

# SP.235 - Chemistry of Sports

**Week 4-Wednesday February 28th, 2007**

## Nutrition

- fueling you body
- picking the best training food, calories
- How to determine how much you need to eat each day

## Readings for this week

- Fats and carbohydrates for exercise (Burke and Hawley, 2006)
  - Protein requirements for athletes (Tipton and Witard, 2007)
- Optional reading:
- Vegetarian diets for athletes (Venderley and Campbell, 2007)
  - Nutritional and functional characteristics of whey proteins (de Wit, 1998)
  - Fluid and Electrolyte balance in ultra-Endurance Sport (Rehrer, 2001)

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## Why do we eat?

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## Why do we eat?

- To provide the energy to our body to carry out chemical reactions
  - carbohydrates in enable us to convert the stored chemical energy into ATP
  - We then use the ATP for anabolic reactions (for instance synthesizing proteins from amino acids)

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## Energy Requirements

- A calorie is the amount of heat necessary to raise the temperature of 1 gram of water 1 °C.
- We use a kilocalorie (kcal) as a unit of measure (1 kcal = 1000 calories) and nutritionists refer to it as the Calorie (Cal)
- Scientists have to be different, 1 joule = 0.239 calories

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## Metabolic rate

- Is a measure of the overall energy needs that must be met by the animals ingestion and digestion of food
- The way to determine your basal metabolic rate is to use the Harris-Benedict formula

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## Harris-Benedict formula

- The Harris Benedict equation is a calorie formula using the factors of height, weight, age, and sex to determine basal metabolic rate (BMR). This makes it more accurate than determining calorie needs based on total bodyweight alone. The only variable it does not take into consideration is lean body mass. Therefore, this equation will be very accurate in all but the extremely muscular (will underestimate caloric needs) and the extremely overfat (will overestimate caloric needs).

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## Harris-Benedict formula

- Men:  $BMR = 66 + (13.7 \times \text{wt in kg}) + (5 \times \text{ht in cm}) - (6.8 \times \text{age in years})$
- Women:  $BMR = 655 + (9.6 \times \text{wt in kg}) + (1.8 \times \text{ht in cm}) - (4.7 \times \text{age in years})$
- Note: 1 inch = 2.54 cm.
- 1 kilogram = 2.2 lbs.

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## Harris-Benedict formula

- Women:  $BMR = 655 + (9.6 \times \text{wt in kg}) + (1.8 \times \text{ht in cm}) - (4.7 \times \text{age in years})$
- Example:
- You are female
- You are 30 yrs old
- You are 5' 6 " tall (167.6 cm)
- You weigh 120 lbs. (54.5 kilos)
- Your BMR =  $655 + 523 + 302 - 141 = 1339$  calories/day

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## Harris-Benedict formula

- Let us calculate our BMR:
- Men:  $BMR = 66 + (13.7 \times \text{wt in kg}) + (5 \times \text{ht in cm}) - (6.8 \times \text{age in years})$
- Women:  $BMR = 655 + (9.6 \times \text{wt in kg}) + (1.8 \times \text{ht in cm}) - (4.7 \times \text{age in years})$
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## BMR modifiers

- Now that you know your BMR, you can calculate total daily energy expenditure (TDEE) by multiplying your BMR by your activity multiplier from the chart below:
- Activity Multiplier
- Sedentary = BMR X 1.2 (little or no exercise, desk job)
- Lightly active = BMR X 1.375 (light exercise/sports 1-3 days/wk)
- Moderately active = BMR X 1.55 (moderate exercise/sports 3-5 days/wk)
- Very active = BMR X 1.725 (hard exercise/sports 6-7 days/wk)
- Extremely active = BMR X 1.9 (hard daily exercise/sports & physical job or 2X day training, i.e marathon, contest etc.)

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## What does this value mean?

- Energy in (food) = energy out - weight stays the same
- Energy in < energy out - lose weight
- Energy in > energy out - gain weight
- You need to make sure you are eating the correct number of calories to fit into the category you want to

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# Food energy and how we use it

