Comprehensive Perinatal & Pediatric RESPIRATORY CARE

Fourth Edition

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Contents

Preface

Respiratory care practitioners working with pediatric and perinatal populations are presented with unique challenges in today's rapidly changing health care environment. Respiratory diseases represent a significant and increasing portion of pediatric and perinatal disorders. *Comprehensive Perinatal and Pediatric Respiratory Care*, fourth edition, has been updated and expanded to provide students with the theory and clinical expertise necessary to embark on their careers and meet these changing needs.

In this new edition, we believe that we have responded to the market's need for current and updated information on ventilators and monitors as well as new modes of ventilation. In this rapidly changing and dynamic specialty area, today's special procedures quickly become tomorrow's common techniques, and we have remained steadfast in our desire to provide students with information on equipment and procedures with which they will be working as they enter their careers.

We also understand that students need their textbooks' content to correlate with information that they will find on their certification exams. To that end, the information in the text is designed to correspond with the NBRC content outline for the perinatal/pediatric specialty exam. As in the previous edition, we have incorporated clinical laboratories and checklists directly into the text. Students will continue to have all the necessary tools and visual aids at hand while conducting laboratory exercises. Clinical competencies are included in the text as well and allow students to assess their proficiency with specific skills.

New to This Edition

- **Now in full color**.
- Reorganized into units—content related to neonatal and infant care is grouped in one unit; content related to and pediatric care is in another; general care of all pediatric populations is grouped together; ventilation and oxygenation is one unit; and the final unit focuses on specialized practice areas. All content has been updated with current accepted practices.

Chapter 1

- Expanded discussion of fertilization and conception
- Expanded discussion of the saccular and alveolar stages of lung development
- Added discussion of transition in fetal circulation to extrauterine life

Chapter 2

- Updates where appropriate

Chapter 3

- Added description of medical terminology used during pregnancy
- Expanded discussion of risk factors for premature labor

Chapter 4

- Thoroughly revised and updated to the latest resuscitation standards including a review of S.T.A.B.L.E training.
- Content focused on the neonate. Content for older children is covered in Unit 2.

Chapter 5

- Content focuses on the neonate. Content for older children is covered in Unit 2.

Chapter 6

- Formerly Chapter 7.

Chapter 7

- Formerly Chapter 10.
- Updates throughout where appropriate to treatment and diseases discussed

Chapter 8

- Formerly Chapter 11.
- Discussion of TORCH complex
- Thoroughly updated discussion of HIV
- Expansion of discussion of *Pneumocystis jirovecii*
- Update of the discussion on prevention of infection
- Deleted discussion of diaphragmatic hernia

Chapter 9

- New chapter
- Focuses on resuscitation techniques of the pediatric patient—following American Heart Association standards
- Discusses management of various traumatic injuries common to children and stabilization of those injuries
- Content moved to this chapter from former Chapter 12 includes: epiglottitis, croup, smoke inhalation, chlorine inhalation, and sudden infant death syndrome.

Chapter 10

- Former Chapter 5 was divided into two chapters: one focusing on the assessment of the neonate (now Chapter 5) and one focusing on assessment of the pediatric patient (now Chapter 10)

Chapter 11

- New chapter focusing on the continuing care needs of the pediatric patient.

Chapter 12

- Content moved from this chapter to Chapter 9 includes: epiglottitis, croup, smoke inhalation, chlorine inhalation, and sudden infant death syndrome

Chapter 13

- Formerly Chapter 6

Chapter 14

- Formerly Chapter 8
- Discussion of newer types of drugs on the market has been added

Chapter 15

- Formerly Chapter 9
- Includes discussion of respiratory rate, color, work of breathing, breath sounds, and tactile fremitus

Chapter 16

- Formerly Chapter 13

Chapter 17

- Formerly Chapter 14

Chapter 18

- Formerly Chapter 15

Chapter 19

- Formerly Chapter 16
- Chapter is completely rewritten to discuss the most current ventilators in use today

Chapter 20

- Formerly Chapter 17

Chapter 21

- Formerly Chapter 18

Chapter 22

- Formerly Chapter 19

Chapter 23

- Formerly Chapter 20

The Clinical Case Studies, formerly in Chapter 21, have been adapted into an interactive supplement for the text. This supplement aims to hone the student's critical thinking and problem-solving skills in real-world applications.

