Infant Nutrition
(formula feeding of the term infant)

COMPETENCY: The resident should be able to identify the developmental changes relevant to infant feeding, know the indications for formula feeding, compare the nutritional content of various formulas with breast milk, understand the definitions of formula intolerance and milk protein allergy and their implications in infant nutrition, and understand the rationales for iron-fortification and the mineral content of infant formula.

CASE: A first-time mother and her term baby boy present to your clinic for a 2 week well-child check. She is planning on working and is not interested in breast feeding, despite education on this subject while she was in the hospital for her delivery. She is however, concerned about what formula will be the best for her baby and provide him with all the required nutrients he'll need to grow. She heard from a friend of hers that soy formula is best, especially if your baby spits up. She asks you to help her understand what nutritional needs her baby has and what would be best to feed him.

QUESTIONS:
1. What are the age-related changes in the ability to absorb and digest different nutrients relevant to infant feeding?
2. What are the indications for the use of infant formulas?
3. Do full-term infants have adequate iron stores? What are the rationales for using iron-fortified formulas and should low-iron formulas be used at all?
4. What is the nutritional adequacy of infant formulas relative to their mineral content? How do minerals contribute to the solute load of infant formulas?
5. What are the general fat, carbohydrate, protein content of infant formulas and how do they compare to breast milk?
6. What are the normal caloric requirements for an infant? What are normal protein requirements?
7. What is milk protein allergy and how does it relate to formula intolerance and lactose intolerance? What are the indications for special infant formulas?
8. What are the effects on development, if any, of long-chain polyunsaturated fatty acid supplementation in formula?

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CASE: A first-time mother and her term baby boy present to your clinic for a 2 week well-child check. She is planning on working and is not interested in breast feeding, despite education on this subject while she was in the hospital for her delivery. She is however, concerned about what formula will be the best for her baby and provide him with all the required nutrients he'll need to grow. She heard from a friend of hers that soy formula is best, especially if your baby spits up. She asks you to help her understand what nutritional needs her baby has and what would be best to feed him.

QUESTIONS:

1. What are the age-related changes in the ability to absorb and digest different nutrients relevant to infant feeding?

The following developmental changes are relevant to absorption and digestion in the neonatal/infant periods:

A. The suck develops after about 6mo gestational age and continues to evolve. Until at least 3mo of age, solid foods placed in the mouth are forced out by tongue movements, so infants this age will not tolerate solid foods well.

B. Gastric emptying times are faster in breastfed infants than in formula-fed infants (nearly 2 times as fast).

C. Salivary amylase increases earlier than pancreatic amylase; Breast milk contains it's own alpha-amylase to aid in carbohydrate digestion.

D. Lactase develops late in the fetal intestine. Even in term infants, some lactose makes it to the small intestine where it contributes to bacterial proliferation and in turn, promotes calcium and phosphorus absorption.

E. Breast milk lipase also helps fat absorption, and infants absorb more from breast milk than formula (although the difference disappears some by age 6mo).

The above developmental stages become important in determining the timing for introduction of solid foods. Solids should not be started until the infant can sit and coordinate chewing and swallowing. By 4-6 months of age the infant can digest and absorb nutrients sufficiently to tolerate cereals and pureed foods, and the kidney are developed enough to handle the increased

solute load that comes with solid foods. Of note breastfeeding and formula should be continued through the first year of life, even after the addition of solids.

2. What are the indications for the use of infant formulas?

The American Academy of Pediatrics recommends exclusive breastfeeding for the first 6 months of life and continuation of breast feeding for the second 6 months of life as the optimal nutrition for infants. However, there are certain indications for the use of infant formula.
The indications are as follows:

A. As substitute or supplement feedings for mothers who do not/cannot provide human milk for their infants

B. For infants who have certain inborn errors of metabolism or other conditions causing intolerance to human milk. Examples include galactosemia and tyrosinemia.

C. For infants whose mothers have certain infections caused by organisms known to be transmitted in human milk (HIV, and rarely CMV, HSV, some bacterial infections)

D. For infants whose mothers are undergoing cancer chemotherapy or taking certain other drugs, foods, medications, environmental agents that are excreted into human milk.

Additionally, formula supplementation should be considered if an infant fails to gain weight after appropriate encouragement and teaching for breastfeeding.

