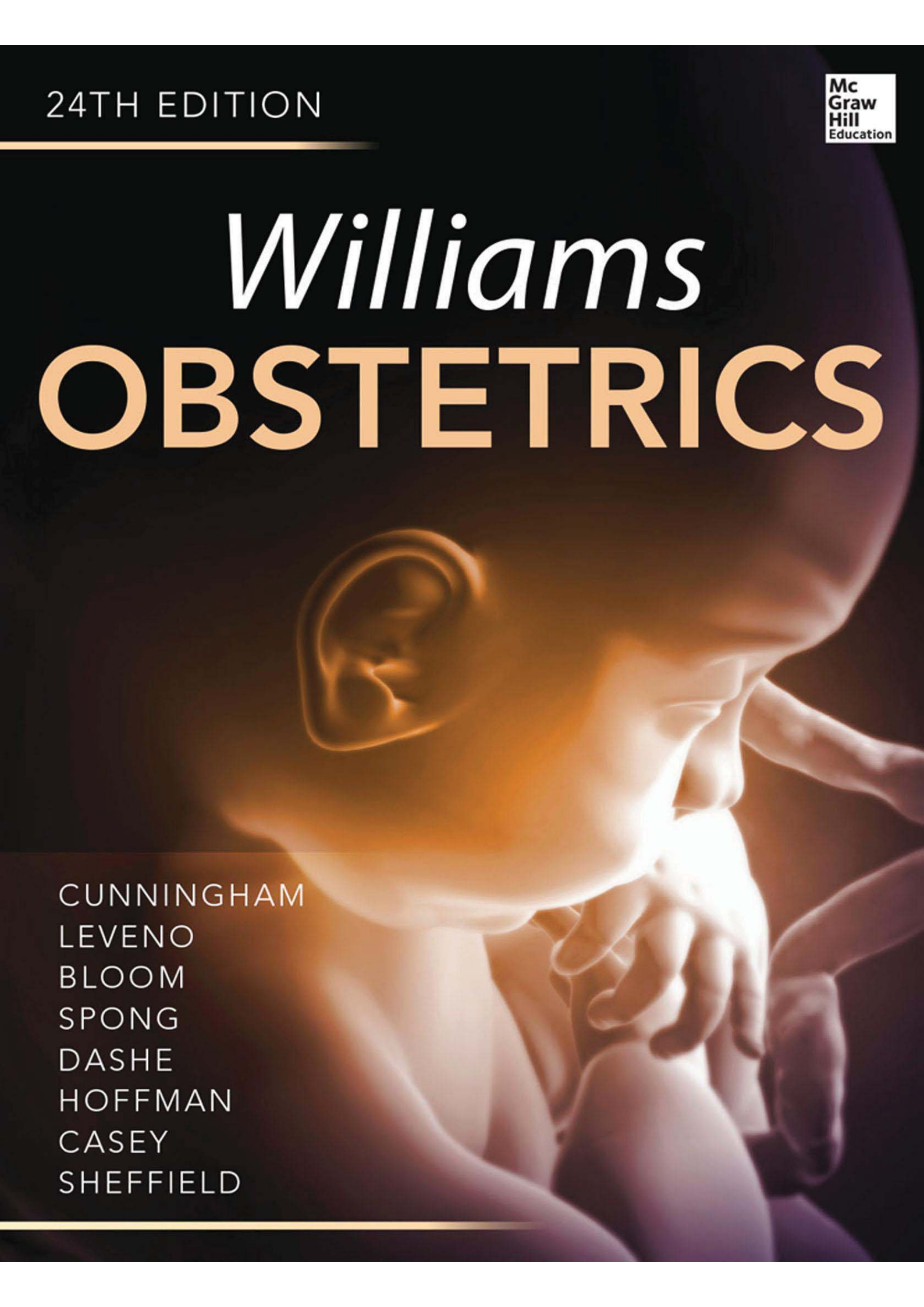


24TH EDITION

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# *Williams* OBSTETRICS

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# *Williams* OBSTETRICS

24TH EDITION

F. Gary Cunningham  
Kenneth J. Leveno  
Steven L. Bloom  
Catherine Y. Spong  
Jodi S. Dashe  
Barbara L. Hoffman  
Brian M. Casey  
Jeanne S. Sheffield



Medical

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# DEDICATION

These are trying times for academic medicine. They are especially vexing for departments of obstetrics and gynecology. Combined with draconian funding shortages, there is burdensome oversight with sometimes meaningless regulations as well as myriad forms and paperwork foisted upon us by an ever-increasing but already bloated bureaucracy. Despite these seemingly overwhelming challenges, the chairs of academic departments and the directors of residency training programs resiliently continue to emphasize the basics that are fundamental to academic training. It is to these stalwart individuals that we dedicate this 24th edition of *Williams Obstetrics*.