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UNIT ONE

The Neonatal Patient

Life is a flame that is always burning itself out,
but it catches fire again every time a child is born.

—George Bernard Shaw

CHAPTER

1 Embryologic Development of the Cardiopulmonary System

OBJECTIVES

Upon completion of this chapter, the reader should be able to:

1. Describe the embryology of the morula, blastocyst, blastoderm, and trophoblast.
2. Identify the three germ layers and the body structures that evolve from each.
3. Describe the development of the placenta and umbilical cord and identify the major anatomical structures of each.
4. Explain the function of amniotic fluid and define the following:
   a. Polyhydramnios
   b. Oligohydramnios
5. Identify the five periods of embryonic lung growth and describe the features of each period.
6. Define surface tension and describe the following:
   a. How it is developed
   b. Laplace's law
   c. Application to alveolar mechanics
7. With regard to surfactant, describe the following:
   a. Function and purpose
   b. The approximate gestational age at which immature and mature surfactant appears
   c. Components and methods to detect its presence
   d. How lung maturity is determined
8. Regarding fetal lung fluid, describe the following:
   a. Composition
   b. Function
   c. The hazards of lung fluid retention
9. Describe the embryologic development of the heart including:
   a. Development of the cardiac chambers
   b. Formation of major vessels and cardiac valves

10. With regard to fetal circulation, describe and explain:
    a. The cause of pressure differences between the right and left heart
    b. The flow of blood from the placenta through the body and back to the placenta
    c. Each shunt that is encountered
    d. Transition from fetal to adult circulation
11. Describe the location and function of the baroreceptors and chemoreceptors.

KEY TERMS

amnion
baroreceptor
blastocyst
blastoderm
blastomere
chemoreceptor
choana
chorionic villi
cotyledon
dichotomy
ductus arteriosus
ductus venosus
ectoderm
embryo
endoderm
fertilization
fetus
foramen ovale
functional residual capacity (FRC)
intervillous space
mesoderm
morula
neonate
oligohydramnios
ovum
phosphatidylglycerol
phospholipid
polyhydramnios
septum primum
sinus venosus
sphingomyelin
surfactant
transition
trophoblast
truncus arteriosus

INTRODUCTION

The purpose of this chapter is to discuss the growth of the fetus from conception to delivery, to explain the physiologic changes that occur throughout this development, and to understand when and why abnormalities may develop during this process. An understanding of embryologic development, allows the respiratory therapist to be better prepared to respond to the needs of the neonate at birth regardless of the gestational age.

BRIEF OVERVIEW OF EMBRYOLOGIC DEVELOPMENT OF THE FETUS

Fertilization, or the union of the sperm cell and the mature ovum, occurs in the outer third of the fallopian tube. From the time of conception, the fetus begins a 40-week process of growth and development that leads to a fully developed baby. In the first month alone, the fetus grows in weight by nearly 3000%.

The duration of human pregnancy is referred to as either 10 lunar months of 4 weeks each, 9 calendar months in which there are 3 trimesters of 3 months each, or 40 weeks, which is the most common time reference in the clinical setting. In this text, gestational age refers to the time since conception.

Development and growth are divided into three distinct stages. The first stage is the period from conception to the completion of implantation or about 12 to 14 days. During this stage of growth and development, the developing organism is called an **ovum**. The first division or cleavage results in two identical cells. Further cleavage of the two cells results in four cells, eight cells, and so forth. The cells that are produced during this rapid cleavage are called **blastomeres** and are surrounded by a transparent tissue envelope, the zona pellucida.

