Vitamins and Minerals

General Concepts

- Divided into two major groups: **fat soluble** and **water soluble**
- fat soluble: A, D, E, K
- most of the 15 shown as essential for fish, but not for all species
- requirements vary with species, size, growth rate, environment (temperature, presence of toxins, etc.) and metabolic function (growth, stress response, disease resistance)
- many species can utilize intestinal bacteria synthesis for meeting vitamin requirements

Vitamin A: retinol

- Can only be found intact in animal sources
- in its natural form, it is alcohol known as retinol
- also isolated from various lipids and beta carotene
  - 1 beta carotene (plants) = 2 retinols (body)
- stored in the liver
- retinol + opsin (protein) = rhodopsin (vision)
- deficiency = improper growth, exophthalmia
- feeds contain non-oxidizable form, proper storage
- requirement level = 1,000 I.U. (international units)
- sources: fish oils

Vitamin D_3: cholecalciferol

- Vitamin D found as ergocalciferol (D_2) and cholecalciferol (D_3)
- most land animals can use both, except chickens (only D_3)
- fish appear to use only D_3
- both activated in plants/animal skin by UV radiation
- D_3 primarily used as precursor for calcium regulation

Vitamin E: tocopherol

- Active form is alpha tocopherol
- good antioxidant: most feed antioxidants have vit E activity, but only 1/6 that of α-tocopherol
- antioxidants used to prevent oxidation of lipids (mainly phospholipids, PUFA's)
- requirement is tied to selenium deficiency (Se is cofactor in glutathione peroxidase)
- deficiency in fish = muscular dystrophy, reduced fertility
- increased dietary requirement in absence of PUFA's
- requirement: 50-100 mg/kg for fish/shrimp
- sources: alfalfa meal, fish meal, rice bran, wheat middlings, barley grains

Vitamin K: menadione

- Originally identified as a fat-soluble factor required for normal blood clotting
- menadione is the most active form
- actually works by activating blood-clotting proteins
- requirement: shrimp (none), fish (unknown)
- dietary sources: alfalfa meal, liver meal

Water Solubles: thiamine (B_1)

- Function: metabolism of COH
- sources: brewers yeast, wheat middlings, rice bran, rice polishings, wheat bran, soybean meal
- deficiency: central nervous system failure
- requirement: 2.5 mg/kg (tilapia), 10-15 mg/kg (salmon)
- requirement: 40-50 mg/kg (shrimp)

Riboflavin: B_2

- Function: metabolic degradation of proteins, COH, lipids
- sources: plants, bacteria, yeast, fish solubles
- deficiency: cataracts (fish), vision, crooked limbs
- requirements: 9 mg/kg (channel catfish), 5 mg/kg (tilapia)
- requirements: 50 mg/kg (shrimp)

Niacin

- Function: transport of hydrogen ions as NADP, NADPH; electron transport, fatty acid, cholestrol synthesis
- forms: niacin, nicotinic acid, nicotinamide
- sources: rice polishings, yeast, rice bran
- deficiencies: pelagra, dermatitis, anemia (fish), skin lesions (fish), sunburning (fish)
- Can fish convert tryptophan to niacin?
- requirements: 14-28 mg/kg (carp, catfish)
- requirements: 400 mg/kg (shrimp)

Folic Acid

- Recently shown as very important for pregnant females to avoid birth defects
- function: synthesis of purines, pyrimidines, nucleic acids
- sources: yeast, alfalfa meal, full-fat soybeans
- deficiencies: anemia, large erythrocytes, pale gills (fish)
- requirements: 1-4 mg/kg (fish, shrimp)

Cyanocobalmine

- Last of 15 vitamins to be identified
- chemically complex, cobalt nucleus
- function: coenzyme in metabolic reactions, maturation of erythrocytes, uracil->thymine
- deficiency: pernicious anemia, nerve disorders
- requirement: very low 0.015 mg/kg or not at all

Ascorbic Acid: C

- Both finfish/shellfish very sensitive to this vitamin, especially as juveniles
- function: antioxidant, stress reducer, bone calcification, iron metab, tyrosine metab, blood clotting
- deficiency: scoliosis (lateral), lordosis (vertical), fin erosion, black death (shrimp)
- toxicity: toxic at over 150-200 mg/kg (shrimp)
- sources: synthesized from glucose, usually added as chemical form
- requirement: 100 mg/kg varies w/age, metabolism


Part 2: Minerals

Preliminary Concepts

- Minerals are inorganic elements found in the body
- not all of them are essential and probably are there simply because of ingestion of feed
- dietary requirement has been demonstrated for at least 22 in one or more species
- those required in large quantities are known as **macro or major minerals**
- those required in trace quantities are known as **trace minerals or elements**

