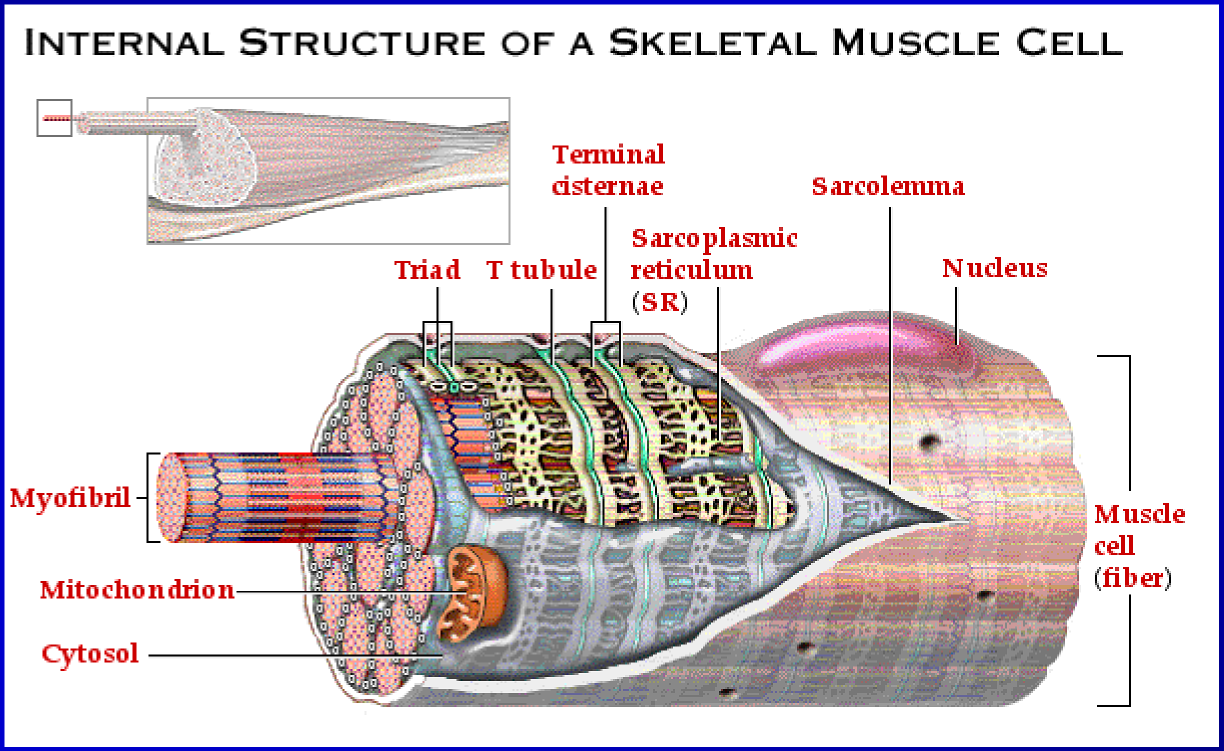
Composition of Muscle

CONSUMER SELECTION AND CARE ANSC 3404


Does this bikini make me look fat?

Composition of Muscle

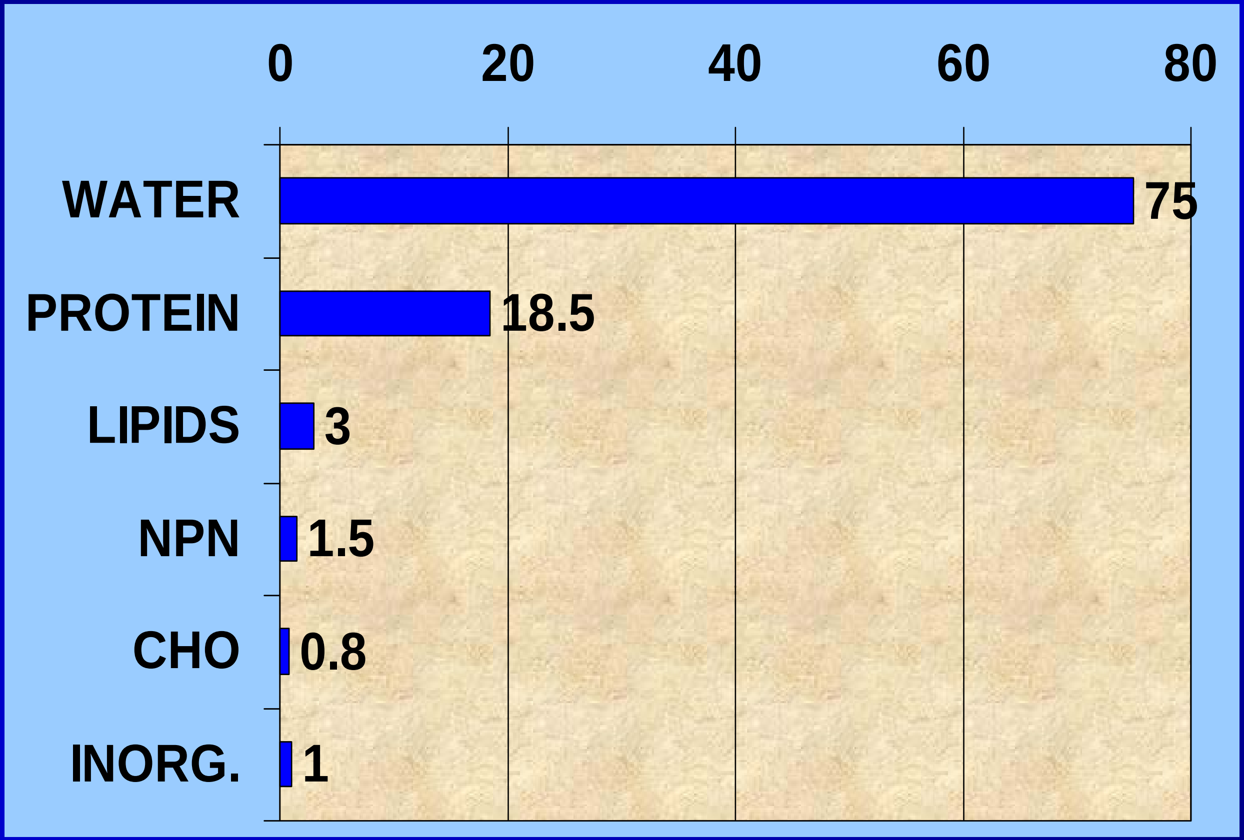


Objectives of this Unit

- To show the structure of animal tissues so that students can understand postmortem events that occur in muscles and how they affect meat properties.

- To show how animals and their muscles differ in composition and how these differences relate to our use of meat for food.

Composition of Muscle



Water (moisture) in muscle

- Varies inversely with fat content;
  - muscles with more fat contain less water. Practical range = 65 to 80%.

- If fat content of a muscle ranges from 0.5 to 30% at the extremes, what would be the water range?

- Affects initial juiciness
  - more water, more initial juiciness.

WATER (CONT'D)

- Water is a carrier of many intra- and inter-cellular constituents.

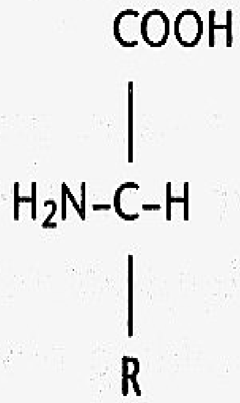
- In low fat meat products, water content is higher than in products with a higher fat content.
  - binders must be added to hold this extra water in the products.

PROTEIN

- Averages 18.5% In Muscle
- Is The Least Variable Major Component
- Is The Most Important Component Nutritionally
- Is The Food Component In Shortest Supply In World Food

PROTEINS ARE COMPOSED OF AMINO ACIDS: NH_2 AND COOH GROUPS

All amino acids have the following basic structure:



Amino Acids

Table 23–1. Amino Acids

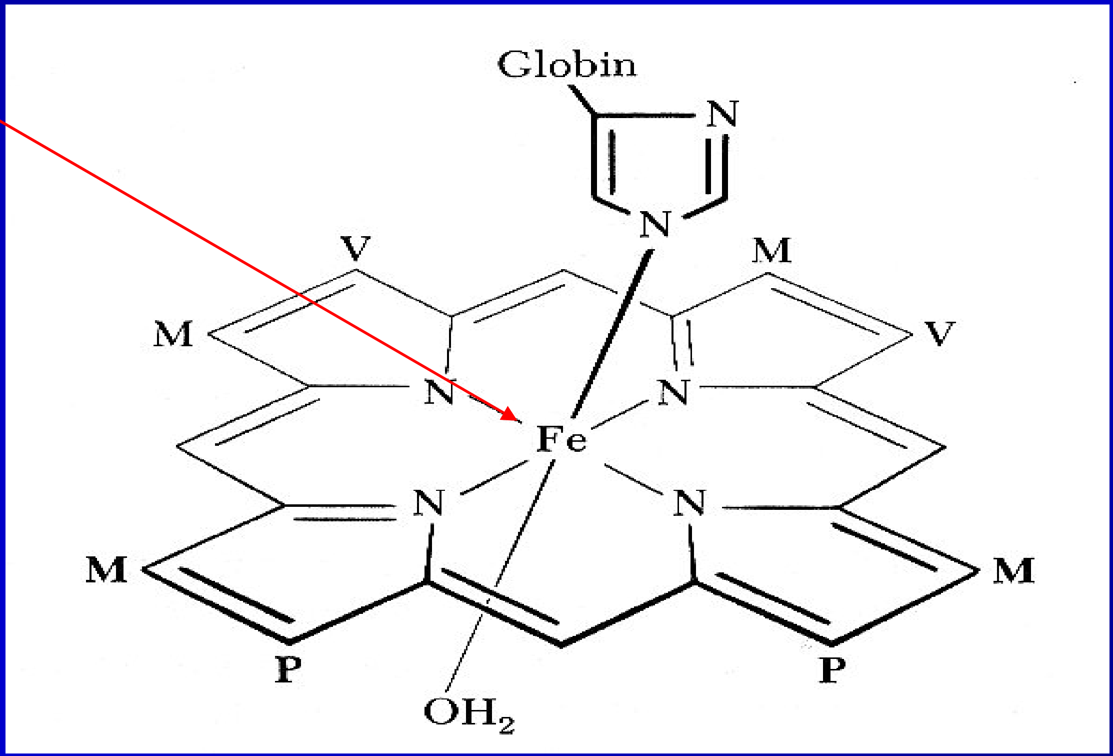
Essential	Nonessential	Less Common, Nonessential
Histidine (His)	Alanine (Ala)	Cystine $(Cys)_2$
Isoleucine (Ile)	Arginine (Arg)	Hydroxyproline (Hyp)
Leucine (Leu)	Asparagine (Asn)	Hydroxylysine (Hyl)
Lysine (Lys)	Aspartic acid (Asp)	Citrulline
Methionine (Met)	Cysteine (Cys)	B-alanine
Phenylalanine (Phe)	Glutamine (Gln)	Aminobutyric acid
Threonine (Thr)	Glutamic acid (Glu)	Diaminopimelic acid
Tryptophan (Trp)	Glycine (Gly)	Dihydroxyphenylalanine
Valine (Val)	Proline (Pro)	Ornithine
	Serine (Ser)	Taurine
	Tyrosine (Tyr)	

KINDS OF PROTEIN IN MUSCLES

- Myofibrillar - 9.5%
  - Principal ones are Actin and Myosin
- Sarcoplasmic - 6.0%
  - Enzymes and pigments.
  - The two principal pigments are Myoglobin and Hemoglobin.
  - Hemoglobin in red blood cells Carries O_2 from the lungs to cells.
  - Myoglobin Stores O_2 in the cells.

Myoglobin

Important



More About Pigments

- Meat color reactions are very important to its appearance and will be studied later in detail. A sample will be shown later.

- Which of the two pigments (hemoglobin or myoglobin) is predominant in postmortem muscle? Why?

Hemoglobin and myoglobin contents of *longissimus* and *psoas major* muscles of five beef carcasses

	Longissimus		*Psoas major*	
Carcass	Hemoglobin	Myoglobin	Hemoglobin	Myoglobin
1	.64	2.66	.75	2.48
2	1.04	2.47	.82	3.93
3	.80	4.27	.83	3.68
4	.91	3.16	1.22	3.63
5	.70	4.65	.972	4.31

Source: Han et al. (1994), J. Food Sci. 59:1279.

Myoglobin State Affects Color

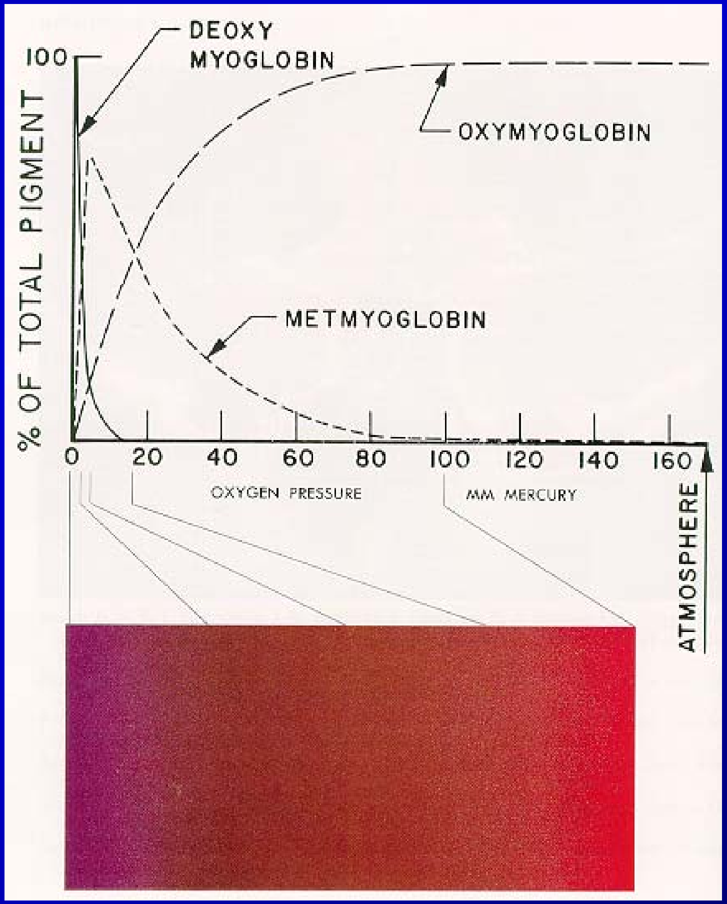
DEOXYMYOGLOBIN

(OXYGENATION)

OXYMYOGLOBIN

(OXIDATION)

METMYOGLOBIN



MYOGLOBIN CONTENT OF MUSCLE

Kind of animal	Myoglobin, %
Pigs	.06
Sheep	.25
Cattle	.50
Blue whale	.91
Sperm whale & seal (long diving species)	5 - 8

More Proteins

- Stromal - 3.0%
  - connective tissues (ct)
  - collagen, elastin , reticulin
  - the "skeleton" of a muscle.
- Collagen predominates (the most abundant protein in mammals) and can affect tenderness greatly
  - as an animal ages, collagen forms a network & becomes less tender.
- Collagen degrades to gelatin at 65°C with moist heat cookery.

Elastin

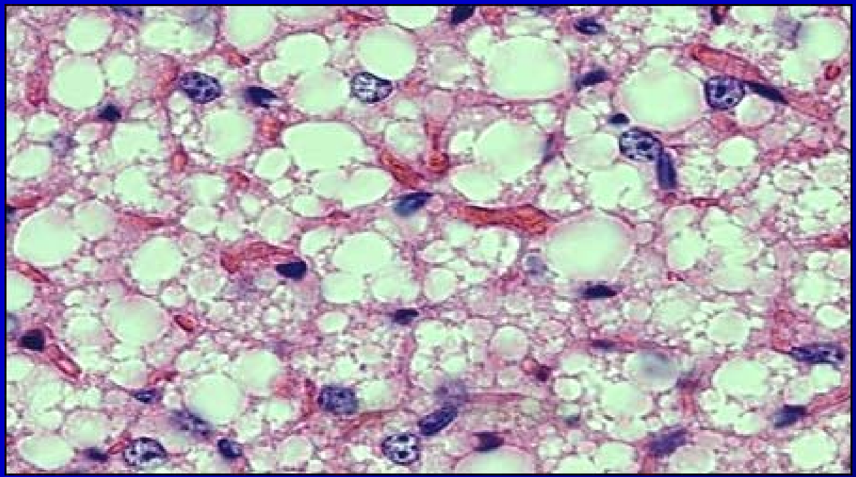
- Elastin does <u>not</u> degrade to gelatin with moist heat cookery
- An example of elastin is the *ligamentum nuchae* (backstrap) that courses along the spinous processes of the cervical vertebrae
- Elastin imparts elasticity to arterial walls

PHOTOMICROGRAPHS OF CONNECTIVE TISSUE

OTHER TISSUES HAVE BEEN LEACHED OUT

Lipids - Fats and Oils

- Influence flavor, juiciness and caloric content of meat
  - Have a small effect on tenderness
- Average 3% in muscle
- Muscle with a “Devoid” marbling score will still have about 0.5% fat content



Kinds of Lipids

- NEUTRAL LIPIDS - 1%
- PHOSPHOLIPIDS - 1%
- CHOLESTEROL - 0.5%

NEUTRAL LIPIDS

Tryglycerides = 3 mole of fatty acid attached to a glycerol

CH_2OH — $H_2C\text{-}O\text{-}C(CH_2)_{16}CH_3$

l — l

$CHOH$ + $3\ HOOC(CH_2)_{16}CH_3$ → $HC\text{-}O\text{-}C\text{-}R$ + $3\ H_2O$

l — l

CH_2OH — $H_2C\text{-}O\text{-}C\text{-}R$

GLYCEROL + STEARIC ACID → TRISTEARIN

KINDS OF TRIGLYCERIDES

- If the same kind of fatty acid occupies all three positions on the glycerol molecule, the result is a simple triglyceride.

- If more than one kind of fatty acid is attached to glycerol, the result is a mixed triglyceride.

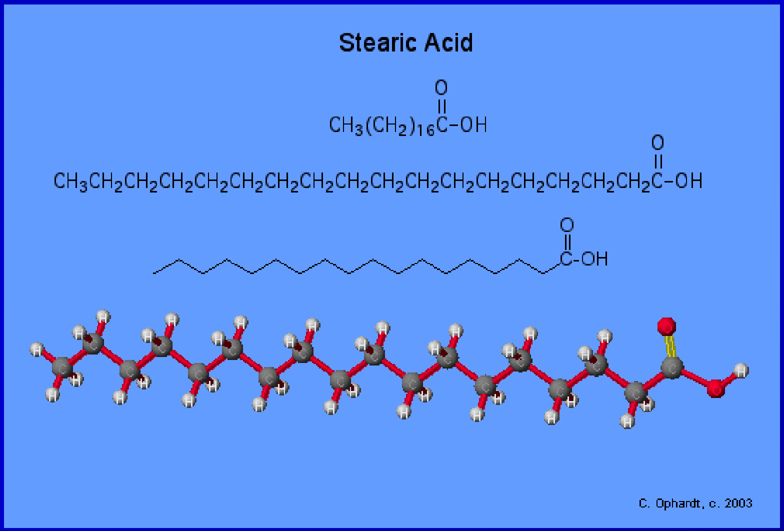
- What determines what kinds of tri- glycerides an animal manufactures?

SATURATED FATTY ACIDS

Stearic Acid – Saturated Fatty Acid

No double bonds between carbon atoms

Third most predominant FA in meat animals

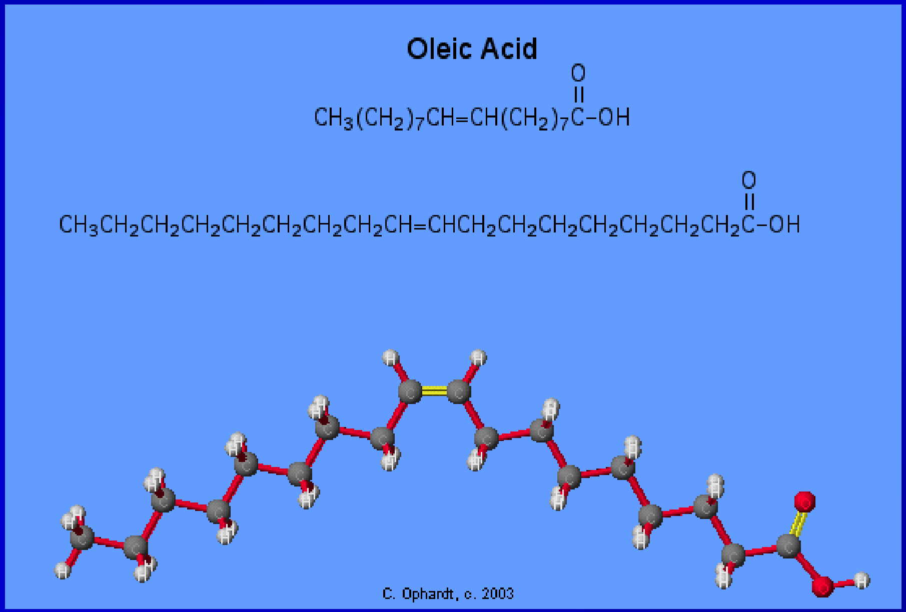


UNSATURATED FATTY ACIDS

OLEIC ACID :

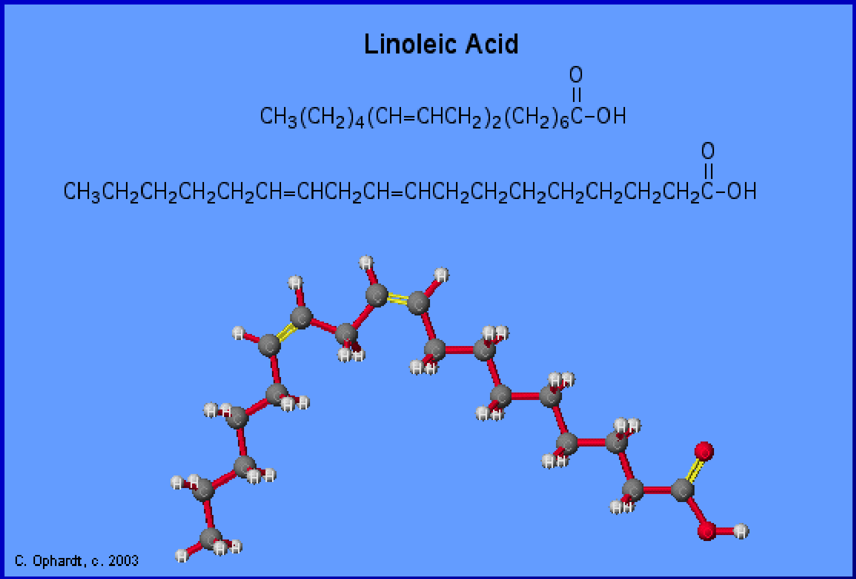
The most prevalent fatty acid in animal fats

Mono-saturate fatty acid (contains one double bond)



Polyunsaturate Fatty Acids

- Linoleic Acid
  - Polyunsaturate fatty acid
  - Has two (or more) double bonds



Reactivity of Fatty Acids

- Unsaturated fatty acids are more reactive
- O_2 attaches at double bonds
  - Results in rancidity and oxidation

Kinds of Fats in Beef and Poultry

Meat	Saturated Fat	Monsaturated Fat	Polyunsaturated Fat	Cholesterol
Top Round	35%	39%	5%	72 mg
T-bone	40%	40%	4%	68 mg
Ground Beef (80% lean)	39%	44%	4%	74 mg
Chicken Breast (skinless)	29%	35%	21%	72 mg
Turkey (skinless)	32%	18%	27%	59 mg

Melting Points of Some Fats

Pork	
Backfat	86°–104°F
Leaf fat	110°–118°F
Beef	
External fat	89°–110°F
Kidney fat	104°–122°F
Lamb	
External fat	90°–115°F
Kidney fat	110°–124°F
Poultry	
Abdominal fat	80°–110°F

WHY THE RANGES AND SPECIES DIFFERENCES?