The newly fertilized ovum advances quickly through various stages of growth. Cellular division begins as the ovum travels through the fallopian tube toward the uterus. Entrance into the uterus, roughly a 10 to 13 cm distance, occurs around the fourth or fifth day. Soon, the cells have grown substantially in number and now form a ball, called a **morula**. It is at this stage of growth that the ovum, consisting of 16 to 50 cells, enters the uterus. The zona pellucida is now replaced by an outer layer of cells, called the **trophoblast**. With the loss of the zona pellucida, the trophoblast attaches itself to the lining of the uterus, the endometrium, to receive nourishment. At this point of development, the cells are called a **blastocyst**. This attachment, or implantation, normally occurs in the upper portion of the uterus. Following implantation, the blastocyst becomes completely covered by the endometrium. The trophoblast grows into the endometrial tissue, forming what will become the placenta. The various stages of development up to implantation are illustrated in Figure 1–1.

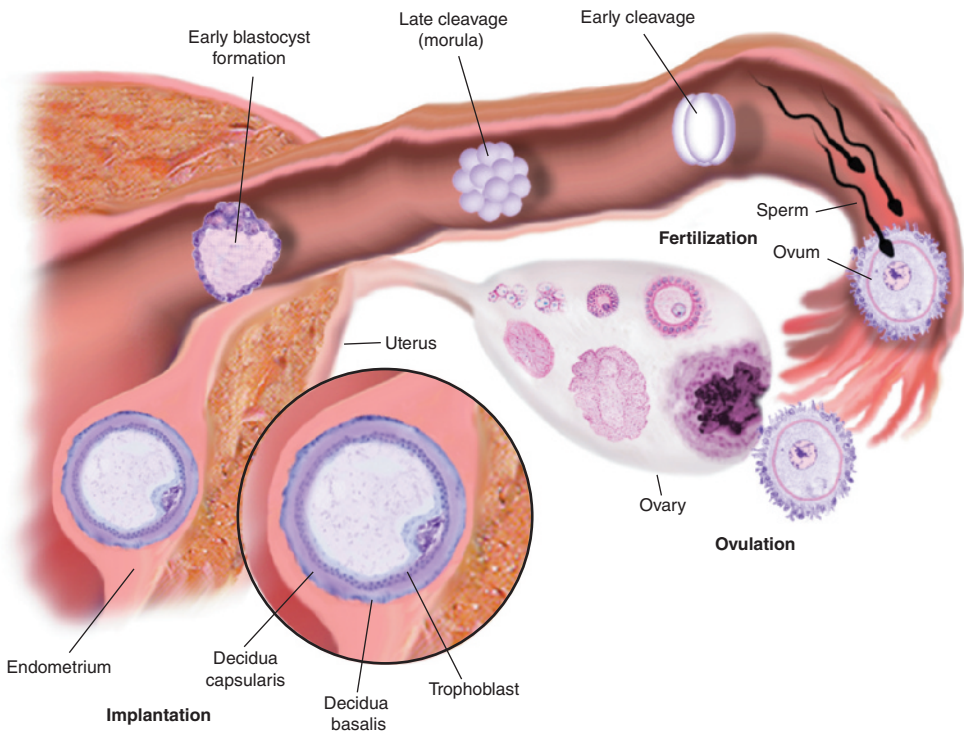

FIGURE 1–1. Stages of embryologic development through implantation.

During the second stage of growth and development, the organism is called an **embryo**. This stage occurs from the end of the ovum stage to the time it measures roughly 3 cm from head to rump or around 54 to 56 days. As the blastocyst continues to expand, some of the cells gather toward one end forming what is known as the **blastoderm** or embryonic disc. The embryonic disc, at this point, includes two layers of cells, the **ectoderm** and the **endoderm**. They are named according to their location, the ectoderm being the outer and thicker layer, and the endoderm being the innermost layer. The third cell layer, known as the **mesoderm**, forms between the other two layers shortly thereafter (Figure 1–2). It is during this stage and from these primary germ layers that all tissues, organs, and organ systems will differentiate. The structures that arise from the three primary germ layers are listed in Table 1–1. The embryo is extremely vulnerable to the effects of drugs, infections, and radiation. Exposure to any of these agents during this period can lead to severe congenital malformations.

