professional?

    Professional societies provide opportunities for professional growth through continuing education, publishing journals, and supporting professionalism.

12. Define American Association of Medical Assistants (AAMA), American Medical Technologists (AMT), American Society for Clinical Laboratory Science (ASCLS), American Society for Clinical Pathology (ASCP), American Society of Phlebotomy Technicians (ASPT), ASCP Board of Certification (ASCP BOC), clinical laboratory science, clinical laboratory scientist (CLS), clinical laboratory technician (CLT), Commission on Accreditation of Allied Health Education Programs (CAAHEP), ethics, Health Insurance Portability and Accountability Act (HIPAA), medical laboratory science, medical laboratory scientist (MLS), medical laboratory technician (MLT), medical technologist (MT), medical technology, National Accrediting Agency for Clinical Laboratory Sciences (NAACLS), National Credentialing Agency for Laboratory Personnel (NCA), and National Phlebotomy Association (NPA).

    See Glossary.

FACT SHEET ANSWERS

Answers to Career Information Fact Sheet and Interview Fact Sheet will differ among students depending on available student resources.

LESSON 1-3

Medical Terminology

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Discuss the importance of healthcare workers understanding and correctly using medical terms.**
- **Define stem words from a selected list.**
- **Define prefixes from a selected list.**
- **Define suffixes from a selected list.**
- **Identify common clinical laboratory abbreviations and acronyms from a selected list.**
- **Pronounce commonly used medical terms from a selected list.**
- **Recognize prefixes, stems, or suffixes in medical terms.**
- **Analyze medical terms based on knowledge of prefixes, suffixes, and stems.**
- **Define the glossary terms.**

GLOSSARY

abbreviation / the shortening of a word, often by removing letters from the end of the word

acronym / combination of the first letters or syllables of a group of words to form a new group of letters that can be pronounced as a word

prefix / modifying word or syllable(s) placed at the beginning of a word

stem / main part of a word; root word; the part of a word remaining after removing the prefix or suffix

suffix / modifying word or syllable(s) placed at the end of a word

terminology / terms used in any specialized field

TEACHING AIDS AND RESOURCES

- Medical dictionary, clinical charts, diagrams, or atlases
- Medical terminology text(s), CD of medical terms with pronunciations
- Transparencies or overheads of Tables 1-10 through 1-13
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
II. Structure of Medical Terms
  A. Prefixes
  B. Stems
  C. Suffixes
  D. Derived from Latin and Greek
III. Pronunciation of Medical Terms
IV. Abbreviations and Acronyms
V. Case Studies
VI. Summary

Case Studies and Answers

Case Study 1

On a very busy day, Dr. Martin handed his medical assistant a handwritten preliminary diagnosis and an order for laboratory tests for his patient Mr. Jones. The medical assistant had difficulty reading Dr. Martin's handwriting and could not decide if the preliminary diagnosis was "temporary arthritis" or "temporal arteritis." Mr. Jones' major symptom was recurring headache and pain in the temple area of the head.

1. Which preliminary diagnosis is most likely the diagnosis written by Dr. Martin?
   Based on the patient's symptoms, Dr. Martin probably wrote "temporal arteritis."

2. Discuss the importance of correctly spelling and understanding medical terms.
   The accurate use of medical terms is required for effective communication and correct patient care. All members of the healthcare team need to understand the patient's condition and use care when interpreting written orders.

Case Study 2

Mr. Benton went to the gastroenterologist because of abdominal pain and rectal bleeding. After examining Mr. Benton, the physician recommended an additional procedure be performed.
After Mr. Benton arrived home, he became confused and could not remember if the test ordered was "colonoscopy" or "cholectomy."
Using only the stem and suffix tables, explain the differences between the two procedures.
Colonoscopy = colon + observation (visual examination of the colon)
Cholectomy = gall bladder + excision (surgical removal of the gall bladder)

Case Study 3

Ms. Jackson consulted a urologist and described several symptoms. The urologist wrote a preliminary diagnosis of "paroxysmal nocturnal hemoglobinuria" and ordered several laboratory tests to help confirm the diagnosis.

1. Examine the name of the suspected condition. What symptom would the patient have reported to cause the physician to diagnose "hemoglobinuria"?
   Hemoglobin or blood + urine (blood in the urine, red urine)

2. What other symptom(s) could have been reported based on the qualifiers "paroxysmal" and "nocturnal"?
   Nocturnal = occurring at night
   Paroxysmal = episodic, occurring suddenly at irregular intervals

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Practice pronouncing the word parts and medical terms in Tables 1-10 through 1-12. Look up pronunciations of 10 terms from each table and practice saying the terms out loud.
3. Study the definitions for prefixes, suffixes, and stems listed in the tables. Select 10 prefixes, suffixes, and stems from each of Tables 1-10, 1-11, and 1-12. Use each of the selected word parts in a word not on the list.
4. Prepare 20 flashcards using terms from tables in this lesson, a medical dictionary, or a textbook glossary. Write the term on the front and the definition on the back.
5. Obtain examples of laboratory requisition or report forms. Look for abbreviations or acronyms used on the forms.

Web Activities

1. Select five terms from each *usage* column in Tables 1-10, 1-11, and 1-12. Write your best definition of the term, using the definitions of stems, prefixes, and suffixes in the tables. Search an online medical dictionary for the terms, and compare your definitions with the dictionary definitions.
2. Search the Internet for free medical terminology tutorials or self-tests. Use these to enhance your knowledge of medical terms.

REVIEW QUESTIONS AND ANSWERS

1. Why is it important for healthcare workers to understand medical terminology?
   Effective communication and the ability to carry out instructions require an understanding of medical terminology.

2. Most medical terms are derived from which languages?
   Greek and Latin

3. How can one learn to correctly pronounce medical terms?
   Pronunciation can be learned by consulting the dictionary, listening to others pronounce terms, and practicing pronouncing terms.

4. Name the stems for cell, heart, head, skin, chest, kidney, muscle, liver, and stomach.
   cell: cyt(o)
   heart: card
   head: ceph(al)
   skin: derm
   chest: thorac
   kidney: ren
   muscle: myo
   liver: hepat(o)
   stomach: gastr(o)

5. Name 10 common suffixes and give a meaning for each.
   See Table 1-12 in the textbook.

6. Name 10 common prefixes and give a meaning for each.
   See Table 1-10 in the textbook.

7. List 10 abbreviations or acronyms frequently used in the clinical laboratory and give the meaning of each.
   See Table 1-13 in the textbook.

8. Define abbreviation, acronym, prefix, stem, suffix, and terminology.
   See Glossary.

Lesson 1-4

Biological Safety

LESSON OBJECTIVES

- **After studying this lesson, the student will:**
- **Explain the purpose of the Bloodborne Pathogens Standard.**
- **Explain the reason for issuing Standard Precautions in 1996.**
- **Explain what is meant by exposure control plan.**
- **List the components of an exposure control plan.**
- **Explain the evolution of safety laws and rules since the 1970s.**
- **Explain the roles of the Centers for Disease Control and Prevention (CDC) and the Occupational Safety and Health Administration (OSHA) in promoting safety in healthcare institutions.**
- **Explain the impact of the Needlestick Safety and Prevention Act of 2000.**
- **Discuss how work practice controls improve safety.**
- **Discuss how engineering controls improve safety.**
- **List types of personal protective equipment (PPE) commonly used in the clinical laboratory.**
- **Discuss infection prevention and healthcare-associated infections (HAIs).**
- **Demonstrate correct hand hygiene techniques.**
- **Demonstrate how to remove and discard contaminated gloves.**
- **Demonstrate the correct way to wear PPE such as face protection and fluid-resistant gowns or laboratory coats.**
- **Discuss how sterilization, disinfection, and antisepsis are used in the clinical laboratory.**
- **Explain the impact of human immunodeficiency virus (HIV) and hepatitis B and C viruses on safety practices in healthcare.**
- **List safety precautions that must be observed when handling biological materials.**
- **List additional safety precautions that must be observed when working in the microbiology laboratory.**
- **Define the glossary terms.**

GLOSSARY

acquired immunodeficiency syndrome (AIDS) / a form of severe immunodeficiency caused by infection with the human immunodeficiency virus (HIV)

aerosol / liquid in the form of a very fine mist

alimentary tract / the digestive tube from the mouth to the anus

antiseptic / chemical used on living tissue to control the growth of infectious agents

biohazard / risk or hazard to health or the environment from biological agents

biological safety cabinet / a special work cabinet that provides protection to the worker while working with infectious microorganisms

bloodborne pathogens (BBP) / pathogens that can be present in human blood (and blood-contaminated body fluids) and that cause disease

Bloodborne Pathogens (BBP) Standard / OSHA guidelines for preventing occupational exposure to pathogens present in human blood and body fluids, including, but not limited to, HIV and hepatitis B virus (HBV); final OSHA standard of December 6, 1991, effective March 6, 1992

community-acquired infection (CAI) / infection acquired through contact with friends, family, and the public or by contact with contaminated environmental surfaces

disinfectant / chemical used on inanimate objects to kill or inactivate microbes

engineering control / use of available technology and equipment to protect the worker from hazards

exposure control plan / a plan identifying employees at risk for exposure to bloodborne pathogens and providing training in methods to prevent exposure

exposure incident / an accident, such as a needlestick, in which an individual is exposed to possible infection through contact with body substances from another individual

hand antisepsis / decontamination of hands using antiseptic soap or waterless antiseptic

hand hygiene / a set of techniques that includes handwashing with soap and water, washing with antiseptic soap, or cleansing with a waterless antiseptic product

healthcare-associated infection (HAI) / infection acquired while being treated for another condition in a healthcare setting; synonym for healthcare-acquired infection; formerly called nosocomial infection

hepatitis B virus (HBV) / the virus that causes hepatitis B infection and is transmitted by contact with infected blood or other body fluids

hepatitis C virus (HCV) / the virus that causes hepatitis C infection and is transmitted by contact with infected blood or other body fluids

human immunodeficiency virus (HIV) / the retrovirus that has been identified as the cause of AIDS

isolation / the practice of limiting the movement and social contact of a patient who is potentially infectious or who must be protected from exposure to infectious agents; quarantine

nosocomial / hospital-acquired; acquired as a result of being hospitalized or institutionalized

other potentially infectious materials (OPIM) / any and all body fluids, tissues, organs, or other specimens from a human source

parenteral / any route other than by the alimentary canal; intravenous, subcutaneous, intramuscular, or mucosal

pathogenic / capable of causing damage or injury to the host

personal protective equipment (PPE) / specialized clothing or equipment used by workers to protect from direct exposure to blood or other potentially infectious or hazardous materials; includes, but is not limited to, gloves, laboratory apparel, eye protection, and breathing apparatus

Standard Precautions / a set of comprehensive safety guidelines designed to protect patients and healthcare workers by requiring that all patients and all body fluids, body substances, organs, and unfixed tissues be regarded as potentially infectious

sterilization / killing or inactivation of living organisms and viruses

Transmission-Based Precautions / specific safety practices used in addition to Standard Precautions when treating patients known to be or suspected of being infected with pathogens that can be spread by air, droplet, or contact

Universal Precautions (UP) / a method of infection control in which all human blood and other body fluids containing visible blood substances are treated as if infectious

work practice controls / methods of performing tasks that reduce the worker's exposure to blood and other potentially hazardous materials

TEACHING AIDS AND RESOURCES

- Biological Safety Worksheet
- Safety Agreement Form for each student to sign
- Safety brochures explaining biohazards; safety charts
- Examples of biohazard labels, sharps containers, PPE, splash guards, etc.
- Guest speaker on biological safety or audiovisual safety materials
- Transparencies or overheads of Figures 1-12 through 1-22
- Transparencies or overheads of Tables 1-14 through 1-20
- CDC "Guide to Infection Prevention in Outpatient Settings" available for download at http://www.cdc.gov/HAI/settings/outpatient/outpatient-care-guidelines.html
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
   A. Increased Biosafety Emphasis Resulting from AIDS and Hepatitis
   B. Biohazard Symbol
II. Evolution of Biological Safety Regulations and Guidelines
   A. Isolation Techniques
      1. Categories and techniques for isolation issued by CDC in 1970
      2. Safe work practices emphasized
   B. Universal Precautions
      1. Safety guidelines to protect against HIV infection in the workplace
      2. Designed to protect from exposure to blood and body fluids containing visible blood
      3. Use Universal Precautions with all patients
   C. Body Substance Isolation and Bloodborne Pathogens Standard
      1. CDC issued Body Substance Isolation (BSI) guidelines in 1987
      2. OSHA issued BBP Standard in 1991, mandating use of Universal Precautions
   D. Standard Precautions
      1. Issued by CDC in 1996 to clarify previous guidelines
      2. Included Transmission-Based Precautions
      3. Purpose is to protect workers and patients
      4. Implementation is mandatory
   E. Needlestick Prevention
III. Standard Precautions Regulations
   A. Comprehensive
      1. Applies to all patients
      2. Applies to all body fluids, excretions, and secretions
      3. Applies to nonintact skin and mucous membranes
      4. Applies to organs and unfixed tissues
      5. Treat every patient and every specimen as if infectious
      6. Use hand hygiene techniques and personal protective equipment
   B. The Exposure Control Plan
   C. Implementing an Exposure Control Plan
      1. Identifying employees at risk
      2. Exposure control methods
         a. Standard Precautions
         b. Personal protective equipment
         c. Engineering controls
         d. Work practice controls

IV. Complying with the Exposure Control Plan
   A. Infection Prevention
      1. Using waterless hand antiseptics
      2. Hand antisepsis
   B. Using Personal Protective Equipment
      1. Gloves
      2. Face and respiratory protection
      3. Disposable laboratory coats or gowns
   C. Exposure Incidents
      1. Immediately clean wound
      2. Notify appropriate supervisor
      3. Seek medical attention
V. Biological Hazards Other Than Bloodborne Pathogens
   A. Microbiology Hazards
   B. Methods of Decontamination
      1. Sterilization
      2. Disinfection
      3. Antisepsis
   C. Microbiology Work Practices
VI. Control of the Laboratory Environment
   A. Air Quality
      1. Humidity
      2. Temperature
      3. Air exchange
      4. Instrument performance
   B. Recordkeeping
   C. Federal Regulation
VI. Case Studies
VII. Summary

Case Studies and Answers

Case Study 1

Janie, a laboratory technician in a group practice clinic, frequently collects blood from clinic patients for laboratory tests. Janie's friend Bonnie came into the clinic for some blood tests. As Janie prepared to perform the venipuncture, Bonnie became offended when Janie put on gloves before collecting the blood.

1. How should Janie handle this situation?
   Janie should reassure Bonnie that there is nothing personal in her actions, and that the rules of the clinic require that Standard Precautions be used with all patients for the protection of both workers and patients.

2. Role-play this situation with a fellow student or co-worker.
   Have students discuss options for handling this situation.

Case Study 2

April is preparing serum chemistry control solutions for analysis in her department. She is wearing a laboratory coat and face shield. However, she does not like to wear gloves when handling the small control vials because she worries about dropping them.

1. Is it permissible for April to not wear gloves in this instance because patients are not involved?
   No.

2. What discussion should her supervisor have with her?
   April is using risky behavior that violates the requirements of Standard Precautions. She must wear gloves when handling any biological substance or reagent derived from a biological substance.

STUDENT ACTIVITIES

1. Complete the written examination on this lesson.
2. Make a poster warning of a biological hazard.
3. Make a poster illustrating or describing proper hand hygiene techniques.
4. Practice the correct technique for removing contaminated gloves.
5. Practice correct hand hygiene techniques using waterless handrubs and antiseptic soaps.
6. Use the biological safety worksheet at the end of this lesson to evaluate the laboratory's biological safety policy.

