Fetal Development and Transition

Perinatal/Pediatric Respiratory Care

RSTH 421

1

Fetal Development

- Cardiopulmonary Function is a major factor in the success of the transition to extrauterine existence.

2

Fetal Development and Circulation

- OBJECTIVES
  - Describe the purpose and function of the placenta.
  - Identify and describe the phases of embryonic lung growth and the time of occurrence of the phases.
  - Identify the significance of the following weeks of gestational age:
    - 8th week
    - 16th week

3

Fetal Development and Circulation

- OBJECTIVES
  - Identify the significance of the following weeks of gestational age:
    - 24 weeks
    - 26 - 28 weeks
    - 34 weeks
    - 36 weeks

4

Fetal Development and Circulation

- Identify anatomical characteristics and limitations of the lung at the 24-26 week developmental stage.
- Describe post-natal lung growth
- Describe the differences between saccules and alveoli.
- Describe the components of surfactant and identify what role surfactant plays in the lung.

5

Fetal Development and Circulation

- Compare the number and level of development of alveoli at birth to that of the adult.
- Describe the various stimuli at birth which facilitate the first breath.
- Identify the range of pressures needed to expand the lungs during the first breath.
- Describe how fluid is cleared from the lung at and just after birth.

6

Fetal Development and Circulation

- Identify the approximate per cent of cardiac output received by the lung of the fetus.
- Describe how fetal hemoglobin benefits the fetus.
- Describe fetal circulation and contrast it to the adult circulatory pattern
- Given a case study differentiate fetal development phases and transition effects

7

Fetal Development and Circulation

- Describe the circulatory changes which occur at birth including the direction of blood flow and pulmonary vascular pressure changes.
- Discuss the physiologic changes which occur at birth to facilitate the circulatory transition.
- Recognize the character and purpose of fetal breathing movements.
- Describe the major anatomical/physiological system differences between the infant/ neonate and the adult.
- Identify relevant Respiratory Care issues of the neonate.

8

The Placenta

- Exchanges across the placenta are of vital importance to the growth and development of the fetus. The transport of a substance from the mother to the fetus or visa versa depends on
- **Note:**
- *The fetus depends on maternal circulation for nutrients and gas exchange, however, there are two separate systems.*
- **No blood is shared between the two systems.**

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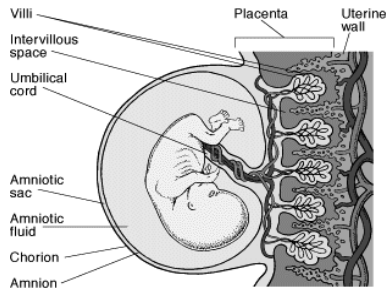
The Placenta

- The concentration of the substance in the lacunae



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The Placenta

- The availability of appropriate carrier proteins if they are required (Stephenson et al., 1993)
- The placental consumption of the substance
- The concentration in the blood feeding the fetal side of the placenta (Stephenson et al., 1990)

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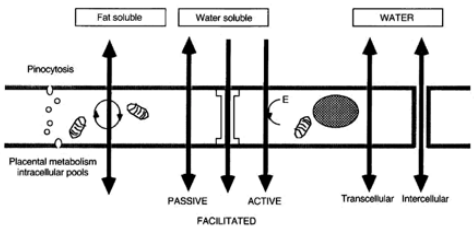
Substances cross **the placenta** by a number of different routes including simple diffusion, active transport, facilitated ionic diffusion, endocytosis or leakage.



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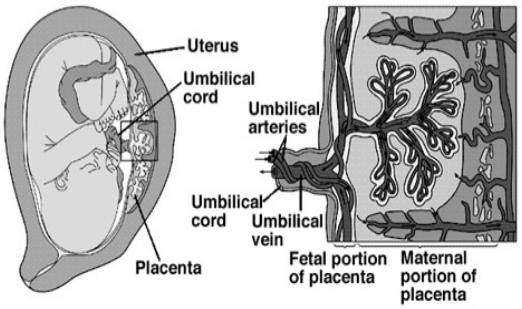
The Placenta and the Umbilical Cord



Embryonic Germ Layers: **Ectoderm**, Mesoderm, Endoderm

- Ectoderm
  - Central nervous system, Cranial nerves, spine, Peripheral nervous system, Sensory epithelia, Eyes, ears, nose, Glandular tissues, Mammary, pituitary, subcutaneous, epidermal tissues, Epidermis, hair, hails, teeth

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Embryonic Germ Layers: Ectoderm, **Mesoderm**, Endoderm

- Mesoderm
  - Cardiovascular system, Heart, blood and lymph vessels, Connective tissue, Bone, cartilage, Muscle tissue, Striated and smooth, Kidney and spleen tissues, Reproductive tissues, Serous linings, Pericardium, pleura, peritoneum.

