# AC-PE Approved Cardiovascular Perfusion Curriculum

ADOPTED APRIL 30, 2004; Revised 6/2010

Foreword:

This document is designed to serve as an aid to perfusion program directors, providing the content areas to be included in any educational curriculum designed to adequately prepare students for entry into the clinical field of cardiovascular perfusion. Its development was based upon the curricula of active accredited programs, the *Knowledge Base for Cardiovascular Perfusion* document prepared by the American Board of Cardiovascular Perfusion, and the curriculum portion of the Standards and Guidelines of the Accreditation Committee – Perfusion Education (AC-PE) and the Commission on Accreditation of Allied Health Education Programs (CAAHEP).

The outlines provided herein cover 11 key content areas. Each ***Outline*** includes a ***Unit Objective*** which identifies the core theme of the topic, and ***Learner Objectives***, which define the expected quantifiable outcome following concentrated study of the subject area.

Some of the subject matter in several units of the curriculum may be covered through prerequisite course requirements for admission into cardiovascular perfusion education programs.

The AC-PE wishes to express its gratitude to the Perfusion Program Directors and faculty members from 1998 through the present who contributed so much time and energy toward the preparation of this curriculum.

# UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*1. MEDIASTINUM CARDIOVASCULAR ANATOMY*

**UNIT OBJECTIVE:**
This unit identifies the position of the heart in the thoracic cage, the surrounding structures and the exterior anatomy of the heart.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the location of the middle mediastinum and its surrounding structures;
(2) Describe the reflections of the pericardium onto surrounding structures
(3) Identify the various layers of the pericardium and heart muscle; and
(4) Identify the gross anatomy of the heart.

**OUTLINE:**

I. The middle mediastinum
   A. Location
   B. Surrounding structures
II. The pericardium
   A. External features
      1. inferior reflection onto the diaphragm
      2. superior and posterior reflections
   B. Cross-section
      1. fibrous pericardium
      2. serous pericardium
      3. pericardial space
      4. myocardium
      5. endocardium
III. Gross anatomy of the heart
   A. Aorta
   B. Pulmonary artery
   C. Superior vena cava
   D. Right atrium
   E. Inferior vena cava
   F. Left atrium
   G. Right ventricle
   H. Left ventricle

# UNIT 1: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*2. HEART*

**UNIT OBJECTIVE:**
This unit identifies the anteroposterior view of the heart, the chamber locations, and the internal features of each of the chambers and great vessels.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Define the apex and the base of the heart;
(2) Locate and identify the sulci;
(3) Use the sulci to identify the position of each heart chamber;
(4) Describe the chamber locations using words such as anterior, posterior, inferior, superior, and lateral; and
(5) Describe the internal features and structures associated with the right atrium, right ventricle, left atrium, and left ventricle.

**OUTLINE:**

I. Anteroposterior view
    A. Apex
    B. Base
    C. Sulci
    D. Chamber location with respect to anteroposterior view
    E. Superior and inferior vena cava
    F. Pulmonary artery
    G. Aorta
    H. Ligamentum arteriosum
II. Right atrium
    A. Sinus venarum
    B. Pectinated muscle
    C. Superior vena cava
    D. Inferior vena cava
    E. Position of the fossa ovalis
    F. Coronary sinus
III. Right ventricle
    A. Inflow — trabeculated muscle
    B. Outflow
    C. Tricuspid valve apparatus
    D. Pulmonary outflow
    E. Pulmonary valve
IV. Left atrium
    A. Left auricular appendage
    B. Pulmonary veins
    C. Position of the fossa ovalis
V. Left ventricle
    A. Inflow — trabeculated muscle
    B. Outflow
    C. Mitral valve apparatus
    D. Aortic outflow
    E. Aortic valve

# UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*3. CARDIAC ARTERIES, VEINS, AND MICROCIRCULATION*

**UNIT OBJECTIVE:**
This unit presents the names and locations of major cardiac arteries and veins and introduces myocardial microcirculation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Trace the right coronary artery through the major sulci of the heart and identify all of its major branches;
(2) Trace the left coronary artery through the major sulci of the heart and identify all of its major branches;
(3) Describe the various routes that blood moves through the myocardium; and
(4) Identify the major veins of the heart with emphasis on those that enter the coronary sinus.

**OUTLINE:**

I. Right coronary artery
   A. Main right coronary artery
   B. Conus branch
   C. Sinoatrialnodal branch
   D. Acute marginal branches
   E. Posterior descending branch
   F. Septal branches
   G. Atrioventricular nodal branch
II. Left coronary artery
   A. Main left coronary artery
   B. Anterior descending branch
   C. Circumflex branch
   D. Ramus medianus
III. Myocardial vasculature
   A. Arterio-luminal vessels
   B. Arterio-sinusoidal vessels
   C. Myocardial sinusoids
IV. Cardiac veins
   A. Thebesian veins
   B. Anterior cardiac veins
   C. Coronary sinus

# UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*4. CONDUCTION SYSTEM*

**UNIT OBJECTIVE:**
This unit identifies the major pathways of the electrical conduction through the heart.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Trace the path of the electrical signal through the atria and ventricles; and
(2) Describe several accessory pathways for this signal to circumvent the normal.

**OUTLINE:**
I. Sinoatrial node
II. Internodal tracts
    A. Middle
    B. Posterior
    C. Anterior
        1. Bacchman's bundle
III. Atrioventricular node
IV. Bundle-of-his
V. Bundle branches
    A. Right
    B. Left fascicles
VI. Accessory fibers

# UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*5. MAJOR ARTERIES, VEINS AND BRANCHES*

**UNIT OBJECTIVE:**
This unit identifies the names and locations of major arteries, arterial branches, major veins, and venous branches through the body.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Identify all of the major arterial branches from the aorta;
(2) Describe the route of arterial blood into the head;
(3) Describe the route of arterial blood into the arm;
(4) Describe the route of arterial blood into the leg;
(5) Identify all of the major venous branches into the superior vena cava;
(6) Identify all of the major venous branches into the inferior vena cava; and
(7) Describe the azygous venous drainage system.

**OUTLINE:**

I. Arteries
  A. Aorta
    1. right and left coronary artery
    2. arch vessels
    3. bronchial arteries
    4. intercostal arteries
    5. celiac artery
    6. superior mesenteric artery
    7. adrenal arteries
    8. renal arteries
    9. gonadal arteries
    10. inferior mesenteric artery
    11. right and left common iliac arteries
  B. To the head
    1. vertebral artery
    2. common carotid artery
    3. circle of Willis
  C. To the arm
    1. subclavian artery
    2. axillary artery
    3. brachial artery
  D. To the leg
    1. common iliac artery
    2. external iliac artery
    3. femoral artery
    4. popliteal artery

II. Veins
  A. Superior vena cava
    1. left and right innominate or brachiocephalic veins
  B. Inferior vena cava
  C. Azygous venous system

# UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*6. DEVELOPMENTAL AND CARDIAC EMBRYOLOGY*

**UNIT OBJECTIVES:**
This unit identifies the embryological development of the heart.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the embryonic stages for fetal development;
(2) Discuss tetatogenic / mal-development influences; and
(3) Describe the major events in the development of the heart and timing sequence.

**OUTLINE:**

I. Embryonic stages
   A. Week 2
      1. implantation
      2. trophoblast
      3. development of embryonic disc
      4. development of amniotic cavity and yolk disc
   B. Week 3
      1. gatrulation
      2. early development of central nervous system
      3. mesodermal differentiation
   C. Week 4
      1. fusion of amnion and chorion
      2. tubular development of head and tail
      3. aortic arch and single tube heart development

II. Teratology
   A. Etiology of human malformations
      1. genetic
      2. fetal environment
      3. drugs, radiation, and chemical
      4. miscellaneous
   B. Periods of susceptibility during organogenesis: weeks 3-8
   C. Prevention

III. Heart development
   A. Events
      1. extraembryonic blood vessels: days 13 –15
      2. blood islands and dorsal aorta: week 3
      3. cardiogenic plate: week 3
      4. single heart tube: by day 21
      5. pulsations of heart tube: day 22
      6. primitive circulation: end of week 3
      7. folding of heart tube: week 4
      8. formation of blood: week 5
      9. septation of heart: weeks 5-7

## UNIT I: BASIC SCIENCE

*A. CARDIOVASCULAR ANATOMY*
*7. VASCULAR EMBRYOLOGY*

**UNIT OBJECTIVES:**
This unit identifies the embryological development of the vasculature.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Identify the embryologic origins of major arteries and veins; and
(2) Describe fetal circulation.

**OUTLINE:**
I. Arteries
   A. Truncus arteriosus
   B. Aortic arches
   C. Intersegmental arteries
   D. Vitelline arteries
II. Veins
   A. Common cardinal veins
   B. Anterior and posterior cardinal veins
   C. Supreacardinal and subcardinal veins
   D. Vitelline arteries
III. Fetal circulation
   A. Ductus arteriosis
   B. Foramen ovale
   C. Umbilical artery and vein
   D. Bradykinin

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*1. ADULT CARDIAC VALVULAR PATHOLOGY AND SURGICAL REPAIR*

**UNIT OBJECTIVE:**
This unit identifies adult valvular cardiac surgical pathology.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Recall the anatomical features of adult valvular disease; and
(2) Discuss the pathophysiology of valvular disease.

**OUTLINE:**

I. Aortic valve
   A. Surgical anatomy
   B. Aspects of stenosis and regurgitation
   C. Pathological features
      1. infective endocarditis
      2. rheumatic heart disease
      3. senescence
      4. stenosis (excluding rheumatic)
      5. regurgitation

II. Mitral valve
   A. Surgical anatomy
   B. Pathological features
      1. rheumatic heart disease
      2. infective endocarditis
      3. prolapse of floppy valve

III. Surgical pathology of tricuspid valve

IV. Surgical anatomy of pulmonary valve

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*2. ADULT CORONARY ARTERY PATHOLOGY*

**UNIT OBJECTIVE:**
This unit identifies adult coronary surgical pathology.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the anatomical features of coronary artery disease; and
(2) Discuss the pathophysiology of adult coronary disease.

**OUTLINE:**
I. Anatomy of coronary arteries
    A. Media
    B. Intima
    C. Adventitia
    D. Endothelium
    E. Vascular smooth muscle
    F. Innervation
    G. Vaso vasorum
II. Risk factors for coronary disease
    A. Modifiable
    B. Unmodifiable
III. Pathogenesis of atherosclerosis
    A. Endothelial cells
    B. Macrophages
    C. Platelets
    D. Vascular smooth muscle
IV. Susceptibility of coronary arteries to atherosclerosis
    A. Size of coronary arteries
    B. Lesions of main stem arteries or distal lesions
    C. Histological aspects of atherosclerosis
V. Relationship with thrombosis
VI. Ischemia vs. infarction
VII. Myocardial infarction
    A. Progression of infarction
    B. Types of infarction
    C. Complications of infarction
    D. Serum markers of infarction
    E. Cardiac markers of infarction and heart failure
VIII. Surgery for coronary artery disease
    A. Coronary artery bypass grafting (CABG)
        1. saphenous vein
        2. internal mammary
        3. radial artery
    B. Transmyocardial revascularization (TMR)
    C. Percutaneous transluminal coronary angioplasty (PTCA)
    D. Off-CPB CABG
    E. Patency and mortality rates

## UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*3. PERFUSION TECHNIQUES FOR AORTIC ANEURYSM DISSECTIONS: THORACIC AND THORACOABDOMINAL*

**UNIT OBJECTIVE:**
This unit introduces adjunctive techniques of extracorporeal circulation for temporary compensation of loss or compromised hemodynamic and oxygenation to a localized area of patient's body required by corrective surgery of thoracic and thoracoabdominal aneurysms.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Identify the various types of thoracic and thoracoabdominal aneurysms;
(2) Understand the concepts of partial hemodynamic support/oxygenation, hypothermia, circulatory arrest and flow distribution to vital organs;
(3) Understand and identify available current technologies for adjunctive extracorporeal techniques after surgical correction of thoracic and thoracoabdominal aneurysm; and
(4) Make technical applications of learned concepts to various clinical situations and pathologies.

