

Examination Model

The American Society for Clinical Pathology Board of Certification (ASCP BOC) CMLT examination is composed of 80 questions given in a 2-hour time frame. All examination questions are multiple-choice with one best answer. The examinations are administered using the format of computer adaptive testing (CAT). More information is available on the ASCP BOC website.

The examination questions may be both theoretical and/or procedural. Theoretical questions measure skills necessary to apply knowledge, calculate results, and correlate patient results to disease states. Procedural questions measure skills necessary to perform laboratory techniques and follow quality assurance protocols.

Examination Content Areas

The examination questions encompass the following content areas within medical laboratory science. Each of these content areas comprises a specific percentage of the overall 80-question examination.

Content Area	Description	Examination Percentage
Urinalysis and Other Body Fluids	Physical and chemical testing, microscopic analysis (urinalysis only), physiology, disease states	10%
Chemistry	Carbohydrates, lipids, heme derivatives, enzymes, proteins and other nitrogen-containing compounds, acid-base determinations (including blood gases), electrolytes, endocrinology, vitamins and nutrition, therapeutic drug monitoring, toxicology	40%
Hematology	Physiology, disease states, laboratory testing, hemostasis (including physiology, disease states, and laboratory determinations)	20%
Immunology	Principles of immunology, diseases of the immune system, infectious disease serology, serologic procedures, test results	10%
Microbiology	Preanalytic procedures (specimen collection and transport, specimen processing, and Gram stain procedure and principle)	5%
Laboratory Operations	Quality assessment/troubleshooting, safety, laboratory mathematics, manual/automated methodology, instrumentation	15%

For a more detailed overview of the examination, refer to the content outline starting on page 2.

Examination Content Outline

- Regulatory questions on the examination are based on U.S. sources (e.g., AABB, FDA, CLIA, etc.).
- The examples provided in this content outline (as indicated by e.g.,) are not limited to those listed.

URINALYSIS AND BODY FLUIDS

10% of total examination

I. Urinalysis

A. Physical

1. Color and clarity
2. Specific gravity/osmolality

B. Chemical

1. Reagent strip
2. Confirmatory tests

C. Microscopic

1. Cells
2. Casts
3. Crystals
4. Microorganisms
5. Contaminants
6. Artifacts

D. Renal Physiology

E. Disease States

II. Body Fluids (e.g., CSF, Amniotic, Synovial, Serous, Semen, Feces)

A. Physical

B. Chemical

C. Physiology

D. Disease States

CHEMISTRY

40% of total examination

I. General Chemistry

A. Carbohydrates

1. Biochemical theory and physiology
 - a. Metabolic pathways
 - b. Normal and abnormal states
 - c. Physical and chemical properties
2. Test procedures
 - a. Principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
 - c. Tolerance testing
 - d. Glycated proteins
3. Test result interpretation
4. Disease state correlation

B. Lipids

1. Biochemical theory and physiology
 - a. Metabolic pathways
 - b. Normal and abnormal states
 - c. Physical and chemical properties
 - 1) Lipoproteins
 - 2) Phospholipids
 - 3) Triglycerides
 - 4) Cholesterol
 - 5) Apolipoproteins
2. Test procedures
 - a. Principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
3. Test result interpretation
4. Disease state correlation



C. Heme Derivatives

1. Biochemical theory and physiology
 - a. Metabolic pathways
 - b. Normal and abnormal states
 - c. Physical and chemical properties
 - 1) Hemoglobin
 - 2) Bilirubin
 - 3) Urobilinogen
 - 4) Myoglobin
2. Test procedures
 - a. Principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
3. Test result interpretation
4. Disease state correlation

II. Proteins and Enzymes

A. Enzymes

1. Biochemical theory and physiology
 - a. Metabolic pathways
 - b. Normal and abnormal states
 - c. Physical and chemical properties
 - 1) LD
 - 2) CK
 - 3) AST/ALT
 - 4) GGT
 - 5) Lipase
 - 6) Amylase
 - 7) Alkaline phosphatase
 - 8) Angiotensin converting enzyme
2. Test procedures
 - a. Principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
3. Test result interpretation
4. Disease state correlation

B. Proteins and Other Nitrogen-Containing Compounds

1. Biochemical theory and physiology
 - a. Metabolic pathways
 - b. Normal and abnormal states
 - c. Physical and chemical properties
 - 1) Proteins
 - 2) Amino acids
 - 3) Urea
 - 4) Uric acid
 - 5) Creatinine
 - 6) Ammonia
 - 7) Tumor markers
 - 8) Cardiac markers
2. Test procedures
 - a. Principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
 - c. Clearances
3. Test result interpretation
4. Disease state correlation