In General:

- Fats with longer carbon chains and more saturation have higher melting points.

- Internal fats are more saturated and have higher melting points than external fats

- Why?

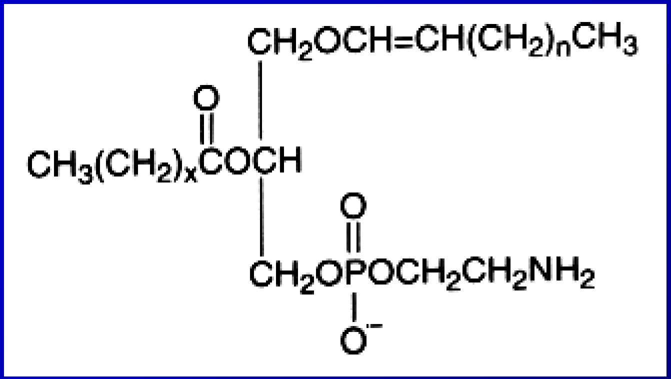
What practical difference does melting point of fats *per se* make in animal bodies and in industry?

The Third Kind of Lipids

- Phospholipids - compounds containing phosphorus and lipids

  An example is ethanolamine

Function in rancidity development in fats.



The Fourth Kind of Lipids

- Cholesterol - that much maligned, essential dietary component.
- Required for hormone function and cell wall integrity.
- About 20% of body needs is consumed whereas, 80% is manufactured.
- If we don't eat enough, our bodies manufacture more.
- Contrary to popular belief, cooked meats of different species vary little in cholesterol content.

NPN – Non - Protein Nitrogen

- About 1.5% in muscle
- Molecules contain nitrogen but are not proteins
- Some NPN compounds contribute to meat flavor
- NPN example
  - ATP (Adenosine triphophate)

CHO - Carbohydrates

- About 1% (0.8%) found in muscle
  - ranges from 0.5 - 1.5% in muscle.
- Although low in amount, CHO's play large roles in meat properties and appearance.
- Best example is Glycogen
  - storage form composed of glucose units

Inorganic Compounds - Minerals

- About 1% in muscle
- Measured as ash after burning samples in a muffle furnace
- Meat (particularly beef) is a good source of some minerals, particularly Fe and Zn.
- Fe in meat is in a heme form that is more readily available than Fe from plants.
- Zn is in many enzymes and hormones, including sex hormones.

How to Calculate Caloric Values

- Fats contain 9 calories/gram

- Proteins and CHO's contain 4 calories/gram

- Fats contain 2.25 (9 / 4) times as many calories as proteins & CHO's

- Calories usually are calculated on a per-100-gram basis

- If so, percentages of composition can be used directly in equations because percentages are parts/100

How Many Calories in 100g of Average Muscle on a Raw Basis?

- 75% water, 3% fat, 18.5% protein, 1% CHO, and 1% ash

- Water and minerals contain no calories so:
  - (3 * 9) + (18.5 * 4) + (1 * 4) = 105 kcal
    - This 3% fat would represent the muscle from Select Grade Beef.

- Is 105 calories per 100 grams a high, medium, or low value for foods?

Assume we Buy Choice Grade Instead of Select Grade

Muscle composition might be 70% water, 8.5% fat, 18% protein, 1% CHO and 1% ash on a raw basis

(8.5 * 9) + (18 * 4) + (1 * 4) = 153 kcal

153 - 105 = 48 more calories by going from Choice to Select beef

Caloric Values for Cooked Meats

Food	**Kcal/100g**
Beef with ¼ inch trim	216
Fried Hamburger – 15% fat	240
Pork Ham	211
Fried Chicken without skin	219
Fried chicken leg without skin	208
Fried catfish	228

Fat, Protein and Caloric Content of Differing Beef Quality Grades

Quality Grade	**Marbling**	**Fat, %**	**Calories from Fat**	**Protein, %**	**Calories from Protein**	**Total Calories**
Select	Slight	3.7	66	26.0	208	275
Low Choice	Small	5.2	93	25.6	204	298
Mid Choice	Modest	6.7	120	25.2	201	322
High Choice*	Moderate	8.2	147	24.8	198	346

* Meets marbling specification for Certified Angus Beef products

Why be Concerned About Calories?

- Assume we eat lower calorie foods and eliminate 47 calories/day
- 47 * 365 = 17,155 calories / year
- About 3,000 calories equate to 1 lb. of body weight gain
- 17,155 / 3,000 = 5.7 lb. of weight not gained each year

Structure and Function of Muscle

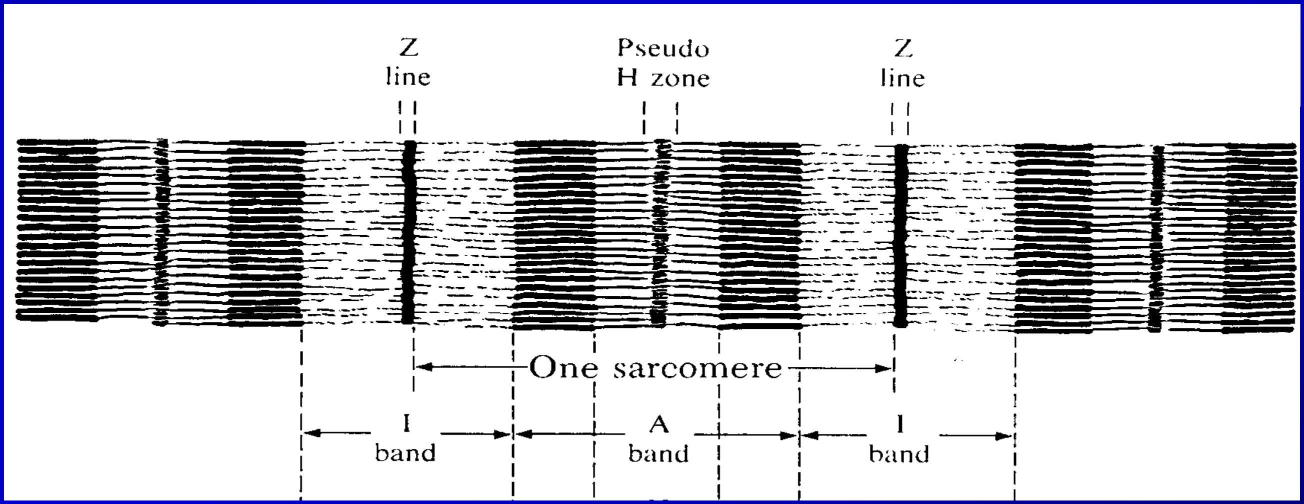
Purpose:

A fully understanding of muscle function is required to understand the conversion of muscle to meat.

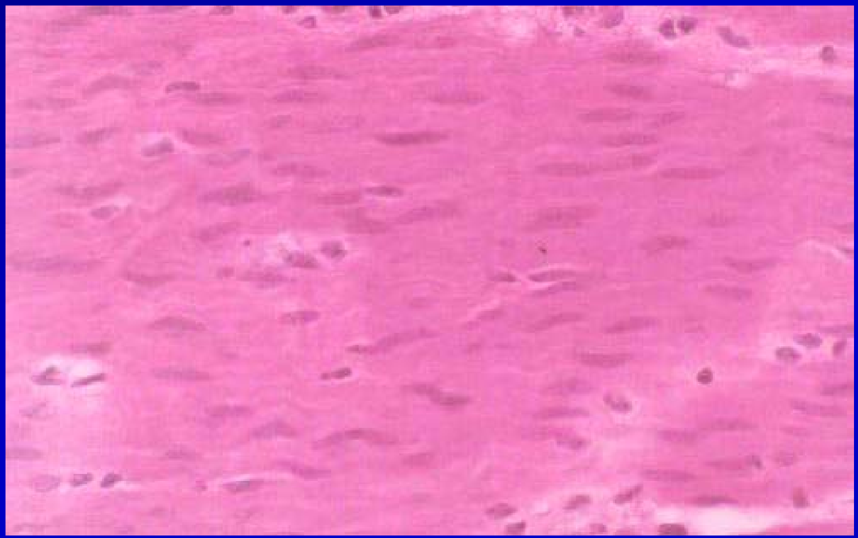
Thaw Rigor

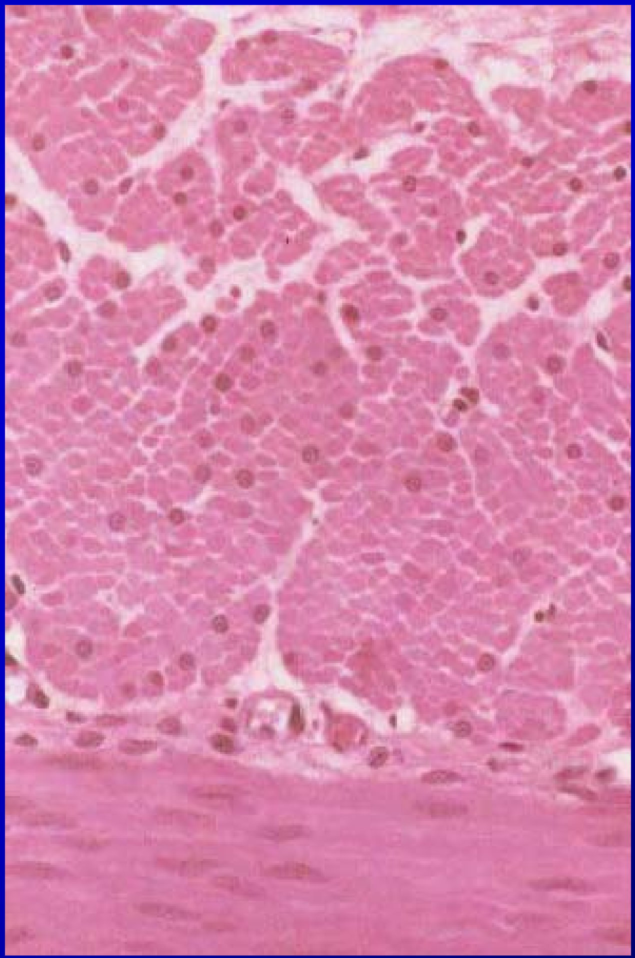
Muscle Types

	SKELETAL	SMOOTH	CARDIAC
METHOD OF CONTROL	VOLUNTARY	INVOLUNTARY	INVOLUNTARY
BANDING PATTERN	STRIATED	NON-STRIATED	STRIATED
NUCLEI/CELL	MULTI	SINGLE	SINGLE