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# PREFACE

This 24th edition of *Williams Obstetrics* has been extensively and strategically reorganized. Primarily writing for the busy practitioner—those “in the trenches”—we continue to present the detailed staples of basic obstetrics such as maternal anatomy and physiology, preconceptional and prenatal care, labor, delivery, and the puerperium, along with detailed discussions of obstetrical complications exemplified by preterm labor, hemorrhage, hypertension, and many more. Once again, we emphasize the scientific-based underpinnings of clinical obstetrics with special emphasis on biochemical and physiological principles of female reproduction. And, as was the hallmark of previous editions, these dovetail with descriptions of evidence-based practices. The reorganized format allows a greater emphasis on the fetus as a patient along with expanded coverage of fetal diagnosis and therapy. These changes are complemented by more than 100 new sonographic and magnetic resonance images that display normal fetal anatomy and common fetal anomalies. Finally, to emphasize the “M” in maternal–fetal medicine, we continue to iterate the myriad medical and surgical disorders that can complicate pregnancy.

To accomplish these goals, the text has been updated with more than 3000 new literature citations through 2014. Moreover, there are nearly 900 figures that include sonograms, MR images, photographs, micrographs, and data graphs, most in vivid color. Much of the original artwork was rendered by our own medical illustrators.

In this edition, as before, we continue to incorporate contemporaneous guidelines from professional and academic organizations such as the American College of Obstetricians and Gynecologists, the Society for Maternal–Fetal Medicine, the National Institutes of Health, and the Centers for Disease Control and Prevention, among others. Many of these data are distilled into almost 100 newly constructed tables, in which information has been arranged in a format that is easy to read and use. In addition, several diagnostic and management algorithms have been added to guide practitioners. While we strive to cite numerous sources to provide multiple evidence-based options for such management schemes, we also include our own clinical experiences drawn from a large obstetrical service. As usual, while we are convinced that these are disciplined examples of evidence-based obstetrics, we quickly acknowledge that they do not constitute the sole method of management.

This 24th edition shows a notable absence of four colleagues who provided valuable editorial assistance for prior volumes of *Williams Obstetrics*. From the University of Alabama at Birmingham, Dr. John Hauth, who served as an editor for the 21st through 23rd editions, has now directed his efforts to research endeavors. Dr. Dwight Rouse, an associate editor of the 22nd and an editor of the 23rd edition, has assumed a clinical and research role at Brown University. We will cer-

tainly miss their insightful wisdom concerning the vicissitudes of randomized controlled trials and their true meanings! Colleagues leaving us from the University of Texas Southwestern Medical Center include Dr. George Wendel, Jr.—associate editor for the 22nd and 23rd editions—who has now assumed the important role of overseeing development of Maintenance of Certification for the American Board of Obstetrics and Gynecology. And leaving for practice in Montana is Dr. Jim Alexander, who served as a contributing editor for the 23rd edition. These talented clinicians provided valuable knowledge, both evidence-based and from the bedside.

To fill the shoes of these departing stalwart colleagues, we have enlisted four new editors—all from UT Southwestern Medical Center—each of whom has expertise in important areas of contemporaneous obstetrics and maternal–fetal medicine. Dr. Jodi Dashe—who contributed extensively to the 21st through 23rd editions—joins us as editor and brings her extensive experiences and incredible skills with obstetrical sonography, fetal diagnosis, and prenatal genetics. Dr. Barbara Hoffman brings widespread clinical knowledge regarding general obstetrics and contraception as well as embryology, anatomy, and placental pathology. Dr. Brian Casey adds his in-depth obstetrical and research experience, with special interests in diabetes, fetal-growth disorders, and thyroid physiology. Dr. Jeanne Sheffield joins us with her knowledge and clinical acumen and research interests in maternal medical disorders, critical care, and obstetrical and perinatal infections.

There are also two returning associate editors who continue to add considerable depth to this textbook. Dr. Diane Twickler uses her fantastic experiences and knowledge regarding clinical and technological advances related to fetal and maternal imaging with ultrasonography as well as with x-ray and magnetic resonance techniques. Dr. Mala Mahendroo is a talented basic scientist who continues to perform a magnificent job of providing a coherent translational version of basic science aspects of human reproduction. Finally, four new contributing editors round out the editorial team that make this book possible. Drs. Kevin Worley and Seth Hawkins bring additional strengths to the areas of clinical and academic maternal–fetal medicine. Dr. Don McIntire provided much of the data garnered from the extensive database that chronicles the large obstetrical service at Parkland Hospital and UT Southwestern Medical Center. Mr. Lewis Calver continues to do an impeccable job of supervising and rendering new artwork for this and prior editions. In toto, the strength of each contributor has added to create the sum total of our academic endeavor.

F. Gary Cunningham  
Kenneth J. Leveno  
Steven L. Bloom



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# ACKNOWLEDGMENTS

During the creation and production of this textbook, we were fortunate to have the assistance and support of countless talented professionals both within and outside the Department of Obstetrics and Gynecology. To begin, we acknowledge that an undertaking of this magnitude would not be possible without the unwavering support provided by Dr. Barry Schwarz, whose financial and academic endorsement has been essential.

