

## Nutrition and Adaptation

## Nutritional Requirements

- As with all heterotrophs, we have to ingest foods to provide several different categories of nutrients:
  - Energy
  - Protein, Lipids, and Carbohydrates
  - Vitamins
  - Minerals
  - Trace Elements

## Nutritional Requirements

- However, unlike other heterotrophs, *Homo sapiens* does not feed, he dines
  - We imbue our eating with social and symbolic significance
  - Meals are family and social affairs
    - Solidify alliances, incur indebtedness
  - Many foods have special meaning
    - Totems, taboos, preferences, health

## Energy

- We require energy from our foods to support the maintenance of our body and our activities
  - Basal Metabolic Rate (BMR) is the energy expended by an individual who is reclining in a thermoneutral state, at least 12 hours post-prandial
  - Activity energy requirements are defined by the physical activity performed by the individual

## Energy, 2

- BMR requirements are affected by many variables
  - Body size and composition
  - Sex
  - Age
  - Climate
  - Pregnancy and Lactation
  - Growth

## Energy, 3

- Activity requirements are also influenced by personal variation
  - Body size and composition
  - Climate
  - Intensity and duration of activity

## Energy, 4

Cost above BMR (kcal/kg/hr)	Example of Activity
0.00	Lying still, thermoneutral
0.25	Sitting quietly
0.50	Standing at ease
1.00	Sitting and sewing or weaving
1.50	Upright, light work like sweeping
2.50	Walking 4.8 km/hr, no load
3.50	Walking 4.8 km/hr, 15 kg load
4.50	Hoeing, ploughing
7.00	Tree felling, chopping
10.00	Near maximum exertion

## Energy, 5

- Dietary sources of energy (calories)
  - Carbohydrates about 4 kcal/gm
  - Ethanol about 7 kcal/gm
  - Protein about 4 kcal/gm
  - Fats about 9 kcal/gm

## Protein

- Required amino acids
  - Nine that we don't synthesize
  - Three more that premature neonates require
  - Timing of ingestion is critical for protein synthesis
- Non-specific nitrogen
- Gluconeogenesis

## Protein, 2

- Requirements difficult to determine in adults because of turnover in body
  - Lower the intake, the more efficient the body becomes at supplying need
- Critical needs:
  - Normal growth
  - Pregnancy, lactation
  - Healing from trauma, illness

## PEM Malnutrition

- This is a continuum from extreme protein undernutrition to extreme calorie malnutrition and combinations of the two
- Kwashiorkor: primarily protein malnutrition
  - Caloric intake may be adequate
- Marasmus: primarily caloric insufficiency
  - Protein intake may be adequate for size



**Kwashiorkor.** This child exhibits thin limbs and a swollen belly, classic symptoms of kwashiorkor, severe protein deficiency. This child, although looking like an infant is probably 3-4 years old. Kwashiorkor is an African word meaning "red boy" referring to the thin, light-colored, reddish hair. Although superficially looking fat, this is a form of malnutrition. At this stage, over all health and mental development can be impaired.

**Extreme wasting in marasmus.** This affects all body tissues and the marked loss of subcutaneous fat and skeletal muscle results in a skin and bone appearance. Body weight may be reduced to only 40% or so of the normal mean for age. The prognosis is especially grave in those cases with 50% or more loss of body weight.



### Early PEM in childhood

**Growth failure:** The children in this picture were aged 2, 4 1/2 and 5 1/2 years from left to right. The first two are normal but the last is grossly retarded in growth although the weight/height ratio is normal and there is no evidence of clinical malnutrition. Stunting is the commonest evidence of chronic, mild PEM.

## Carbohydrates

- Glucose is most important form for storage, transportation, utilization in the body
  - Efficient formation of ATP for cellular work
  - Active transport into peripheral cells requires insulin
    - Defects in this transport can produce diabetes
- No specific minimum intake, but we have evolved from fruit eaters and our bodies expect substantial intake of carbohydrates

## Lipids

- Important source of energy
- Should comprise less than 30% of total caloric intake
  - Saturated versus unsaturated; trans fat
- Essential fatty acids:  $\omega$ -3 and  $\omega$ -6
  - $\omega$ -3 fatty acids show a CVD protective effect
    - Available from fatty fish: eicosapentaenoic acid and docosahexaenoic acid; tofu and other plant foods contain alpha-linolenic acid which can convert into an  $\omega$ -3 in the body
      - Decrease risk of arrhythmias, which can lead to sudden cardiac death
      - Decrease triglyceride levels
      - Decrease growth rate of atherosclerotic plaque
      - Lower blood pressure (slightly)
  - $\omega$ -6 (linoleic acid): necessary for fatty acid metabolism