During the third stage of growth and development, the organism is called a **fetus**, which is what it will remain until the end of the pregnancy. The major organs have developed and now proceed to grow during this period. Because the organ systems are mostly developed, they are less susceptible to drugs, infections, and radiation. However, exposure may lead to an interruption of normal functional development of the organ systems.

Following delivery, developmental stages in this text are identified by the following terms:

- **Neonate** is used from delivery through the first month of life.
- Infant is used for the period from 1 month to 1 year of life,
- Child identifies the patient above 1 year of age.

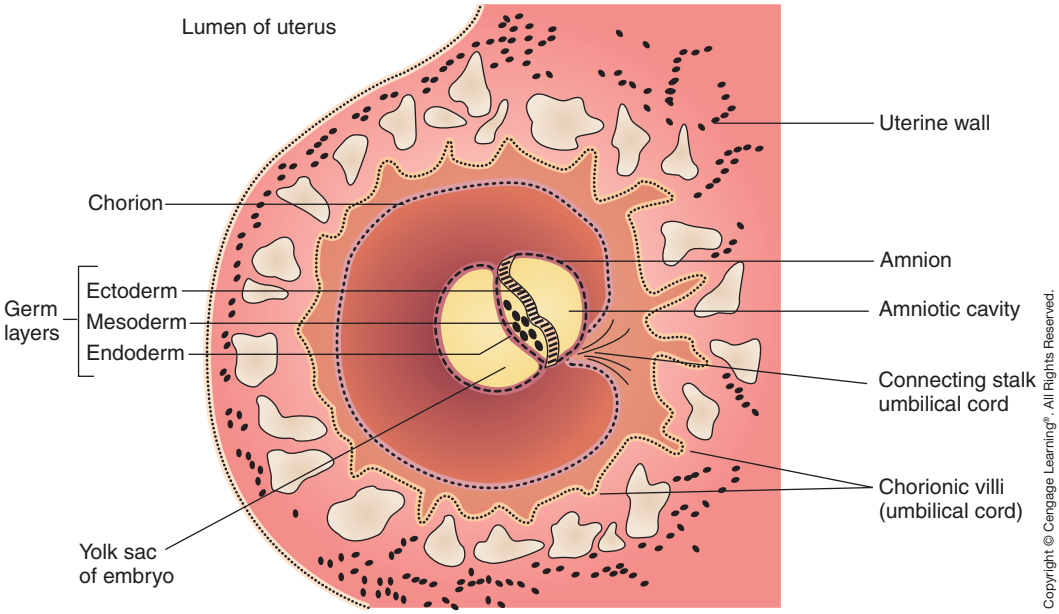

FIGURE 1–2. The germ layers of the developing embryo.

Table 1–1

STRUCTURES ARISING FROM THE THREE GERM LAYERS

Endoderm	Mesoderm	Ectoderm
• Respiratory tract • Epithelium of the digestive tract, bladder, thyroid • Primary tissue of the liver and pancreas	• Dermis • Muscles • Bone, connective tissue, lymphoid tissue • Reproductive organs • Cardiovascular system	• Epidermis • Hair, nails • Lens of the eye • Central and peripheral nervous system • Skin glands

DEVELOPMENT AND FUNCTION OF INTRAUTERINE STRUCTURES

The intrauterine structures include the placenta, the umbilical cord, the amnion, and the amniotic fluid.

Placenta

During the 40 weeks of gestational development, the placenta acts as the organ of respiration for the fetus. It is through the placenta that the growing fetus receives nutrients and oxygen and rids itself of CO_2 and other wastes. Soon after the embryo implants itself in the wall of the uterus, small projections of the trophoblast begin invading the endometrium, not unlike a seed sending roots into the soil. These projections, known as **chorionic villi**, are the beginning of the placenta. The anatomy of the term placenta is illustrated in Figure 1–3.