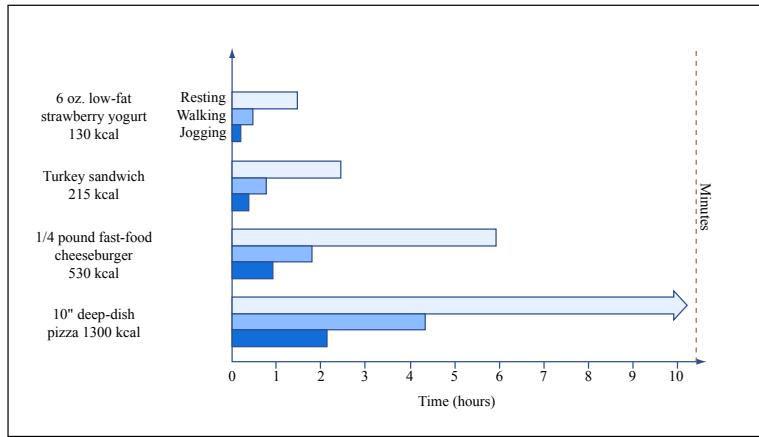


Figure by MIT OCW.

## A balanced diet

- Carbohydrates - 45 - 65 %
- Fats -20-35 %
- Proteins -10 - 35 %

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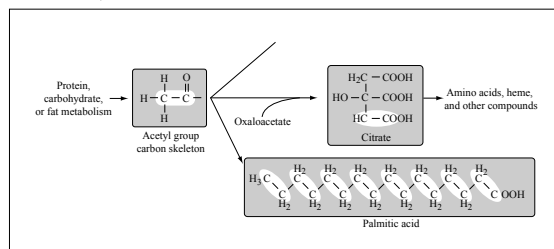
## Essential amino acids

- These are the amino acids that can not be synthesized by the body
- In humans there are 8 amino acids - isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.
- All available in milk, eggs, meat and soybean products (but most plan foods do not contain all eight)

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## Fats

- Humans can synthesize almost all of the lipds required by the body using acetyl groups obtained form food except linoleic acid
- Linoleic acid is an unsaturated fatty acid need to serve as a starting material for the synthesis of other unsaturated fatty acids (for instance arachidonic acid, which is a component of several signaling molecules including prostaglandins)



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Figure by MIT OCW.

## Energy storage in the body

- Carbohydrates are stored in liver and muscle cells as glycogen but the total glycogen store represents only about a days' basal energy requirements (1,500 - 2,000 Cal)

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## Energy storage in the body

- Fats is the most important form of stored energy in the bodies of animals
- Fat has more energy per gram than glycogen and since it is stored with little associated water, it is more compact

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## Energy storage in the body

- Proteins are not used as energy storage compounds, although body protein can be metabolized as an energy source of last resort

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## What happens if you are undernourished

- The body makes up the shortfall by metabolizing some of the molecules of its own body
- The consumption of self beings with the energy storage compounds of glycogen and fat
- Protein loss is minimized for as long as possible, but eventually a starving animal begins to break down its own proteins for fuel

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## Metabolizing self

- Blood proteins are among the first to be used, resulting in loss of fluid to the intercellular spaces (edema)
- Additional consequences of protein deficiency are breakdown of the immune system and degeneration of the liver
- Muscles waste away and eventually even brain protein is lost, leading to mental retardation
- If starvation continues, the breakdown of body proteins eventually leads to death.

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## Overnourished

- Excess nutrients are stored as increased body mass
- First, glycogen reserves are built up
- Then additional dietary carbohydrates, fats and proteins are converted to body fat.

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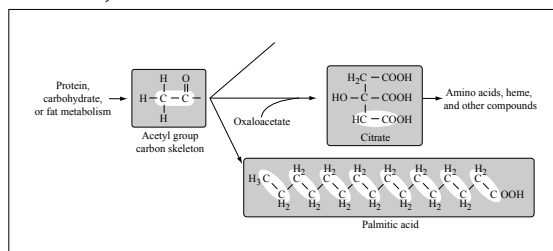


Figure by MIT OCW.

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## Mineral elements

- **Macronutrients** - elements required in large amounts
- **Micronutrients** - elements only required in tiny amounts

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## Macronutrients

Mineral Elements Required by Animals (Part 1)		
Element	Source in Human Diet	Major Functions
<i>MACRONUTRIENTS</i>		
Calcium (Ca)	Dairy foods, eggs, green leafy vegetables, whole grains, legumes, nuts	Found in bones and teeth; blood clotting; nerve and muscle action; enzyme activation
Chlorine (Cl)	Table salt (NaCl), meat, eggs, vegetables, dairy foods	Water balance; digestion (as HCl); principal negative ion in tissue fluid
Magnesium (Mg)	Green vegetables, meat, whole grains, nuts, milk, legumes	Required by many enzymes; found in bones and teeth
Phosphorus (P)	Dairy, eggs, meat, whole grains, legumes, nuts	Found in nucleic acids, ATP, and phospholipids; bone formation; buffers; metabolism of sugars
Potassium (K)	Meat, whole grains, fruits, vegetables	Nerve and muscle action; protein, synthesis; principal positive ion in cells
Sodium (Na)	Table salt, dairy foods, meat, eggs, vegetables	Nerve and muscle action; water balance; principal positive ion in tissue fluid
Sulfur (S)	Meat, eggs, dairy foods, nuts, legumes	Found in proteins and coenzymes; detoxification of harmful substances

Figure by MIT OCW.