Preliminary Concepts

- Major: calcium, phosphorus, magnesium, sodium, potassium, chlorine and sulfur

- Trace: iron, iodine, manganese, copper, cobalt, zinc, selenium, molybdenum, fluorine, aluminum, nickel, vanadium, silicon, tin and chromium

- determination of dietary or tissue mineral levels is via combustion and collection of residual ash

Principle Mineral Constituents

Element	Percent
calcium	1.33
phosphorus	0.74
sodium	0.16
potassium	0.19
chlorine	0.11
magnesium	0.04
sulfur	0.15

General Functions of Minerals

- Provide rigidity and strength to skeletal structures, exoskeletons
- primary components of bones and teeth
- constituents of organic compounds such as proteins and lipids
- enzyme activators (**coenzymes**)
- osmoregulation, acid/base equillibria
- effect irritability of muscles and nerves

Requirements by Fish/Shrimp

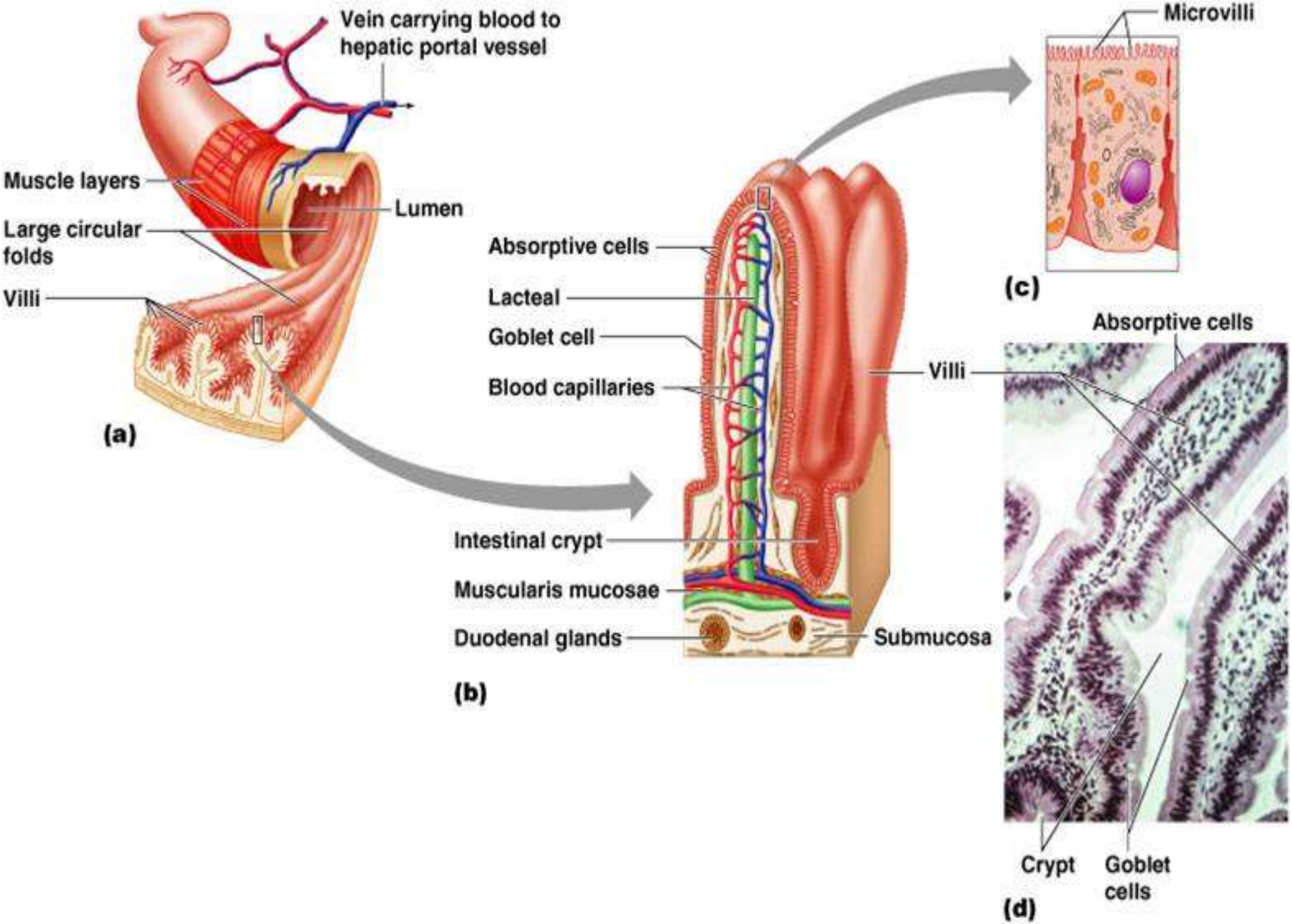
- Similar to warm blooded animals for tissue formation and various metabolic functions
- can absorb dissolved minerals from the water across gill membrane/exoskeleton
- also via drinking (for drinking species)
- most Ca required comes from water
- for marine species, seawater provides most iron, magnesium, cobalt, potassium, sodium and zinc
- phosphorus not typically available in water

