Adipose Tissue

- What impact does adipose tissue growth and development have on livestock production?
  - meat quality, economics
  - health concerns in consuming extra fat
  - calorie density-obesity
  - source of hormones and signal molecules regulate body metabolism
- Adipose Tissue (A.T.) = connective tissue classification, consists of many cell types

Adipose Tissue

- Meat Quality and economics

Korea	1^{++}				1^{+}		1^{st}		2^{nd}		3^{rd}
			No9	No8	No7	No6	No5	No4	No3	No2	No1
USA	Prime							Choice			Sel.
Japan	5^{th}				4^{th}			3^{rd}		2^{nd}	1^{st}
	No12	No11	No10	No9	No8	No7	No6	No5	No4	No3	No2	No1

Comparison with carcass grade among Korea, Japan, and USA

Comparison of Angus and American Wagyu beef

Choice Angus

Wagyu

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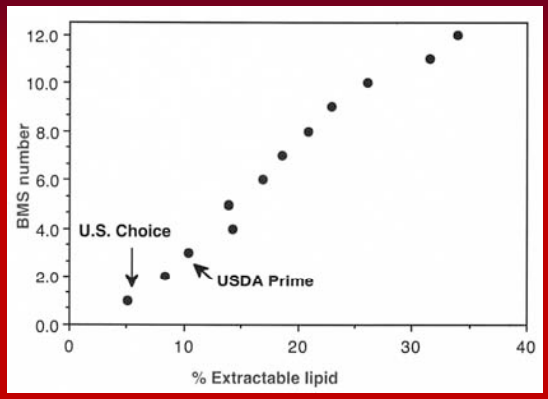
Adipose Tissue

- **Health concerns in consuming extra fat**



The Beef Marbling Score (BMS) is directly related to the percentage extractable lipid.

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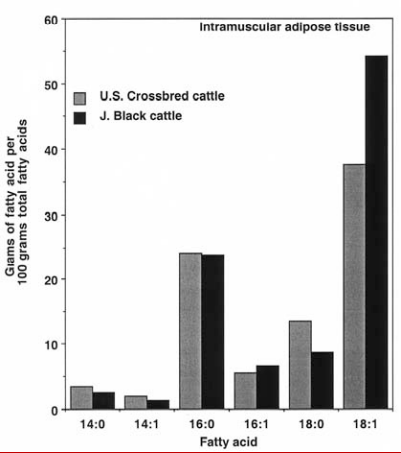
Adipose Tissue

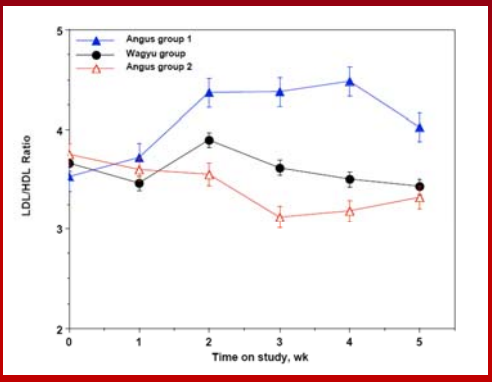
- Health concerns in consuming extra fat



Fatty acid composition of intramuscular adipose tissue (marbling) of U.S. crossbred cattle or Japanese Black cattle raised in Japan. (Adapted from Sturdivant et al., 1992.)

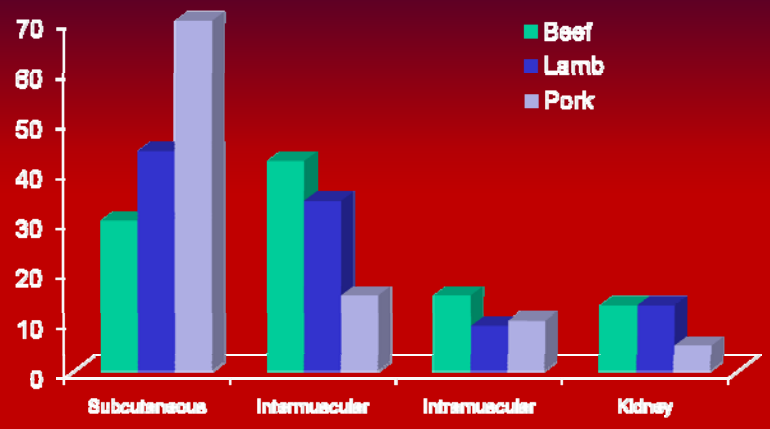
MUFA on cholesterol metabolism in human subjects