**OUTLINE:**

I. Type of Pathologies
   A. DeBakey's classification of thoracic aneurysm
      1. Stanford Type AB
      2. DeBakey Type I II III
   B. Crawford's classification of thoracoabdominal aortic aneurysm
      1. Type I
      2. Type II
      3. Type III
      4. Type IV

II. Extracorporeal Circulatory Concepts
   A. Hypothermia (review hypothermia section)
      1. Q10
      2. Threshold/gradient
      3. Thermodynamics of oxygen consumption/demand
      4. Hypothermic response – shivering – anesthesia
      5. Alpha-stat/pH stat strategy
   B. Circulatory Arrest – DHCA
      1. Coagulopathy – DIC
      2. Hemostasis
      3. Pathology
      4. Rheology – sludging
      5. Fluid shift – oncotic pressure – capillary leakage
   C. Current Available Technologies
      1. Coated Circuits
      2. Hemostatic monitors
      3. Pharmacological agents
      4. Spinal Drainage
      5. Ice helmet
      6. Cerebral Oximetry

7. In-line blood gas monitors
8. Special cannulaes

D. Applications of Techniques and Extracorporeal Techniques
1. Retrograde cerebral perfusion
2. Antegrade cerebral perfusion
3. Circulatory arrest
4. Hemostasis management
5. Coated circuitry
6. Technical circuitry relative to operable lesions: heat exchanger; oxygenator; and reservoir
7. Cannulation sites relative to operable lesions
8. Distal aortic operation techniques
9. Proximal aortic operation techniques
10. Left-sided heart bypass and selective visceral perfusion
11. Hemodynamic monitoring techniques – including renal artery interpretations and flow adjustments

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*4. CONGESTIVE HEART FAILURE*

**UNIT OBJECTIVE:**
This unit introduces the etiology and presentation of congestive heart failure.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the pathophysiology of congestive heart failure
(2) Describes the history, clinical signs, surgical techniques, and complications associated with congestive heart failure.

**OUTLINE:**

I. Determinants of myocardial performance
   A. Preload
   B. Ejection fraction
   C. Oxygen consumption
II. Clinical causes of CHF
   A. Viral
   B. Ischemic
   C. Idiopathic
   D. Antibody

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*5. CONGENITAL HEART DEFECTS: LEFT TO RIGHT SHUNTS*

**UNIT OBJECTIVE:**
This unit introduces the anatomy, pathological presentation and surgical correction of congenital left to right shunts.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the anatomy of the typical left to right shunts;
(2) Describe the pathological presentation of the typical left to right shunts;
(3) Describe the standard surgical corrections for the typical left to right shunts; and
(4) Discuss extracorporeal circuitry and techniques as they relate to the typical left to right shunts.

**OUTLINE:**

I. Atrial septal defect (ASD)
  A. Anatomy
    1. sinus venosus
    2. septum secundum
    3. ostum primum
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques
II. Ventricular septal defect (VSD)
  A. Anatomy
    1. types
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques
III. Patient ductus arteriosus (PDA)
  A. Anatomy
    1. types
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques
IV. Atrioventricular septal defect
  A. Anatomy
    1. endocardial cussion defect variable

- B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
- C. Surgical correction
- D. Extracorporeal circuitry and techniques

V. Double outlet right ventricle
- A. Anatomy
    1. endocardial cussions defect variable
- B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
- C. Surgical correction
- D. Extracorporeal circuitry and techniques

VI. Aortopulmonary window (APW)
- A. Anatomy
    1. endocardial cussions defect variable
- B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
- C. Surgical correction
- D. Extracorporeal circuitry and techniques

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*6. CONGENITAL HEART DEFECTS: CYANOTIC ANOMALIES*

**UNIT OBJECTIVE:**
This unit introduces the anatomy, pathological presentation and surgical correction of congenital cyanotic anomalies.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the anatomy of the typical cyanotic anomalies;
(2) Describe the pathological presentation of the typical cyanotic anomalies;
(3) Describe the standard surgical corrections for the typical cyanotic anomalies; and
(4) Discuss extracorporeal circuitry and techniques as they relate to the typical cyanotic anomalies.

**OUTLINE:**

I. Tetrology of fallot (TOF)
  A. Anatomy
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
    1. palliative shunts
    2. complete repairs
  D. Extracorporeal circuitry and techniques
II. Transposition of the great arteries (TGA)
  A. Anatomy
    1. simple
    2. complex
      a. VSD
      b. pulmonary stenosis
  B. Pathophysiology
    1. parallel circulations and mixing
  C. Surgical correction
    1. palliative procedures
    2. atrial switch
    3. arterial switch
  D. Extracorporeal circuitry and techniques
III. Truncus arteriosis
  A. Anatomy
    1. types I-IV
    2. associated anomalies
  B. Pathophysiology
  C. Surgical correction
  D. Extracorporeal circuitry and techniques

IV. Total anomalous pulmonary venous tryutn (TAPVR)
    A. Anatomy
        1. supracardiac
        2. cardiac
        3. infracardiac
        4. mixed
    B. Pathophysiology
    C. Surgical
    D. Extracorporeal circuitry and techniques
V. Ebsteins's anomaly
    A. Anatomy
        1. atrialized ventricular tissue
    B. Pathophysiology
    C. Surgical
    D. Extracorporeal circuitry and techniques

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*7. CONGENITAL HEART DEFECTS: OBSTRUCTIVE ANOMALIES*

**UNIT OBJECTIVE:**
This unit introduces the anatomy, pathological presentation and surgical correction of obstructive anomalies.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the anatomy of the obstructive anomalies;
(2) Describe the pathological presentation of the typical obstructive anomalies;
(3) Describe the standard surgical corrections for the typical obstructive anomalies; and
(4) Discuss extracorporeal circuitry and techniques as they relate to the typical obstructive anomalies.

**OUTLINE:**

I. Aortic stenosis
  A. Anatomy
    1. valvular
    2. sub valvular
    3. supra valvular
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques
II. Pulmonary stenosis
  A. Anatomy
    1. valvular
    2. sub valvular
    3. supra valvular
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques
III. Coarciation of the aorta
  A. Anatomy
    1. relationship to ductus artorious
  B. Pathophysiology
    1. natural history
    2. clinical presentation
    3. diagnosis
  C. Surgical correction
  D. Extracorporeal circuitry and techniques

IV. Interrupted aortic arch
    A. Anatomy
        1. types A, B, C
    B. Pathophysiology
        1. natural history
        2. clinical presentation
        3. diagnosis
    C. Surgical correction
    D. Extracorporeal circuitry and techniques

# UNIT I: BASIC SCIENCE

*B. PATHOLOGY AND SURGICAL REPAIR*
*8. CONGENITAL HEART DEFECTS: MISCELLANEOUS ANOMALIES*

**UNIT OBJECTIVE:**
This unit introduces the anatomy, pathological presentation and surgical correction of miscellaneous congenital anomalies.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the anatomy of the unusual congenital anomaly;
(2) Describe the pathological presentation of the unusual congenital anomaly;
(3) Describe the standard surgical corrections for the unusual congenital anomaly; and
(4) Discuss extracorporeal circuitry and techniques and they relate to the unusual congenital anomaly.

**OUTLINE:**

I. Hypoplastic left heart syndrome
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction
   D. Extracorporeal circuitry and techniques
II. Single ventricle
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction including hybrid procedures
   D. Extracorporeal circuitry and techniques
III. Pulmonary atresia
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction
   D. Extracorporeal circuitry and techniques
IV. Corrected transportation
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction
   D. Extracorporeal circuitry and techniques

V. Cor triatriatum
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction
   D. Extracorporeal circuitry and techniques
VI. Coronary anomalies
   A. Anatomy
   B. Pathophysiology
      1. natural history
      2. clinical presentation
      3. diagnosis
   C. Surgical correction
   D. Extracorporeal circuitry and techniques

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*1. CARDIOVASCULAR PHYSIOLOGY*

**UNIT OBJECTIVE:**
This unit introduces cardiovascular physiology.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Understand the basis of action potentials in controlling heart contraction;
(2) Understand the role of calcium and calcium cycling proteins in cardiac contraction;
(3) Understand the determinants of arterial blood pressure;
(4) Understand the determinants of cerebral, pulmonary and coronary blood flow; and
(5) Understand the normal cardiac cycle and can explain myocardial performance with Starlings laws and Wigger diagrams.

**OUTLINE:**

I. The heart as a pump
II. Action potentials (AP)
III. Mechanism of contraction: excitation-contraction coupling
IV. Regulation of mean arterial blood pressure (MAP)
V. Cerebral circulation
    A. Cerebral blood flow (CBF)
    B. Regulation
VI. Pulmonary circulation
    A. Hypoxic pulmonary vasoconstriction (HPV)
    B. Pulmonary hypertension
VII. Coronary circulation
    A. Determinants of coronary blood flow
    B. Metabolites
    C. Determinates of oxygen supply to the myocardium
    D. Determinants of oxygen consumption
VIII. Myocardial performance
    A. Starling's law of the heart
        1. starling curves
    B. Pressure - volume loops
        1. the ventricular cycle Wiggers diagram
        2. the atrial cycle
        3. cardiac valves
IX. Heart sounds
X. Determination of cardiac output

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*2. CARDIOVASCULAR HEMODYNAMICS*

**UNIT OBJECTIVE:**
This unit introduces cardiovascular hemodynamics.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the anatomical components of the vasculature; and;
(2) Describe the hemodynamic principles associated with blood flow through the circulatory system.

**OUTLINE:**

I. Circuitry of the cardiovascular system
    A. Interdependence of the pulmonary and systemic circulations
    B. Direction of blood flow is due the cardiac and venous valves
II. Hemodynamics
    A. Components of the vasculature
        1. arteries
        2. arterioles
        3. capillaries
        4. venules
        5. veins
    B. Velocity of blood flow
    C. Blood flow
        1. determinants of cardiac output
            a. stroke volume
            b. vascular resistance
            c. heart rate
            d. filling pressure
        2. vascular regulation of blood flow
    D. Resistance
    E. Capacitance (compliance)

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*3. RENAL PHYSIOLOGY*

**UNIT OBJECTIVE:**
This unit presents the basics of renal physiology.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the basic functions of the kidney;
(2) Describe how various ions, sugars, and proteins are managed by the kidney; and
(3) Describe endocrine regulation of blood pressure and hematopoiesis.

**OUTLINE:**

I. Function of the kidney
   A. Water balance
   B. Electrolyte balance
   C. Plasma volume
   D. Acid-base balance
   E. Osmolarity balance
   F. Excretion
   G. Hormone secretion
II. Renal processes
   A. Glomerular filtration
   B. Tubular reabsorption
   C. Tubular secretion
III. Endocrine regulation
   A. Renin-angiotension-aldosterone system
   B. ACE inhibitors
   C. Erythropoietin – formation of RBCs

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*4. VENTILATION, OXYGENATION, RESPIRATION*

**UNIT OBJECTIVE:**
This unit presents the basics of pulmonary physiology.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the basic functions of the lungs;
(2) Describe basic pulmonary functional parameters; and
(3) Describe physical and biological principles relating to gas exchange.

**OUTLINE:**
I. Function of the lungs
   A. The airways
   B. The alveolus
   C. Alveolar-capillary membrane
   D. Pressures of the respiratory system
   E. Sequence of ventilation
II. Ventilation mechanics
   A. Lung volumes and capacities
   B. Inspiration
   C. Expiration
   D. Compliance
   E. Chest elastic recoil
III. Pathology
   A. Obstructive lung disease (emphysema and asthma)
   B. Restrictive lung disease (pulmonary fibrosis)
IV. Gas exchange
   A. Whole body diffusion gradients
      1. oxygen
      2. carbon dioxide
   B. Determinants of alveolar gas tensions
      1. alveolar oxygen tensions
      2. alveolar carbon dioxide tensions
      3. correcting for water vapor pressure
      4. alveolar air equation
      5. changes in alveolar gas partial pressures
   C. Mechanisms of diffusion
      1. barriers to diffusion
      2. Fick's law
      3. pulmonary diffusion gradients
      4. diffusion coefficients
      5. time limitations to diffusion
      6. measurement of diffusion capacity
   D. Anatomic shunts
      1. bronchial venous drainage
      2. thebesian venous drainage
   E. Regional inequalities in ventilation and perfusion
      1. effect of increasing alveolar ventilation
      2. effect of altering pulmonary capillary blood flow

F. Effect of altering $V_A/Q_C$ ratio
    1. perfusion in excess of ventilation
    2. ventilation in excess of perfusion
G. Oxyhemoglobin dissociation curve

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*5. MYOCARDIAL PHYSIOLOGY*

**UNIT OBJECTIVE:**
This unit describes myocardial metabolism, myocardial electrical potentials, and the pathophysiology of myocardial ischemia.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the metabolic requirements of the cardiac muscle;
(2) Explain the myocardial energy sources and the difference between aerobic and anaerobic energy production;
(3) Describe the membranous and ionic basis for cardiac electrical potential; and
(4) Recognize the metabolic, cellular, and functional changes that occur during ischemia and reperfusion injury.