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Embryonic Germ Layers: Ectoderm, Mesoderm, **Endoderm**

- Endoderm
  - Epithelial tissue, Respiratory system, Digestive system, Urinary system, Liver, and pancreatic tissues, Large gland parenchyma, Tonsils, thymus, thyroid, Auditory epithelial structures,

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Stages of Lung Development

- Period
  - Embryonic (4-6 weeks)
    Development of proximal airways
  - Pseudoglandular (7-16 weeks)
    Development of conducting airways
  - Canalicular(17-24 weeks)
    Development of acinus

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Stages of Lung Development

- Terminal air sac(24 weeks - birth)
  - Entrance into this stage is variable
  - Development of gas exchange units
- Postnatal
  - Birth - 8 years
    - Increase in alveolar number and size
    - Most of increase in number within 1st year

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Lung Phases/Embryonic

Embryonic

Embryo at
4 Weeks

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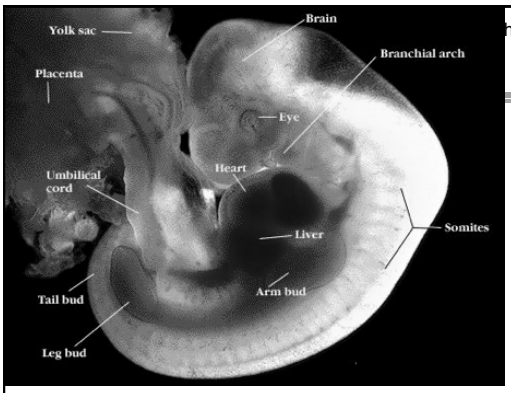

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Lung Growth Phases

Glandular/Pseudoglandular(7-16)

- Branching of Tracheobronchial tree.

8 weeks: Diaphragm is completed

Diaphragmatic Hernia

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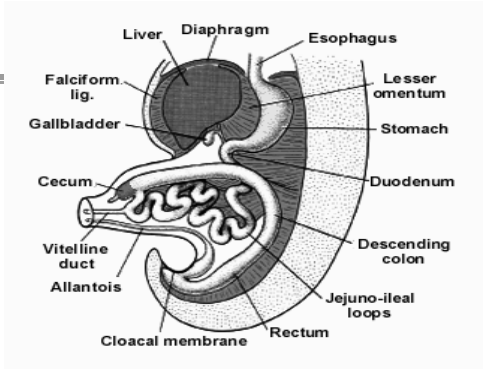

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Lung Growth Phases

Glandular/Pseudoglandular(7-16)

- Pleura, pulmonary lymphatics (8-10 weeks)
- Mucous glands (12 weeks).
- Formation of heart completed.

14 Weeks

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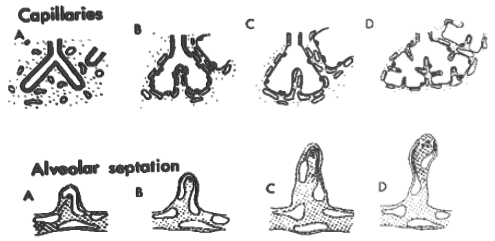
Lung Growth Phases

- Canalicular (17-24 Weeks)
  - Period of acinar development.
  - Structures of gas-exchanging portion of the lung is formed and vascularized.
  - Cardiac malformations can be echocardiographically identified.

