unit 6

The Newborn

chapter 17

Newborn Adaptation

KeyTERMS

cold stress
jaundice
meconium
neonatal period
neurobehavioral response
neutral thermal
environment (NTE)
periodic breathing
reflex
thermoregulation

LearningOBJECTIVES

After studying the chapter content, the student should be able to accomplish the following:

1. Define the key terms.
2. Identify the major changes in body systems that occur as the newborn adapts to extrauterine life.
3. Describe the primary challenges faced by the newborn during the adaptation to extrauterine life.
4. Explain the three behavioral patterns of newborn behavioral adaptation.
5. Identify the five typical behavioral responses of the newborn.

WOW

A newborn cannot always be judged by its outer wrapping, but rather by the gift inside that is so awesome.

“Congratulations on the birth of your child” is a common expression heard by many parents after the labor and birth experience is over. Hearing their newborn’s first cry typically ushers in feelings of relief and accomplishment for both parents. Although the exhaustion and stress of labor is over for the parents, the newborn now must begin the work of physiologically and behaviorally adapting to the new environment. The first 24 hours of life can be the most precarious (Verklan, 2002).

The **neonatal period** is defined as the first 28 days of life. After birth, the newborn is exposed to a whole new world of sounds, colors, smells, and sensations. The newborn, previously confined to a warm, dark, wet intrauterine environment is now thrust upon an environment that is much brighter and cooler. As the newborn adapts to life after birth, numerous physiologic changes occur.

Awareness of these adaptations that are occurring forms the foundation for providing support to the newborn during this crucial time. Physiologic and behavioral changes occur quickly during this transition period. Being aware of any deviations from the norm is crucial to ensure early identification and prompt intervention.

This chapter describes the physiologic changes of the newborn’s major body systems. It also discusses the behavioral adaptations, including behavioral patterns and the newborn’s behavioral responses, occurring during this transition period.

Physiologic Adaptations

The mechanics of birth require an obligatory change in the newborn for successful survival outside the uterus. Immediately, respiratory gas exchange, along with circulatory modifications, must occur to sustain extrauterine life. During this time, as newborns strive to attain homeostasis, they also experience complex changes in major organ systems. Although the transition usually takes place within the first 6 to 10 hours of life, many adaptations may take weeks to attain full maturity.

Cardiovascular System Adaptations

During fetal life, the heart relies on certain unique structures that assist it in providing adequate perfusion of vital body parts. The *umbilical vein* carries oxygenated blood from the placenta to the fetus. The *ductus venosus* allows the majority of the umbilical vein blood to bypass the liver and merge with blood moving through the vena cava, bringing it to the heart sooner. The *foramen ovale* allows more than half the blood entering the right atrium to cross immediately to the left atrium, thereby passing the pulmonary circulation. The *ductus arteriosus* connects the pulmonary artery to the aorta, which allows bypassing of the pulmonary circuit. Only a small portion of blood passes through the pulmonary circuit for the main purpose of perfusion of the structure, rather than for oxygenation. The fetus depends on the placenta for providing oxygen and nutrients, and removing waste products.

At birth, the circulatory system must switch from fetal to newborn circulation and from placental to pulmonary gas exchange. The physical forces of the contractions of labor and birth, mild asphyxia, increased intracranial pressure as a result of cord compression and uterine contractions, as well as **cold stress** immediately experienced after birth lead to an increased release in catecholamines that is critical for the changes involved in the transition to extrauterine life. The increased levels of epinephrine and norepinephrine stimulate increased cardiac output and contractility, surfactant release, and promotion of pulmonary fluid clearance (Mercer & Skovgaard, 2002).

Fetal Structures

Changes in circulation occur immediately at birth as the fetus separates from the placenta. When the umbilical cord is clamped, the first breath is taken, and the lungs begin to function. As a result, systemic vascular resistance increases and blood return to the heart via the inferior cava decreases. Concurrently, with these changes, there is a rapid decrease in pulmonary vascular resistance and an increase in pulmonary blood flow (Asenjo, 2004). The foramen ovale functionally closes with a decrease in pulmonary vascular resistance, which leads to a decrease in right-side heart pressures. An increase in systemic pressure, after clamping of the cord, leads to an increase in left-side heart pressures. Ductus arteriosus, ductus venous, and umbilical vessels that were vital during fetal life are no longer needed. Over a period of months these fetal vessels form nonfunctional ligaments.

Before birth, the *foramen ovale* allowed most of the oxygenated blood entering the right atrium from the inferior vena cava to pass into the left atrium of the heart. With the newborn’s first breath, air pushes into the newborn’s lungs, triggering an increase in pulmonary blood flow and pulmonary venous return to the left side of the heart. As a result, the pressure in the left atrium becomes higher than in the right atrium. The increased left atrial pressure causes the foramen ovale to close, thus allowing the output from the right ventricle to flow entirely to the lungs. With closure of this fetal shunt, oxygenated blood is now separated from nonoxygenated blood. The subsequent increase in tissue oxygenation further promotes the increase in systemic blood pressure and continuing blood flow to the lungs. The foramen ovale normally closes functionally at birth when left atrial pressure increases and right atrial pressure decreases. Permanent anatomic closure, though, really occurs throughout the next several weeks.

During fetal life, the *ductus arteriosus,* located between the aorta and the pulmonary artery, protected the lungs against circulatory overload by shunting blood (right to left) into the descending aorta, bypassing the pulmonary circulation. Its patency during fetal life is promoted by continual production of prostaglandin E2 (PGE2) by the ductus (Neish, 2004). The ductus arteriosus becomes functionally closed within the first few hours after birth. Oxygen is the most important factor in controlling its closure. Closure depends on the high oxygen content of the aortic blood resulting from aeration of the lungs at birth. At birth, pulmonary vascular resistance decreases, allowing pulmonary blood flow to increase and oxygen exchange to occur in the lungs. It occurs secondary to an increase in PO_2 coincident with the first breath and umbilical cord occlusion when it is clamped.

The *ductus venosus* shunted blood from the left umbilical vein to the inferior vena cava during intrauterine life. It closes within a few days after birth, because this shunting is no longer needed as a result of activation of the liver, which now assumes the functions of the placenta (which has been expelled at birth). The ductus venosus becomes a ligament in extrauterine life.

The two umbilical arteries and one umbilical vein begin to constrict at birth, because with placental expulsion, blood flow ceases. In addition, peripheral circulation increases. Thus, the vessels are no longer needed and they too become ligaments.

