Chapter 8: Nutrition for Reproduction

8.1 Nutrient Needs for Pregnancy and Lactation

Objectives

- Demonstrate how the additional nutrient needs for pregnancy and lactation are calculated
- Differentiate between nutrients that have more reliable intake recommendations, from those that are estimated using adequate intake data.

Learning Objectives

- Recognize which nutrients are needed in higher, lower and similar daily quantities during pregnancy and lactation
- Identify which nutrients are most critical to include in the prenatal and lactation diet

A lively and robust newborn human baby is the product of conception and fetal and infant nutrition. Since the growing baby is completely sustained by the maternal nutrient supply throughout the reproductive period, adjustments must be made to the maternal diet to sustain the increased nutrient demands of sustaining a second human life.

Changes in smell and taste sensitivity and food preferences in pregnancy may cause imbalances in daily food intake that are deleterious to optimal fetal and maternal recovery outcomes. While women's changing **sense perception** during pregnancy and the effect of these changes on maternal nutritional status is not entirely understood, most pregnant women report some level of increase in their sensitivity to odors and taste perceptions that stimulate or mitigate appetite signals. Reduced sensitivity to pleasurable tastes and smells can also result in cravings for more salty, sweet, acidic or spicy foods than those that are satisfying when not pregnant. It has been hypothesized that these altered gustatory and olfactory thresholds are caused by a change of neurohormonal activity in the brain, and possibly by an interaction of adjacent uterine and gustatory neurons that are displaced in the early stages of uterine expansion. Pregnancy **food cravings** have been studied more extensively, and while the exact underlying mechanism is also not clear, there are many postulations rooted in psychology, genetics, neurology and even immunology. For instance, neurochemical sensitivity to leptin signaling in the hypothalamus may be suppressed in pregnancy so that the hunger pathways are left unopposed.

In the first trimester, many women also experience symptoms of nausea and vomiting accompanied by weak appetite and, in some, poor nutritional status. Pregnancy-associated hormones such as human chorionic gonadotropin (hCG), estrogen, progesterone and thyroid hormone are likely involved in the onset of **nausea symptoms**. The levels of hCG peak at the end of the first trimester when most women report the greatest frequency of nausea symptoms. Nausea is also more frequent in pregnancies with high levels of hCG, like twin pregnancies. Historically, it was postulated that morning sickness's heightened gustatory senses were an adaptive mechanism of pregnancy that would prevent a pregnant woman from consuming potentially teratogenic or other hazardous substances (i.e., strong-tasting and smelling foods) during the critical first one-half to one-third of the pregnancy. In any case, cravings, sensory changes, and morning sickness certainly influence food intake.

Table 8.1. EAR for Daily Energy, Carbohydrates and Protein Intake

The **estimated average requirements** (EARs) for pregnant women are generated using theoretical models of fetal nutrient needs, plus the additional amounts needed for maternal tissue deposition in pregnancy. Fetal nutrient requirements are estimated using balance data that indicate changes in nutrient absorption and retention between pregnant and non-pregnant women. Other methods use cord blood nutrient concentrations compared to maternal serum, and other analytical measures assess placental nutrient transfer. The EAR is the most precise estimate of the requirements incurred daily by pregnancy, so they are discussed first and separately.

Total daily energy expenditure (TDEE) increases in pregnancy. The basal component of energy expenditure supports uterine and tissue growth, blood volume expansion, and in later phases of gestation, fetal energy expenditure. The cumulative increase in basal energy expenditure is estimated to be approximately 30-50 thousand calories across the entire pregnancy or about 100-180 calories per day. Since most of this amount accrues in the latter two trimesters, the additional calories are only added to the daily intake in . The averaged sized fetus uses approximately 25-30 grams of maternal glucose daily in the third trimester; thus, the EAR for pregnant women is the adult EAR plus 35 grams, or 135 grams of per day. By the third trimester, deposition for new tissues requires seven grams of protein per day. This is added to the ten grams required daily for maintenance of that new tissue, multiplied by a protein efficiency factor of .43 to derive approximately 21 grams per day.

Indicators used to estimate daily requirements for **vitamins and minerals** during pregnancy include fetal nutrient uptake and retention, fetal tissue accretion, and estimates of placental nutrient transfer. Other indicators are based on maternal status and the level of daily intake observed to prevent deficiency, as is the case with vitamin C, iodine, and folate.

Table 8.2. EAR for Daily Micronutrient Intake Comparing Pregnant and Non-Pregnant Women

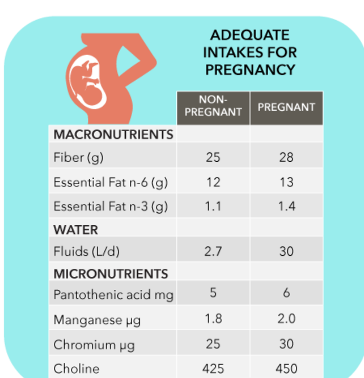
Folate requirements double in pregnancy to accommodate the increasing methylation reactions required for rapid cell division. Adequate maternal erythrocyte count is the indicator of maternal folate status and, in early pregnancy, is critical to the closure of the fetal neural tube. The EAR for pregnant women is 600 µg/day of dietary folate equivalents (DFEs), or 300 µg/day of synthetic folic acid on an empty stomach, or 353 µg/day of synthetic folic acid with a meal. A daily supplement of 400-800 µg of folic acid, in addition to consuming food folate from a varied diet, is recommended for all women planning or capable of pregnancy.

Iron requirements also double in pregnancy. Iron needs are calculated using factorial methods that predict the additional stored and absorbed iron that is required to adequately supply iron for blood cell expansion, fetal tissue deposition, and basal iron losses incurred in delivery. Iron needs in the first trimester are technically less than the non-pregnant EAR because of the cessation of menstruation. Because of the increased demands for the mineral during the second and third trimesters of pregnancy, iron supplementation is usually recommended beginning at 12 weeks.

Iodine requirements are increased by more than 45% during pregnancy. In the US, most diets are more than adequate in iodine, but in other countries where salt is not iodized, iodine deficiency can be problematic. The indicator for iron requirements in pregnancy is based on normal thyroid function and size. If the maternal diet is inadequate in iodine, the thyroid gland enlarges and its hormonal role is compromised.

Zinc requirements increase by almost 40% in pregnancy. Zinc requirements are derived from factorial modeling that uses absorbed zinc as an indicator of daily zinc requirements. Since the bioavailability of zinc changes throughout pregnancy, peak zinc absorption was used to establish the pregnancy EAR. This is the most conservative approach and likely overestimates zinc requirements in the first and part of the second trimester.