- Health concerns in consuming extra fat



- 10 men consumed ground beef fomulated with Angus or Wagyu fat trim.
  - Angus 1: MUFA:SFA ratio = 0.82
  - Angus 2: MUFA:SFA ratio = 1.34
  - Wagyu: MUFA:SFA ratio = 1.34
- High MUFA diet reduce LDL cholesterol in plasma (Smith et al., Unpublished)

Adipose Tissue



Distribution of fat between the subcutaneous, intermuscular, intramuscular, and kidney fat in beef, lamb, and pork carcass. Livestock & Carcasses by Boggs et al., 1998

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Adipose Tissue

- Functions of AT
  - Energy Storage = 2.25 x Gross energy as protein or CHO
  - Insulation
  - Protection of vital organs
  - Non-shivering thermogenesis
    - Brown adipose tissue
    - release of heat
      - newborn animals
      - cold adaptation
      - hibernation

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Adipose Tissue

- Four major depots of AT
  - visceral
  - intermuscular ("seam fat")
  - subcutaneous ("backfat")
  - intramuscular ("marbling")

Adipose Tissue

- Largest triglyceride in animal adipose tissue
  - Palmitodiolein (Glycerol + palmitic, oleic, oleic acid)
  - Oleopalmitostearin (Glycerol + oleic, palmitic, stearic acid)
  - Oleic acid is largest portion in animal adipose tissue

Adipose Tissue

- Adipose Tissue (A.T.) = connective tissue classification, consists of many cell types
- Adipose tissue generally composed of:

76-94% lipid

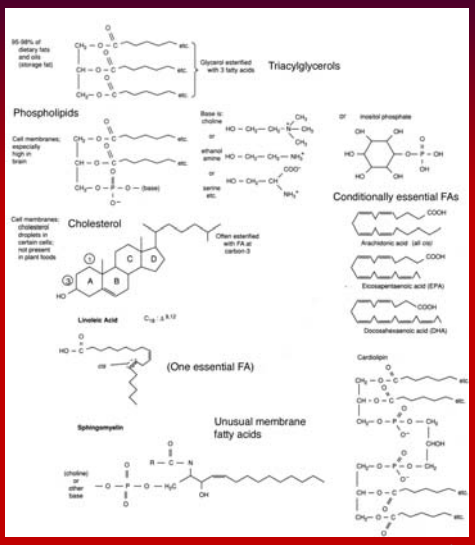
1-4% protein

5-20% water.

Adipose Tissue

- Lipid or Fat ≠ AT
  - Lipid/Fat is just one portion of AT
  - adipocyte stores lipid/fat
- Lipids = mainly triacylglycerols (TAGs)
- Adipose Tissue Structure
  - eyelids and scrotum completely devoid of AT
  - largest "organ" in body
  - Human males AT = 15-20% of body weight, females 20-25% of body wt.
  - tremendous capacity to expand mainly because it is very vascular
  - vascularity related to # of cells at the specific AT deposition
  - metabolically active, based on energy balance of animal

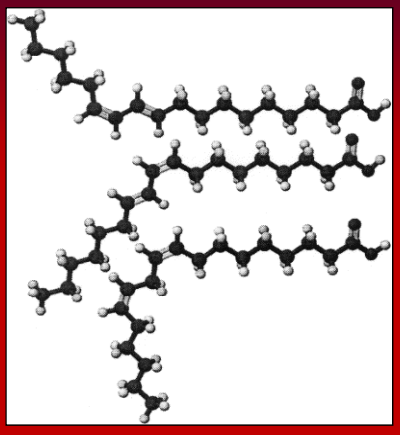
Adipose Tissue



- Types of lipids
- Ruminant Animal contained cis-9 trans-11, trans-10, cis-12 conjugated linoleic acid (CLA)