**OUTLINE:**

I. Myocardial metabolism
   A. Myocardial oxygen supply and demand
   B. Aerobic vs. anaerobic metabolism, ATP production and byproducts
   C. Energy sources - glucose, lactate, fatty acids
II. Cardiac electrical conduction
   A. Action potential and ion gradients
   B. Depolarized and hyperpolarized arrest
III. Ischemic injury and cellular necrosis
   A. Diastolic dysfunction
   B. Reperfusion injury

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*6. HEMATOLOGY*

**UNIT OBJECTIVE:**
This unit introduces the cellular components of blood and the collection, processing and storage of individual blood components.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the cellular elements of blood and their function;
(2) List the primary plasma proteins and their function;
(3) Describe the collection and processing of individual blood components; and
(4) Explain the purpose of ABO blood grouping and Rh typing.

**OUTLINE:**

I. Cellular elements
   A. Erythrocytes
   B. Platelets
   C. Leukocytes
II. Plasma proteins
   A. Albumin
   B. Fibrinogen
   C. Globulins
III. Blood banking
   A. Storage solutions
   B. Component therapy
   C. Crossmatching
   D. Complications
IV. Transfusion products
   A. RBC
   B. FFP
   C. Platelets
   D. Cryoprecipitate
V. The methods used to insure safe transfusion practices

# UNIT I: BASIC SCIENCE

*C. PHYSIOLOGY*
*7. COAGULATION MANAGEMENT*

**UNIT OBJECTIVE:**
This unit describes the process of and management of hemostasis as applicable to the practice of perfusion care.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the physiology of coagulation and the process of hemostasis;
(2) Describe the various components of hemostasis;
(3) Discuss various coagulopathic states and treatments thereof; and
(4) Discuss measurement of laboratory values regarding normal and abnormal hemostatic states.

**OUTLINE:**

I. Physiology of coagulation and hemostasis
    A. Elements, proteins, and cellular and other anatomic structures associated with hemostasis
    B. Initiation of hemostasis
    C. Amplification phase of clot formation
    D. Development of primary hemostatic mass
    E. Contraction of smooth muscle
    F. Healing and restoration of endothelial continuity
II. The platelet and formation of the primary hemostatic plug
    A. Platelet production and destruction
    B. Platelets activation
        1. stimulators
        2. secretors
        3. platelet receptor sites
III. Coagulation cascade and formation of the fibrin clot
IV. The fibrinolytic system
V. Assessment of coagulation
VI. Coagulation Disorders, etiology and treatment
    A. Heparin resistance
    B. HIT
    C. DIC
    D. platelet dysfunction
    E. Factor deficiency

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*1. PHARMACODYNAMICS & PHARMACOKINETICS*

**UNIT OBJECTIVE:**
This unit describes the effect of cardiopulmonary bypass on the pharmacodynamics and pharmacokinetics of drugs used during open-heart surgical procedures**.**

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the pharmacodynamic effects of administration of drugs through oral, and intra-venous routes;
(2) Identify the routes of clearance of drugs;
(3) Describe the concept of volume of distribution of drugs; and
(4) Describe the effect of protein binding of drugs.

**OUTLINE:**

I. Pharmacodynamics
II. Pharmacokinetics
    A. Absorption
    B. Distribution
    C. Elimination (metabolism, excretion, clearance)
III. Effects of hypothermia on drug action
IV. Effects of hemodilution on drug action
V. Effects of hemoconcentration on drug blood levels
VI. Effects of blood salvage techniques on drug levels
    A. Hemoconcentration
    B. Blood salvage
VII. Effects of altered perfusion
VIII Factors affecting drug-receptor interaction
IX. CPB affecting receptor-mediated events

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*2. PHARMACOLOGY OF ANESTHETIC AGENTS*

**UNIT OBJECTIVE:**
This unit introduces the pharmacologic agents and techniques used during cardiac surgery.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the metabolism and mechanism of action of the specific agents in each of the primary classes of anesthetic drugs; and
(2) Describe standard anesthetic practice as it relates to the cardiac surgical patient.

**OUTLINE:**

I. Opioids
   A. Classification
   B. Metabolism
   C. Mechanism of action
   D. Specific opioids used in anesthesia
      1. morphine
      2. fentanyl
      3. sufentanil
      4. remifentanil

II. Non-opioids
   A. Classification
   B. Metabolism
   C. Mechanism of action
   D. Specific non-opioids used in anesthesia
      1. barbiturates
      2. thiopental
      3. benzodiazapines
      4. diazepam
      5. midazolam and lorazepam
      6. ketamine
      7. propofol
      8. etomidate

III. Inhalation agents
   A. Classification
   B. Metabolism
   C. Mechanism of action
   D. Specific non-opioids used in anesthesia
      1. halothane
      2. isoflurane
      3. enflurane
      4. nitrous oxide

IV. Muscle Relaxants
    A. Classification
    B. Metabolism
    C. Mechanism of action
    D. Specific non-opioids used in anesthesia
        1. pancuronium
        2. vercuronium
        3. rocuronium
V. Reversal of neuromuscular blockade
VI. Induction and maintenance of anesthesia
    A. High-dose narcotic technique
    B. Fast-tracking technique
VII. Anesthesia for pediatrics

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*3. ANTI-ARRHYTHMIC PHARMACOLOGY*

**UNIT OBJECTIVE:**
This unit presents the names, uses, and mechanism of action of antiarrhythmic drugs used during cardiac surgery.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the use and dosage of each classification of antiarrhythmic; and
(2) Identify the mechanism of action of the classes of antiarrhythmias.

**OUTLINE:**
I. Classification of antiarrhythmic drugs
   A. Class I
   B. Class II
   C. Class III
   D. Class IV
II. Drugs used in treatment of dysrhythmias
   A. Ventricular tachycardia
   B. Atrial fibrillation or flutter
   C. Malignant arrhythmias
   D. Bradycardia or heart block
   E. Special considerations
      1. pediatric patient
      2. transplant patient

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*4. INOTROPHIC AND VASOPRESSOR PHARMACOLOGY*

**UNIT OBJECTIVE:**
This unit presents the names, uses, and mechanism of action of cardiotrophics drugs used during cardiac surgery.

**LEANER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the genesis of cardiac heart failure;
(2) Describe the use and dosage of each classification of cardiotrophic agent; and
(3) Identify the mechanism of action of the classes of cardiotrophic drugs.

**OUTLINE:**

I. Background pathogenesis of congestive heart failure
   - A. Ischemic
   - B. Idiopathic
   - C. Viral
   - D. Antibody

II. Inotropes and vasopressors
   - A. Autonomic nervous system (ANS)
     1. sympathetic
     2. cholinergic
   - B. Autonomic receptor types and result of stimulation or blocking of receptor site
     1. alpha
     2. beta
     3. muscarinic
   - C. Drugs that effect PNS
     1. agonists
     2. antagonists
   - D. Sympathomimetic drugs
     1. adrenergic
     2. non-adrenergic
   - E. Non-sympathomimetic inotropic drugs
   - F. Special considerations

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*5. VASODILATORS*

**UNIT OBJECTIVE:**
This unit describes vasodilators, their mechanism of action and their role in managing hypertensive states and congestive heart failure.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Identify the classification of vasodilators;
(2) Identify the mechanism of action of each class; and
(3) Identify the clinical use of each vasodilator.

**OUTLINE:**
I. Sites of action
   A. Veins
   B. Arteries
   C. Mixed
II. Mechanisms of action
   A. Direct vasodilators
   B. $\beta$ -blockers
   C. ACE-inhibitors
   D. $D_1$-receptor agonists
III. Clinical uses
IV. Side effects (blocked by $\beta$ -blockade)
V. Nitroprusside toxicity
VI. Special considerations

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*6. PHARAMCOLOGICAL TREATMENT OF CONGESTIVE HEART FAILURE (CHF)*

**UNIT OBJECTIVE:**
This unit presents the basic pharmacological agents used for treatment of heart failure.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the therapeutic approach for medical treatment of heart failure;
(2) Identify the classes of drugs used for heart failure; and
(3) Describe the mechanism of action of each class of therapeutics.

**OUTLINE:**

I. Possible means of increasing myocardial contractility
   A. Mechanism of action
II. Inotropic agents
III. Diuretics
IV. Vasodilators

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*7. ANTIMICROBIAL AGENTS/ANTIBIOTICS*

**UNIT OBJECTIVE:**
This unit introduces the basics of antimicrobial therapeutics and introduces organismal contamination during open heart surgery and its therapeutic treatment with antimicrobials.

**LEARNER OBJECTIVE:**
Upon completion of this unit the student will be able to:

(1) Identify the sources of infection and the common contaminating organisms during open heart surgery.

**OUTLINE:**

I. Sources of infection in the cardiac surgery patient
II. Bacteria
    A. Gram negative
    B. Gram positive
    C. Fungal
III. Definition & characteristics of antibiotics
IV. Mechanism of action
    A. Resistance of microorganisms to antimicrobial agents
    B. Selection of agents
    C. Prophylaxis of infection with antibiotics
    D. Specific agents
        1. bactericidal drugs that work on the cell wall
            a. cephalosporins
            b. vancomycin (vancocin)
        2. bactericidal inhibitors of protein synthesis - aminoglycosides
        3. anti-fungal agents
V. Use of topical antibiotics in the cardiac surgery O.R.
VI. Contraindications in use of antibiotics and cell savers

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*8. ANTICOAGULANTS*

**UNIT OBJECTIVES:**
This unit describes the pharmacology of anticoagulants.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Discuss the different mechanisms of anticoagulation; and
(2) Describe clinical application of specific anticoagulants.

**OUTLINE:**
I. Agents that affect clot formation
  A. Heparin
    1. monitoring heparin anticoagulation
    2. heparin induced thrombocytopenia (hit)
    3. heparin neutralization
  B. Warfarin
  C. Low molecular weight heparins
  D. Hirudin
II. Anti-platelet agents
  A. Aspirin
  B. GP IIb/IIIa receptor antagonists
  C. Ticlopidine
  D. Dipyridamole
III. Others
  A. Dextran

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*9. HEPARIN INDUCED THROMBOCYTOPENIA (HIT)*

**UNIT OBJECTIVE:**
This unit describes the immunological basis and the clinical approach to HIT.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Discuss patient risk associated with receiving chronic heparin therapy;
(2) Explain the immunological basis for HIT; and
(3) Identify clinical management approaches that a perfusionist should use for HIT positive patients.

**OUTLINE:**

I. Background
   A. Heparin
   B. Thrombocytopenia
II. Consequence of HIT
   A. Arterial thrombosis
   B. DIC
III. Mechanism
   A. LgG antibody
   B. Antiheparin antibody
   C. Heparin–PF 4 on platelet membranes
IV. Management
   A. Stopping the heparin
   B. Warfarin
   C. Ticlopidine
V. Alternate anticoagulation
   A. The low-molecular-weight heparins
   B. The low-molecular-weight heparinoids
   C. Hirudin, bivalirudin (Hirulog), and argatroban
   D. Platelet aggregarion inhibitors
VI. Assays
   A. Factor xa assays
   B. Activated clotting time (ACT)
   C. Reversal of anticoagulation at the end of CPB
   D. Protamine
   E. Ancrod

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*10. ANTITHROMBIN III DEFICIENCY*

**UNIT OBJECTIVE:**
This unit introduces AT III deficiency and describes its management.

**LEARNER OBJECTIVES:**
Upon completion of the unit the student will be able to:

(1) Describe the etiology of AT III deficiency;
(2) Discuss the management of the AT III deficient patient; and
(3) Discuss bypass considerations and management of the AT III deficiency.