Lung Development



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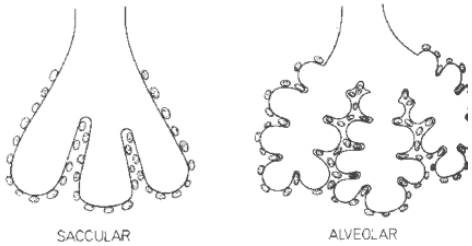
Alveolarization



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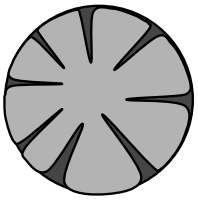
Alveolar Development



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Quantitative Lung Development

- Time
  - Late gestation - early childhood
- Tasks
  - Decrease in airspace wall thickness
  - Decrease in relative volume of conducting airspace
  - Increase in alveolar number and gas-exchange surface area

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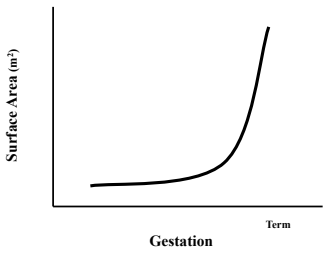
Gas Exchange Surface Area



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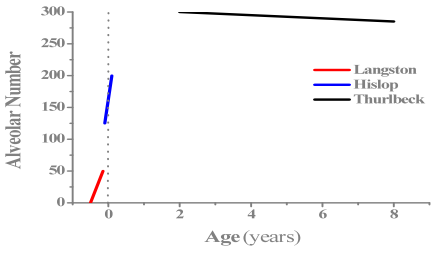
Alveolar Number



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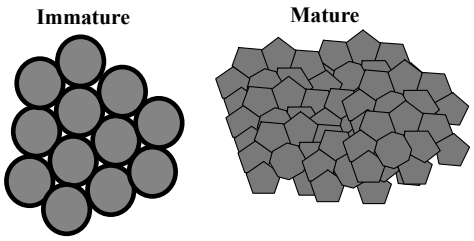
Alveolar Structure



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Connective Tissue Development

- Collagen
  - Dominant tissue in:
    - Airways
    - Blood vessels
    - Non-respiratory components
- Elastin
  - Dominant tissue in:
    - Gas-exchanging parenchyma
    - Structural organization of the acinus

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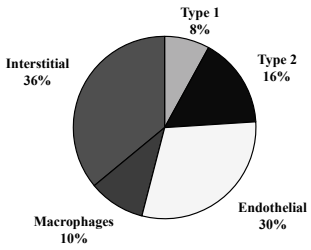
Cellular Constituents



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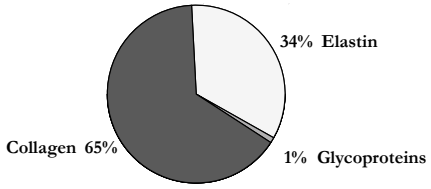
Matrix Constituents



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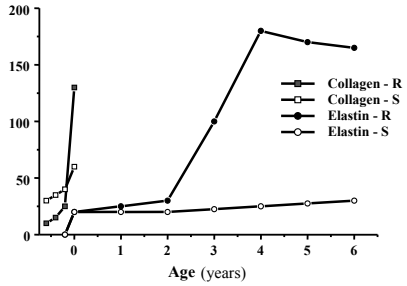
Collagen and Elastin Development



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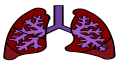
Lung Growth Phases



- 16th – 17th week
  - All conducting airways have been developed.
  - Arteries leading to conducting airways finished developing.
  - Vascular tissue around terminal and respiratory bronchioles begin to develop.

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Airways Function

- Conduction of gases
  - Regulation of distribution
- Barrier to infection
  - Mucous
  - Immunoglobulin - A
- Clearance of foreign substances

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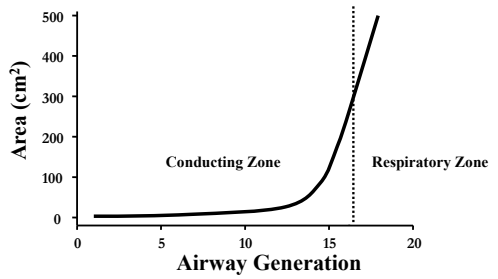
Airways Cross - Sectional Area



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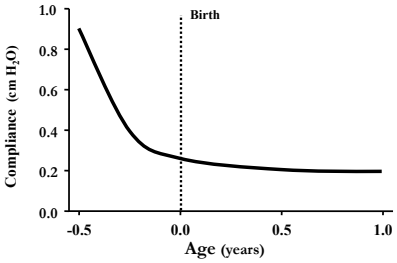
Airways Compliance



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Other Airway Components

- Smooth muscle
- Cartilage
- Nerves
- Chemoreceptors

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Lung Growth Phases

Saccule

Variable entry date into this phase, influencing viability issues.

