MEAT TECHNOLOGY

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*Meat composition

*Post mortem changes in muscle

*Conversion of muscle to meat

Chemical composition of muscle meat

- In general, meat is composed of water, protein, fat, minerals and a small portion of carbohydrate.

- The most valuable component from the nutritional and processing point of view is protein.

Component	Percentage (%)
Water	68-80
Protein	16-22
Fat	1.5-13.0
Non-protein nitrogen	1.5
Carbohydrate	0.5-1.5
Inorganic constituents	1.0
Vitamins	Trace

CHEMICAL COMPOSITION OF MEAT

Component	Per cent
WATER (range 65 to 80)	75.0
PROTEIN (range 16 to 22)	19.0
A) Myofibrillar	11.5
Myosin	5.5
Actin	2.5
Tropomyosin	0.6
Troponin	0.6
M protein and C protein	0.2
α , β and γ actinin	0.5
Desmin, F and I protein etc.	0.4
B) Sarcoplasmic	5.5
Soluble sarcoplasmic and mitochondrial enzyme	4.5
Myoglobin	0.3
Haemoglobin, Cytochromes and flavoproteins	0.7
C) Stroma	2.0
Collagen and reticulin	1.0
Elastin	0.05
Other insoluble proteins	0.95
LIPIDS (variable range 1.5 to 13.0)	2.5
Neutral lipids, Phospholipids, Cerebrosides	2.0
Cholesterol	0.5
NON-PROTEIN NITROGENOUS SUBSTANCES	1.65
Creatine and Creatine phosphate	0.55
Free amino acids	0.35
Peptides (anserine, carnosine etc.)	0.35
Other [creatinine, urea, inosine monophosphate(IMP), adenosine triphosphate (ATP), adenosine diphosphate (ADP), nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP)]	0.4
CARBOHYDRATES (range 0.5 to 1.5)	1.2
Glycogen (variable range 0.5 to 1.3), Glucose, intermediate products of cell metabolism [hexose and triose phosphates, lactic acid, citric acid, fumaric acid, succinic acid, acetoacetic acid etc.]	
INORGANIC CONSTITUENTS	0.65
Potassium	0.35
Total phosphorus [phosphates and inorganic phosphorus]	0.2
Magnesium	0.02
Sodium	0.05
Others [including, calcium, iron, cobalt, copper, zinc, nickel, manganese etc.]	0.03
VITAMINS (various fat and water soluble vitamins, quantitatively minute).	

Water- 75% (changes between 55-80%)

- Factors influencing moisture content:
  - Age of animal
  - Lipid and protein content (inverse relationship)

- Significance of water
  - Palatability
  - Product weight
    - Evaporative losses
    - Drip (purge) losses

PROTEINS- 19%

Classes of muscle proteins

- Sarcoplasmic proteins (5.5%)
- Myofibrillar proteins (11.5%)
- Stromal proteins (2%)

Classes of proteins
sarcoplasmic proteins

- 30-35% of total muscle proteins
- Classified as water-soluble proteins
  - Metabolic enzymes
  - Myoglobin (pigment)

- Functionality
  - Contributes to approx. 5% of total WHC of meat

Classes of proteins
Myofibrillar proteins

- 52-56% of total muscle proteins
- Classified as salt-soluble proteins
- General subclasses
  - Contractile proteins- Actin and myosin
  - Regulatory proteins-Tropomyosin, troponin, etc.
  - Cytosceletal proteins-α-actinin, β-actinin, titin, nebulin, etc.

✓ Myofibrillar proteins (continued)

- Contributions:
  - Palatability
    - Tenderness
    - Juiciness
  - Functionality
    - Contributes to approx. 90% of WHC of meat
    - Largely responsible for the «emulsifying capacity (EC)» of meat

**EC: ability of proteins to encapsulate of entrap fat molecules

Classes of proteins
stromal proteins

- 10-15% of total muscle proteins
- Classified as insoluble proteins
- Cellular and sub-cellular membranes
- Connective tissue

Stromal proteins (continued)

- Connective tissue proteins
  - Collagen
    - Principle protein of white connective tissue
    - Properties:

      Amino acids- approx.
    - 33% glycine
    - 13% proline
    - 10% hydroxy-proline
    - 10% alanine
    - Resistant to weak acids and most enzymes
    - Thermal transformation in moist heat environment

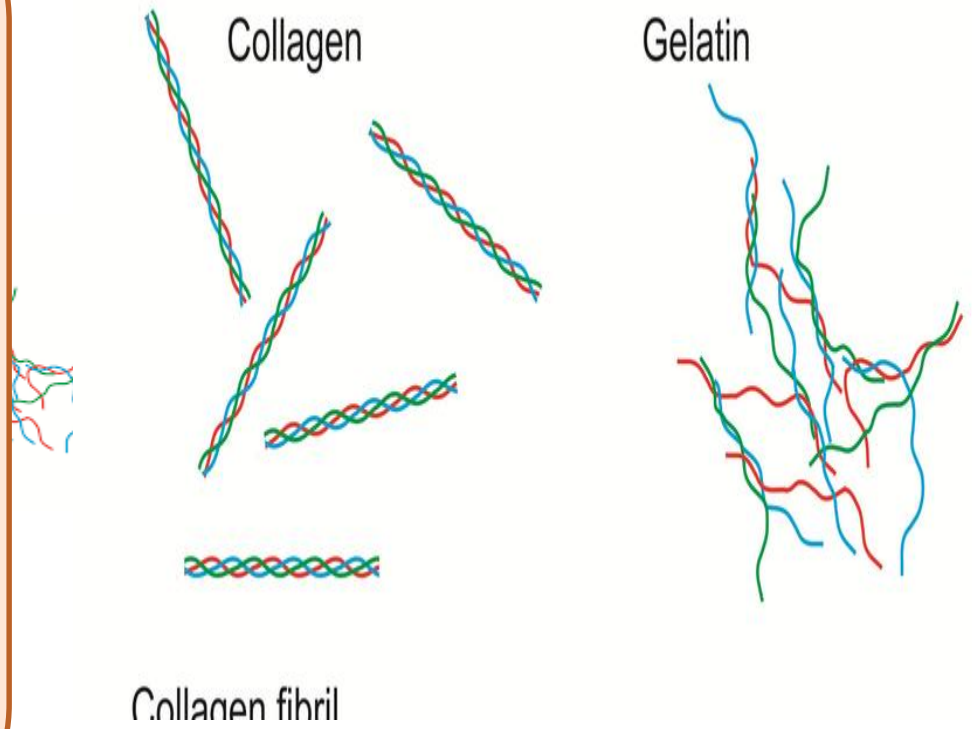
✓ COLLAGEN

NATIVE COLLAGEN

HEAT AND WATER

SHRINKAGE (1/3 LENGHT

GELATIN



Biochemical Postmortem Changes

Content:

- Exsanguinations
- Loss of Homeostasis
- Postmortem pH Decline
- Rigor Mortis
- Resolution of Rigor
- Conditioning of Meat
- Loss of Structural Integrity
- Loss of Protection from Bacterial Invasion

HOMEOSTASIS

- Homeostasis is the maintenance of a physiologically balanced internal environment.

EXSANGUINATION

- the first step where blood is removed from the animal.

- Sheep and goat bleed better in vertical position whereas cattle bleed better in horizontal position.

-

- As the blood pressure begins to drop following exsanguinations, the circulatory system starts to adjust its functions to maintain a blood supply to vital organs.

