MLT-2501: CLINICAL CHEMISTRY

Cuyahoga Community College

Viewing: MLT-2501 : Clinical Chemistry

Board of Trustees:
2016-01-28

Academic Term:
2016-08-22

Subject Code
MLT - Medical Laboratory Technology

Course Number:
2501

Title:
Clinical Chemistry

Catalog Description:
Principles, procedures and application of basic and advanced diagnostic tests in clinical chemistry for all body fluids. Emphasis on correlation of results with clinical significance, interpreting quality control data, and mastering basic lab skills.

Credit Hour(s):
5

Lecture Hour(s):
3

Lab Hour(s):
6

Requisites

Prerequisite and Corequisite
MLT-1000 Introduction to Medical Laboratory Technology, and MLT-1351 Problem Solving Techniques for the Medical Laboratory, and departmental approval.

Outcomes

Course Outcome(s):
Apply basic principles and practices utilized in clinical chemistry.

Essential Learning Outcome Mapping:
Written Communication: Demonstrate effective written communication for an intended audience that follows genre/disciplinary conventions that reflect clarity, organization, and editing skills.

Objective(s):
1. Describe and discuss different units of measurement.
2. Evaluate test data to determine if results are within the normal range.
3. Determine what additional test(s) are necessary when results are abnormal.
4. List steps to inform appropriate personnel of abnormal results.
5. Discuss transmission, documentation and privacy protocol for result reporting.
6. Convert results from one unit format to another using the Systems International (SI) system.
7. Select, use and calibrate pipettes including automatic and manual varieties for preparing reagents and performing chemistry determinations.
8. Differentiate reagent grades; including technical grades, practical grades and National Bureau of Standards (NBS).
9. Identify, describe and evaluate sample types as acceptable for testing in clinical chemistry.
10. Identify the pre-analytical, analytical and post analytical variables that can adversely affect laboratory results listing and taking corrective action as needed.
11. Describe the steps to correct a sample for hemolysis and lipemia.
12. Perform, interpret and report clinical chemistry tests according to laboratory procedures.
13. Define a stat request and discuss protocol for stat testing and result reporting.

Course Outcome(s):

Discuss carbohydrate metabolism, function, methodology and clinical significance.

Objective(s):

1. Define glycogenolysis, glycogenesis, gluconeogenesis, and glycolysis.
2. Define the term reducing substance and explain its significance.
3. Discuss the preparation, collection and stability of specimens for glucose testing.
4. Discuss the clinical significance of the results and implications for further testing by evaluating a fasting glucose level.
5. Interpret the results of a glucose tolerance test, interpret the results according to currently accepted criteria.
6. Correlate whole blood, serum and urine glucose levels.
7. Compare and contrast different methodologies available for glucose determinations.
8. Describe the anatomy, physiology, function and secretory products of the pancreas.
9. Compare and contrast glucagon and insulin.
10. Discuss Diabetes, current classification, symptoms, family history and current testing methods.
11. Discuss the clinical application of tests measuring carbohydrate metabolism.
12. Give the reference interval and significance for Cerebrospinal Fluid (CSF) sugars.
13. Discuss symptoms, family history and current testing methods of carbohydrate metabolism by evaluating a case history.
14. Describe carbohydrate metabolism and its relationship to the liver.
15. State four functions of carbohydrates.
16. Describe carbohydrate metabolism and its relationship to the liver.
17. Explain the different ways in which glucose may be metabolized.
18. Explain the effects of hormones on glucose metabolism.

Course Outcome(s):

Discuss lipid and lipoprotein metabolism, function, analysis and clinical significance.

Objective(s):

1. Explain the major functions of fatty acids, cholesterol, and triglycerides.
2. Differentiate saturated from unsaturated fatty acids.
3. Describe the process of lipid digestion and absorption.
4. Explain the role of phospholipids in respiration.
5. List the three major categories of lipids in the diet.
6. Explain why lipids require transport proteins.
7. List the four classes of lipoproteins and electrophoretic migration pattern.
8. Name the two lipoprotein classes that contain the greatest amounts of cholesterol and have major roles in triglyceride transport.
9. State the principle of lipoprotein electrophoresis and list the migration order of the lipoprotein fractions.
10. Discuss the forms of and assays for cholesterol.
11. Discuss the effectiveness of HDL in removing cholesterol from cells.
12. Explain the diagnostic value of HDL in assessing the risk of developing coronary heart disease.
13. Describe how HLD cholesterol is measured.
14. Discuss the specimen of choice and collection requirements for Apo lipoproteins A and B, cholesterol and triglyceride.
15. Discuss the methods, principle, normal ranges and clinical correlation of lipid assays for triglycerides, cholesterol and lipoproteins.
16. Using the Fredrickson Classification relate serum lipid patterns to their phenotypes.
17. Describe hypo lipoprotein disorders.
18. Evaluate laboratory data and case histories to determine possible lipid disorders.