Heart Rate

During the first few minutes after birth, the newborn's heart rate is approximately 120 to 180 bpm. Thereafter, it begins to decrease to an average of 120 to 130 bpm (Sherman et al., 2002). The newborn is highly dependent on heart rate for maintenance of cardiac output and blood pressure. Although the blood pressure is not taken routinely for the healthy term newborn, it is usually highest after birth and reaches a plateau within a week after birth. Transient functional cardiac murmurs may be heard during the neonatal period as a result of the changing dynamics of the cardiovascular system at birth (Hockenberry, 2005).

The fluctuations in both the heart rate and blood pressure tend to follow the changes in the newborn's behavioral state. An increase in activity, such as wakefulness, movement, or crying, corresponds to an increase in heart rate and blood pressure. In contrast, the compromised newborn demonstrates markedly less physiologic variability overall. Tachycardia may be found with volume depletion, cardiorespiratory disease, drug withdrawal, and hyperthyroidism. Bradycardia is often associated with apnea and is often seen with hypoxia.

Blood Volume

The blood volume of the newborn depends on the amount of blood transferred from the placenta at birth. It is usually estimated to be 80 to 85 mL/kg of body weight in the term infant (London et al., 2003). However, the volume may vary as much as 25 to 40%, depending on when clamping of the umbilical cord occurs. Early or late clamping of the umbilical cord changes circulatory dynamics during transition. Recent studies show the benefits of delayed cord clamping as improving the newborn's cardiopulmonary adaptation, preventing anemia, increasing blood pressures, improving oxygen transport, and increasing RBC flow (Mercer, 2001). However, concerns exist about volume overload and polycythemia (Mercer & Skovgaard, 2002). Further research is needed to explain the relationship among oxygen transport, RBC volume, and initiation of breathing, thereby indicating whether early or delayed cord clamping is beneficial.

Blood Components

Fetal RBCs are large, but few in number. After birth, the RBC count gradually increases as the cell size decreases, because they live in an environment with much higher PO_2. A newborn's RBCs have a life span of 80 to 100 days in comparison with an adult's RBC life span of 120 days.

Hemoglobin initially declines as a result of a decrease in neonatal red cell mass (physiologic anemia of infancy). Leukocytosis (elevated white blood cells) is present as a result of birth trauma soon after birth. The newborn's platelet count and aggregation ability are the same as adults.

The newborn's hematologic values are affected by the site of the blood sample (capillary blood has higher levels of hemoglobin and hematocrit compared with venous blood), placental transfusion (delayed cord clamping and normal shift of plasma to extravascular spaces, which causes higher levels of hemoglobin and hematocrit), and gestational age (increased age is associated with increased numbers of RBCs and hemoglobin) (Blackburn & Loper, 2002). See Table 17-1 for normal newborn blood values.

Table 17-1 Normal Newborn Blood Values

Lab Data	Normal Range
Hemoglobin	17–20 g/dL
Hematocrit	52–63%
Platelets	100,000–300,000/μL
RBCs	5.1–5.8 (1,000,000/μL)
WBCs	10–30,000/mm^3

Respiratory System Adaptations

The first breath of life is a gasp that generates an increase in transpulmonary pressure and results in diaphragmatic descent. Hypercapnia, hypoxia, and acidosis resulting from normal labor become stimuli for initiating respirations. Inspiration of air and expansion of the lungs allow for an increase in tidal volume (amount of air brought into the lungs). Surfactant lining the alveoli enhances aeration of gas-free lungs, thus reducing surface tension and lowering the pressure required to open the alveoli. The newborn's first breath, in conjunction with surfactant, overcomes the surface forces to permit aeration of the lungs. In addition, vaginal births allow intermittent compression of the thorax, which facilitates removal of lung fluid.

The chest wall of the newborn is floppy because of the high cartilage content and poorly developed musculature. Thus, accessory muscles to help in breathing are ineffective.

One of the most crucial adaptations that the newborn makes at birth is adjusting from a fluid-filled intrauterine environment to a gaseous extrauterine environment. During fetal life, the lungs are expanded with an ultrafiltrate of the amniotic fluid. During and after birth, this fluid must be removed and replaced with air. Passage through the birth canal squeezes the thorax, which helps eliminate the fluid in the lungs. Pulmonary capillaries and the lymphatics remove the remaining fluid.

If fluid is removed too slowly or incompletely, such as what happens with decreased thoracic squeezing during birth or diminished respiratory effort, transient tachypnea (respiratory rate > 60 bpm) of the newborn occurs. Examples of situations involving decreased thoracic compression and diminished respiratory effort include cesarean birth and sedation in newborns (Askin, 2002).

Lungs

Before the newborn's lungs can maintain respiratory function, the following events must occur:

- Initiation of respiratory movement
- Expansion of the lungs
- Establishment of functional residual capacity (ability to retain some air in the lugs on expiration)
- Increased pulmonary blood flow
- Redistribution of cardiac output (Hockenberry, 2005)

Initial breathing is probably the result of a **reflex** triggered by pressure changes, noise, light, chilling, compression of the fetal chest during the delivery process, and high carbon dioxide and low oxygen concentrations of the newborn's blood. Many theories address the initiation of respiration in the newborn, but most are based on speculation from observations rather than on empirical research (Verklan, 2002). Research continues to search for answers to these questions.

Respirations

After respirations are established in the newborn, they are shallow and irregular, ranging from 30 to 60 breaths per minute, with short periods of apnea (<15 seconds). The newborn's respiratory rate varies according to its activity; the more active the newborn, the higher the respiratory rate, on average. Respirations should not be labored, and the chest movements should be symmetric. In some cases, **periodic breathing** may occur, which is the cessation of breathing that lasts 5 to 10 seconds without changes in color or heart rate (Murray et al., 2006). Periodic breathing may be observed in newborns within the first few days of life and requires close monitoring. Apneic periods lasting more than 15 seconds with cyanosis and heart rate changes require further evaluation (Hockenberry, 2005).

Body Temperature Regulation

Newborns are dependent on their environment for the maintenance of body temperature, much more immediately after birth than later in life. One of the most important elements in a newborn's survival is obtaining a stable body temperature to promote an optimal transition to extrauterine life.