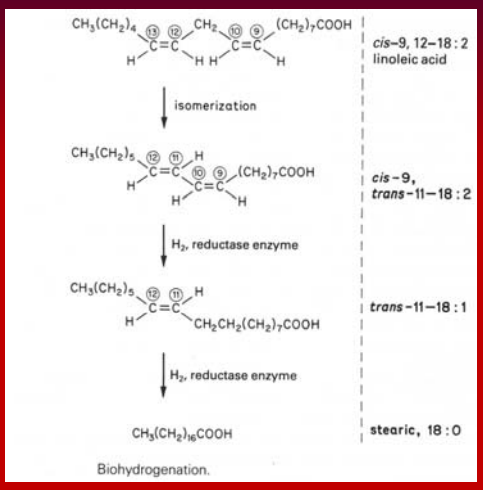
Conjugated linoleic acid

- trans-10, cis-12 CLA
- cis-9, trans-11 CLA
- linoleic acid



J. Chem. Edu, 73:302–303, 1996.

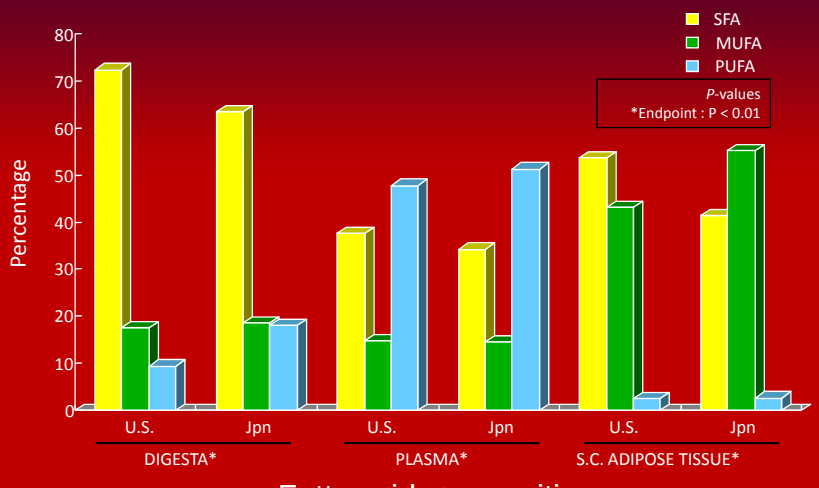
Adipose Tissue



Biohydrogenation.

- **Biohydrogenation in ruminants.**

Adipose Tissue



Fatty acid composition

Adipose Tissue Growth

- The increase of adipose tissue
  - Adipocyte Number + Adipocyte Size.
- The source of new fat cell
  - Fibroblast, Fibroblast-like cell --- Adipocyte
- Brown Adipocyte
  - precursor for white adipocyte
  - No brown fat in piglet.
- Net lipid accretion rate = rate of lipigenesis-rate of lipolysis

Adipose Tissue Growth

- Adipose tissue : major lipogenesis in cattle, sheep, pig
- Liver : major lipogenesis in rodents, avian, human

Adipose Tissue Growth

- Monogastric animal : Dietary FA used for body adipocyte triglyceride synthesis

- Glucose is major substrate for lipogenesis

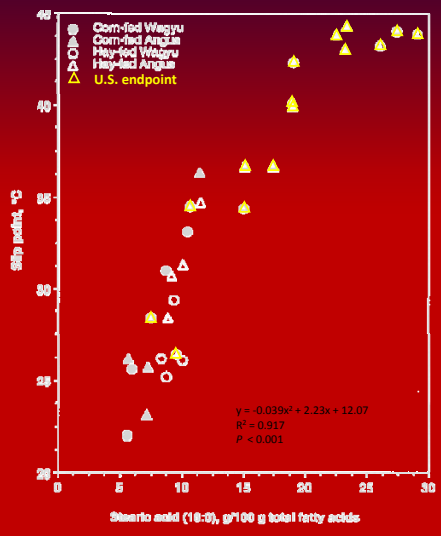
- Ruminants : Biohydrogenation changed dietary FA from unsaturated to saturated