B vitamin needs (i.e., thiamin, riboflavin, niacin and pyridoxine) are all estimated to be approximately 30% higher during the second and third trimesters of pregnancy. At around 13 weeks, the fetus begins to move in utero and expend a significant amount of energy. These additional energy expenditures of the fetus are included in the estimates for B vitamin requirements. This amount, plus the additional metabolic activity, are added to the non-pregnant adult woman EAR


ADEQUATE INTAKES FOR PREGNANCY

	NON-PREGNANT	PREGNANT
MACRONUTRIENTS		
Fiber (g)	25	28
Essential Fat n-6 (g)	12	13
Essential Fat n-3 (g)	1.1	1.4
WATER		
Fluids (L/d)	2.7	30
MICRONUTRIENTS		
Pantothenic acid mg	5	6
Manganese µg	1.8	2.0
Chromium µg	25	30
Choline	425	450

Table 8.3. Adequate Intake Values for Non-Pregnant vs. Pregnant Women

Adequate intake (AI) values have been developed for several of the dietary nutrients in the absence of qualifying data to establish EARs. The absence of qualifying data is justifiable for some nutrients as thousands of pregnant women have healthy and optimal pregnancy outcomes with dietary intake levels that are far below the median national reported intake. This is especially true for essential fatty acids since a good portion of fetal needs are supplied by bountiful maternal stores.

For ten of the dietary micronutrients, adjustments to daily intake during pregnancy are not warranted. For the large fat-soluble vitamins E, D, and K, maternal stores do not change significantly during gestation, and transfer across the placenta to the fetus is minimal. For most of the others, especially sodium and chloride, there is such limited risk of deficiency with increasing caloric intake that, if anything, reducing intake is recommended.

NO CHANGE FOR PREGNANCY

	Non-pregnant RDA/AI*	Pregnant RDA/AI*
Vitamins		
Vitamin D*	5	5
Vitamin E	15	15
Vitamin K*	90	90

Table 8.4. Nutrients that do not require additional daily intake

While the demands for **calcium** increase as a pregnancy progresses, the daily requirements for dietary calcium intake do not. This is because a woman's body becomes increasingly efficient at processing dietary calcium so that twice the amount of the mineral is absorbed from foods in the diet, and a significant amount more is retained in normal filtration. Regardless of dietary calcium intake or calcium supplemental level, fetal calcium needs are partially met by mobilization of the maternal skeletal stores. Maternal bone calcium is restored postpartum. The increased efficiency in intestinal absorption of calcium also will lead to increased intestinal absorption of phosphorus.

Lactation

Breastfeeding a newborn complements the attention given to diet during the pregnancy. Breast milk is the ideal source of nutrition for the infant and recommended by the World Health Organization as the exclusive source of nutrition during the first months of life, and a continued source nutrition for up to two years postpartum, as mutually desired by the mother and child.

ENERGY & MACRONUTRIENTS FOR LACTATION

	Non-lactating Ear	+Daily milk need	Lactation ear	Lactation RDA	Non-lactation RDA
Energy 0-6 postpartum	EER	500	EER+500 (-170)		
Energy 7-12 postpartum	EER	400	EER + 400		
Carbohydrate g	100	60	160	210	130
Protein	0.66 g/kg/d	8.18	1.05	1.3	46 g/d

Table 8.5. EARs for Daily Energy, Carbohydrate and Protein Intake for Lactation

The daily nutrient requirements of lactating women are based non-lactating adult EARs plus the nutrients that required for to sustain milk production. Daily milk volume averages .78 liters per day from months 1-6, and .67 liters per day from 7-12 months. The **EER** for lactation is slightly higher to account for increasing resting metabolic rate that is associated with the cost of milk production. The lactation EER also accounts for the mobilization of accumulated energy from fat tissues during pregnancy so that across the first six months, the additional energy needs of lactation are reduced by 170 calories each day. After that, the infant will likely get some calories from solid foods, so increases in energy intake to support continued breastfeeding is likely not needed.

Carbohydrates must be supplied in the diet to protect maternal proteins in the production of lactose, which requires 60 additional grams of glucose per day, **Protein** requirements for lactating women are EAR plus total protein and non-protein nitrogen in their milk, or 22 to 25 grams extra per day. Like lactose, protein is adequately supplied in breast milk independent of the maternal diet and at the expense of maternal body proteins, which are only spared when dietary protein intake is at least 1.0 g/kg /day.

MICRONUTRIENTS FOR LACTATION

	Non-Lactation Ear	+ Daily milk output	Lactation ear	Lactation RDA	Non-lactation RDA
Iron mg	8.1	0.27	6.5	9	27
Folate µg	320	0.66	450	500	600
Niacin mg	11	1.4	13	17	18
Thiamin mg	0.9	0.16	1.2	1.4	1.4
Molybdenum µg	34	2	36	50	50
Pyridoxine mg	1.1	0.10	1.7	2	1.9
Cyanocobalamin µg	2.0	0.33	2.4	2.8	2.6
Zinc mg	6.8	1.35	10.4	12	11
Riboflavin mg	0.9	0.3	1.3	1.6	1.4
Selenium µg	45	14	59	70	60
Vitamin E mg	12	4	16	19	15
Copper µg	700	200	1000	1300	1000
Iodine µg	95	114	209	290	220
Vitamin C mg	60	40	100	120	85
Vitamin A µg	500	400	900	1300	770

Table 8.6. EARs for Daily Micronutrient Intake for Lactation. (Listed in order by percent change from pregnancy from high to low)

Lactation is extremely micronutrient-demanding. For most **micronutrients,** there is an established EAR for lactating women calculated by adding the amount necessary to replace daily human milk secretion as well as the amount required by non-lactating women to maintain a healthy nutrient status. For some of those micronutrients, like several B vitamins involved with metabolism, an additional amount is added to account for the metabolic cost of breast milk production.

For **iron and folate**, there is a in micronutrient requirements post-partum. Slowing rates of cell growth and division, and the cushion provided by a reducing hemoglobin mass, yield daily intake requirements that actually after giving birth. There is little variation in the requirements for **water-soluble** B vitamins and vitamin C in the maternal diet when transitioning from pregnancy to lactation. The amount in breast milk directly reflects the amount in the maternal diet. In general, **minerals** in breast milk fluctuate less with intake than vitamins because their concentrations in breast milk are more reliant on maternal body stores.

For some vitamins and minerals, increased micronutrient requirements for lactation are based on the median reported daily intake of thousands of healthy lactating women that are sufficiently producing quality breast milk. When that type of data is unavailable, the AI is calculated by adding the amount expended in milk to the adequate intake for women who are not lactating or pregnant.

Lactation requires a significant amount of **water**. There is no evidence to suggest that renal function and hydration status are different during lactation; thus, the daily needs for water can be estimated by milk output (.78 L) x 87% water, or .67 L/day. Using this approach, water needs during lactation would be calculated by adding the latter amount to a non-lactating woman's AI, which totals 3.-3.6 L/day for lactating females. Increased needs for **micronutrients** like potassium, chromium, choline, vitamin, pantothenic acid and manganese are estimated similarly, that is, on the basis of the daily secretions in human milk plus the AI for women.

NO CHANGE FOR LACTATION

	Lactation RDA/AI *	Non-lactation RDA/AI *
Vitamin K µg *	30	30
Vitamin D µg *	5	5
Biotin µg *	3	3
Calcium mg *	1000	1000
Fluoride mg *	90	90
Sodium Chloride mg *	3.8	3.8
Magnesium mg	320	320
Phosphorus mg	700	700

Table 8.7. RDA and AI* for nutrients that stay the same during lactation

Micronutrients that need no adjustments to accommodate pregnancy requirements are listed in table 8.6. For mothers that do not get UV light from the sun, 2,000 IU/day vitamin D supplements for baby or maternal diet may be justified. The RDA for vitamin D for lactating women is 600 IU/day, but intake at this level in the absence of sun exposure likely results in insufficient provisions for the infant. Compensatory changes in the efficiency of absorption and retention of several minerals, like **calcium**, provide the additional calcium needed for lactation.