## Micronutrients

- Vitamins function as enzymes and coenzymes in various metabolic processes, and support diverse other bodily activities
- Minerals: Serve as structural elements and co-factors of bone, tooth, muscle, connective tissue, receptor site, binding sites

## Vitamins

- Vitamins are nutritional requirements either because we lack the ability to synthesize them, or we fail to synthesize them in sufficient quantity for normal metabolism
- Vitamins fall into two broad categories depending on intrinsic chemical properties
  - Water soluble: B complex, C
  - Fat soluble: A, D, E, K

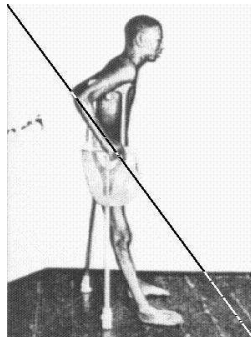
## Vitamins

- Water soluble vitamins are present in all body fluids, and are subject to normal excretion
  - Storage is minimal, and daily or near daily intake is necessary to prevent deficiency conditions
- Fat soluble vitamins form lipoprotein complexes and can be stored by the body
  - Excesses are only slowly metabolized out and excreted

## B-1 or Thiamin

- Sources: Pork, organs, whole grains, legumes
- Functions: Oxidative decarboxylation of ketones for TCA cycle. Coenzyme in reactions removing CO<sub>2</sub> in Pentose Phosphate shunt
- Deficiency: Beriberi with symptoms of peripheral nerve changes, edema, heart failure
- Excess: Not Reported
- Polished Rice Disease: *Shipboard beriberi* known from Japanese navy--addition of meat to normal rice ration reduced occurrence

## Individual with Beriberi



## B-2 or Riboflavin

- Sources: Dairy, meat, fish, cereals
- Functions: Coenzyme in energy metabolism (electron transport system), aiding in synthesis of ATP
- Deficiency: Reddened lips, cracks at mouth corner (cheilosis) eye lesions
- Excess: Not reported
- Requirement increases with increasing caloric intake.



Cheilosis

## Niacin

- Sources: Liver, grains, legumes
- Functions: Hydrogen acceptor as Nicotinamide Adenine Phosphate (NAP and NADP)
- Deficiency: Pellagra (skin, g.i. lesions, nervous, mental disorder)
- Excess: Flushing, burning, tingling around neck, face, hands
- Synthesized from tryptophan
  - Lime processing in maize is necessary to breakdown glutelin, make tryptophan available

## Patient with Pellagra

- Patient also had diarrhea and mental changes



## B-6 or Pyridoxine

- Sources: Meats, vegetables, whole grains
- Functions: Coenzyme in amino acid metabolism
- Deficiency: Convulsions, skin rash, anemia
- Excess: Not reported
- Requirement increases with increasing protein intake

## Pantothenic Acid

- Sources: Liver, yeast, whole grains
- Functions: Part of CoAcetoacetyl-TCA cycle (energy metabolism)
- Deficiency: Fatigue, sleep disturbances, rare in man
- Excess: Not reported

## Folic Acid

- Sources: Legumes, green vegies, whole wheat
- Functions: DNA synthesis
- Deficiency: Glossitis, megalocytic anemia, diarrhea; Rats show spontaneous abortion
- Excess: Not reported
- May be involved in distribution of skin color
  - Denatured by UV light



## B-12

- Sources: Muscle, eggs, Not in vegies
- Functions: DNA synthesis
- Deficiency: Pernicious anemia, neurological disorders
- Excess: Not reported
- Pernicious anemia shows Megaloblastic cells, pallor, defective RBC production, deterioration of spinal cord tissue, tingling of extremities



## Biotin

- Sources: Legumes
- Functions: Fat synthesis, amino acid metabolism, glycogenesis
- Deficiency: Fatigue, depression, nausea, dermatitis, muscle pain
- Excess: Not reported



## Choline

- Sources: Phospholipids, egg yolk, liver, grains, legumes
- Functions: Acetylcholine precursor
- Deficiency: Not reported
- Excess: Not reported

## C or Ascorbic Acid

- Sources: Citrus, tomatoes, green peppers, salad greens
- Functions: Connective tissue synthesis
- Deficiency: Scurvy: skin, teeth, blood vessel degeneration
- Excess: Diarrhea, kidney stones
- 1780: Limeys discovered importance of citrus fruits to prevent scurvy on long sea voyages
  - Scurvy was the cause of more deaths than anything else during voyages of exploration