In constructing such an expansive academic compilation, the expertise of many colleagues was needed to add vital and contemporaneous information. It was indeed fortuitous for us to have access to a pantheon of contributors here as well as from other academic medical centers. From the University of Texas Southwestern Medical Center, Dr. April Bailey of the Departments of Radiology and Obstetrics and Gynecology added insights and provided illustrative maternal and fetal magnetic resonance images. These were further complimented by other visual contributions from Drs. Elysia Moschos, Michael Landay, Jeffrey Pruitt, and Douglas Sims. From the Department of Pathology, Drs. Kelley Carrick and Brian Levenson generously donated exemplary photomicrographs. From the Department of Dermatology, Dr. Amit Pandya provided a number of classic figures. From the Division of Urogynecology, our nationally known pelvic anatomist, Dr. Marlene Corton, prepared graphic masterpieces for the anatomy chapter. Drs. Claudia Werner and William Griffith lent valuable insight into the management of cervical dysplasia. Much of the Appendix of this textbook was originally compiled by Drs. Mina Abbassi-Ghanavati and Laura Greer. Finally, clinical photographs were contributed by many current and former faculty and fellows, including Drs. Patricia Santiago-Muñoz, Julie Lo, Lisa Halvorson, Kevin Doody, Michael Zaretsky, Judith Head, David Rogers, Sunil Balgobin, Manisha Sharma, Michael Hnat, Rigoberto Santos-Ramos, Shayzreen Roshanravan, April Bleich, and Roxane Holt.

Several contributions were made by our national and international colleagues. Experts in placental pathology who shared their expertise and images include Drs. Kurt Benirschke, Ona Marie Faye-Petersen, Mandolin Ziadie, Michael Conner, Jaya George, and Erika Fong. Input for hypertensive disorders was provided by Drs. Marshall Lindheimer and Gerda Zeeman and for operative vaginal delivery by Dr. Edward Yeomans. Seminal images were contributed by Drs. Timothy Crombleholme, Togas Tulandi, Edward Lammer, Charles Read, and Frederick Elder.

In addition to these contributors, we relied heavily on numerous other colleagues and coworkers for their intellectual and clinical input. Specifically, we cite the entire Division of Maternal–Fetal Medicine, whose faculty, in addition to providing expert content, graciously assisted us to cover clinical duties when writing and editing were especially time consuming. These include Drs. Scott Roberts, Oscar Andujo, Vanessa Rogers, Morris Bryant, Stephan Shivvers, Stephanie Chang, Robyn Horsager, Patricia Santiago-Muñoz, Julie Lo, Ashley Zink, Ed Wells, and Mark Peters.

We also note that production of *Williams Obstetrics* would not be feasible without the help of our maternal–fetal medicine fellows and residents in obstetrics and gynecology. Their insatiable curiosity serves to energize us to find new and effective ways to convey age-old truths, new data, and cutting-edge concepts. Their logical and critical questions lead us to weaknesses in the text, and thereby, always help us to improve our work. In addition, we sincerely thank them for their vigilance in capturing photographs of spectacular examples of both obstetrical pathology and normal findings. For example, included in this edition are photographs contributed by Drs. Elaine Duryea, Stacey Thomas, Jonathan Willms, Kara Ehlers, Nidhi Shah, Abel Moron, Kyler Elwell, Rebecca Stone, Angela Fields, Emily Adhikari, and Elizabeth Mosier.

Thanks to generous funding from the McGraw-Hill Companies, this 24th edition now contains more than 200 color illustrations. Most of these were crafted by several skilled medical illustrators, including Ms. Marie Sena, Ms. Erin Frederikson, Ms. Mollie Gove, Mr. Jordan Pietz, Ms. SangEun Cha, and Ms. Jennifer Hulsey. All of these talented artists trained here at UT Southwestern under the tutelage of Mr. Lewis Calver. Additional artistic support came from Mr. Joseph Varghese, Ms. Dharmesh Thakur, and their team at Thomson Digital, who provided the full-color graphs and line art used to enhance this edition. They were aided by medical-content expert Dr. Shetoli Zhimomi, who precisely translated our academic vision to each image. Their team tirelessly coordinated efforts between author and artist and graciously accommodated our numerous changes and tweaks.

Production of the 5000-page manuscript would not have been possible without a dedicated team to bring these efforts together. Once again, we are deeply indebted to Ms. Connie Utterback for her untiring efforts as production coordinator. She received able assistance with manuscript production from the Dallas group that included Ms. Melinda Epstein, Ms. Dawn Wilson, Ms. Marsha Zint, Ms. Minnie Tregaskis, Ms. Dina Trujillano, and Ms. Ellen Watkins. Information technology support was provided by the very knowledgeable and responsive Mr. Charles Richards and Mr. Thomas Ames. For these and many more that go unnamed, we could not have done our job without their expertise.

It again has been a privilege and a pleasure to work with the dedicated professionals from McGraw-Hill Education. Ms. Alyssa Fried has brought her considerable intelligence, energetic work ethic, and creativity to this edition of *Williams Obstetrics*. Her dedication to creating the best textbook possible equaled our efforts, and we are in awe of her unflappable, productive, and gracious style. Mr. Peter Boyle shepherded our book through production. We greatly appreciate his calm and efficient efforts. Mr. Richard Ruzycka served as production supervisor for this edition of the textbook. He skillfully kept our project on track through an array of potential hurdles. Last, we have had the pleasure to work with Mr. Armen Ovsepyan

in coordinating the artwork for many of our editions. His organization and efficiency are unrivaled.