8.1 Homework 1

Review

Touch the set of nutrients that pregnant women need MORE of each day.

Targets placed: 2/2

Undo Delete selected Remove All

You can place up to 2 targets

Show Submitted Answer

Show Correct Answer

Check My Answer

8.1 Homework 2

Review

Which nutrient is needed in a lesser daily amount postpartum?

A Calcium

B Iron

C Fiber

D Vitamin K

Explanation

Yes, iron needs are reduced postpartum

Show Submitted Answer Show Correct Answer Check My Answer

8.2 Foods, Beverages and Supplements for Pregnancy and Lactation

Objective

- Introduce foods and supplements that meet the nutrient requirements of pregnancy, as well as the dietary constituents that should be avoided in certain cases.

Learning Objective

- Identify rich dietary sources of folate, iron, vitamin C, protein and essential fat.

While the typical healthy diet pattern is adequate to supply the additional needs imposed by pregnancy and lactation for most dietary nutrients, still, for most women, vitamin and mineral supplements are prescribed with standard pre-natal health care plans. This strategy reduces the risk of nutrient deficiencies in diets that could pose a risk of poor pregnancy outcomes.

Figure 8.1. Typical Pre-Natal Supplement Vitamin and Mineral Content and Specialty Ingredients

Prescription and over-the-counter **prenatal supplements** provide calculated doses of **micronutrients** to satisfy the majority of the additional maternal and fetal micronutrient requirements discussed in the control section of this chapter. The majority of prenatal vitamins are sold with vitamins and minerals in tablet or candy forms. They include anywhere from ten to thirty nutrients that are either difficult to get in the daily diet, difficult to absorb from whole foods, or that are strongly related to pregnancy demands and healthy pregnancy outcomes. **Folate and iron** are almost always featured in prenatal supplements at a level that satisfies 100% of the daily pregnancy need. **Vitamin D** levels in these supplements are much higher than the RDA to account for less than optimal sun exposure but contain only a small portion of the daily need for calcium.

Many prenatal supplements are made for enhanced bio-efficiency. These supplements may use chelated minerals and combinations of other **functional ingredients** that enhance absorption, and even enzymes and probiotics. The most common ingredient added to standard vitamin and mineral pre-natal supplements is omega-3. Some supplements use the letters **DHA and EPA**, which means that the essential fat in the supplement is pre-formed from an animal source, or from a plant that was synthetically induced to perform the fatty acid bio-conversion. The label of supplements that use plant omega-3 will list alpha-linoleic acid (ALA). Vegan supplements and supplements that are “GMO-free” are increasing in popularity while operating in a grey area of regulatory guidelines. For instance, DHA made from algae is marketed as organic and natural but, in some instances, is made with GMO algae. Powdered, whole plant-based ingredients like spirulina kale and prune are increasingly used in natural supplement lines, along with many types of proprietary blends of pregnancy-affiliated plants like root ginger and chamomile. Products marketed to women to support postpartum lactation often include a dose of the lactation-stimulating herb fenugreek. Continued use of prenatal supplements in the postpartum transition is gaining popularity too, as lactation imposes an even higher demand than pregnancy for several nutrients including, but not limited to, **thiamin, pyridoxine** and **cyanocobalamin**. Maintaining adequate levels of nutrients like these is especially important because they fluctuate in breast milk with maternal intake.

Fortified foods for pregnancy have similar basic micronutrient platforms as dietary supplements but are part of energy-providing meals and recipes. Usually, synthetic nutrients are used for fortification since for most pregnancy-critical nutrients, especially folate and iron, natural food forms are less absorbable than synthetic counterparts. Designer shakes, bars, cookies, teas and juice products have been developed to feature these nutrients at a level that usually provides around 50-70% of the additional pregnancy iron needs, at the top end, all of the folate needs and, depending on the product positioning, a significant portion of the increased fiber, protein and/or DHA needs, to name just a few. Prenatal beverage shakes and smoothies are also good platforms for adding micronutrients and dosing healthy amounts of added fiber, calcium and protein. Most of the products marketed in the pregnancy and lactation category are sweet and are perceived as treats or desserts. Other less foundational prenatal food products, such as teas and candies, may be formulated with compounds that help with common pregnancy and lactation problems. For instance, teas are now adding herbs thought to help with nausea, like fenugreek, to stimulate lactation.

Table 8.7. Additional nutrient needs satisfied by one (1) serving of fortified breakfast cereal and DHA added milk. Notice that only protein, Vitamin C and Calories are still needed to meet daily nutrient needs.

Ready-to-eat breakfast cereals have one of the most concentrated vitamin and mineral profiles of any food in the human supply. Micronutrient levels are designed to meet 100% of the daily needs for non-pregnant women. The breakfast meal platform is an effective one for preventing nutrient deficiencies because breakfast choices are often limited and purchased repetitively for home consumption. Dry, ready-to-eat cereals are especially effective because they can be sprayed with liquid vitamins and minerals that supply almost 100% of the non-pregnant-to-pregnant and lactation nutrient requirement gaps without affecting the sensory qualities of the cereal. If paired with a 6-8 ounce serving of vitamin A and D-fortified milk, the meal provides 8 grams of protein, additional B vitamins and, most importantly, riboflavin — a relatively sparse micronutrient in most diets. By adding a fruit serving atop the meal, women can secure additional vitamin C to enhance absorption of other micronutrients, like food folate.

Fortified grain flours made into breads and pastas also provide a good portion of the RDAs for many nutrients, especially iron, folic acid and B-vitamins. However, these products lack the nutrient punch of ready-to-eat breakfast cereals because they cannot be sprayed with special liquid vitamin and mineral mixes after baking. The powdered vitamin and mineral mixes are added to flours prior to baking may change the physical and sensory characteristics of bread and pasta products, and therefore must be used more judiciously.

Natural whole foods and meals that are not fortified, but rather naturally rich in nutrients, can also effectively meet the needs of pregnant and lactating women. Their consumption must simply be planned more carefully to ensure that the nutrient density of the diet is adequate. For instance, rice, quinoa and oats are excellent **whole grains** that naturally contribute additional protein, essential fats and fiber. **Legumes**, too, are typically high in fiber and can provide the additional 1-2 grams of daily essential fatty acids needed for pregnant women. Some legumes, like garbanzo beans, are also rich in folate and can provide up to 200 mcg per 1/3 cup serving. Iron from legumes can also help meet the nutritional demands of reproduction but, unfortunately, dietary iron is only about 10% absorbable. Plant foods, specifically high phytic acid legumes and seeds, should be paired with ascorbic acid-rich fruits and vegetables to maximize iron bio-availability.

Figure 8.2. Whole foods that contribute to the additional daily nutrient requirements during pregnancy. Bolded and highlighted values satisfy 100% of more of the additional daily requirement for one or more nutrients.