- Acetate is major substrate for lipogenesis

- Relatively low ATP-citrate lyase, NADP-malate dehydrogenase in liver

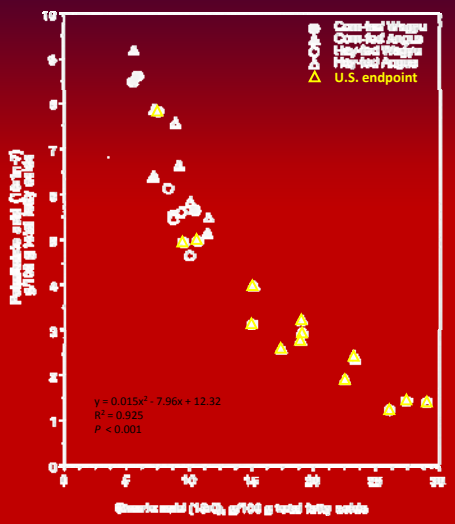
- Poultry : Used VLDL for transfer lipid in body

Stearic acid vs. slip point



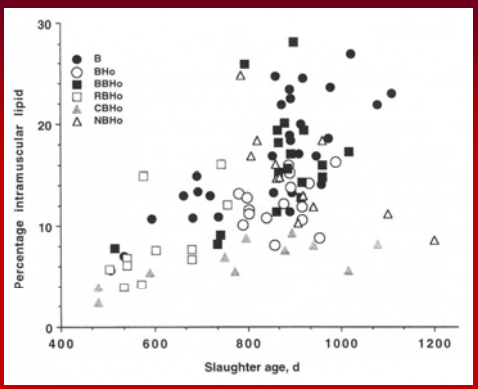
- Positive correlation.
- Slip point was highest in hay-fed steers.
- U.S. endpoint steers were distributed in high Slip point and high 18:0.

Stearic acid vs. palmitoleic acid



- Negative correlation.
- 16:1n-7 was highest in corn-fed steers.
- Japanese endpoint steers were distributed in high 16:1 and low 18:0.

Percentage intramuscular lipid as a function of slaughter age.



Abbreviations for breed types:
B, Japanese Black;
BHo, J. Black x Holstein;
BBHo, J. Black x J.Black/Holstein;
RBHo, J. Brown x J.Black/Holstein;
CBHo, Charolais x J. Black/Holstein; NBHo, J. Shorthorn x J. Black/Holstein.

All cattle were fed a high concentrate finishing diet. Zembayashi et al. (1999).

Diet effects on lipogenesis

- High-energy diet increased lipogenic enzyme activities (Prior and Scott, 1980).
- Corn diet increased ACC, FAS, ATP-citrate lyase, and NADP-malate dehydrogenase activities (Smith et al., 1984).
- Acetate is used as major carbon source in s.c. adipose tissue (Smith and Crouse, 1984).

Diet effects on lipogenesis

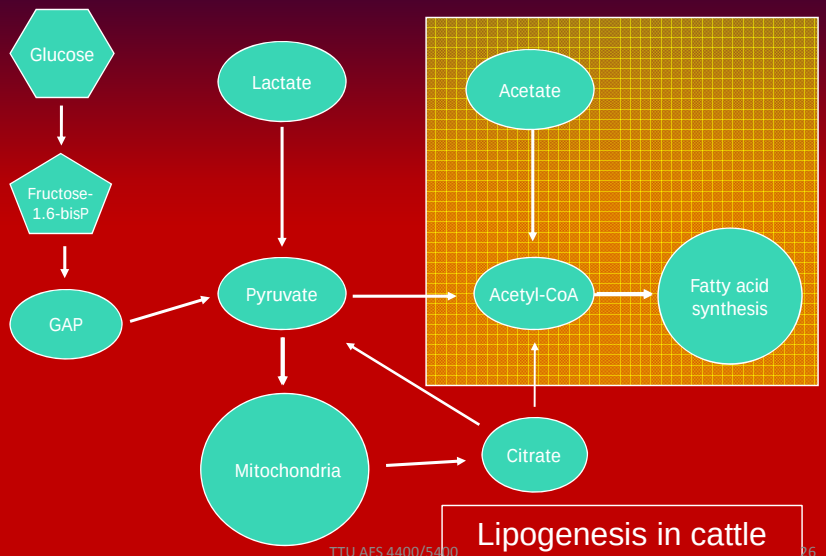
- Glucose is used as major carbon source in i.m. adipose tissue (Smith and Crouse, 1984).
- Corn-based diets increase bypass ratio.
- Corn-based diets increase propionate production in rumen.