**OUTLINE:**

I. Defining the AT III deficient patient
   A. Inherited
   B. Acquired
   C. Normal AT III level
   D. Age considerations
   E. Patients at risk, preexisting conditions
II. Management of the AT III deficient patient
   A. Heparin resistance
   B. DIC considerations
   C. Heparin administration (min ACT achieved, u/kg administered)
III. Cardiopulmonary bypass considerations
   A. Patient evaluation
   B. Confidence of heparin administration
   C. Alternative source of heparin administration
   D. Redosing the patient

# UNIT I: BASIC SCIENCE

*D. PHARMACOLOGY*
*11. CHEMOTHERAPEUTIC, IMMUNOSUPPRESSIVE AND DIABETIC AGENTS*

**UNIT OBJECTIVE:**
This unit introduces chemotherapeutic, immunosuppressive and diabetic agents.

**LEARNER OBJECTIVE:**
Upon completion of this unit the student will be able to:
(1) Describe the role and mechanism of action of each class of drugs.

**OUTLINE:**
I. Chemotherapeutic agents
II. Anti-inflammatory drugs
III. Buffers
IV. Immunosuppression
V. Anticonvulsants
VI. Diabetic therapy

# UNIT I: BASIC SCIENCE

*E. PHYSICS*

**UNIT OBJECTIVES:**
This unit introduces principles and concepts from physics and relates them to extracorporeal circulation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the relationship between velocity, acceleration and motion in one or more dimensions;
(2) Describe the relationship between temperature of an object and the average kinetic energy of the atoms and molecules composing the object; and
(3) Apply the laws of mechanics to viscous and nonviscous fluids.

**OUTLINE:**

I. The general laws of motion
   A. Newton's three laws of motion
   B. Work, energy and power
II. Heat
III. Fluids
   A. The mechanics of nonviscous fluids
   B. Viscous fluid flow
      1. cohesive forces in liquids
      2. physics of the circulatory system
IV. Ideal gas
   A. Temperature
   B. Pressure
   C. Volume
V. Electricity and magnetism
   A. Electric currents
   B. Work
   C. Transmit information
   D. Electromagnetic waves
VI. Wave motion

# UNIT I: BASIC SCIENCE

*F. CHEMISTRY*

**UNIT OBJECTIVE:**
This unit introduces principles and concepts from chemistry and relates them to extracorporeal circulation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe various properties of aqueous solutions; and
(2) Discuss amino acids, lipids, active transport and enzymes as they relate to cellular physiology.

**OUTLINE:**

I. Aqueous solutions
   A. Molar
   B. Normality
   C. Molarity
   D. Molecular weights
   E. Buffers
   F. Osmolality
II. Amino acids
III. Lipids
IV Active transport
V. Enzymes

# UNIT I: BASIC SCIENCE

*G. MATHEMATICS*

**UNIT OBJECTIVE:**
This unit identifies mathematical computations commonly associated with cardiopulmonary bypass.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the basis of each calculation; and
(2) Apply the formulas to clinical scenarios.

**OUTLINE:**

I. Volumes
   A. Blood volume
   B. Extracellular volume
   C. Circuit volumes
II. Velocity of blood flow
III. Blood flow
IV. Resistance
   A. Poiseuille's equation
   B. Laminar flow vs. turbulent flow
V. Capacitance (compliance)
VI. Arterial pressure
VII. Vascular resistances
VIII. Blood oxygen calculations
   A. Content
   B. Delivery/transport
   C. Consumption/extraction
IX. $HCO_3$ correction
X. Serum $K^+$ correction
XI. Resultant hematocrit
XII. Body surface area

# UNIT I: BASIC SCIENCE

*H. IMMUNOLOGY*
*1. IMMUNOLOGY OF BLOOD CONTACT WITH ARTIFICIAL MATERIALS*

**UNIT OBJECTIVE:**
This unit illustrates the pathways responsible for an immunological response to blood contact with artificial materials.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the pathways that contribute to inflammation following blood contact with artificial materials; and
(2) Identify the pathways that can be modulated to reduce induction of these immune pathways.

**OUTLINE:**

I. Artificial surfaces
   A. Plastics
      1. types
      2. characteristics
   B. Metals
      1. types
      2. characteristics
   C. Others
      1. varieties
      2. characteristics
II. Complement system
   A. Cascade
   B. Factors modulating the complement cascade
III. Immune system
   A. Cytokines
   B. Cells
   C. Inflammatory response

# UNIT I: BASIC SCIENCE

*H. IMMUNOLOGY*
*2. IMMUNOLOGY OF REPERFUSION INJURY*

**UNIT OBJECTIVE:**
This unit describes the basic immunological basis for reperfusion injury.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe when reperfusion injury may occur;
(2) Describe the immunological basis of reperfusion injury; and
(3) Identify the pharmacological agents that may reduce reperfusion injury.

**OUTLINE:**

I. Definition of reperfusion injury
II. Immunology
    A. Reperfusion injury causes vascular endothelial damage and that event may lead to myocyte dysfunction
    B. Cellular mediators
    C. Soluble mediators
III. Pharmacological modulation
    A. Neutrophil modulation
    B. Platelet modulation
    C. Protection of vascular endothelium
    D. Protection of cardiac myocyte

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*

*1. PERFUSION CIRCUITS*

**UNIT OBJECTIVE:**

This unit describes the individual circuit components for cardiopulmonary bypass.

**LEARNER OBJECTIVES:**

Upon completion of this unit the student will be able to:

(1) Describe the characteristics of the components of a perfusion circuit;
(2) Describe all of the safety devices for the perfusion circuit; and
(3) Discuss how all of the above fit together for a safe and controllable system.

**OUTLINE:**

I. Perfusion circuits
   - A. Open
   - B. Closed
   - C. Adult
   - D. Pediatric
   - E. Infant
   - F. Mini bypass circuit with and without venous reservoir

II. Safety
   - A. Response time
   - B. Alarms
   - C. Servoregulation

III. Design considerations

IV. Designing the circuit
   - A . Venous line
     1. pre-bypass filter
     2. diameter
   - B. Arterial pump line
     1. occlusion
     2. flow monitoring
   - C. Arterial outlet line
   - D. Arterial filter
   - E. Arterial line
   - F. Suckers and vent lines
   - G. Cardiotomy line
   - H. Quick prime line
   - I. Gas line
     1. gas filter
     2. gas mixer
     3. oxygen analyzer
   - J. Manifold system
   - K. Cardioplegia delivery system
     1. pressure monitoring
     2. temperature monitoring
     3. flow monitoring
   - L. Oxygenator

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*2. TUBING*

**UNIT OBJECTIVE:**

This unit introduces the variety of tubing types used in cardiopulmonary bypass circuits.

**LEARNER OBJECTIVES:**

Upon completion of this unit the student will be able to:

(1) Describe the types of extracorporeal tubing used in the past and present;
(2) Define spallation;
(3) State the volumes contained per foot of common tubing sizes;
(4) Define durometer;
(5) Describe methods for sterilizing extracorporeal circuitry; and
(6) Discuss surface modified tubing and its clinical application.

**OUTLINE:**

I. Tubing
   A. Type
   B. Manufacturing process
   C. Wall thickness
   D. Physical characteristics
   E. Internal diameter
   F. Volume
   G. Spallation
   H. Wall thickness
   I. Durometer
II. Connectors
   A. Tie bands
   B. Bonding
   C. Materials
III. Sterility
   A. Methods of sterilization
   B. Care in packaging
IV. Surface modifications

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*3. PUMPS*

**UNIT OBJECTIVE:**
This unit introduces the various types of pumps used during cardiopulmonary bypass.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Identify the different types of pumps used during CPB and explain their function; and
(2) Discuss safety concerns and methods of servoregulating each type of pump.

**OUTLINE:**
I. Historical blood pumps
   A. General description
   B. Safety concern
II. Roller pumps
   A. General description
   B. Safety concerns
   C. Servoregulation
III. Centrifugal pumps
   A. General description
   B. Safety concerns
   C. Servoregulation
IV. Other pumps
   A. General description
   B. Safety concerns
   C. Servoregulation

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*4. EXTRACORPOREAL FILTERS*

**UNIT OBJECTIVE:**
This unit introduces the various types of filters used during cardiopulmonary bypass.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the different types of filtering technology used during CPB; and
(2) Discuss the characteristics of individual filter types used during CPB.

**OUTLINE:**
I. Description of filter technology
   A. Depth
   B. Screen
   C. Affinity
   D. Defoaming agent
   E. Air handling characteristics
   F. Bubble point pressure
II. Specific CPB filters
   A. Arterial line filter
   B. Cardiotomy/reservoir filters
   C. Cardioplegia filters
   D. Pre-bypass filters
   E. Transfusion filters
   F. Gas filters
   G. Leukodepletion
   H. Lipid removal
   I. Hydrophobic filters for air removal

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*5. OXYGENATORS*

**UNIT OBJECTIVE:**
This unit introduces the variety of oxygenators used in cardiopulmonary bypass circuits.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the characteristics of an ideal oxygenator;
(2) Discuss the historical development of oxygenator techniques;
(3) Describe different types of membrane oxygenators; and
(4) Discuss the oxygen characteristics of different membrane oxygenators.

**OUTLINE:**
I. Characteristics of an ideal oxygenator
II. Historical oxygenation technologies
  A. Screen
  B. Disk
  C. Bubble
III. Membrane oxygenator
  A. Materials
    1. silicone
    2. microporous polypropylene
      a. flat sheet
      b. hollow fiber
    3. polymenthylpentene (PMP)
  B. Design characteristics
    1. pressure drop
    2. prime volume
    3. maximum rating
    4. air handling
    5. integrated arterial filtration
  C. Evaluating oxygenator performance
  D. Special considerations (eg. PMP)

# UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*6. HEAT EXCHANGERS*

**UNIT OBJECTIVE:**
This unit introduces the various types of heat exchangers used during cardiopulmonary bypass.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the design characteristics of heat exchangers; and
(2) Discuss the placement of heat exchangers in the CPB circuit.

**OUTLINE:**
I. Extracorporeal heat exchange technology
  A. Materials
    1. stainless steel
    2. aluminum
    3. plastic
  B. Characteristics
    1. prime volume
    2. design specifics
II. Specific CPB heat exchangers
  A. Venous reservoir
  B. Integral with oxygenators
  C. Cardioplegia
III. Evaluating heat exchanger efficiency
IV. Heater – cooler devices

## UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*
*7. RESERVOIRS*

**UNIT OBJECTIVE:**
This unit introduces the various types of reservoirs used during cardiopulmonary bypass.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the difference between a reservoir and a cardiotomy;
(2) Describe different reservoir technologies and configurations;
(3) Describe internal filtering systems found in cardiotomy systems; and
(4) Discuss safety issues as they relate to reservoir.

**OUTLINE:**
I. Reservoirs versus cardiotomy
II. Reservoir systems
  A. Open vs. closed systems
  B. Hard shell
  C. Bag reservoirs
III. Internal filtering systems
IV. Safety issues
  A. Servoregulation
  B. Air handling pressure relief valve

## UNIT 2: CARDIOPULMONARY BYPASS

*A. EXTRACORPOREAL CIRCUIT COMPONENTS FOR CARDIOPULMONARY BYPASS*

*8. HEMOCONCENTRATORS/ULTRAFILTERS/DIALYSIS*

**LEARNER OBJECTIVES:**

Upon completion of this unit the student will be able to:

(1) Describe the different types of ultrafiltrators;
(2) Describe the operational characteristics of ultrafilters;
(3) Discuss the impact of hemoconcentration of circulating concentrations of drugs and ions; and
(4) Describe the use of the hemoconcentration before, during and after CPB.

