

## Lecture 5 Lipids and Fatty Acids



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### Lipid Characteristics

- Lipid = a compound that is insoluble in water, but soluble in an organic solvent (e.g., ether, benzene, acetone, chloroform)
- “lipid” is synonymous with “fat”, but also includes waxes, phospholipids, sterols etc.

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### Nutritional characteristics of Lipids

- Dense source of energy (9.15 kcal/g)
- Essential fatty acids (marine and cold water fish)
- Provide means whereby fat soluble nutrients (e.g., sterols, vitamins) can be absorbed by the body
- Structural element of cell, subcellular components
- Sterols/hormones/precursors for prostaglandin
- Texture
- Flavor/taste/attractant

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# Lipids

- **Simple:** 3 FA's esterified with glycerol
- **Compound:** same as simple, but with other compounds also attached
  - **Phospholipids:** glycerol with 1 and 2 positions esterified with LC-FA. Position 3 containing phosphoric acid and nitrogen (lecithin)
  - **Sphingolipids:** do not contain glycerol, but consist of the amino alcohol sphingosine to which is added a fatty acid, phosphate and either choline or ethanolamine. (nerve tissue)
  - **Glycolipids:** FA's compounded with CHO, but no N (found in leaves of plants)
  - **Derived lipids:** substances from the above derived by hydrolysis
- **Sterols:** large molecular wt. alcohols found in nature and combined w/FA's (e.g., cholesterol, ergosterol, bile acids)
- **Prostaglandins:** 20 carbons and a cyclic structure between the 19 and 25 carbon atom.

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# Saturated vs. Unsaturated

- **Saturated**
  - FA's of a lipid have all of their H
  - No double bonds between carbons in chain

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# Saturated vs. Unsaturated

- **Unsaturated:** the FA's of a lipid do NOT have all of their H, double bonds are present
  - **polyunsaturated:** there is/are more than one double bond(s) in the chain
  - Common polyunsaturated fats (PUFAs) oleic, linoleic and linolenic acid
  - unsaturated fats have lower melting points
    - stearic (sat.) melts at 70°C, oleic (PUFA) at 26°C

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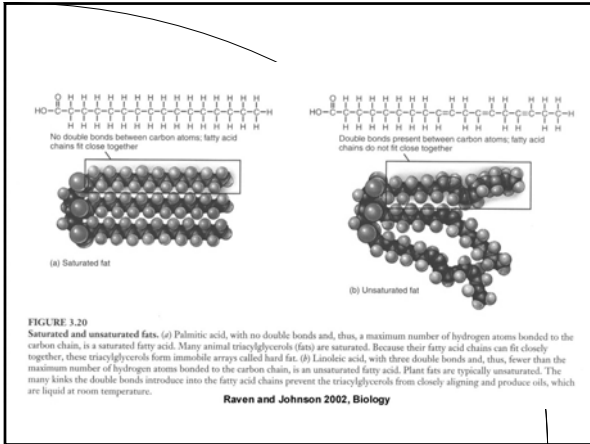
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## Fatty Acid Nomenclature

- Common names (e.g., oleic, stearic, palmitic)
- Nomenclature
  - reflects location of double bonds
  - Linoleic (18:2n6) this means the FA is 18 carbons in length, has 2 double bonds, the first of which is on the 6th carbon from the methyl group.
    - $\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
  - Linolenic (18:3n3)
    - $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
  - Eicosapentaenoic (20:5n3)
  - Docosahexaenoic (22:6n3)

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## Plant vs. Animal Fat

corn	soy	tallow	Lard
		3	
7.0	8.5	27	32.2
2.4	3.5	21	7.8
45.6	17	40	48
45.0	54.4	2	11
	7.1	0.5	0.6
Oil		Fat	

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## Characterization

- Melting point
  - Oils liquid at room temp 20C
  - Fats are solid at room temp
- Iodine number – unites with unsaturated fat at the double bond, two moles of iodine per double bond.
  - Grams of iodine absorbed by 100g fat.