Thermoregulation is the process of maintaining the balance between heat loss and heat production. It is a critical physiologic function that is closely related to the transition and survival of the newborn. An appropriate thermal environment is essential for maintaining a normal body temperature. Compared with adults, newborns tolerate a narrower range of environmental temperatures and are extremely vulnerable to both under- and overheating as well. Nurses play a key role in providing an appropriate environment to help newborns maintain thermal stability.

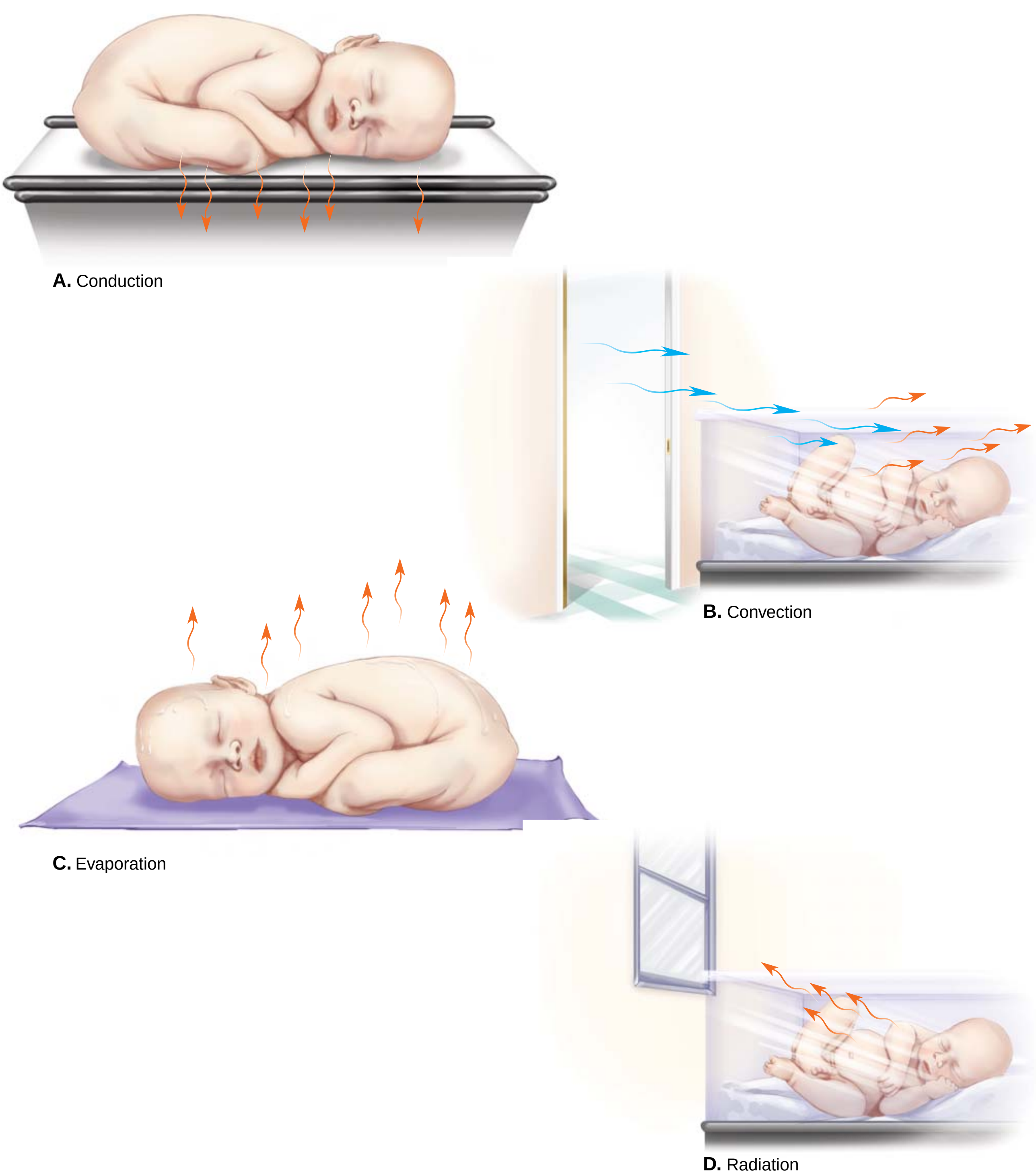
Heat Loss

Newborns have several characteristics that predispose them to heat loss:

- Thin skin with blood vessels close to the surface
- Lack of shivering ability to produce heat involuntarily
- Limited stores of metabolic substrates (glucose, glycogen, fat)
- Limited use of voluntary muscle activity or movement to produce heat
- Large body surface area relative to body weight
- Lack of subcutaneous fat, which provides insulation
- Little ability to conserve heat by changing posture (fetal position)
- No ability to adjust own their clothing or blankets to achieve warmth
- Inability to communicate that they are too cold or too warm

Every newborn struggles to maintain body temperature from the moment of birth, when the newborn's wet body is exposed to the much cooler environment of the birthing room. The amniotic fluid covering the newborn cools as it evaporates rapidly in the low humidity and airconditioning of the room. During the period immediately after birth, the newborn's temperature may decrease 3° to 5° within minutes after leaving the warmth of the mother's uterus (99.6°F) (Thomas, 2003).

The transfer of heat depends on the temperature of the environment, air speed, and water vapor pressure or humidity. Heat exchange between the environment and the newborn involves the same mechanisms as those with any physical object and its environment. These mechanisms are conduction, convection, evaporation, and radiation. Prevention of heat loss is a key nursing intervention (Fig. 17-1).



● Figure 17-1 The four mechanisms of heat loss in the newborn. (**A**) Conduction. (**B**) Convection. (**C**) Evaporation. (**D**) Radiation.

Consider THIS!

When I look down at my little miracle of life in my arms, I can't help but beam with pride at this great accomplishment. They seem so vulnerable and defenseless, and yet are equipped with everything they need to survive when they are born. When the nurse brought my daughter in for the first time after birth, I wanted to see and feel every part of her. Much to my dismay, she was wrapped up like a mummy in a blanket and she had a pink knit cap on her head. I asked the nurse why all the babies had to look like they were bound for the North Pole with all these layers on. Wasn't she aware it was summertime and probably at least 80° outside?

The nurse explained that newborns lose body heat easily and needed to be kept warm until their temperature stabilizes. Even though I wanted to get up close and personal with my baby, I decided to keep the pink polar bear outfit on her.