Our text took its final shape under the watchful care of our compositors at Aptara, Inc. We thank Ms. Indu Jawwad for her talents in skillfully coordinating and overseeing composition. Her dedicated attention to detail and organization were vital to completion of our project. Also at Aptara, Mr. Mahender Singh served a crucial task of quality control and assisted in creating beautiful chapter layouts to highlight our content aesthetically and informatively.

Finally—but certainly not last—we acknowledge our significant debt to the women who have allowed us to participate in their care. The clinical expertise and many graphic illustrations presented in this text would not have been possible without their collaborative spirit to help us advance obstetrical knowledge. We also offer enthusiastic and heartfelt appreciation to our families and friends. Without their patience, generosity, and encouragement, this task would have been impossible.

The Editors

SECTION 1  
**OVERVIEW**



## CHAPTER 1

# Overview of Obstetrics

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Obstetrics is concerned with human reproduction and as such is always a subject of considerable contemporary relevance. The specialty promotes health and well-being of the pregnant woman and her fetus through quality perinatal care. Such care entails appropriate recognition and treatment of complications, supervision of labor and delivery, ensuring care of the newborn, and management of the puerperium. Postpartum care promotes health and provides family planning options.

The importance of obstetrics is reflected by the use of maternal and neonatal outcomes as an index of the quality of health and life among nations. Intuitively, indices that reflect poor obstetrical and perinatal outcomes would lead to the assumption that medical care for the entire population is lacking. With those thoughts, we now provide a synopsis of the current state of maternal and newborn health in the United States as it relates to obstetrics.

### VITAL STATISTICS

The National Vital Statistics System of the United States is the oldest and most successful example of intergovernmental data sharing in public health. The National Center for Health Statistics collects and disseminates official statistics through contractual agreements with vital registration systems. These systems that operate in various jurisdictions are legally responsible for registration of births, fetal deaths, deaths, marriages, and divorces. Legal authority resides individually with the 50 states;

two regions—the District of Columbia and New York City; and five territories—American Samoa, Guam, the Northern Mariana Islands, Puerto Rico, and the Virgin Islands.

Standard certificates for the registration of live births and deaths were first developed in 1900. An act of Congress in 1902 established the Bureau of the Census to develop a system for the annual collection of vital statistics. The Bureau retained authority until 1946, when the function was transferred to the United States Public Health Service. It is presently assigned to the Division of Vital Statistics of the National Center for Health Statistics, which is a division of the Centers for Disease Control and Prevention (CDC). The standard birth certificate was revised in 1989 to include more information on medical and lifestyle risk factors and obstetrical practices.

In 2003, an extensively revised *Standard Certificate of Live Birth* was implemented in the United States to enhance collection of obstetrical and newborn clinical information. The enhanced data categories and specific examples of each are summarized in [Table 1-1](#). By 2011, 36 states had implemented this revised birth certificate representing 83 percent of all births (Hamilton, 2012).

### Definitions

The uniform use of standard definitions is encouraged by the World Health Organization as well as the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists (2012). Such uniformity allows data comparison not only between states or regions of the country but also between countries. Still, not all definitions are uniformly applied. For example, the American College of Obstetricians and Gynecologists recommends that reporting include all fetuses and neonates born weighing at minimum 500 g, whether alive or dead. But not all states follow this recommendation. Twenty-eight states stipulate that fetal deaths beginning at 20 weeks' gestation should be recorded as such; eight states report all products of conception as fetal deaths;

**TABLE 1-1.** General Categories and Specific Examples of New Information Added to the 2003 Revision of the Birth Certificate

Risk Factors in Pregnancy—Examples: prior preterm birth, prior eclampsia
Obstetrical Procedures—Examples: tocolysis, cerclage, external cephalic version
Labor—Examples: noncephalic presentation, glucocorticoids for fetal lung maturation, antibiotics during labor
Delivery—Examples: unsuccessful operative vaginal delivery, trial of labor with prior cesarean
Newborn—Examples: assisted ventilation, surfactant therapy, congenital anomalies

and still others use a minimum birthweight of 350 g, 400 g, or 500 g to define fetal death. To further the confusion, the National Vital Statistics Reports tabulates fetal deaths from gestations that are 20 weeks or older (Centers for Disease Control and Prevention, 2009). This is problematic because the 50th percentile for fetal weight at 20 weeks approximates 325 to 350 g—considerably less than the 500-g definition. Indeed, a birthweight of 500 g corresponds closely with the 50th percentile for 22 weeks.

Definitions recommended by the National Center for Health Statistics and the Center for Disease Control and Prevention are as follows:

**Perinatal period.** The interval between the birth of an infant born after 20 weeks' gestation and the 28 completed days after that birth. When perinatal rates are based on birthweight, rather than gestational age, it is recommended that the perinatal period be defined as commencing at 500 g.

**Birth.** The complete expulsion or extraction from the mother of a fetus after 20 weeks' gestation. As described above, in the absence of accurate dating criteria, fetuses weighing < 500 g are usually not considered as births but rather are termed *abortuses* for purposes of vital statistics.

**Birthweight.** The weight of a neonate determined immediately after delivery or as soon thereafter as feasible. It should be expressed to the nearest gram.