3. Do full-term neonates have adequate iron stores? What are the rationales for using iron-fortified formulas and should low-iron formulas be used at all?

In a term infant, iron stores are abundant at birth, therefore, until the age of 4-6months, iron-deficiency anemia is unlikely. While breast milk has lower concentrations of iron than formula (0.3mg/L compared to 12.2mg/L in iron fortified formulas) it is more bioavailable to the infant. AAP recommends iron supplementation for breastfed infants with 1mg/kg/d beginning at 4-6mo of age, typically in the form of iron-fortified cereal.

All iron-fortified formulas have >6.7mg/100kcal (4-12 mg/L) of iron. Studies have failed to show any correlation between iron-fortified formula and complaints such as constipation, colic, feeding intolerance. Therefore, the AAP recommends that only iron-fortified formula be used in exclusively formula fed infants.

Additionally, infants who are fed pasteurized cow-milk before the age of 12 months are at risk for depleting iron stores and developing iron-deficiency anemia because of low concentration and bioavailability of iron in cow milk and due to the possibility of intestinal blood loss. For this reason, along with the high renal solute load and limited amount of other essential vitamins and minerals, cow milk, goat milk, evaporated milk, or other non-formulated milks are not recommended before the age of 1 year. Goat milk has specific risks, in that infants who are fed goat milk exclusively are at risk for megaloblastic anemia secondary to folate deficiency.

4. What are the normal caloric requirements for an infant? What are normal protein requirements?

In general, infants require approximately 95-115 kcal/kg/day for the first six months of life. The total caloric requirement for a child is best estimated by body surface area. Of these calories, 8-12% should be protein, 30-50% fat, 40-60% carbohydrate. Formula intake should be ad lib with goal weight gain 25-30g/day for the first 3 months, 15-20g/d for the second 3 months, and 10-15g/d for the next six months.

It is also important to recognize that infants with a single nutritional source are at risk for nutritional deficiency if this source fails to provide adequate calories or nutritional requirements.

5. What is the nutritional adequacy of infant formulas relative to their mineral content?

Infant formulas have been standardized to contain adequate mineral and vitamin content to meet the nutritional needs of infants in the first year of life. The exception to this is fluoride, which should be supplemented in the infant diet after 6months of age (if the fluoride concentration in the water supply is less that 0.3 ppm).
(Please also refer to Table 1).

6. What are the general fat, carbohydrate, protein contents of infant formulas and how do they compare to breast milk?

Refer to Table 1 below for comparison of nutrient composition between common cow-milk-based formulas and breast milk. Of note, the whey:casein ratios differ between formulas and breast milk. In fact, the bovine whey-dominant formulas produce different amino acid patterns than the human whey proteins, but there is no evidence of any adverse effect from this different pattern. Also, the RDAs should be seen as starting points for estimating the caloric requirements in children.

Table 1 contains the most common brand formulas, however, it should be noted that generic formulas are held to the same standards of nutrient composition and vary little from the formulas seen in table 1. The Harriet Lane Handbook lists many generic formulas as well, with their main carbohydrate and electrolyte contents.

7. What is milk protein allergy and how does it relate to formula intolerance and lactose intolerance? What are the indications for special infant formulas?

Cow-milk protein allergy is an immuno-mediated (IgE) reaction to cow's milk proteins that may involve the gastro-intestinal tract, skin, respiratory tract, or multiple systems.[2] Its prevalence 2 to 3% in developed countries, (highest in infants and lowest in adults). Approximately 50 to 60% have cutaneous symptoms, 50 to 60% have gastrointestinal symptoms, and approximately 20 to 30% respiratory symptoms.[5] It can cause serious morbidity and mortality if unaddressed, however, dietary elimination of the offending protein is associated with good prognosis.

Symptoms typically begin between 4-6 weeks of age and are characterized by bloody stools, along with diarrhea and vomiting. Many infants with milk protein allergy may do well when fed soy formulas, however, it is important to note that soy milks may be allergenic in infants with IgE mediated reaction to cow-milk proteins. Phytate present in soy formulas decreases the absorption of substances such as iron, calcium, zinc, so minerals and vitamins are added to soy formulas in greater concentrations than cow-milk based formulas.
The AAP recommends soy formulas be used as follows:[6]

1. As a supplement to breast milk for infants whose nutritional needs are not met by breast milk alone.
2. Term infants with galactosemia or lactase deficiency.
3. Term infants with transient lactase deficiency (with reintroduction of cow-milk based formula after the symptoms improve).
4. Infants with IgE mediated allergy to cow milk protein (as most infants will tolerate soy based formulas)
5. As a vegetarian based diet for an infant.