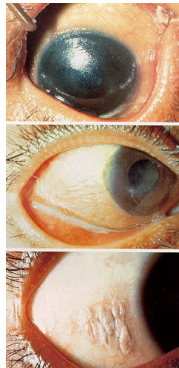
## Scurvy

- Scrobutic rosary, bleeding gums
- Typical rash

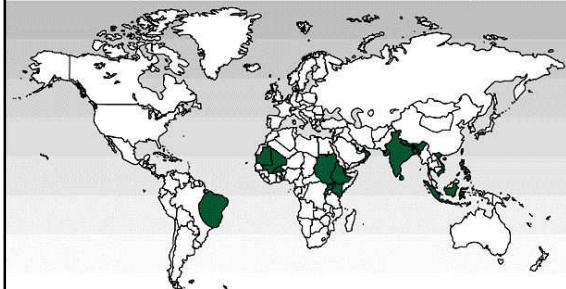


## A or Retinol

- Sources: Green or yellow vegies, dairy foods, liver and liver oils, especially concentrated in predator's livers
- Function: Part of visual pigment rhodopsin, epithelial cell differentiation, cell membranes, mucopolysaccharides
- Deficiency: Xerophthalmia including night blindness to corneal ulcerations
- Excess: Headache, vomit, anorexia, long bone swelling, lysosome membrane breaks down, cells self-digest



## Areas of Blindness Caused by Vitamin A Deficiency



■ = Countries or regions where xerophthalmia is a significant public health problem according to World Health Organization criteria

## A or Retinol, 2

- Acute toxicity has occurred in Arctic explorers who consumed large quantities of polar bear liver
- ½ pound of polar bear liver contains about 9,000,000 I.U., a very lethal dose
- A taboo on polar bear liver consumption among Eskimos may be because of toxicity
  - Or may be due to fact that polar bears are mean mothers

## D or Cholecalciferol

- Sources: Eggs, dairy products, cod liver oil, fortified milk
- Functions: Calcium absorption, promotes bone growth
- Deficiency: Rickets, Osteomalacia
- Excess: Vomit, diarrhea, kidney damage, soft tissue calcification
- Synthesized in dermis with UV exposure
  - May play a role in the distribution of skin color

## E or Tocopherol

- Sources: Seeds, leafy greens/vegetables
- Functions: Antioxidant, maintains cell wall integrity
- Deficiency: Hemolysis, anemia
- Excess: Gastrointestinal disturbances
- Increased polyunsaturated fatty acid intake requires increased E
- Has been claimed as wonder drug: prevent heart attack, increase sexual potency
  - Research findings support an anti-oxidant role

## K or Menaquinone

- Sources: Green leafies
- Functions:  $O_2$  and  $CO_2$  combine with K to liberate energy used to activate the blood clotting cascade
- Deficiency: Only seen when induced by antibiotics or gall bladder disease, produces internal hemorrhage
- Excess: Not very toxic, although the possibility exists of internal clots
- Is synthesized by bacteria in intestine, in addition to dietary sources

## Calcium

- Sources: Dairy goods, lime salts
- Functions: Bone, tooth formation and growth; nerve transmission
- Deficiency: Stunted growth, rickets, osteoporosis, convulsions
- Excess: Not well absorbed without additional Vitamin D
- Andeans chew coca with burnt lime and fat

## Calcium, 2

- Controversy about calcium deficiency causing osteoporosis versus inactivity effects on bone density
  - Calcium absorption decreases with age
- An increase in protein intake leads to an increase in Ca requirement, while an increase in phosphorus intake leads to a decrease in Ca needs
  - Both effects mediated by kidney tubular reabsorption

## Iron

- Sources: Eggs, meat, whole grains, leafy greens
  - Stored in the spleen, liver and bone marrow
- Functions: Hemoglobin constituent, also functions in energy metabolism
- Deficiency: Iron-deficiency anemia
- Excess: Hemosiderosis, cirrhosis-like illness
- Heme iron (from animal sources) is highly absorbable
  - Non-heme iron absorption is increased by presence of animal tissue, Vitamin C, low iron stores
  - Absorption decreased by phytates, bran, tea,  $CaPO_4$

## Iron, 2

- Popeye myth based on a typo in early food tables suggesting spinach had 10 times as much iron as it does
- Known toxicity from taking supplements and among Africans cooking in iron pans and storing beer in iron containers
- Post-menarcheal, pre-menopausal females have increased iron requirements