Thoughts: Newborns may be born with "everything they need to survive" on the outside, but they still experience temperature instability and lose heat through radiation, evaporation, convection, and conduction. Because the newborn's head is the largest body part, a great deal of heat can be lost if a cap is not kept on the head. What guidance can be given to this mother before discharge to stabilize her daughter's temperature while at home? What simple examples can be used to demonstrate your point?

Conduction

Conduction involves the transfer of heat from one object to another when the two objects are in direct contact with each other. Conduction refers to heat fluctuation between the newborn's body surface when in contact with other solid surfaces, such as a cold mattress, scale, or circumcision restraining board. Heat loss by conduction can also occur when touching a newborn with cold hands or when the newborn has direct contact with a colder object such as a metal scale. Using a warmed cloth diaper or blanket to cover any cold surface touching a newborn directly helps to prevent heat loss through conduction.

Convection

Convection involves the flow of heat from the body surface to cooler surrounding air or to air circulating over a body surface. An example of convection-related heat loss would be a cool breeze that flows over the newborn. To prevent heat loss by this mechanism, keep the newborn out of direct cool drafts (open doors, windows, fans, air conditioners) in the environment, work inside an isolette as much as possible and minimize opening portholes that allow cold air to flow inside, and warm any oxygen or humidified air that comes in contact with the newborn. Using clothing and blankets in isolettes is an effective means of reducing the newborn's exposed surface area and providing external insulation. Also, transporting the newborn to the nursery in a warmed isolette, rather than carrying him or her, helps to maintain warmth and reduce exposure to the cool air.

Evaporation

Evaporation involves the loss of heat when a liquid is converted to a vapor. Evaporative loss may be insensible (such as from skin and respiration) or sensible (such as from sweating). Insensible loss occurs, but the individual isn't aware of it. Sensible loss is objective and can be noticed. It depends on air speed and the absolute humidity of the air. For example, when the newborn is born, the body is covered with amniotic fluid. The fluid evaporates into the air, leading to heat loss. Heat loss via evaporation also occurs when bathing a newborn. Drying newborns immediately after birth with warmed blankets and placing a cap on their head will help to prevent heat loss through evaporation. In addition, drying the newborn after bathing will help prevent heat loss through evaporation. Promptly changing wet linens, clothes, or diapers will also reduce heat loss and prevent chilling.

Radiation

Radiation involves loss of body heat to cooler, solid surfaces in close proximity, but not in direct contact with the newborn. The amount of heat loss is dependent on the size of the cold surface area, the surface temperature of the body, as well as the temperature of the receiving surface area. For example, when a newborn is placed in a single-wall isolette next to a cold window, heat loss from radiation occurs. Newborns will become cold even though they are in a heated isolette. To reduce heat loss by radiation, keep cribs and isolettes away from outside walls, cold windows, and air conditioners. Also, using radiant warmers for transporting newborns and when performing procedures that may expose the newborn to the cooler environment will help reduce heat loss.

A warmed transporter is an enclosed isolette on wheels. A radiant warmer is an open bed with a radiant heat source above. This type of environment allows healthcare professionals to reach the newborn to carry out procedures and treatments.

Overheating

The newborn is also prone to overheating. Large body surface area, limited insulation, and limited sweating ability can predispose any newborn to overheating. Control of body temperature is achieved via a complex negative feedback system that creates a balance between heat production, heat gain, and heat loss. The primary heat regulator is located in the hypothalamus and the central nervous system. The immaturity of the newborn's central nervous system makes it difficult to create and maintain this balance. Therefore, the newborn can become overheated easily. For example, an isolette that is too warm or one that is left too close to a sunny window may lead to hyperthermia. Although heat production can substantially increase in response to a cool environment, BMR and the resultant heat produced cannot be reduced. Overheating increases fluid loss, the respiratory rate, and the metabolic rate considerably.

Thermoregulation

Thermoregulation, the balance between heat loss and heat production, is related to the newborn's rate of metabolism and oxygen consumption. The newborn attempts to conserve heat and increase heat production in the following ways: increasing the metabolic rate, increasing muscular activity through movement, increasing peripheral vasoconstriction, and assuming a fetal position to hold in heat and minimize exposed body surface area.

An environment in which body temperature is maintained without an increase in metabolic rate or oxygen use is called a **neutral thermal environment (NTE).** Within an NTE, the rates of oxygen consumption and metabolism are minimal, and internal body temperature is maintained because of thermal balance (LeBlanc, 2002). Because newborns have difficulty in maintaining their body heat through shivering or other mechanisms, they need a higher environmental temperature to maintain an NTE. If the environmental temperature decreases, the newborn responds by consuming more oxygen. The respiratory rate increases (tachypnea) in response to the increased need for oxygen. As a result, the newborn's metabolic rate increases.

The newborn's primary method of heat production is through nonshivering thermogenesis, a process in which brown fat (adipose tissue) is oxidized in response to cold exposure. Brown fat is a special kind of highly vascular fat found only in newborns. The brown coloring is derived from the fat's rich supply of blood vessels and nerve endings. These fat deposits, which are capable of intense metabolic activity—and thus generate a great deal of heat—are found between scapulae, at the nape of the neck, in the mediastinum, and in areas surrounding the kidneys and adrenal glands. Brown fat makes up about 2 to 6% of body weight in the full-term newborn (Hockenberry, 2005). When the newborn experiences a cold environment, the release of norepinephrine increases, which in turn stimulates brown fat metabolism by the breakdown of triglycerides. Cardiac output increases, increasing blood flow through the brown fat tissue. Subsequently, this blood becomes warmed as a result of the increased metabolic activity of the brown fat.

Newborns can experience heat loss through all four mechanisms, ultimately resulting in cold stress. Cold stress is excessive heat loss that requires a newborn to use compensatory mechanisms (such as nonshivering thermogenesis and tachypnea) to maintain core body temperature (London et al., 2003). The consequences of cold stress can be quite severe. As the body temperature decreases, the newborn becomes less active, lethargic, hypotonic, and weaker. All newborns are at risk for cold stress, particularly within the first 12 hours of life. However, preterm newborns are at the greatest risk for cold stress and experience more profound effects than full-term newborns because they have less fat stores, poorer vasomotor responses, and less insulation to cope with a hypothermic event.

Cold stress in the newborn can lead to the following problems if not reversed: depleted brown fat stores, increased oxygen needs, respiratory distress, increased glucose consumption leading to hypoglycemia, metabolic acidosis, **jaundice,** hypoxia, and decreased surfactant production (Hockenberry, 2005).