Web Activities

1. Visit the CDC or OSHA web site to find information on the Needlestick Safety and Prevention Act. Look for publications or posters that emphasize safe practices.
2. Search the Internet for examples of engineering controls used to increase safety in the clinical laboratory. Obtain information on engineering controls such as safety needles, sharps containers, and acrylic splash shields.
3. Search the Internet for videos showing proper glove removal. Sketch the procedure in four or five simple drawings.
4. Report on the various types of gloves available for use in the clinical laboratory, using an online healthcare or laboratory supply catalog. Note which types provide chemical protection and which provide protection from infectious agents.

5. Access the CDC web site and find the October 25, 2002, *Morbidity and Mortality Weekly Report* (Vol. 51/No. RR-160). Read the "Guideline for Hand Hygiene in Health-Care Settings" and compare the CDC guidelines with your laboratory's written safety plan. Should your laboratory policy be strengthened? If so, how?
6. Search the Internet for safety videos demonstrating correct work practice controls and exposure control methods. Look for videos of hand hygiene, donning gloves, and cleaning work surfaces. Compare the techniques shown in the video with techniques you have learned from your instructor.

REVIEW QUESTIONS AND ANSWERS

1. How have biological safety rules changed in recent decades? Why have they become more stringent?

   As the hazard of transmitting agents such as HIV and hepatitis B and C viruses became recognized, more stringent biological safety procedures were mandated. Before the discovery of HIV, early safety guidelines relied on isolation techniques. Universal Precautions applied to blood and body fluids containing visible blood for all patients. Standard Precautions apply the principles of work practice controls and exposure controls to all patients and all patient specimens to prevent exposure of workers to potentially infectious agents and to protect patients.

2. Explain the reason for the Bloodborne Pathogens Standard. Why was it revised in 2001?

   The BBP Standard outlines requirements for protection of workers who have potential for exposure to human blood or body fluids in the workplace. In 2001, the BBP Standard was revised to emphasize prevention of needlesticks in the workplace.

3. What is meant by exposure control plan or infection control plan?

   The exposure control plan (or infection control plan) identifies employees at risk for exposure to blood and body fluids, defines safe work practices, and requires documentation of safety training of employees.

4. List the exposure control methods that are included in the exposure control plan.

   The exposure control methods include:

   a. Standard Precautions

   b. Engineering controls

   c. Work practice controls

   d. Personal protective equipment

5. What is meant by the terms Universal Precautions and Standard Precautions?

   Universal Precautions is a method of infection control in which all human blood and body fluids containing visible blood are treated as if infectious. Standard Precautions clarify and combine Universal Precautions and BSI. Standard Precautions require that all patients, organs, tissues, and body fluids be treated as if infectious, even if blood is not visible in a body fluid. Protective barriers such as gloves, mask, gown, and goggles prevent exposure of skin or mucous membranes to biological specimens.

6. What additional safety rules and equipment are used in the microbiology laboratory?

   Procedures in the microbiology laboratory use aseptic technique, and some procedures may require use of a biological safety cabinet. Special care must be taken to prevent exposure to culture materials and pathogenic organisms.

7. What class of biological safety cabinet is most commonly used in medical laboratories?

   Class II

8. Name three work practice controls that should be used in the laboratory workplace.

   Any three of the following are acceptable:

   a. Wash hands before donning gloves, after glove removal, or any other time necessary.

   b. Wear appropriate PPE when cleaning up biological spills.

   c. Remove and dispose of PPE when leaving the work area or on completion of a task.

   d. Use surface disinfectant such as 10% bleach to clean work area before and after each use and anytime a spill occurs.

   e. Use needlestick prevention practices

9. What are the OSHA rules regarding the handling and disposal of used needles?

   OSHA prohibits the recapping of needles or removal of needles from used blood-drawing devices. The rule mandates use of safety needles/devices, immediate activation of safety feature after needle use, and discarding of needle into a readily accessible sharps container.

10. What personal protective equipment is commonly worn when working in the biological laboratory?

    See Figures 1-15 and 1-16. Gloves and fluid-resistant gown or laboratory coat should be worn; mucous membrane protection such as goggles, mask, or face shield, should be worn if splashes are reasonably expected.

11. Explain how to properly put on and take off gloves.

    See Figure 1-21. Gloves must be changed frequently when working in the laboratory, and hands must be cleansed with antiseptic between each glove change. Gloves that provide both chemical and biological protection should be worn. Gloves are put on by pulling the cuff or wrist area up so that all exposed skin is covered. Workers should not have long fingernails or wear sharp rings or jewelry that can puncture gloves.

To remove gloves, hold gloved hands over biohazard disposal container and grasp the outside of one glove cuff; pull the glove down over the hand inside out and contain the removed glove in the palm of the remaining gloved hand; insert bare fingers inside the remaining glove cuff, pull the glove inside out down over the hand taking care not to touch the outside of glove, and discard both gloves into biohazard container.

12. Discuss the advantages of wearing fluid-resistant disposable gowns or laboratory coats.
    Fluid-resistant disposable coats provide an inexpensive way to protect clothing from potentially infectious materials, contamination, spills, or stains and eliminate the need to launder contaminated coats.

13. What action(s) should be taken in case of an exposure incident?
    If an accident or exposure incident occurs, the employee must immediately:
    a. Flood the exposed area with water and clean any wound with antiseptic and water
    b. Report incident to supervisor, risk control officer, or infection prevention officer
    c. Seek immediate medical attention

14. How does a disinfectant differ from an antiseptic?
    Disinfectants are chemicals used to kill or inactivate microorganisms on inanimate objects or surfaces such as countertops, floors, instruments, or labware. Antiseptics are chemicals used on skin or tissue to inhibit growth of microbes.

15. Name four types of laboratory disinfectants and two antiseptics. Explain when and how antiseptics and disinfectants should be used.
    a. Any four of the following disinfectants are acceptable: dilute chlorine bleach (hypochlorite), 1:10 dilution; alcohols, 70% to 85%; iodophors, 75 parts/million (ppm); phenols; quaternary ammonium compounds.
    b. Any two of the following antiseptics are acceptable: alcohols, hydrogen peroxide, triclosan, chlorhexidine (Hibiclens), and iodine.
    Disinfectants are used on inanimate objects or surfaces; antiseptics are used on skin or tissues. Work surfaces should be cleaned with disinfectant any time a spill occurs and frequently during the work day. Hands should be cleansed with antiseptic before donning gloves, after removing gloves, and any other time contamination is suspected.

16. Explain the proper technique for washing hands with antiseptic.
    See Figure 1-20. Hands should be wet with warm or room temperature water and an amount of hand antiseptic recommended by the manufacturer applied to the hands. Hands and wrists should be lathered, and hands should be rubbed together vigorously for 15 to 30 seconds, covering all surfaces of the hands and fingers and cleaning fingernails and under rings. The arms or wrists and hands should be rinsed by holding the hands in a downward position and rinsing toward the tips of the fingers. The hands should be dried thoroughly with a disposable towel. Hand-operated faucets should be turned on and off using a clean disposable towel to avoid contaminating hands with organisms or substances that can be present on faucet handles. The use of hot water during handwashing should be avoided because repeated exposure to hot water can increase the risk for dermatitis.

17. What is the purpose of a safety agreement?

    The safety agreement documents annual safety training of employees.

18. Define acquired immunodeficiency syndrome, aerosol, alimentary tract, antiseptic, biohazard, biological safety cabinet, bloodborne pathogens, Bloodborne Pathogens Standard, community-acquired infection, disinfectant, engineering control, exposure control plan, exposure incident, hand antisepsis, hand hygiene, healthcare acquired infection (HAI), hepatitis B virus, hepatitis C virus, human immunodeficiency virus (HIV), isolation, other potentially infectious materials (OPIM), parenteral, pathogenic, personal protective equipment (PPE), Standard Precautions, sterilization, Transmission-Based Precautions, Universal Precautions, and work practice controls.

    See Glossary.

WORKSHEET ANSWERS

Answers to Biological Safety Worksheet will differ depending on available laboratory facilities.

LESSON 1-5

Chemical, Fire, and Electrical Safety

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Describe the evolution of the Occupational Safety and Health Administration (OSHA) safety laws.**
- **Explain the "right to know" provisions of OSHA.**
- **Explain why safety rules must be observed.**
- **List three general categories of laboratory hazards.**
- **Give two examples of physical hazards and ways to prevent or correct each one.**
- **Give two examples of chemical hazards and ways to prevent or correct each one.**
- **List five components of a chemical hygiene plan.**
- **Interpret and use the information on a material safety data sheet (MSDS).**
- **Explain the importance of wearing appropriate clothing in the laboratory.**
- **Discuss how personal protective equipment (PPE) is used in the laboratory.**
- **List 16 laboratory safety work practices designed to protect against physical and chemical hazards.**
- **Define the glossary terms.**

GLOSSARY

autoclave / an instrument that uses pressurized steam for sterilization

carcinogen / a substance with the potential to produce cancer in humans or other animals

caustic / a chemical substance having the ability to burn or destroy tissue

centrifuge / instrument with a rotor that rotates at high speeds in a closed chamber

chemical hygiene plan / comprehensive written safety plan detailing the proper use and storage of hazardous chemicals in the workplace

fume hood / a device that draws contaminated air out of an area and either cleanses and recirculates it or discharges it to the outside

material safety data sheet (MSDS) / written safety information that must be supplied by manufacturers of chemicals and hazardous materials

mutagen / a substance or agent, such as radiation, certain chemicals, or some viruses, that causes a stable change in a gene that can then be passed on to offspring

National Institute for Occupational Safety and Health (NIOSH) / federal agency responsible for workplace safety research and that makes recommendations for preventing work-related illness and injury

Occupational Safety and Health Act (OSH Act) / Congressional Act of 1970 created to help reduce on-the-job illnesses, injuries, and deaths and requiring employers to provide safe working conditions

Occupational Safety and Health Administration (OSHA) / the federal agency that creates workplace safety regulations and enforces the Occupational Safety and Health Act of 1970

personal protective equipment (PPE) / specialized clothing or equipment used by workers to protect from direct exposure to blood or other potentially infectious or hazardous materials

radioisotope / an unstable form of an element that emits radiation and can be incorporated into diagnostic tests, medical therapies, and biomedical research; radioactive isotope

teratogen / a substance or agent capable of causing birth defects by direct harm to a fetus or embryo, or by interfering with normal fetal development

TEACHING AIDS AND RESOURCES

- Examples of safety equipment, fire extinguishers, and PPE
- Examples of MSDS sheets, hazard symbols, chemical labels, etc.
- Chemical, Fire and Electrical Safety Worksheets I and II
- Guest speaker from the community or institution such as a fire safety officer or chemical safety officer
- Transparencies or overheads of Figures 1-23 through 1-31
- Transparencies or overheads of Tables 1-21 through 1-23
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
   A. Physical Hazards
   B. Chemical Hazards
   C. Biological Hazards

II. Workplace Safety
   A. Federal Regulation
      1. OSHA's Hazard Communication Rule
      2. Enforcement of the OSH Act
   B. State Safety Codes
   C. Safety Training
   D. Personal Protective Equipment
      1. Eye, face, and skin protection
      2. Respirator and fume hood
      3. Gloves
      4. Laboratory clothing
III. Physical Hazards
   A. Electrical Safety
   B. Fire Safety
   C. Laboratory Equipment Safety
   D. Glassware Safety
IV. Chemical Hazards
   A. Chemical Hygiene Plan
      1. Standard operating procedures for hazardous chemicals
      2. Reduce exposure—PPE, work practice controls
      3. Proper function of fume hood and PPE
      4. Provide specific hazard information about chemicals in the workplace
      5. Provisions for employee training
   B. Material Safety Data Sheets
   C. Chemical Labels
      1. NFPA labeling system
      2. Caustic chemicals
      3. Toxic chemicals
      4. Carcinogens, mutagens, teratogens, and radioisotopes
   D. Chemical Storage
   E. Chemical Disposal
V. Laboratory Clothing
VI. Safety Resources
VII. General Laboratory Safety Rules
   A. Report accidents immediately.
   B. Be familiar with MSDS information.
   C. Do not eat, drink, chew gum, or apply cosmetics in the work area.
   D. Wear laboratory coat or apron and closed-toe shoes.

E. Pin long hair back.
F. Do not wear chains or loose jewelry.
G. Use chemical-resistant gloves when working with hazardous chemicals.
H. Clean work area before and after performing procedures.
I. Wash hands before and after procedures and after removing gloves.
J. Wear protective facewear or work behind a shield when splashes are possible.
K. Wipe up spills promptly and appropriately.
L. Use fume hood or appropriate mask or respirator to avoid inhalation of chemical dust and fumes.
M. Follow manufacturers' instruction for operating equipment.
N. Report frayed cords, exposed electrical wires, or damaged equipment.
O. Use dustpan and broom to pick up broken glass; discard in rigid containers.
P. Follow institution's policy about visitors in work area.

VIII. Case Studies
IX. Summary

Case Studies and Answers

Case Study 1

Michelle, a phlebotomist in the laboratory of a small clinic, arrived at work a few minutes early dressed neatly in scrubs and new sandals. After putting on her laboratory coat and buttoning it, she began work. Within the hour her supervisor told her she was inappropriately dressed. What do you think is the problem?

Michelle should be wearing closed-toe shoes in the laboratory. These protect the feet from chemical spills or splashes, and from injury in case of an accident.

Case Study 2

Doug began preparing laboratory surface disinfectant from chlorine bleach. He put on a chemical resistant apron and gloves and then removed the bleach container from the special chemical cabinet. He carefully placed the container on the laboratory benchtop and began to add the chlorine bleach to distilled water. Nearby workers began complaining of burning eyes. Doug was reprimanded by the supervisor. Explain why.

Doug should have prepared the reagent in a fume hood to prevent release of fumes into the work area.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Make a poster warning of a physical or chemical hazard.

3. Use Chemical, Fire, and Electrical Safety Worksheet I at the end of this lesson to inspect the laboratory for physical or chemical hazards. Check for frayed cords, exposed wires, fire extinguisher, safety posters, and posting of fire exit routes.
4. Practice the procedure to follow in case of fire and the use of the fire extinguisher; learn the fire escape route.
5. Inspect the chemicals in the laboratory and make a report using Chemical, Fire, and Electrical Safety Worksheet I. Are chemicals labeled with appropriate information? Do chemical labels contain instructions for accidental exposure? Note the procedure to follow in case of skin contact or chemical spill.
6. Make an inventory of six chemicals in your laboratory, using the inventory form on Chemical, Fire, and Electrical Safety Worksheet II at the end of this lesson. Consult the MSDS to determine the hazard class and type of PPE required when using each chemical.

Web Activities

1. Use the Internet to find MSDS information for NaOH, HCl, and Clorox (hypochlorite). Report on the reactivity, flammability, and health hazard of each; list the PPE that should be worn when working with each of these chemicals.
2. Visit the OSHA or NIOSH web site and find out what safety information is available. Look for free safety posters or brochures and order or download and print free copies for your laboratory or class.
3. Search the Internet for videos or tutorials demonstrating chemical, fire, and electrical safety practices.
4. Search the Internet for tutorials or self-tests covering laboratory safety.