Course Outcome(s):

Discuss the regulation of electrolytes, methods of analysis and the clinical significance of test results.

Objective(s):

1. Define electrolyte, electrolyte balance and anion gap.
2. Describe the function of electrolytes and explain factors controlling fluid movement and the regulation of electrolytes in the body.
3. List intracellular and extracellular electrolytes and those found in plasma and interstitial fluid.
4. Describe the role of the kidney in maintaining electrolyte balance.
5. State the common methods and normal values for determining sodium (Na), potassium (K) and chloride (Cl) levels.
6. List and describe physiological conditions associated with abnormal K levels.
7. Describe methods of measuring sweat chloride and possible sources of error.
8. Explain the use of the anion gap in evaluating a patient's condition.
9. Evaluate a case study and laboratory data to determine a possible cause of the physiological state or laboratory results.

Course Outcome(s):

Discuss acid-base balance, pH, regulatory mechanisms and clinical significance.

Objective(s):

1. Describe the appropriate procedure and precautions in obtaining a venous or arterial blood sample for the measurement of blood gasses.
2. List the forms in which CO2 may be transported by the blood and their concentrations.
3. Describe the in vitro changes in specimens for blood gas analysis.
4. Discuss buffer systems and how they regulate balance in the body.
5. Explain the action of a buffer using the relationship of HCO3 and H2CO3.
6. State the normal range for total CO2, HCO3, PCO2, pH and acid/base ratio.
7. Discuss the role of the respiratory system on pH and the location of its major controls.
8. State the Henderson-Hassel Balch equation and give its clinical significance.
9. Describe how PCO2 and pH are commonly measured.
10. Discuss the role of the kidneys in acid-base balance and alterations in renal tubular acidosis.
11. Differentiate compensated, partially compensated and uncompensated acidosis and alkalosis.
12. Evaluate case histories and test results to determine if the state is metabolic or respiratory, alkalosis or acidosis, and compensated or uncompensated.

Course Outcome(s):

State and observe laboratory safety protocol and regulations for clinical chemistry.

Objective(s):

1. List the responsibilities of employer and employee in providing a safe workplace.
2. Identify hazards and implement safety protocols related to chemicals, biological specimens, radiological materials and fires.
3. Select appropriate personal protective equipment when working in the clinical chemistry laboratory.
4. Identify classes of fires and types of fire extinguishers used for each class of fire.
5. Identify the location and explain the use of an Material Safety Data Sheet (MSDS) manual.
6. Identify the location of and follow the evacuation plan in the event of an emergency.
7. Identify the governmental agency that regulates safety.
8. Select the correct means for disposal of wastes generated in the clinical laboratory.
9. Practice Universal Precautions in the laboratory.
10. List the steps required to properly document a workplace accident.

Course Outcome(s):

Describe the regulatory mechanism, physiology and clinical significance of trace elements levels found in the body.

Objective(s):

1. 1. State the biochemical function and describe the common laboratory testing for the minerals.
2. 2. Identify the three forms of calcium in the blood, recognizing the form that is physiologically active.
3. Describe the regulatory effects of the proteins, hormones and metabolites on calcium levels in the blood.
4. Name and describe two ways by which the precursor to the active form of vitamin D can be obtained.
5. Discuss appropriate precautions in the collection of specimens for calcium and phosphorus assays.
6. Describe the methods employed for measuring parathyroid hormone, calcitonin, and vitamin D metabolites.
7. List the three forms of magnesium found in the blood.
8. Describe the absorption, transport and storage of iron.
9. Describe the symptoms associated with Wilson's disease and the role of ceruloplasmin in copper metabolism.
10. Correlate abnormal levels of calcium, phosphorus, magnesium and iron with various disease states.

Course Outcome(s):

Summarize quality control (QC) and quality assurance (QA) protocols utilized in the clinical chemistry laboratory.