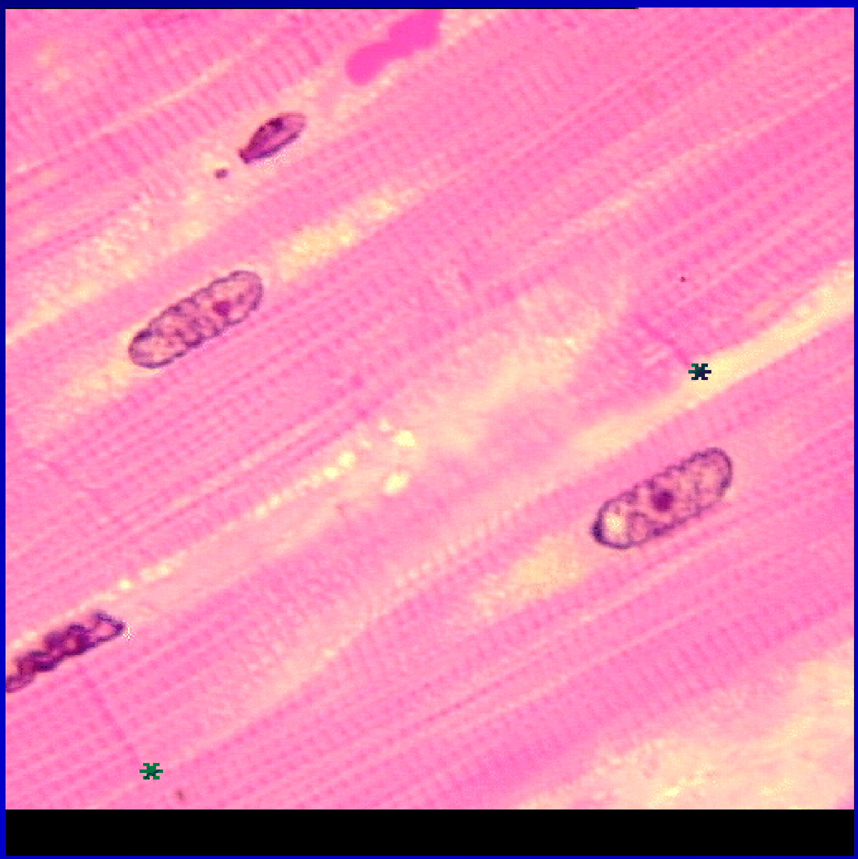


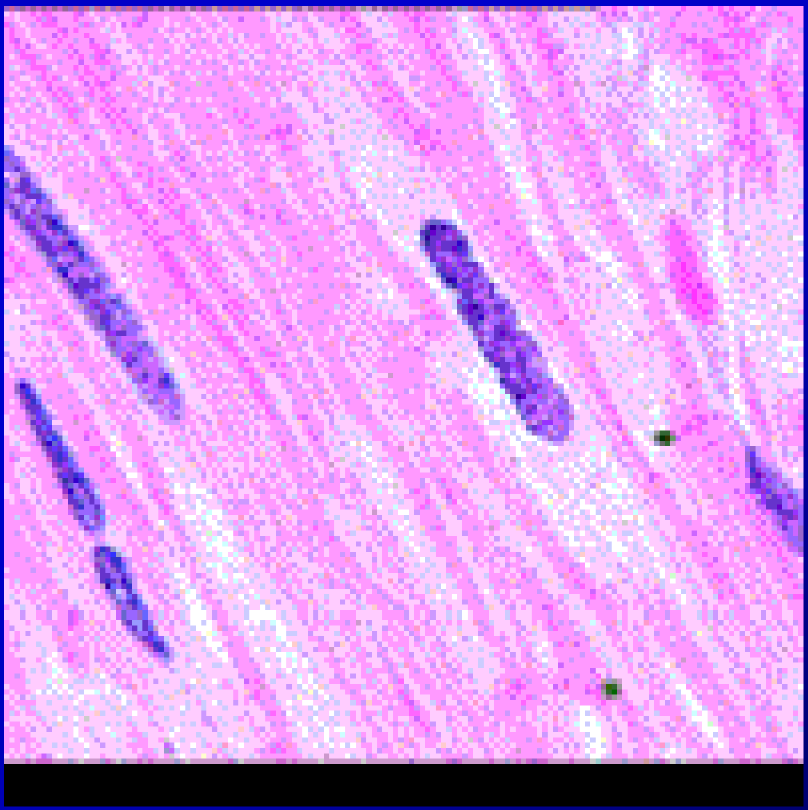
SMOOTH MUSCLE



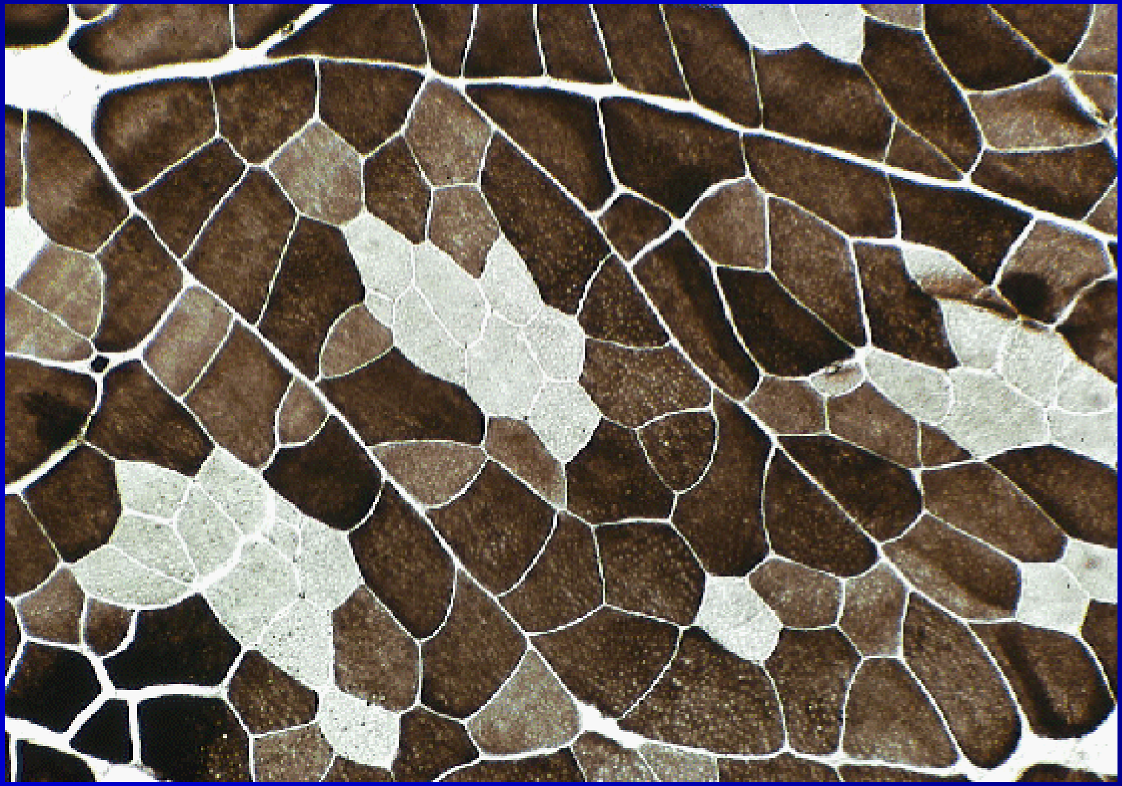


Cardiac Muscle





Red and White Fibers in Muscle

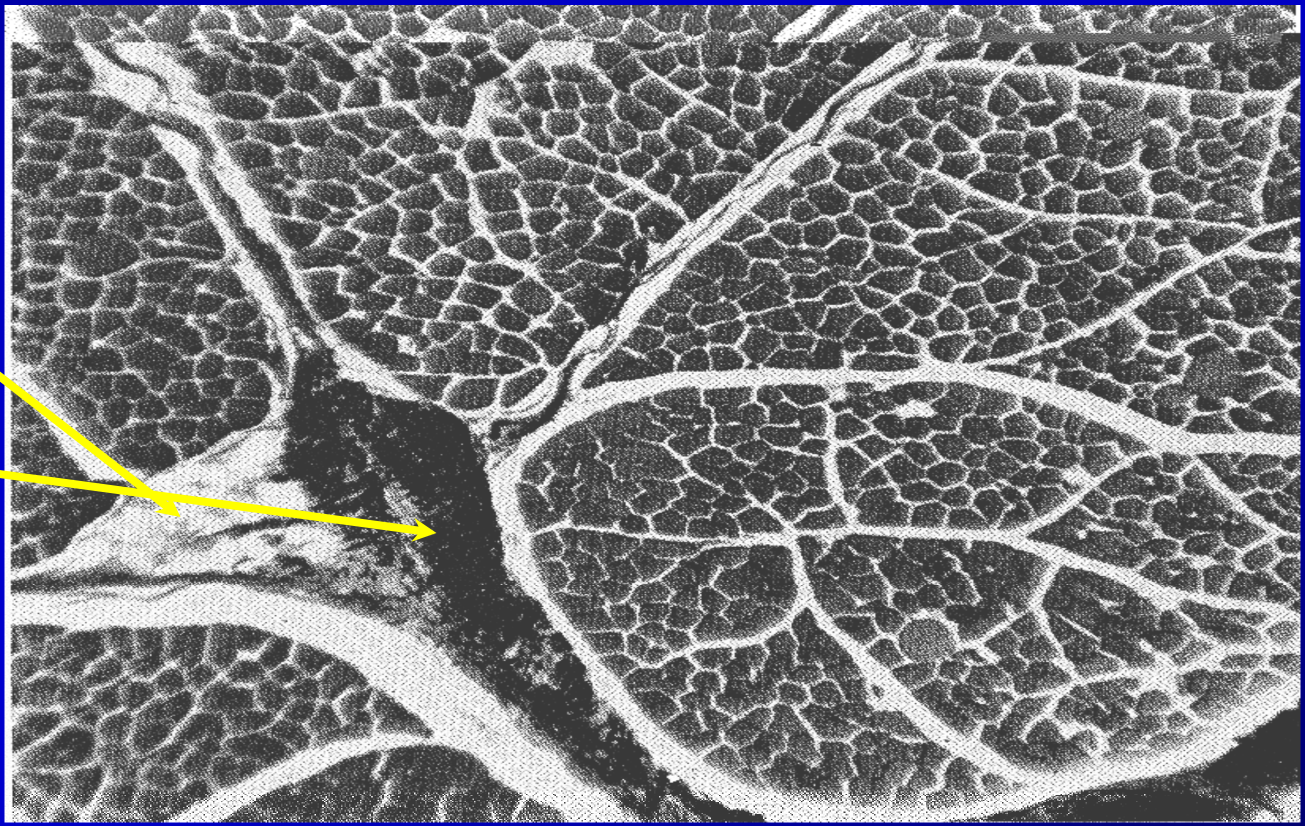


Fibertypes

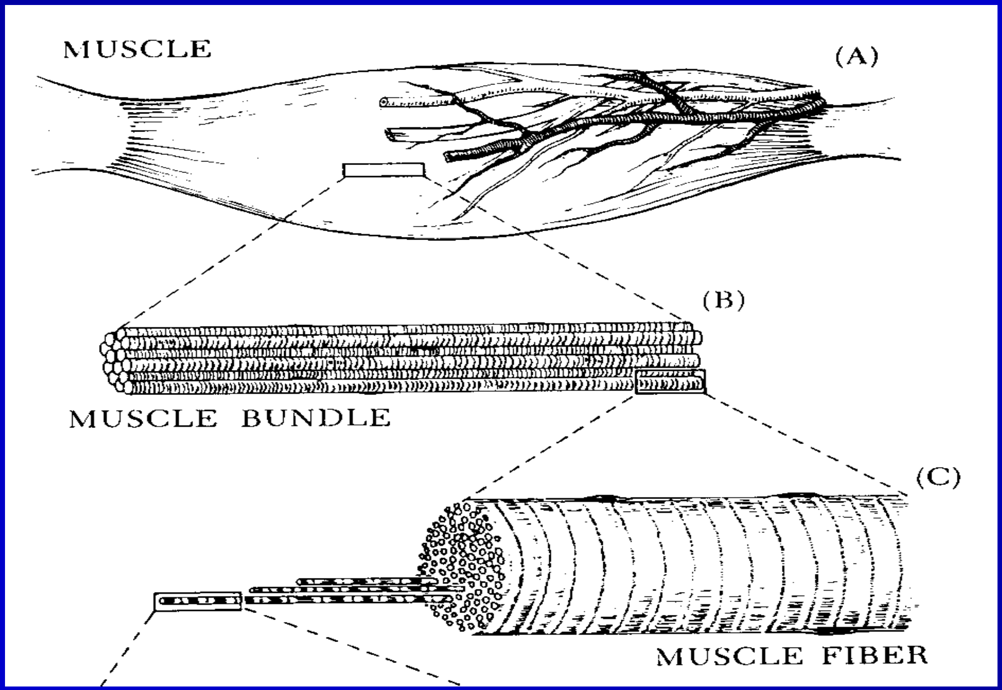
Characteristics	Type 1	Type 2A	Type 2X(D)	Type 2B
Reddness	++++	+++	+	+
Myoglobin content	++++	+++	+	+
Fiber diameter	+	+	+++	++++
Contraction speed	+	+++	+++	++++
Fatigue resistance	++++	+++	+	+
Contractile action	tonic	tonic	phasic	phasic
Number of mitochondria	++++	+++	+	+
Mitochondria size	++++	+++	+	+
Capillary density	++++	+++	+	+
Oxidative metabolism	++++	++++	+	+
Glycolytic metabolism	+	+	+++	++++
Lipid content	++++	+++	+	+
Glycogen content	+	+	++++	++++
Z disk width	++++	+++	+	+

* The characteristics are relative to the other fiber types.

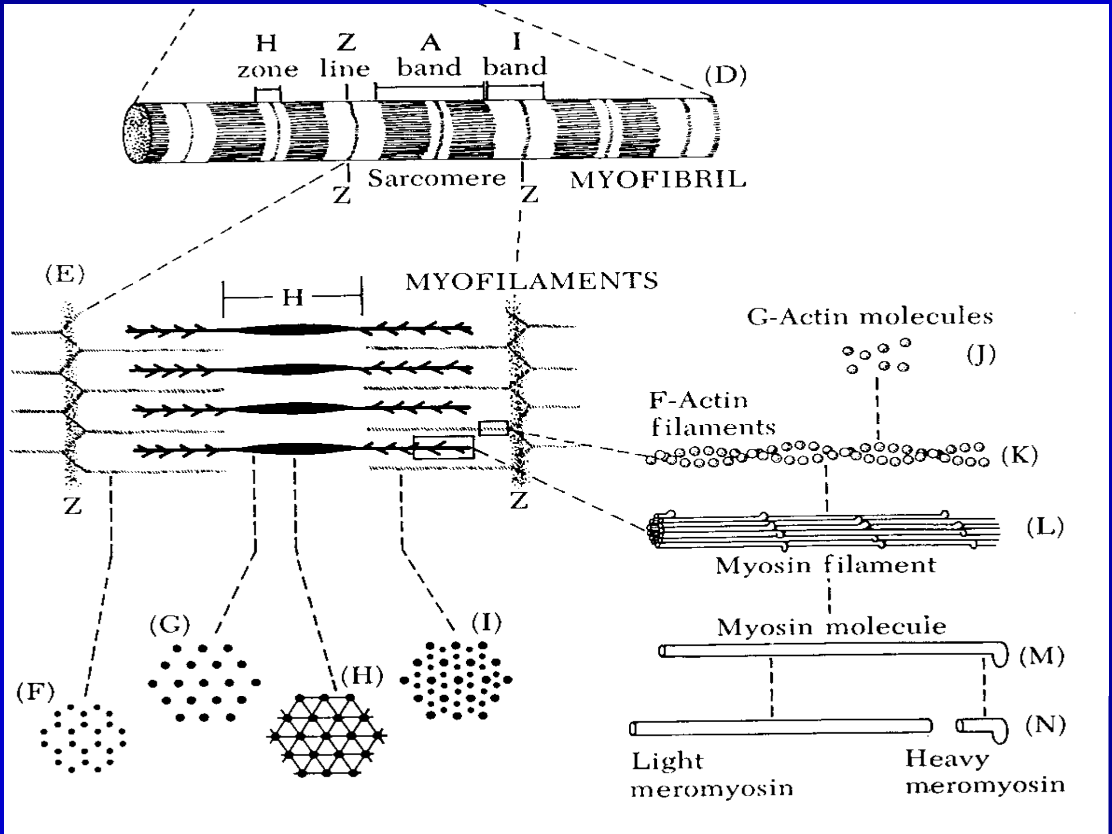
Muscle Cross Sections Showing Bundles of Myofibers



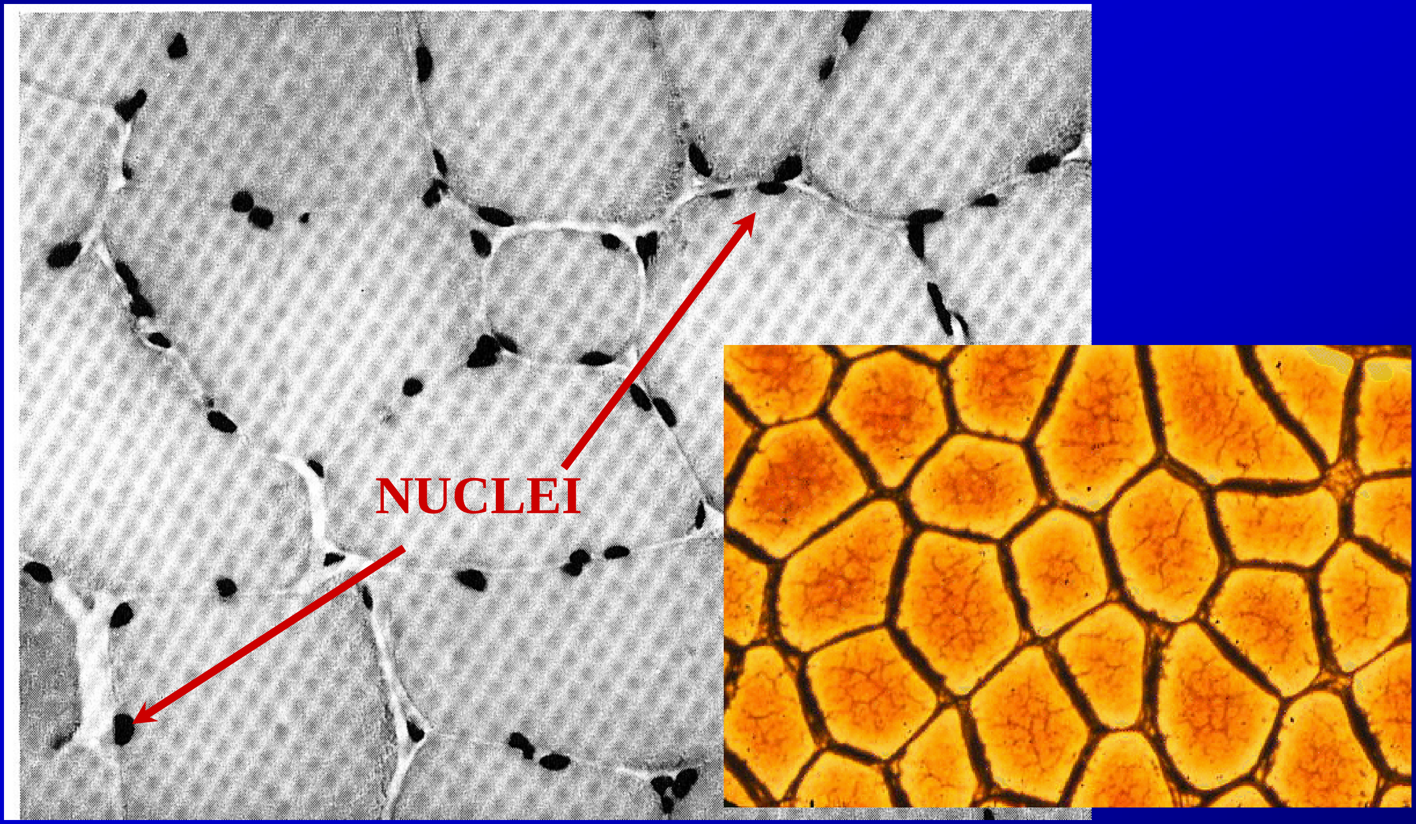
Structure of Muscle



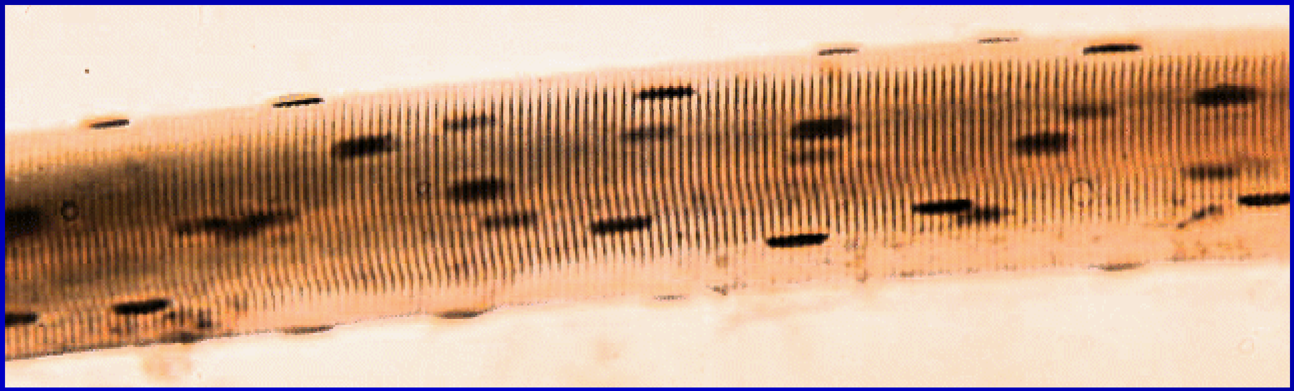
Structure of Muscle (Cont)



Cross Section of Muscle Fibers

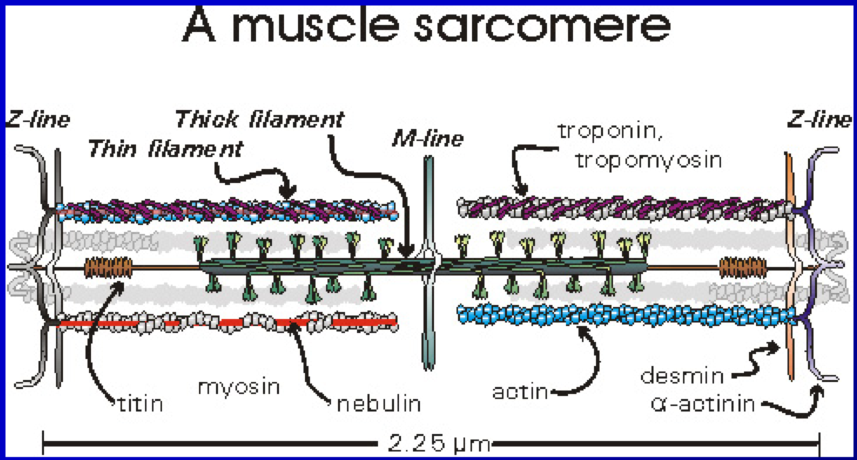


Myofiber



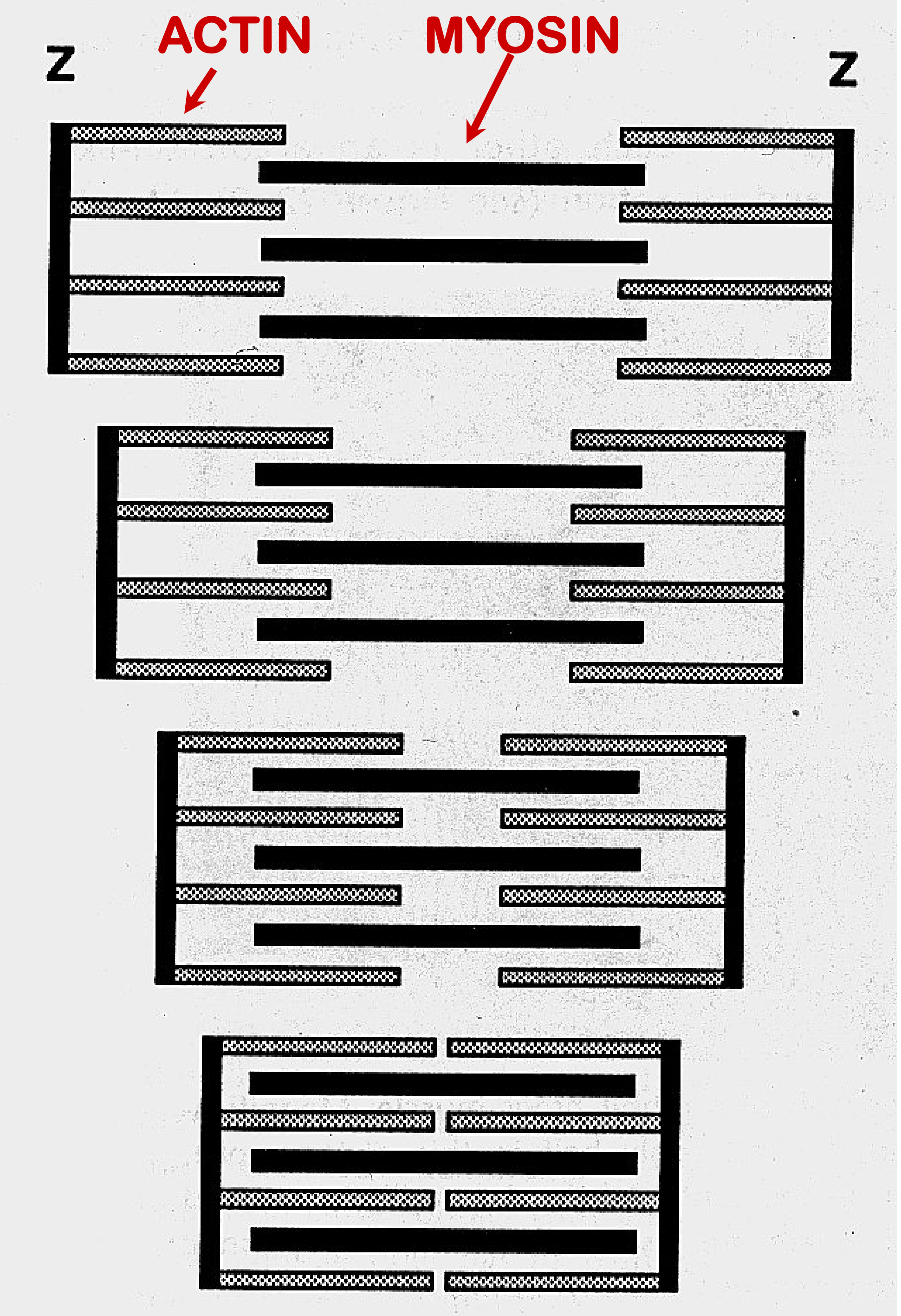
Sarcomere

- Functional unit of a muscle
- Runs from z-line to z-line
  - Actin
  - Myosin

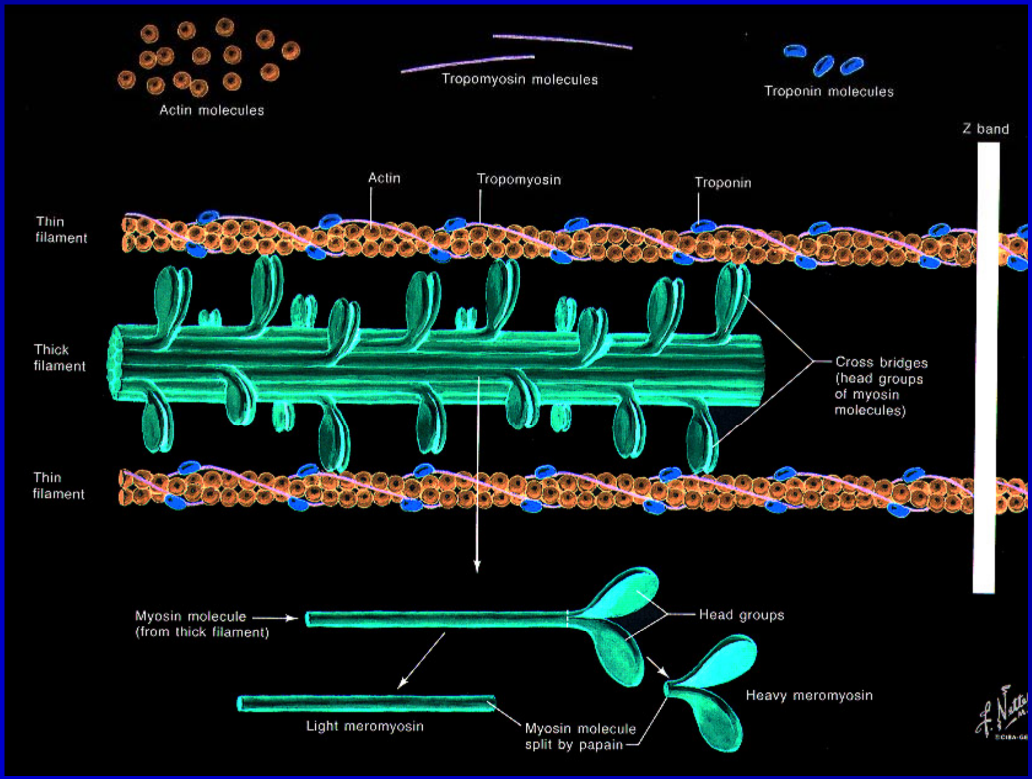


A sarcomere contracting

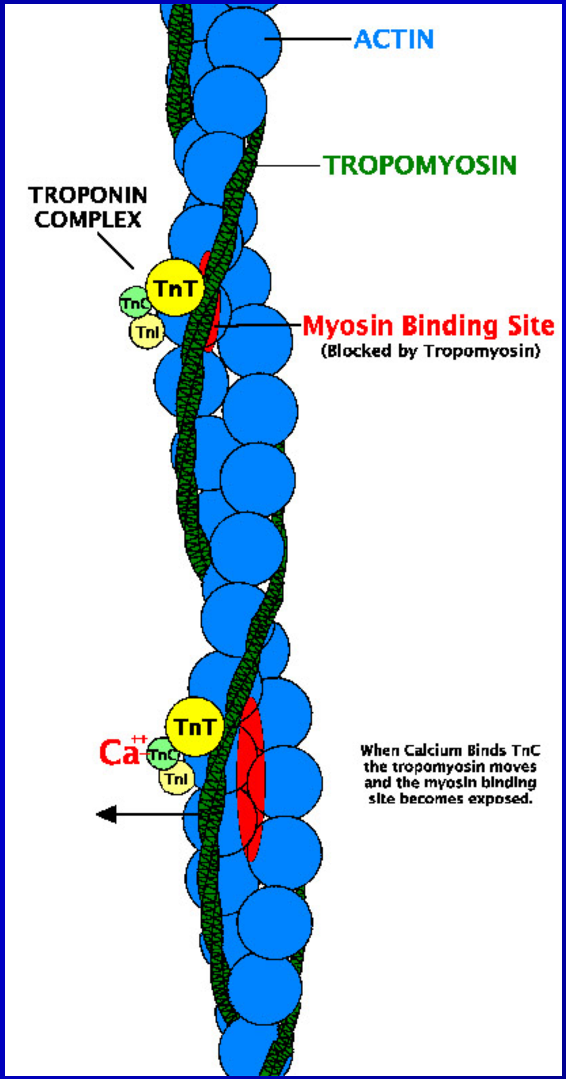
Notice that neither filament changes length