To minimize the effects of cold stress and maintain an NTE, the following interventions are helpful:

- Prewarming the blankets and hats to reduce heat loss through conduction
- Keeping the infant transporter (warmed isolette) fully charged and heated at all times
- Drying the newborn completely after birth to prevent heat loss from evaporation
- Encouraging skin-to-skin contact with the mother if the newborn is stable
- Promoting early breast-feeding to provide fuels for nonshivering thermogenesis
- Using heated and humidified oxygen
- Always using radiant warmers and double-wall isolettes to prevent heat loss from radiation
- Deferring bathing until the newborn is medically stable and using a radiant heat source (Fig. 17-2)
- Avoiding the placement of a skin temperature probe over a bony area or one with brown fat because it does not give an accurate assessment of the whole body temperature (Most temperature probes are placed over the liver when the newborn is supine or side lying.)

Hepatic System Function

At birth, the newborn's liver assumes the functions that the placenta once handled during fetal life. These functions include iron storage, carbohydrate metabolism, blood coagulation, and conjugation of bilirubin.

Iron Storage

As RBCs are destroyed after birth, the iron is released and is stored by the liver until new RBCs need to be produced. Newborn iron stores are determined by total body hemoglobin content and length of gestation. At birth, the term newborn has iron stores sufficient to last approximately 4 to 6 months (Hockenberry, 2005).

Carbohydrate Metabolism

When the placenta is lost at birth, the maternal glucose supply is cut off. Initially, the newborn's serum glucose levels decline. Usually, a term newborn's blood glucose level is 70 to 80% of the maternal blood glucose level (Johnson, 2003).

Figure 17-2 Bathing a newborn under a radiant warmer to prevent heat loss.

Glucose is the main source of energy for the first several hours after birth. With the newborn's increased energy needs after birth, the liver releases glucose from glycogen stores for the first 24 hours. Initiating feedings helps to stabilize the newborn's blood glucose levels. Typically a newborn's blood glucose levels are assessed using a chemical reagent strip (such as a Chemstrip) on admission to the nursery and again in approximately 4 hours.

Bilirubin Conjugation

The liver is also responsible for the conjugation of bilirubin—a yellow to orange bile pigment produced by the breakdown of RBCs. In utero, elimination of bilirubin in the blood is handled by the placenta and the mother's liver. However, once the cord is cut, the newborn must now assume this function.

Bilirubin normally circulates in plasma, is taken up by liver cells, and is changed to a water-soluble pigment that is excreted in the bile. This conjugated form of bilirubin is excreted from liver cells as a constituent of bile.

The principal source of bilirubin in the newborn is the hemolysis of erythrocytes. This is a normal occurrence after birth, when fewer RBCs are needed to maintain extrauterine life.

When RBCs die after approximately 80 days of life, the heme in their hemoglobin is converted to bilirubin. Bilirubin is released in an *unconjugated* form called *indirect bilirubin,* which is fat soluble. Enzymes, proteins, and different cells in the reticuloendothelial system and liver process the unconjugated bilirubin into *conjugated bilirubin* or *direct bilirubin.* This form is water soluble and now enters the GI system via the bile and is eventually excreted through feces. A small amount is also excreted by the kidneys.

Newborns produce bilirubin at a rate of approximately 6 to 8 mg/kg/day. This is more than twice the production rate in adults, primarily because of relative polycythemia and increased RBC turnover. Bilirubin production typically declines to the adult level within 10 to 14 days after birth (Porter & Dennis, 2002). In addition, the metabolic pathways of the liver are relatively immature and thus are unable to conjugate bilirubin as fast as it needs to be.

Failure of the liver cells to break down and excrete bilirubin can cause an increased amount of bilirubin in the bloodstream, leading to jaundice (O'Toole, 2003). Bilirubin is toxic to the body and must be excreted. Blood tests ordered to determine bilirubin levels measure bilirubin in the serum. Total bilirubin is a combination of indirect (unconjugated) and direct (conjugated) bilirubin.

When unconjugated bilirubin pigment is deposited in the skin and mucous membranes, jaundice typically results. Jaundice, otherwise known as *icterus,* refers to the yellowing of the skin, sclera, and mucous membranes as a result of increased bilirubin blood levels. Visible jaundice as a result of increased blood bilirubin levels occurs in more than half of all healthy newborns. Even in healthy term newborns, extremely elevated blood levels of bilirubin during the first week of life can cause kernicterus, a permanent and devastating form of brain damage (Palmer et al., 2003).

Common risk factors for the development of jaundice include fetal–maternal blood group incompatibility, prematurity, breast-feeding, drugs (such as diazepam [Valium], oxytocin [Pitocin], sulfisoxazole/erythromycin [Pediazole], and chloramphenicol [Chloromycetin]), maternal gestational diabetes, infrequent feedings, male gender, trauma during birth resulting in cephalohematoma, cutaneous bruising, polycythemia, previous sibling with hyperbilirubinemia, infections such as TORCH (toxoplasmosis, other viruses, rubella, cytomegalovirus, herpes simplex viruses), and ethnicity such as Asian or Native American (Riskin et al., 2003).

The causes of newborn jaundice can be classified into three groups based on the mechanism of accumulation:

1. Bilirubin overproduction such as from blood incompatibility (Rh or ABO), drugs, trauma at birth, polycythemia, delayed cord clamping, and breast milk jaundice

2. Decreased bilirubin conjugation as seen in physiologic jaundice, hypothyroidism, and breast-feeding, for example
3. Impaired bilirubin excretion, as seen in biliary obstruction (biliary atresia, gallstones, neoplasm), sepsis, chromosomal abnormality (Turner syndrome, trisomy 18 and 21), and drugs (aspirin, acetaminophen, sulfa, alcohol, steroids, antibiotics) (Porter & Dennis, 2002)

Jaundice in the newborn is discussed in more detail in Chapter 24.

Gastrointestinal System Adaptations

The full-term newborn has the capacity to swallow, digest, metabolize, and absorb food taken in soon after birth. At birth, the pH of the stomach contents is mildly acidic, reflecting the pH of the amniotic fluid.