**OUTLINE:**

I. Types of ultrafilters
   A. Semipermeable membrane
      1. hollow fiber
      2. flat plate
      3. coil

II. Operational characteristics
   A. Trans membrane pressure
   B. Serving coefficient
      1. pore size
      2. molecular weight
      3. drug removal
      4. protein binding
      5. ion removal

III. Ultrafiltration circuits/techniques
   A. Pre bypass
      1. pre-buff
   B. During bypass
      1. conventional ultrafiltration (cuf)
      2. zero-balance ultrafiltration (z-buf)
      3. dilutional ultrafiltration (duf)
   C. After bypass
      1. modified ultrafiltration (muf)
      2. residual circuit volume hemoconcentration

IV. Dialysis
   A. Circuit design
   B. Solutions
   C. CVVH/D

# UNIT 2: CARDIOPULMONARY BYPASS

*B. CARDIOPULMONARY BYPASS TECHNIQUES*
*1. CONDUCT OF CARDIOPULMONARY BYPASS*

**UNIT OBJECTIVE:**
This unit introduces the sequence of events associated with a generic CPB procedure.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe and discuss the actions necessary prior to surgery;
(2) Describe a method of initiating CPB;
(3) Describe the parameters monitored during maintenance of CPB; and
(4) Describe a method for weaning from CPB.

**OUTLINE:**

I. Preoperative
   A. Chart review
   B. Component selection
   C. Circuit assembly
   D. Circuit priming
      1. solutions
      2. drugs
   E. Checklist
II. Initiation
   A. Assessing venous drainage/cannulation
   B. Assessing arterial cannulation
III. Maintenance of CPB
   A. Blood flow
   B. Blood pressure
   C. Circuit pressure
   D. Blood gas
   E. Sweep gas
   F. Temperature
   G. Hematocraft
   H. Electrolytes
IV. Weaning
   A. Filling pressures
   B. Terminating CPB
   C. Re-initiating CPB

# UNIT 2: CARDIOPULMONARY BYPASS

*B. CARDIOPULMONARY BYPASS TECHNIQUES*
*2. CPB CANNULATION AND MONITORING*

**UNIT OBJECTIVE:**
This unit describes methods of cannulating for CPB and presents the physiologic monitoring of the cardiac surgery patient.

**LEARNING OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe cannulation as it relates to the CPB patient; and
(2) Describe the methods of physiologic monitoring for the CPB patient.

**OUTLINE:**
I. Cannulation
  A. Arterial
    1. ascending aortic
    2. femoral artery
    3. other
  B. Venous
    1. right atrium
    2. vena cava
    3. femoral vein
  C. Venting
    1. ascending aorta
    2. left ventricle
    3. other
II. Monitoring
  A. Electrocardiogram (EKG)
  B. Blood pressure (BP)
  C. Cardiac filling pressures Swan-Ganz catheter
  D. Cardiac output
  E. Temperature
    1. bladder
    2. tympanic membrane
    3. nasopharyngeal
    4. blood temperature
  F. Renal function
  G. Flows
  H. Blood gases and electrolytes
  I. Coagulation and anticoagulation measurements
  J. TEE
  K. Cerebral monitoring
    1. EEG/BIS
    3. oximetry
III. Troubleshooting

# UNIT 2: CARDIOPULMONARY BYPASS

*C. ADEQUACY OF PERFUSION*

**UNIT OBJECTIVE:**
This unit identifies the parameters monitored to determine adequacy of perfusion.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Identify the important monitoring variables that would assure that CPB delivery of nutrients meets the tissue demands;
(2) Define homeostasis and physiological mechanisms that assure adequate uptake and removal of metabolic products; and
(3) Describe the physiological variables used to assess cellular energy balance during CPB.

**OUTLINE:**

I. Definition of term adequacy
II. Factors influencing the adequacy of extracorporeal circulation
    A. Mechanical
    B. Biological
    C. Hemodynamic
    D. Thermal
III. Oxygen and nutrient delivery
    A. Content of oxygen in blood
    B. Hemoglobin
    C. Oxygen dissociation curve
    D. Delivery of oxygen
    E. Miscellaneous factors affecting oxygen delivery
IV. Determinants of total oxygen consumption
    A. Temperature
    B. Anesthesia
    C. BMR
    D. Other pathological considerations
V. Assess of adequacy of perfusion
    A. Oxygen consumption
    B. Regional oxygen consumption
    C. Perfusion pressure
    D. Arterial / venous blood gasses pO2/oxygen saturation
    E. Acid-base status
    F. Lactate concentrations
    G. Temperature
    H. Anesthesia
    I. Cerebral oxygen saturation
    J. Miscellaneous factors

# UNIT 2: CARDIOPULMONARY BYPASS

*D. MYOCARDIAL PRESERVATION*
*1. CARDIOPLEGIA ADMINISTRATION TECHNIQUES*

**UNIT OBJECTIVE:**
This unit presents the physiological and technical considerations associated with cardioplegia administration.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the physiology of myocardial preservation;
(2) Discuss the determinants of appropriate myocardial preservation techniques; and
(3) Discuss the technical details related to cardioplegia administration.

**OUTLINE:**

I. Cardiac anatomy
II. Cell (patho-) physiology
    A. Respiration and aerobic metabolism
    B. Anaerobic metabolism
    C. Myocardial $0_2$ supply and consumption
    D. Myocardial stunning
    E. Reperfusion injury
    F. Stone heart
    G. Ischemic preconditioning
III. Cardioplegia
    A. Components and their function
    B. Delivery pressure
    C. Temperature/myocardial temperature
    D. Delivery intervals
    E. Delivery methods
    F. Routes of delivery
IV. Considerations of patient variables

# UNIT 2: CARDIOPULMONARY BYPASS

*D. MYOCARDIAL PRESERVATION*
*2. CARDIOPLEGIA SOLUTIONS*

**UNIT OBJECTIVE:**
This unit defines the purpose of various components used in cardioplegia solutions and their role in reducing ischemic and reperfusion injury.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the desired characteristics of cardioplegia solutions;
(2) Discuss the role of each component used to achieve this ideal solution; and
(3) Recognize optional pharmacological agents and explain their purpose.

**OUTLINE:**
I. Pharmacological components
   A. $0_2$ free radical scavengers
   B. Electrolytes
   C. Buffers
   D. Osmolar agents
   E. Membrane protection
   F. Amino acids
   G. ATP-sensitive potassium channel openers
II. Cardioplegia
   A. Osmolarity
      1. myocardial edema
   B. Extracellular vs. intracellular solutions
      1. potassium
      2. magnesium
   C. Blood vs. crystalloid
      1. oxygen delivery and uptake
      2. buffering
   D. Calcium
      1. calcium paradox
      2. citrate phosphate dextrose
   E. Other
      1. steroids
      2. local anesthetics
      3. calcium channel blockers
   F. Reperfusion injury
      1. role of neutrophils and leukocyte depletion
      2. oxygen-free radicals and scavengers - mannitol and superoxide dismutase
   G. Amino acid enrichment - aspartate and glutamate
III. Miscellaneous additives
   A. Substrates
      1. glucose/insulin
      2. glutamate
      3. aspartate
      4. adenosine (ATP)
      5. mannitol

- B. Osmotic agents
    1. glucose
    2. albumin
    3. starch
- C. Pharmacological agents.

IV. Blood cardioplegia

V. Special considerations
- A. Failure of the heart to arrest

# UNIT 2: CARDIOPULMONARY BYPASS

*E. SYSTEMIC HYPOTHERMIA*

**UNIT OBJECTIVE:**
This unit describes the physiologic basis of and the technical considerations associated with systemic hypothermia.

**LEARNER OBJECTIVES:**
At the completion of this unit the student will be able to:

(1) Describe the physiology of systemic hypothermia; and
(2) Discuss application of systemic hypothermia to specific surgical procedures.

**OUTLINE:**

I. The physiology of hypothermia
   A. $VO_2$
   B. Thermal gradients
   C. Degrees of hypothermia
   D. Duration of safe circulatory arrest
   E. Glucose control
   F. Electrolyte control
   G. Blood gas control
II. Blood gas strategies
   A. Alpha stat
   B. pH stat
III. Alterations in organ function
   A. Arrhythmias
   B. Renal function
   C. Cerebral blood flow
   D. Edema
   E. Hormonal response
   F. Viscosity
IV. Procedures requiring hypothermia
V. Hematological considerations
   A. Coagulation
   B. DIC
   C. Emboli
VI. Cold agglutinins

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*1. STANDARDS FOR PERIOPERATIVE AUTOLOGOUS BLOOD COLLECTION AND ADMINISTRATION*

**UNIT OBJECTIVE:**
This unit defines the AABB Standards for Perioperative Autologous Blood Collection and Administration.

**LEARNER OBJECTIVE:**
Upon completion of this unit the student will be able to:
(1) Understand and apply the requirements of the AABB Standards for Perioperative Autologous Blood Collection and Administration.

**OUTLINE:**
I. Organization
II. Resources
III. Equipment
IV. Supplier and Customer Issues
V. Process Control
VI. Documents and Records
VII. Deviations and Nonconforming Products and Services
VIII. Assessments: Internal and External
IX. Process Improvement Through Corrective and Preventive Action
X. Facilities and Safety

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*2. HEMODILUTION*

**UNIT OBJECTIVE:**
This unit describes the physiological effects of hemodilution.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the effects of hemodilution on the rheology of blood;
(2) Discuss how hemodilution changes the oxygen content and colloid osmotic pressure; and
(3) Apply the formulas to calculate the hematocrit and colloid osmotic pressure after hemodilution.

**OUTLINE:**

I. Rheology of blood
   A. Viscosity
   B. Shear rate
   C. Shear stress
II. Oxygen delivery and transport
   A. On-bypass hematocrit calculation
   B. Oxygen content and saturation
   C. Fick equation for oxygen delivery
III. Colloid osmotic pressure
   A. COP calculation
   B. Plasma volume calculation

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*3. INTRAOPERATIVE AUTOTRANSFUSION*

**UNIT OBJECTIVE:**
This unit describes indications, contraindications, equipment operation, product storage and quality control issues related to cell washing.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the indications for cell washing;
(2) Describe the contraindications for autotransfusion;
(3) Describe the general operation of the appropriate cell saving device;
(4) Discuss proper procedure for storage reinfusion and discard of end product; and
(5) Discuss record keeping preventive maintenance and quality control.

**OUTLINE:**

I. Indications for autotransfusion
   A. Recovery of shed blood
   B. Post-bypass pump volume
   C. Appropriate surgical procedures
II. Contraindications
   A. Drugs
   B. Antibiotics and topical solutions
   C. Infection
   D. Malignancy
   E. Exposure to contaminants
III. Salvaged blood characteristics
   A. Noncellular debris
   B. Cellular debris
   C. Lipids, fatty acids
   D. Intracellular enzymes released by WBC and platelets
   E. Activated coagulation factors
IV. Operation of autotransfusion device
   A. Manufacturer guidelines
   B. Institutions policy and procedure guidelines
V. Equipment selection and set up
   A. Appropriate equipment selected for size of patient
   B. Tubing and solutions according to policy and procedure of independent institutions and manufacturer
   C. Processing of product manufacturer guidelines
VI. Storage, reinfusion and discard of end product
   A. Immediate reinfusion
   B. Storage temperature
   C. Expiration of stored end product
   D. Biohazard concerns
VII. Medical record document collection
   A. Documenting product salvaging
   B. Type of salvage device
   C. Time, date, procedure
   D. Documentation of procedure

VIII. Preventive maintenance and quality control
   A. Biomedical engineer
   B. Corporate technical representative
   C. Weekly, monthly testing of end product

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*3a. HIGH VOLUME AUTOLOGOUS PLATELET CONCENTRATION*

**UNIT OBJECTIVE :**
This unit describes the use of the Intraoperative Autotransfusion device as a possible source for large volume platelet concentration.

**LEARNER OBJECTIVES :**
Upon completion of this unit the student will be able to:

(1) Describe how using a full size Autotransfusion device may be employed as a cell separator for packed Red Blood, Concentrated Platelets and Plasma ;
(2) Describe the technique required for the production of Platelet Gel.