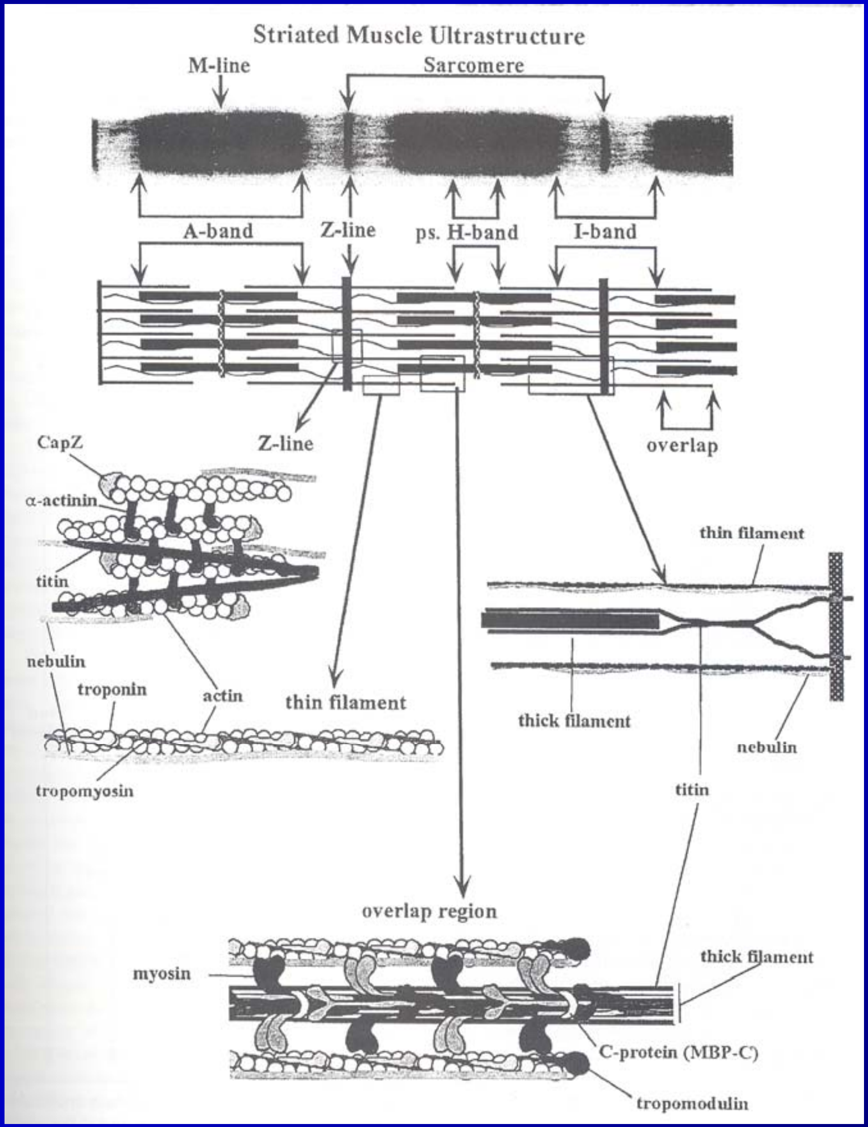
Myosin Filament



Actin Filament



Muscle Structure



Critical Contractile Proteins

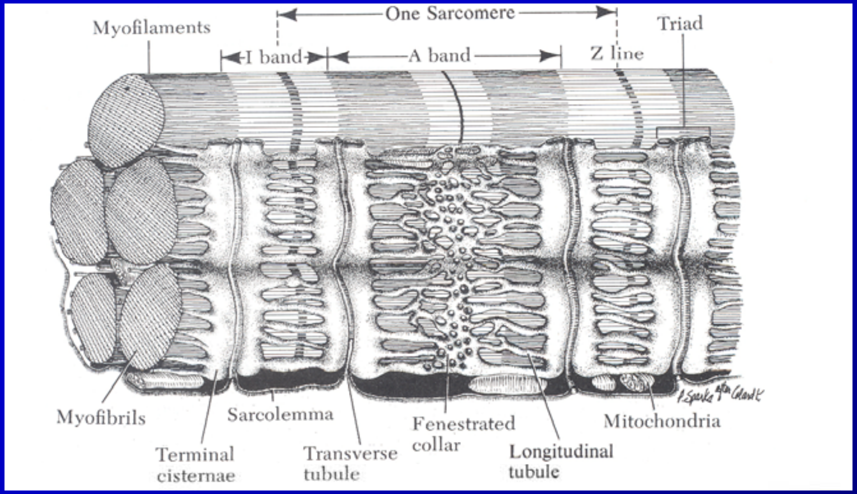
Table 22–2. Proteins of the Myofibril

Protein	Molecular Weight	Subunits	Location	% Myo-fibrillar Protein
Contractile				
Myosin	520,000	2 of 220Kd[1], 4 of 20Kd	Thick filaments	43
Actin	42,000		Thin filaments	22
Tropomyosin	68,000	2 of 34Kd	Thin filaments	5
Troponin	69,000	30Kd, 21Kd, 18Kd	Thin filaments	5
Structural				
Titin	2,800,000		Full sarcomere	8
Nebulin	600,000		Thin filaments	3
C protein	140,000		Thick filaments	2
α–actinin	200,000	2 of 100Kd	Z lines	2
M protein	160,000		M lines	2
Desmin	55,000		Z lines	<1

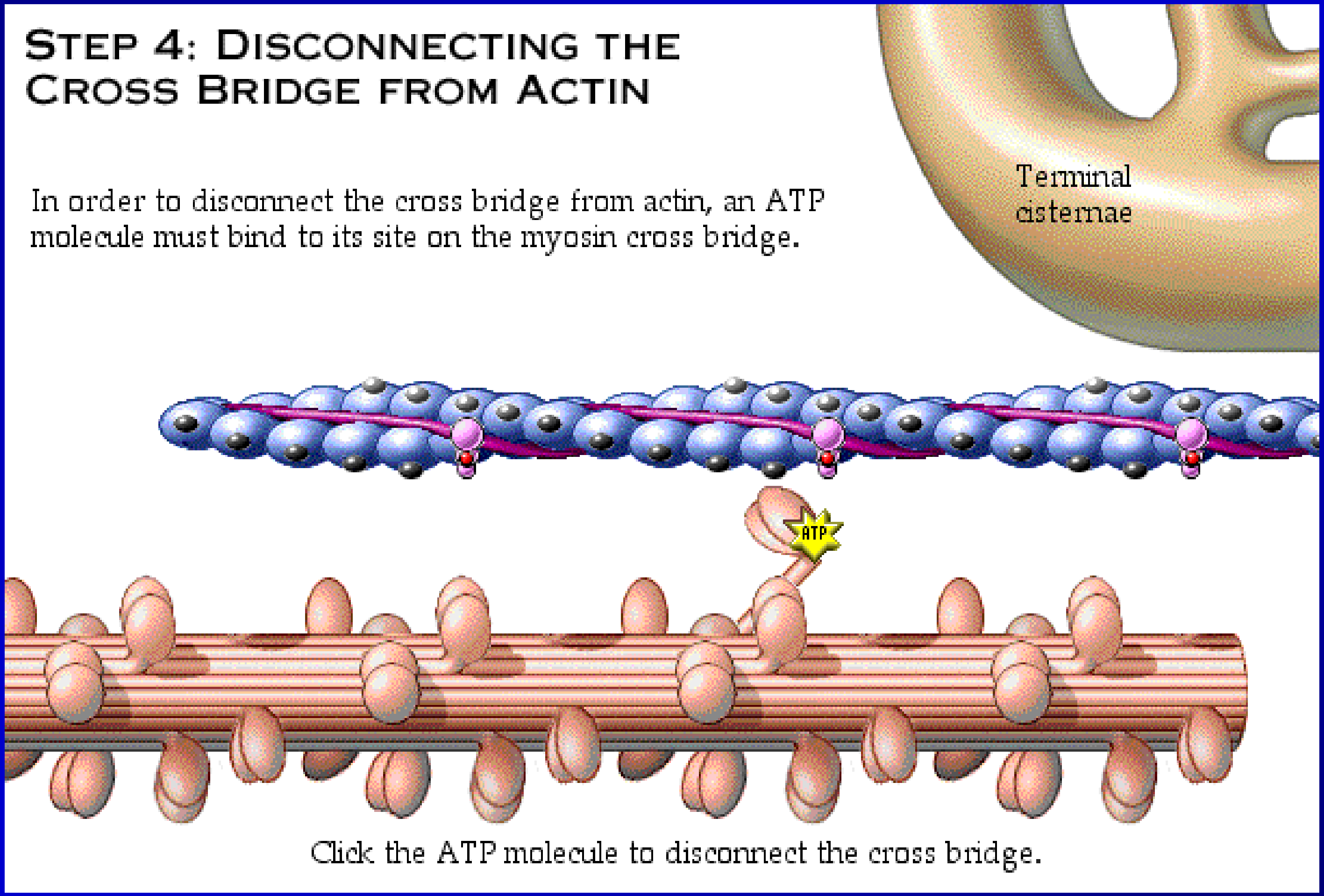
[1]Kilodalton = 1,000 daltons. One dalton is a unit of mass very nearly equal to that of a hydrogen atom.

The Sarcoplasmic Reticulum

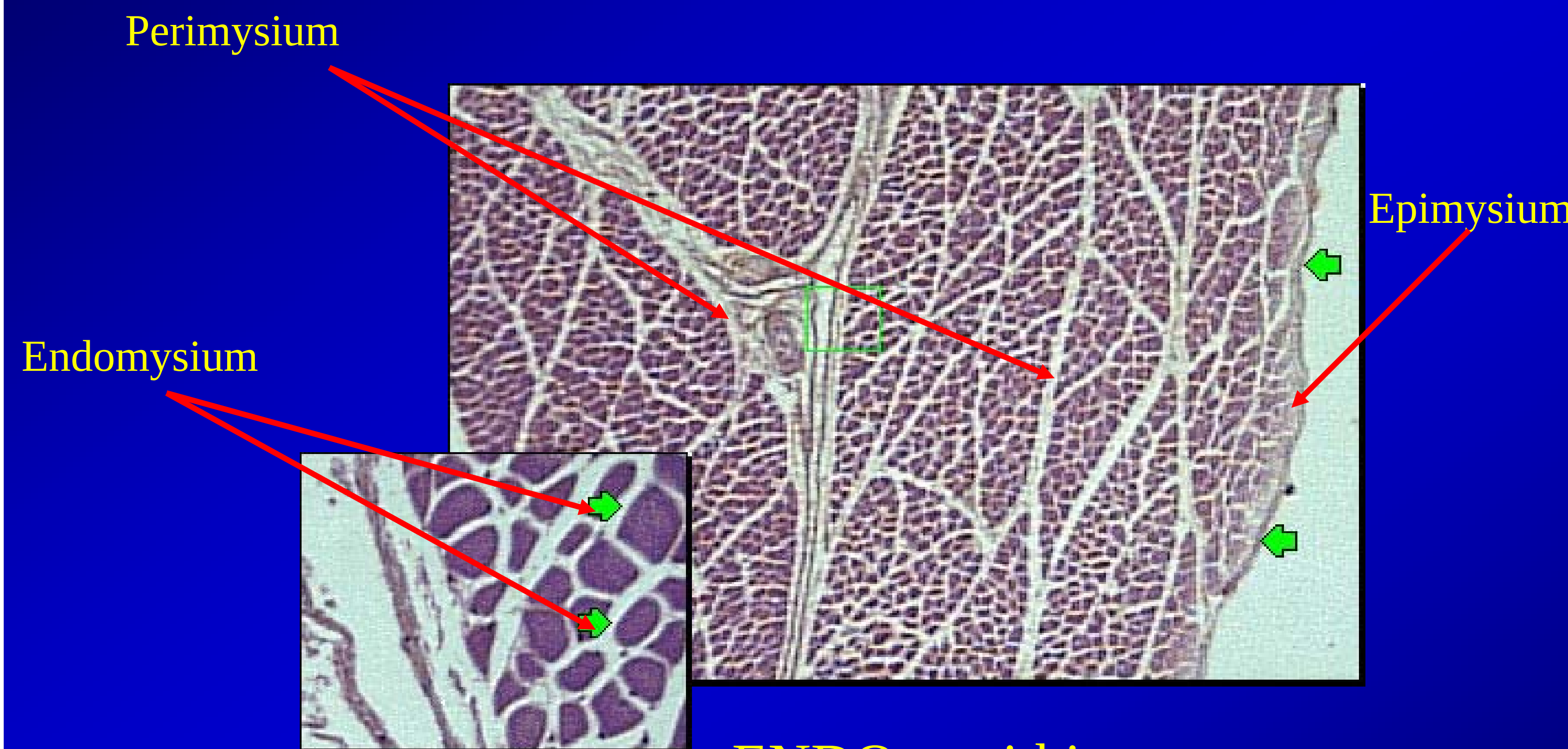
- Sarcoplasmic reticulum
  - T-tubule
- Calcium Storage
- Required for contraction



Contraction

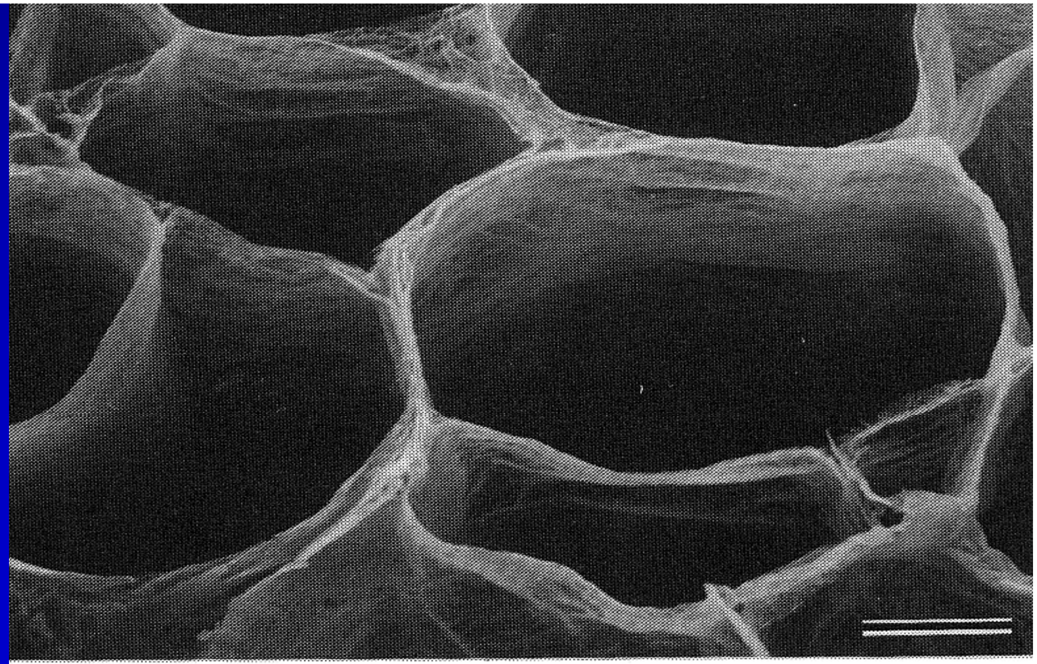


Position of Mysiums in Muscle



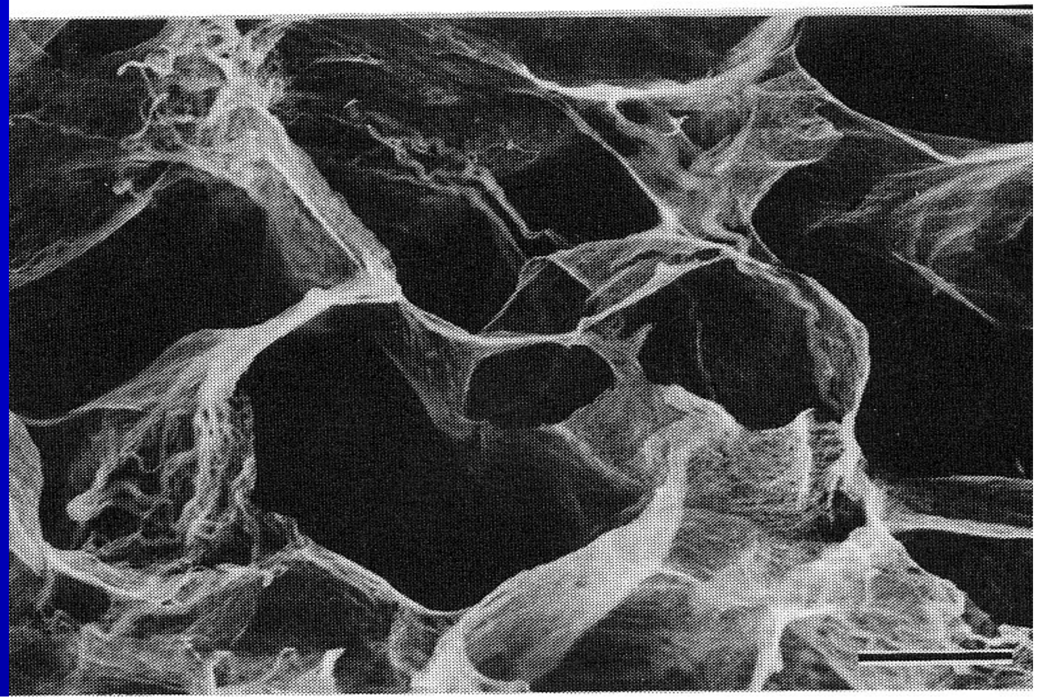
ENDO = within
PERI = around
EPI = upon

• Endomysium from muscle not aged

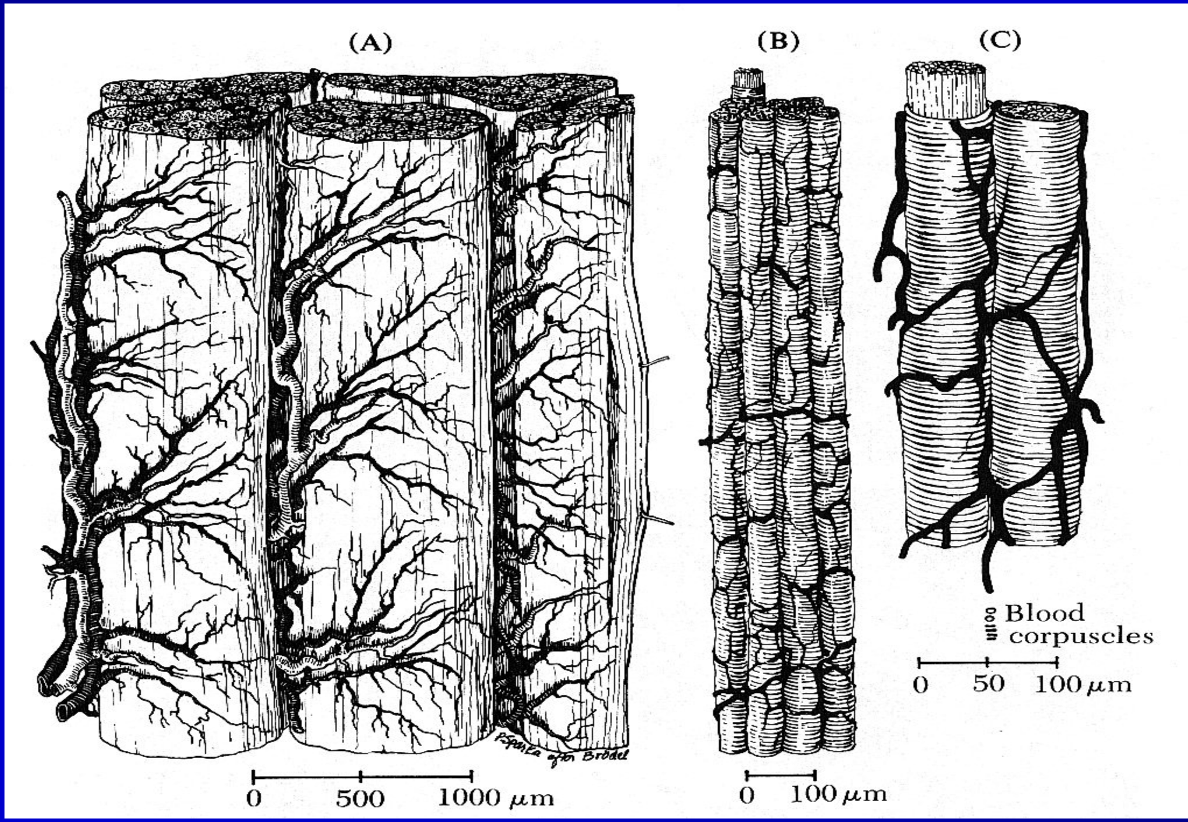


(a)

• Endomysium after cooler aging (28 D At 4^{o}C)