III. Acid-Base, Blood Gases, and Electrolytes

A. Acid-Base Determinations (Including Blood Gases)

1. Biochemical theory and physiology
 - a. Henderson-Hasselbach equation
 - b. pH and H⁺ ion concentration
 - c. CO₂ and O₂ transport
 - d. Normal and abnormal states
2. Test procedures
 - a. Analytical principles
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
3. Test result interpretation
4. Disease state correlation



B. Electrolytes

- Biochemical theory and physiology
 - Sodium, potassium, chloride, CO₂, bicarbonate
 - Calcium, magnesium, phosphorus, iron, TIBC
 - Trace elements
 - Normal and abnormal states
- Test procedures
 - Principles
 - Special precautions, specimen collection and processing, troubleshooting, and interfering substances
- Calculations (osmolality, anion gap)
- Test result interpretation
- Disease state correlation

IV. Special Chemistry

A. Endocrinology

- Biochemical theory and physiology
 - Metabolic pathways
 - Normal and abnormal states
 - Mechanism of action
 - Physical and chemical properties
 - Steroid hormones (e.g., cortisol, estrogen, hCG)
 - Peptide hormones (e.g., insulin, prolactin)
 - Thyroid hormones
 - Catecholamines
- Test procedures
 - Principles
 - Fluorescence
 - Immunoassay
 - Special precautions, specimen collection and processing, troubleshooting, and interfering substances
 - Stimulation/suppression tests
- Test result interpretation
- Disease state correlation

B. Vitamins and Nutrition

- Biochemical theory and physiology
 - Metabolism and action
 - Normal and abnormal states
 - Properties
- Test procedures
 - Principles
 - Special precautions, specimen collection and processing, troubleshooting, and interfering substances
- Test result interpretation
- Disease state correlation

C. Therapeutic Drug Monitoring

- Pharmacokinetics
 - Therapeutic states
 - Toxic states
 - Metabolism and excretion
- Chemical and physical properties
 - Aminoglycosides (e.g., gentamicin)
 - Cardioactive (e.g., digoxin)
 - Anticonvulsants (e.g., phenobarbital)
 - Antidepressants (e.g., lithium)
 - Immunosuppressants (e.g., tacrolimus)
- Test procedures
 - Principles
 - Immunoassay
 - Special precautions, specimen collection and processing, troubleshooting, and interfering substances
- Test result interpretation
- Disease state correlation

D. Toxicology

- Toxicokinetics
 - Toxic effects, signs and symptoms
 - Metabolism and excretion
- Chemical and physical properties
 - Alcohols
 - Heavy metals (e.g., lead)
 - Analgesics (e.g., acetaminophen)
 - Drugs of abuse



3. Test procedures
 - a. Principles
 - 1) Immunoassay
 - 2) Enzymatic methods
 - b. Special precautions, specimen collection and processing, troubleshooting, and interfering substances
4. Test result interpretation
5. Disease state correlation

B. Leukocytes (WHO classification)

1. Benign leukocyte disorders
 - a. Myeloid
 - b. Lymphoid
2. Myeloid neoplasia
 - a. Acute leukemia
 - b. Myelodysplastic syndromes
 - c. Myeloproliferative neoplasms
3. Lymphoid neoplasia
 - a. Acute leukemia
 - b. Chronic leukemia/lymphoma
 - c. Plasma cell dyscrasias
4. Hereditary anomalies

C. Platelets

1. Quantitative abnormalities
 - a. Thrombocytopenia
 - 1) Increased destruction (e.g., ITP, TTP, HIT)
 - 2) Decreased production
 - 3) Pseudothrombocytopenia
 - b. Thrombocytosis
2. Qualitative defects
 - a. von Willebrand disease
 - b. Bernard-Soulier syndrome
 - c. Glanzmann thrombasthenia

HEMATOLOGY

20% of total examination

I. Hematology Physiology (to include blood, body fluids, and bone marrow)

- A. Production
- B. Destruction
- C. Function

II. Hematology Disease States

A. Erythrocytes

1. Anemia
 - a. Microcytic
 - 1) Iron deficiency
 - 2) Thalassemia
 - 3) Sideroblastic
 - 4) Chronic inflammation
 - b. Normocytic
 - 1) Hereditary hemolytic
 - 2) Acquired hemolytic
 - 3) Hypoproliferative
 - 4) Acute hemorrhage
 - c. Macrocytic
 - 1) Megaloblastic
 - 2) Non-megaloblastic
 - d. Hemoglobinopathies
2. Erythrocytosis
 - a. Relative
 - b. Absolute

III. Hematology Laboratory Testing

A. Cell Counts (to include blood and body fluids)

1. Automated
2. Reticulocytes
3. Spurious results

B. Differentials

C. Hemoglobin

1. Quantitative
2. Qualitative (e.g., sickle solubility)

D. Hematocrit

E. Indices

F. Hemolytic Indicators (e.g., haptoglobin, LD)

G. Other Studies (e.g., ESR)



IV. Hemostasis

A. Physiology

1. Coagulation pathways
2. Fibrinolytic pathway
3. Vascular system

B. Disease States

1. Coagulation factor deficiencies
 - a. Acquired
 - b. Hereditary
2. Fibrinolytic system
3. Hypercoagulable states
4. DIC