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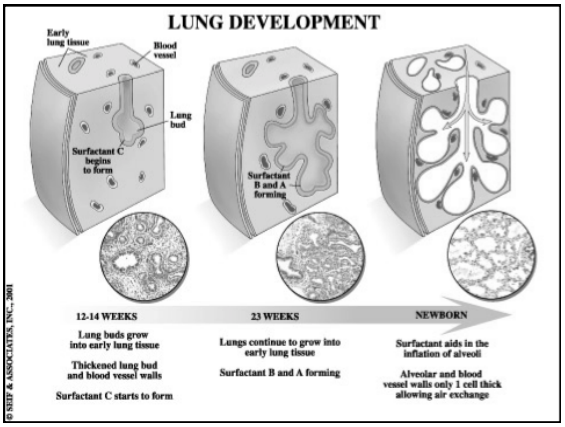

Lung Growth Phases

- Surfactant present
- Area now highly vascularized
- Age of viability (23-24 weeks)

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Surfactant System Development

- Composition
- Synthesis and Secretion
- Timing of Secretion
- Functional Characteristics
- Effects of Immaturity on Surfactant Function

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Composition of Adult Surfactant

- Phospholipid (80%)
  - Phosphatidylcholine
  - Phosphatidylglycerol
  - Phosphatidylinositol
- Neutral Lipid (10%)
- Protein (10%)
  - SP - A SP - C
  - SP - B SP - D

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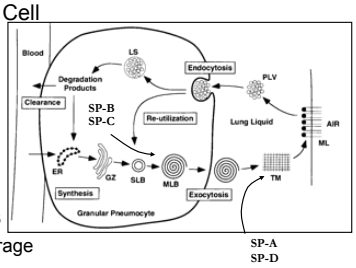
Surfactant Synthesis and Secretion

- Type II Alveolar Cell
  - Synthesized
  - Stored
  - Secreted
  - Resorbed
- Lamellar Bodies
  - Intracellular storage site



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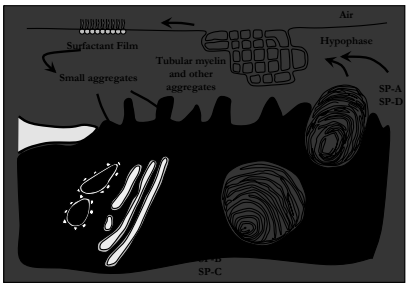
Surfactant Cycle



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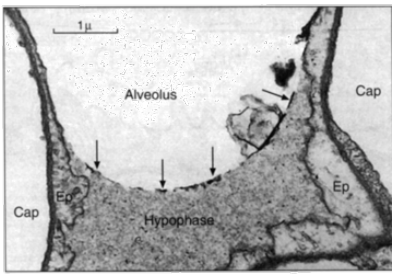
Relationship of Alveolus and Capillary



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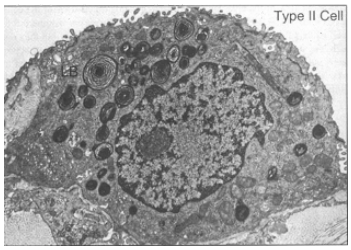
Type II Cell



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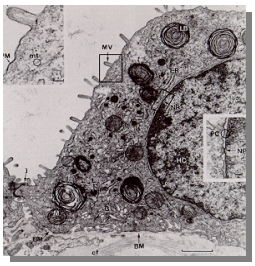
Type II Pneumocyte



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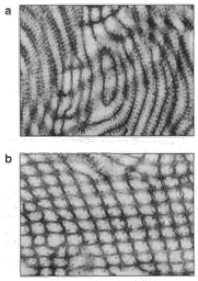
Tubular Myelin



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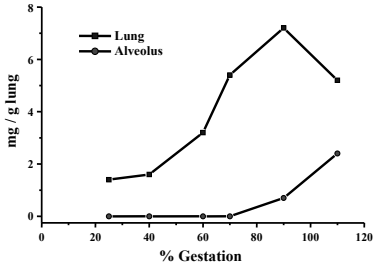
Timing of Surfactant Synthesis



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Functional Characteristics

- Variable surface tension
- Spreads rapidly
- Absorption

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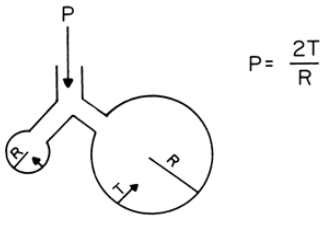
La Place's Law