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# Micronutrients

Mineral Elements Required by Animals (Part 2)		
Element	Source in Human Diet	Major Functions
<i>MICRONUTRIENTS</i>		
Chromium (Cr)	Meat, dairy, whole grains, legumes, yeast	Glucose metabolism
Cobalt (Co)	Meat, tap water	Found in vitamin B <sub>12</sub> ; formation of red blood cells
Copper (Cu)	Liver, meat, fish, shellfish, legumes, whole grains, nuts	Found in active site of many redox enzymes and electron carriers; production of hemoglobin, bone formation
Fluorine (F)	Most water supplies	Found in teeth; helps prevent decay
Iodine (I)	Fish, shellfish, iodized salt	Found in thyroid hormones
Iron (Fe)	Liver, meat, green vegetables, eggs, whole grains, legumes, nuts	Found in active sites of many redox enzymes and electron carriers, hemoglobin, and myoglobin
Manganese (Mn)	Organ meats, whole grains, legumes, nuts, tea, coffee	Activates many enzymes
Molybdenum (Mo)	Organ meats, dairy, whole grains, green vegetables, legumes	Found in some enzymes
Selenium (Se)	Meat, seafood, whole grains, eggs, milk, garlic	Fat Metabolism
Zinc (Zn)	Liver, fish, shellfish, and many other foods	Found in some enzymes and some transcription factors; insulin physiology

Figure by MIT OCW.

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# Vitamins

- Essential nutrients
- Carbon compounds required for normal growth and metabolism, but cannot synthesize for itself (except for vitamin D)
- Function as coenzymes or parts of coenzymes
- Required in very small amounts

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## Vitamins in the Human diet

Vitamins in the Human Diet (Part 1)			
Vitamin	Source	Function	Deficiency Symptoms
<i>WATER-SOLUBLE</i>			
B <sub>1</sub> , thiamin	Liver, legumes, whole grains,	Coenzyme in cellular respiration	Beriberi, loss of appetite, fatigue
B <sub>2</sub> , riboflavin	Dairy, meat, eggs, green leafy vegetables	Coenzyme in FAD	Lesions in corners of mouth, eye irritation, skin disorders
Niacin	Meat, fowl, liver, yeast	Coenzyme in NAD and NADP	Pellagra, skin disorders, diarrhea, mental disorders
B <sub>6</sub> , pyridoxine	Liver, whole grains, dairy foods	Coenzyme in amino acid metabolism	Anemia, slow growth, skin problems, convulsions
Pantothenic acid	Liver, eggs, yeast	Found in acetyl CoA	Adrenal problems, reproductive problems
Biotin	Liver, yeast, bacteria in gut	Found in coenzymes	Skin problems, loss of hair
B <sub>12</sub> , cobalamin	Liver, meat, dairy foods, eggs	Formation of nucleic acids, proteins, and red blood cells	Pernicious anemia
Folic acid	Vegetables, eggs, liver, whole grains	Coenzyme in formation of heme and nucleotides	Anemia
C, ascorbic acid	Citrus fruits, tomatoes, potatoes	Formation of connective tissues; antioxidant	Scurvy; slow healing, poor bone growth

Figure by MIT OCW.

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## Vitamins in the Human diet

Vitamins in the Human Diet (Part 2)			
Vitamin	Source	Function	Deficiency Symptoms
<i>EAT-SOLUBLE</i>			
A, retinol	Fruits, vegetables, liver, dairy	Found in visual pigments	Night Blindness
D, calciferol	Fortified milk, fish oils, sunshine	Absorption Ca <sup>2+</sup> and phosphate	Rickets
E, tocopherol	Meat, dairy foods, whole grains	Muscle maintenance, antioxidant	Anemia
K, menadione	Intestinal bacteria, liver	Blood clotting	Blood-clotting problems

Figure by MIT OCW.