**OUTLINE :**
I. Set-up of equipment
II. Disposables required
III. Technique

## UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*4. LOW VOLUME AUTOLOGOUS PLATELET CONCENTRATION SYSTEMS*

**UNIT OBJECTIVE:**
This unit describes the use of low volume Autologous Platelet Separators.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe how low volume Platelet Concentration systems operate;
(2) Describe the technique required for the production of Platelet Gel.

**OUTLINE:**
I. Equipment
II. Equipment Set-up
III. Disposables
IV. Technique

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*5. HEMOCONCENTRATION*

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the different types of ultrafiltrators;
(2) Describe the operational characteristics of ultrafilters;
(3) Discuss the impact of hemoconcentration of circulating concentrations of drugs and ions; and
(4) Describe the use of the hemoconcentration during CPB to control hematocrit.

**OUTLINE:**

I. Types of ultrafilters
   A. Semipermeable membrane
      1. hollow fiber
II. Operational characteristics
   A. Trans membrane pressure
   B. Serving coefficient
      1. pore size
      2. molecular weight
      3. drug removal
      4. protein binding
      5. ion removal
III. Conventional ultrafiltration during cardiopulmonary bypass
   A. Indications
   B. Limitations
   C. Circuitry

# UNIT 2: CARDIOPULMONARY BYPASS

*F. BLOOD CONSERVATION TECHNIQUES*
*6. PHARMACOLOGICAL INTERVENTIONS*

**UNIT OBJECTIVE:**
This unit presents the pharmacological options available to reduce blood loss.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the actions of the various drugs available to reduce the amount of blood loss during and after cardiac surgery;
(2) Describe the indications and contraindications for each of the drugs; and
(3) Discuss dosing and CPB considerations for each drug.

**OUTLINE:**

I. EACA (amicar)
   A. Mechanism of action
   B. Indications
   C. Contraindications
   D. Dosing
   E. CPB considerations
II. Erythropoeitin
   A. Mechanism of action
   B. Indications
   C. Contraindications
   D. Dosing
III. Transexemic acid
   A. Mechanism of action
   B. Indications
   C. Contraindications
   D. Dosing
IV. Desmopressin acetate DDAVP
   A. Mechanism of action
   B. Indications
   C. Contraindications
   D. Dosing

# UNIT 2: CARDIOPULMONARY BYPASS

*G. SPECIAL CONSIDERATIONS IN PERFUSION*
*1. MALIGNANT HYPERTHERMIA*

**UNIT OBJECTIVE:**
This unit defines malignant hyperthermia, identifies the symptoms of a malignant hypothermic event, the conditions which may predispose a patient to malignant hypothermia, considerations for CPB and the treatment.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the pariophysiology and presention of malignant hyperthermia;
(2) Identify agents known to trigger malignant hypotherm events;
(3) Describe pharmacologic treatment; and
(4) Discuss the considerations for CPB.

**OUTLINE:**

I. Mechanisms of malignant hyperthermia
   A. Sarcoplasmic reticulum and calcium
   B. Elevated calcium levels and the effect on muscle
   C. ATP depletion
   D. Sodium/calcium pump
II. Triggers
   A Depolarizing muscle relaxants
   B. Inhalation agents
   C. Agents which increase myoplasmic calcium levels
      1. cardiac glycosides
      2. calcium salts
   D. Catecholamine
      1. caffeine
      2. alpha agonist
      3. lidocaine
III. Signs and treatment
   A. Heart rate
   B. Dysrrythmias
   C. Muscle reaction, types of muscle
   D. Temperature
   E. DIC
   F. Venous saturation
   G. Electrolytes
   H. Blood gas evaluation
   I. Drug administration and dosage
   J. Hyperthermia
   K. Glucose and insulin administration
   L. Renal failure considerations
   M. Prime solutions
IV. Pharmacology treatment
   A. Dantrolene
   B. Anesthetic considerations
V. CPB considerations
   A. Drugs indicated, and acceptable to use with the compromised patient
   B. Hypothermic treatment

# UNIT 2: CARDIOPULMONARY BYPASS

*G. SPECIAL CONSIDERATIONS IN PERFUSION*
*2. PERFUSION OF THE PREGNANT PATIENT*

**UNIT OBJECTIVE:**
This unit details the specific perfusion techniques for the pregnant patient.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the perfusion techniques unique to the pregnant patient;
(2) Describe the physiological and anticoagulation needs of this patient; and
(3) List the most frequent open-heart procedures for the pregnant patient.

**OUTLINE:**
I. Pregnancy
    A. Cardiac surgical indications for pregnant patient
    B. Optimal timing for procedure
II. Monitoring for pregnant patient
    A. Mother
        1. blood pressure cuff
        2. peripheral oximeter
        3. EKG
        4. end-tidal $CO_2$
        5. neuromuscular blockade monitor
        6. Swan Ganz $SvO_2$
        7. TEE
        8. foley temperature monitor
    B. Fetus
        1. heart rate monitor
III. Concerns regarding perfusion
    A. Morbidity/mortality
    C. Risks/timing
IV. Physiology
V. Anti-coagulation
VI. Pharmacology
    A. Effects of catecholamines on maternal uterus blood flow (UBF)
    B. Oxygen consumption
    C. Coumadin
    D. Nipride
VII. Cardioplegia

# UNIT 2: CARDIOPULMONARY BYPASS

*G. SPECIAL CONSIDERATIONS IN PERFUSION*
*3. SICKLE CELL AND OTHER BLOOD DISORDERS*

**UNIT OBJECTIVE:**
This unit provides a detailed description of blood disorders that may affect perfusion techniques.

**LEARNER OBJECTIVES:**
At the completion of this unit the student will be able to:
(1) List the inherited and acquired blood disorders that are important to CPB;
(2) Discuss the mechanism of action of each; and
(3) Describe the therapeutic approaches to each to be able to perform CPB.

**OUTLINE**:
I. Sickle cell
  A. Pathophysiology
  B. Considerations for CPB
  C. Other blood disorders
II. Methemoglobinemia
  A. Pathophysiology
  B. Considerations for CPB
III. Thalassemia
IV. Spherocytosis & elliptocytosis
V. Hemosiderosis & hemochromatosis
VI. Erythrobolastosis fetalis
VII. Hereditary coagulation disorders
  A. Von Willebrand's disease
    1. Type I
    2. Type II
    3. Type III
  B. Hemophilia A
  C. Hemophilia B
VIII. Acquired coagulation disorders
  A. Disseminated intravascular coagulation (DIC)
  B. Primary fibrinolysis
  C. Vitamin K dependent deficiency
  D. Protein C and Protein S deficiency
IX. Platelet disorders
  A. Thrombocytopenia
  B. Cold agglutinins

# UNIT 2: CARDIOPULMONARY BYPASS

*H. CATASTROPHE MANAGEMENT*

**UNIT OBJECTIVE:**
This unit details the components of catastrophe and catastrophe management.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Discuss the potential for a catastrophe; and
(2) Describe the proper responses and actions to a catastrophe.

**OUTLINE:**
I. Incidence of perfusion accidents
II. Causes of accidents
    A. Device
    B. Human error
III. Systems analysis
    A. Complex interaction
        1. intrinsic complexity
            a. highly technical - close coordination among various components
        2. proliferation complexity
            a. multiple simple components
        3. uncertainty complexity
            a. relatively straight forward - not well understood
    B. Tightness
        1. tight
            a. leaves no room for error
        2. loose coupling
            a. margin of error between coupling
IV. Cardiopulmonary bypass
    A. Personnel
        1. background
        2. communication
        3. ability to perform multiple tasks
    B. Scope of practice
        1. complexity
        2. uncertainty
    C. Interfacing
        1. more tasks - more errors
        2. reaction time
        3. preventative measures
V. Errors
    A. Inadequate experience
    B. Unfamiliarity with equipment
    C. Inadequate communication
    D. Haste
    E. Distraction
    F. Lack of vigilance

# UNIT 2: CARDIOPULMONARY BYPASS

*I. ADJUNCTIVE TECHNIQUES*
*1. ASSISTED VENOUS DRAINAGE*

**UNIT OBJECTIVE:**
This unit details assisted venous drainage techniques.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Discuss the rationale for using assisted venous return;
(2) Compare VAVD with KAVD; and
(3) Describe the equipment required for each system.

**OUTLINE:**
I. Vacuum-assisted venous drainage (VAVD)
  A. Concept is to apply a negative pressure in the venous reservoir to augment the rate of venous return.
  B. The advantages of this method are:
    1. increased venous return
    2. smaller venous cannulae for a given flow rate
    3. heart remains empty
  C. The disadvantages of VAVD are:
    1. additional cost
    2. blood trauma if vacuum is too high
    3. potential of pulling air into the arterial blood stream of hollow fiber oxygenators
  D. Hardware for VAVD
    1. hard shell venous reservoir – VAVD can not be applied to soft-shell reservoirs
    2. vacuum source
    3. vacuum regulator
    4. positive and negative relief valves
II. Kinetically-assisted venous drainage (KAVD)
  A. Concept is to apply a centrifugal pump in the venous return line to augment the rate of venous return
  B. The advantages of this method are:
    1. increased venous return
    2. smaller venous cannulae for a given flow rate
    3. heart remains empty
    4. no need to apply a vacuum in the venous reservoir
    5. KAVD can be used for soft-shell reservoir as well as heard shell
  C. The disadvantages of KAVD are:
    1. additional cost for centrifugal pump head
    2. blood trauma if pump rate is too high
  D. Hardware for KAVD
    1. centrifugal pump
    2. centrifugal pump head

# UNIT 2: CARDIOPULMONARY BYPASS

*I. ADJUNCTIVE TECHNIQUES*
*2. SELECTIVE CEREBRAL PERFUSION*

**UNIT OBJECTIVE:**
This unit details the concepts and techniques for cerebral perfusion.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the indications for this technique;
(2) Discuss the perfusion circuit; temperatures; pressures; and flows used with the technique; and
(3) Discuss the outcomes of the technique compared to only profound hypothermic circulatory arrest.

**OUTLINE:**
I. Indications
*A. Aortic aneurysm*
1. ascending
2. ascending including aortic valve
3. transverse

II. Technique
A. EEG monitoring
B. Profound hypothermic circulatory arrest
C. Cardioplegia administration
D. Antegrade cerebral perfusion
1. hypothermia
2. blood flow rate
3. cannulation sites

E. Retrograde cerebral perfusion (RCP)
1. hypothermia
2. blood flow rate
3. cannulation sites
4. pressure of 25 mmHg
5. flows < 500 ml/min
6. when nasopharyngeal temperatures are < 12$^{o}$C RCP is halted.
7. arch replacement
8. with head down, RCP restarted
9. at rewarming an arterial sidearm is inserted into transverse graft to deliver antegrade flow
10. air is removed from LV and proximal Anastomosis
11. patient weaned from CPB at appropriate temperature and protamine sulfate is given in the normal fashion

III. Outcomes
A. Mortality
B. Stroke rate

# UNIT 2: CARDIOPULMONARY BYPASS

*J. PATIENT MONITORING*

**UNIT OBJECTIVE:**
This unit describes the systems used for patient monitoring during open-heart surgical procedures.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Interpret an ECG;
(2) Describe the technical aspects associated with hemodynamic monitoring;
(3) Discuss the relationship of ECG blood pressure, blood gas, chemistry, and temperature as they relate to patient status.

**OUTLINE:**

I. ECG
II. Pressure monitoring
    A. Noninvasive
    B. Intravascular
        1. radial arterial
        2. femoral Arterial
        3. pulmonary artery – Swan-Ganz
        4. strain gauges
III. Blood gas
    A. Blood gas measurements sampling
        1. sample handling
        2. temperature
        3. anaerobic
        4. anticoagulation
    B. Inline blood gas monitoring
IV. Pulse oximetry
V. Temperature monitoring
    A. Patient temperature
        1. bladder
        2. nasopharyngeal
        3. rectal
        4. skin versus internal
    B. CPB bypass temperature
        1. venous
        2. arterial
        3. cardioplegia
VI. Cerebral blood flow monitoring/Cerebral oximetry
VII. Renal function monitoring
    A. BIS

# UNIT 2: CARDIOPULMONARY BYPASS

*K. ORGAN TRANSPLANTATION*
*1. HEART TRANSPLANTATION: DONOR RECIPIENT CONSIDERATIONS*

**UNIT OBJECTIVE:**
This unit introduces the donor and recipient selection considerations as they relate to heart transplantation.