REVIEW QUESTIONS AND ANSWERS

1. What are three categories of laboratory hazards?
   - **a. Physical**
   - **b. Chemical**
   - **c. Biological**

2. Give two examples of physical hazards and tell how each might be avoided or corrected.

   Any two of the following physical hazards are acceptable (the student may think of others as well):
   - **a. Frayed electrical cords: Inspect cords frequently and repair when necessary.**
   - **b. Repairing electrical instruments: Unplug instruments before attempting repair; follow manufacturer's instructions; allow only experienced technicians to work on instruments with high-voltage wiring.**
   - **c. Overloaded circuits: Upgrade electrical capacity**
   - **d. Flammable chemicals: Store in a fireproof cabinet**
   - **e. Fire: Replace Bunsen burners with alternative heating sources.**
   - **f. Broken glassware: Use plasticware when possible; do not handle broken glass, use broom and dustpan**

3. Give two examples of chemical hazards and tell how each might be avoided or corrected.

   Any two of the following chemical hazards are acceptable (the student may think of others as well):

   a. Chemicals can be caustic, corrosive, carcinogenic, mutagenic: Wear appropriate protective clothing when handling

   b. Chemicals such as strong acids and bases burn skin: Wear appropriate protective clothing such as chemical resistant gloves

   c. Chemicals that can produce toxic fumes: Use these in a fume hood.

   d Inhalation of chemical dust: Use fume hood or respirator

4. Why is it important to conduct frequent fire drills?

   Fire drills should be held frequently so that all workers will know the escape route and the procedure to follow if the exit is blocked.

5. Why must safety rules be strictly observed?

   Safety rules must be strictly observed so that the work environment will be safe for workers and patients.

6. Name the governmental agency responsible for enforcing safety regulations in the workplace.

   OSHA

7. Describe the type of clothing that should be worn by laboratory workers.

   Proper clothing should include a buttoned, fluid-resistant laboratory coat or jacket; shoes with closed toes; gloves; and protective facewear appropriate for the task.

8. State 16 general laboratory safety rules and explain the rationale for each.

   (Also See General Laboratory Safety Rules in the textbook.)

   a. Report any accident immediately to the supervisor.
   b. Be familiar with MSDS information before working with a chemical or reagent.
   c. Do not eat, drink, chew gum, or apply cosmetics in the work area.
   d. Wear a laboratory apron or buttoned, fluid-resistant laboratory coat and closed-toe shoes.
   e. Pin long hair back to prevent contact with chemicals or moving equipment.
   f. Do not wear chains, bracelets, large rings, or other loose jewelry.
   g. Use chemical-resistant gloves when working with hazardous chemicals.
   h. Clean the work area before and after laboratory procedures and any other time it is needed.
   i. Wash hands before donning gloves, after removing gloves, and any other time necessary.
   j. Wear safety glasses, goggles, and face shield or use a countertop acrylic splash shield to protect from splashes into eyes or mucous membranes; do not wear contact lenses in the laboratory.
   k. Wipe up spills promptly, using the appropriate procedure for the type of spill.
   l. Use a fume hood or appropriate mask or respirator when working with chemicals or other materials that create dust or emit fumes.

- **m. Follow manufacturers' instructions for operating all equipment; handle all equipment with care and store properly.**
- **n. Report any broken or frayed electrical cords, exposed electrical wires, or any damage to equipment.**
- **o. Use a broom or brush and dustpan to pick up broken glass; discard into special rigid, thick-walled containers.**
- **p. Allow visitors in the laboratory work area only if institution policy permits.**

9. Discuss the importance of reading and understanding the MSDS information for each chemical used.

   The MSDS describes the hazard(s) of the chemical, the PPE required to prevent exposure, the body organs that could be adversely affected following exposure to the chemical, appropriate first aid, and further medical treatment required on exposure.

10. Define autoclave, carcinogen, caustic, centrifuge, chemical hygiene plan, fume hood, material safety data sheet (MSDS), mutagen, National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health (OSH) Act, Occupational Safety and Health Administration (OSHA), personal protective equipment, radioisotope, and teratogen.

    See Glossary.

WORKSHEET ANSWERS

Answers to Chemical, Fire, and Electrical Safety Worksheets I and II will vary depending on available laboratory facilities.

LESSON 1-6

General Laboratory Equipment

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Identify five basic types of containers used in the laboratory and explain the use of each.**
- **Explain the differences between critical and noncritical measurements.**
- **Identify glassware that can be used for critical measurements.**
- **Identify heat-resistant glassware.**
- **Discuss the advantages and disadvantages of using plastic containers in the laboratory.**
- **Describe the proper care of and cleaning procedures for laboratory glassware and plasticware.**
- **Explain how the condition of labware can affect the outcome of test procedures.**
- **Explain the proper use of a centrifuge.**
- **Explain the function of a pH meter.**
- **Discuss the operation of an autoclave.**
- **List four rules for using a laboratory balance.**
- **Explain how temperature-controlled chambers are used in the laboratory.**
- **Discuss safety precautions that must be followed when using the labware and laboratory equipment such as centrifuge, autoclave, pH meter, and balances.**
- **Explain the importance of performing regular equipment maintenance and keeping maintenance and repair records.**
- **Define the glossary terms.**

GLOSSARY

autoclave / a device that uses pressurized steam for sterilization

beaker / a wide-mouthed, straight-sided container with a pouring spout formed from the rim and used to make estimated measurements

borosilicate glass / nonreactive glass with high thermal resistance commonly used to make high-quality labware

centrifuge / an instrument with a rotor that rotates at high speeds in a closed chamber

critical measurements / measurements made when the accuracy of the concentration of a solution is important; measurements made using glassware manufactured to strict standards

flask / a container with an enlarged body and a narrow neck

flint glass / inexpensive glass with low resistance to heat and chemicals

graduated cylinder / an upright, straight-sided container with a flared base and a volume scale

labware / article(s) or container(s) intended for laboratory use

meniscus / the curved upper surface of a liquid in a container

microfuge / a centrifuge that spins microcentrifuge tubes at high rates of speed; microcentrifuge

National Institute for Standards and Technology (NIST) / a federal agency that promotes international standardization of measurements; formerly the National Bureau of Standards

noncritical measurements / estimated measurements; measurements made in containers that estimate volume (such as beakers)

pH / a measurement of the hydrogen ion concentration expressing the degree of acidity or alkalinity of a solution

pipet / a slender calibrated tube used in the laboratory for measuring and transferring liquids

polyethylene / plastic polymer of ethylene used for containers

polypropylene / lightweight plastic polymer of propylene that resists moisture and solvents and withstands heat sterilization

polystyrene / clear, colorless polymer of styrene used for labware

quartz glass / expensive glass with excellent light transmission; glass used for cuvettes; silica glass

reagent / substance or solution used in laboratory analyses; substance involved in a chemical reaction

rotor / the part of a centrifuge that holds the tubes and rotates during the operation of the centrifuge

serological centrifuge / a centrifuge that spins small tubes such as those used in blood banking; serofuge

solute / the substance dissolved in a given solution

solvent / a dissolving agent, usually a liquid

tare / in chemical analysis, a determination of the net weight of a chemical by subtracting the weight of the container from the overall weight of the container and the chemical being weighed

TEACHING AIDS AND RESOURCES

- General laboratory equipment worksheet
- Laboratory equipment such as various types of glassware, pH meter, pH papers, laboratory balance, and centrifuges
- Transparencies or overheads of Figures 1-32 through 1-43
- Transparency or overhead of Table 1-24
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
II. General Labware
    A. Glassware
    B. Plasticware
III. Types and Functions of Labware
    A. Bottles
    B. Test tubes
    C. Beakers
    D. Graduated Cylinders
    E. Flasks
IV. Care and Cleaning of Labware
    A. Routine Cleaning
    B. Cleaning Contaminated Labware
V. Safety Precautions
    A. Labware Safety
    B. Equipment Safety
        1. Electrical hazards
        2. Moving parts
        3. Exposure to blood or OPIM
        4. Follow manufacturer's directions
VI. Quality Assessment
    A. Labware
    B. Laboratory Equipment
        1. Maintenance program
        2. Performance checks
        3. Documentation

VII. Common Laboratory Equipment
   A. Centrifuges
      1. Types
         a. Clinical
         b. Microcentrifuge
         c. Serological
         d. Refrigerated
         e. Ultracentrifuge
      2. Centrifuge safety
         a. Use approved tubes
         b. Balance tubes in rotor
         c. Keep tubes capped during centrifugation
         d. Do not open while rotor is spinning
         e. Clean spills immediately
      3. Quality assessment
         a. Verify centrifuge speed
         b. Verify timer
   B. Autoclaves
      1. Use pressurized steam
         a. Sterilize instruments and media
         b. Decontaminate biological materials
         c. 121° C, 15 to 20 minutes, 15 psi
      2. Autoclave safety
         a. Use tongs or special gloves to prevent burns
         b. Do not open until chamber pressure is 0 psi
         c. Schedule regular maintenance by qualified technician
      3. Quality assessment
         a. Record temperature of each run
         b. Use *Bacillus* indicator strips to check effectiveness of sterilization conditions
   C. Laboratory Balances
      1. Types
         a. Beam, top-loading, and cabinet
         b. Different capacities and sensitivity levels
      2. Laboratory balance safety
         a. Use PPE to protect from chemicals and chemical dusts
         b. Clean up spills
      3. Quality assessment
         a. Protect balance from jarring
         b. Protect from drafts and vibrations

        c. Observe sensitivity limits
        d. Calibrate on regular schedule
  D. pH meters
    1. Measure hydrogen ion concentration
        a. pH above 7 is alkaline solution
        b. pH below 7 is acid solution
        c. pH of 7 is neutral solution
    2. Electrodes
    3. pH meter safety
        a. Use care with caustic or acid solutions for adjusting pH
        b. Clean spills
    4. Quality assessment
        a. Calibrate electrodes
        b. Store electrodes properly
  E. Temperature-Controlled Units
    1. Types
        a. Refrigerators
        b. Freezers
        c. Incubators
        d. Water baths
    2. Temperature-controlled chamber safety
        a. Do not use for storing or heating food
        b. Use Standard Precautions when cleaning
    3. Quality assessment
        a. Monitor and record temperatures daily
        b. Use calibrated thermometers
        c. Alarm systems notify when temperature goes outside accepted range
        d. Backup power supply
        e. Equipment temperature stability affected by air flow, room temperature, and instrument maintenance
  F. Equipment Maintenance Records

VIII. Safety Reminders
IX. Procedural Reminders
X. Critical Thinking Problem
XI. Case Study
XII. Summary

Critical Thinking Problem and Answer

June was working in clinical chemistry when a blood specimen came in with orders for STAT (immediate) testing. The main clinical centrifuge was in use, so June located the backup centrifuge.

However, a sign was on the backup centrifuge stating that the interlock was broken. June considered using the centrifuge anyway, but decided to wait the 5 minutes until the main centrifuge was available.

Since the test was ordered STAT, and the result was needed as soon as possible, did June do the right thing? Explain your answer.

Yes. The need to save a few seconds in a test procedure is not a reason to disregard laboratory safety rules and operate an unsafe instrument.

Case Study and Answer

Jamie was in training in the Specimen Collection and Processing section of a small hospital laboratory. One of the laboratory employees asked him to measure the volume of a 24-hour urine specimen received in the laboratory that morning. At the work area were a 1000-mL beaker, a 1000-mL Erlenmeyer flask, and a 1000-mL graduated cylinder.

1. Which item(s) would give the most accurate measurement of volume? Explain your answer.

   The 1000-mL graduated cylinder should be used. Graduated cylinders are somewhat more accurate than beakers and flasks but are not used for critical measurements.

2. Which of the three items available can be used for critical measurements?

   None of the three can be used for critical measurements

STUDENT ACTIVITIES

1. Complete the written examination on this lesson.
2. Measure 100 mL of water in a beaker and transfer it to another beaker or flask. Does it measure 100 mL in the second container?
3. Measure 100 mL of water in an Erlenmeyer flask and transfer it to a 100-mL volumetric flask. Is the volume exactly 100 mL?
4. Practice measuring volumes using a graduated cylinder: Hold cylinder with desired volume marking at eye level and carefully pour water into the cylinder until it reaches the volume marking. Observe the meniscus: the lowest point should be level with the volume marking (Figures 1-34 and 1-36). If necessary, adjust volume by adding or removing solution dropwise until the meniscus is at the proper level. Repeat procedure using a different size cylinder.
5. Practice measuring volumes using a volumetric flask: identify the fill line in the neck of the flask; pour water into the flask slowly until the fluid level nears the fill line; hold the flask so the fill line is at eye level and use a transfer pipet to deliver water dropwise until the low point of the meniscus is level with the fill line.
6. Depending on the instruments available, complete activities 6a–6c. Read the instruction manual carefully before attempting to use an instrument. Then be sure to follow the instructions carefully when using that instrument.
   a. If a pH meter is available, practice measuring the pH of solutions such as 0.9% saline and 0.9% buffered saline. Note how the pH changes when a drop or two of 0.1% HCl or 0.1% NaOH is added to each solution. Dilute the solution by adding 1 part water to 1 part

solution. Now measure the pH. Did it change? How can the result be explained? How does the pH of the nonbuffered saline differ from that of the buffered saline?

b. If a balance is available, practice weighing a nontoxic chemical or a substance such as NaCl (salt) or glucose (sugar). Be sure to zero the balance before beginning and tare the balance with the empty weighing container on the pan. Note the capacity of the balance; what is the largest weight that can be measured? What is the smallest increment that can be read (1 g, 0.1 g, 0.01 g, etc.)?
c. If a centrifuge is available, practice centrifuging a sample, using appropriately sized tubes and balance tubes. Note the speed scale; what is the maximum rpm the centrifuge can achieve? What size tubes can the centrifuge handle safely? Does the centrifuge have a cover interlock?

7. Use the general laboratory equipment worksheet at the end of this lesson to record the performance and maintenance of any available equipment.

Web Activities

1. Search the product listing of an online laboratory supply catalog for information about types of centrifuges that are available. Compare three sizes including maximum speed, types of tubes, and type of rotor.
2. Visit the NIST web site. Find information on certified glassware.
3. Look in online scientific catalogs for calibrators or standards for general laboratory equipment:
   a. Find examples of thermometers for use in clinical refrigerators, freezers, and incubators. List the various designs available. Are the thermometers NIST certified?
   b. Determine what devices are available for calibrating centrifuge speed and how they are used.
   c. Find examples of calibration weight sets for use with laboratory balances. How are the weight sets used to calibrate a laboratory balance?
   d. Find information on pH standard solutions for calibrating pH meters.
4. Search the Internet for instrument calibration services for clinical equipment such as centrifuges and laboratory balances. What calibration service intervals are recommended for different types of equipment?
5. Search the Internet for online videos or tutorials demonstrating the correct use of laboratory glassware such as graduated cylinders or beakers.
6. Search the Internet for online videos or tutorials demonstrating the safe and correct use of laboratory equipment such as centrifuges or laboratory balances. Try to find demonstration videos for the type of instruments available in your laboratory.

REVIEW QUESTIONS AND ANSWERS

1. Name five types of containers used to hold liquids.
   a. Bottles
   b. Beakers
   c. Flasks
   d. Test tubes
   e. Graduated cylinders

2. Name two types of laboratory flasks.
   a. Erlenmeyer
   b. Volumetric

3. Which types of glassware are used to make critical measurements?
   Volumetric flasks and volumetric pipets are used for critical volume measurements.

4. Why is it important that damaged glassware not be used?
   Damaged glassware can break unexpectedly and injure the worker. Pipets with chipped tips are not accurate.

5. Why should reusable glassware be immediately rinsed after use?
   Immediate rinsing of labware after use avoids the need for harsh cleaning to dissolve dried reagent or sample residue.

6. Why is it important that glassware be rinsed until it is free of detergent?
   Detergent residues can interfere with test results.

7. How do flint glass and borosilicate glass differ?
   Flint glass is inexpensive, has low heat and chemical resistance, and is often used to make disposable containers. Borosilicate glass does not react with most chemicals, is of high thermal resistance, and is more expensive than flint glass.

8. Name three types of plastics commonly used in the laboratory and give characteristics of each.
   Commonly used plastics include polystyrene and polyethylene, which are clear, inexpensive, but not heat resistant; and polypropylene, which is opaque and is heat-sterilizable.