**Birth rate.** The number of live births per 1000 population.

**Fertility rate.** The number of live births per 1000 females aged 15 through 44 years.

**Live birth.** The term used to record a birth whenever the newborn at or sometime after birth breathes spontaneously or shows any other sign of life such as a heartbeat or definite spontaneous movement of voluntary muscles. Heartbeats are distinguished from transient cardiac contractions, and respirations are differentiated from fleeting respiratory efforts or gasps.

**Stillbirth or fetal death.** The absence of signs of life at or after birth.

**Early neonatal death.** Death of a liveborn neonate during the first 7 days after birth.

**Late neonatal death.** Death after 7 days but before 29 days.

**Stillbirth rate or fetal death rate.** The number of stillborn neonates per 1000 neonates born, including live births and stillbirths.

**Neonatal mortality rate.** The number of neonatal deaths per 1000 live births.

**Perinatal mortality rate.** The number of stillbirths plus neonatal deaths per 1000 total births.

**Infant death.** All deaths of liveborn infants from birth through 12 months of age.

**Infant mortality rate.** The number of infant deaths per 1000 live births.

**Low birthweight.** A newborn whose weight is < 2500 g.

**Very low birthweight.** A newborn whose weight is < 1500 g.

**Extremely low birthweight.** A newborn whose weight is < 1000 g.

**Term neonate.** A neonate born any time after 37 completed weeks of gestation and up until 42 completed weeks of gestation (260 to 294 days). The American College of Obstetricians and Gynecologists (2013b) and the Society for Maternal-Fetal Medicine endorse and encourage specific gestational age designations. *Early term* refers to neonates born at 37 completed weeks up to 38<sup>6/7</sup> weeks. *Full term* denotes those born at 39 completed weeks up to 40<sup>6/7</sup> weeks. Last, *late term* describes neonates born at 41 completed weeks up to 41<sup>6/7</sup> weeks.

**Preterm neonate.** A neonate born before 37 completed weeks (the 259th day).

**Postterm neonate.** A neonate born anytime after completion of the 42nd week, beginning with day 295.

**Abortus.** A fetus or embryo removed or expelled from the uterus during the first half of gestation—20 weeks or less, or in the absence of accurate dating criteria, born weighing < 500 g.

**Induced termination of pregnancy.** The purposeful interruption of an intrauterine pregnancy that has the intention other than to produce a liveborn neonate and that does not result in a live birth. This definition excludes retention of products of conception following fetal death.

**Direct maternal death.** The death of the mother that results from obstetrical complications of pregnancy, labor, or the puerperium and from interventions, omissions, incorrect treatment, or a chain of events resulting from any of these factors. An example is maternal death from exsanguination after uterine rupture.

**Indirect maternal death.** A maternal death that is not directly due to an obstetrical cause. Death results from previously existing disease or a disease developing during pregnancy, labor, or the puerperium that was aggravated by maternal physiological adaptation to pregnancy. An example is maternal death from complications of mitral valve stenosis.

**Nonmaternal death.** Death of the mother that results from accidental or incidental causes not related to pregnancy. An example is death from an automobile accident or concurrent malignancy.

**Maternal mortality ratio.** The number of maternal deaths that result from the reproductive process per 100,000 live births. Used more commonly, but less accurately, are the terms *maternal mortality rate* or *maternal death rate*. The term *ratio* is more accurate because it includes in the numerator the



number of deaths regardless of pregnancy outcome—for example, live births, stillbirths, and ectopic pregnancies—whereas the denominator includes the number of live births. Pregnancy-associated death. The death of a woman, from any cause, while pregnant or within 1 calendar year of termination of pregnancy, regardless of the duration and the site of pregnancy.

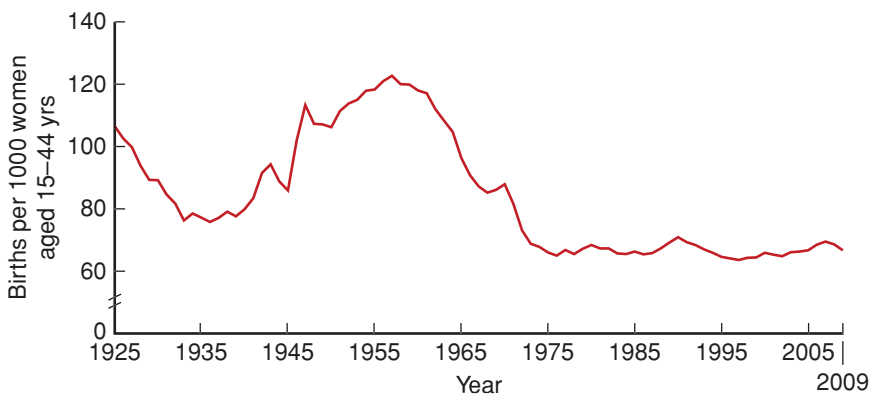
Pregnancy-related death. A pregnancy-associated death that results from: (1) complications of pregnancy itself, (2) the chain of events initiated by pregnancy that led to death, or (3) aggravation of an unrelated condition by the physiological or pharmacological effects of pregnancy and that subsequently caused death.