LA PLACE RELATION

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Immature Surfactant Function

- Qualitative deficiency
  - Decreased release
  - Abnormal structure
- Alveolar-epithelial permeability
  - Protein contamination
  - Surfactant inhibition
- Immature metabolism
  - Imbalance in degradation / repletion

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Stages of Lung Development

- Period
  - Embryonic (4-6 weeks)
    Development of proximal airways
  - Pseudoglandular (7-16 weeks)
    Development of conducting airways
  - Canalicular(17-24 weeks)
    Development of acinus
  - Terminal air sac(24 weeks - birth)
    Entrance into this stage is variable
    Development of gas exchange units
- Postnatal
  Birth - 8 years

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24 - 26 week Respiratory System

- Minimal lung surface area
- Immature surfactant
- Immature respiratory control center
- Thickened alveolar-capillary membrane
- Flexible chest wall
- A/C membrane leaky

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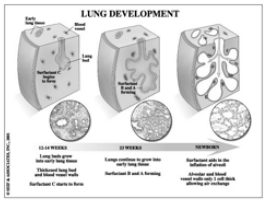
26-28 weeks

- Alveolar-capillary surface area sufficiently developed to support extrauterine life.



28-32 weeks

- Surfactant secreted into the alveolar sacs in sufficient quantities to maintain patency with air.
- 30-32 weeks
  - First mature alveoli

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34 weeks

- Surfactant now has phosphotidlyglycerol.
- Surfactant produced by mature enzyme system.

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36 weeks

- Alveolarization of lung well under way
- Maturity of all systems

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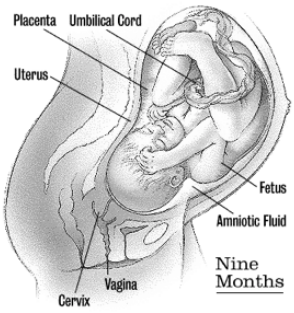
Nine Months



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Delivery

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Fetal Breathing Movements

- **Normal**
  - –Rapid, irregular breathing
  - –Hiccups
- **Abnormal**
  - –Gasping

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Fetal Breathing Movements

- Normal diaphragmatic excursions association with positive fetal well-being
- Movement of fluid is out of lung, into oropharynx, into amniotic fluid.

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Fetal Breathing Movements

- Gasping
  - Large diaphragmatic excursion
  - Associated with fetal asphyxia
  - Movement of amniotic fluid into the lungs

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Fetal Breathing

- Stretch and Filling
- Late 1st trimester
- Irregular

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DRAMATIC CHANGES OCCUR IN THE CIRCULATORY SYSTEM AT BIRTH

- The transition from fetal dependence on maternal support via the placenta to the independent existence after birth brings about dramatic changes in the pattern of circulation in the newborn

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FETAL AND NEONATAL CIRCULATION

- **Three structures become important:**
  - *** Ductus venosus**
  - ***Foramen ovale**
  - ***Ductus arteriousus**

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Macroscopic Circulatory Development

- Time
  - Complete by 16 - 20 weeks
- Constituents
  - Pulmonary
    - Arteries
    - Capillaries
    - Veins
  - Bronchial
    - Arteries
    - Capillaries
    - Veins

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Characteristics of Pulmonary Circulation

- High resistance in fetal life
- Low resistance in postnatal life
- Vast distribution system
- Intimate contact with gas-exchange area
- Can accommodate large changes in volume

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Fetal Circulation

- Placenta
  - Low resistance
- Pulmonary vascular bed
  - High resistance
- Central Shunts
  - Ductus arteriosus
  - Foramen ovale

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Changes at Birth

- Umbilical clamp
  - Increase SVR
- Lung expansion
  - Decrease PVR
- Closure of shunts
  - Increase LA pressure
  - Decrease prostaglandin production

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Fetal Circulatory Changes

- Closure of the foramen ovale
- Closure fo the Ductus Arteriosus
  - 1. Bradykinin
  - 2. Higher Pa02
  - 3. Decreased circulating prostaglandin levels