**LEARNER OBJECTIVES:**
Upon completion of the unit the student will be able to:

(1) Discuss the history, criteria for recipient and donor selection, operative techniques, immunosuppression; and
(2) Discuss outcomes of heart, heart-lung, and lung transplantation.

**OUTLINE:**

I. History
II. Recipient selection
    A. Age: newborn to 65 years.
    B. Irremediable cardiac disease-class IV NYHA
III. Donor selection
    A. Age
    B. Normal EKG
IV. Operative techniques
    A. Orthotopic
    B. Heterotopic
V. Immunosuppression
VI. Postoperative surveillance
    A. Rejection
    B. Infection
        1. viral
        2. bacterial
        3. fungal
    C. Other
VII. Outcomes
VIII. Myocardial preservation for heart transplantation

# UNIT 2: CARDIOPULMONARY BYPASS

*K. ORGAN TRANSPLANTATION*
*2. LUNG AND HEART-LUNG TRANSPLANTATION*

**UNIT OBJECTIVE:**
This unit introduces the donor and recipient selection considerations as they relate to lung and heart-lung transplantation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Discuss the history, criteria for recipient and donor selection, operative techniques; and
(2) Discuss immunosuppression, and outcomes of heart-lung, and lung transplantation.

**OUTLINE:**

I. History
   A. Clinical
   B. Experimental
II. Recipient selection
   A. Goals of recipient selection
   B. General guidelines
   C. Contraindications to transplant
   D. Diseases
   E. Prognosis and timing of selection
      1. chronic obstructive pulmonary disease
      2. primary pulmonary hypertension
      3. cystic fibrosis
   F. Choice of procedure
      1. single lung
      2. bilateral single lung
      3. heart-lung
III. Donor issues
   A. Criteria for selection
      1. history, illicit drugs, and sexual practices
      2. demography
      3. immunology
      4. pulmonary status
      5. microbiology-serology
      6. size match
   B. Donor management
   C. Donor surgery
      1. lung preservation
      2. ischemic times
   D. Immunosuppression
IV. Surgical techniques
   A. Single lung transplant
   B. Bilateral single lung transplant
   C. Heart-lung transplant

# UNIT 2: CARDIOPULMONARY BYPASS

*K. ORGAN TRANSPLANTATION*
*3. LIVER TRANSPLANTATION – PERFUSION SUPPORT*

**UNIT OBJECTIVE:**
This unit presents the rationale and technique to support orthotopic liver transplantation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the surgical procedure for orthotopic liver transplantation;
(2) Discuss why circulatory support is needed in some liver recipients; and
(3) Describe the cannulation sites, perfusion configuration, and flow rates.

**OUTLINE:**
I. Background
  A. Common causative diseases requiring liver transplantation
    1. hepatitis
    2. primary biliary cirrhosis
    3. hepatic malignancies
    4. primary sclerosing cholangitis
    5. acute hepatic necrosis
  B. Contraindications
    1. active hepatitis B
    2. cardiac, renal, or pulmonary failure
    3. sepsis
II. Surgery
  A. During removal of the native liver there is an anhepatic phase
  B. There is a time of obstruction of the inferior vena cava and portal vein
  C. Obstruction leads to a 50% reduction in cardiac output
  D. Splanic engorgement
  E. Excessive bleeding – due to hepatic failure
III. Perfusion support
  A. Veno-venous bypass
    1. heparinized tubing, cannulae, flow probe, and centrifugal cone
    2. outflow from external iliac vein and hepatic portal vein
    3. inflow to axillary vein
  B. Technique
    1. no heparin
    2. no oxygenators
    3. initial flow rate of 1000 ml/min
    4. prime plasmalyte
IV. Ancillary equipment and supplies
  A. Blood recovery – cell saver
  B. Blood gas machine
  C. Rapid transfusion device
V. Complications
  A. Bleeding diathesis
  B. Air or thrombus embolization

# UNIT 3: MECHANICAL ASSIST

*A. EXTRACORPOREAL LIFE SUPPORT TECHNIQUES*
*1. ECMO*

**UNIT OBJECTIVES:**
This unit presents the basic concepts of ECMO for neonatal and pediatric patients.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the indications for ECMO;
(2) Discuss the advantages of each cannulation technique;
(3) Discuss management of the ECMO patient – especially flows and anticoagulation; and
(4) Describe how to terminate ECMO.

**OUTLINE:**

I. ECMO patient categories
   - A. Neonatal respiratory failure
     1. indications
     2. exclusion
   - B. Pediatric respiratory failure
     1. indications
     2. exclusion
   - C. Adult respiratory failure
     1. indications
     2. exclusions
   - D. Cardiac failure
     1. indications
     2. exclusions

II. Methods of ECMO
   - A. Venoarterial ECMO
     1. cannulation
     2. device selection – oxygenators, pumps
     3. disadvantages
   - B. Venovenous ECMO
     1. cannulation
     2. device selection – oxygenators, pumps
     3. disadvantages

III. Physiology of infants on ECMO

IV. ECMO management
   - A. Setup and initiation of ECMO
   - B. Management of surgical procedures on ECMO

V. Post-ECMO management
   - A. Ventilator management
   - B. Sedation

VI. Outcome studies

# UNIT 3: MECHANICAL ASSIST

*A. EXTRACORPOREAL LIFE SUPPORT TECHNIQUES*
*2. CPS*

**UNIT OBJECTIVE:**
This unit presents the basic concepts of CPS.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Describe the indications for CPS;
(2) Describe the technical considerations of CPS; and
(3) Discuss complications associated with CPS.

**OUTLINE:**
I. Definition of CPS
  A. The CPS is a system the permits temporary circulatory and/or oxygenation support of the critically ill patient
  B. The CPS is normally configured for peripheral arterial and venous cannulation
  C. The CPS provides
    1. oxygenated blood flow retrograde up the aorta via the femoral artery
    2. pump is usually a centrifugal pump head
      a. provides kinetically assisted venous return
      b. non-pulsatile
    3. membrane oxygenators
    4. heat exchange
    5. hemoconcentrator can be inserted into the system
  D. Anti-coagulation is a key management issue of CPS
    1. anti-coagulation management
    2. blood product usage
II. Patient selection
  A. Reversible clinical condition
    1. pulmonary failure
      a. viral
      b. aspiration
    2. cardiac failure
      a. stunned heart
      b. MI
      c. endotoxin
  B. Temporary support for diagnostic procedures
III. Complications
  A. Embolization
  B. Oxygenator failure
  C. Pulmonary failure with some cardiac output
    1. carotid and coronary perfusion supplied by heart output – desaturated blood
    2. low body supplied with highly oxygenated blood from CPS
  D. Bleeding
    1. loss of ATIII
    2. reduced platelet function

# UNIT 3: MECHANICAL ASSIST

*B. INTRA-AORTIC BALLOON PUMPING (IABP)*

**UNIT OBJECTIVE:**
This unit introduces the theory and practice of intraaortic balloon pumping.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) List the indications and contraindications for the IABP;
(2) Identify the equipment required for the procedure;
(3) Describe the purpose for IABP; and
(4) Discuss proper timing.

**OUTLINE:**

I. Indications for IABP
   A. Unstable angina
   B. Cardiogenic shock
   C. Postcardiotomy support
   D. Augmentation of circulation
II. Contraindications for IABP
   A. Aortic insufficiency
III. Equipment
   A. Types of IABP
   B. Gas used for counterpulsation
   C. ECG monitoring devices
   D. Electrosurgical interference suppression devices
   E. Insertion devices
IV. Purpose
   A. Counterpulsation– increase coronary perfusion through increasing diastolic pressures
   B. Reduction of LV heart afterload
   C. Increasing cardiac output
V. Procedure
   A. Controls
   B. Function
   C. Manufacturers recommendations
   D. Leak test
   E. Acquiring EKG, 12 lead/slave
   F. Pressure tracing transducer/fiberoptic
   G. Selecting trigger-ECG or pressure
   H. Filling the gas chamber
   I. Identify proper selection of alarms and settings

# UNIT 3: MECHANICAL ASSIST

*C. VENTRICULAR ASSIST DEVICES*

**UNIT OBJECTIVES:**
This unit describes patient selection, surgical implantation, and patient management for a variety of different VAD techniques.

**LEARNING OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Discuss the indications and contraindications for VAD implantation;
(2) Compare and contrast the different VAD systems and indications for use;
(3) Describe the cannulation techniques or VADS; and
(4) Describe the long-term management requirements for each VAD system.

**OUTLINE:**

I. Indications for VAD
   A. Patient evaluation
   B. Hemodynamic stability
   C. Age considerations
      1. left heart failure
      2. right heart failure
      3. biventricular failure
   D. Body surface area limitations
   E. Pharmacologic considerations
   F. Failure to wean from CPB
   G. Bridge to transplant
   H. Destination device
II. Contraindications for VAD
III. VAD technologies
   A. External devices
   B. Implantable devices
   C. Pneumatic devices
   D. Electric devices
   E. Pulsatile devices
   F. Non-pulsatile devices
IV. Cannulation/implantation
V. Patient management
   A. Anticoagulation
   B. Volume management/hemodynamics
   C. Patient mobility

Formatted: Bullets and Numbering

# UNIT 4: PRINCIPLES OF LABORATORY ANALYSIS

*A. OVERVIEW - LABORATORY ANALYSIS*

**UNIT OBJECTIVE:**
This unit introduces the use of laboratory tests in clinical practice.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the purpose of laboratory testing in different patient populations;
(2) Define the predictive value of positive and negative test results and how they vary with changes in the prevalence of disease; and
(3) Relate patient factors that alter test results such as age, sex, habits, and underlying disease.

**OUTLINE:**

I. Role of laboratory testing
    A. Mass screening
    B. Diagnosis
        1. establish diagnosis
        2. rule out disease
        3. confirm diagnosis
    C. Therapy
II. Limitations of laboratory tests
    A. Testing parameters
        1. sensitivity
        2. specificity
        3. reliability
        4. accuracy
    B. Variables
        1. pre-analytical
        2. analytical
        3. post-analytical
III. System analysis through laboratory testing
    A. General tests
        1. urinalysis
        2. complete blood count
        3. chemical screening
    B. Specific tests
        1. cardiac
        2. renal
        3. pulmonary
        4. electrolytes
        5. blood gases
        6. endocrine

# UNIT 4: PRINCIPLES OF LABORATORY ANALYSIS

*B. LABORATORY ANALYSIS-SPECIAL CHEMISTRY*

**UNIT OBJECTIVE:**
This unit describes methodology used to monitor acid-base status in the clinical setting.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) Define methodology utilized in blood gas analysis; and
(2) Describe quality control procedures required to ensure adequacy of results.

**OUTLINE:**
I. Blood gas analysis
   A. Quality control
   B. Instrumentation
   C. Principles of operation
   D. Calibration
II. Parameters monitored and reference ranges
   A. pH, $pCO_2$, $pO_2$
   B. $HCO_3$
   C. Lactate
   D. Electrolytes, anion gap

# UNIT 4: PRINCIPLES OF LABORATORY ANALYSIS

*C. LABORATORY ANALYSIS-BLOOD CHEMISTRY*

**UNIT OBJECTIVE:**
This unit describes the laboratory test used in diagnosing specific disease states.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Define laboratory test utilized in the determination of renal function;
(2) Define laboratory test utilized in the diagnosis of cardiac disease; and
(3) Define laboratory test utilized in the evaluation of liver function.

**OUTLINE:**

I. Renal function
   A. Urinalysis
   B. Clearance tests
   C. Blood urea nitrogen
   D. Serum creatine
   E. Osmolality
II. Cardiac disease
   A. Aspartate aminotransferase (AST)
   B. Lactic dehydrogenase / isoenzymes (LDH)
   C. Creatine kinase / isoenzymes (CK)
   D. Troponin-T
III. Liver disease
   A. Serum bilirubin
   B. Urine bilirubin and urobilinogen
   C. Alkaline phosphatase (ALP)
   D. Serum aspartate aminotransferase (AST/ SGOT)
   E. Serum alanine aminotransferase (ALT/SGPT)
   F. Lactic dehydrogenase (LDH)
   G. Prothrombin time (PT)
   H. Serum proteins and electrolytes
   I. Blood ammonia

# UNIT 4: PRINCIPLES OF LABORATORY ANALYSIS

*D. LABORATORY ANALYSIS-COAGULATION*

**UNIT OBJECTIVE:**
This unit describes tests used in assessing coagulation in the clinical setting.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:
(1) List methods of testing the coagulation system; and
(2) Relate clinical history to coagulation status.