Fruits and vegetables should be consumed often with meals and as snacks to enhance overall daily nutrient density and mineral absorption, and to curtail symptoms of morning sickness and constipation. Fruits also provide **vitamin C** that is needed to support fetal ascorbic acid uptake and to sustain the concentrations secreted in breast milk. Fruit intake is especially important in the lactating diet, since postpartum vitamin C and A needs increase by 40% and 68%, respectively, during that period. Just one serving of a vitamin C and A-rich fruit or vegetable, like strawberries or red bell peppers, will entirely close the gap between daily non-pregnant and pregnant RDAs.

Animal meat is a more efficient form of iron, zinc and protein for pregnant and lactating women. Red meat, chicken and certain fish also provide significant amounts of dietary fat. Species that are high in saturated fat and cholesterol, like beef and dark poultry meat, should be consumed less than species of meat that are lower in fat overall, or species that are higher in the preformed essential fats DHA and EPA, like fish and specialty eggs. Guidelines for fish intake during pregnancy and lactation are the same as for non-pregnant women and should total at least eight ounces per week.

Salmon, tilapia, trout seabass, catfish and cod are all good fish choices for pregnant and lactating women as they are high in essential fat but relatively low in mercury. Certain fish that are high in **mercury**, such as tilefish, big-eye tuna, shark, swordfish and king mackerel, however, should be avoided by women who are pregnant or planning a pregnancy. Pregnant women should also avoid processed meats such as those with added nitrates and sodium. They should also be sensitive to temperatures of dietary meats. Raw fish and fish served cold or closer to room temperature, such as sushi, should be avoided as pregnant women are more susceptible to illness from pathogens in meats that can be killed by adequate cooking.

Dairy intake in pregnancy and lactation is important to preserve maternal bone mineral density. However, being that additional calcium and phosphorus, the primary dairy nutrients, are not critical in pregnancy and lactation, the 2-3 servings recommended in the typical 2,600 kcal/day diet should suffice. Adding a serving of dairy to satisfy the additional 300-500 energy calories is certainly appropriate for some meals and snacks, but un-pasteurized dairy products should be avoided. Pregnant women are also more prone to food borne pathogens, like listeria, which is commonly found in in raw, soft cheese.

Snacks play an important role in the pregnancy and lactation diet. They are often recommended to supplement nutrients and help curtail common pregnancy symptoms. Snacks should provide protein or fiber and be limited in salt and sugar. Crackers and other grain snacks, salty or sweet, should be from whole grain flour sources that are baked, not fried, and provide at least 10% of the daily needs for fiber. Sweet snacks including desserts, should contain mostly natural sugars (e.g., fruits and yogurt), and should be limited in calories and fat. Empty calorie sweet snacks that are more calorie than nutrient dense, like ice cream and candy confections, should be avoided.

Beverage consumption increases in the pregnant and lactating diet, as total fluid intake increases by 11% and 40% during those two periods. **Plain water** is the best choice of beverages for hydration. Sugar-sweetened beverages, including regular sodas, sports drinks, energy drinks, and fruit drinks with added sugars should be limited. **Electrolyte (i.e., sports) drinks** may provide additional hydration if vomiting or physical activity is continued, but should otherwise be avoided. Energy drinks may contain substantial amounts of sugar and stimulants like caffeine, taurine, carnitine, inositol, ginkgo, milk thistle and other herbal compounds and chemicals that have not yet been thoroughly evaluated in pregnant or lactating women. Since limited research addresses the safety of non-nutritive sweeteners used in diet beverages, their consumption should also be limited. The half-life of caffeine increases significantly in pregnancy, from 3 hours in T1 to as much as 100 hours in T3. Thus, pregnant women are advised by the American College of Obstetricians and Gynecologists to consume no more than 200 mg of caffeine per day — the approximate amount in one 12-oz cup of **coffee**. Since caffeine is also transmitted to breast milk, caffeine intake while lactating should be limited similarly. **Tea** is a popular drink for pregnant and lactating women. Designer tea brands are marketed to mitigate symptoms of nausea, to promote milk production, and to give way to relaxation and sleep. Pregnancy and lactation teas typically feature herbal blends of ginger root, chamomile, peppermint or raspberry leaf, in bags or jarred and pre-steeped.

Alcohol should not be consumed by **pregnant women** or those who may become pregnant as no safe level of alcohol consumption during pregnancy is established. **Lactating women** are not generally discouraged from reasonable alcohol intake, as the absolute amount of alcohol transferred into breastmilk is ordinarily low. In fact, in some cultures, there are widely held beliefs that beer stimulates lactation; however, it is the polysaccharide from barley beer, not ethanol, that has been reported to stimulate prolactin levels, thus, non-alcoholic beer would be equally effective. Lactating mothers who drink alcohol should be mindful that alcohol does passively flow into mother's milk and peaks about 30 to 60 minutes after consumption, or 60 to 90 minutes when consumed with food.

8.2 Homework 1

Review

Put the following foods in order from most to least **folate** per serving

Drag and drop to order

1

2

3

4

Show Submitted Answer

Show Correct Answer

Check My Answer

8.2 Homework 2

Review

Which pair of foods would best satisfy the additional vitamin C needed in pregnancy and lactation?

- A Fruits and Vegetables
- B Nuts and Seeds
- C Meats and Legumes

Show Submitted Answer Show Correct Answer Check My Answer

8.2 Homework 3

Review

VISIT USDA National Nutrient Database
LOCATE the nutrient composition per one ounce of English Walnuts
Does the alpha-linoleic acid in one ounce of English Walnuts provide enough to cover the additional n-3 needed for pregnancy?

- A yes
- B no

Explanation

Just one ounce of English Walnuts provides 2.5 grams of n-3 alpha linoleic acid.

Show Submitted Answer Show Correct Answer Check My Answer

8.3 Nutrient Processing for Reproduction

Section Objectives

- Highlight the major physiologic changes that impact nutrient processing in pregnancy
- Reinforce recognition of critical pregnancy nutrients and how they are processed by the pregnant body

Learning Outcomes

- Recall the pregnancy hormones and what major change they signal in the GI tract
- Describe the hemopoietic changes that occur in pregnancy
- Explain how calcium metabolism changes in pregnancy to maintain serum calcium homeostasis
- Differentiate between oxytocin and prolactin in regulating breast milk production and let down

Nutrient transformation systems are more efficient during the reproductive period to accommodate maternal, fetal and infant growth and development. The major physiological changes that take place during pregnancy are driven by neuro-hormonal responses and subsequent actions at cellular, tissue and organ system levels. These adaptations are apparent across the three stages of pregnancy and two major phases of lactation, and they include major body tissue targets such as the gastrointestinal tract, blood and homeostatic organs, and anabolic pathways of energy metabolism.

Figure 8.2. Summary of Major Digestive Changes in Pregnancy

Changes to the gastrointestinal tract during pregnancy and lactation start in the mouth. In pregnancy, the mouth is more vascularized and produces more acidic saliva, which increases gum sensitivity, bleeding and tooth decay. Increases in **estrogen** and **progesterone**, two primary endocrine pregnancy hormones, also influence the structural alterations in the gastrointestinal tract, beginning near the end of the first trimester. Hormonal increases cause abnormalities in gastric neural activity and smooth muscle function to an extent that the muscular junction of the esophagus and the stomach relax and stomach contents flow back into the esophagus, causing esophageal reflux, or GERD. This lowered gastrointestinal tone and motility can also cause **constipation,** even in early pregnancy, as food moves more slowly through the intestines.