## PREGNANCY IN THE UNITED STATES

### Pregnancy Rates

Data from diverse sources have been used to provide the following snapshot of pregnancy in the United States during the first two decades of the 21st century. According to the Centers for Disease Control and Prevention, the fertility rate in the United States in 2011 of women aged 15 to 44 years was 63.2 live births per 1000 women (Sutton, 2011). As shown in [Figure 1-1](#), this rate began slowly trending downward in 1990 and has now decreased below that for replacement births, indicating a population decline (Hamilton, 2012). There were 3.9 million births in 2011, and this constituted the lowest birth rate ever recorded for the United States of 12.7 per 1000 population. The birth rate decreased for all major ethnic and racial groups, for adolescents and unmarried women, and for those aged 20 to 24 years. For women older than 30 years, the birth rate was either unchanged or it increased slightly. Virtually half of newborns in 2010 in the United States were minorities: Hispanic—25 percent, African-American—14 percent, and Asian—4 percent (Frey, 2011).

The total number of pregnancies and their outcomes in 2008 are shown in [Table 1-2](#). Of the 6,578,000 total pregnancies, most—65 percent—ended with live births. Of births in the United States, approximately 37 percent are unintended at the time of conception (Mosher, 2012). Importantly, the overall proportion of unintended births has not declined significantly since 1982. Unmarried women, black women, and women with less education or income are more likely



**FIGURE 1-1** Fertility rate: United States, 1925–2009. (From Sutton, 2011.)

**TABLE 1-2.** Total Number of Pregnancies and Outcomes in the United States in 2008

Outcomes	Number (%)
Live births	4,248,000 (65)
Induced abortions	1,212,000 (18)
Spontaneous abortions	1,118,000 (17)
Total pregnancies	6,578,000 (100)

Data from Ventura, 2012.

to have unplanned pregnancies. That said, of the remaining pregnancies in 2008, 35 percent were almost equally divided into induced or spontaneous abortions. The induced abortion information is based on CDC abortion surveillance data from 45 states combined with Guttmacher Institute data on induced abortion. These data have been collected beginning in 1976. If the annual totals for 1976 to 2008 are tabulated, it can be estimated that approximately 46,657,000 women in the United States have elected induced abortions since *Roe v. Wade* legalization of abortion (Chap. 18, p. 363). Thus, legalized abortions have been chosen by more than 46 million American women. As discussed later, this provides a compelling argument for easily accessible family planning.

## MEASURES OF OBSTETRICAL CARE

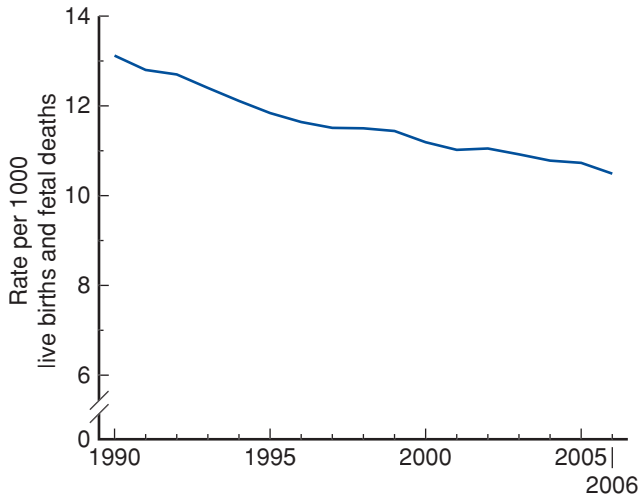
### Perinatal Mortality

There are a number of indices—several among the vital statistic definitions described above—that are used as a yardstick of obstetrical and perinatal outcomes to assess quality of care.

As previously defined, the perinatal mortality rate includes the numbers of stillbirths and neonatal deaths per 1000 total births. According to the National Vital Statistics Reports by MacDorman and colleagues (2012a), the perinatal mortality rate in 2006 was 10.5 per 1000 births ([Fig. 1-2](#)). There were 25,972 fetal deaths in gestations 20 weeks or older. Fetal deaths at 28 weeks or more have been declining since 1990, whereas the rates for those between 20 and 27 weeks have been static ([Fig. 1-3](#)). By way of comparison, there were a total of 19,041 neonatal deaths in 2006—meaning that nearly 60 percent of the perinatal deaths in the United States were fetal. Thus, it is seen that fetal deaths have eclipsed neonatal deaths as a cause of perinatal mortality.

### Infant Deaths

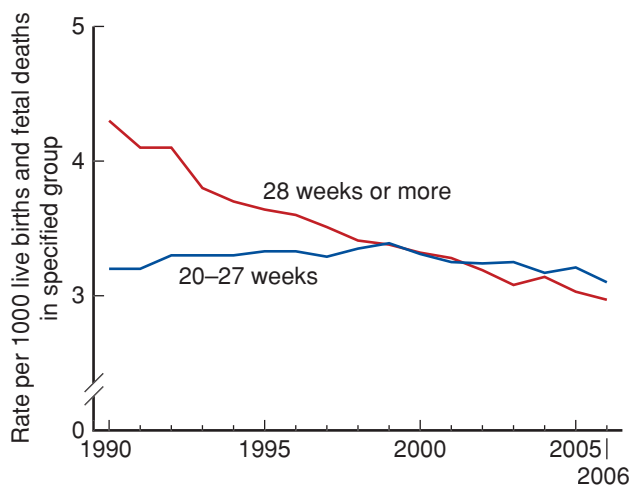
There were 6.1 infant deaths per 1000 live births in 2011 compared with 6.8 in 2001 (Hamilton, 2012). The three leading causes of infant death—congenital malformations, low birthweight, and sudden infant death syndrome—accounted for almost half of all deaths. Infants born at the lowest gestational ages and birthweights add substantively