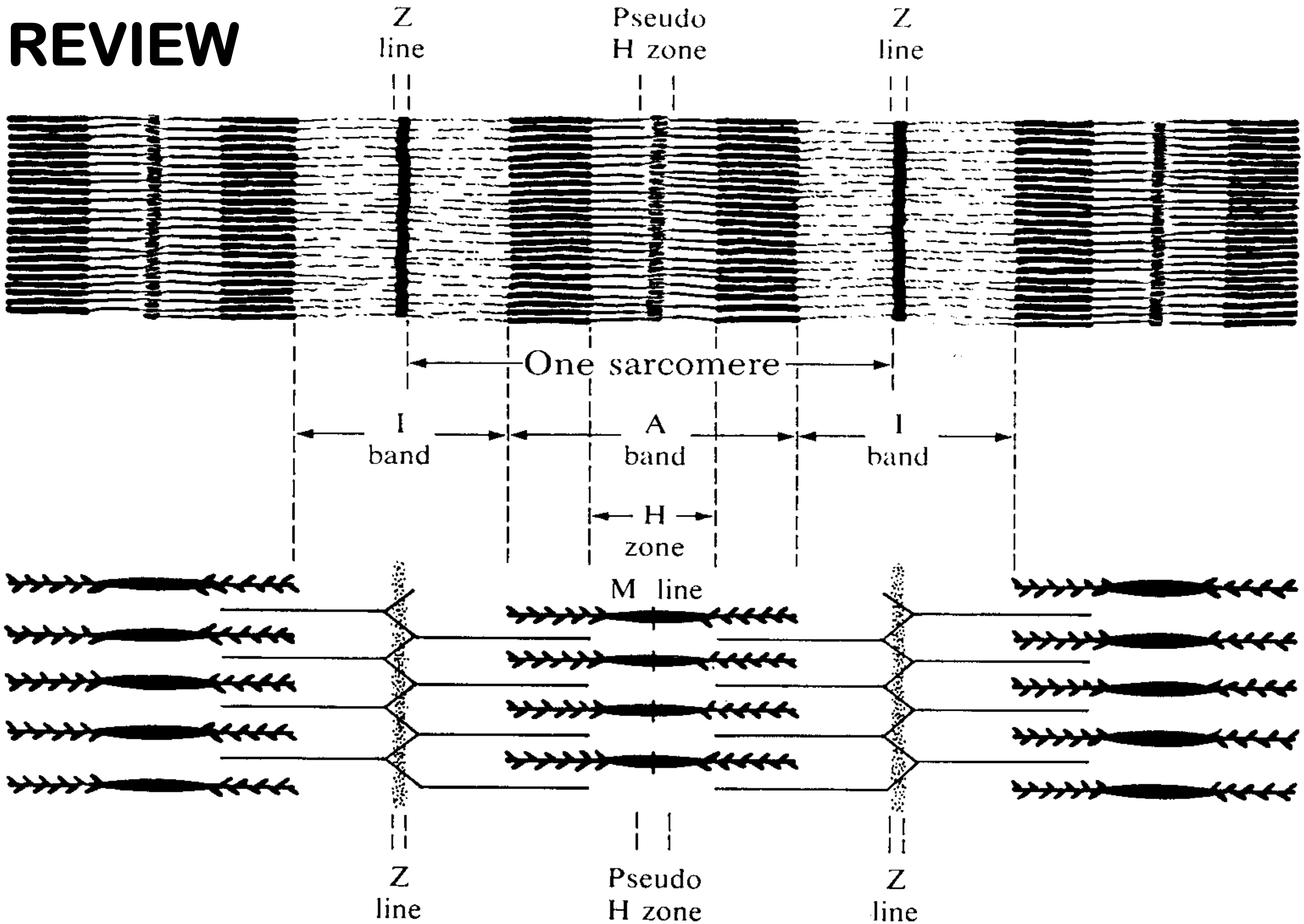
The Blood Supply for Myofibers



Be Able To:

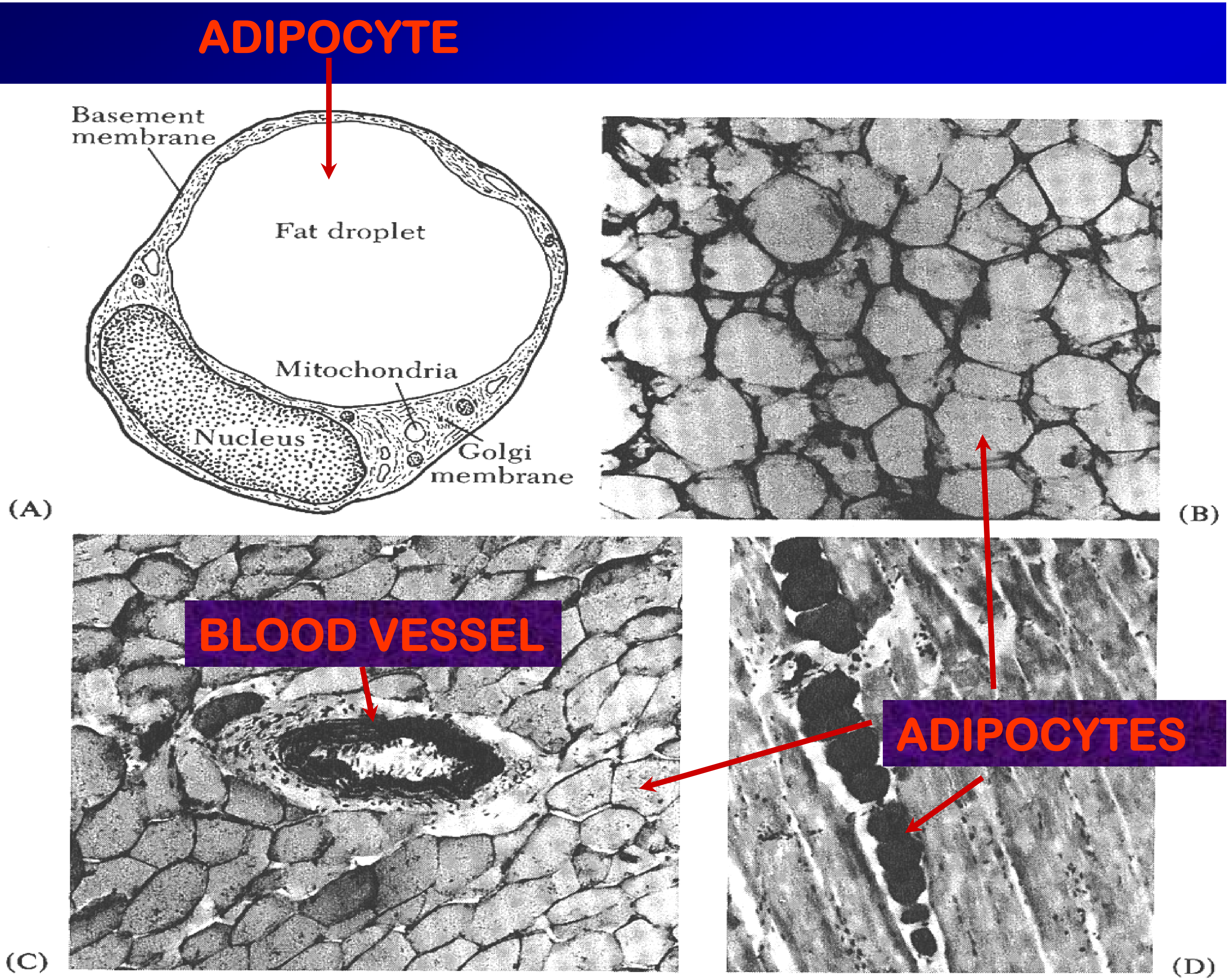
- Draw a sarcomere showing:
  - Myosin
  - Actin
  - Z Line
  - A Band
  - I Band
  - H Zone
  - M Line
- Explain how a muscle contracts and relaxes
  - starting with a nerve impulse and including the SR role (SEE Pp.895-6 In MWE)
- Explain the role of ATP in muscle contraction and relaxation

REVIEW



Z
line
Pseudo
H zone
Z
line
One sarcomere
I
band
A
band
I
band
H
zone
M line
Z
line
Pseudo
H zone
Z
line

ADIPOSE TISSUE

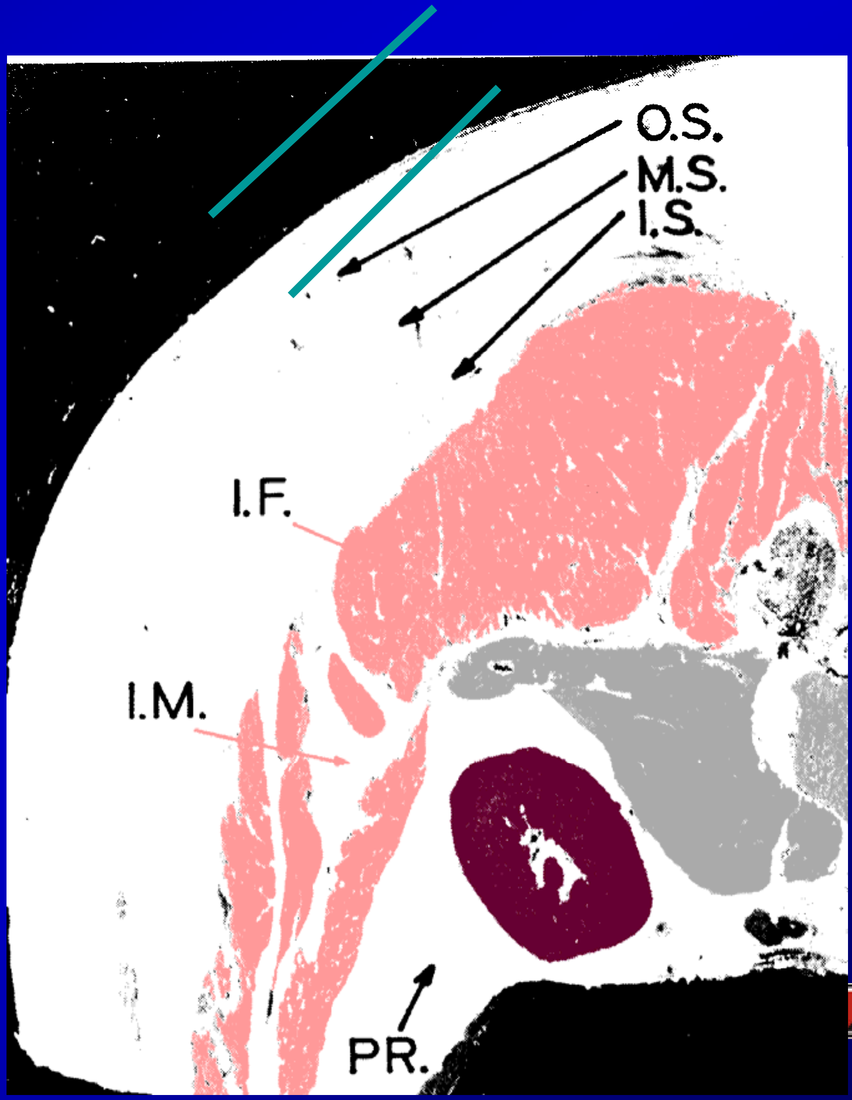


Fat Layers and Depots

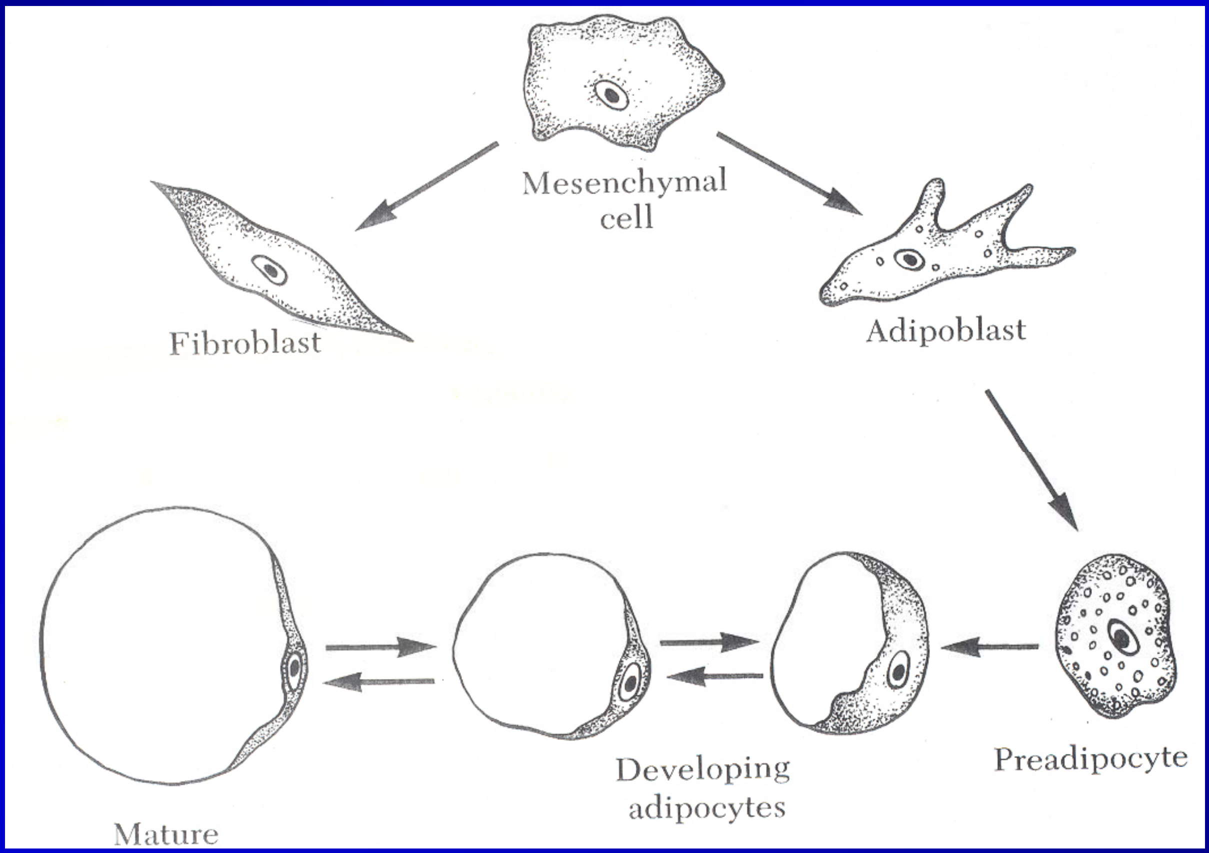
I.F. = Inter-fasicular

I.M. = Inter-muscular

PR. = Peri-renal

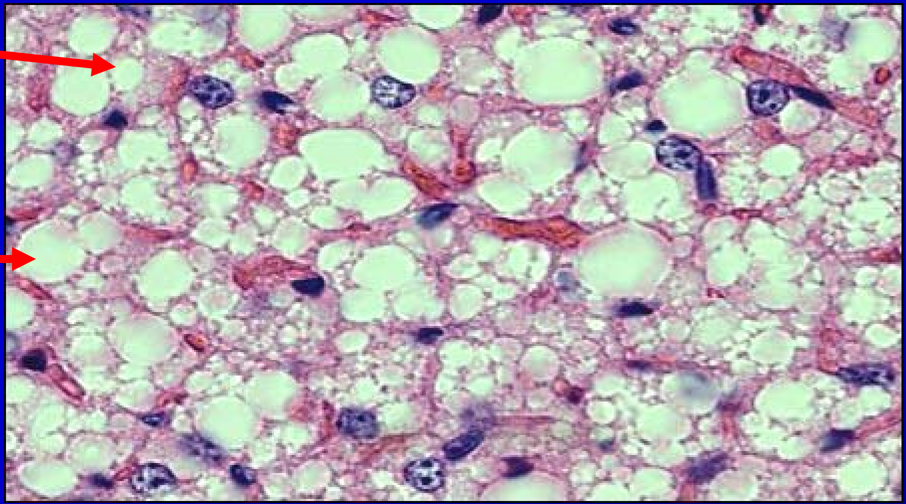


FAT CELLS


Mesenchymal
cell
Fibroblast
Adipoblast
Preadipocyte
Developing
adipocytes
Mature

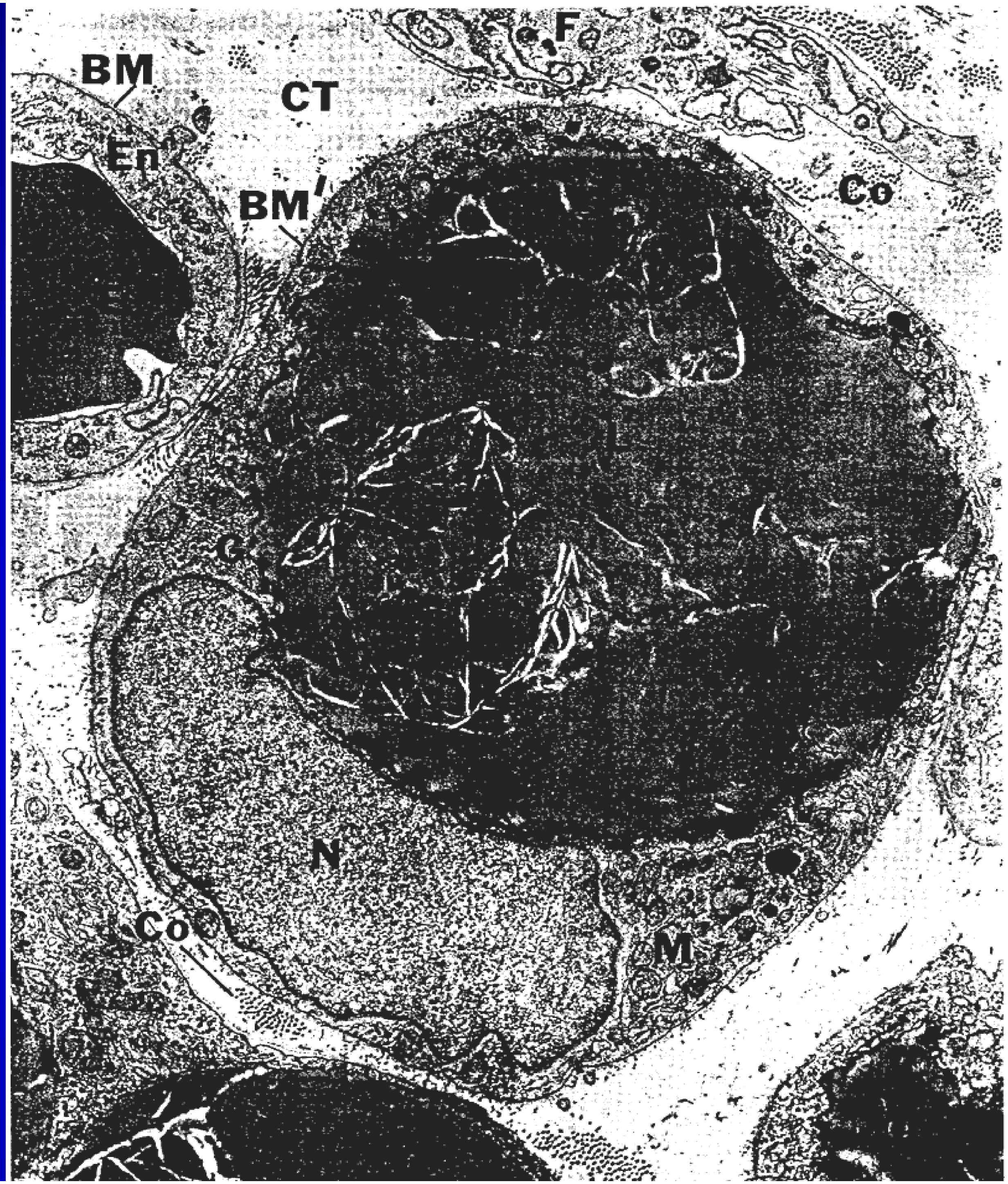
Adipogenesis

- Adipoblasts
  - 20 microns in diameter
- Adipocytes
  - 120 micron in diameter
  - 300 micron in obese

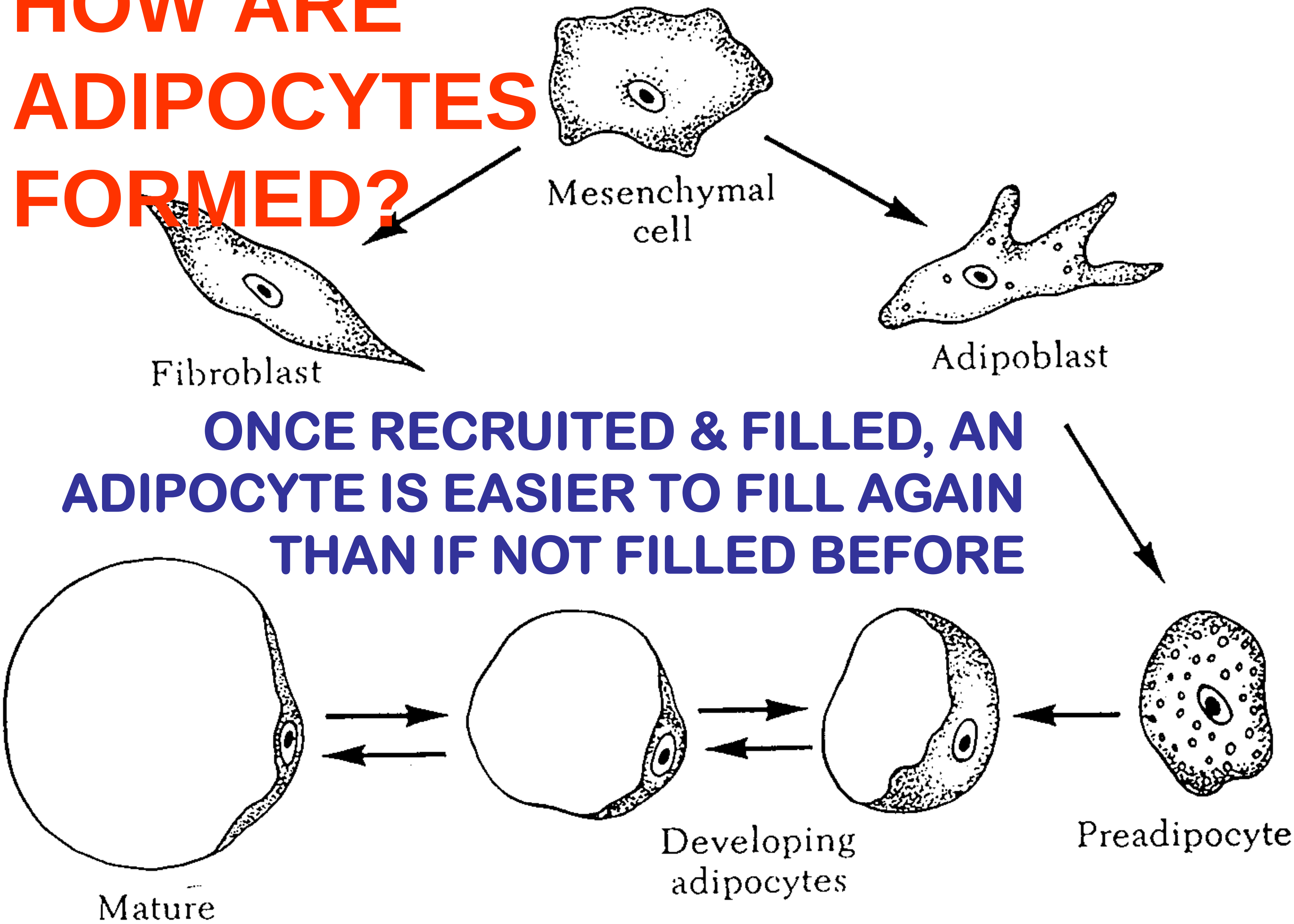


- Cellular make-up
  - 95% of cytoplasm is lipid
  - Remainder primarily nucleus

A D I P O C Y T E



HOW ARE ADIPOCYTES FORMED?