Objective(s):

1. Differentiate QC from QA.
2. Define and apply terminology in data analysis and documentation.
3. Evaluate instrumentation and or test data, recognizing problem(s) taking corrective action to ensure the reporting of accurate data.
4. Perform and record the results of routine quality control procedure including temperature checks and spectrophotometer calibration.
5. Given a case history identify the source(s) of pre-analytic, analytical and post analytic error.
6. Explain the purpose of a laboratory inspection and proficiency survey programs.

Course Outcome(s):

Describe the function of the endocrine system, hormones produced and disease correlation.

Objective(s):

1. Discuss the general function and control of the endocrine system.
2. 2. Explain feedback inhibition.
3. Name the hormone(s) produced/secreted by the endocrine system and state its clinical significance.
4. List examples of hormones classified as peptide, steroid, amino acids or catecholamines.
5. Explain the production and function of releasing factors including the release stimuli of rennin.
6. Discuss the location, structure and function of the thyroid gland.
7. Explain the action of Thyrotropin Release Hormone (TRH), Thyroid-Stimulating Hormone (TSH) and thyroglobulin in thyroid hormone synthesis.
8. Explain the physiology and half time of T3 and T4.
9. State the concentration of T3 and T4 in the blood naming binding proteins and major carrier protein.
10. Identify the three categories and function of steroid hormones.
11. Describe the procedure and primary purpose for measuring urine 17-ketosteroids.
12. Identify the type of steroids that react in the Porter-Silber and Zimmermann reactions.
13. Name the glands which produce cortisol and adrenocorticotropic hormone (ACTH).
14. Describe the regulation of cortisol and ACTH explaining the diurnal rhythm associated with their synthesis.
15. List the major physiological characteristics associated with Cushing's syndrome and Addison's disease and the laboratory tests used in their diagnosis.
16. Identify the primary site of catecholamine synthesis and storage.
17. Name the end products of catecholamine metabolism.
18. Identify dietary causes of false elevations of Vanillylmandelic Acid (VMA).
19. Define pheochromocytoma and neuroblastoma and state the major physiological characteristics associated with these tumors.

Course Outcome(s):

Review analytic techniques and instrumentation.

Objective(s):

1. Define Beer's Law and use it to calculate concentration.
2. Describe instrumentation that is available in a clinical chemistry laboratory.
3. Review the principle or process of analytic techniques.
4. Define an antibody and identify parts of an antibody chains.
5. List the factors that affect antigen and antibody reactions.
6. Compare and contrast the general types of labels used in immunoassays.
7. Classify an immunoassay, given its format, as homogeneous or heterogeneous, competitive or noncompetitive, and by its label.
8. State the principle of method(s) for Radio-immune assay(RIA), Enzyme-linked assay (EIA), and Enzyme-linked immunosorbent assay(ELISA) .

Course Outcome(s):

Discuss Point-of-Care Testing (POCT).

Objective(s):

1. Describe the role of medical laboratory technicians in POCT.
2. List the requirements for point-of-care analyzers and kits.
3. Discuss the selection and evaluation of methods used in point-of-care testing.
4. Perform POCT using methods selected by the instructor including QC.
5. Describe procedures for reporting POCT results.
6. Explain amino acid and protein metabolism, function, analysis and clinical significance.
7. Differentiate proteins from carbohydrates and lipids.
8. Diagram the classic protein structure.
9. Explain the effects of protein deprivation on the human body.
10. Name the chief end-product of protein metabolism.
11. Discuss the normal function of proteins correlating abnormalities with probable disease states.
12. Identify an acceptable specimen for protein and amino acid testing.
13. Describe three methods used for the determination of total serum protein.
14. Identify methods use for the separation of proteins.
15. Identify the site of synthesis for serum protein fractions.
16. Identify screening tests and reagents used in amino acid testing.
17. Discuss the principle, procedure, and disease correlation of electrophoretic methods used in clinical chemistry.
18. Evaluate laboratory data and case histories and determine if additional testing is necessary

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Course Outcome(s):

Discuss toxicology and therapeutic drug testing.

Objective(s):

1. Explain the metabolism and excretion of drugs including the effects of age, pregnancy and renal output.
2. State two reasons for measuring drug levels in body fluids.
3. List three major routes for drug administration.
4. Define therapeutic range, half life and steady state.
5. Discuss the importance of dosage time in sample collection for therapeutic drug testing and monitoring.
6. 6. Explain the therapeutic uses of lithium carbonate, theophylline, salicylate, and acetaminophen.
7. Discuss legal aspects of drug testing (drugs of abuse including alcohol).
8. Describe the procedure for sample collection and testing.
9. Describe the criteria for an acceptable sample.
10. Discuss factors that can affect the validity of test results in litigation.
11. Discuss tests for toxic substances.

