



## **The Choline Connection**

A Healthcare Professional's Guide  
to Choline, Fetal Development,  
Maternal Health & More



## Presentation Overview

- Discuss Function & Benefits of Choline
- Highlight Dietary Sources & Recommended Intake of Choline
- Discuss Current & Emerging Choline Research
- Call to Action



## Learning Objectives

- Define the health benefits of choline
- Discuss the role of choline in fetal and early childhood development
- Understand areas of emerging choline research and the interaction between choline and homocysteine
- Identify dietary sources of choline



# Choline: An Overview

- Choline is an **essential** nutrient
- Functions
  - Strengthens cell membranes
  - Aids in memory development and cognition
  - Needed for proper fetal brain development
  - Maintains normal maternal homocysteine levels
  - Decreases the incidence of neural tube defects
  - Needed to make acetylcholine, a major neurotransmitter
  - Precursor for sphingomyelin, an essential element of cell membranes



**Choline needs increase during pregnancy and again during lactation**

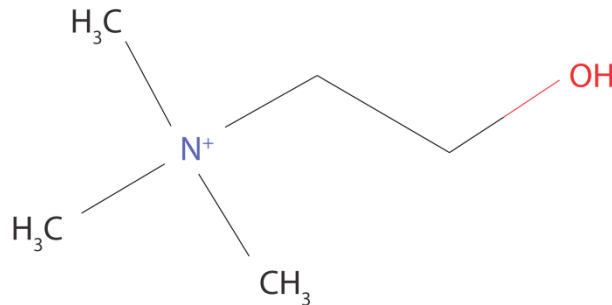


## Historical Information

- Choline was discovered in 1862 by Andreas Strecker
- In 1998 the Food and Nutrition Board of the Institute of Medicine evaluated numerous research studies about choline to set Dietary Reference Intakes (DRIs)
- Choline was recognized as an **essential** nutrient and Adequate Intake (AI) levels were established

Source: Dietary Reference Intakes, Institute of Medicine of the National Academies, National Academies Press, Washington, DC, 2006.

# Biochemical Structure



Chemical Structure of Choline

- Choline is a natural amine found as free choline and in lipids of cell membranes
- Choline is classified as a water-soluble nutrient and is usually grouped within the vitamin B complex
- There is a relationship between folate and choline metabolism in the liver



## Mechanism of Action

- Choline and folate provide methyl groups for the conversion of homocysteine in the synthesis of the amino acid methionine
- When choline is deficient in the diet, folate metabolism is disturbed

When folate is deficient in the diet, choline becomes a limiting nutrient



# Why is Choline Essential?

- Choline is a basic cell building block that:
  - is necessary for production of the phospholipids
  - is used to make acetylcholine, a neurotransmitter
  - is used to make lipoproteins, which shuttle nutrients around the body
- Choline is necessary for fetal and infant brain development
  - Maternal choline becomes depleted when fetal demand increases
  - Choline is vital to the proper development of the brain and spinal cord
  - Choline aids in memory development and cognition
  - Choline intake is critical up to the age of four in humans as the brain develops new cells





# Why is Choline Essential?

- Choline is necessary for maintaining normal maternal homocysteine levels
  - Choline deficiency results in elevated serum homocysteine
- Choline helps decrease the incidence of neural tube defects
  - Insufficient choline intake during pregnancy is associated with a four-fold increase in the risk of neural tube defects such as spina bifida
  - Higher levels of total blood choline are associated with a 2.5-fold reduction in risk for neural tube birth defects.



#### Sources:

Zeisel SH. Choline: Needed for normal development of memory. *JACN* 2000;19 (5): 528S-531S.

Shaw GM, et al. Choline and risk of neural tube defects in a folate-fortified population, *Am J Epidemiol* 2009; 20:714-719.