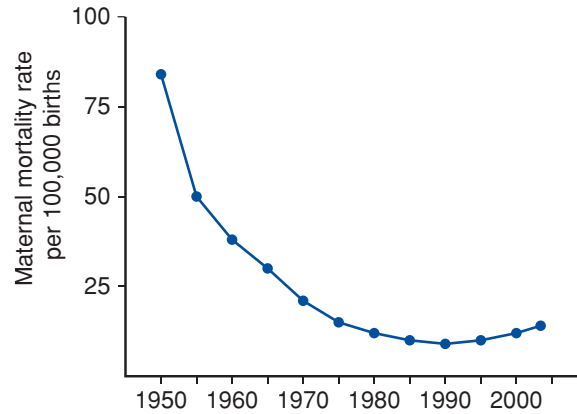
**FIGURE 1-2** Perinatal mortality rate: United States, 1990–2006. *Perinatal* includes infant deaths under age 28 days and fetal deaths at 20 weeks or more. (From MacDorman, 2012a.)

to these mortality rates. For example, 55 percent of all infant deaths in 2005 were in the 2 percent of infants born before 32 weeks’ gestation. Indeed, the percentage of infant deaths related to preterm birth increased from 34.6 percent in 2000 to 36.5 percent in 2005. When analyzed by birthweight, two thirds of infant deaths were in low-birthweight neonates. Of particular interest are those birthweights < 500 g, for which neonatal intensive care can now be offered. In 2001, there were 6450 liveborns weighing less than 500 g, but 86 percent of these newborns died during the first 28 days of life. Of the 1044 who survived the first 28 days of life, there were 934 who lived for at least 1 year. Thus, only 14 percent of all neonates weighing < 500 g survived infancy. Importantly, adverse developmental and neurological sequelae are common in the survivors (Chap. 42, p. 832).

More than a decade ago, St. John and associates (2000) estimated the total cost of initial newborn care in the United States to be \$10.2 billion annually. Almost 60 percent of this



**FIGURE 1-3** Fetal mortality rates by period of gestation: United States, 1990–2006. (From MacDorman, 2012a.)

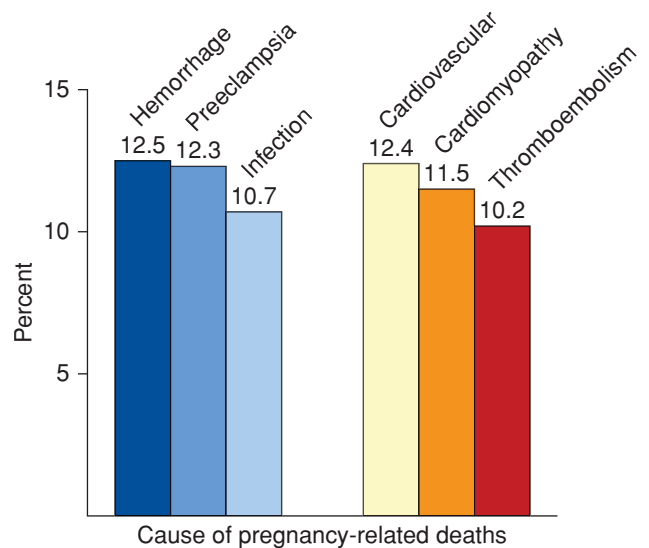


**FIGURE 1-4** Maternal mortality rates for the United States, 1950–2003. (Data from Berg, 2010; Hoyert, 2007.)

expenditure is attributed to preterm births before 37 weeks, and 12 percent is spent on neonates born between 24 and 26 weeks.

### Maternal Mortality

As shown in Figure 1-4, maternal mortality rates decreased precipitously in the United States during the 20th century. Pregnancy and childbirth have never been safer for women in this country. In fact, pregnancy-related deaths are so uncommon as to be measured per 100,000 births. The CDC since 1979 has maintained data on pregnancy-related deaths in its *Pregnancy Mortality Surveillance System* (Mackay, 2005). In the latest report, Berg and coworkers (2010) described 4693 pregnancy-related deaths during the 8-year period 1998 to 2005. Approximately 5 percent were early-pregnancy deaths due to ectopic gestation or abortive outcomes. The deadly obstetrical triad of hemorrhage, preeclampsia, and infection accounted for a third of all deaths (Table 1-3). Thromboembolism, cardiomyopathy, and other cardiovascular disease together accounted for another third (Fig. 1-5). Other significant contributors in this group were amniotic fluid



**FIGURE 1-5** Six common causes of maternal deaths for the United States, 1998–2005. (Data from Berg, 2010.)



**TABLE 1-3.** Causes of Pregnancy-Related Maternal Deaths in the United States<sup>a,b</sup> During Two Time Periods

Cause of Death	1991–1999 <sup>a,c</sup>	1998–2005 <sup>b,d</sup>
	n = 4200 (%)	n = 4693 (%)
Embolism	19.6	10.2
Hemorrhage	17.2	12.5
Gestational hypertension	15.7	12.3
Infection	12.6	10.7
Other pregnancy-related	34.1	33.2
Cardiomyopathy	8.3	11.5
Stroke	5.0	6.3
Anesthesia	1.6	1.2
Others <sup>e</sup>	19.2	14.2
Unknown	0.7	2.1

<sup>a</sup>Data from Centers for Disease Control and Prevention reported by Chang, 2003.