Mechanical changes in the alimentary tract occur as the uterus and fetus grow. The stomach is increasingly displaced upwards and laterally, leading to an altered axis and increased intra-gastric pressure. Esophageal sphincter tone is also decreased and these factors can induce feelings of nausea or vomiting and cause or exacerbate symptoms of GERD. In late pregnancy, a portion of the stomach can even be pushed all the way up into the chest, producing a hiatal hernia.

The absorption efficiency for several nutrients is significantly higher during pregnancy and lactation in response to increased nutrient demands. Calcium absorption efficiency, for instance, doubles between week 12 and the end of gestation. The rate of calcium absorption grows in conjunction with increases in serum 1.25-dihydroxyvitamin D, and correlates with rising rates of fetal calcium transfer in the third trimester of pregnancy. During lactation, changes in calcium absorption are independent of maternal calcium intake, but these changes subside postpartum, and absorption fluctuates with intake again on the return of ovarian function. With the return of ovarian function, intestinal calcium absorption increases as does serum $1,25(OH)_2D$ concentration, while renal retention of calcium persists.

Vitamin B12 is also absorbed in higher concentrations in pregnancy. The placenta hormone, placental lactogen, is suspected to increase in the number of intrinsic factor-B12 receptors. For iron, absorption increases with demands for red blood cell production during the second and third trimester. Like in non-pregnant and non-lactating women, iron is better absorbed on an empty stomach and in the presence of ascorbic acid. Zinc absorption increases from 27 to 71% under these conditions.

Farther down the GI tract, the enlarging uterus pushes forward on the abdominal wall and on the colon, which may cause or exacerbate constipation with the passing of digestive waste. The enlarging uterus also pushes down on the pelvic veins, which can cause hemorrhoids.

Figure 8.3. Body water changes driven by endocrine system

Normal pregnancy is associated with a steady 30-50% total increase in **extracellular water volume** between 6 and 24 weeks under the influence of the hormone aldosterone. This large increase in aldosterone levels from trimester one to three is driven primarily by the Renin-Angiotensin-Aldosterone System (RAA). The liver is also stimulated by pregnancy to produce angiotensin II, and the adrenal gland is stimulated to produce renin by the action of placental estrogen. Collectively, this cascade of hormonal events results in a greater net retention of water, which becomes the pregnant woman's new threshold for detecting thirst. The hypothalamic adjustments in arginine vasopressin create more easily sensed thirst and, as a result, increase fluid intake. Coupled with an increasing rate of flow to the kidneys (i.e., glomular filtration rate), frequent urination or polyuria is typical in pregnancy despite the above-referenced increases in water retention and water weight.

In pregnancy, increasing plasma aldosterone and subsequent water retention causes hemo-dilution. The concentration of serum proteins and total blood cell counts are reduced, as the maternal blood volume expands by an approximated 45%. For several nutrients that depend on serum proteins for transportation, pregnant women have lower serum values. For nutrients that can travel free in the blood, like ionized calcium, serum levels are relatively unchanged.

Figure 8.4. Blood Volume Increases in Pregnancy

While pregnancy is characterized as a hypo-osmotic state, there are substantial increases in the production of many whole blood cells. PNL (vitamin B6 metabolite) and its associated enzymes initiate neutrophilic leukocyte production, stimulating an increase in total **white blood cells**. The white blood cell count starts to increase during the second trimester and peaks in the third trimester to reach a count as high as 29,000 during labor – two to three times higher than the typical white blood cell count of non-pregnant women.

By the latter part of the third trimester, by the action of erythropoietin in the bone marrow, **red blood cell mass** has expanded by nearly 30%. Iron is needed to synthesize these red blood cells. Maternal iron stores (i.e., hemosiderin) from the liver and spleen may be used to expand the red blood cell mass if dietary intake is inadequate. Despite the massive increase in heme production, there is a net 2 mg/dL reduction in total hemoglobin until the last few weeks of pregnancy.

Cardiovascular responses to increasing blood volume include an increase in **cardiac output** as a function of increasing total stroke volume and, in trimester two, a reduction of arterial **blood pressure**. Blood pressure reductions are elicited by hormonal responses that blunt the sensitivity of the blood vessels to the vasoconstriction hormone, angiotensin, which lead to reduced total peripheral resistance (TPR). Enhanced peripheral vasodilation of the arterial vessels surrounding the uterus, mammary glands, and the GI tract are a major accommodation in pregnancy, and ensure adequate nutrient and oxygen delivery to the fetus. By the middle of the second trimester, vasodilation is also apparent at the kidneys at a time when renal plasma flow and GFR are twice that of their pre-pregnant states. To accommodate these increases, the kidneys enlarge and the urethra and ureters elongate. In later phases of pregnancy, the enlarged uterus presses against the bladder, which causes more frequent urination.

The thyroid hormone stimulates a 20% increase in **basal metabolism** during pregnancy and 4-5% during lactation. These increases are contributed from the uterus and fetus and increased work output of the heart and lungs. Some pregnancy activities expend little energy, like blood volume expansion, but others, like fetal tissue and uterine growth, expend significantly more. In later stages of pregnancy, approximately one-half of the additional energy expenditure is attributed to the fetus, which uses around 56 calories per kilogram of body weight per day, which is just under 170 kcals per day in a 3.5 kg fetus.

Altered metabolic processes that direct nutrients to the growing fetus are facilitated by a number of counter-regulatory hormones that facilitate maternal fat breakdown and opposition to the action of insulin. In the second and third trimesters, insulin resistance progresses in concert with the release of placental lactogen and other diabetogenic hormones including growth hormone, progesterone, cortisol and prolactin. These hormones together impair insulin sensitivity in the periphery, most-heavily impacting the insulin signaling receptors of fat and skeletal muscle.

Glucose metabolism is increased during pregnancy and lactation as women in both conditions have a higher respiratory quotient, which is an indicator of increased carbohydrate utilization. Pregnancy and lactation are hypoglycemic conditions as a result of reduced hepatic glucose output coupled with increased hepatic, skeletal gluconeogenesis and, in pregnancy, increased fetal glucose uptake. In trimesters two and three, the placental glucose transfer rate increases up to 17-26 grams of glucose per day, which is estimated to satisfy around 70% of the average 350-gram fetal brain needs. The fetal brain can also use ketoacids, which are thought provide the remaining 30% of fetal brain fuel needs.

Fat anabolism is predominant in early pregnancy so that fat is deposited at a greater rate than it is accessed. Placental lactogen, the hormone with a principal action of supplying the fetus with glucose, stimulates fatty acid oxidation throughout the pregnancy, so that glucose and amino acids are preserved for the fetus. Other accommodations to shunt glucose to the developing infant include an increase in total serum cholesterol, free fatty acids and triglyceride.