9. What is the procedure for cleaning labware that is contaminated with blood or OPIM?
   Labware that has come into contact with any serum control, blood, body fluid, patient specimen, or OPIM must be decontaminated by soaking in disinfectant before it is washed.

10. What rules should be followed when using a laboratory balance?
    Balances should be calibrated regularly, kept clean, kept free from jarring or vibration, and used at the appropriate sensitivity.

11. A solution with a pH of 8.5 is ______ (acidic, neutral, alkaline).
    Alkaline

12. Give five general rules to follow when operating a centrifuge.
    a. Use appropriate tubes for the centrifuge used.
    b. Spin tubes with lids on.

c. **Balance the tubes in the rotor.**
d. **Always operate centrifuge with lid closed.**
e. **Clean spills with disinfectant.**

13. Name three types of centrifuges that can be found in a clinical laboratory.

Any three of the following are acceptable:

a. **Clinical centrifuges**
b. **Serological**
c. **Microfuges**
d. **Refrigerated centrifuges**
e. **Ultracentrifuges**

14. Explain how autoclaves operate.

Autoclaves sterilize items by heating them under pressurized steam for a specified time, temperature, and pressure (psi).

15. Why is it important to be careful when using an autoclave?

Burns can occur from the pressurized steam or from contact with hot items that have been autoclaved.

16. What quality assessment procedures are used for temperature-controlled chambers?

Temperature-controlled chambers are monitored with calibrated thermometers, and the temperatures are recorded daily or once per shift.

17. Explain why equipment maintenance records are important.

Equipment used in all parts of the testing process must operate correctly. Records of performance checks, maintenance, and repairs are required in quality assessment programs and provide a way to document that equipment was functioning normally at a specified time. When a problem in a procedure occurs, these records can help pinpoint the problem.

18. Why is it important to maintain a stable laboratory environment?

Laboratory airflow, room air exchange, and air temperature stability influence the operation of temperature-controlled units such as waterbaths and other temperature-controlled chambers. Increased airflow over waterbaths will contribute to rapid water evaporation. Fluctuating room temperatures and increased airflow can also make it more difficult for temperature-controlled units to maintain their set temperatures. The laboratory environment must be kept stable, without abrupt temperature changes or drafts. Either of these conditions can cause temperature-controlled units to be unable to maintain their set temperatures.

19. Name a hazard associated with: autoclave, centrifuge, pH meter, and laboratory balance.
    a. **Autoclave hazard: Burns**
    b. **Centrifuge hazard: Broken specimen tubes, injuries to the face and hands if operated when open**
    c. **pH meter hazard: Exposure to acids and bases, electrical hazard**
    d. **Laboratory balance hazard: Chemicals in eyes, breathing chemical dusts, or chemical contact with skin and clothing**

20. Define autoclave, beaker, borosilicate glass, centrifuge, critical measurements, flask, flint glass, graduated cylinder, labware, meniscus, microfuge, National Institute for Standards and Technology, noncritical measurements, pH, pipet, polyethylene, polypropylene, polystyrene, quartz glass, reagent, rotor, serological centrifuge, solute, solvent, and tare.

    See Glossary.

WORKSHEET ANSWERS

Answers to the General Laboratory Equipment Worksheet will vary depending on available laboratory facilities.

LESSON 1-7

The Metric System

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Discuss the importance of understanding metric units and using the metric system in the laboratory.**
- **Name common prefixes used to denote small and large metric units.**
- **Convert English units to metric units.**
- **Convert metric units to English units.**
- **Convert units within the metric system.**
- **Perform measurements of distance, volume, and weight (mass) using the metric system.**
- **Make temperature conversions between the Fahrenheit and Celsius scales.**
- **Define the glossary terms.**

GLOSSARY

Celsius (C) scale / temperature scale having the freezing point of water at 0° C and the boiling point at 100° C

centi / prefix used to indicate one-hundredth (10^{-2}) of a unit

Clinical and Laboratory Standards Institute (CLSI) / an international institute composed of representatives from government, industry and patient-testing professions that develops and publishes standards and guidelines for regulatory agencies and accrediting bodies; formerly National Committee for Clinical and Laboratory Standards (NCCLS)

deci / prefix used to indicate one-tenth (10^{-1}) of a unit

English system of measurement / system of measurement in common use in the United States for nonscientific measurements; sometimes called U.S. customary system

Fahrenheit (F) scale / temperature scale having a freezing point of water at 32° F and boiling point at 212° F

femto / prefix used to indicate 10^{-15}

gram (g) / basic metric unit of weight or mass

kilo / prefix used to indicate 1000 (10^3) units

liter (L) / basic metric unit of volume

meter (m) / basic metric unit of length or distance

metric system / the decimal system of measurement used internationally for scientific work

micro / prefix used to indicate one-millionth (10^{-6}) of a unit

milli / prefix used to indicate one-thousandth (10^{-3}) of a unit

nano / prefix used to indicate one-billionth (10^{-9}) of a unit

National Institute of Standards and Technology (NIST) / a federal agency that promotes international standardization of measurements; formerly the National Bureau of Standards

pico / prefix used to indicate 10^{-12} of a unit

SI units / standardized units of measure; international units

TEACHING AIDS AND RESOURCES

- Meter stick, yard stick, balance or scales; glassware such as beaker, graduated cylinder, medicine cup
- Worksheets I, II, and III
- Metric wall chart
- Transparencies or overheads of Figures 1-44 through 1-46
- Transparencies or overheads of Tables 1-25 through 1-33
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
   A. Common Laboratory Measurements
      1. Concentration or number
      2. Weight
      3. Volume
      4. Size
      5. Temperature
      6. Time
   B. Need for Accurate Measuring System

II. Systems of Measurement
    A. English System of Measurement
    B. The Metric System
        1. Used for scientific work
        2. Three basic units
            a. Meter
            b. Gram
            c. Liter
    C. International System of Units (SI Units)
        1. Adopted in United States in 1991
        2. National Institute of Standards and Technology (NIST)
        3. Standardizes scientific reporting worldwide
III. Metric System Terminology
    A. Seven Basic SI units
    B. Standard Prefixes and Suffixes
    C. Increments of 10
IV. Conversion Factors
    A. English-Metric Conversions
    B. Converting Units within the Metric System
        1. Converting to Larger Units
        2. Converting to Smaller Units
V. Standardized Reporting of Laboratory Results
VI. Time and Temperature
    A. Time
        1. Twelve-hour clock (AM/PM)
        2. Military clock (24-hour)
    B. Temperature
        1. Celsius scale
        2. Fahrenheit scale
VII. Metric Problems
VIII. Summary

Metric Problems and Answers

Problem 1

Jeremy was the only person working the night shift in his town's hospital laboratory. As he prepared to perform a chemistry test, he noticed that the waterbath thermometer was missing. The reagent he needed was frozen and the instructions were to thaw at 30° C to 32° C. He located a thermometer, but it was in Fahrenheit scale. What Fahrenheit temperature range would be acceptable for thawing his reagent?

Using the formula in Figure 1-46, a Fahrenheit range of 86° F to 89.6° F is equivalent to the Celsius temperature range of 30° C to 32° C and would be acceptable for thawing the reagent.

Problem 2

Shirley was on duty when laboratory test results were called in for Dr. Simpson's patient. The results, reported in SI units, were as follows: total protein, 70.0 g/L; hemoglobin, 150.0 g/L; and WBC count, 9.5×10^9/L. Shirley related the test results to Dr. Simpson, but he asked her to give him the results using the "old" units (total protein and hemoglobin in g/dL, and WBC count in cells/µL).

Convert the SI units.

Total protein	70.0 g/L	= **7.0**	g/dL
Hemoglobin	150.0 g/L	= **15.0**	g/dL
WBC count	9.5×10^9/L	= **9.5×10^3 (or 9,500)**	cells/µL

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Practice measuring metric volumes, lengths, and weights and converting metric units using Worksheets I, II, and III.
3. Obtain a laboratory report form from a clinical laboratory in your area. Are reference ranges listed? Are SI units used?

Web Activities

1. Search the Internet for information on the International System of Units. Find information about using SI units in reporting laboratory results. Determine what units are used to report results of laboratory tests such as platelet counts, BUN, potassium, sodium, and bilirubin.
2. Use the Internet to locate lists of reference ranges for laboratory tests. Examine each list to determine what system of measurement is used to report results. Are SI units used?
3. Search the Internet for metric system tutorials, practice exercises, or self-tests and use these to enhance and test your knowledge.

REVIEW QUESTIONS AND ANSWERS

1. What is the basic metric unit of distance or length?

   Meter

2. What is the basic metric unit of volume?

   Liter

3. What is the basic metric unit of weight?

   Gram

4. What are the meanings of deca and hecto?

   a. **Deca means 10.**

   b. **Hecto means 100.**

5. Why is the metric system preferred over the English system for scientific measurements?

   The metric system is more accurate (for measuring small increments) than the English system.

6. Use the tables in this lesson to convert the following English measurements to metric units:

   3 inches = **7.6** cm or **76** mm

   5 qt = **4.75** L or **4750 (or 4.75 × 10^3)** mL

   64 oz = **1,792** g or **1.792** kg or **1.792 × 10^6** mg

7. Convert the following units:

   12 mg = **12,000 (or 1.2 ×10^4)** µg or **0.012** g

   50 mL = **50,000 (or 5.0 × 10^4)** µL or **50** cc or **0.5** dL

8. Convert the following temperatures using the formulas in Figure 1-46:

   101° F = **38.3**° C

   25° C = **77**° F

9. Define Celsius (C) scale, centi, Clinical and Laboratory Standards Institute (CLSI), deci, English system of measurement, Fahrenheit (F) scale, femto, gram, kilo, liter, meter, metric system, micro, milli, nano, National Institute of Standards and Technology (NIST), pico, and SI units.

   See Glossary.

WORKSHEET ANSWERS

Answers to Metric Worksheet I—Distance

Note to instructor: Answers to questions 2 and 7 are not given. The student must draw the answer to question 2 and question 7 answers will vary from student to student.
Obtain a meter stick or metric ruler and an English ruler from the instructor. Use the information in Tables 1-26 through 1-29 to answer the questions below.

1. Look at the meter stick. Locate the cm and mm divisions. How many centimeters are in a meter? __**100**__ How many mm in a cm? __**10**___ How many mm in a meter? __**1000**___

2. Draw the indicated length of line beside each number, beginning at the dot.
   35 mm**.**
   6 cm**.**

3. Measure the lines above (question 2) using a ruler marked in English units (inches):
   35 mm = _**approximately 1.4**___ inches
   6 cm = _**approximately 2.4**___ inches
   Which of the measurements (English or metric) do you feel is the most accurate?
   __**metric**________

4. How many mm in 1 inch? ___**25.4**____ 1 mm = _**0.039 (or 3.9 × 10^{-2})**_ inch
   How many cm in 1 inch? ___**2.54**____ 1 cm = _**0.39**_______ inch
   Convert the following units:
   4 inches = ___**10.16**___ cm
   0.5 inches = ___**1.27**____ cm
   38 cm = ___**15**_____ inches
   7 cm = ___**2.76**____ inches

5. How many inches are in a meter? ___**39.24**____

6. What English unit of measurement is closest in size to the meter? __**yard**___

7. Measure your height or the height of another student using the meter stick. What is the height in cm? __________ in meters? _________
   Convert the height in cm to inches: _________ . Now measure the height in inches and compare the results. **(Answers to this question will vary from student to student.)**

Answers to Metric Worksheet II—Weight

Use Tables 1-26 through 1-29 to answer the questions below.

1. What is the basic metric unit of weight? __**gram**__

2. How many mg in a g? _**1000**_ How many μg in a g? __**10^6 (or 1,000,000)**__
   How many g in a kg? _**1000**_

3. Convert the following units:

   80 g = **0.08** kg
   300 mg = **0.3** g = **0.0003 (or 3×10^{-4})** kg
   50 mg = **0.05** g = **0.00005 (or 5×10^{-5})** kg
   4000 mg = **4** g = **0.004 (or 4×10^{-3})** kg
   200 µg = **0.2** mg = **0.0002 (or 2×10^{-4})** g
   750 µg = **0.75** mg

   What decimal rule did you follow to make the conversions? **Move decimal to the left to convert smaller units to larger units.**

4. Convert the following units:

   0.4 kg = **400,000 (or 4.0×10^5)** mg = **4.0×10^{11}** µg
   0.6 g = **6.0×10^5** µg
   15 mg = **15,000 (or 1.5×10^4)** µg = **1.5×10^{10}** pg
   280 mg = **280,000 (or 2.8×10^5)** µg = **2.8×10^8** ng

   What decimal rule did you follow to make the conversions? **Move decimal to the right to convert larger units to smaller units.**

5. A man who weighs 165 pounds would weigh **75 (or 74.9)** kg.

6. A child who weighs 32 pounds would weigh **14.5** kg or **14,500** g.

7. Is a man who is 178 cm tall and weighs 135 kg overweight, underweight, or of normal weight? **Overweight (he is 70 inches tall, or 5 ft. 10 in, and weighs 297 pounds).**

8. If a balance is available, weigh a container, add 10 mL of water, and weigh again. How much does the water weigh? **~10 g** Does 1 mL of water weigh approximately 1 g? Yes **X** No______

9. Weigh yourself or another student. What is the weight in g? ______ in kg? ______
   (Answers will vary from student to student.)

Answers to Metric Worksheet III—Volume

Obtain a medicine cup, a 50-mL graduated cylinder, and a 50-mL beaker from the instructor. Use Tables 1-26 through 1-29 to answer the questions below.