C. Laboratory Determinations

1. PT/INR
2. APTT
3. Fibrinogen
4. D-dimer
5. Thrombin time
6. Mixing studies
7. Platelet function (e.g., PFA)
8. Hypercoagulability assessment (e.g., protein S, protein C)

D. Complement

1. Classical and alternative pathway mechanisms
2. Biologic properties

II. Diseases of the Immune System

A. Autoimmunity

1. Systemic (e.g., SLE)
2. Organ-specific (e.g., Graves disease)

B. Hypersensitivity

1. I, II, III, IV

C. Immunoproliferative Diseases

1. Monoclonal gammopathies (e.g., plasma cell myeloma, Waldenström macroglobulinemia)

D. Immunodeficiency

1. Hereditary (e.g., SCID)
2. Acquired (e.g., HIV)

III. Infectious Disease Serology

- A. Clinical Significance and Epidemiology of Viral Pathogens (e.g., hepatitis [A, B, C], EBV, HIV, CMV, rubella, measles)

IV. Serologic Procedures

- A. Thyroid Antibodies
- B. Rheumatoid Factor
- C. Nontreponemal Syphilis Testing (e.g., RPR)

V. Test Results

- A. Interpretation
- B. Confirmatory Testing
- C. Disease State Correlation

IMMUNOLOGY

10% of total examination

I. Principles of Immunology

A. Immune System Physiology

1. Primary and secondary response
2. B and T cells, macrophages
3. Genetics

B. Immunoglobulins

1. Classes and subclasses
2. Structure
3. Biologic and physical properties

C. Antigen-Antibody Interactions

1. Principles
2. Testing
 - a. Principles
 - b. Methods



MICROBIOLOGY

5% of total examination

I. Preanalytic Procedures

A. Specimen Collection and Transport

1. Patient identification and specimen labeling
2. Specimen collection
3. Specimen transport systems and conditions for all organisms

B. Specimen Processing

1. Specimen prioritization and rejection criteria
2. Biosafety cabinet and personal protective equipment
3. Specimen preparation methods and applications
4. Media
5. Inoculation of media
6. Incubation conditions (e.g., temperature, atmosphere, duration)
7. Preparation methods for slides used for stains

C. Gram Stain: Procedure and Principle

LABORATORY OPERATIONS

15% of total examination

I. Quality Assessment/Troubleshooting

- A. Preanalytical, Analytical, Postanalytical
- B. Quality Control
- C. Point-of-care Testing (POCT)
- D. Compliance
- E. Regulation (e.g., proficiency testing, competency assessment, accreditation standards)

II. Safety

A. Safety Programs and Practices

1. Prevention of infection with bloodborne pathogens
2. Use of personal protective equipment (PPE)
3. Safe work practices
4. Packaging and transportation of specimens and microorganisms
5. Safety data sheets (SDS) for chemicals and reagents

B. Emergency Procedures (e.g., needlesticks, splashes to mucous membranes, fire)

III. Laboratory Mathematics

A. Concentration, Volume, and Dilutions

B. Molarity, Normality

C. Standard Curves

D. Mean, Median, Mode, and Confidence Intervals

E. Sensitivity, Specificity, and Predictive Value

IV. Manual/Automated Methodology and Instrumentation

A. Basic Laboratory Equipment

B. Spectrophotometry and Photometry

C. Osmometry

D. Electrochemistry

E. Fluorometry

F. Nephelometry

G. Automated Microbiology Processors

H. Hematology Instrumentation

Additional calculations and reference ranges:

Calculations

Examinees are expected to know the following calculations:

- % Transferrin saturation/UIBC/TIBC
- Unconjugated/indirect bilirubin
- LDL/Friedewald equation/non-HDL
- A/G ratio
- Timed urine calculations
- Creatinine clearance calculations
- Beer's law
- Red blood cell indices (e.g., MCV, MCH, MCHC)
- Absolute cell counts given the relative values (e.g., WBCs, reticulocytes)

Reference Ranges

In support of effective examination preparation, the ASCP BOC provides the following composite reference ranges, inclusive of all genders and ethnic populations, as derived from published sources such as textbooks. These reference ranges are reviewed annually by the Hematology and Chemistry Examination Committees. All corresponding laboratory values on the examination can be interpreted using these reference ranges. These reference ranges are for examination purposes only and will not be provided during the examination. Other reference ranges will be provided as needed during the examination. These reference ranges should not be considered for clinical applications.

The laboratory results and reference ranges on the examination will be provided in both conventional and SI units.