<sup>b</sup>Data from the Centers for Disease Control and Prevention reported by Berg, 2010.

<sup>c</sup>Includes abortion and ectopic pregnancy.

<sup>d</sup>Excludes abortion and ectopic pregnancy.

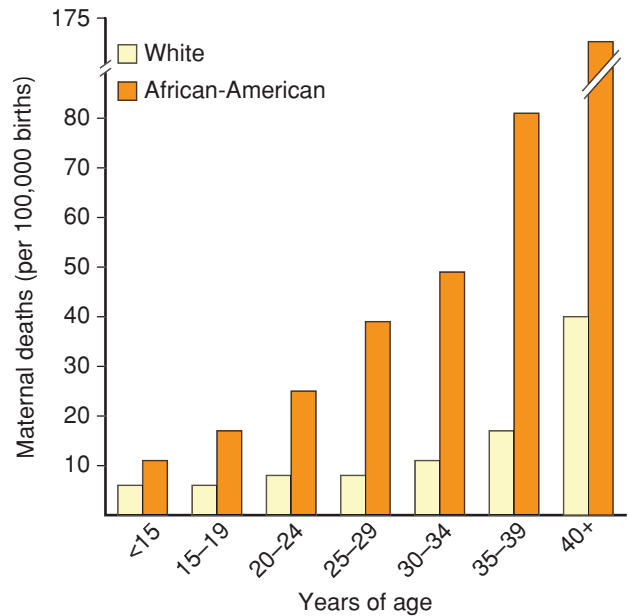
<sup>e</sup>Includes cardiovascular, pulmonary, neurological, and other medical conditions.

embolism (7.5 percent) and cerebrovascular accidents (6.3 percent). Anesthesia-related deaths were at an all-time low of only 1.2 percent. It is also important to consider the role that the increasing cesarean delivery rate has on maternal mortality risks (Clark, 2008; Deneux-Tharoux, 2006; Lang, 2008).

The pregnancy-related mortality ratio for this 1998 to 2005 period of 14.5 per 100,000 live births is the highest during the previous 20 years (Berg, 2010). This simply may mean more women are dying, however, it may be due to improved reporting or to an artificial increase caused by the new International Statistical Classification of Diseases, 10th Revision (ICD-10), implemented in 1999. There is no doubt that maternal deaths are notoriously underreported, possibly by as much as half (Koonin, 1997).

A second important consideration is the obvious disparity of increased mortality rates in African-American compared with white women as shown in [Figure 1-6](#). The disparity with indigent women is exemplified by the study of maternal deaths in women cared for in a third-party payer system, the Hospital Corporation of America. In this study of nearly 1.5 million pregnant women, Clark and associates (2008) reported an impressively low maternal mortality rate of 6.5 per 100,000.

The third important consideration is that many of the reported maternal deaths are considered preventable. In an earlier report, Berg and colleagues (2005) stated that this may be up to a third of pregnancy-related deaths in white women and up to half of those in African-American women. And even in the insured women described above and reported by Clark, 28 percent of 98 maternal deaths were judged preventable.



**FIGURE 1-6** Maternal mortality ratio—deaths per 100,000 live births—by age and according to race for the United States, 1998–2005. (Data from Berg, 2010.)

Thus, although significant progress has been made, measures to prevent more deaths are imperative for obstetrics in the 21st century.

### Severe Maternal Morbidity

Because maternal deaths have become so uncommon, the practice of analyzing severe maternal morbidity evolved as a surrogate to improve obstetrical and perinatal care. Because avoidance of medical errors serves to decrease the risks for maternal mortality or severe maternal morbidity, the concept of *near misses* or *close calls* was also introduced. These are defined by the Joint Commission and the Institution for Safe Medication and Practices (2009) as unplanned events caused by error that do not result in patient injury but have the potential to do so. These are much more common than injury events, but for obvious reasons, they are more difficult to identify and quantify. Systems designed to encourage reporting have been installed in various institutions and allow focused safety efforts. One example is the system described by Clark and associates (2012) and used for more than 200,000 annual deliveries within the Hospital Corporation of America ([Table 1-4](#)).

There are now a number of statistical data systems that measure indicators of unplanned events caused by errors that had potential to injure patients. This evolution followed inadequacies in how well hospitalization coding reflected the severity of maternal complications. Thus, coding indicators or modifiers are used to allow analysis of serious adverse clinical events (Clark, 2012; King, 2012). Such a system was implemented by the World Health Organization. It has been validated in Brazil and accurately reflects maternal death rates (Souza, 2012). Similar systems are in use in Britain as the *UK Obstetric Surveillance System—UKOSS* (Knight, 2005, 2008). Australia and New Zealand have also devised such a system—the