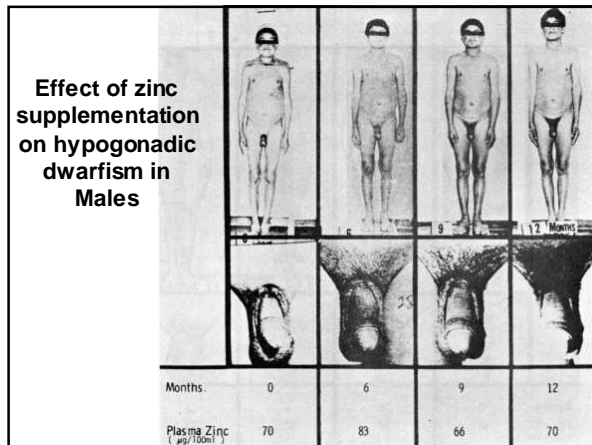
## Iodine

- Sources: Marine foods, dairy products, vegetables where soils contain iodine
- Function: Constituent of Thyroxin
- Deficiency: Goiter, cretinism in children born to goiterous mothers
- Excess: Depress thyroid activity, goiter
- Cretinism among the Maring due to non-iodized trade salt
  - Deficiency can be induced by goitrin present in Cruciferae (e.g., cabbage, rutabagas)
  - Thiocyanate contained in cassava also suppresses absorption

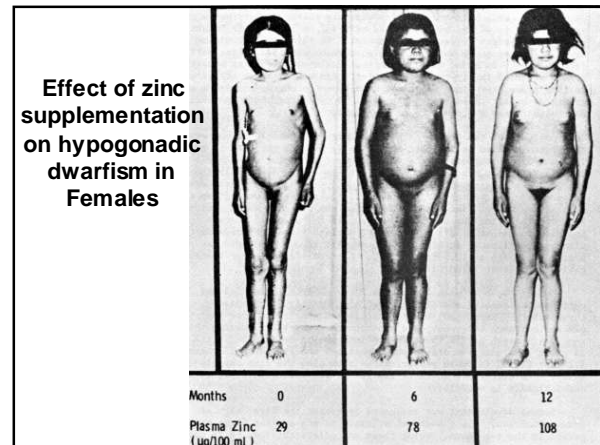
## Zinc

- Sources: Widely distributed, most absorbable from animal foods
- Functions: Constituent of DNA polymerase necessary for cell division
- Deficiency: Hypogonadic dwarfism, stunting
- Excess: Fever, nausea, diarrhea
- Deficiency can be induced by calcium or cadmium which may be obtained through geophagia and which selectively suppress zinc absorption
  - Also, phytates present in whole-grain bread (e.g., in Shiraz, Iran) can complex the zinc, making it unabsorbable

**Effect of zinc supplementation on hypogonadic dwarfism in Males**



**Effect of zinc supplementation on hypogonadic dwarfism in Females**



## Assessment based on questions being asked

- Dietitian, M.D., Epidemiologist
  - Diagnosis of individual or population for treatment
    - Problems of sensitivity and specificity with most assessment techniques:
    - Measures are likely to catch a high percentage of malnourished (e.g., good sensitivity)
      - Short, sick, dead people likely to have been malnourished
    - Measures are likely to catch many people not suffering from malnutrition (e.g., poor specificity)
      - Short may be genetic, sickness may be infectious not nutrition, death can be from other causes, i.e., non-malnourished may be diagnosed as malnourished

## Dietary Intake

- Retrospective
  - Recent: (intake over last 1-7 days).
    - Tradeoffs: quality of recollection versus completeness of habitual measures
    - Need minimum of 3-6 24-hour recalls to get a good valid estimate of habitual dietary intake
      - Example: Sunday intake ranges from 7% higher to 72% higher than weekday caloric intake in Pelletier's Western Samoa sample
  - Habitual: Diet History versus food frequency
    - Burke's style based on 24-hour recall.
    - Food frequency accuracy depends on appropriateness of food list
      - Example: HHHQ modified for use in low income Southern black population by substituting chicken pot pie, Kool-Aid,

## Dietary Intake

- Prospective
  - Self-recorded: diaries, records for 3-7 days. Need multiple records per subject.
  - Observed: weighed and measured, ethnographic observer
- Problems with all intake data
  - Food-tables
  - Sampling of subjects and time periods
  - observer effect