Figure 8.5. Calcium Homeostasis During Pregnancy and Lactation

Bone metabolism is increased during pregnancy and lactation. Bone turnover is low in the first trimester and increases in the third, when fetal calcium needs are increased. The primary source of calcium for pregnant women in the third trimester is stored maternal skeletal calcium, which changes the micro-architectural pattern and mineral content of the maternal skeleton. In preparation, far in advance of fetal calcium demands, there is a thyroid response that, in conjunction with adequate serum vitamin D, yield serum calcium increases by acting on bone tissues, the GI tract and the kidneys. During lactation, the difference between bone resorption and formation represents a net flow of calcium from bone into the extracellular fluid calcium compartment for a net bone loss of about 2 mg/day. In response, PTH is released from the pituitary and calcium absorption and renal retention are improved.

Ten to twelve kilograms is gained in in the average American pregnancy. Early in pregnancy, cells multiply rapidly in association with placental development and expansion of maternal erythrocyte count and uterus size. Despite the fact there is a significant amount of tissue in T1, only a small weight change with increasing body water occurs. The rate of tissue accretion accelerates in the second and third trimesters to approximately 350-400 grams per week. **Protein accretion** increases significantly around 13-15 weeks as growth hormone promotes **nitrogen retention** to yield 8.4 grams of protein per day throughout T2, and double that amount by T3. These values are comparable to estimated gains in fetal weight.

Figure 8.6 Distribution of Tissue Deposition Across Major Maternal Tissues

Maternal tissues represent more than half of the total weight gain in pregnancy. **Uterine tissue** hypertrophy creates double the uterine mass, and a 1,000% increase in volume capacity from pre-pregnancy values of 4 ml, all the way up to 5000 ml. Uterine protein is supplied by increased uterine vascularization and near doubling of uterine artery lumen size so that, in total, the uterus receives 500 ml of blood flow per day — more than five times pre-pregnancy amounts. The uterus also fills with amniotic fluid, which has a small amount of protein, but no fat.

In early pregnancy, estrogen and progesterone from the ovaries, and prolactin from the pituitary and placenta, stimulate an increase in **breast cell lobules**. By month 6 of gestation, mammary glands in the mother's breasts enlarge, now fully developed, and increase by about 30% in size. By the end of the pregnancy, nearly 100 grams of breast tissue has grown, most of which is myoepithelial cells (i.e., proteins), and some of which is accumulated fat.

Placental and fetal tissues are estimated to represent about one-third (5 of the l 16 kg total) of pregnancy weight. Development of the fetal-placental unit begins with conception and fertilization of an ovum by a sperm cell to form a zygote. The zygote travels up the fallopian tubes to the uterus, where it implants itself in the uterine wall, or womb. Some of the cells in the cluster of zygotes begin to develop the embryo, and the rest become the **placenta**. Over the life of the pregnancy, the placental protein accretion is estimated to total slightly more than 500 grams.

Table 8.7 Fetal Growth and Development across Trimesters 1-3

The cells in the cluster of zygotes that progress to an **embryo** start as a layered disk that is converted into different areas of the body. The outer layer, or ectoderm, develops into skin, hair, nails, and the nervous system. The inner layer, or endoderm, develops into the intestines and lungs. The middle layers develop into the heart, bones, and muscles. By the fourth week following fertilization, organs of the body are present and bulges appear that will become the ears and nose. The gut and mouth are formed from pouches within the embryo that push forward until an opening forms. At this point, the embryo is about 1/4 inch (5 cm) long, has a mass of 5 grams, and has a cell count that has increased by two thousand percent since conception.

The second trimester begins in the 13th week. Organ tissues and frameworks are formed and the fetus begins spontaneously expending small amounts of energy with movement. By the fourth month, the fetus has grown to four to five inches long and weighs three ounces. Keratin-rich nails form on the fingers and toes and the fetal skeleton begins to calcify about the same time that tooth buds form in the mouth. The fetus starts to swallow amniotic fluid and activate the muscles of the intestines to contract and relax, as if digesting food. Skeletal muscles begin to work under neural control so the fetus can move in response to local pressure.

The third trimester is the most focal stage of tissue accretion and growth. The fetus doubles its length and increases its weight by three to four times. By 32 weeks, the fetus is approximately 23 cm and 3,000 grams By the eighth month of gestation, the fetus is 16-18 inches long and weighs three to four pounds. The final preparations for independent existence occur during the ninth month. Fat is deposited under the skin and the brain and retina accumulate long-chain polyunsaturated fatty acids, docosahexaenoic acid (DHA). Mineral accretion, especially iron phosphorus and calcium, also peaks in third trimester. Fetal liver vitamin A stores expand and placental vitamin A uptake increases in the third trimester, as well. Collectively, by the final month of pregnancy, the fetus is usually 20-22 inches long and weighs seven to eight pounds.

Breast Milk Production and Letdown

Serum prolactin, serum progesterone and estradiol levels each increase considerably throughout pregnancy. Together, these hormones act to delay breast milk production and milk let down until after birth. At the end of pregnancy, the posterior lobe of the pituitary gland increases the production and secretion of oxytocin (OT) until, eventually, the level is high enough to initiate labor. In sync, levels of progesterone and estrogen fall rapidly, prolactin is no longer blocked, and milk production begins.

Milk in the breast tissue is synthesized from a mix of maternal circulating nutrients and macromolecules. Glucose, for instance, is delivered to the breast tissue by the breast lobules where it combines with galactose to form lactose. Amino acids, on the other hand, are delivered from maternal serum lacto-albumin. Milk proteins are synthesized in the breast from these amino acids. Many materials needed for breastmilk production are secured by mobilization of the mother's body tissues by actions of lipolysis, bone resorption, or proteolysis of maternal muscle mass.

The suckling or crying of a newborn stimulates the mother's hypothalamus to release oxytocin. In response to oxytocin, the myoepithelial cells around the alveoli contract and expel milk. Milk is expressed from the breast by infant suckling, hand expressing, or pumping with manual or electric devices. Milk production is controlled in the breast by a substance dubbed, the feedback inhibitor of lactation, or FIL, a polypeptide. FIL is present in breast milk and locally controls breast milk production. Because FIL acts locally (i.e., within the breast), if a baby suckles only on one side so that the breast milk from the other is not expressed, the FIL collects and the breast stops making milk. If the milk from that side is removed, however, secretion will resume. This mechanism protects the breast from the harmful effects of engorgement and enables the baby's needs to determine milk production.

8.3 Homework 1

Review

Which of the following physiological adjustments to accommodate reproduction only happens in pregnancy and not lactation ?

- ○ **A** Increased bone turnover
- ○ **B** Enhanced gastrointestinal absorption
- ○ **C** Higher rates of metabolism
- ◉ **D** Expansion of blood volume

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8.3 Homework 2

Review

Oxytocin stimulates the release of milk from the breast, and in conjunction with **this hormone**, breast milk production.

- A Insulin
- B Lactogen
- C Estrogen
- D Prolactin

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8.3 Homework 3

Review

Which of the following pregnancy organs requires the most protein deposition?

- A Breasts
- B Blood
- C Uterus
- D Placenta

Explanation

The placenta requires approximately 500 grams of protein compared the second most protein containing pregnancy organ, the uterus.