1. What is the basic unit of volume in the metric system? **liter**

2. How many milliliters in a liter? **1000** How many deciliters in a liter? **10** How many microliters in a liter? **1,000,000 (or 10^6)**

3. Convert the following units:

   550 mL = **0.55** L
   4 dL = **0.4** L
   60 mL = **0.06** L = **0.6** dL

0.1 dL = **0.01** L
6,700 mL = **6.7** L
What decimal rule did you follow to make the conversions? **Move decimal to left when converting smaller units to larger units.**

4. Convert the following units:
   0.3 L = **3.0** dL = **300** mL
   5 L = **5000** mL
   3 dL = **300** mL = **300,000** µL
   0.1 dL = **10** mL
   What decimal rule did you follow to make the conversions? **Move decimal to right when converting larger units to smaller units.**

5. What English unit is closest in volume to the liter? **quart**

6. Convert the following English units:
   3.5 pints = **1663** mL = **1.66** L
   3 quarts = **2850** mL = **2.85** L
   5 fl. oz. = **150** mL = **0.15** L

7. If gasoline is $2.20 per gallon at station A and 60 cents a liter at station B, which has the cheapest gasoline? **Station A is cheapest—gas is 58 cents per L. Gas at station B is 60 cents per L. (One gallon = 4 quarts; one quart = 0.95 liters; therefore, station A gas is 55 cents per quart which is equal to 55 cents × 1.05, or 58 cents per liter.)**

8. Fill the medicine cup to the 1 fl oz mark with water. Then transfer the water to a 50-mL graduated cylinder. How many milliliters of water are in 1 fl oz? **30** Fill the medicine cup again with 1 fl oz of water and transfer to a 50-mL beaker. Which gives the most accurate measurement, the beaker or the graduated cylinder? **graduated cylinder**

LESSON 1-8

Laboratory Math and Reagent Preparation

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Identify volumetric and graduated pipets and explain the correct use of each.**
- **Measure and transfer liquids using pipets and micropipetters.**
- **Discuss the use of pipets in the preparation of reagents.**
- **Describe the differences between pipets and micropipets.**
- **Explain how distilled water and deionized water are made.**
- **List the types of water used in the laboratory and discuss their correct uses.**
- **Prepare percent solutions.**
- **Prepare a reagent using ratio or proportions.**
- **Prepare dilutions of a reagent.**
- **State the formula for preparing a dilute solution from a concentrated solution.**
- **Prepare molar (mol/L) solutions.**
- **Explain the difference between normal and molar solutions.**
- **Perform serial and compound dilutions.**
- **Discuss safety precautions that must be observed when pipetting and when preparing laboratory reagents.**
- **Explain the quality assessment procedures that should be used to ensure high-quality laboratory reagents.**
- **Define the glossary terms.**

GLOSSARY

Beral pipet / a disposable plastic pipet with a built-in bulb on one end that usually can deliver up to 2 mL and can have a graduated stem; also called a transfer pipet

deionized water/ water that has had most of the mineral ions removed

diluent / a liquid added to a solution to make it less concentrated

dilution / a solution made less concentrated by adding a diluent; the act of making a dilute solution; the degree to which a solution is made less concentrated

dilution factor / reciprocal of the dilution

distilled water / the condensate collected from steam after water has been boiled

formula weight (F.W.) / the sum of the atomic weights of the atoms in a compound; molecular weight

gram equivalent weight / the number obtained by dividing the formula weight by the valence

lyophilize(d) / remove water from a frozen solution under vacuum; freeze-dry

micropipet / a pipet that measures or holds 1 milliliter or less

micropipetter / a mechanical pipetter that can measure or deliver very small volumes, usually 1 mL or less

molar solution (M) / solution containing 1 mole of solute per liter of solution

mole / formula weight of a substance expressed in grams

molecular weight (M.W.) / the sum of the atomic weights of the atoms in a molecule or compound; formula weight

normality (N) / the number of gram equivalents of a compound per liter of solution

percent solution / a solution made by adding the units of solute per 100 units of solution

physiological saline / 0.85% (0.15 M) sodium chloride solution

pipet / a slender calibrated tube used for measuring and transferring liquids

proportion / relationship in number or amount of one portion compared to another portion or to the whole

ratio / relationship in number or degree between two things

reagent / substance or solution used in laboratory analyses; substance involved in a chemical reaction

reverse osmosis / purification of water by forcing water under high pressure through a semi-permeable membrane

solute / the substance dissolved in a given solution

solution / a homogeneous mixture of two or more substances

solvent / a dissolving agent, usually a liquid

TC / on pipets, a mark indicating *to contain*

TD / on pipets, a mark indicating *to deliver*

titer / the measure of reactivity or strength of a component as determined by testing serial dilutions; the reciprocal of the highest dilution that gives the desired reaction

valence / the positive or negative charge of a molecule; a number representing the combining power of an atom

TEACHING AIDS AND RESOURCES

- Student Performance Guide
- Laboratory Math and Reagent Preparation Worksheet

- Calculator
- Samples of lyophilized (freeze-dried) control sera or reagents
- Bottles of purchased reagents with molarity listed on label or reagents with formula weights
- Bottles of percent solutions such as 70% ethyl alcohol, 10% bleach solution, or hydrogen peroxide
- Transparency or overhead of Table 1-34
- Transparencies or overheads of Figures 1-47 through 1-55
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
  A. Solution
  B. Solvent
  C. Solute
  D. Dilution
II. Common Laboratory Reagents
  A. Disinfectants
  B. Dilute Acids
  C. Stock Solutions and Working Solutions
  D. Lyophilized Controls
III. Chemical Purity
  A. Reagent or Analytical Grade
  B. Ultrapure
  C. Purified, Practical or Technical Grades Not Used for Reagents
IV. Types of Laboratory Reagent Water
  A. New CLSI Classification
    1. Replaces Types I, II, and III classifications
    2. Reagent water made from distilled, deionized and reverse osmosis water
    3. Types
      a. Clinical Laboratory Reagent Water (CLRW)
      b. Instrument Feed Water
      c. Autoclave and Wash Water
      d. Other
  B. Distilled, Deionized, and Reverse Osmosis Water
    1. Distilled made from steam condensate
    2. Deionized made using resin column

3. Reverse osmosis—semi-permeable membrane
4. All require further treatment to bring them to standard of reagent water

C. Clinical Laboratory Reagent Water (CLRW)
1. Purest grade
2. All bacteria must be removed

D. Instrument feed water
1. Formerly Type II
2. Sterilize for use in microbiology

E. Autoclave and Wash Water
1. Formerly Type III
2. Initial washing of glassware

F. Water Testing Requirements

V. Pipets
A. To Deliver (TD) Pipets
B. To Contain (TC) Pipets
C. Volumetric Pipets
D. Serological or Graduated Pipets
E. Micropipets and Micropipetters

VI. Safety Precautions
A. Consult MSDS and Chemical Labels
B. Use Standard Precautions with Controls

VII. Quality Assessment
A. Use Correct Formulas
B. Perform Calculations Correctly
C. Measure and Pipet Correctly
D. Store Reagents Correctly
E. Observe Expiration Dates

VIII. Preparing Laboratory Solutions
A. Using Proportion to Make Dilutions
B. Preparing a Dilute Solution from a Concentrated Solution
C. Using Ratios to Prepare Dilutions
D. Preparing Percent Solutions
1. Weight/volume (w/v) solutions
2. Volume/volume (v/v) solutions
3. Weight/weight (w/w) solutions—rarely used

E. Preparing Molar Solutions
F. Preparing Normal Solutions

G. Preparing Serial Dilutions
1. Making a two-fold serial dilution
2. Making a compound dilution

IX. Safety Reminders
X. Procedural Reminders
XI. Case Studies
XII. Summary

Case Studies and Answers

Case Study 1

Carl is reconstituting clinical chemistry standards. He needs them in a hurry and there is no CLRW water in the chemistry department. He sees a full container of Autoclave and Wash Water and decides to use it.

1. Is Carl's action acceptable?

   No.

2. What are the possible consequences?

   Standards must be prepared using the highest quality water (CLRW) that contains no impurities. Because standards are used to calibrate procedures and analyzers, use of lower grade water could introduce contaminants into the standard. This could cause inaccurate calibration, which could lead to incorrect analysis results when using that instrument.

Case Study 2

Jody, a medical assistant in a small clinic, ran out of surface disinfectant while cleaning the counters in the clinic laboratory. The label of the disinfectant bottle she was using contained instructions for preparing the surface disinfectant from the concentrated stock solution. The instructions read "Dilute the concentrate 1:50 with water." Jody was using a disinfectant bottle with a 500 mL capacity.

1. Jody should prepare the replacement surface disinfectant by:
   a. Adding 1 mL of concentrate to 50 mL of water
   b. Adding 10 mL of concentrate to 500 mL of water
   c. Adding 10 mL of concentrate to 100 mL of water
   d. Adding 10 mL of concentrate to 490 mL of water

2. Justify your answer.

   The ratio 1:50 means that 1 "part" or volume should be added to a volume to create a total of 50 "parts." Therefore, 1 mL concentrate added to 49 mL of water would equal a 1:50 dilution. To make 500 mL, each part should be multiplied by 10 (i.e., 10 parts concentrate + 490 parts water.) The answer is d.

Case Study 3

A laboratory scientist made a serial dilution of a patient's serum sample to determine the titer of an antibody. She found that the endpoint, the last dilution in which a reaction occurred, was in the tube with the 1/128 serum dilution. What is the titer of the test?

The titer is 128.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Practice the calculations for percent solutions, proportions, ratios, normality and molarity using the laboratory math and reagent preparation worksheet.
3. Find examples of solutions prepared using percent, dilutions, or ratios in a chemistry or similar textbook. Examine labels of reagents and solutions in the laboratory and find different types of solutions (percent, dilution, molar, etc.).
4. If materials are available, practice preparing some of the solutions and serial dilutions from the worksheet as directed by the instructor.
5. Practice pipetting techniques following the procedure in the Student Performance Guide.

Web Activities

1. Find MSDS information about the following chemicals using the Internet: sodium hydroxide, potassium hydroxide, sodium carbonate, ammonium hydroxide, dextrose, and glutamic acid. For each chemical, list the molecular weight and state the precautions that should be used when working with the chemical or solutions containing the chemical.
2. Use the Internet to find tutorials or videos demonstrating pipetting techniques or preparation of solutions.

REVIEW QUESTIONS AND ANSWERS

1. Name two types of glass pipets and explain the differences between them.
   - **a. Volumetric pipets have a wide opening on the suctioning end, an oval bulb in the center, and a tapered tip on the dispensing end (Figure 1-47A). Volumetric pipets are usually labeled TD and are used when critical measurements are required.**
   - **b. Graduated or serological pipets have a uniform diameter and contain graduated markings for delivering several different volumes.**

2. The last drop is forced out of which kind of pipet?

   The last drop is forced out of TD pipets that have a frosted band.

3. Explain how a volumetric pipet is used.

   Volumetric pipets are used by attaching a suctioning aid or pipet filler to the pipet mouth. The liquid is suctioned into the pipet to the marking on the stem above the center bulb. Excess fluid is wiped away from the outside of the pipet stem with tissue, being careful that the tissue does not contact the fluid inside the pipet tip. The pipet is held nearly vertical, and the tip is placed against the inner wall of the container into which the liquid is to be transferred. Suction is released and the liquid is allowed to flow into the container. The tip is left in contact with the container wall a few seconds to completely drain the pipet. A small drop will remain in the pipet tip.

4. List the three basic types of water used to prepare reagent water.

   Distilled, deionized, and reverse osmosis waters.

5. What grade of water is used to make or reconstitute laboratory standards and controls?

   Clinical Laboratory Reagent Water (CLRW)

6. What are the advantages of micropipetters? How are they used?

   Micropipetters provide better accuracy than manual pipets, eliminate the need for pipet-aids or safety bulbs, and use plastic, disposable tips that eliminate the possibility of cross-contamination and allow delivery of small volumes.

   Micropipetters are used by depressing the plunger, placing the tip in a liquid, and then releasing the plunger to draw the liquid into the micropipetter tip. The liquid is dispensed when the plunger is depressed again.

7. Give an example of a percent solution used in the laboratory.

   Examples include 0.85% saline and 10% chlorine bleach.

8. What dilution is created when one part of concentrate is added to nine parts solvent?

   1:10 dilution

9. What formula is used to prepare a dilute solution from a concentrated solution?

   $(C_1)(V_1) = (C_2)(V_2)$

10. How is a 1% (v/v) solution prepared?

    One mL of solute is added to each 99 mL of solvent.

11. How is a 5% (w/v) solution prepared?

    5 g of solute is dissolved in enough solvent to make a final total volume of 100 mL.

12. Explain how to prepare 1 liter of 0.1 M potassium hydroxide (KOH). (Molecular weight 56; valence is 1). What is the normality (N) of the solution?

    To prepare 1 liter of 0.1 M KOH solution, 5.6 g of KOH, a weight equal to the molecular weight (56) times 0.1, is dissolved in water and then brought to a total volume of 1 liter in a volumetric flask. Stated another way, a l M solution of KOH would contain 1 molecular

weight in grams (56 g) in 1 liter of solution; a 0.1 M solution of KOH would contain 1/10 the concentration of the 1 M solution. A 0.1 M solution of KOH is equal to a 0.1 N solution of KOH.

13. List three safety precautions that must be followed when preparing reagents.

    Any three of the following safety precautions are acceptable:

    a. Consult MSDS and chemical labels to identify hazards
    b. Use Standard Precautions when working with biological specimens or controls
    c. Wear appropriate PPE
    d. Use a fume hood when working with chemicals that produce fumes
    e. Use plasticware instead of glass
    f. Use splash shield to protect from splashes

14. In what circumstances must Standard Precautions be used when preparing laboratory reagents?

    Standard Precautions must be used when working with serum, controls, or any biological fluid.

15. Define Beral pipet, deionized water, diluent, dilution, dilution factor, distilled water, formula weight, gram equivalent weight, lyophilize(d), micropipet, micropipetter, molar solution, mole, molecular weight, normality, percent solution, physiological saline, pipet, proportion, ratio, reagent, reverse osmosis, solute, solution, solvent, TC, TD, titer, and valence.

    See Glossary.

WORKSHEET ANSWERS

Answers to Laboratory Math and Reagent Preparation Worksheet

1. A 1% solution of hydrochloric acid (HCl) is required for a procedure. A 5% solution is available. How much of the 5% solution will be required to make 500 mL of a 1% solution?

   100 mL of 5% HCl is required (the 100 mL would be added to 400 mL of diluent to make 500 mL of the 1% solution).

2. A procedure calls for acetic acid and water, with the proportions being 1 part acetic acid to 3 parts water. One hundred milliliters is needed. How much acetic acid and water are required? **25 mL acetic acid + 75 mL water** What dilution is made? **1:4 dilution**

3. One liter (L) of 70% alcohol is needed. How much 90% alcohol is required to make the 70% solution? **778 mL of 90% alcohol is required (this would be added to 222 mL of diluent to make 1 L of the 70% alcohol).**

4. How would 1 liter (L) of a 10% solution of chlorine bleach be prepared?
   100 mL of bleach would be added to 900 mL of diluent.

5. How could 250 mL of a 4.0 N solution of hydrochloric acid (HCl) be prepared from a 10.0 M solution of HCl? **100 mL of the 10.0 M solution must be added to 150 mL of diluent.**

6. Give the instructions for preparing a two-fold serial dilution of serum from 0.5 mL serum and using 0.5 mL saline in each of five numbered tubes.
   Each dilution is 2 times as dilute as the previous dilution: 5 tubes are set up, each containing 0.5 mL of saline. A serum sample is diluted 1:2 by adding 0.5 mL of serum to tube 1 (containing 0.5 mL saline) and mixing. Then 0.5 mL from tube 1 is transferred to tube 2 and mixed with the 0.5 mL of diluent in tube 2. This creates a two-fold dilution in tube 2 (2 times more dilute than tube 1). Tube 2 now contains a 1:4 dilution of the original serum. The dilution series is continued by sequentially transferring 0.5 mL to the next tube in the series until tube 5 is reached. After the 0.5 mL transferred from tube 4 has been mixed with the diluent in tube 5, 0.5 mL of the mixture in tube 5 is discarded. This leaves all tubes in the series containing 0.5 mL each, and provides serum dilutions ranging from 1:2 in tube 1 to 1:32 in tube 5.