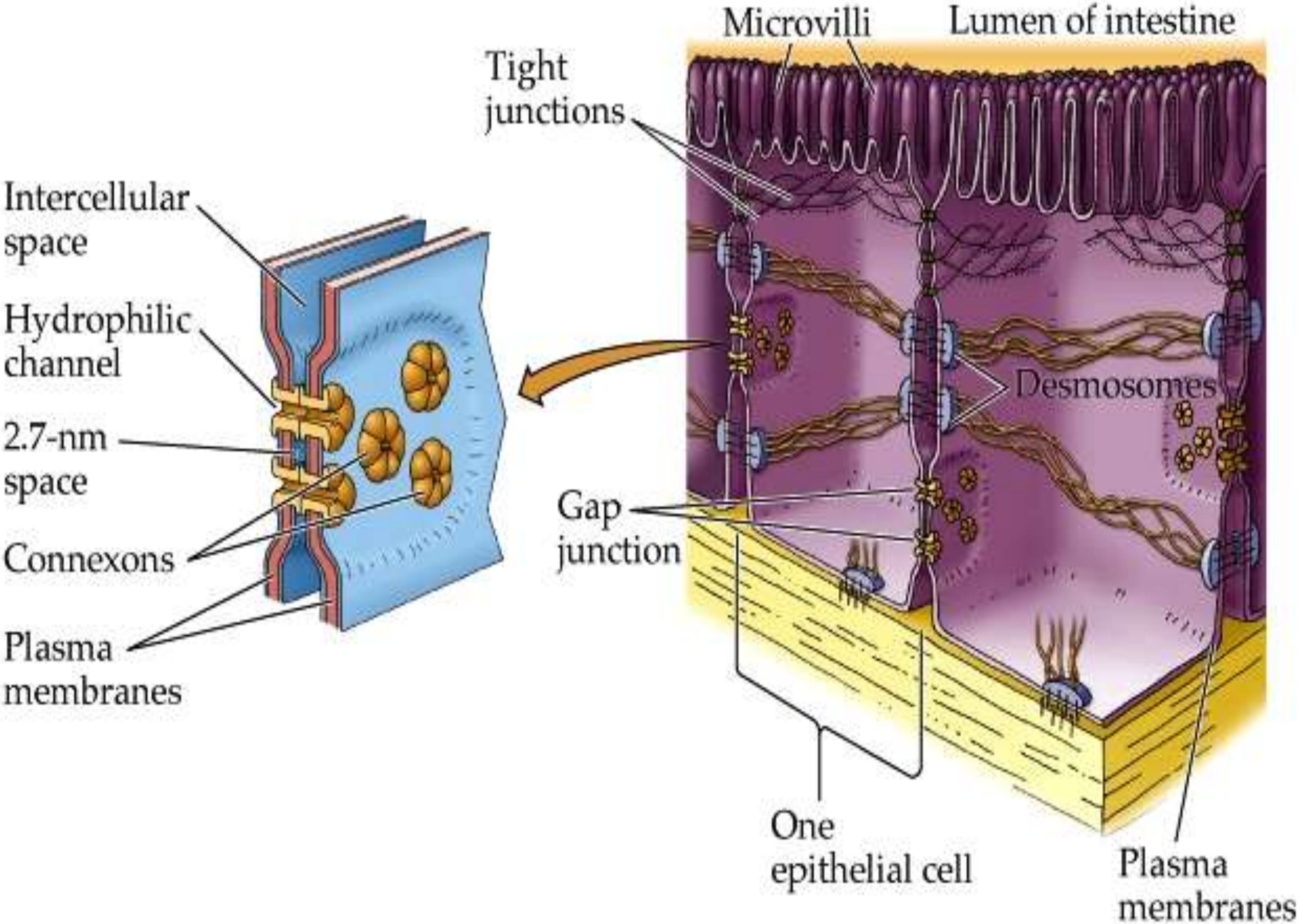
Calcium and Phosphorus

- Ca and P are two of the major inorganic constituents of feeds
- Ca: essential for blood clotting, muscle function, proper nerve pulse transmission, osmoregulation
- P: component of ADP, ATP, P-lipids, DNA, RNA
- Phosphates serve as pH buffer systems