Adipose Tissue

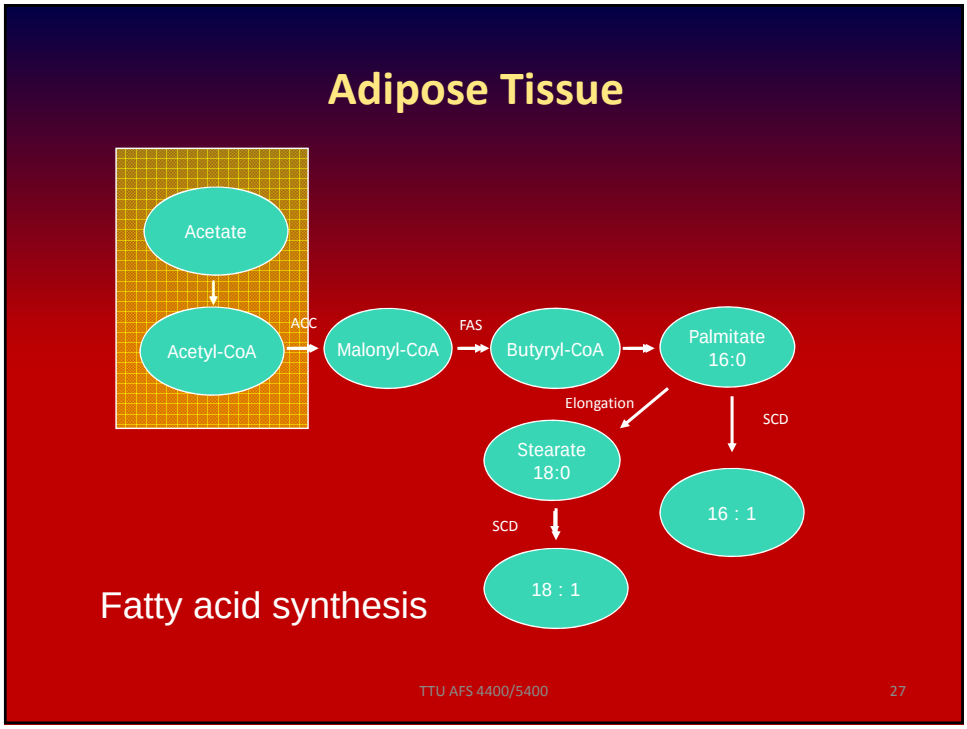
- **Fatty acid synthesis**

1. ***De novo* synthesis : synthesis from non-fatty acid precursors**
   a) **Carbohydrate precursors (glucose, lactate, and pyruvate)**
   b) **Amino acid precursors (alanine, branched-chain amino acids)**
   c) **Short-chain organic acids (acetate, propionate)**
2. **Lipogenesis : fatty acid or triacylglycerol synthesis**
   a) **From preformed fatty acids (from diet or *de novo* fatty acid synthesis)**
   b) **Requires source of carbon for glycerol backbone**