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# Human digestive tract

Different compartments within the long tubular gut specialize in digesting food, absorbing nutrients and storing and expelling wastes. Accessory organs contribute secretions containing enzymes and other molecules

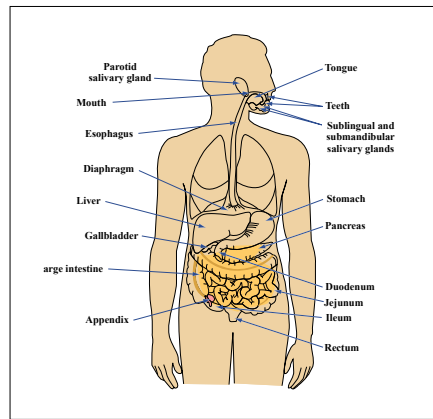


Figure by MIT OCW.

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## Chemical digestion

- Digestion starts in the mouth with the enzyme amylase
- Pepsin starts to degrade the peptide bond in proteins
- In the small intestine, the digestion of carbohydrates and proteins continues and the absorption of fats and nutrients begin

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## Digestion of Fats

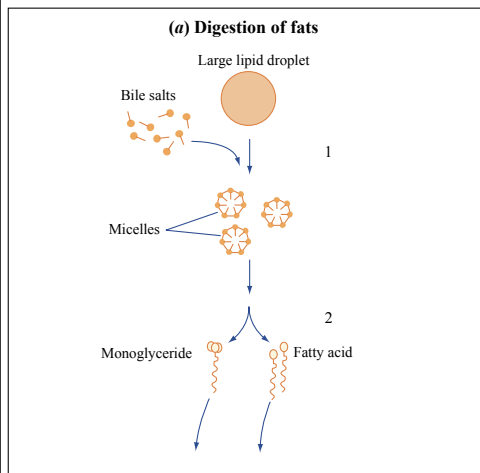


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1. Dietary fats are emulsified into tiny droplets called micelles through the action of bile salts in the intestinal lumen
2. Pancreatic lipase hydrolyzes fats in the micelles to produce fatty acids and monoglycerides

## Digestion of fats part 2

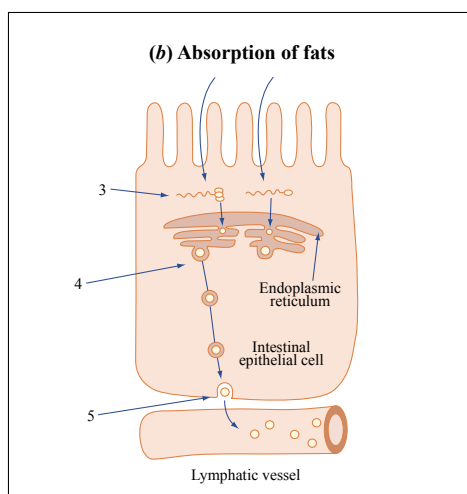


Figure by MIT OCW.

3. Fatty acids and monoglycerides are lipid-soluble and readily dissolve in the plasma membrane and enter the cell, where they are resynthesized into triglycerides.
4. Triglycerides are packaged with cholesterol and phospholipids to form protein-coated chylomicrons (water soluble)
5. Chylomicrons are enclosed in vesicles and leave the cell by exocytosis

## Fate of carbs and proteins

- Final digestion of proteins and carbohydrates takes place among the microvilli of the small intestine
- Mucosal cells produce peptidases which will cleave the polypeptides
- Mucosal cells also produce maltase, lactase and sucrase which cleaves these disaccharides into monosaccharides glucose, galactose and fructose

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## Lactase

- Many humans stop producing the enzyme lactase around the age of 4 years and have difficulty digesting lactose (sugar in milk) in glucose and galactose
- If a substantial amount of lactose remains unabsorbed and passes into the large intestine, its metabolism by bacteria in the large intestine causes abdominal cramps, gas and diarrhea

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## The role of Sodium

- Sodium will diffuse from the gut into the cells lining the gut (mucosal cells) and then is actively transported (using ATP) into the submucosal
- Sodium then diffuses back to the mucosal cells bound to nutrient molecule (for instance glucose). This is called sodium cotransport.

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## The final stop

- Water and ions are absorbed in the large intestine (or colon)
- Bacteria live in the colon and helps its human hosts by producing vitamin K and biotin.
- These bacteria are anaerobic and their metabolic by-products are methane and hydrogen sulfide (flatulence).
- Large percentage of the mass of feces consists of the cell walls of dead intestinal bacteria

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## Next week

- Fuel metabolism

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## The Ironman diet

- Steve Lyons will talk to us about his food intake to survive the Ironman

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