They should not be used as follows:[6]

1. For preterm infants (BW<1800g)
2. Prevention of colic or allergy
3. Infants with cow milk protein-induced enterocolitis or enteropathy.

Another alternative formula for infants with cow-milk protein allergy is protein hydrolysate formula. The protein in these formulas has been hydrolyzed so that the peptides are much less likely to induce an immuno-response. They are indicated for milk protein allergy as well as for infants with malabsorption secondary to significant gastrointestinal or hepatobiliary disease (CF, short gut, etc).

Cow-milk protein allergy is a type of formula intolerance. However, formula intolerance also refers to non-immunologic reactions to cow's milk, including disorders of digestion, absorption, or metabolism of cow milk components.[2] Formula intolerance can involve symptoms such as loose stools, spitting up, vomiting, irritability, gaseousness. The most common cause of cow-milk intolerance is lactase deficiency, which is mostly acquired during late childhood or adulthood—the incidence of congenital lactase deficiency is rare. Some infants may present with post-diarrheal lactose intolerance and there are some advocates for short term use of soy or lactose free formulas in this case. (All the cow-milk based formulas contain lactose, while all the special formulas [soy, lactose-free, and protein hydrolysate] are lactose free). However, it is recommended to re-challenge these infants with cow-milk based formula as it is likely a transient phenomenon.

8. What are the effects on development, if any, of long-chain polyunsaturated fatty acid supplementation in formula?

There has been significant debate, over the past decade, as to the benefits of the addition of polyunsaturated fatty acids (DHA/ARA) to infant formulas. The most recent evidence suggests that there are no adverse effects of the additives, and that they support visual and cognitive development. A randomized-controlled trial showed no difference between the formulas with DHA and/or ARA added and breast fed groups: no adverse effects, nor any beneficial effects when comparing visual, cognitive, and language assessments[8]. The groups also did not differ in

weight, length, or head circumference. This data follows infants out for the longest period of time.

TABLE 1. Human Milk and Commerical Formulas for Term Infants

NUTRIENT COMPOSITION PER LITER					
	RDA 0 TO 12 MO	**HUMAN MILK**	**ENFAMIL WITH IRON**	**SIMILAC WITH IRON**	**CARNATION GOOD START**
Energy (kcal)	98-108 kcal/kg	680	676	676	676
Protein (g)	13-14	10.5	114.2	14.0	16.2
Source					
Whey (% total)		70	60	18	100
Casein (% total)		30	40	82	0
Fat (g)		30	35.8	36.5	34.5
Source					
Polyunsaturated (%)		14	29	37	32
		42	16	17	26
Monounsaturated (%)		44	55	46	43
Saturated (%)		Human milk fat	Palm olein, soy, coconut, sunflower	Soy, coconut, safflower	Palm olein, soy, coconut, safflower
Predominant oil					
Carbohydrate (g)					
Source					
Lactose		73	74	73	74
Minerals					
Calcium (mg)	400-600	280	528	527	433
Phosphorus (mg)	300-500	140	358	284	243
Magnesium (mg)	40-60	35	54	41	45
Iron (mg)	6-10	0.3	12.2	12.2	10.1
Zinc (mg)	5.0	1.2	6.8	5.1	5.1
Copper (mcg)	400-700	252	507	610	541
Iodine (mcg)	40-50	110	68	41	54
Sodium (mEq)	5-9	8	8	8	7
Potassium (mEq)	13-18	14	19	18	17
Chloride (mEq)	5-9	12	12	12	11
Renal solute load (mOsm)		91	131	127	136
Osmolality (mOsm/kg H20)		286	300	300	265
Fat-soluble Vitamins					
A (IU)	1240	2230	2027	2027	2027
D (IU)	300-400	21	405	405	405

E (IU)	3-4	3	14	20	14
K (mcg)	5-10	2	54	54	55

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