ONCE RECRUITED & FILLED, AN ADIPOCYTE IS EASIER TO FILL AGAIN THAN IF NOT FILLED BEFORE

CONVERSION OF MUSCLE TO MEAT

OBJECTIVE

To learn the process of converting live muscle to meat.

Events: Muscle to Meat

- Animal is slaughtered.
- Metabolism Shifts From Aerobic To Anaerobic State When O_2 Is Depleted.
- Glycogen is converted to lactic acid, lowering muscle pH from about 7 to 5.6.
- Creatine Phosphate and ATP decline.
- W/O ATP for relaxation, myosin heads form a tight bond with actin (Actomyosin). Muscle goes into rigor mortis (The "Stiffness Of Death").
- Proteolysis begins, tenderizing muscle

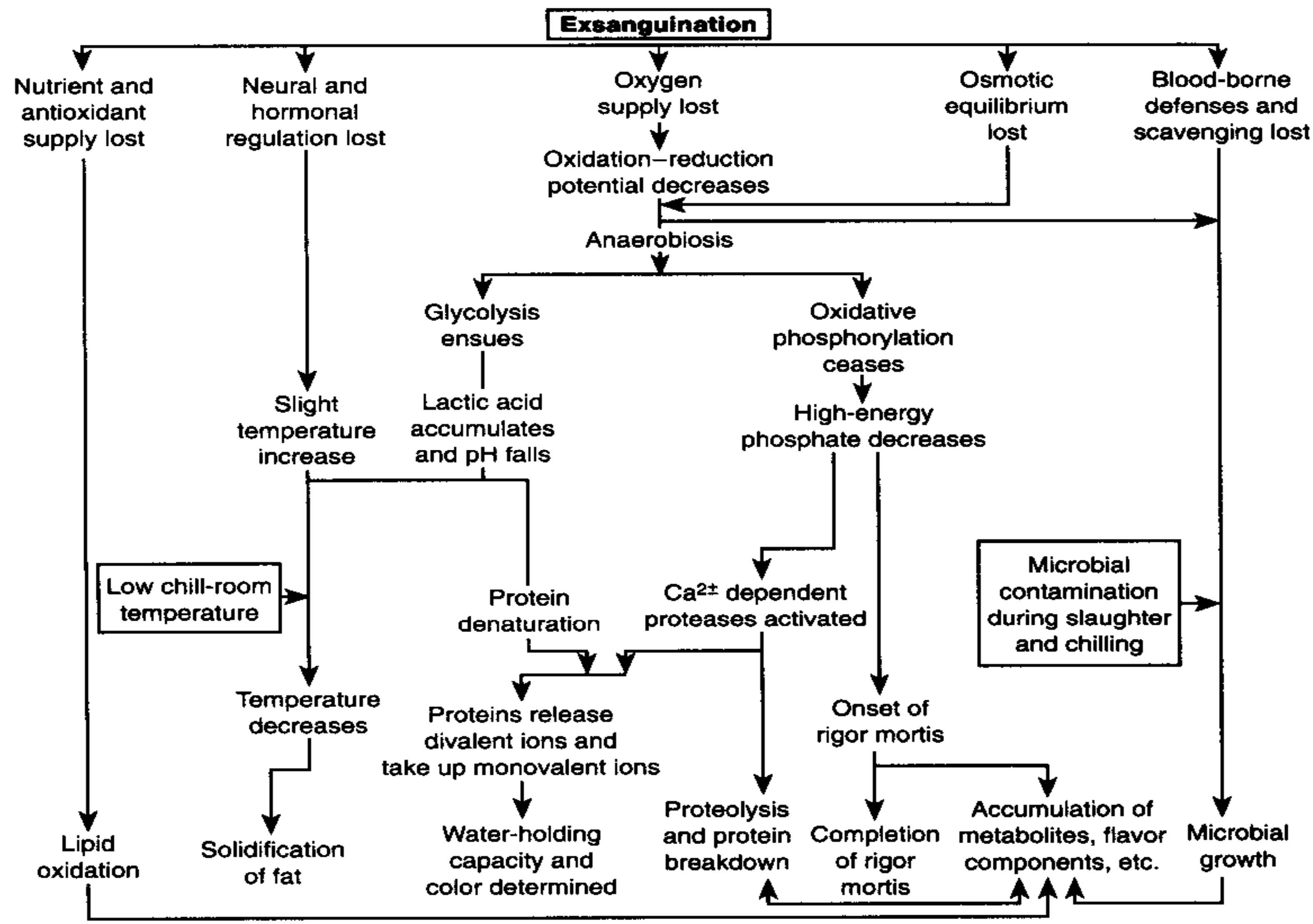
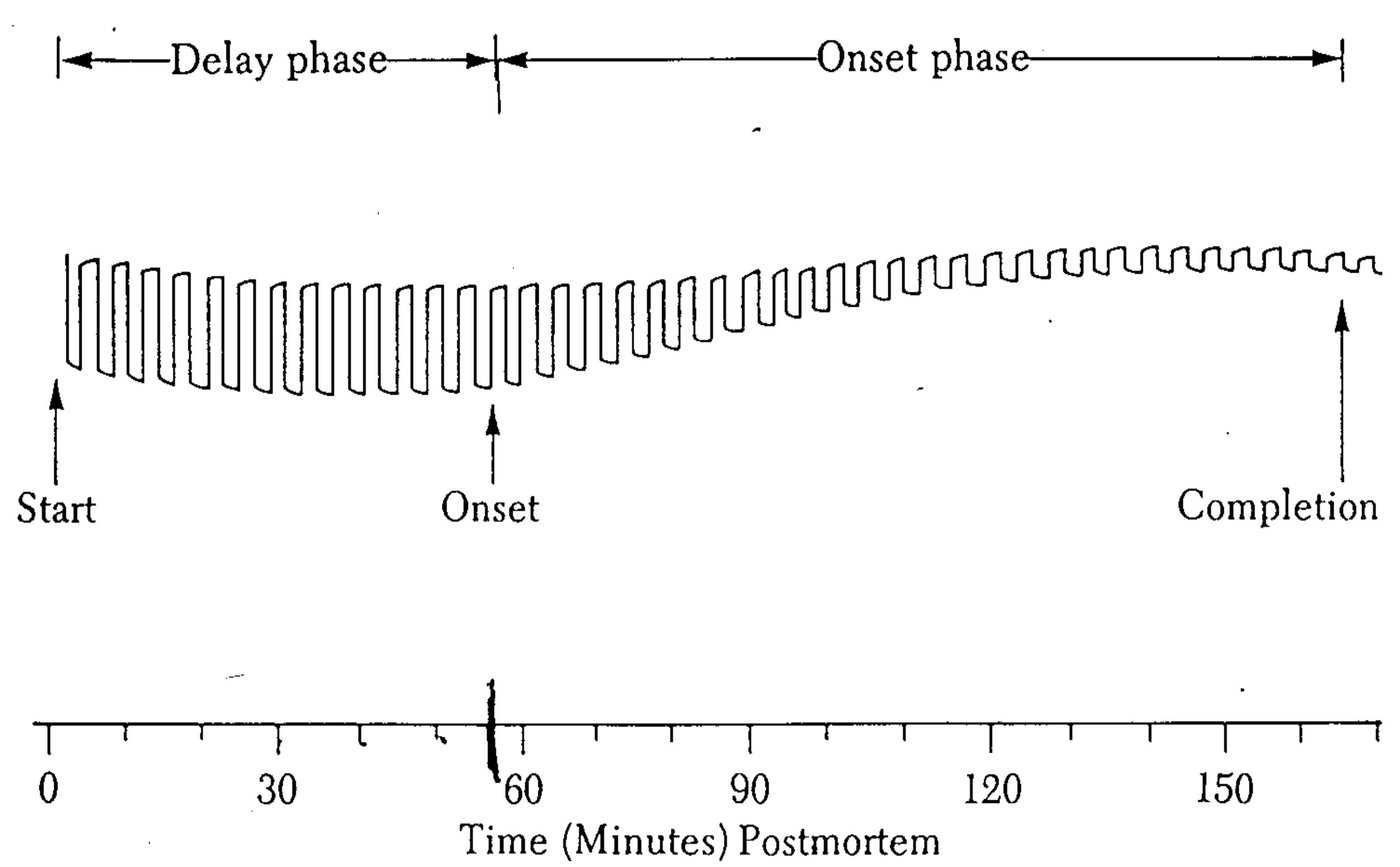


Figure 5.5. Flow diagram of changes in postmortem muscle.

Time to the Onset of Rigor

Species	*Hours*
Beef	6–12
Lamb	6–12
Pork	1/4–3
Turkey	< 1
Chicken	< 1/2
Fish	< 1

Extensibility of Muscle During Rigor Development



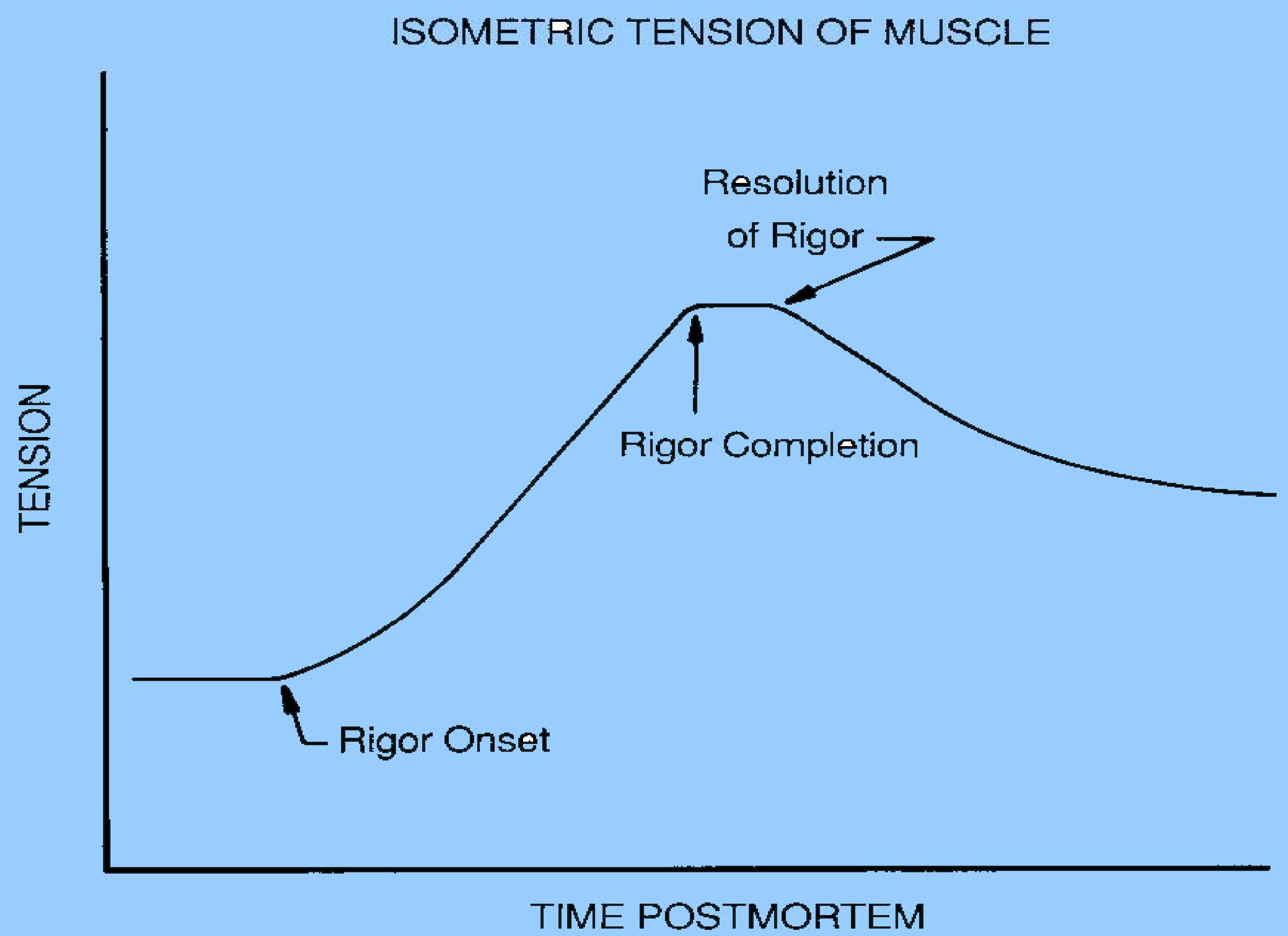


Figure 5.3. Isometric tension development in muscle during phases of rigor mortis.

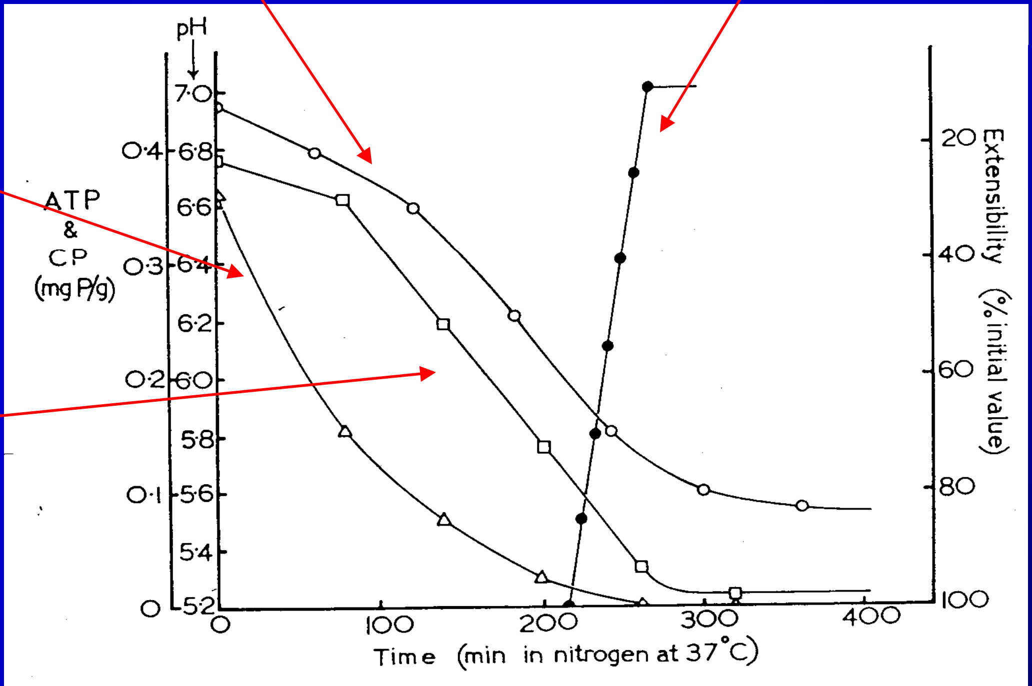
ATP, CP, pH and Extensibility Postmortem

Muscle pH

Muscle Extensibility

ATP

Creatine Phosphate



Calpains and Calpastatins

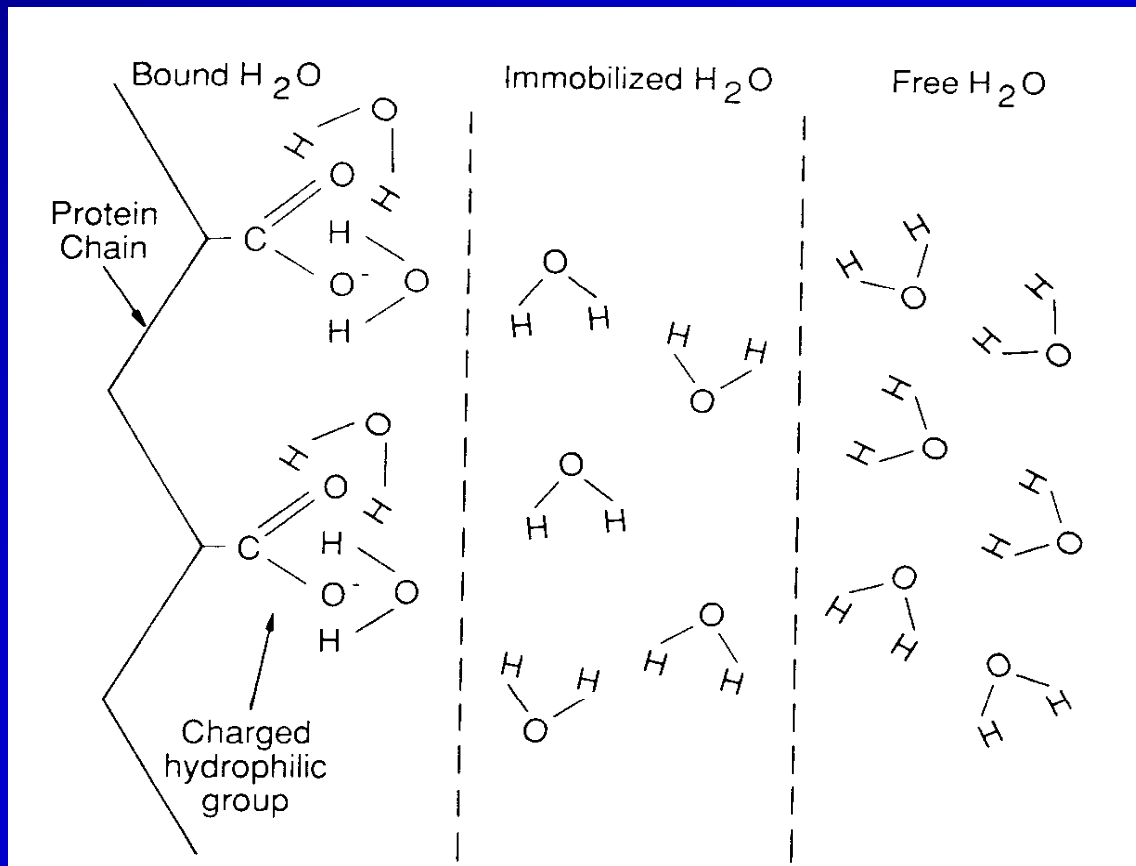
- Calpains (Calcium-activated Proteins) degrade proteins during cooler aging

- Calpastatins inhibit the action of calpains

- Thus, If an animal has a higher calpastatin level, the calpains are less active, and cooler aging has less effect on muscle tenderness. Conversely, ---

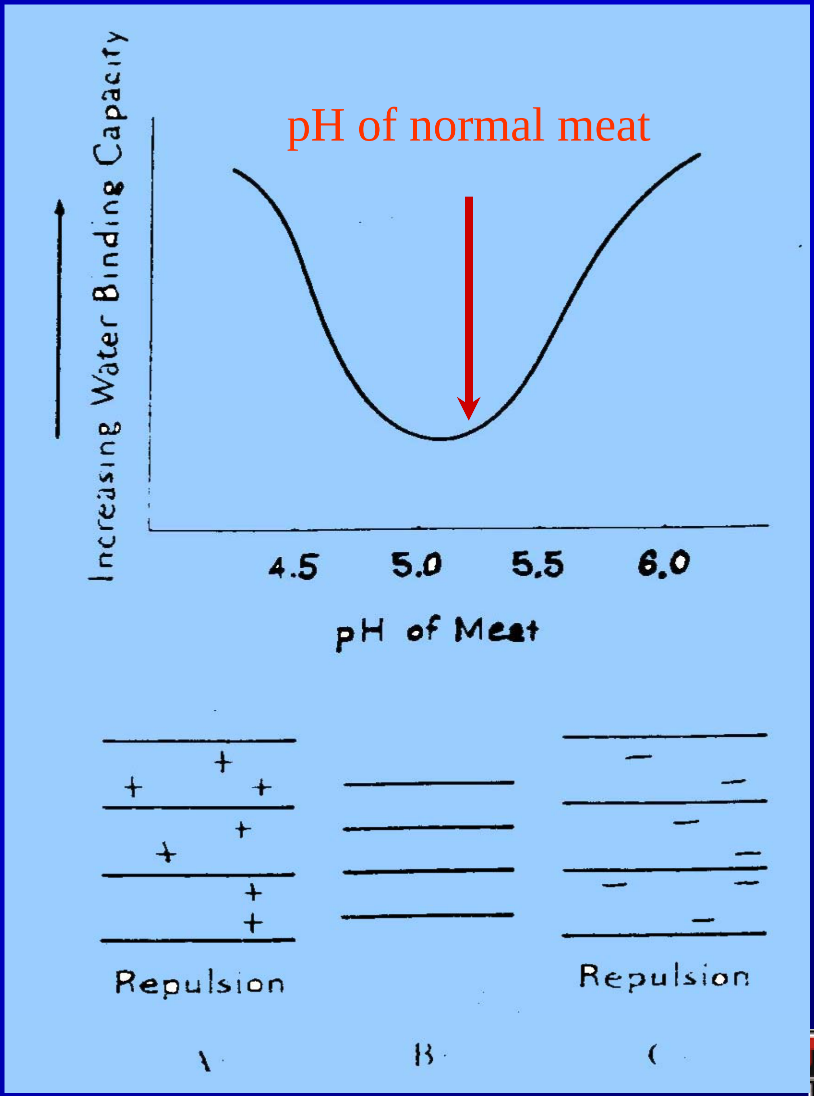
Water holding capacity

- Dependent upon the properties of the meat
- Chemical binding
- Net charge effect
- Steric effects


Bound H_2O
Immobilized H_2O
Free H_2O
Protein Chain
Charged hydrophilic group

Isoelectric point of muscle vs. its pH

Greatly affects its water-holding capacity



Thaw Rigor Events

- Muscle is frozen before rigor mortis occurs –
  - ATP hasn't been used in rigor mortis events and is high when the muscle is frozen.

- Freezing damages the SR.