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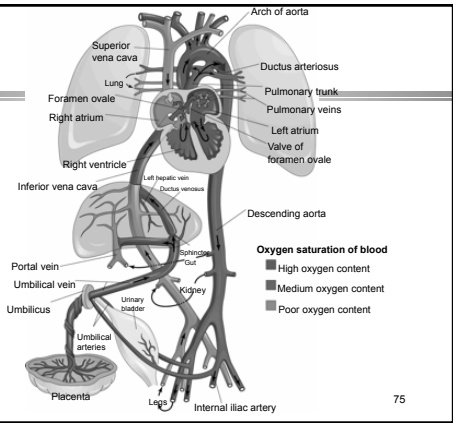

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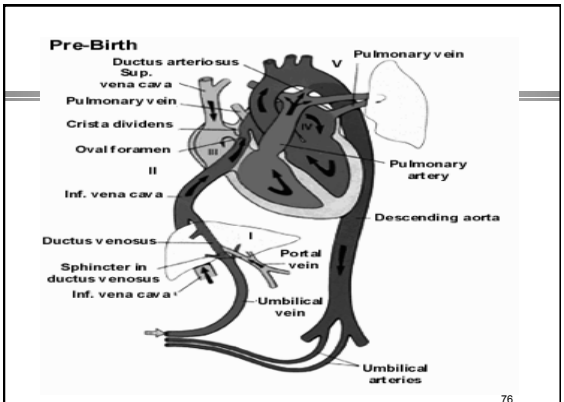

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Physical Factors and Fetal Lung Growth

- Mass Effects
  - Diaphragmatic hernia
  - Pleural effusion
  - Cyst adenomatoid malformation
- Intrauterine crowding
  - Renal aplasia / dysplasia
  - Prolonged oligohydramnios

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AERATION OF THE LUNGS AT BIRTH is associated with:

- **a dramatic fall in <u>pulmonary vascular pressure</u>**
- **a marked increase in <u>pulmonary blood flow</u>**
- **a progressive <u>thinning of walls</u> of the <u>pulmonary</u> arteries; mainly from stretching as lungs increase in size with new breaths**

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Fetal Oxygenation

- Fetal Hemoglobin
  - Higher affinity for oxygen than HbA
    - Causes left-shifted curve
    - Reason: Does not have high affinity for 2,3 DPG
- Total amount of Hemoglobin
  - Increased in the fetus

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The Cardiovascular System

- Fetal hemoglobin: 60% of circulating Hb
  - HbF shifts the 02 dissociation curve to the left.
    - ☞HbF can carry up to 30% more 02 at lower Pa02. This improves oxygen delivery to the tissues of the infant during hypoxic conditions (this is the condition of the pre-term infant).

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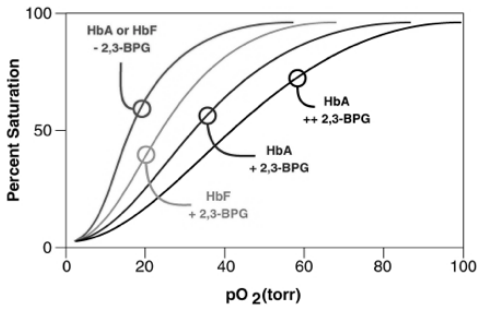
Relative Oxygen Affinities of Adult and Fetal Hemoglobin with or without 2,3-BPG



Transition

- Initiation of Respiration
  - Tactile
  - Thermal
  - Chemical
    - –Removal of maternal serotonin sources
  - Chemical
    - –Blood gas changes

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Removal of fetal lung fluid

- Intravascular
- Lymphatic
- Upper airway

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Fetal Lung Fluid

- Active secreted by fetus
- Actively absorbed at term
- Expelled by external chest wall compression
- Failure to expel
  - Transient tachypnea of the newborn

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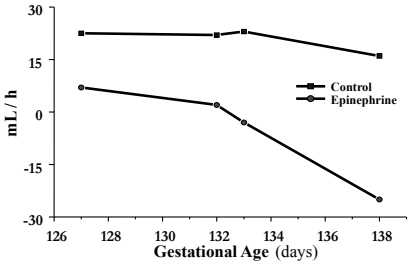
Fetal Lung Fluid



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Transition

- Breathing mechanics
  - High subatmospheric pressure
    - -60 to -80 cm H20
  - High interstitial pressure
    - stretching forces
- Liquid replaced by air, FRC established
- Surfactant released

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Transition

- Expansion of lung leads to vasodilation
  - Pulmonary circulation increases 200%
- Breathing takes 40 minutes to normalize

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