7. A 1-to-25 dilution of blood is required for a procedure. How can it be prepared? **One part blood must be added to 24 parts diluent (such as 0.l mL blood + 2.4 mL diluent).**

8. How could a 1:10 dilution of serum be prepared**? One part serum is added to 9 parts diluent (such as 1 mL serum + 9 mL diluent).**

9. What is the dilution when 0.5 mL is diluted to a total of 100 mL? **1:200 dilution**

10. Give instructions for preparing 500 mL of a 0.15 M solution of NaCl (FW 58). **4.35 g of NaCl is weighed out and dissolved in approximately 400 to 450 mL of diluent/water in a 500 mL volumetric flask. When the NaCl is dissolved, the flask is filled to the 500-mL line with the diluent.**

LESSON 1-9

Quality Assessment

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Explain the importance of quality assessment programs in the laboratory.**
- **Explain the importance of quality assessment programs in point-of-care testing.**
- **Discuss the use of standards and controls.**
- **Explain the differences between external controls and equivalent controls.**
- **Discuss the role of CLIA '88 in mandating laboratory quality assessment programs.**
- **Explain the difference between accuracy and precision.**
- **Discuss preanalytical, analytical and postanalytical factors.**
- **Explain how preanalytical, analytical, and postanalytical factors can affect the reliability of test results.**
- **Determine the mean value for a set of test results.**
- **Calculate the standard deviation for an analytical method.**
- **Describe how a Levey-Jennings chart is used.**
- **Detect a result that is out of control.**
- **Explain how to detect the development of a trend in a method.**
- **Explain how to calculate a coefficient of variation and discuss its usefulness.**
- **Describe safety procedures that must be followed when performing quality assessment procedures.**
- **Define the glossary terms.**

GLOSSARY

accuracy / the closeness of agreement of a measured value with the true value

average / the sum of a set of values divided by the number of values in the set; the mean

blind sample / an assayed sample that is provided as an unknown to laboratories participating in proficiency testing programs

calibration / the process of checking, standardizing, or adjusting a method or instrument so that it yields accurate results

coefficient of variation (CV) / a calculated value that compares the relative variability between different sets of data

controls / commercially available assayed solutions that are chemically and physically similar to the unknown and are tested in the same manner as the unknown to monitor the precision of a test method

Gaussian curve / a graph plotting the distribution of values around the mean; normal frequency curve

Levey-Jennings chart / a quality control chart used to record daily quality control values

mean / the sum of a set of values divided by the number of values in the set; the average

population / the entire group of items or individuals from which the samples under consideration are presumed to have come

precision / reproducibility of results; the closeness of obtained values to each other

quality assessment (QA) / in the laboratory, a program that monitors the total testing process with the aim of providing the highest quality patient care; formerly called quality assurance

quality assurance (QA) / see quality assessment

quality control (QC) / a system that verifies the reliability of analytical test results through the use of standards, controls, and statistical analysis

quality systems (QS) / in an institution, a comprehensive program in which all areas of operation are monitored to ensure quality with the aim of providing the highest quality patient care

random error / error that is inconsistent and whose source cannot be definitely identified

sample / in statistics, a subgroup of a population

shift / an abrupt change from the established mean indicated by the occurrence of all control values on one side of the mean

standard / a chemical solution of a known concentration that can be used as a reference or calibration substance

standard deviation (s) / a measure of the spread of a population of values around the mean

statistics / the branch of mathematics that deals with the collection, classification, analysis, and interpretation of numerical data; a collection of quantitative data

systematic error / error that is introduced into a test system and is not a random occurrence

trend / an indication of error in the analysis, indicated by a progressive drift of control values in one direction for at least 5 consecutive runs

variance (s^2) / the square of the standard deviation; mean square deviation

Westgard's rules / a set of rules used to determine when a method is out of control

TEACHING AIDS AND RESOURCES

- Quality Assessment Worksheet
- Examples of quality control charts, controls, and calibrators
- Transparencies or overheads of Figures 1-56 through 1-60
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
  A. Changing Terminology
    1. Quality assessment (QA)
    2. Quality systems
  B. QA Programs Mandated by CLIA '88
  C. Goal: To Provide Quality Patient Care by Ensuring Reliable Test Results
II. Components of a Quality Systems Program
  A. Personnel Qualifications and Training
  B. Quality Assessment
    1. Preanalytical factors
      a. Patient identification—two patient identifiers
      b. Specimen collection—following specimen rejection criteria
    2. Postanalytical factors
      a. Reporting results
      b. Charting results
      c. Use of computers and bar codes reduces many postanalytical errors
    3. Analytical Factors Affecting Laboratory Test Results
      a. Laboratory preparation of samples
      b. Instrument maintenance and calibration
      c. Use of standards and controls
      d. Test procedure and operator technique
      e. Interfering substances or conditions
      f. Statistical analysis of control results
  C. Proficiency Testing
    1. Blind samples
    2. Compare results to other laboratories' results
III. Quality Control—A Component of Quality Assessment
  A. Safety Precautions
    1. Standard Precautions must be used with controls and instruments
    2. Most controls are made from human serum
  B. External Controls
    1. Have been assayed so concentrations of analytes are known
    2. Analyze with patient samples
    3. Use at least two levels of controls
    4. Plot results on Levey-Jennings charts
  C. Equivalent or Internal Controls

D. Standards and Calibration
E. Accuracy and Precision
1. Accuracy is degree of closeness to true value
2. Precision is reproducibility of results
F. Random and Systematic Errors
1. Random error—source cannot be identified
2. Systematic error—variation caused by a problem in reagents, instrument or technique

IV. Quality Programs in Point-of-Care Testing
V. Basic Statistics
A. Calculating the Mean, Variance, and Standard Deviation
1. Calculating the mean
2. Calculating the variance
3. Calculating the standard deviation
B. Using the Standard Deviation in the Laboratory
1. Normal distribution curve
2. 95% of values should fall within ±2 standard deviations—control limits or confidence limits
3. Reference ranges
4. Reportable ranges—linear range

VI. Quality Control Charts
A. Levey-Jennings Charts
B. Trend
C. Shift
D. Westgard's Rules

VII. Coefficient of Variation
VIII. Safety Reminders
IX. Procedural Reminders
X. Case Study
XI. Critical Thinking Problems
XII. Summary

Case Study and Answer

Karen was working the day shift in the hematology laboratory. The laboratory's protocol called for three levels of blood cell controls to be run at the following times: (1) at the beginning of the shift, (2) within each run of patient samples during the day, and (3) any time reagents were changed. The mean for the low (abnormal) control for the red blood cell count was given as 2.00×10^{12}/L, the standard deviation was 0.15, and the confidence limit (acceptable control range) was 2.00×10^{12}/L ± 2 *s* (or ± 0.3).

The first morning low control result was 2.10 ($\times 10^{12}$/L). In five subsequent runs, the low control results were 2.16, 2.19, 2.20, 2.22, and 2.25.

1. These values represent:
   a. a shift
   b. a trend
   c. neither shift nor trend

2. Should Karen be concerned about these values? Explain.

   Yes, Karen should be concerned. Controls in the six consecutive runs are increasing all in the same direction, indicating a trend. Something can be wrong with the procedure, a reagent, the instrument, the technique, or the control serum.

3. Does Karen need to take any action?

   Yes. She must find the source of error in the procedure by testing a new lot of control, recalibrating the instrument, checking technique, etc. Patient samples should not be tested until the problem is resolved.

Critical Thinking Problems and Answers

Critical Thinking Problem 1

Is it possible for an analytical procedure to be "out-of-control" if all of the control values fall within the 95% confidence range? Explain your answer.

Yes. A shift occurs when several consecutive control values lie on one side of the mean but are within 95% limits. Or a trend can occur when several consecutive values trend steadily in one direction but remain within the 95% limits.

Critical Thinking Problem 2

What are the 95% confidence limits for a control mean of 140 mg/dL and a standard deviation (s) of 2.5 mg/dL?

Confidence limits at the 95% level are defined by the mean ± 2s (± 2 SD). In this case the lower limit (– 2s) would be 135 mg/dL and the upper limit (+ 2s) would be 145 mg/dL.

STUDENT ACTIVITIES (with answers to activities 2 and 3)

1. Complete the written examination for this lesson.
2. Calculate the standard deviation using this group of 10 numbers: 10, 9, 15, 10, 12, 11, 10, 12, 14, and 12.

   The mean of the 10 values is 11.5. The sum of the deviations squared of the 10 values is 28.5. The variance (sum of squares divided by n-1) = 3.17. The standard deviation (square root of variance) = 1.8

3. Using the results of the calculations from activity 2, construct a Levey-Jennings quality control chart showing the mean, +1*s*, +2*s*, +3*s*, –1*s*, –2*s*, and –3*s*.

   The mean bar should be marked at 11.5. The ± 1*s* bars should be labeled 9.7 and 13.3; the ± 2*s* bars should be labeled 7.9 and 15.1; the ± 3*s* bars should be labeled 6.1 and 16.9.
4. Complete the quality assessment worksheet at the end of this lesson.

Web Activities

1. Use the Internet to find information about quality control. One source is www.westgard.com.
2. Search terms such as Levey-Jennings chart, trend, and shift using the Internet. From the information in your text and on the web, write a brief set of rules for determining when a control value for an instrument available in your laboratory is "out of control." Give a list of remedies or checks to perform to identify the problem.

REVIEW QUESTIONS AND ANSWERS

1. What is the importance of quality assessment and quality control in the laboratory?

   A QC program ensures quality in the analytical phase of the test, such as correct operation of instruments and accurate patient results. A QA program ensures the quality of the test, from the ordering of the test through specimen collection to the posting of the result on the patient chart.

2. Explain the use of standards and controls in the laboratory's daily operation.

   Standards are used to calibrate a method at required intervals, such as daily or once per shift; controls are used to verify assays by inserting normal and abnormal levels in each run of patient samples.

3. How and when are equivalent controls used?

   For certain test systems, regulations allow laboratories to reduce the number or frequency of using external controls if an instrument can be shown to have internal monitoring systems that are reliable. Advances in instrument technologies have led to the manufacture of test systems that include internal monitoring systems and do not require operator calibration or standardization at every use. These are called internal, electronic, or procedural controls. Use of these internal check systems is called *equivalent QC*. The type of monitoring performed by the instrument differs according to the instrument—the color detection system might be monitored, or the electronics can go through a self-check. To be permitted to use equivalent QC, the laboratory must demonstrate to CMS that the test system is reliable. The use of equivalent QC is most common for small POC instruments.

4. Explain how results can be precise but not accurate.

   A test method can yield control results that are very close to each other (precise, reproducible) even though the results are not necessarily accurate (close to the true value). This can happen when technique is consistent but there is an instrument malfunction or a reagent has deteriorated. An example would be if a pipetter needed recalibrating and was not delivering the correct volume.

5. How is the mean of a set of values determined?

   All of the sample results are added together. The sum is then divided by the number of results in the set, giving the mean (average) of the set.

6. Describe how to calculate the standard deviation.

   To calculate a standard deviation:

   a. Calculate the variance of the sample

   $$\text{Variance } (s^2) = \frac{\Sigma(\overline{X} - X)^2}{n - 1}$$

   b. Then calculate the standard deviation (the square root of the variance):

   The standard deviation (*s*) is the square root of the variance (s^2): $s = \sqrt{s^2}$

7. How are Levey-Jennings charts used in the laboratory?

   Levey-Jennings charts display the confidence limits of a test method determined by establishing the mean and standard deviation of a control serum. Daily control values are charted on the Levey-Jennings charts. The charts are used to evaluate a method's accuracy and precision and as a way to detect problems in a test system.

8. Explain the differences in confidence limits, reportable range, and reference range.

   The confidence limits define the acceptable upper and lower values of a control.
   The reference range defines the upper and lower values of test results expected in a normal population.
   The reportable range defines the upper and lower limits of reliability and accuracy of a test method.

9. Explain how an out-of-control result can be detected.

   Controls plotted daily (or every time they are run) on a Levey-Jennings chart will show when a control value falls outside the ±2s limit. A shift or trend can also be detected from the chart.

10. Explain how to detect a trend in a procedure.

    A trend occurs when several control results consecutively increase or decrease in one direction.

11. How can the coefficient of variation be used to compare methods of analysis?

    The coefficient of variation measures the relative precision between two sets of values, such as from two different methods of analysis of the same constituent. The lower the coefficient of variation, the more precise the method.

12. What is the CV when the mean = 290 g/dL and one (1) *s* (SD) = 12

    CV = *s* ÷ mean × 100
    CV = 12 ÷ 290 × 100
    CV = 4%

13. What is the purpose of Westgard's rules?

    Westgard's rules are guidelines used to help decide whether or not a method is out of control. The rules give specific limits about how much variation is acceptable in control values before patient results are rejected.

14. What are preanalytical and postanalytical factors? Give an example of each.

    Preanalytical refers to events before analysis begins; examples are patient misidentification or drawing blood into the incorrect anticoagulant. Postanalytical refers to events after the analysis is completed; examples are incorrect calculations, using incorrect units, or charting results to the wrong patient chart.

15. What are the differences in systematic error and random error?

    Random error is error for which the cause cannot definitely be identified, such as temporary variations in voltage, air bubbles in a reagent line, or differences in technique among workers. Systematic error is a variation that makes results consistently higher or lower than the actual value as a result of factors such as out-of-date reagents or mechanical problems in an instrument.

16. Define accuracy, average, blind sample, calibration, coefficient of variation, controls, Gaussian curve, Levey-Jennings chart, mean, population, precision, quality assessment, quality control, quality systems, random error, sample, shift, standard, standard deviation, statistics, systematic error, trend, variance, and Westgard's rules.

    See Glossary

WORKSHEET ANSWERS

Answers to Quality Assessment Worksheet

A. Calculate the Mean and the Standard Deviation

   1. Use this worksheet to calculate the mean and the standard deviation of a set of red blood cell (RBC) counts performed using a RBC control: 3.2, 3.3, 3.5, 3.2, 3.0, 3.4, 3.8, 3.5, 3.4, and 3.3.

   2. Write the formula for finding the mean $\overline{X} = \frac{\Sigma X}{n}$

3. Substitute the values (from A-1) into the formula. The mean of the red cell counts is **3.36** .

4. Following the example in Figure 1-58, calculate the deviation squared for each of the RBC values (from A-1).

5. Calculate the sum of the deviation squared of the 10 values: **0.424**

6. Write the formula for variance: $\text{Variance } (s^2) = \dfrac{\Sigma(\bar{X} - X)^2}{n - 1}$

7. Determine the variance using the answer in step 5. **0.424 ÷ 9 = 0.047**

8. Write the formula for determining the standard deviation.
   The standard deviation is the square root of the variance (s^2): $s = \sqrt{s^2}$

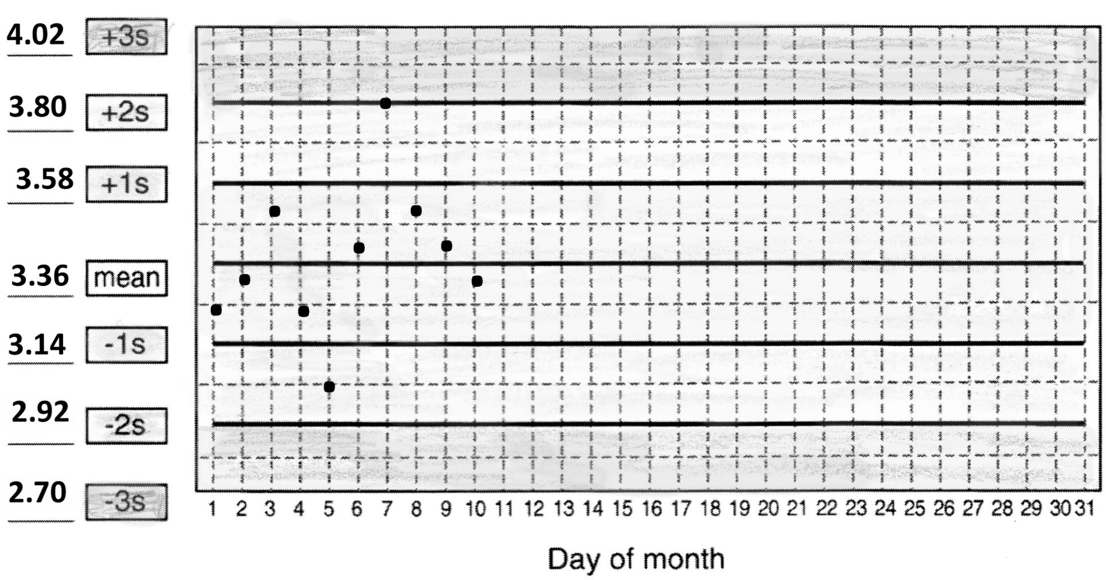
9. Substitute the value from step 7 into the formula: $s = \sqrt{0.047} =$ **0.22**

10. What is the standard deviation (s)? **± 0.22** What is ± 2 s? **± 0.44** What is ± 3 s? **± 0.66**

B. Construct a Levey-Jennings Chart

1. Use the chart below and the mean and standard deviation (s) from part A to construct a Levey-Jennings chart. Indicate the mean value, ±1s, ±2s, and ±3s (from part A) on the appropriate lines.

2. Plot the following control values obtained for days 1 to 10 on the chart: Day 1 = 3.2, Day 2 = 3.3, Day 3 = 3.5, Day 4 = 3.2, Day 5 = 3.0, Day 6 = 3.4, Day 7 = 3.8, Day 8 = 3.5, Day 9 = 3.4, and Day 10 = 3.3.