Mucosal Barrier Protection

An important adaptation of the GI system is the development of a mucosal barrier to prevent the penetration of harmful substances (bacteria, toxins, and antigens) present within the intestinal lumen. At birth, the newborn must be prepared to deal with bacterial colonization of the gut. Colonization is dependent on oral intake. It usually occurs by 4 to 6 days of age and is required for the production of vitamin K (Verklan & Walden, 2004). If harmful substances are allowed to penetrate the mucosal epithelial barrier under pathologic conditions, they can cause inflammatory and allergic reactions (Walker, 2001). Human milk provides a passive mechanism to protect the newborn against the dangers of a deficient intestinal defense system. It contains antibodies, viable leukocytes, and many other substances that can interfere with bacterial colonization and prevent harmful penetration.

Stomach and Digestion

The stomach of the newborn has a capacity ranging from 30 to 90 mL, with a variable emptying time of 2 to 4 hours. The cardiac sphincter and nervous control of the stomach is immature, which may lead to uncoordinated peristaltic activity and frequent regurgitation. Immaturity of the pharyngoesophageal sphincter and absence of lower esophageal peristaltic waves also contribute to the reflux of gastric contents. Avoiding overfeeding and stimulating frequent burping may help minimize regurgitation. Most digestive enzymes are available at birth, allowing newborns to digest simple carbohydrates and protein. However, they have limited ability to digest complex carbohydrates and fats, because amylase and lipase levels are low at birth. As a result, newborns excrete a fair amount of lipids, resulting in fatty stools.

Adequate digestion and absorption are essential for newborn growth and development. Normally, term newborns lose 5 to 10% of their birth weight as a result of insufficient caloric intake within the first week after birth, shifting of intracellular water to extracellular space, and insensible water loss. To gain weight, the term newborn requires an intake of 120 cal/kg/day (London et al., 2003).

Bowel Elimination

The frequency, consistency, and type of stool passed by newborns vary widely. The evolution of a stool pattern begins with a newborn's first stool, which is **meconium.** Meconium stool is composed of amniotic fluid, shed mucosal cells, intestinal secretions, and blood. It is greenish black, has a tarry consistency, and is usually passed within 12 to 24 hours of birth. The first meconium stool passed is sterile, but changes rapidly with ingestion of bacteria through feedings. After feedings are initiated, a transitional stool develops, which is greenish brown to yellowish brown, thinner in consistency, and seedy in appearance. Newborns who are fed early pass stools sooner, which helps to reduce bilirubin buildup.

The last development in the stool pattern is the milk stool. The characteristics differ in breast-fed and formula-fed newborns. The stools of the breast-fed newborn are described as yellow-gold, loose and stringy to pasty in consistency, and typically sour smelling. In comparison, the stool of the formula-fed newborn will vary depending on the type of formula ingested. It may be yellow, yellow-green, or greenish; loose, pasty, or formed in consistency; with an unpleasant odor.

Renal System Changes

The majority of term newborns void immediately after birth, indicating adequate renal function. Although the newborn's kidneys are able to produce urine, they are limited in their ability to concentrate it, until about 3 months of age, when the kidneys mature. Until that time, a newborn voids frequently and the urine has a low specific gravity (1.001–1.020). About 6 to 10 voidings daily is average for most newborns and indicative of adequate fluid intake (Ladewig, London, & Davidson, 2006).

The renal cortex is relatively underdeveloped at birth and does not reach maturity until 12 to 18 months of age. At birth, the GFR is approximately 30% of normal adult values, reaching approximately 50% of normal adult values by the 10th day of life and full adult values by the first year of life (Askin, 2002). The low GFR, and limited excretion and conservation capability of the kidney affect the newborn's ability to excrete for salt, water loads, and drugs. The possibility of fluid overload is increased and must be considered when administering IV therapy to a newborn.

Immune System Adaptations

Essential to the newborn's survival is an ability to respond effectively to hostile environmental forces. The developing newborn's immune system is initiated early in gestation, but many of the responses do not function adequately during the early neonatal period. The intrauterine environment usually protects the fetus from harmful microorganisms and the necessity for defensive immunologic responses. With exposure to a wide variety of microorganisms at birth, the newborn must develop a balance between its host defenses and the hostile environmental organisms to ensure a safe transition in the outside world.

Responses of the immune system serve three purposes: defense (protection from invading organisms), homeostasis (elimination of worn-out host cells), and surveillance (recognition and removal of enemy cells). The newborn's immune system response involves recognition of the pathogen or other foreign material, followed by activation of mechanisms to react against and eliminate it. All immune responses primarily involve leukocytes (white blood cells).

The immune system's responses can be divided into two categories: natural and acquired immunity. These mechanisms are interrelated and interdependent; both are required for immunocompetency.

Natural Immunity

Natural immunity includes responses or mechanisms that do not require previous exposure to the microorganism or antigen to operate efficiently. Physical barriers (such as intact skin and mucus membranes), chemical barriers (such as gastric acids and digestive enzymes), and resident nonpathologic organisms make up the newborn's natural immune system. Natural immunity involves the most basic host defense responses, that of ingestion and killing of microorganisms by phagocytic cells.

Acquired Immunity

Acquired immunity involves two primary processes: (1) the development of circulating antibodies or immunoglobulins capable of targeting specific invading agents (antigens) for destruction and (2) formation of activated lymphocytes designed to destroy foreign invaders. Acquired immunity is absent until after the first invasion by a foreign organism or toxin.

Immunoglobulins are subdivided into five classes: IgA, IgD, IgE, IgG, and IgM. The newborn depends largely on three immunoglobulins for defense mechanisms: IgG, IgA, and IgM.

IgG is the major immunoglobulin and the most abundant, comprising about 80% of all circulating antibodies (Schnell et al., 2003). It is found in serum and interstitial fluid. It is the only class able to cross the placenta, with active placental transfer beginning at approximately 20 to 22 weeks' gestation. IgG produces antibodies against bacteria, bacterial toxins, and viral agents.

IgA is the second most abundant immunoglobulin in the serum. IgA does not cross the placenta, and maximum levels are reached during childhood. This immunoglobulin is believed to protect mucous membranes from viruses and bacteria. IgA is predominantly found in the GI and respiratory tracts, tears, saliva, colostrum, and breast milk. A major source of IgA is human breast milk, so breastfeeding is believed to have significant immunologic advantages over formula feeding (Madden et al., 2004).

IgM is found in blood and lymph fluid and is the first immunoglobulin to respond to infection. It does not cross the placenta, and levels are generally low at birth unless there is a congenital intrauterine infection. IgM offers a major source of protection from blood-borne infections. The predominant antibodies formed during neonatal or intrauterine infection are of this class.