Calcium and Phosphorus

- Dietary Ca is primarily absorbed from the inestine by active transport
- in vertebrates, blood levels of Ca and P are regulated by the vitamin/hormone **cholecalciferol**
- absorption depends upon whether the mineral is soluble at the pH of the gut
- Ca, for example, can be put in the diet as Ca-lactate, Ca-PO_4 tribasic, or $CaCO_3$
- digestibility of above: 58%, 37%, 27%, respectively


Vein carrying blood to hepatic portal vessel
Muscle layers
Lumen
Large circular folds
Villi
(a)
Absorptive cells
Lacteal
Goblet cell
Blood capillaries
Intestinal crypt
Muscularis mucosae
Duodenal glands
Submucosa
(b)
Microvilli
(c)
Absorptive cells
Villi
Crypt
Goblet cells
(d)


Intercellular space
Hydrophilic channel
2.7-nm space
Connexons
Plasma membranes
Microvilli
Lumen of intestine
Tight junctions
Desmosomes
Gap junction
One epithelial cell
Plasma membranes

Phosphorus Availability

- The main question regards whether the mineral is soluble in water
- monobasic sources (sodium phosphate) are highly digestible (90-95%)
- availability of di- and tri-basic phosphorus sources varies with species, but is generally around 45-65%
- monobasic sources are more expensive

Calcium and Phosphorus

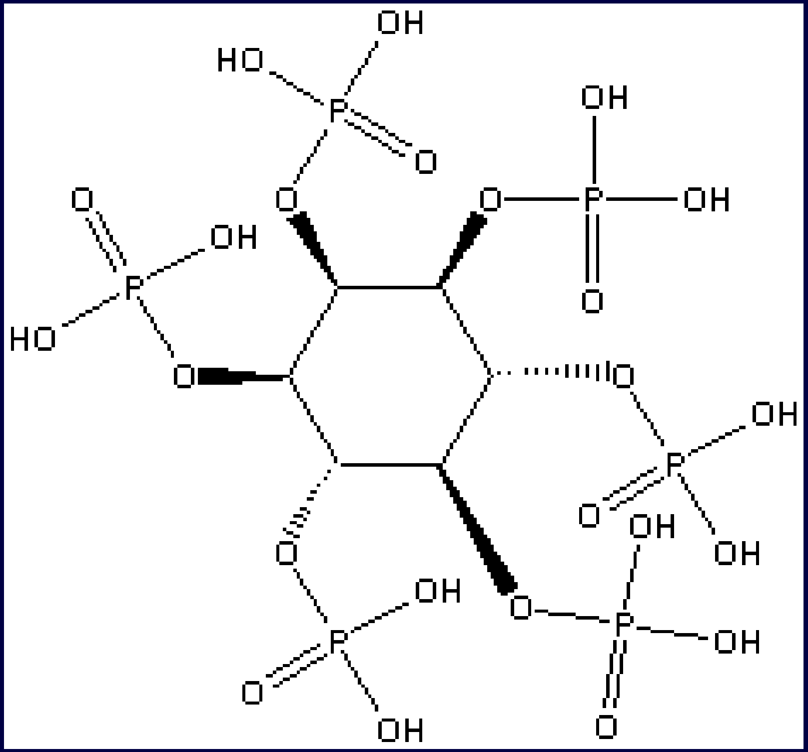
- Besides the form in which it is included in the diet, availability of Ca and P can depend upon:
- 1) level of lactose intake
- 2) dietary form of Vitamin D
- 3) iron, aluminum, manganese, potassium and magnesium intake
- 4) level of fat intake
- 5) level of dietary phytate (phytic acid)
- obviously, many interactions

Calcium and Phosphorus

- No dietary Ca for shrimp grown in seawater (why?)
- Since levels of P are low in most natural waters, there is a dietary requirement
- Supplementation of dietary Ca inhibits P availability
- Thus, dietary ratios of less than 2:1 Ca:P are recommended

Phosphorus Availability

- The major source of P in natural grains (67%) is a compound known as **phytate phosphorus**
- this form of P is poorly available
- the presence of phytate inhibits the availability of dietary Ca and other sources of P
- forms insoluble complexes in the digestive system



phytic acid

Phosphorus Availability

- Question: how do we make P more available? Why should we?
- Answer: possible that addition of phytase to feeds could make grain-based P more available (also could work for Zn)
- Probable inclusion level is around 1-2,000 FTU
- Recent studies with mammalian systems have shown that phytate inhibits uptake of iron
- It also has been shown *in vitro* to inhibit activation of zymogens responsible for destruction of the extracellular matrix associated with various forms of breast, gastric, colon, neck and pancreatic cancer.