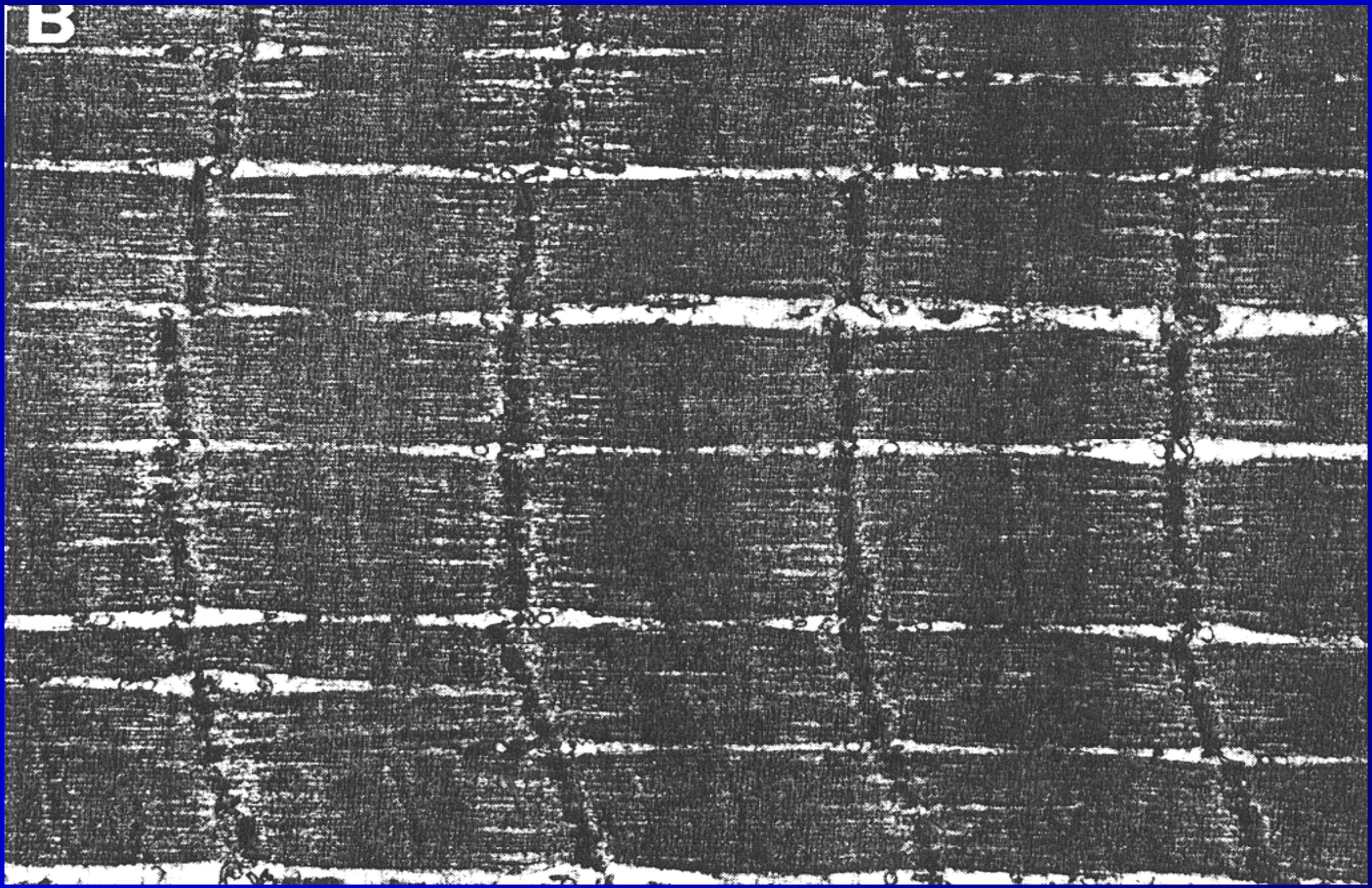
- When thawing occurs, calcium is released from the SR, causing a massive contraction because of the high ATP level. Toughening results.

Thaw Rigor

Cold Shortening

- Similar events occur when a muscle cold shortens except it isn't frozen.
- Because of too quick chilling, the SR is unable to hold the calcium.
- Muscle contraction occurs while ATP still is available.
- Electrical stimulation helps prevent cold shortening by using up the ATP in contractions.

Cold Shortened Muscle



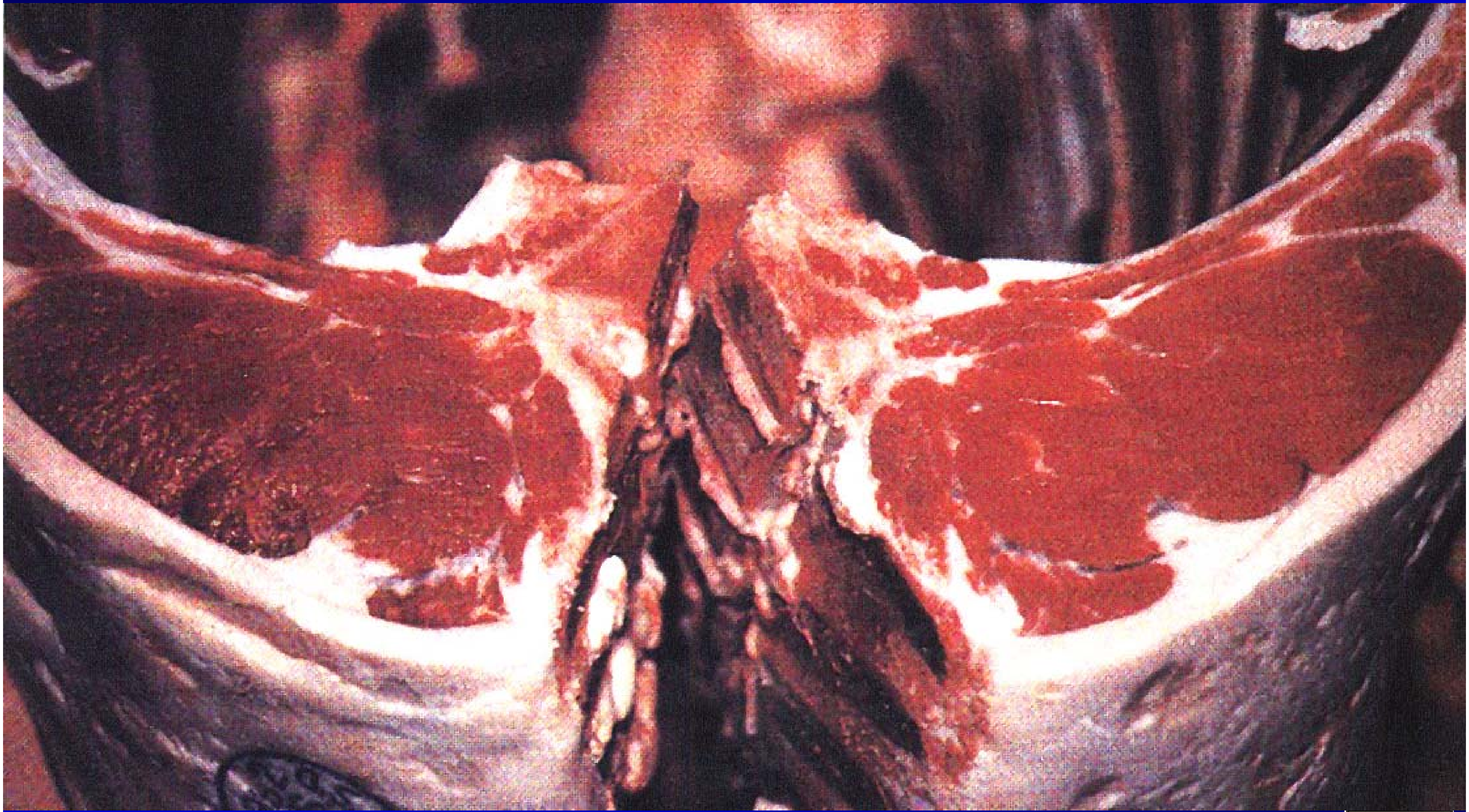
Heat Ring

- Found in carcasses with a thin rind
- Outer ring of muscle gets cold too quickly
  - has slower glycolytic rate
  - slower pH decline
  - longer time until rigor develops
- Result is an undesirable ring around the muscle that is darker in color, coarser in texture, and may drop down

Electrical Stimulation

- Passing electrical current through carcasses to cause muscles to contract and use up their ATP.
- Reduces heat ring and cold shortening and may increase tenderness of low grading carcasses.
- Brighter muscle color causes marbling to show better.
- ES will improve overall carcass merit?

NO ES ES



A beef side being stimulated in a laboratory setting - muscle contractions are violent.

Contracture Band after Electrical Stimulation

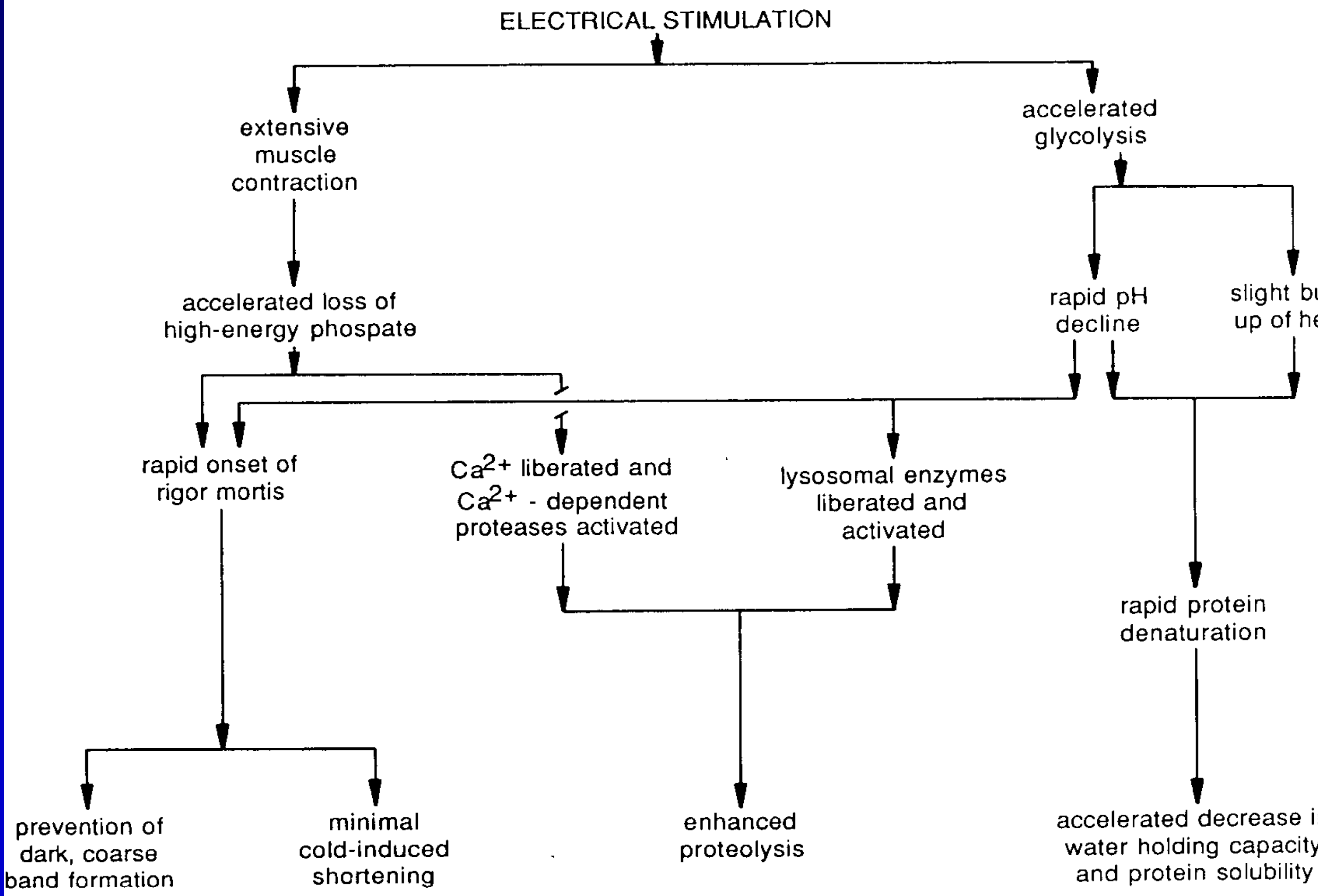


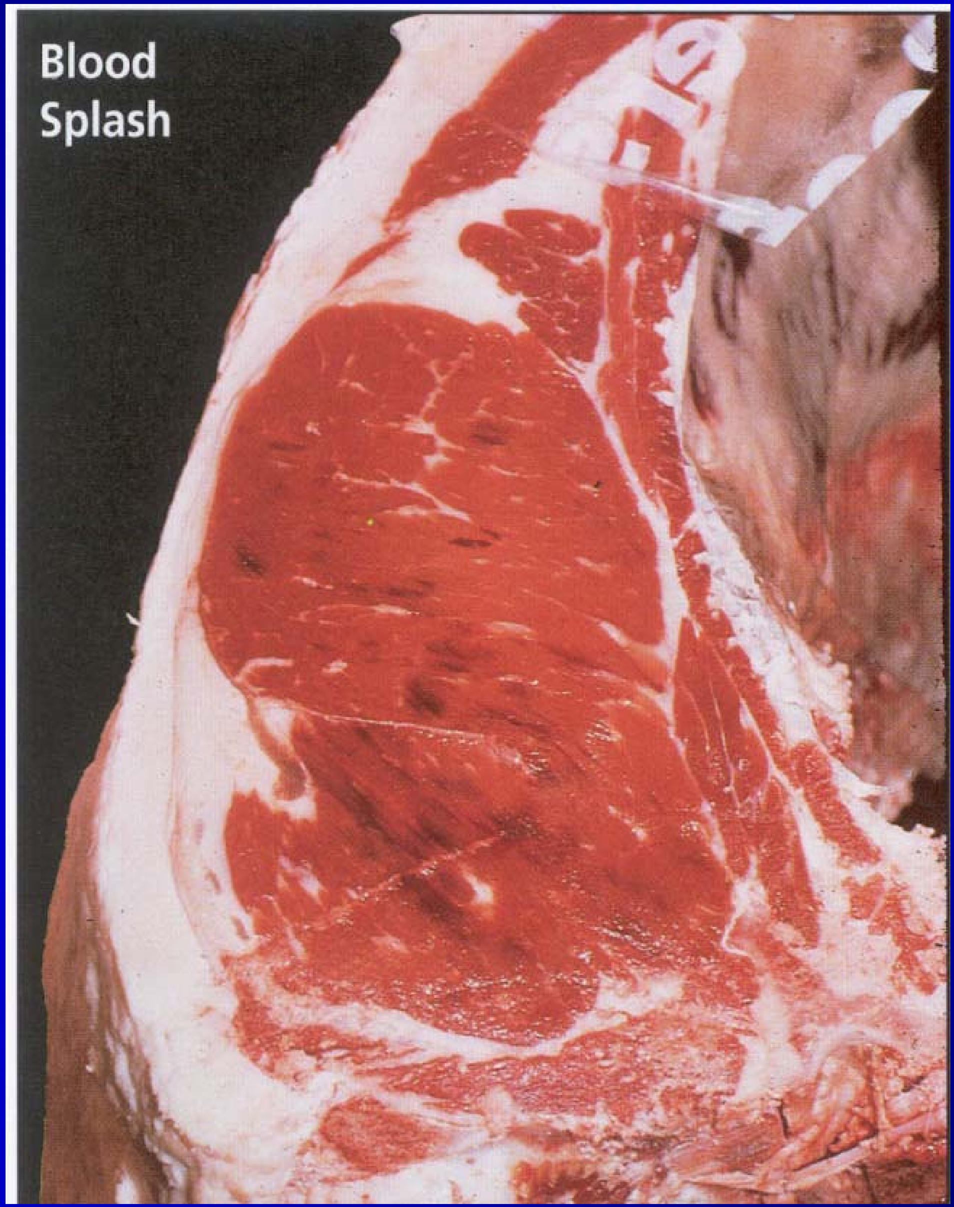
Figure 5.16. Flow diagram of effects of carcass electrical stimulation.

Blood Splash

- Caused by rupture of capillaries, usually between stunning and sticking times; blood pressure skyrockets after stunning
- Result is small blood spots in muscles; most problem in hogs and poultry.
- An excessive stun:stick interval can cause blood splashing as can excitement before stunning.
- If in fat, is called “Fiery Fat”.

HEMORRHAGES

Blood Splash Lean



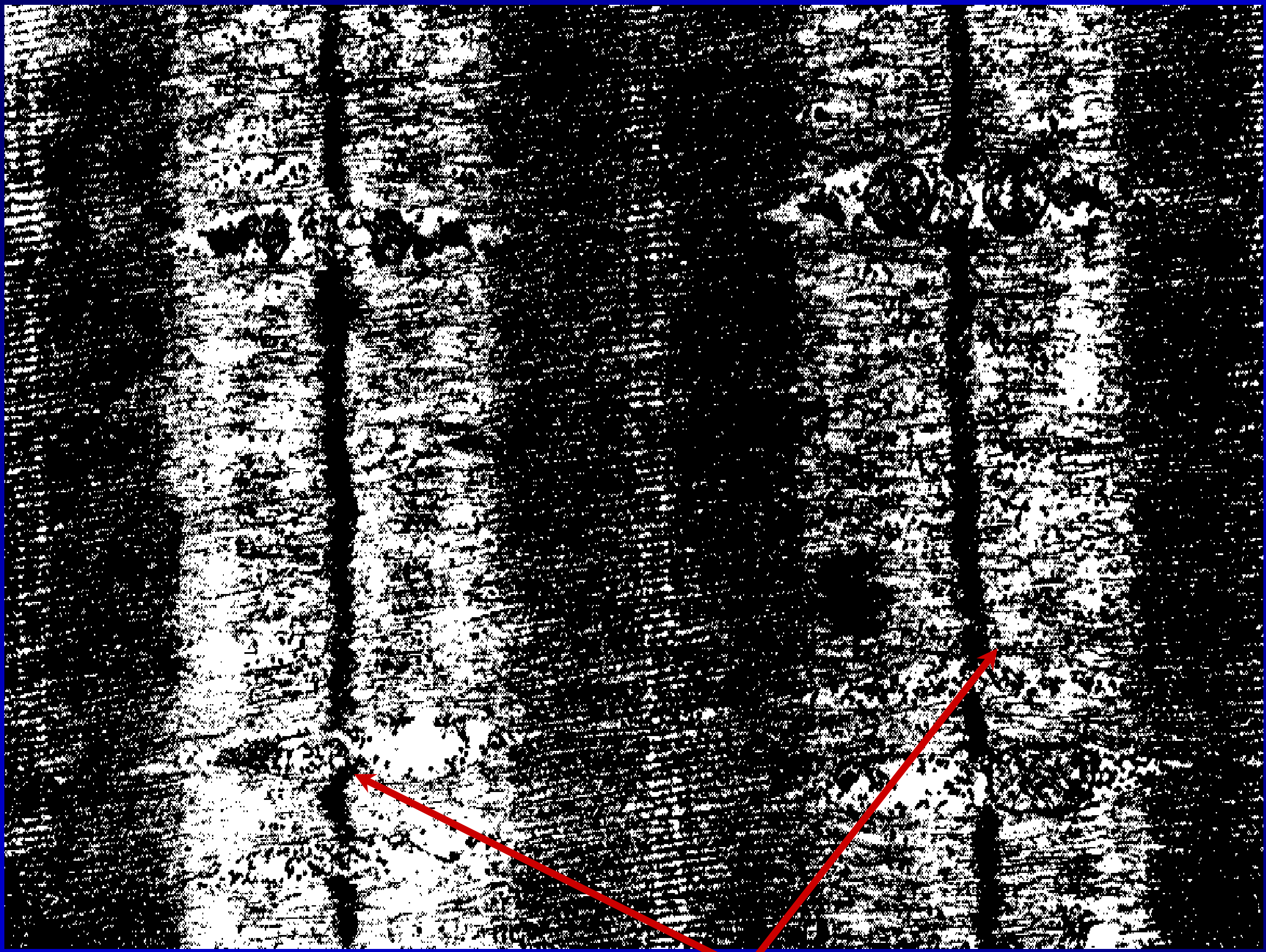
Hot Boning

- Is desirable because hot-boned meat has a higher water holding capacity.
- Prevents rapid pH drop
- Without skeletal restraint, muscles shorten and become tough if allowed to go through rigor not ground.
- Injecting muscles with salt & PO_4 can lessen tenderness problems.