Integumentary System

The most important function of the skin is to provide a protective barrier between the body and the environment. It limits the loss of water, prevents absorption of harmful agents, and protects against physical trauma. The epidermal barrier begins to develop during mid-gestation and is fully formed by about 32 weeks' gestation. Although the neonatal and adult epidermis is similar in thickness and lipid composition, skin development is not complete at birth (Hoeger & Enzmann, 2002). Although the basic structure is the same as that of an adult, the less mature the newborn, the less mature the skin function. Fewer fibrils connect the dermis and epidermis in the newborn when compared with the adult. Also in a newborn, the risk of injury producing a break in the skin from tape, monitors, and handling is greater than that for an adult. In addition, sweat glands are present at birth, but full adult functioning is not present until the second or third year of life (Mancini, 2001). Exposure to air after birth accelerates epidermal development in all newborns (Rutter, 2003).

Newborns vary greatly in appearance. Many of the variations are temporary and reflect the physiologic adaptations that the newborn is experiencing. Skin coloring varies, depending on the newborn's age, race or ethnic group, temperature, and whether he or she is crying. Skin color changes with both the environment and health status. At birth, the newborn's skin is dark red to purple. As the newborn begins to breathe air, the skin color changes to red. This redness normally begins to fade the first day.

Neurologic System Adaptations

The nervous system consists of the brain, spinal cord, 12 cranial nerves, and a variety of spinal nerves that come from the spinal cord. Neurologic development follows cephalocaudal (head to toe) and proximal–distal (center to outside) patterns. Myelin develops early on in sensory impulse transmitters. Thus the newborn has an acute sense of hearing, smell, and taste. The newborn's sensory capabilities include

- Hearing—well developed at birth, responds to noise by turning to sound

- Taste—ability to distinguish between sweet and sour by 72 hours old
- Smell—ability to distinguish between mother's breast milk and breast milk from others
- Touch—sensitivity to pain, responds to tactile stimuli
- Vision—ability to focus on objects close by (10–12 in away), tracks objects in midline or beyond (Mattson & Smith, 2004).

Successful adaptations demonstrated by the respiratory, circulatory, thermoregulatory, and musculoskeletal systems indirectly indicate the central nervous system's successful transition from fetal to extrauterine life, because it plays a major role in all these adaptations. In the newborn, congenital reflexes are the hallmarks of maturity of the central nervous system, viability, and adaptation to extrauterine life.

The presence and strength of a reflex is an important indication of neurologic development and function. A reflex is an involuntary muscular response to a sensory stimulus. It is built into the nervous system and does not need the intervention of conscious thought to take effect (O'Toole, 2003). Many neonatal reflexes disappear with maturation, although some remain throughout adulthood.

The arcs of these reflexes end at different levels of the spine and brainstem, and reflect the function of the cranial nerves and motor systems. The way newborns blink, move their limbs, focus on a caretaker's face, turn toward sound, suck, swallow, and respond to the environment are all indications of their neurologic abilities. Congenital defects within the central nervous system are frequently not overt, but may be revealed in abnormalities in tone, posture, or behavior (Askin, 2002). Damage to the nervous system (birth trauma, perinatal hypoxia) during the birthing process can cause delays in the normal growth, development, and functioning of that newborn. Early identification may help to identify the cause and to start early intervention to decrease long-term complications or permanent sequelae.

Newborn reflexes are assessed to evaluate neurologic function and development. Absent or abnormal reflexes in a newborn, persistence of a reflex past the age when the reflex is normally lost, or redevelopment of an infantile reflex in an older child or adult may indicate neurologic pathology. (See Chapter 18 for a description of newborn reflex assessment.)

Behavioral Adaptations

In addition to adapting physiologically, the newborn also adapts behaviorally. All newborns progress through a specific pattern of events after birth, regardless of gestational age or type of birth they experienced.

Behavioral Patterns

The newborn usually demonstrates a predictable pattern of behavior during the first several hours after birth, characterized by two periods of reactivity separated by a sleep phase. Behavioral adaptation is a defined progression of events triggered by stimuli from the extrauterine environment after birth.

First Period of Reactivity

The first period of reactivity begins at birth and lasts for the first 30 minutes after birth. The newborn is alert and moving, and may appear hungry. This period is characterized by myoclonic movements of the eyes, spontaneous Moro reflexes, sucking motions, chewing, rooting, and fine tremors of the extremities (Littleton & Engebretson, 2005). Respirations and heart rates are elevated and gradually begin to slow as the next period occurs.

This period of alertness allows parents to interact with their newborn and to enjoy close contact with their new baby (Fig. 17-3). The appearance of sucking and rooting behaviors provides a good opportunity for initiating breast-feeding. Many newborns latch on the nipple and suck well at this first experience.

Period of Deceased Responsiveness

At 30 to 120 minutes of age, the newborn enters the second stage of transition—that of sleep or a decrease in activity. This phase is referred to as a *period of decreased responsiveness.* Movements are less jerky and less frequent. Heart and respiratory rates decline as the newborn enters the sleep phase. The muscles become relaxed, and responsiveness to outside stimuli diminishes. During this phase, it is difficult to arouse or interact with the newborn. No interest in sucking is shown. This quiet time can be used for both mother and newborn to remain close and rest together after sustaining the laboring and birthing experience.

Second Period of Reactivity

The second period of reactivity begins as the newborn awakens and shows an interest in environmental stimuli. This period lasts 2 to 8 hours in the normal newborn (Thureen et al., 2005). Heart and respiratory rates

● Figure 17-3 The first period of reactivity is an optimal time for interaction.

increase. Peristalsis also increases. Thus, it is not uncommon for the newborn to pass meconium during this period. In addition, motor activity and muscle tone increase in conjunction with an increase in muscular coordination (Fig. 17-4).

Interaction between the mother and the newborn during this second period of reactivity is encouraged if the mother has rested and desires it. This period also provides a good opportunity for the parents to examine their newborn and ask questions about their observations. Teaching about feeding, positioning for feeding, and diaper-changing techniques can be reinforced during this time.

Newborn Behavioral Responses

Newborns demonstrate several predictable responses when interacting with their environment. How they react to the world around them is termed a **neurobehavioral response.** It comprises predictable periods that are probably triggered by stimuli from external stimuli.