LESSON 1-10

The Microscope

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Locate and name the parts of a bright-field microscope.**
- **Explain the function of each part of the bright-field microscope.**
- **Explain the correct use of the coarse and fine adjustments.**
- **Adjust the condenser and iris diaphragm.**
- **Use Köhler illumination to align the microscope light path.**
- **Explain how to perform dioptic and interpupillary distance adjustments.**
- **Use the low-power objective to view a specimen.**
- **Use the high-power objective to view a specimen.**
- **Use the oil-immersion objective to view a specimen.**
- **Explain when Standard Precautions and personal protective equipment (PPE) should be used while using the microscope.**
- **Explain how light microscopes differ from electron microscopes.**
- **Discuss the differences in the images produced by the two types of electron microscopes.**
- **Explain why electron microscopes are not used in the typical clinical laboratory.**
- **Discuss situations requiring use of the epi-fluorescence microscope.**
- **Compare the differences in designs and uses of microscopes equipped with dark field, phase contrast, polarizing, and differential interference contrast (DIC) optics.**
- **Explain how the use, care, and storage of the microscope can affect the quality of results.**
- **Define the glossary terms.**

GLOSSARY

binocular / having two oculars or eyepieces

birefringence / the characteristic of double refraction; the characteristic of being able to split a beam of polarized light into two light beams

coarse adjustment / control that adjusts position of microscope objectives and is used to initially bring objects into focus

condenser / apparatus located below the microscope stage that directs light into the objective

confocal laser scanning microscope / a microscope using a laser as the light source and producing images of very high resolution

differential interference contrast (DIC) microscope / a microscope equipped with special Nomarski optics that enhance contrast in unstained, transparent specimens, producing a three-dimensional image

electron microscope / a microscope using an electron beam to create images from a specimen and that is capable of much greater magnification and resolving power than a light microscope

eyepiece / ocular

field diaphragm / adjustable aperture attached to microscope base

fine adjustment / control that adjusts position of microscope objectives and is used to sharpen focus

fluor / a substance that absorbs short wavelength (exciting) light and emits longer wavelength (emitting) light

iris diaphragm / device that regulates the amount of light striking the specimen being viewed through the microscope

Köhler illumination / alignment of illuminating light for microscopy; double diaphragm illumination

lens / a curved transparent material that spreads or focuses light

lens paper / a special nonabrasive material used to clean optical lenses

magnification / in microscopy, the size of the image produced compared to the actual size of the object being viewed

micrometer / a ruled device for measuring small objects

microscope arm / the portion of the microscope that connects the lenses to the base

microscope base / the portion of the microscope that rests on the table and supports the microscope

monocular / having one ocular or eyepiece

nosepiece / revolving unit to which microscope objectives are attached

numerical aperture (N.A.) / a mathematical expression of the resolving power of a lens

objective / magnifying lens closest to the object being viewed with a microscope

ocular / eyepiece of the microscope that contains a magnifying lens

ocular micrometer / a clear glass disk that fits in the microscope eyepiece, is etched with a precise scale, and is used to measure objects viewed with the microscope; also called ocular reticle

parfocal / having objectives that can be interchanged without varying the instrument's focus

resolving power / the ability of a microscope to produce separate images of two closely spaced objects

reticle / a glass circle etched with a pattern of calibrated grids, lines, or circles and inserted into a microscope eyepiece to allow the etched pattern to be imposed on the field of view

stage / platform that holds the object to be viewed microscopically

stage micrometer / a transparent glass slide marked with a precise scale in micrometers and used to calibrate ocular micrometers by aligning the ocular scale with the stage scale

working distance / distance between the microscope objective and the microscope slide when the object is in sharp focus

TEACHING AIDS AND RESOURCES

- Several types of microscopes: bright-field, phase-contrast, epi-fluorescence, etc.
- Guest speaker who is experienced in several types of microscopy
- Student Performance Guide
- Transparencies or overheads of Figures 1-61 through 1-70
- Transparency or overhead of Table 1-35
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction

II. Types of Microscopes
- A. Light Microscopes –The Bright-Field Microscope
- B. Modifications of the Light Microscope
  1. Phase-contrast microscope
  2. Dark-field microscope
  3. Polarizing and differential interference contrast (DIC) microscopes
  4. Epi-fluorescence microscope
  5. Confocal laser scanning microscopes

III. Electron Microscopes
- A. Transmission Electron Microscope (TEM)
- B. Scanning Electron Microscope (SEM)

IV. Parts of the Microscope
- A. Oculars
  1. Binocular
  2. Usually 10× magnification
- B. Objective Lenses
  1. Magnification
  2. Low power: 10× or 20×
  3. High power: 40×, 43×, or 45×
  4. Oil immersion: 95×, 97×, or 100×
  5. Determine magnification by multiplying power of ocular by power of objective
  6. Numerical aperture—resolving power
  7. Plan and achromatic lenses
- C. Light Source, Condenser, and Diaphragm
  1. Light illuminates object
  2. Condenser focuses light into objective

        3. Diaphragm regulates amount of light
        4. Field diaphragm used to align light in Köhler illumination procedure
    D. Coarse and Fine Focus Adjustments
        1. Focusing
        2. Working distance
    E. Stage
V. How the Image Is Produced
VI. Using the Bright-Field Microscope
    A. Microscope Safety
    B. Quality Assessment
        1. Care and cleaning of lenses
        2. Immersion oil
    C. Focusing with the Low-Power Objective
    D. Adjusting the Oculars
        1. Interpupillary distance
        2. Dioptic adjustment
    E. Alignment of illumination
        1. Field diaphragm
        2. Köhler illumination
    F. Using the High-Power Objective
        1. Parfocality
        2. Use only fine adjustment because of small working distance
    G. Using the Oil-Immersion Objective
        1. Use only immersion oil
        2. Never use coarse adjustment
        3. Maximum light needed
        4. Clean all oil from objective, stage, and condenser after use
    H. Transporting and Storing the Microscope
        1. Avoid jarring
        2. Store in a dust-free place
VII. Safety Reminders
VIII. Procedural Reminders
IX. Critical Thinking Problems
X. Summary

Critical Thinking Problems and Answers

Critical Thinking Problem 1

Cheryl was performing urine microscopic examinations when the light went out on her microscope. She removed the microscope slide, turned the microscope over, and opened up the light compartment. She removed the light bulb with difficulty, saw that the filament was broken, and replaced the bulb. As soon as the bulb was fitted into the holder, the microscope light came on. Comment on Cheryl's microscope repair technique.

Before attempting repair of the microscope (or any electrical instrument), Cheryl should have disconnected the instrument from the power source. Not only is the potential for electrical shock present when the instrument is still plugged in, but the filament of the new bulb could have been ruined by replacing it while the microscope was still turned on. Cheryl needs a refresher course in electrical safety.

Critical Thinking Problem 2

Roberta needed to use a microscope to examine a blood smear. She cleaned the oculars and the 10×, 40×, and 100× oil-immersion objectives with lens paper, using a clean section of lens paper for each objective. The lens paper used to clean the oil-immersion objective revealed oil on the objective. Roberta mentioned this to Jack, a technician who worked regularly with that microscope, and he replied that it was only necessary to remove oil from the objective once a shift because the objective might be used as many as 10 to 12 times during the day. Is Jack correct? Explain your answer.

Jack is incorrect. The oil-immersion objective should be cleaned before and after every use. Leaving oil on the lens can loosen the cement that holds the lens in place.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Obtain a microscope and locate and identify the following parts: oculars, condenser, condenser adjustment knob, condenser centering knobs, field diaphragm, iris diaphragm, light, light intensity control, nosepiece, arm, base, stage, stage controls, coarse and fine adjustment knobs, and diopter adjustment ring. Note which (if any) parts are not found on your microscope.
3. Obtain a stained slide from your instructor. View the specimen with the low-power, high-power, and oil-immersion objectives. Draw the structure(s) you see when using each objective. Observe the specimen when the condenser is raised and when it is lowered, and with the iris diaphragm wide open and closed. Discuss the differences in the image you see in each of these conditions. Which conditions or microscope adjustments reveal the most information about your specimen?
4. If you live near a university or a large research laboratory, find out if they have an electron microscope or a confocal laser scanning microscope. If so, try to arrange a visit to the facility to tour the microscope laboratory.
5. Practice using a microscope following the procedure outlined in the Student Performance Guide.

Web Activities

1. Find images taken with transmission and scanning electron microscopes using the Internet.
2. Use the Internet to find information about various types of light microscopes. Try to find examples of images obtained with phase-contrast, polarizing, DIC, epi-fluorescence, and confocal microscopes. Compare these images to the way stained images appear with the bright-field microscope in your laboratory.
3. Search the Internet for tutorials or videos describing the correct use and care of the bright-field microscope.

REVIEW QUESTIONS AND ANSWERS

1. Explain the functions of the iris diaphragm and condenser.
   The iris diaphragm regulates the amount of light reaching the objective lens; the condenser focuses or directs light into the objective.

2. Name the three objectives commonly used on a clinical microscope.
   a. **Low power (10× or 20×)**
   b. **High power (40×, 43×, or 45×)**
   c. **Oil immersion (97× or 100×)**

3. Explain the uses of the coarse and fine adjustments.
   The coarse adjustment is used with the low-power objective only, to bring objects into initial focus; the fine adjustment is used with all objectives to give a sharper image.

4. Describe the proper method of cleaning a microscope after use.
   Lenses should be cleaned with lens paper and lens cleaner, being careful to remove all oil residue.

5. How should a microscope be stored when not in use?
   Microscopes should be stored under a dust cover with low-power objective in position, nosepiece lowered, and stage centered.

6. When is the oil-immersion objective used?
   The oil-immersion objective is used for observing stained cells, tissues, and microorganisms and after immersion oil has been applied to the slide.

7. When is immersion oil used on a slide? What is the function of the immersion oil?
   Immersion oil is used only with the oil-immersion objective. The function of immersion oil is to improve resolution by filling in the space between the objective and the object.

8. Explain how to adjust the interpupillary distance on a binocular microscope.

   The adjustment is made similar to adjusting binoculars; the distance between the oculars is increased or decreased so that it is the same as the distance between the viewer's pupils and one image is seen.

9. What is the purpose of making a dioptic adjustment? Explain how the adjustment is made.

   The dioptic adjustment is made to accommodate differences in vision between the left and right eye. The object is brought into sharp focus with the coarse and fine adjustments while looking through the right ocular with the right eye. The right eye is then closed, and the left ocular's knurled collar is used to bring the object into sharp focus while viewing the object through the left ocular using the left eye.

10. How is total magnification calculated in the compound microscope?

    The degree of magnification is determined by multiplying the magnification on the ocular times the magnification on the objective being used. See Table 1-35.

11. How do electron microscopes differ from light microscopes?

    Electron microscopes use an electron beam to produce an image; light microscopes use visible light.

12. When must Standard Precautions be used with the microscope?

    Standard Precautions must be used if an unfixed or fluid biological specimen (such as urine sediment) is to be examined.

13. What is Köhler illumination? How is it performed?

    Köhler illumination is a procedure for aligning the light so that it strikes the center of the objective. It is performed by centering the field diaphragm.

14. Why is a condenser not used in epi-fluorescence microscopes?

    A condenser is not needed for epi-fluorescence because the light is coming from above the object.

15. Why are electron microscopes not in routine use in clinical laboratories?

    Electron microscopes require much expertise to operate; sample preparation is lengthy. Most clinical work requires much quicker results.

16. Explain how the image formed in the TEM differs from that formed in the SEM.

    For the TEM the electron beam is passed through the object being examined; for SEM the beam scans over a specimen surface that has been coated with a metal.

17. Explain the difference between objective lenses that are parfocal and those that are parcentric.

    Parfocal lenses allow the subject to remain in focus as the objectives are changed from low to high to oil immersion. Parcentric means an object in the center of the field of view using one objective will be centered when another objective is used.

18. Define binocular, birefringence, coarse adjustment, condenser, confocal laser scanning microscope, differential interference contrast microscope, electron microscope, eyepiece, field diaphragm, fine adjustment, fluor, iris diaphragm, Köhler illumination, lens, lens paper, magnification, micrometer, microscope arm, microscope base, monocular, nosepiece, numerical aperture, objective, ocular, ocular micrometer, parfocal, resolving power, reticle, stage, stage micrometer, and working distance.

    See Glossary

LESSON 1-11

Capillary Puncture

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Explain why a capillary puncture might be performed.**
- **Identify suitable sites for capillary punctures.**
- **Discuss capillary puncture in infants, children, and adults.**
- **Choose and prepare a site for capillary puncture.**
- **Perform a capillary puncture.**
- **Collect a blood specimen from a capillary puncture.**
- **Discuss how collection procedure affects capillary specimen quality.**
- **List the safety precautions to be observed when performing a capillary puncture.**
- **Define the glossary terms.**

GLOSSARY

capillary / a minute blood vessel that connects the smallest arteries to the smallest veins and serves as an oxygen exchange vessel

capillary action / the action by which a fluid enters a tube because of the attraction between the fluid and the tube

capillary tube / a slender glass or plastic tube used for laboratory procedures

heparin / an anticoagulant used therapeutically to prevent thrombosis; also used as an anticoagulant in certain laboratory procedures

lancet / a sterile, sharp-pointed blade used to perform a capillary puncture

lateral / toward the side

TEACHING AIDS AND RESOURCES

- Student Performance Guide
- Various types of lancets, capillary collection containers, and capillary tubes (plastic, Mylar-coated, and self-sealing)
- Examples of biohazard containers and sharps containers
- Transparencies or overheads of Figures 1-71 through 1-78
- Videos demonstrating capillary puncture techniques
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction
    A. Capillary or Dermal Puncture
    B. Frequent Use at Point-of-Care
II. The Capillary Puncture
    A. Capillary Puncture Sites
        1. Fingertip—adults and children
        2. Lateral portion of heel pad—newborns, infants
    B. Capillary Puncture Equipment
        1. Lancets
            a. Sterile, single-use, disposable
            b. Different lengths of blades
        2. Capillary collection containers
            a. Capillary tubes
                i. Used for microhematocrits
                ii. Plain or heparinized
                iii. Precalibrated
                iv. Mylar-coated, plastic, flexible, self-sealing
            b. Capillary collection vials
                i. Use when serum or plasma is needed
                ii. Available with or without anticoagulant
    C. Procedures That Use Capillary Blood
        1. Manual cell counts
        2. Microhematocrit
        3. Blood smear
        4. Point-of-care analyzers

III. Performing Capillary Blood Collection
  A. Safety Precautions
    1. Use Standard Precautions
    2. Wear gloves and face protection
    3. Use safety capillary tubes
  B. Quality Assessment
    1. Proper technique important
    2. Perform quickly before blood can clot
  C. Selecting the Puncture Site
    1. Choose site with good circulation
    2. Avoid recent puncture sites
  D. Preparing the Puncture Site
    1. Cleanse with alcohol
    2. Allow to dry before performing puncture
  E. Performing the Puncture
    1. Use safety lancet
    2. Use longer blade for calloused fingertips
  F. Collecting the Blood Sample
    1. Wipe away first drop of blood
    2. Allow well-rounded drop to form before collecting
    3. Hold vial or tube at slight downward angle
    4. Avoid squeezing finger
  G. Caring for the Puncture Site
    1. Sterile gauze or cotton ball
    2. Apply pressure until bleeding stops
IV. Safety Reminders
V. Procedural Reminders
VI. Case Studies
VII. Summary

Case Studies and Answers

Case Study 1

Mr. Stewart, a construction worker, came into the clinic for a blood cholesterol test. When Robert, the laboratory technician, performed a capillary puncture on him, he was unable to obtain the amount of blood needed for the procedure ordered. Explain the steps Robert can take to obtain adequate capillary blood flow before he repeats the capillary puncture.