The villi continue to branch and develop, embedding themselves deeply in the endometrium. Each villus has an outer epithelial layer and an internal connective tissue core that contains the fetal vessels. As the villi continue to expand and grow, the endometrium begins to erode, creating pockets around the villi that will contain the maternal blood. These irregular spaces are known as the **intervillous spaces**.

At term, the normal placenta is round, occupies about one third of the uterine surface, and weighs around 1 pound, or 15% to 20% of the fetal weight at term. The maternal surface contains 15 to 28 segments, known as **cotyledons**. Each cotyledon contains the chorionic villus and an intervillous space.

Blood coming from the fetus follows the two umbilical arteries to the placenta, at which point they branch into smaller and smaller vessels. This branching supplies each cotyledon with a portion of the fetal blood. Upon reaching the cotyledon, the fetal blood advances throughout the branches of the chorionic villi. It is here that the exchange of nutrients, oxygen, CO_2, and waste takes place between maternal and

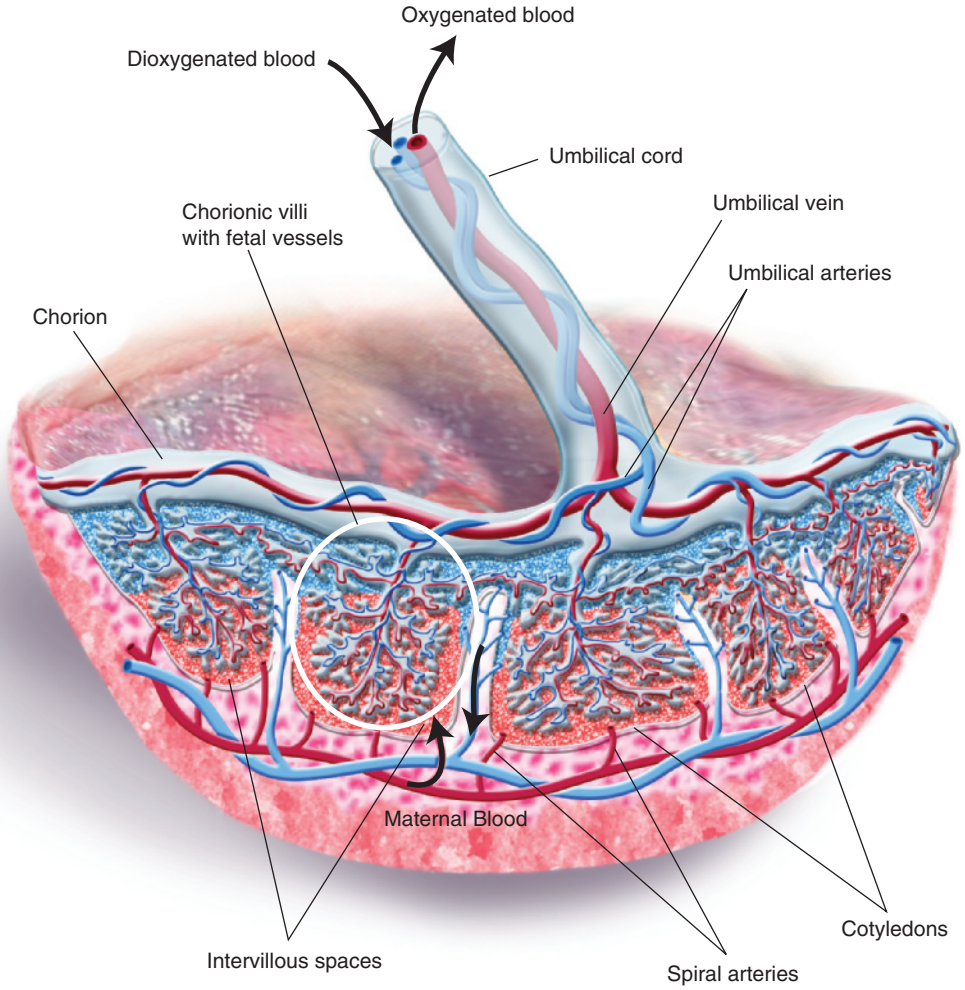

FIGURE 1–3. Anatomical structurs of the placenta.

fetal blood. There is no contact between the two blood supplies. They are separated by the thin epithelial layer of the villus. This allows passive exchange to proceed quite easily.