Expected newborn behaviors include orientation, habituation, motor maturity, self-quieting ability, and social behaviors. Any deviation in behavioral responses requires further assessment, because it may indicate a complex neurobehavioral problem.

Orientation

The response of newborns to stimuli is called *orientation.* They become more alert when they sense a new stimulus in their environment. Orientation reflects newborns' response to auditory and visual stimuli, demonstrated by their movement of head and eyes to focus on that stimulus. Newborns prefer the human face and bright shiny objects. As the face or object comes into their line of vision, newborns respond by staring at the object intently. Newborns use this sensory capacity to become familiar with people and objects in their surroundings.

● Figure 17-4 Newborn during the second period of reactivity. Note the newborn's wide-eyed interest.

Habituation

Habituation is the newborn's ability to process and respond to visual and auditory stimuli—that is, how well and appropriately he or she responds to the environment. Habituation is the ability to block out external stimuli after the newborn has become used to the activity. During the first 24 hours after birth, newborns should increase their ability to habituate to environmental stimuli and sleep. Habituation provides a useful indicator of their neurobehavioral intactness.

Motor Maturity

Motor maturity depends on gestational age and involves evaluation of posture, tone, coordination, and movements. These activities enable newborns to control and coordinate movement. When stimulated, newborns with good motor organization demonstrate movements that are rhythmic and spontaneous. Bringing the hand up to the mouth is an example of good motor organization. As newborns adapt to their new environment, smoother movements should be observed. Such motor behavior is a good indicator of the newborn's ability to respond and adapt accordingly—that is, process stimuli appropriately by the central nervous system.

Self-Quieting Ability

Self-quieting ability refers to newborns' ability to quiet and comfort themselves. Newborns vary in their ability to console themselves or to be consoled. "Consolability" is how newborns are able to change from the crying state to an active alert, quiet alert, drowsy, or sleep state. They console themselves by hand-to-mouth movements, and sucking, alerting to external stimuli and motor activity (Hockenberry, 2005). Assisting parents to identify consoling behaviors to quiet their newborn if the newborn is not able to self-quiet is important. These behaviors include rocking, holding, gently patting, and softly singing to them.

Social Behaviors

Social behaviors include cuddling and snuggling into the arms of the parent when the newborn is held. Usually newborns are very sensitive to being touched, cuddled, and held. Cuddliness is very important to parents, because they frequently will gauge their ability to care for their newborn by the newborn's acceptance or positive repose to their actions. Specifically, it can be assessed by the degree to which the newborn nestles into the contours of the holder's arms. Most newborns cuddle, but some will resist. Assisting parents to assume comforting behaviors (e.g., by cooing while holding their newborn) and praising them for their efforts can help foster cuddling behaviors.

KEY CONCEPTS

- The neonatal period is defined as the first 28 days of life. As the newborn adapts to life after birth, numerous physiologic changes occur.
- At birth, the cardiopulmonary system must switch from fetal to neonatal circulation and from placental to pulmonary gas exchange.
- One of the most crucial adaptations that the newborn makes at birth is the adjustment of a fluid medium exchange from the placenta to the lungs and that of a gaseous environment.
- Neonatal RBCs have a life span of 80 to 100 days in comparison with the adult RBC life span of 120 days, which causes several adjustment problems.
- Thermoregulation is the maintenance of balance between heat loss and heat production. It is a critical physiologic function that is closely related to the transition and survival of the newborn.
- Heat loss in the newborn is the result of four mechanisms: conduction, convection, evaporation, and radiation.
- Responses of the immune system serve three purposes: defense (protection from invading organisms), homeostasis (elimination of worn-out host cells), and surveillance (recognition and removal of enemy cells).
- In the newborn, congenital reflexes are the hallmarks of maturity of the central nervous system, viability, and adaptation to extrauterine life.
- The newborn usually demonstrates a predictable pattern of behavior during the first several hours after birth, characterized by two periods of reactivity separated by a sleep phase.

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Web Resources

Academy of Neonatal Nursing, **www.academyonline.org**
American Academy of Pediatrics, **www.aap.org**
National Association of Neonatal Nurses, **www.nann.org**
Neonatal Network, **www.neonatalnetwork.com**

Chapter WORKSHEET

MULTIPLE CHOICE QUESTIONS

1. When assessing the term newborn, the following are observed: newborn is alert, heart and respiratory rates have stabilized, and meconium has been passed. The nurse determines that the newborn is exhibiting behaviors indicating

a. Initial period of reactivity

b. Second period of reactivity

c. Decreased responsiveness period

d. Period of sleep

2. When caring for a newborn, the nurse ensures that the doors of the nursery are closed and minimizes opening the portholes of the isolette to prevent heat loss via which mechanism?

a. Conduction

b. Evaporation

c. Convection

d. Radiation

3. After teaching a group of nursing students about thermoregulation and appropriate measures to prevent heat loss by evaporation, which of the following student behaviors would indicate successful teaching?

a. Transporting the newborn in an isolette

b. Maintaining a warm room temperature

c. Placing the newborn on a warmed surface

d. Drying the newborn immediately after birth

4. After birth, the nurse would expect which fetal structure to close as a result of increases in the pressure gradients on the left side of the heart?

a. Foramen ovale

b. Ductus arteriosus

c. Ductus venosus

d. Umbilical vein

CRITICAL THINKING EXERCISE

1. As the nurse manager, you have been orienting a new nurse in the nursery for the past few weeks. Although she has been demonstrating adequacy with most procedures, today you observe her bathing several newborns without covering them, weighing them on the scale without a cover, leaving the storage door open with the transporter nearby, and leaving the newborns' head covers and blankets off after showing them to family and relatives through the nursery observation window.

a. What is your impression of this observation?

b. What principles concerning thermoregulation need to be reinforced?

c. How will you evaluate your instruction after the in-service is presented?

STUDY ACTIVITIES

1. While in the nursery clinical setting, identify the period of behavioral reactivity (first, inactivity, or second period) for two newborns born at different times. Share your findings in post conference that clinical day.

2. Obtain a set of vital signs (temperature, pulse, respiration) of a newborn on admission to the nursery. Repeat this procedure and compare changes in their values several hours later. Discuss what changes in the vital signs you would expect during this transitional period.

3. Find two Internet Web sites about transition to extrauterine life that can be shared with other nursing students as well as nursery nurses.

4. The most frequent mechanism of heat loss in the newborn is ___________________.