Course Outcome(s):

Review kidney function describing the formation, analysis and clinical significance of non-protein nitrogen compounds.

Objective(s):

1. Describe the location, structure and function of the kidney.
2. List the components of non-protein nitrogen compounds and indicate their relative concentrations.
3. Explain the biochemical formation of creatinine, urea, and uric acid.
4. Compare serum urea nitrogen and serum creatinine as indicators of renal function.
5. Describe the principle(s) used in the analysis and the clinical significance of abnormal levels of nitrogenous compounds in the blood.
6. Give the procedure(s), principle(s) and reference range(s) for clearance and osmolality tests.
7. Calculate a creatinine clearance (corrected for body surface) given the required information.
8. Discuss sample criteria and handling precautions for ammonia determinations.
9. Evaluate laboratory data and case histories and determine if additional testing is necessary.

Course Outcome(s):

Discuss the function and clinical significance of tumor markers.

Objective(s):

1. Explain the role of tumor markers in cancer management.
2. Discuss the use of enzymes and hormones as tumor markers.
3. Describe the major properties, method of analysis and clinical significance of alpha-fetoprotein, Cancer Antigen (CA) 125, CA 15-3, Carcinoembryonic Antigen (CEA), Human Chorionic Gonadotropin (hCG) and Prostate Specific Antigen (PSA).

Course Outcome(s):

Review liver anatomy, structure and function of the liver including related test procedures and clinical significance.

Objective(s):

1. Name the basic anatomic unit of the liver.
2. List four liver functions.
3. Describe the liver's involvement in hemoglobin breakdown and excretion.
4. Discuss the chemical/physiological effects and clinical significance of the different forms of bilirubin.
5. Compare bilirubin methods.
6. Correlate findings for conjugated, unconjugated and total bilirubin with disease states.
7. Explain the procedure for the determination of urobilinogen.
8. Differentiate between hemolytic, hepatocellular and obstructive jaundice by evaluating case study and laboratory data.

Course Outcome(s):

Describe gastric analysis.

Objective(s):

1. List three tests used to assess gastric and intestinal function.
2. Explain the clinical significance of gastric analysis.

Course Outcome(s):

Discuss the formation, synthesis, function and analysis of porphyrins.

Objective(s):

1. Identify the specimen of choice for porphyrin testing.
2. Discuss the theory, instrumentation and common tests used to measure porphyrins and their metabolites.
3. Compare the different metabolites found in excess in the porphyrias.
4. Correlate porphyrin results with clinical significance.

Course Outcome(s):

Discuss the properties, reactions, analysis and clinical significance of enzymes.

Objective(s):

1. Define terminology.
2. List in order the six classifications of enzymes giving two examples from the first four.
3. Give four types of specificity exhibited by enzymes.
4. Explain the use of the Michaelis-Menten equation (KM) in relation to substrate concentration and velocity.
5. Differentiate competitive, noncompetitive, and uncompetitive inhibition.
6. Describe the factors that affect the reaction rate of enzymes.
7. Discuss assays for enzymes and isoenzymes including stability, specimen acceptability, proper storage and sources of error.
8. Discuss the use of the NAD-NADH system in enzyme methodology and give the clinical significance.
9. Discuss the use of appropriate enzyme determinations in diagnostic evaluations.
10. Correctly perform kinetic enzyme analysis, selecting an appropriate area for measurements and calculating the results using an appropriate factor.
11. Identify the most likely disorder by evaluating case study, laboratory data, or clinical information and recommend any further testing.

Methods of Evaluation:

1. Discussion Boards
2. Homework assignments
3. Case studies
4. Exams
5. Quizzes
6. Lab practical exams
7. Individual projects
8. Class Participation

Course Content Outline:

1. Basic principles and practices
   a. Units of measurement
   b. SI system
   c. Pipette calibration
   d. Reagent grade
   e. Acceptable sample criteria
   f. Variables affecting testing
   g. Correction for hemolysis and lipemia
   h. Perform tests
   i. Stat tests
   j. Evaluation of test data
   k. Abnormal results
   l. Communication protocol for abnormal results
   m. Privacy and transmission of data
2. Laboratory safety protocol and regulations
   a. Responsibilities of employer and employee
   b. Hazards and safety protocols
   c. Personal protective equipment (PPE)
   d. Fires and extinguishers
   e. MSDS manual
   f. Evacuation plan
   g. Governmental agency regulating safety
   h. Waste disposal

   i. Universal Precaution
   j. Workplace accident documentation
3. Quality control (QC) and quality assurance (QA)
   a. Differentiate QC from QA
   b. Terminology
   c. Instrumentation and data evaluation
   d. Routine QC Procedures
   e. Case histories and error identification
   f. Laboratory inspection and proficiency surveys
4. Analytic techniques and instrumentation
   a. Beer"s Law
   b. Chemistry instrumentation
      i. Rational and components
      ii. Calibration techniques and maintenance procedures
      iii. Reagent, serum blanks and standards
      iv. Batch mode or random access
   c. Principle and processes
      i. Fluorescence
      ii. Spectrophotometry
      iii. Ion selective electrodes
      iv. Chemiluminescence
      v. Electrophoresis
      vi. Chromatography
      vii. Continuous flow analysis
      viii. Centrifugal analysis and calibration
      ix. Photometric analysis
      x. Dry slide system
5. Principle(s) and classification of immunoassays
   a. Antibody and antibody chains
   b. Antigen and antibody reactions
   c. Labels used in immunoassays
   d. Classification of immunoassays
   e. Principle of methods
6. Point-of-care testing (POCT)
   a. Role of MLT(medical laboratory technicians) in POCT
   b. Requirements for POCT analyzers and kits
   c. Selection and evaluation of methods used in POCT
   d. Perform POCT including QC
   e. Procedures for reporting POCT results
7. Amino acid and protein metabolism
   a. Proteins, carbohydrates and lipids
   b. Protein structure
   c. Protein deprivation
   d. End-product of protein metabolism
   e. Proteins and disease states
   f. Acceptable specimen
   g. Total serum protein determinations
   h. Separation of proteins
   i. Serum protein fractions
   j. Screening tests and reagents
   k. Electrophoretic methods
   l. Case history
8. Kidney function and non-protein nitrogen compounds
   a. Anatomy and physiology of the kidney
   b. Components and concentration of non-protein nitrogen compounds
   c. Creatinine, urea, and uric acid formation
   d. Indicators of renal function
   e. Abnormal nitrogenous compounds in the blood

   f. Clearance and osmolality tests
   g. Ammonia determinations
   h. Case history
9. Liver and test procedures
   a. Anatomy of the liver
   b. Liver functions
   c. Hemoglobin breakdown and excretion
   d. Effects and clinical significance of bilirubin
   e. Jendrassik-Grof and Evelyn-Malloy bilirubin methods
   f. Bilirubin and disease
   g. Determination of urobilinogen
   h. Obstructive jaundice
   i. Case history
10. Porphyrins.
   a. Acceptable specimen
   b. Analysis porphyrins and their metabolites
   c. Porphyrias
   d. Clinical significance
11. Enzymes
   a. Terminology
   b. Classification
   c. Specificity
   d. Michaelis-Menten equation
   e. Competitive, noncompetitive, and uncompetitive inhibition
   f. Reaction rate of enzymes
   g. Enzymes and isoenzymes assays
   h. NAD-NADH system
   i. Determinations in diagnostic evaluations
   j. Enzyme analysis
   k. Additional testing
12. Carbohydrates
   a. Types of carbohydrates
   b. Functions of carbohydrates
   c. Carbohydrate metabolism and liver function
   d. Glucose metabolism
   e. Effect of hormones on glucose metabolism
   f. Glycogenolysis, glycogenesis, gluconeogenesis, and glycolysis
   g. Reducing substance(s)
   h. Specimens for glucose testing
   i. Fasting glucose test
   j. Blood, serum and urine glucose levels
   k. Methodologies for glucose determinations
   l. Pancreas anatomy and physiology
   m. Glucagon and insulin
   n. Diabetes
   o. Tolerance and other rests of carbohydrate metabolism
      i. Glucose tolerance
      ii. Insulin tolerance
      iii. Lactose tolerance
      iv. Galactose tolerance
      v. Hgb AIC (glycosylated hemoglobin)
      vi. C-Peptide
   p. Cerebrospinal Fluid (CSF) sugars
   q. Case history
13. Lipids and lipoproteins
   a. Fatty acids, cholesterol, and triglycerides
   b. Saturated and unsaturated fatty acids
   c. Lipid digestion and absorption

d. Phospholipids and respiration
e. Lipids in the diet
f. Transport proteins
g. Electrophoretic migration patterns
h. Lipoprotein fractions and triglyceride transport
i. Principle of lipoprotein electrophoresis
j. Forms of and assays for cholesterol
k. Cholesterol and coronary heart disease
l. Function, specimen, collection requirements of lipids
m. Assays for triglycerides, cholesterol and lipid proteins
n. Frederickson classification
o. Lipoprotein disorders
p. Case history