## Anthropometric Measurements

- Early warning of malnutrition; nutritional surveillance (quick, relatively cheap, useful for large samples)
  - Measure overall nutritional status through changes in body size and composition, not indicative of specific deficiencies. Since most malnutrition is caused by general undernutrition, this is not as big a problem as may seem
  - "Growth Monitoring" Examples

## History and Physical Exam

- Good for populations, quick, cheap, easy to observe
  - Medical History: detect increased risk of malnutrition
  - Clinical observations
    - Eyes: Vit. A deficiency: dry, pus, spots, opaque cornea
    - Skin: sun exposed rash (niacin def.); hair follicle inflammation (vit. A)
    - Hair: lightening "flag": protein deficiency
    - Mouth: corner cracks (riboflavin); soft spongy gums (vit. C)
    - Teeth: mottling: too much fluorine
    - Tongue: loss of papillae, raw, red (niacin)
    - Thyroid enlargement: iodine
    - Lower extremities edematous (thiamine; protein deficiency)
- Problems: Only a few symptoms are specific for malnutrition

## Biochemical Measurements

- More specific than clinical symptoms, can be seen earlier in course of disease
- New tests coming on line all the time to measure functional results of various nutrient intakes
- Problems
  - Expensive, can be difficult to interpret
  - Specificity: Many diseases will alter biochemistry of body
  - Some nutrients are hard to find (most A is sequestered in the liver)

## Archaeologists

- What did people eat, how did it affect them?
  - Diet history: recovery of refuse as an indication of potential food
    - Case study: Cassidy: Hardin Village and Indian Knoll, Kentucky
      - Description of subsistence:
        - » Hardin village: primarily corn, beans, squash cultivated supplemented with wild flora and fauna like deer, elk, turkey
        - » Indian Knoll shell mound, primary food source is river mussels and snails with deer, turkey, fish, gathered plants (very few plant remains)

## Archaeologists

- Analysis of diet
  - Hardin village appears to have a higher intake of carbohydrates and lower of protein than Indian Knoll
  - Possibility of protein deficiency at Hardin Village

## Archaeologists

- Clinical evaluation of remains
  - Paleopathologies that can be linked to diet
    - Rickets (curvature of femora, spine, parietals, pelvis) indicates vitamin D deficiency during growth and development
    - Osteomalacia (thin bones, demineralization) indicates vit D in adults
    - Harris lines may indicate vitamin C deficiency with growth stoppage or just about any other growth stopping condition
    - Porotic hyperostosis (thick frontals): response to anemia, increase RBC producing tissue. Can be iron deficiency or any other cause.
    - Enamel hypoplasia: growth disruption may be Vitamin A related

## Archaeologists

- Growth and anthropometry
  - Mayans show stature differences related to status inferred from burial goods
    - Taller folks are higher status
- Biochemical tests
  - Bone strontium: higher strontium, more plants in diet, lower strontium more meat—good for within site differences
  - C<sup>13</sup>/C<sup>14</sup> ratio: high C<sup>13</sup> relative to C<sup>14</sup> indicates a diet that is high in maize
  - Trace mineral analysis can tell about sufficiency of minerals in diet

## Archaeologists

- Ecological measures
  - Population size and structure is related to nutritional status
    - Larger population or growth through time should indicate more food available
    - Decrease in infant and childhood mortality should be associated with better nutritional status
- Problems
  - Sampling
    - Preservation, recovery
    - Never know for sure you have everything

## Anthropologist

- Investigate food within its cultural context
- Understanding household food use
  - Dietary Histories
    - Can modify individual techniques for use with household
      - Have food preparer give 24-hour recall or food frequency answers or keep records of foods consumed

## Anthropologists

- Wilkins on how to evaluate household intake
  - Record the family larder and weigh all foods each day (or at beginning and end of period)
  - Grouped data for all family must be broken down to individual composition of household for nutritional assessment
    - Adult eating three meals a day = 1 adult unit
    - Child under 1 year = 0 adult units
    - Child 1 – 5 years = 0.25 adult units
    - Child 6 – 10 years = 0.5 adult units
    - Child over 10 = 1.0 adult units
    - Adult breakfast = 0.2 adult units
    - Adult midday or evening meal = 0.4 adult units
  - Take total household consumption of food per day and divide by the number of adult units

## Anthropologists

- Other household consumption techniques are LESS precise than this
  - Record of purchased and produced food for several weeks is good in sedentary population with little food storage
  - Food list: recall of one week of household consumption by gatekeeper

## Ecologist

- How are decisions made in population:
  - Energy Flow
    - Need kind and amount of food (usually by household)
  - Optimal foraging
    - Need kind and amount of food (usually by household)