Delayed Chilling

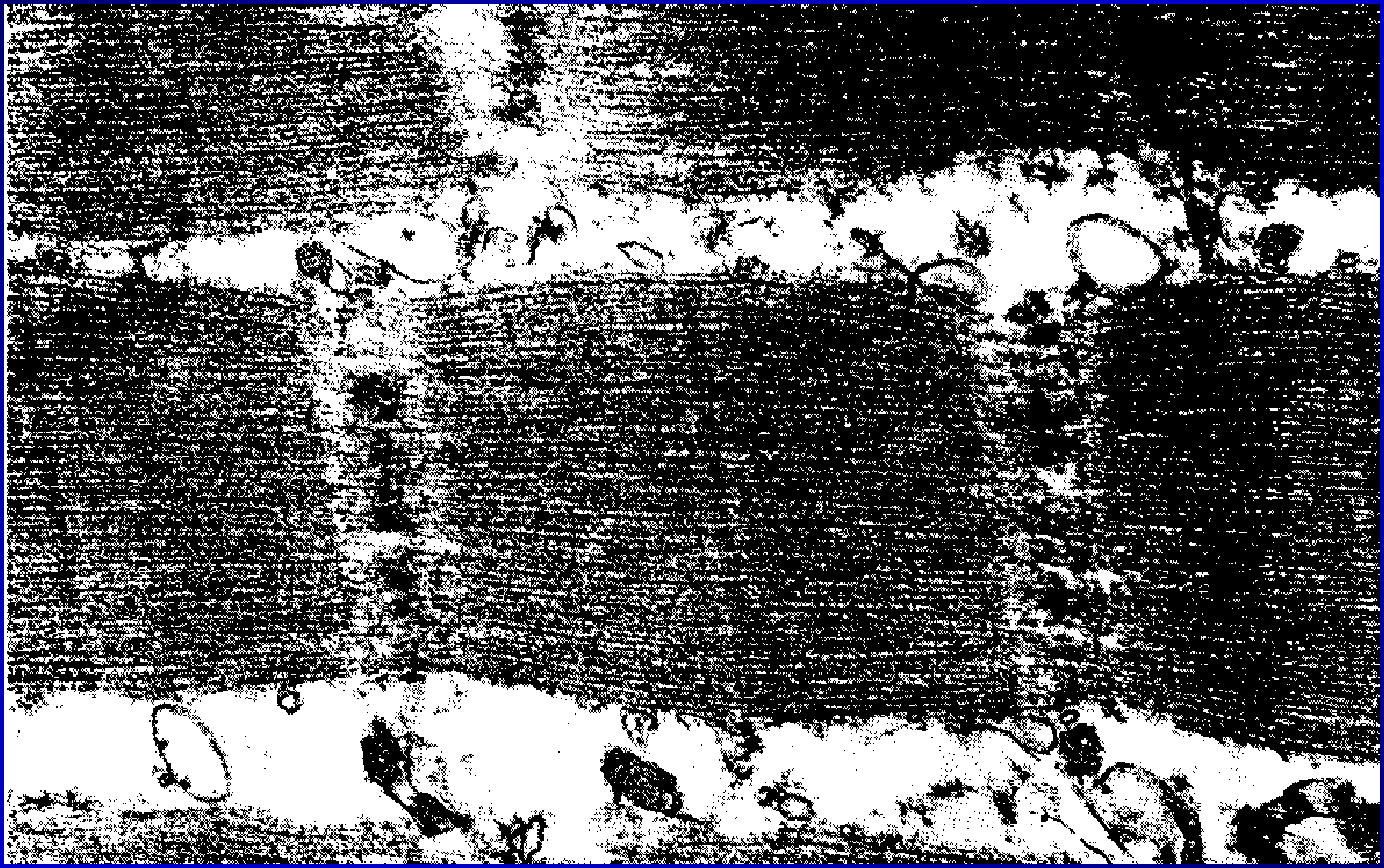
- Hold carcasses at room temperature for 2 to 4 hours after dressing.
- Presents microbial problems.
- Glycolytic rate is faster at the higher temperatures, ATP is depleted, and cold shortening is prevented. Aging is accelerated.
- Is used on lambs in New Zealand

Bovine Muscle at Death (X 14,800)



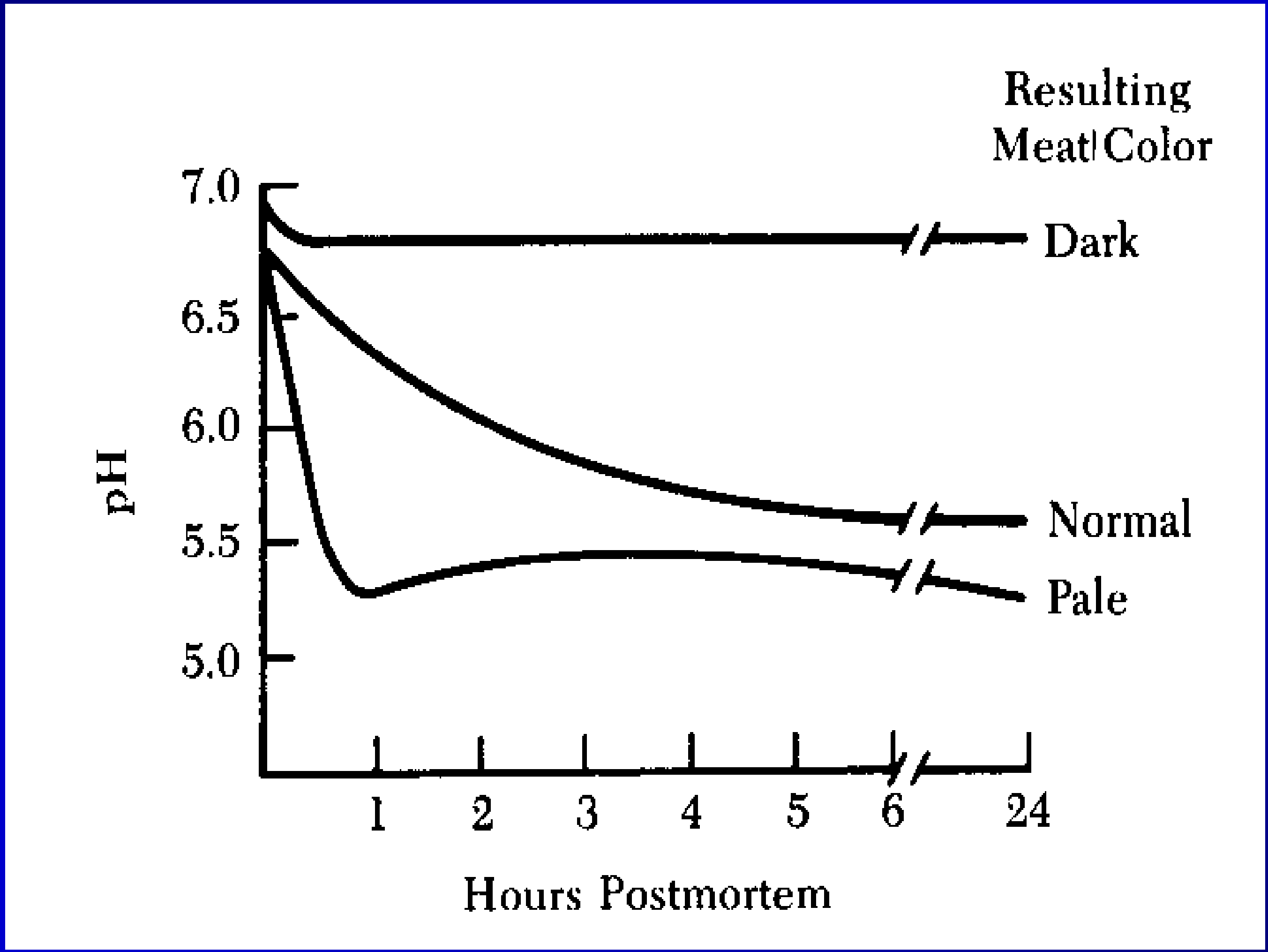
Note the Integrity of the Z Disks

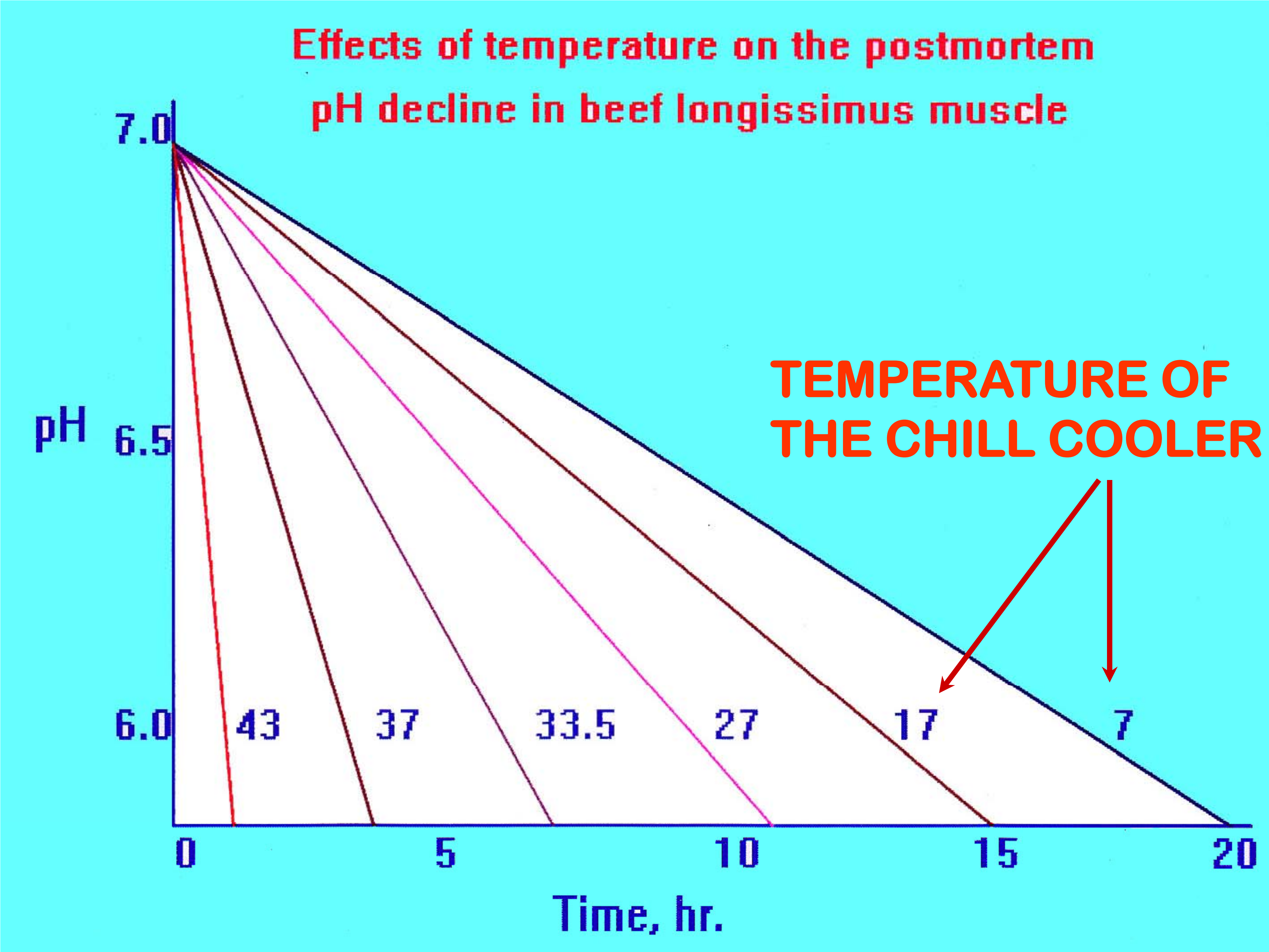
Bovine Muscle After 24h

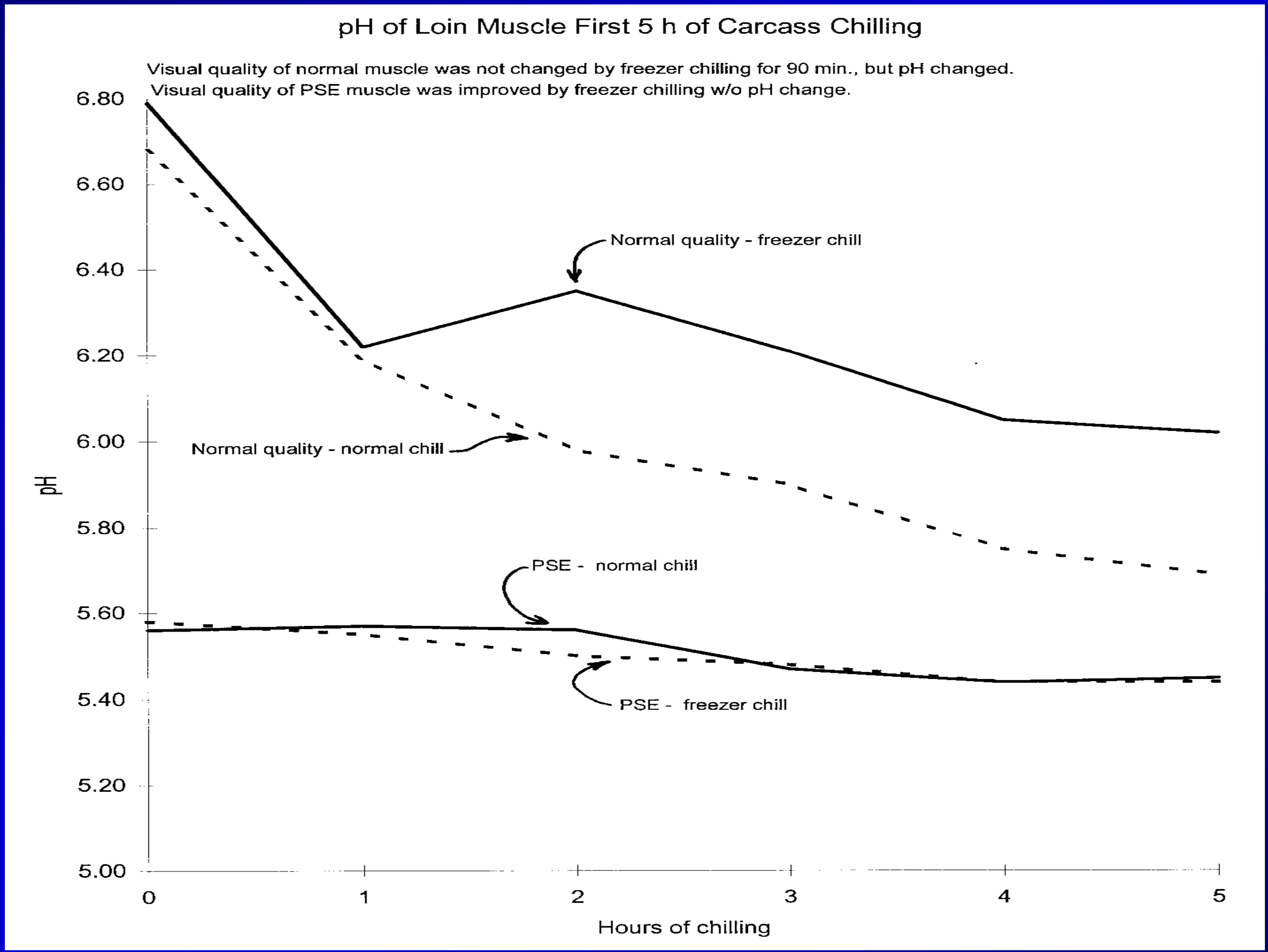


NOTE DEGRADATION OF THE Z DISKS

Rate of pH Decline Affects Muscle Properties




Effects of temperature on the postmortem
pH decline in beef longissimus muscle
TEMPERATURE OF
THE CHILL COOLER
pH
7.0
6.5
6.0
43
37
33.5
27
17
7
0
5
10
15
20
Time, hr.



pH of Loin Muscle First 5 h of Carcass Chilling
Visual quality of normal muscle was not changed by freezer chilling for 90 min., but pH changed.
Visual quality of PSE muscle was improved by freezer chilling w/o pH change.
6.80
6.60
6.40
6.20
6.00
5.80
5.60
5.40
5.20
5.00
pH
Normal quality - freezer chill
Normal quality - normal chill
PSE - normal chill
PSE - freezer chill
0
1
2
3
4
5
Hours of chilling

Summary of Temperate Effects

POSTMORTEM TEMP.

Reduce temp. to minimize degradation and microbial growth

Reducing temp. too rapidly causes:

-Cold shortening

-Thaw rigor

Not reducing temp. enough causes:

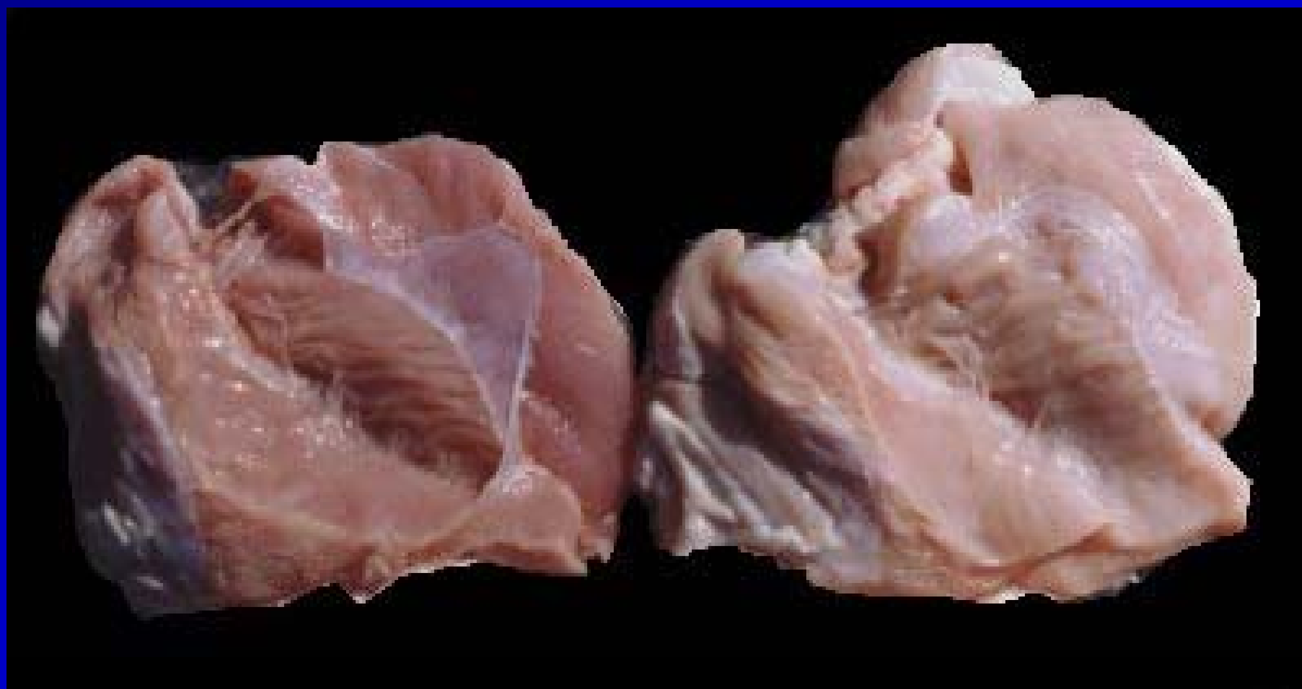
-Heat rigor

Maintain 15 - 16^{o}C during rigor onset

PSE and DFD Muscle

- Poultry and pigs carry one or two copies of the Malignant Hypothermia (Halothane) gene
  - These animals are prone to pale, soft, and exudative (PSE) muscle.
- Antemortem stress usually increases the severity of PSE.
- Muscle pH drops very fast, the meat has little sales appeal, and shrinkage is greatly increased.
- PSE can be triggered in halothane free animals

PSE in Turkey

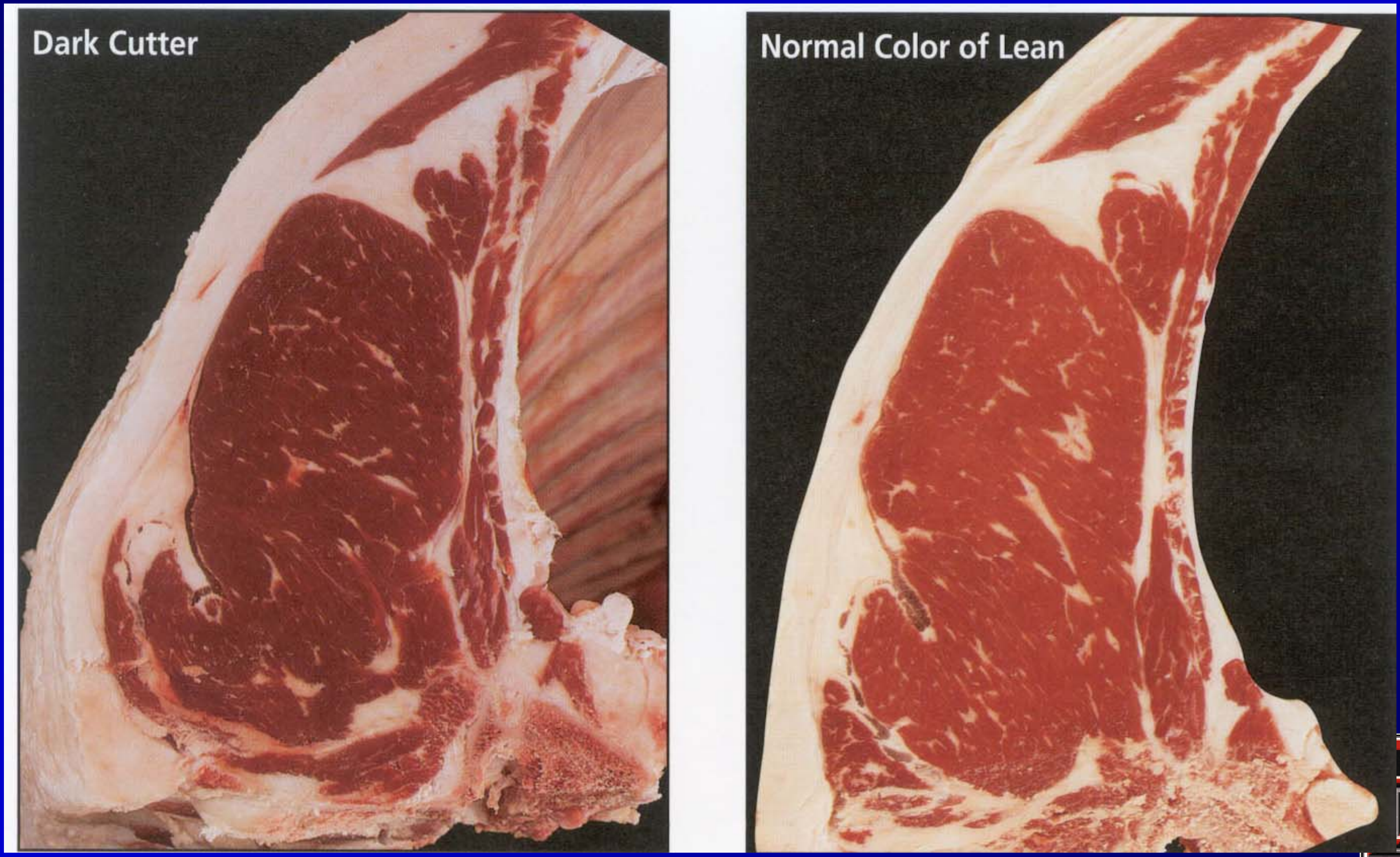


Normal PSE

DFD - "DARK CUTTERS"

- Caused by a shortage of glycogen at slaughter.
- Without enough glycogen to convert to lactic acid, the muscle pH stays too high, spoils easier.
- Antemortem stressors cause DFD.
- Resultant muscle is too dark in color, firm, and dry (the opposite of PSE muscle); is sweeter.
- Beef has the most DFD problems.
- Rare in poultry

Dark Cutter vs Normal



End