14. Electrolytes
    a. Electrolyte balance and anion gap
    b. Function of electrolytes and fluid control
    c. Plasma and interstitial fluid electrolytes
    d. Kidneys and electrolyte balance
    e. Electrolyte determinations
    f. Abnormal K levels and disease
    g. Sweat chloride determination
    h. Anion gap and patient condition
    i. Case history
15. Acid-Base balance
    a. Specimens for blood gas testing
    b. CO_2 concentration and transport
    c. In vitro changes in blood gases
    d. Buffer systems
    e. Relationship of HCO_3 and H_2CO_3
    f. Normal ranges of blood gases
    g. Respiratory system and pH
    h. Henderson-Hasselbalch equation
    i. Measurement of PCO_2 and pH
    j. Kidneys and acid-base balance
    k. Acidosis and alkalosis
    l. Case histories
16. Trace elements
    a. Function of and testing for trace elements
        i. Calcium
        ii. Magnesium
        iii. Iron
        iv. Zinc
        v. Phosphorous
        vi. Copper
        vii. Manganese
        viii. Cobalt
        ix. Chromium
        x. Nickel
    b. Forms of calcium
    c. Effect of compounds/proteins on calcium levels
    d. Active form of vitamin D
    e. Calcium and phosphorus assays
    f. Parathyroid hormone, calcitonin, and vitamin D assays
    g. Magnesium
    h. Iron
    i. Wilson"s disease and copper metabolism
    j. Disease states

17. Endocrine system
    a. Function and control of the endocrine system
    b. Glands and organs producing hormones
    c. Hormones classification
    d. Releasing factors
    e. Function of the thyroid gland
    f. Thyroid hormone synthesis
    g. T_3 and T_4
    h. Binding proteins and carrier proteins
    i. Categories and function of steroid hormones
    j. Porter-Silber and Zimmermann reactions
    k. Cortisol and ACTH
    l. Regulation and diurnal variation
    m. Cushing"s syndrome and Addison"s disease
    n. Catecholamine synthesis, metabolism and storage
    o. VMA
    p. Pheochromocytoma and neuroblastoma
18. Toxicology and therapeutic drug testing
    a. Metabolism and excretion of drugs
    b. Rationale for drug testing
    c. Routes for drug administration
    d. Therapeutic range, half life and steady state
    e. Dosage time
    f. Common therapeutic drugs
    g. Legal aspects of drug testing
    h. Test for toxic substances
19. Function and clinical significance of tumor markers
    a. Tumor markers in cancer management
    b. Enzymes and hormones as markers
    c. Properties, analysis and clinical significance of markers
20. Gastric analysis
    a. Tests
    b. Clinical significance

Resources

Essridge, Barbara and Reynolds, Anna. *Basic Clinical Laboratory Techniques.* 6th ed. Clifton Park, NY: Delmar Cengage Learning, 2012.

Doucette, Lorraine. *Mathematics for the Clinical Laboratory.* 2nd ed. Maryland Hts., MO, 2011.

Bishop, Michael. *Clinical Chemistry, Principles, Procedures, Correlations.* 7th ed. Philadelphia: LWW, 2013.

Mundt, Lillian and Shanahan, Kristy. *Graff's Textbook of Urinalysis and Body Fluids.* 2nd ed.,. Philadelphia: Wolters Kluwer/LWW, 2011.

Turgeon, Mary Louise. *Linné Ringsrud's Clinical Laboratory Science : The Basics and Routine Techniques.* 6th ed.,. Maryland Hts., MO:Elsevier/Mosby, 2012.

Sunheimer, Robert L. and Graves, Linda. *Clinical Laboratory Chemistry.* 1st ed. Boston:Pearson, 2011.

"MLO Articles" various.

"Advance Articles" various.

ASCLS. "Clinical Laboratory Science" various.

ASCP. "Laboratory Medicine" various.

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