**OUTLINE:**
I. Blood coagulation theory
   A. Extrinsic system
   B. Intrinsic system
   C. Protein C/ protein S anticoagulant system
   D. AT III
II. Clinical history
   A. Massive transfusions
   B. Cardiopulmonary bypass procedures
III. Personal history
   A. Previous surgery
   B. Frequency of abnormal bleeding
   C. Medical diseases
   D. Medication history
IV. Basic coagulation assessment tests
   A. Platelet count and function
   B. Bleeding time
   C. Clot retraction
   D. Prothrombin time and INR
   E. Activated partial thromboplastin time
   F. Thrombin time
   G. Fibrinogen / fibrinogen split products
   H. D-dimer
   I. Factor assays
   J. Activated clotting time
   K. Thromboelastograph

# UNIT 5: BIOMEDICAL ENGINEERING

## *A. BIOMEDICAL INSTRUMENTATION*

**UNIT OBJECTIVE:**
This unit presents the theory and application of biomedical instrumentation.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the basics of electrical theory including voltage, current, resistance, and capacitance;
(2) Describe various biopotentials emitted from the body and their source;
(3) Discuss how a physiological signal is transduced, processed, and displayed; and
(4) Identify potential sources of error in signal processing and display.

**OUTLINE:**

I. Electrical theory
    A. Ohm's law
    B. Capacitance
II. Bio-electric potentials
    A. Electrocardiogram
    B. Electroencephalogram
III. Electrodes, sensors, and transducers
    A. Transduction - definition
    B. Signal Acquisition
    C. Electrodes for biophysical sensing
        1. surface electrodes
        2. microelectrodes
    D. Mechanical transducers
        1. pressure
        2. flow
IV. Frequency content of physiologic signals
V. Amplifiers
VI. Digital signal processing
    A. Data acquisition
        1. analog to digital conversion
        2. sampling
    B. Data analysis
    C. Data display
        1. digital to analog conversion
        2. monitors

# UNIT 5: BIOMEDICAL ENGINEERING

*B. BIOPHYSICAL TRANSPORT PHENOMENON*

**UNIT OBJECTIVE:**
This unit introduces the core principles of biophysical transport phenomenon.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the fluid dynamics and heat transfer as they pertain to extracorporeal technology; and
(2) Discuss, using mathematical formulas, the relevance of pressure, flow and resistance relationships to the physiological state of the patient.

**OUTLINE:**

I. Fluid dynamics
   A. Shear stress and strain
   B. Viscosity
   C. Poiseuille's law
   D. Reynold's number
II. Heat transfer
   A. Conduction
   B. Convection
   C. Radiation

# UNIT 5: BIOMEDICAL ENGINEERING

*C. BIOMEDICAL ELECTRICAL SAFETY*

**UNIT OBJECTIVE:**
This unit introduces electrical safety as it pertains to patients and operating room personnel.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the concept of leakage current as it relates to electrical equipment in direct contact with patients or operating room;
(2) Discuss and identify electrical hazards associated with operating room hardware along with the electrical safety equipment and grounding systems designed to protect patients and personnel from electrocution; and
(3) Describe preventative maintenance scheduling as it relates to extracorporeal equipment.

**OUTLINE:**

I. Leakage current
II. Line isolation system
III. Equipotential grounding systems
IV. Ground fault interrupters
V. Proper power wiring, distribution, and ground system in reducing electrical shock hazard
VI. Preventive maintenance

# UNIT 5: BIOMEDICAL ENGINEERING

*D. MEDICAL AND DIAGNOSTIC IMAGING TECHNOLOGY*

**UNIT OBJECTIVE:**
This unit introduces the various imaging technologies utilized in medicine with particular emphasis on those utilized in the diagnosis and treatment of cardiothoracic disorders.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the pre-operative, diagnostic tests falling under the category of Nuclear Medicine including cardiolyte stress tests, MUGA scans, and V/Q scans;
(2) Describe the various medical applications of ultrasound including echocardiography, doppler flow transduction, and ultrasonic blood pressure monitoring; and

**OUTLINE:**

I. Radiology
   A. X-ray
   B. Fluoroscopy
   C. Digital subtraction angiography (DSA)
   D. Computed tomography (CT)
II. Nuclear medicine
   A. Cardiolyte stress test
   B. MUGA scans
   C. V/Q scans
III. Ultrasound
   A. Echocardiography
   B. Doppler flow transducers
   C. Blood pressure monitors
IV. Magnetic resonance
   A. MRA
   B. MRI

# UNIT 6: SAFETY

*A. BLOOD/FLUID EXPOSURE*

**UNIT OBJECTIVE:**
This unit describes the importance of standard precautions.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Define the health care workers risk of contacting bloodborne pathogens;
(2) Identify measures to be taken to protect against the transmission of bloodborne pathogens in the workplace; and
(3) Describe standard precautions.

**OUTLINE:**

I. Bloodborne pathogens
   A. Hepatitis B
   B. Hepatitis C
   C. Human immunodeficiency virus (HIV)
II. Standard precautions
   A. Handling of blood and body fluids
   B. Biohazard labeling
   C. Disposal of biohazardous material
   D. OHSA standards
   E. Handling exposure

# UNIT 6: SAFETY

*B. PATIENT SAFETY*

**UNIT OBJECTIVE:**
This unit describes standard practice with regard to conducting safe perfusion.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Discuss rationale for using safety devices within the extracorporeal circuit;
(2) Describe what is involved in performing CP safely; and
(3) Describe the principles of risk management.

**OUTLINE:**

I. Safety devices
   A. Level sensors
   B. Bubble detectors
   C. High pressure alarms
   D. Arterial line filters / bubble traps
   E. One way valves
   F. Automatic clamp
II. Safe conduct
   A. Prebypass checklist
   B. Conduct on bypass
III. Risk management
   A. Establishing policies and protocols
   B. Establishing national standards
   C. Adhering to policies, protocols, and standards

# UNIT 7: CONTINUOUS QUALITY ASSURANCE

*A. CQI FOR THE PERFUSIONIST*

**UNIT OBJECTIVE:**
This unit provides the definition and implementation of CQI in health care.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the basis of CQI;
(2) Describe what CQI can accomplish; and
(3) Discuss how CQI is implemented in perfusion health care.

**OUTLINE:**

I. Definition of continuous quality improvement
II. Core concepts of CQI
III. Core steps in continuous improvement
IV. Model for improvement
    A. Commonly used CQI tools and methods
    B. Brainstorming
    C. Nominal group technique (NGT)
    D. Multivoting
    E. Cause & effect/fishbone diagram
    F. Control charts
    G. Flowchart
    H. Histogram
    I. Pareto chart
    J. Run (trend) chart
    K. Scatter diagram
    L. Storyboard
    M. Conducting effective meetings
    N. Quality indicators
    O. Evidence based practice

# UNIT 8: ETHICS

*A. MEDICAL ETHICS*

**UNIT OBJECTIVE:**
This unit introduces contemporary issues related to medical ethics.

**LEARNER OBJECTIVE:**
Upon completion of this unit the student will be able to:
(1) Discuss the contemporary ethical issues related to medicine and research.

**OUTLINE:**
I. Ethics: a sense of morality and responsibility
II. Medical ethics: defined as relating to moral action, conduct, motive or character in medicine
III. Perfusionist's ethics: our responsibility is to the well-being of the patient
    A. Bioethics
    B. History
IV. Research ethics
    A. Informed consent
    B. Institutional review board (IRB)
    C. Data collection/record keeping
V. Defining death
VI. Reproductive medicine
VII. Economic issues
VIII. Society versus the individual
IX. Future directions in medical ethics
    A. The human genome
    B. Gene therapies
X. Physician-assisted suicide
XI. Fertility and genetic controversy
XII. Organ transplantation
XIII. Artificial devices

# UNIT 9: HISTORY

*A. HISTORICAL DEVELOPMENT OF EXTRACORPOREAL TECHNOLOGY*

**UNIT OBJECTIVE:**
This unit describes the key historical discoveries and events in perfusion and cardiac surgery.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe the key medical and scientific developments that led to cardiopulmonary bypass; and
(2) List the individuals who pioneered the development of cardiopulmonary bypass.

**OUTLINE:**

I. Key scientific developments for extracorporeal technology
II. Key technical developments for extracorporeal technology
    A. Pumps
    B. Oxygenators
    C. Membrane oxygenators with new materials
    D. Hypothermia & myocardial preservation
III. Significant pioneers in extracorporeal technology
IV. Key developments facilitating the progress of open-heart surgery

# UNIT 10: RESEARCH

*A. INTRODUCTION TO RESEARCH METHODS*

**UNIT OBJECTIVES:**
This unit introduces the foundational knowledge base for research methodology in the biological sciences.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) Describe hypothesis development for biological research;
(2) Describe experimental design and data analysis for biological research; and
(3) Discuss various methods of presenting the results of biological research.

**OUTLINE:**

I. Hypothesis development
II. Experimental design
    A. Control and experimental groups
    B. Dependant and independent variables
    C. Sample size
III. Data analysis
    A. Group demographics
    B. Statistical analysis
IV. Methods of presentation
    A. Abstract
    B. Poster presentation
    C. Oral presentation
    D. Manuscript preparation

# UNIT 11: BUSINESS PRACTICES

## *A. BUSINESS PRACTICES REGULATORY AGENCIES*

**UNIT OBJECTIVE:**
This unit introduces the various regulatory agencies with oversight responsibilities within the domain of the perfusionist and describes the responsibilities of the perfusionist in complying with his/her employing institution's policies and procedures.

**LEARNER OBJECTIVES:**
Upon completion of this unit the student will be able to:

(1) List the agencies with regulatory oversight over the domain of the perfusionist; and
(2) Discuss the necessity to comply with employing institution's policies and procedures.

**OUTLINE:**

I. Regulatory and standards setting agencies
   A. Joint Commission on the Accreditation of Healthcare Organizations (JCAHO)
   B. Occupational and Safety Association (OSHA)
   C. Healthcare Finance Administration (HCFA)
   D. College of American Pathologists and Clinical Laboratories Improvement Amendment I (CAP/CLIA)
   E. American Association of Blood Banks (AABB)
   F. American Association for the Advancement of Medical Instrumentation (AAMI)
II. Regulatory mandates regarding policies and procedures including HIPPA
III. Perfusion policies and procedures

# UNIT 12: EMERGENCY PREPAREDNESS

**UNIT OBJECTIVE:**
This unit describes the various types of disasters and the need for emergency preparedness. The various options for management of patients and the role of the perfusionist during the treatment of patients in these situations will be discussed.

**LEARNER OBJECTIVES:**

(1) To describe the various types of emergencies that can occur and the response of the health care system to manage these events.
(2) To plan for managing patients using perfusion technology under the various conditions expected in a disaster situation.

**OUTLINE:**

I. Types of disaster
   A. Internal
   B. External
II. Threats in Health Care
   A. Natural - Hurricane, flooding, ice storms
   B. Mass causalities
   C. Cyber crimes / Sabotage
   D. Terrorism
   E. Weapons of mass destruction
   F. Nuclear
   G. Radiological
   H. Incendiary
   I. Biological
III. Disaster Planning
   A. Law Enforcement
   B. Fire Service
   C. Emergency Medical Service
   D. Public Works / Utility Companies
   E. State and National Resources
   F. Disaster Response Team
   G. County, State and National Planning
   H. Disaster Medical Assistance Teams
IV. Healthcare Emergency Management
   A. Hospital / Healthcare Emergency Management Structure
   B. Hospital Emergency Preparedness
V. Interventions
   A. Massive Transfusion/Autotransfusion
   B. Emergency ECMO Support
   C. Transportation of Patients on Life Support Devices