Chemistry Reference Ranges:

	Conventional Units	SI Units
Sodium	136 – 145 mmol/L	136 – 145 mmol/L
Potassium	3.5 – 5.1 mmol/L	3.5 – 5.1 mmol/L
Chloride	98 – 107 mmol/L	98 – 107 mmol/L
Total CO₂	22 – 33 mmol/L	22 – 33 mmol/L
Creatinine	0.8 – 1.2 mg/dL	71 – 106 μmol/L
Blood urea nitrogen (BUN)	6 – 20 mg/dL	2.1 – 7.1 mmol/L



Glucose (fasting)	74 – 100 mg/dL	4.1 – 5.6 mmol/L
Hemoglobin A_{1c}	< 5.7%	< 39 mmol/mol
Haptoglobin	30 – 200 mg/dL	0.3 – 2.0 g/L
<u>Arterial blood gases</u>		
pH	7.35 – 7.45	7.35 – 7.45
pCO₂	35 – 44 mm Hg	4.7 – 5.9 kPa
pO₂	> 80 mm Hg	> 10.6 kPa
O₂ saturation	> 95%	> 95%
HCO₃⁻ (bicarbonate)	23 – 29 mmol/L	23 – 29 mmol/L

Hematology Reference Ranges:

	Conventional Units	SI Units
RBC	4.00 – 6.00 x 10 ⁶ /μL	4.00 – 6.00 x 10 ¹² /L
HGB	12.0 – 18.0 g/dL	120 – 180 g/L
HCT	35 – 50%	0.35 – 0.50 L/L
MCV	76 – 100 fL	76 – 100 fL
MCH	26 – 34 pg	26 – 34 pg
MCHC	32 – 36 g/dL	320 – 360 g/L
RDW	11.5 – 14.5%	0.115 – 0.145
Reticulocytes (absolute)	20 – 115 x 10 ³ /μL	20 – 115 x 10 ⁹ /L
Reticulocytes (relative)	0.5 – 2.5%	0.005 – 0.025
nRBCs	0 nRBC/100 WBC	0 nRBC/100 WBC



Platelets	150 – 450 x 10 ³ /μL	150 – 450 x 10 ⁹ /L
WBC (Total)	3.6 – 10.6 x 10 ³ /μL	3.6 – 10.6 x 10 ⁹ /L
Neutrophils (absolute)	1.7 – 7.5 x 10 ³ /μL	1.7 – 7.5 x 10 ⁹ /L
Neutrophils (relative)	50 – 70%	0.50 – 0.70
Lymphocytes (absolute)	1.0 – 3.2 x 10 ³ /μL	1.0 – 3.2 x 10 ⁹ /L
Lymphocytes (relative)	18 – 42%	0.18 – 0.42
Monocytes (absolute)	0.1 – 1.3 x 10 ³ /μL	0.1 – 1.3 x 10 ⁹ /μL
Monocytes (relative)	2 – 11%	0.02 – 0.11
Eosinophils (absolute)	0 – 0.3 x 10 ³ /μL	0 – 0.3 x 10 ⁹ /L
Eosinophils (relative)	1 – 3%	0.01 – 0.03
Basophils (absolute)	0 – 0.2 x 10 ³ /μL	0 – 0.2 x 10 ⁹ /L
Basophils (relative)	0 – 2%	0.00 – 0.02

Body Fluid Reference Ranges:

	Conventional Units	SI Units
<u>Cerebrospinal Fluid (CSF)</u>		
WBC and RBC	0 – 5/μL	0 – 5 x 10 ⁶ /L
Glucose	50 – 80 mg/dL	2.8 – 4.4 mmol/L
Protein	15 – 45 mg/dL	150 – 450 mg/L
<u>Seminal Fluid</u>		
Volume	2 – 5 mL	2 – 5 mL
Sperm concentration	> 20 x 10 ⁶ /mL	> 20 x 10 ⁹ /L



Urine

Specific gravity	1.003 – 1.035	1.003 – 1.035
pH	4.5 – 8.0	4.5 – 8.0
Protein	< 10 mg/dL, trace, or negative	< 0.1 g/L, trace, or negative
Bilirubin	negative	negative
Blood	negative	negative
Glucose	≤ 15 mg/dL or negative	≤ 0.8 mmol/L or negative
Nitrite	negative	negative
Leukocyte esterase	negative	negative
Urobilinogen	< 1.0 EU	< 17.0 μmol/L
Ketones	< 5 mg/dL or negative	< 0.5 mmol/L or negative
Microscopic		
RBC	0 – 3/HPF	0 – 3/HPF
WBC	0 – 8/HPF	0 – 8/HPF
Casts	0 – 2 hyaline/LPF	0 – 2 hyaline/LPF
Epithelial cells	0 – 5/HPF	0 – 5/HPF

END OF CONTENT GUIDELINE