Robert should examine the patient's fingertips and try to find one that does not have thickened skin, perhaps the little finger. He can gently massage the patient's hand and/or

place the hand in warm water for a few minutes. He can also use a lancet with a slightly longer blade.

Case Study 2

In the multi-physician office a young couple is told to take their 4-month-old infant to the laboratory to have blood taken. The requested test requires just two drops of blood. Jackie, the laboratory technician, is not sure if she should collect the blood from the baby's heel or finger.

1. Which site should she use?

   She should use the baby's heel.

2. Explain your answer.

   Blood should not be collected by fingerstick until an infant is about 1 year old, about the age they start walking.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Practice performing a capillary puncture as outlined on the Student Performance Guide.
3. Find out how capillary punctures are performed on newborns in a local hospital nursery.

Web Activities

1. Search online laboratory supply catalogs to find examples of plastic or Mylar-coated capillary tubes.
2. Search the Internet for reliable sources offering tutorials or videos that demonstrate capillary or dermal puncture techniques.

REVIEW QUESTIONS AND ANSWERS

1. What is a capillary puncture?

   A capillary puncture is a puncture of skin and superficial capillaries to obtain a small quantity of blood.

2. Why are capillary punctures performed?

   A capillary puncture is performed when only a small amount of blood is required, when obtaining blood from infants, and when veins are not in good condition.

3. What are the usual puncture sites for adults and for infants?

   The usual puncture site in adults is the fingertip; for newborns and infants the lateral portion of the heel pad is used. Once an infant begins to walk (about the age of 1 year) blood should be collected from a fingerstick.

4. How is a capillary puncture site prepared?

   The site should be checked to see if the skin feels warm, which indicates good circulation. The skin should be cleansed with an alcohol swab and allowed to dry before puncture is performed.

5. What is the procedure if circulation seems poor at the selected site?

   Cold hands should be warmed by placing them in warm water or gently massaging them.

6. Why is the first drop of blood wiped away?

   The first drop of blood contains tissue fluid.

7. List the safety precautions that must be observed when performing a capillary puncture.

   a. Observe Standard Precautions.

   b. Wear gloves and other appropriate PPE, such as protective eye or facewear.

   c. Use plastic, flexible, or Mylar-coated self-sealing capillary tubes.

   d. Discard used sharps immediately into sharps container.

   e. Discard all contaminated gauze or cotton balls into a biohazard container.

8. When is a capillary tube with a blue band used?

   Blue-banded capillary tubes are used to hold venous blood that has an anticoagulant already added.

9. When is a capillary tube with a red band used?

   Red-banded tubes are heparinized and are used to prevent clotting when collecting blood directly from the fingerstick.

10. Why must the blood from capillary puncture be used quickly?

    Capillary blood will clot quickly.

11. What is the advantage of using plastic capillary tubes?

    Plastic capillary tubes minimize risk of injury or exposure to blood caused by tube breakage.

12. List three important aspects of quality assessment in capillary puncture.

    Any three are acceptable:

    a. **Personnel must be adequately trained in correct collection techniques.**
    b. **The capillary puncture procedure should be completed quickly so that blood will not clot during the collection process.**
    c. **The puncture site must not be squeezed excessively.**
    d. **The first drop of blood must be wiped away.**

13. Define capillary, capillary action, capillary tube, heparin, lancet, and lateral.

    See Glossary.

LESSON 1-12

Routine Venipuncture

LESSON OBJECTIVES

After studying this lesson, the student will:

- **Explain why venipuncture is performed.**
- **Describe the venipuncture procedure.**
- **Discuss three methods for performing venipuncture.**
- **Select the equipment necessary to perform a venipuncture.**
- **Apply a tourniquet.**
- **Select a proper venipuncture site.**
- **Perform a venipuncture.**
- **List the safety precautions to be observed when performing a venipuncture and give the rationales.**
- **Discuss factors that can affect the quality of a blood specimen obtained by venipuncture.**
- **Name three common anticoagulants in blood collecting tubes and state why they are used.**
- **Explain the reasons why the order of draw is important.**
- **Define the glossary terms.**

GLOSSARY

basilic vein / large vein on inner side (“pinky” side) of arm
cephalic vein / a superficial vein of the arm (thumb side) commonly used for venipuncture
ethylenediaminetetraacetic acid (EDTA) / an anticoagulant commonly used in hematology
gauge / a measure of the internal diameter (or bore) of a needle
hematoma / the swelling of tissue around a vessel resulting from leakage of blood into the tissue
hemoconcentration / increase in the concentration of cellular elements in the blood
hemolysis / rupture or destruction of red blood cells resulting in the release of hemoglobin
hypodermic needle / a hollow needle used for obtaining fluid specimens or for injections
lumen / the open space within a tubular organ or tissue

median cubital vein / a superficial vein located in the bend of the elbow (cubital fossa) that connects the cephalic vein to the basilic vein

order of draw / a prescribed order for filling vacuum tubes during blood collection to prevent contaminating one tube with the additive of another

palpate / to examine by touch

phlebotomy / venipuncture; entry of a vein with a needle

syringe / a hollow, tube-like container with a plunger, used for withdrawing fluids or for injections

tourniquet / a band used to constrict blood flow

vein / a blood vessel that carries deoxygenated blood from the tissues to the heart

venipuncture / entry of a vein with a needle; a phlebotomy

winged collection set/ a small-gauge needle with attached plastic tabs (wings), six or more inches of tubing and a Luer-Lok or vacuum tube holder connector; sometimes called a "butterfly" set

TEACHING AIDS AND RESOURCES

- Anatomical model or chart of arm, showing basilic, cephalic, and median cubital veins
- Examples of venipuncture materials incorporating latest safety designs: safety needles and holders, various types and sizes of vacuum tubes, safety syringes, sharps containers, tourniquets, bandages, phlebotomy tray
- Student Performance Guides
- Transparencies or overheads of Figures 1-79 through 1-92
- Transparency or overhead of Table 1-36
- Instructor's Resources CD accompanying *Basic Clinical Laboratory Techniques,* 6th edition, including computerized test bank and PowerPoint

LESSON CONTENT

I. Introduction

II. Venipuncture Materials and Supplies

   A. Needles

      1. 21-gauge needle, 0.75 to 1.5 inches long
      2. Several safety designs

   B. Vacuum Tubes

      1. Several sizes
      2. Glass or plastic

- C. Anticoagulants and Additives
  1. Type of anticoagulant designated by stopper color
  2. Red-topped tubes contain no anticoagulant
  3. Tubes draw an exact volume
  4. Order of draw

III. Performing a Venipuncture Using a Vacuum Tube System

- A. Safety Precautions
  1. Observe Standard Precautions
  2. Wear gloves and other PPE
  3. Use products with safety features
  4. Needles must not be recapped
  5. Do not use basilic vein
- B. Quality Assessment
  1. Quality test results rely on properly collected blood
  2. Patient ID—two identifiers
  3. SOP manual provides guidelines
  4. Problems associated with improper venipuncture technique
     - a. Hemolysis
     - b. Hemoconcentration
- C. Selecting the Equipment
  1. Select correct vacuum tubes
  2. Use safety needle and needle holder
- D. Preparing the Patient
  1. Verify patient identification
  2. Explain procedure
  3. Provide support to patient's arm
  4. Be prepared for adverse reaction such as fainting
- E. Applying the Tourniquet
  1. Place 3 to 4 inches above elbow
  2. Do not leave in place more than 1 minute
- F. Selecting the Venipuncture Site
  1. Median cubital or cephalic vein
  2. Do not collect from arm with intravenous line
  3. Palpate the vein
- G. Preparing the Venipuncture Site
  1. Cleanse with alcohol
  2. Allow site to dry

H. Obtaining the Blood
   1. Hold needle with bevel facing up
   2. Anchor the vein
   3. Enter vein at 15- to 20-degree angle
   4. Push vacuum tube onto sheathed needle in holder
   5. Fill clot tube first
   6. Gently invert tubes containing blood and anticoagulant

I. Completing the Venipuncture and Caring for the Patient
   1. Release tourniquet
   2. Remove last vacuum tube from needle
   3. Place gauze over puncture as needle is removed
   4. Apply pressure to site
   5. Activate safety feature and immediately dispose of needle and holder
   6. Label tubes
   7. Be sure bleeding has stopped before leaving patient

IV. Performing a Venipuncture Using a Syringe
V. Performing a Venipuncture Using a Winged Collection Set
VI. Action to Take in Case of Exposure Incident
VI. Safety Reminders
VII. Procedural Reminders
VIII. Case Studies
IX. Summary

Case Studies and Answers

Case Study 1

Jerry was completing his fourth week of MLS internship at Pleasant Valley Hospital. All interns were required to collect blood from eight to 10 patients each morning before beginning the day's clinical rotation. Jerry had completed his phlebotomy rotation the previous week, so he was collecting blood on his own (without supervision). One of the patients on his collection list was 72 years old. Jerry saw only one adequate vein in the patient's left arm but was unable to obtain blood when he attempted venipuncture.

1. What should Jerry do?
   a. Stick the same vein again
   b. Try a different vein using a syringe or winged collection set

2. Discuss factors that cause venipuncture to be difficult and explain how these venipunctures can be handled.

   Venipuncture can be difficult in elderly patients because of loss of elasticity of vessels. It can also be difficult in poorly hydrated patients. Use of winged collection sets or syringes is often required to avoid vessel collapse caused by the vacuum in vacuum tubes. When good veins for venipuncture are scarce in a patient, it is important to consult experienced phlebotomists for assistance with the venipuncture. This prevents unnecessary pain to the patient and preserves the patient's veins as much as possible.

Case Study 2

Katie, a medical assistant in a POL, is asked to collect blood for transport to a reference laboratory. After consulting the specimen collection manual, she determined that she will need to collect a gray-capped tube, an EDTA tube, and a serum (red) tube.

1. Which is the correct order of draw for filling these tubes?
   a. gray first, then lavender, then red
   b. red first, then lavender, then gray
   c. red first, then green, then gray
   d. lavender first, then gray, then red

2. If the orders had included collection of a citrate tube for coagulation studies, what would the order of draw be for the four tubes?

   The citrate tube should be drawn first, followed by the serum (red), EDTA, and gray tubes.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Practice applying a tourniquet and locating suitable veins for venipuncture.
3. Practice performing a venipuncture as outlined in the Student Performance Guides. NOTE: You must be supervised during venipuncture practice until the Instructor has approved your technique.

Web Activities

1. Use the Internet to find information on three safety devices used for venipuncture. Explain how each type protects the worker from accidental needlesticks.
2. Visit web sites of agencies such as the Centers for Disease Control and Prevention, Occupational Safety and Health Administration, and National Institute for Occupational Safety and Health. Look for information on preventing needlestick or sharps injury. Try to find free brochures, PowerPoint presentations, or other safety information that can be downloaded.

3. Search the Internet for videos or tutorials showing how to apply a tourniquet or how to perform a venipuncture. Use reliable sources such as phlebotomy equipment manufacturers, healthcare education programs, government sites, or online phlebotomy resources.
4. Search the Internet for videos showing how to activate various types of safety needles used for venipuncture.

REVIEW QUESTIONS AND ANSWERS

1. Why is a venipuncture performed?

   Venipuncture is a quick, safe way to obtain a large sample of blood when several analyses are to be performed.

2. What is the purpose of a tourniquet?

   A tourniquet makes veins more prominent.

3. How long can a tourniquet be left on?

   Tourniquet should not be left on longer than 1 minute.

4. Name five precautions that must be observed when performing a venipuncture.

   Any five of the following are acceptable:

   a. Observe Standard Precautions.
   b. Wear gloves and appropriate PPE when performing a venipuncture.
   c. Never recap needles; engage needle safety feature immediately after use.
   d. Students perform venipuncture only under the supervision of a qualified instructor.
   f. Be prepared for a patient who may faint.
   g. Do not allow the tourniquet to remain on the arm for more than 1 minute.
   h. Always release the tourniquet before removing the needle from the vein to prevent the formation of a hematoma.
   i. Disinfect phlebotomy trays frequently
   j. Do not use the basilic vein for venipuncture.

5. How can hemoconcentration affect the quality of the blood specimen?

   Hemoconcentration can occur when the tourniquet is left on too long before the venipuncture is performed, causing localized stasis in the vein. This can artificially alter the concentration of blood constituents in the blood specimen.

6. List the steps in performing a venipuncture.

   See Figure 1-89. The steps in performing a venipuncture are:

   a. Observing Standard Precautions and other safety measures throughout procedure
   b. Selecting the proper equipment
   c. Identifying the patient using two identifiers

d. **Preparing the patient**
e. **Selecting and preparing the puncture site**
f. **Applying the tourniquet**
g. **Obtaining the blood**
h. **Caring for the puncture site**
i. **Observing the patient for adverse reaction**
j. **Labeling blood specimens immediately following blood collection**

7. What is the most common venipuncture site?

   The most common venipuncture site is the median cubital vein or cephalic vein in the bend of the elbow.

8. Why must the tourniquet be released before removing the needle from the vein?

   The tourniquet must be released to reduce bleeding at the venipuncture site and prevent the formation of a hematoma.

9. How should the puncture site be cared for after the needle is removed?

   The patient should be instructed to press sterile gauze on the puncture site for 2 to 5 minutes with the arm extended; the phlebotomist should check to be sure bleeding has stopped before leaving the patient and apply a bandage if necessary.

10. Explain briefly the vacuum system of obtaining venous blood.

    An evacuated tube (one with air removed, leaving a vacuum) is used with a tube holder, which contains a double-ended needle. The vein is entered with the needle, the tube is pushed onto the end of the needle inside the holder, and the blood is drawn into the tube by vacuum.

11. What precautions should the phlebotomist take to avoid exposure to blood when performing a venipuncture?

    The phlebotomist must wear appropriate PPE to protect from splashes or spills of blood; the needle safety feature must be immediately activated and needle discarded into sharps container after procedure; plastic vacuum tubes should be used when possible.

12. Name three anticoagulants used in collecting blood. Which one is most commonly used in hematology?

    Examples of anticoagulants include EDTA, heparin, and sodium citrate; EDTA is the one most commonly used in hematology.

13. Why is it important to verify patient identification before performing a venipuncture?

    To be sure blood is being obtained from the correct patient

14. Name a situation that might require the use of a syringe or winged collection set for venipuncture.

    Winged collection sets are used to obtain blood from small children, patients with very small veins or veins that tend to roll, and in other conditions in which the use of a small-diameter needle is an advantage. Syringes can be used to obtain blood from elderly patients or patients with small veins that make routine venipuncture with vacuum tubes difficult.

15. Explain the advantages of using a winged collection set for venipuncture.
    a. **Winged collection sets have a small-diameter needle.**
    b. **A low angle is used to puncture the vein in relation to the surface of the skin and is useful for superficial veins such as veins on the top of the hand.**
    c. **The sets have a Luer-Lok assembly on the end of the tubing for attaching a vacuum tube holder or syringe.**
    d. **Winged sets have safety features to prevent accidental needlestick, such as push-button retraction of the needle as it is withdrawn from the vein.**

16. List the three actions that must be taken in case of an exposure incident.
    a. **Immediately flood the exposed area with water, and clean skin with antiseptic soap and water.**
    b. **Report accident immediately to supervisor, risk control officer, or other appropriate person.**
    c. **Seek immediate medical attention.**

17. Define basilic vein, cephalic vein, ethylenediaminetetraacetic acid, gauge, hematoma, hemoconcentration, hemolysis, hypodermic needle, lumen, median cubital vein, order of draw, palpate, phlebotomy, syringe, tourniquet, vein, venipuncture, and winged collection set.

    See Glossary.