# Beyond Fetal Development

- Emerging research demonstrates benefits of choline beyond fetal development
  - Optimal Memory Function
  - Reduced Breast Cancer Risk
  - Improved Cardiovascular Health



## Choline & Memory Function

- Animal model studies have shown that choline availability during embryogenesis and prenatal development is important for long-term memory
- Normal age-associated memory decline in rat offspring is lessened when the dam (mother rat) receives choline supplementation during pregnancy



Source: Zeisel SH, et al. Choline dietary requirements and role in brain development. *Nutr Today* 2007, 42; 4




# Choline and Breast Cancer

- Research funded by the National Institutes of Health found that higher levels of choline consumption were associated with a 24% reduction in breast cancer risk
- Results are consistent with two previous National Institutes of Health funded studies which showed that egg consumption was associated with a reduced risk of breast cancer



Source: Xu X. Choline metabolism and risk of breast cancer in a population-based study. *FASEB*, 2008; 22:1-8.



# Choline & Cardiovascular Health

- Elevated plasma homocysteine is a known risk factor for cardiovascular disease
  - High dietary choline and betaine consumption are related to lower plasma homocysteine concentrations
  - Betaine is a metabolite of choline and, like choline, it is involved in the methylation of homocysteine to methionine.
- Individuals who consume the highest amounts of choline and betaine have significant decreases in cardiovascular disease biomarkers: plasma concentrations of C-reactive protein, interleukin-6 and tumor necrosis factor-alpha



Source: Detopoulou P et al. Dietary choline and betaine intakes in relation to concentrations of inflammatory markers in healthy adults: the ATTICA study. *Am J Clin Nutr*, 2008;87:424–430.



# Recommended Intake

Adequate Intake (AI) levels for choline set by the Institute of Medicine:

| Life Stage   | Adequate Intake (mg)                               |
|--|--|
| Infants:<br>(0-6 months)<br>(7-12 months)                | 125 milligrams<br>150 milligrams                   |
| Children:<br>(1-3 years)<br>(4 -8 years)<br>(9-13 years) | 200 milligrams<br>250 milligrams<br>375 milligrams |
| Adolescents:<br>(14-18 years)                            | 400 milligrams (Female)<br>550 milligrams (Male)   |
| Adults:<br>(19 and older)                                | 425 milligrams (Female)<br>550 milligrams (Male)   |
| Pregnant women   | 450 milligrams                                     |
| Breastfeeding women                                      | 550 milligrams                                     |

Source: Dietary Reference Intakes, Institute of Medicine of the National Academies, National Academies Press, Washington, DC, 2006.



# Choline: Low Awareness Among Consumers

**Three out of four** moms are not at all familiar with the benefits of choline

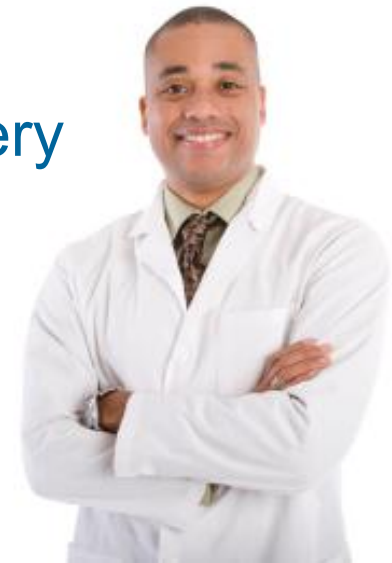
- Research shows that **only 1 out of 10** Americans are meeting Adequate Intake (AI) guidelines for choline
- **78 percent** of mothers do not know the food sources of choline