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## Melting points

		Temp C
Myristic acid	14:0	54
Palmitic acid	16:0	63
Stearic acid	18:0	70
Oleic acid	18:1n-9	16.3
Linoleic acid	18:2n-6	-5
Linolenic acid	18:3n-3	-10
Arachidonic acid	20:4n-6	-49.5
Eicosapentaenoic acid	20:5n-3	-54.4
Docosahexaenoic acid	22:6n-3	-44.5

Saturated; mono-unsaturated; poly-unsaturated

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	Meting point C	Iodine no
Corn	<20	105-125
Soy	<20	130-137
Safflower	<20	
Coconut	20-35	8-10
Butter	28-36	26-38
Tallow	36-45	46-66
Lard	35-45	40-70

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## Lipid Metabolism/Absorption

- Function:
  - Fats serve a structural function in cells
  - Sources of energy
  - Precursors
- Digestion
  - Extent depends on chain length and saturation
  - Fats having FA's over 18 carbons in length are less digestible
  - Some low molecular wt. FA's can be absorbed directly into gut mucosa

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## Lipid Metabolism/Absorption

- Short chain FA's are absorbed and passed directly to the lymphatic system and enter the portal vein to the liver.
- Long chain FA: Tryglyceride re-formed from FA and monoglyceride that were absorbed into mucosal cell, packaged into chylomicrons and pass to the lymphatic system
- some FA's entering the liver are oxidized for energy, others stored, others modified.
- blood lipids: 45% phospholipids, 35% triglycerides, 15% cholesterol esters, 5% free FA's

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## Characteristics of Fat Storage

- Most of the body's energy stores are triglycerides
- storage is in adipose tissue
  - Dietary or anabolism (synthesis) from COH or AA carbon skeletons
  - adipose can remove FA's from the blood for storage and release into the blood when needed
  - MCT are generally not stored in adipose tissue (energy)
  - Sit of storage depends on species
    - muscle generally lean but can be fatty
    - stomach (viscera) area major site of storage

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## Fatty acid chemistry

- Fatty acid oxidation
  1. Priming (activation) of FA by linking to CoA
  2. Beta oxidation – cyclic reaction producing acetyl CoA units
- Fatty acid synthesis produces Palmitic acid C16:0
  - Elongases – produce longer chain FA
  - Desaturases – produces unsaturated FA

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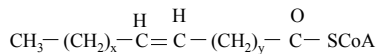
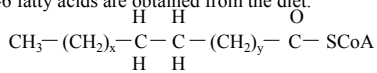
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## Desaturases

- Three enzymes working on C9, C6 and C5 carbons (using delta, you count from the amino end). Animals can not desaturate beyond 9 carbons.
- The other FA are created by bacteria and plants. Hence n-3 and n-6 fatty acids are obtained from the diet.




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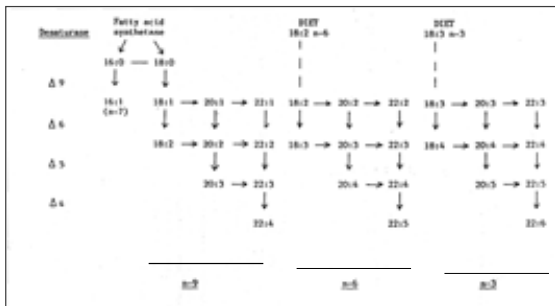
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If 16 FA, delta 9 desaturase can only make n7 FA's (16-9=7)  
 If 16 FA, desaturated and elongated will make n9 FA (18-9=9)  
 Hence, n3 and n6 FA must originate from the diet.




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## Essential Fatty Acids

- Only recently determined essential (1930)
  - requirement determined by depleting fat reserves of subject animal
  - Difficult to identify
    - EFA are conserved
    - Some animals can elongate to a limited degree
    - Very important in early development

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## Essential Fatty Acids (fish)

- EFA requirements generally reflect
  - Lipid profile of the prey
- Fresh water species
  - Prey has n-3 and n-6 FA (18 C)
  - Capable of elongation
    - 18:3n-3 → 18:4n-3 → 20:5n-3 (EPA) → 22:6n-3 (DHA)
    - 18:2n-6 → 18:3n-6 → 20:3n-6 → 20:4n-6 (AA)
- Marine general have these in the diet
  - Reduced ability to elongate (required in diet)

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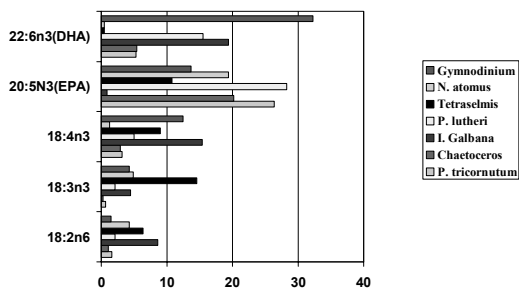
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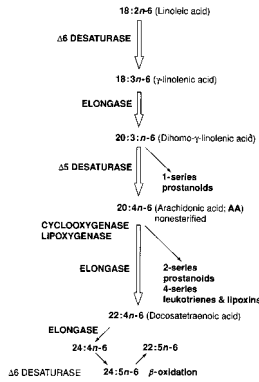
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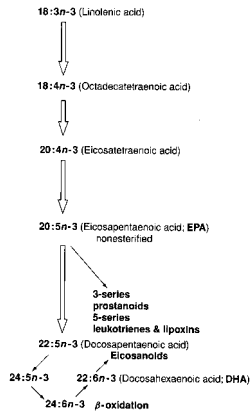
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## EFA Function