Adipose Tissue



Lipogenesis in cattle


Adipose Tissue
Acetate
Acetyl-CoA
ACC
Malonyl-CoA
FAS
Butyryl-CoA
Palmitate 16:0
Elongation
SCD
Stearate 18:0
16 : 1
SCD
18 : 1
Fatty acid synthesis
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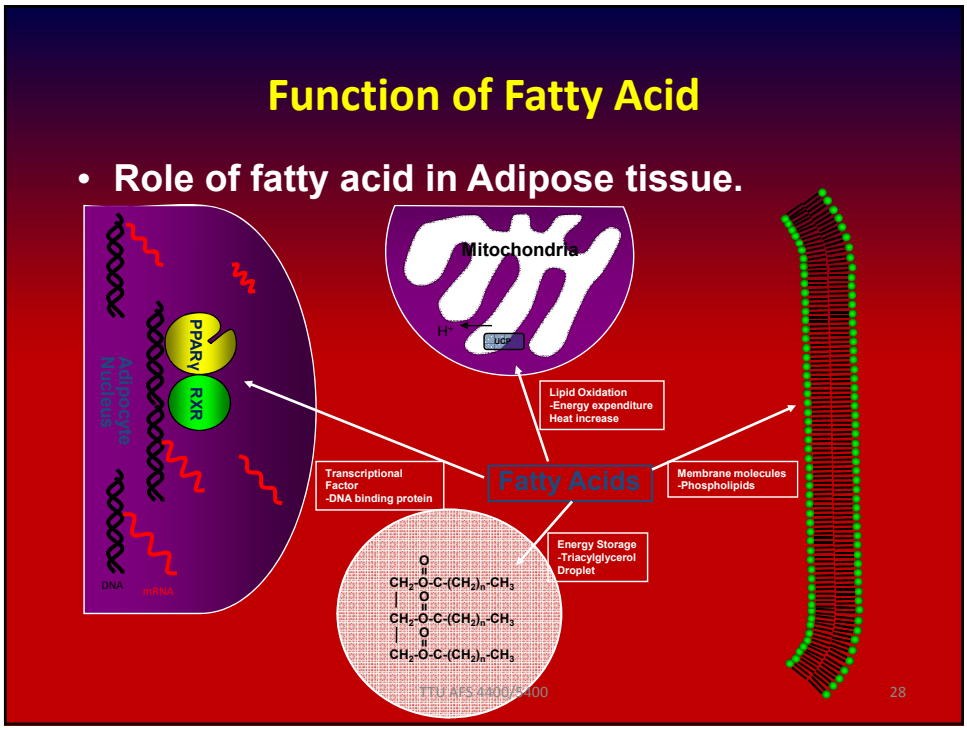
Function of Fatty Acid
• Role of fatty acid in Adipose tissue.
Mitochondria
H+
ucp
PPARγ
RXR
Adipocyte Nucleus
DNA
mRNA
Lipid Oxidation
-Energy expenditure
Heat increase
Transcriptional Factor
-DNA binding protein
Fatty Acids
Membrane molecules
-Phospholipids
Energy Storage
-Triacylglycerol
Droplet
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Adipose Tissue

- Types of Adipose Tissue
  - White adipose tissue (WAT)
    - signet ring, mature cell surrounded by clear epithelial layer
    - larger than brown (35-200 μm)
    - nucleus pushed to the outside by the lipid droplet

Adipose Tissue

- Brown adipose tissue (BAT)
  - small cells (20-25 μm)
  - much more connective tissue
  - gland-like appearance
  - many mitochondria
  - uncoupling proteins (UCP-1)

Adipocyte

Adipocytes = primary cell of AT; AT also contains other connective tissue, vascular tissue, and nerve cells

Preadipocyte Differentiation

- Preadipocyte Proliferation/Differentiation
  - cell line: 3T3-L1 → once differentiation begins, proliferation ceases
  - early marker of differentiation of 3T3-L1 is *SCD* (stearoyl coenzyme A desaturase)

Adipocyte

- Differentiation of Adipocytes
  - adipocytes are major TG-containing components of adipose tissue (85-95% of cell type)
  - adipocytes are differentiated from mesenchymal precursors
  - adipoblasts → preadipocytes (*in utero*)
    - both undergo cell division
  - preadipocytes are immature adipocytes that can still proliferate
  - hard to isolate preadipocytes in embryonic development
  - Thus, the majority of research has utilized a secondary cell line (3T3-L1; preadipocytes) derived from murine fibroblasts

Morphology of Adipocyte

- Perirenal adipocytes
- Proliferation: 10% fetal bovine serum + DMEM
- Differentiation: 5% fetal bovine serum + DMEM + insulin + Pioglitazone + MIX
- 15 d after treatment with differentiation media