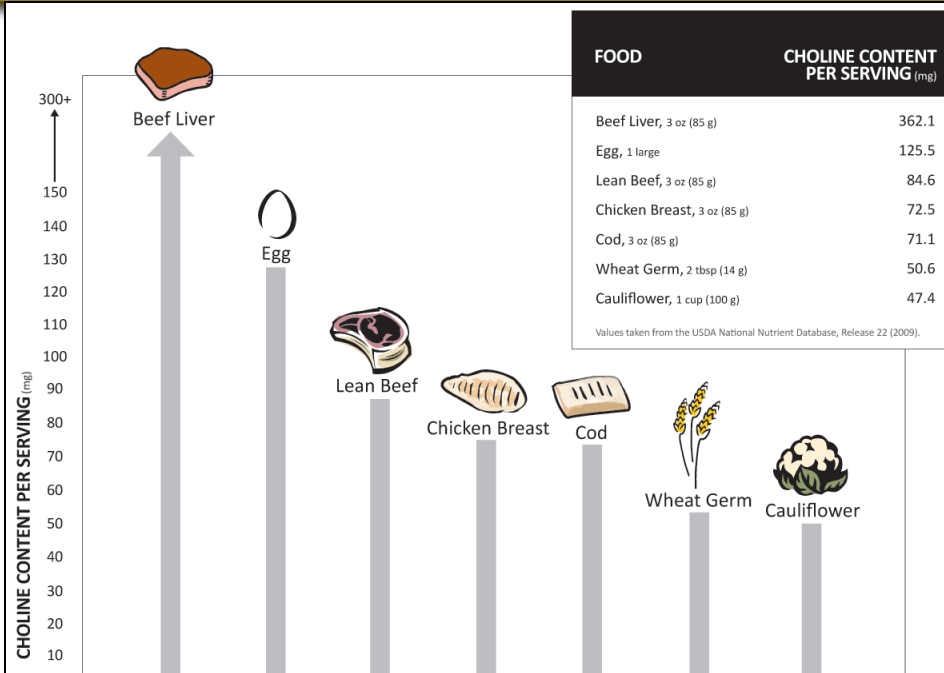


## Choline: Low Awareness Among Health Professionals

- Health professional awareness of choline is low
  - Familiarity with choline ranks behind other vitamins & minerals
  - Only **6 percent** of OB/GYNs are “very likely” to recommend choline to pregnant women



# Dietary Sources of Choline



In 2001, the Food and Drug Administration (FDA) allowed a nutrient content claim on labels of foods that meet the following criteria to be termed "good" or "excellent" sources of choline:

**Excellent**  
source of choline

Must contain at least 110 mg of choline per serving, (20% of the Daily Value for choline based on 550 mg reference).

**Good**  
source of choline

Must contain at least 55 mg of choline per serving, (10% of the Daily Value for choline based on 550 mg reference).



## Sources of Dietary Choline

- An excellent source of choline provides 20 percent or more of the recommended amount of choline per serving
  - Beef liver\*, chicken liver\* and eggs are excellent sources of choline, providing 20% or more of the Daily Value for choline
  - Other good food sources of choline include lean beef, chicken breast, cod, wheat germ and cauliflower.
- Choline-rich foods are the best source of choline
- Most prenatal vitamins and regular multivitamins do not contain choline
- Baby formulas made from soy have less choline than breast milk or bovine-derived formulas

\*The March of Dimes recommends that pregnant women minimize their intake of liver due to its excessive vitamin A levels.



## Choline & Eggs

- Eggs are an excellent source of choline
- The choline in eggs is found in the yolk
- One egg – including the yolk – contains 126 milligrams of choline, or roughly one-quarter of the recommended daily amount
- Eggs are also a source of high-quality protein – which has been associated with improved birth weight – and other essential nutrients
- Eggs are nutritious, delicious, convenient and affordable.





## Key Takeaway

- Choline is an **essential** nutrient that is needed by individuals of all ages for optimal health.





## Key Takeaway

- Choline is especially important for pregnant and breastfeeding moms for proper fetal brain development
  - For women whose diets are deficient in choline, the risk of having a pregnancy affected by neural tube defects increases four-fold





## Key Takeaway

- Choline is widely unknown and chronically under consumed. It is simple to get the recommended amount of choline in the diet by:
  - Enjoying eggs for breakfast
  - Eating vegetables such as broccoli and cauliflower
  - Enjoying beef as part of a balanced diet
  - Keeping hard-cooked eggs on hand as a simple, nutrient-rich snack



## Call to Action

- Stay informed about the latest choline research by regularly visiting the Research Library on [www.cholineinfo.org](http://www.cholineinfo.org)
- Include choline in guidance for pregnant and breastfeeding patients
- Encourage patients to increase choline intake through easy, affordable meals and snacks such as eggs
  - Distribute patient education materials available at [www.cholineinfo.org](http://www.cholineinfo.org)

**Choline**  
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**Thank You!**