- Component of membranes and precursor to metabolically active compounds
- Membranes must be in a fluid state. Based on balance of saturated and unsaturated FA as a component of membrane phospholipids
  - Relative percentage and distribution within the phospholipid molecule is regulated and changes.

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## EFA Deficiency

- Dermal degradation (fin rot)
- Shock syndrome
- Myocarditis (inflammation of the heart muscle)
- Reduced growth, survival and feed intake
- Poor reproductive performance
- Larvae
  - Under developed swim bladder
  - Scoliosis

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## Lipids

- Dietary lipids
  - 8-16% (marine)
    - Exceptions salmonids and bream (>20%)
  - 5-12% (freshwater)
- Marine fish: Essential fatty acids
  - 10-20% dietary lipid from n-3 HUFA
    - Red drum
    - Gilthead seabream
    - Milkfish
    - Yellowtail
    - Asian seabass
    - Red seabream
    - Striped bass 0.5 EPA and DHA (can not elongate 18:3n3)
- Phospholipids 0.5 %

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## Note: maturation diets

- Docosahexaenoic acid (DHA)
- Eicosapentaenoic acid (EPA)
  - Are critical for the development of neural tissues and compounds important in stress response and adaptation.
- Multiple spawning species
  - Red (*Pagrus major*) and gilthead sea bream (*Sparus aurata*)
  - Eggs will respond within 15 day of dietary changes

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## Lipids

- Fresh water fish
- Linolenic acid (18:3n3) or EPA and DHA
  - Ayu, channel catfish, coho salmon, rainbow trout
- Linoleic (18:2n6) or AA
  - Nile tilapia, zilli's tilapia
- Chum salmon, common carp and Japanese eel require a mix.

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## Lipids

- Catfish
  - only require Linolenic acid (18:3 n3) at 1-2% or 0.5-0.75 EPA and DHA
  - Catfish can desaturate/elongate linoleic acid to meet HUFA requirements
  - Diets generally contain 5% lipid (3% from ingredients, 2% mixed oil sprayed on the feed)
- Nile Tilapia 0.5% linoleic acid (18:2n6)
- Phospholipids 0.5 %

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## Lipids

- Dietary lipids growout diets
  - Marine fish: Marine origin or (1:1 ratio marine to plant)
  - Freshwater fish: 1:1 fish oil and plant (often use oils from fish processing)
  - Excess lipids
    - Increase chance of oxidation
    - Increased fat deposition
      - Reduced dress out
      - Reduced shelf life
    - Decrease palatability
  - Antioxidants and proper storage is essential
    - BHA or BHT 0.2% lipid
    - Ethoxyquin, 150 mg/kg diet

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## Lipid Requirement: Shrimp

- Dietary lipid
  - 5-12% of diet
  - High levels general reduce feed intake
    - reduced growth
    - reduced consumption
    - High levels in midgut gland

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- Crustaceans have little ability at synthesis lipids
- if fed acetate,
  - most converted to monounsaturated FA's, little chain elongation
  - less than 2% went to PUFA formation (linoleic, linolenic)
- thus, these FA's as well as others (docosahexanoic, eicosapentaenoic, arachidonic) must be in diet

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- Penaeids
  - Dietary lipids 6 %
  - Phospholipids 0.5 %
  - FA's (0.4% each)
    - Linoleic (18:2n6)
    - Linolenic (18:3n3)
    - Eicosapentaenoic (20:5n3)
    - Decosahexaenoic (22:6n3)
  - Cholesterol – 0.5% diet

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## Notes

- Humans: Saturated FA and Cholesterol increases risk of heart attack and reduces immunocompetence.
  - N3 family influences protoglandin synthesis and other hormones which overall reduce the deposition of platelets along arterial walls.
- Fish: Excess of n-6FA (but adequate in n-3) resulted in cardiomyopathy in salmon
- N-3 and N-6 ratio's although not well defined are important

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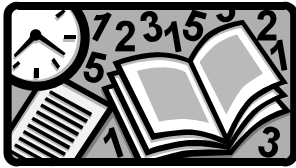
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## TEST II



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