The maternal blood enters at the base of the intervillous space by way of spiral-arteries. The maternal arterial blood completely surrounds the chorionic villus, allowing a tremendous surface area for exchange. The fetal blood has high levels of CO_2 and waste materials but is low in oxygen and nutrients. In contrast, the maternal blood has high levels of oxygen and nutrients but is low in CO_2 and waste materials.

Following gradients of high to low concentrations, the fetal blood gets its needed oxygen and nutrients, while giving up the CO_2 and waste to the maternal blood. Maternal blood returns to the mother's venous system by way of venous openings in the chorionic villi, which drain into larger vessels and eventually reach the maternal vena cava.

Fetal blood, now carrying needed oxygen and nutrients, exits the villi through small veins. These veins collect the fetal blood from each cotyledon and return it to the fetus by way of the umbilical vein.

Umbilical Cord

The umbilical cord is the lifeline between mother and fetus. To perform this vital role, the umbilical cord has a unique makeup. A cross section of the umbilical cord (Figure 1–4) reveals three vessels surrounded by a tough, gelatinous material, called Wharton's jelly. Wharton's jelly insulates and protects the umbilical vessels. The three vessels consist of two smaller arteries and one large floppy vein. The umbilical arteries have relatively thick walls, whereas the vein is thin walled.

Because of the constant movement of the fetus in utero, it is possible that the umbilical cord could bend and pinch off, stopping the flow of blood to the infant. The presence of Wharton's jelly prevents this from occurring. While it is flexible enough to allow bending and movement of the cord, it is also rigid enough to prevent the cord from kinking and occluding blood flow. However, as the fetus nears term and has grown significantly in size, there is a possibility for cord compression, which can be life threatening. This is rare, and when it occurs, it is most often during the birthing process. Following delivery, ubrupt temperature changes cause the Wharton's jelly to collapse the umbilical vessels within about 5 minutes.

Amnion

The **amnion** is the sac that surrounds the growing fetus and contains the amniotic fluid. It arises from the trophoblast around the seventh gestational day. It begins as a small vesicle and develops into a sac, which covers the dorsal surface of the embryo. As gestation progresses it enlarges and surrounds the embryo.

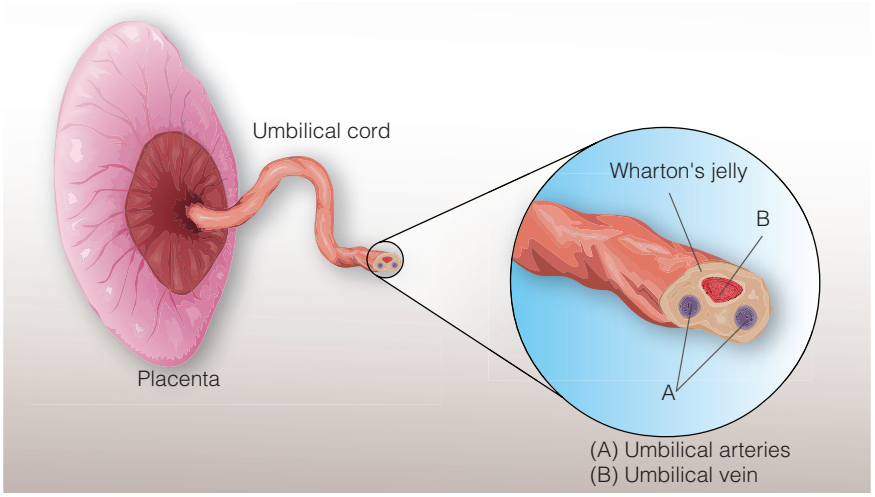

FIGURE 1–4. Cross-sectional view of the umbilical cord.