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8.4 Nutrient Functions for Pregnancy

Section Objectives

- Foreshadow the nutrient needs of infants in Chapter 9
- Introduce the main features of breast milk

Learning Outcomes

- Recall the tissue (body) composition of the healthy, full term new born
- Distinguish between colostrum and fore milk
- Describe the key nutritional features of breast milk

The outcomes of adequate nutrition are apparent at every stage of the reproductive period, and at molecular, cellular, tissue and organ levels. The placenta, for instance, is a pregnancy organ that has an endocrine function, reducing power, and a specialized concentration gradient for selective vitamin absorption, is a product of protein deposition and vitamin catalyzed reactions. Another isolated nutrient-related pregnancy outcome is the hormone-driven expansion of total body **water**. Increased thirst sensation and kidney water retention double plasma volume in order to maintain blood pressure and utero-placental perfusion. **Iron**-dependent hemoglobin expansion is another good example – even in the face of reduced lung expiratory capacity and red blood concentrations, oxygen delivery remains constant.

Figure 8.8. Healthy Newborn Tissue Distribution

While these lower-level and discrete outcomes are important, the larger and more holistic nutrition-related outcomes of the human reproductive phases are a healthy newborn baby and breasts capable of lactation. A healthy **full-term** baby is born between 38-40 weeks' gestation; weighs between 3-4 kilograms; is pink all over at birth and 5 minutes afterward; has a sustained heart rate of 100 beats per minute or more; and promptly demonstrates deep and regular crying.

Early consumption of sufficient amounts of enzyme cofactors folate, B12, and B6 greatly enhances fetal outcomes that depend on methylation reactions during embryonic and fetal development stages. Methylation reaction outcomes in early pregnancy include gene expression, cell division and synthesis of DNA (nucleic acid) which are all needed for differentiation of the central nervous system.

The major outcome of adequate nutrition post-partum is breast milk. During pregnancy, the breasts are enlarged and vascularized to produce **breast milk** — the optimal source of nutrition for human newborns. Breast milk quenches the baby's thirst and hunger and is adequate to be the sole source of nutrition for the first months of human life. It is easily digested and highly bioavailable. Breast milk also contains bioactive factors that help with nutrient digestion and absorption and augment the infant's immature immune system, providing protection against infection. The very first milk produced after birth is colostrum.

Colostrum is a thick and high-protein secretion that is sweeter and slightly more yellow than normal breast milk.

Figure 8.9. Shades of Let Down Beast Milk

It is produced during the first few days after birth in volumes averaging 40–50 ml. Colostrum contains high levels of protein antibodies including: immunoglobulin, principally, secretory immunoglobulin A (sIgA), which coats the intestinal mucosa and prevents bacteria from entering the cells; white blood cells that kill micro-organisms; whey proteins (lysozyme and lactoferrin), which kill bacteria, viruses and fungi; and oligosacccharides that prevent bacteria from attaching to mucosal surfaces. Antibodies and immune cells in colostrum pass directly through the infant's GI tract into circulation which, interestingly, is the only time in our entire lives that we absorb whole protein. Colostrum seals the permeable spaces in the intestines, which initiates the removal of the meconium (i.e., first stools) from the intestinal tract. As the first week of life progresses, colostrum production decreases and normal breast milk production and secretion increases.

Breast milk composition is different and more variable than colostrum. Breast milk contains complex proteins, lipids, carbohydrates and other biologically active components that change in concentration throughout the lactation period and even during the course of one feeding. Milk begins to be produced in larger amounts between 2 to 4 days after delivery, making the breasts feel full, or engorged. On the third day, an infant is typically consuming 300–400 ml of milk per day, and by the fifth day, 500–800 ml. From day 7 to 14, the milk is called , and after 2 weeks, it is called

Figure 8.10 Macronutrients in Breast Milk

The main **carbohydrate** in mature breast milk is the sugar, lactose. Lactose is a disaccharide that is produced in the breast in dehydration synthesis of the monosaccharides, glucose and galactose, supplied from the maternal diet. Breast milk contains about 7g lactose per 100 ml, measurably more than in most other species' milk. Also unique to humans, breast milk contains lactose-based oligosaccharides that are used to nurture the newborn's growing colony of intestinal microflora, which blocks disease causing pathogens from receptor access in the GI tact.

The principal **proteins** in breast milk are alpha-lactalbumin, lactoferrin, IgA, lysozyme and serum albumin. Alpha lactalbumin, the primary human milk protein, is a soluble one that forms soft, easy to digest curds with a perfect balance of amino acids to accommodate human growth. The concentration of protein in breast milk is approximately 0.9 g per 100 ml, of which an estimated 25% is **non-protein nitrogen** containing compounds such as urea, uric acid, creatine, creatinine and nucleotides.

Breast milk contains about 3.5g of **fat** per 100 ml, which provides about one-half of its energy content. The amount of fat in breast milk increases as the feed progresses. The hind milk that is secreted towards the end of a feed is rich in fat and has a creamier and whiter appearance than the bluish-grey colored lower fat expelled at the beginning of a feed. Breast milk also contains a unique fatty acid profile that includes long chain polyunsaturated fatty acids such as endocannabinoids, several prostaglandins, docosahexaenoic acid, or DHA, and arachidonic acid, or ARA.

Breast milk normally contains sufficient **vitamins** for an infant unless the mother herself is vitamin-deficient. The vitamin D content of breast milk, however, is low but adequate if the infant is exposed to sunlight. **Minerals** like iron and zinc are present in relatively low concentrations, but their bioavailability and absorption are relatively high. Provided that maternal iron status is adequate, term infants are born with a store of iron to supply their needs; only infants born with low birth weight need supplements before 6 months.

Milk nutrient composition can fluctuate based on the methods and circumstances in which the milk is expressed from the breast. For instance, hand expressed milk is higher in sodium, and a massaged and relaxed breast produces milk that is higher in fat. Breast milk ducts should be maximally stimulated, and milk let down mechanisms should reach max potential for adequate milk production. Infants who are fed on demand (i.e., feed and release at infant lead) typically empty about 63-72% of the breast milk storage capacity, which ensures a tight fit between milk production and infant appetite to obtain what they need for satisfactory growth.

Breast feeding also provides several benefits to restore pre-pregnancy condition, such as weight loss, reduction of uterine size, and prevention of pregnancy too soon.

8.4 Homework 1

Review

Which statement describing breast milk is false?

- A Colostrum is higher in protein antibodies
- B The primary carbohydrate is lactose
- C Fat is approximately 50% of the energy calories
- D Micronutrients are adequate regardless of maternal status

Explanation

Some micronutrients do fluctuate in concentration in the breast milk depending on maternal nutrient status or dietary intake

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8.4 Homework 2
Review

What is the heaviest newborn organ?

- A Skin
- B liver
- C Brain
- D Heart

Explanation

The brain is the heaviest newborn organ by more than three time the next nearest, skin

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8.5 Nutrient Status Measures during Pregnancy and Post-Natal Period

Section Objectives

- Highlight the major consequences of under and over nutrition in pregnancy
- Reinforce recognition of the critical nutrients for pregnancy

Learning Outcomes

- Recall appropriate pregnancy weight gain in each trimester
- Match nutrients with clinical deficiencies that can occur during pregnancy

A number of clinical assessments are used to measure intermediate pregnancy and lactation outcomes across all phases of the process. Routine prenatal assessments ensure that kidney and endocrine functions are healthy and that certain appropriate physiological adjustments are underway. In addition to regular biochemical analyses of urine and serum, a record of changing body weight is updated monthly. Lactation feedback is also provided as part of routine infant care.

Table 8.11. Rate of Appropriate Weight Gain in Trimesters 1-3

Excessive calorie intake and **excess weight gain** is related to increasing maternal health risks such as obesity, diabetes, dyslipidemia and cardiovascular disease. In addition to health risks, gestational weight gain beyond required amounts increases the risk of excess post-pregnancy weight retention. Weight gain during pregnancy outside the recommended range is also associated with increased risk to maternal and child health during initial and later stages of life.

While pregnancy is characterized by a mild state of hyperglycemia, excessive weight gain can lead to **gestational diabetes** (GD). GD is a condition that affects about 5-10% of all pregnancies in the US. Gestational diabetes usually appears in the second or third trimester and is clinically recognized as high blood glucose. Blood glucose concentrations must be tightly controlled to prevent adverse effects on the developing fetus and the mother herself. After delivery, glucose tolerance generally reverts to normal, but these mothers are at a much higher risk of developing type 2 diabetes, even after pre-pregnancy weight is restored.

Pregnancy-induced **hypertension** is classified as abnormally high blood pressure (>140/90 mm Hg) that typically develops after the twentieth week of pregnancy. Nearly 1 in 10 pregnancies in the US results in gestational hypertension. If hypertension is accompanied by organ damage and edema, the clinical condition, **pre-eclampsia**, is diagnosed. About 5% of women with preeclampsia progress to **eclampsia**, a significant cause of maternal death that is characterized by life-threatening seizures and increased risk of severe bleeding. Although the specific causes of preeclampsia are not known, several vitamin and mineral deficiencies have been correlated to the condition.

Low calcium status during pregnancy may influence the risk for **pregnancy-induced hypertension** and pre-eclampsia by stimulating the release of parathyroid hormone, thereby increasing intracellular calcium and vascular smooth muscle contractility. The increase in PTH may also stimulate the kidneys to release renin, which triggers vasoconstriction and sodium and fluid retention. Calcium supplementation during pregnancy at the daily intake (1,000 mg/day) is associated with lower risks of high blood pressure and preeclampsia. Inadequate vitamin B12 status and resulting elevated serum homocysteine concentrations are also associated with pre-eclampsia, as are intracellular deficiencies in riboflavin depended flavocoenzymes that are needed for nitric oxide release. Vitamin C deficiency may, through a different mechanism, similarly and is thus associated with the progression of

Several micronutrient deficiencies are also associated with **preterm labor**. Preterm labor is defined as regular contractions of the uterus resulting in changes in the cervix that start before 37 weeks of pregnancy. Changes in the cervix include effacement (i.e., thinning cervix) and dilation (i.e., opening cervix). **Iron deficiency anemia** during the first two trimesters of pregnancy increases the risk for preterm labor by as much as 400%. Elevated blood homocysteine concentrations, considered an indicator of functional vitamin B12 and folate deficiencies, have also been associated with increased risk of **premature delivery**, as have low zinc intakes (6mg/d or less) in gravid (i.e., zinc deficient) women. Preterm delivery is actually less common when maternal diet is adequate in calcium, magnesium and vitamin C. Without adequate levels of vitamin C, the membranes that support the growing pregnancy are more likely to prematurely rupture.

Figure 8.12 Newborn Apgar Scores

A number of **fetal measures** are taken at birth, including: appearance of the baby's skin color; his or her facial responses to stimulation; strength of the pulse and first cry; and the amount of activity in the baby's arms and legs. These measures are part of the **APGAR newborn scoring** system. The most familiar indicators of newborn health and vitality, however, are birth weight and height. Infants that are born weighing less than 2.5 kg (or 5.5 pounds) within one hour after birth, regardless of gestational age, are considered **low birth weight**. Birth weight <1,500 grams is considered a very low birth weight.

Birth Defects

Neural Tube Defects (NTD) are a devastating outcome of **low folate** intake during pregnancy. Low maternal serum folate levels, defined as less than 4 nmol/L, leads to megaloblastic marrow changes in mother and **neural tube defects** in fetus. NTDs occur between 21 to 27 days after conception; thus, maternal folate status during this period is critical. It can prevent devastating birth defects like anencephaly or spina bifida. Inadequate folate status may also be linked to other birth defects including, among others, cleft lip, cleft palate and limb malformations. Low serum levels of vitamin B12 during pregnancy have also been linked to NTD, a notion particularly important for vegans and vegetarians who supplement folate in early pregnancy. The fact that folate can mask vitamin B12 deficiency in routine clinical tests, is one another justification for including vitamin B12 in the prenatal supplement line up.

Iodine deficiency associated with pregnancy is widely considered as the most common cause of preventable **fetal brain damage** in the world. If the maternal diet is iodine-deficient, the size of her thyroid gland enlarges by about 25%. If inadequate production of thyroid hormone continues into week ten, irreversible damage to fetal brain tissues can occur. Severe maternal iodine deficiency is also associated with increased incidence of miscarriage and congenital hyperthyroidism — a condition that can lead to cretinism in one of two forms. The neurologic form of cretinism is characterized by mental and physical retardation and deafness; it results from maternal iodine deficiency that affects the fetus before its own thyroid is functional. The myxedematous or hypothyroid form of cretinism is characterized by short stature and mental retardation. Consuming supplemental iodine prior to conception and early in pregnancy before the tenth week of gestation effectively reduces rates of cretinism and improves neurocognitive outcomes. Iodine-deficient women who are **lactating** may not be able to provide sufficient iodine to their infants who are particularly vulnerable to the effects of iodine deficiency. Prenatal supplements and some multivitamin/mineral supplements on the market in the US do not contain iodine, presumably because manufacturers assume that women receive sufficient iodine through iodized salt and other food sources. However, a daily supplement providing 150 μg of iodine can help to ensure that US breast-feeding women consume sufficient iodine during these critical periods.

Population-based research provides evidence that problematic maternal metabolism may be associated with less apparent **neurodevelopmental problems** that present later on, including autism and other types of learning and social developmental delays. **Maternal vitamin B12** deficiency can also negatively affect infant growth and development during lactation. Vegan mothers who have untreated pernicious anemia from vitamin B12 deficiency may produce milk with inadequate B12 levels, which can impair fetal brain development and cause neurological problems. Vitamin B12 deficiency that results from pernicious anemia can easily be corrected with daily supplementation or with monthly intramuscular injections of the vitamin.

8.5 Homework 1
Review

A pregnant women with a healthy pre-pregnancy BMI should gain about ______________ pounds per week during the **third trimester**.

- **A** 1
- **B** 2
- **C** 3
- **D** 4

Explanation

A pregnant women with a healthy pre-pregnancy BMI should gain .4 pounds per week during the **third trimester**.

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