EXSANGUINATION

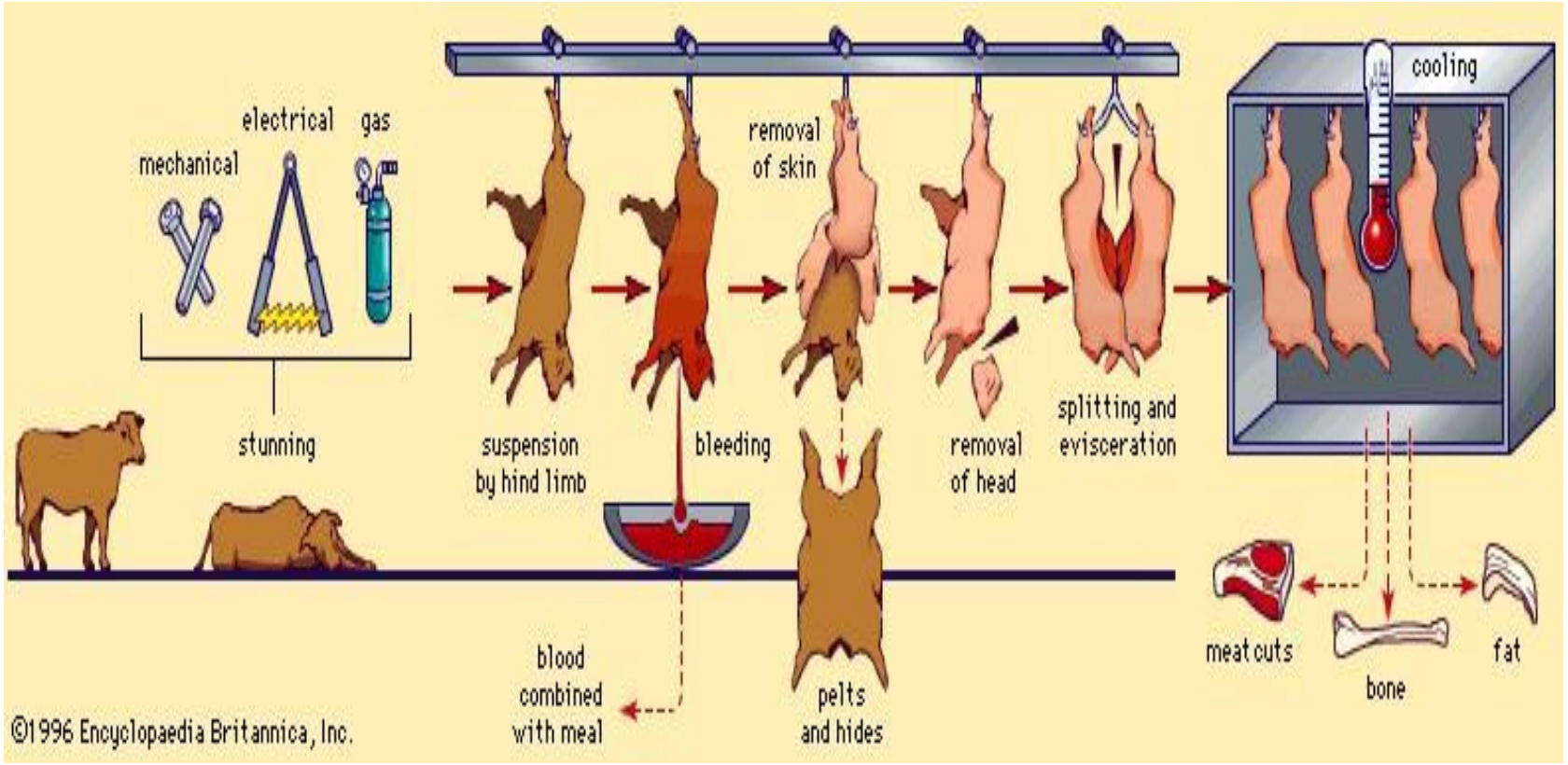
- Generally, 50 per cent of total blood volume is removed from the body of the animal and remaining 50 per cent is retained in the vital organs.

Loss of homeostasis

- Following exsanguinations, all homeostatic mechanisms are eventually lost.
- Within 4-6 minutes after exsanguinations, nervous control from central nervous system is lost and uncontrolled impulses result in twitching of muscles for a considerable time.
- Body temperature also starts to decline as there is loss of mechanism for maintaining it at original level.

Circulatory failure to the muscles

- Blood act as transport medium.
- After exsanguinations, it failures.
- As the stored oxygen supply becomes depleted after exsanguinations the aerobic path way of metabolic process must stop functioning.
- Energy metabolism is them shifted to the anaerobic pathway and less energy in the form of ATP is produced through the anaerobic path.


mechanical
electrical
gas
stunning
suspension by hind limb
bleeding
removal of skin
removal of head
splitting and evisceration
cooling
meat cuts
bone
fat
blood combined with meal
pelts and hides
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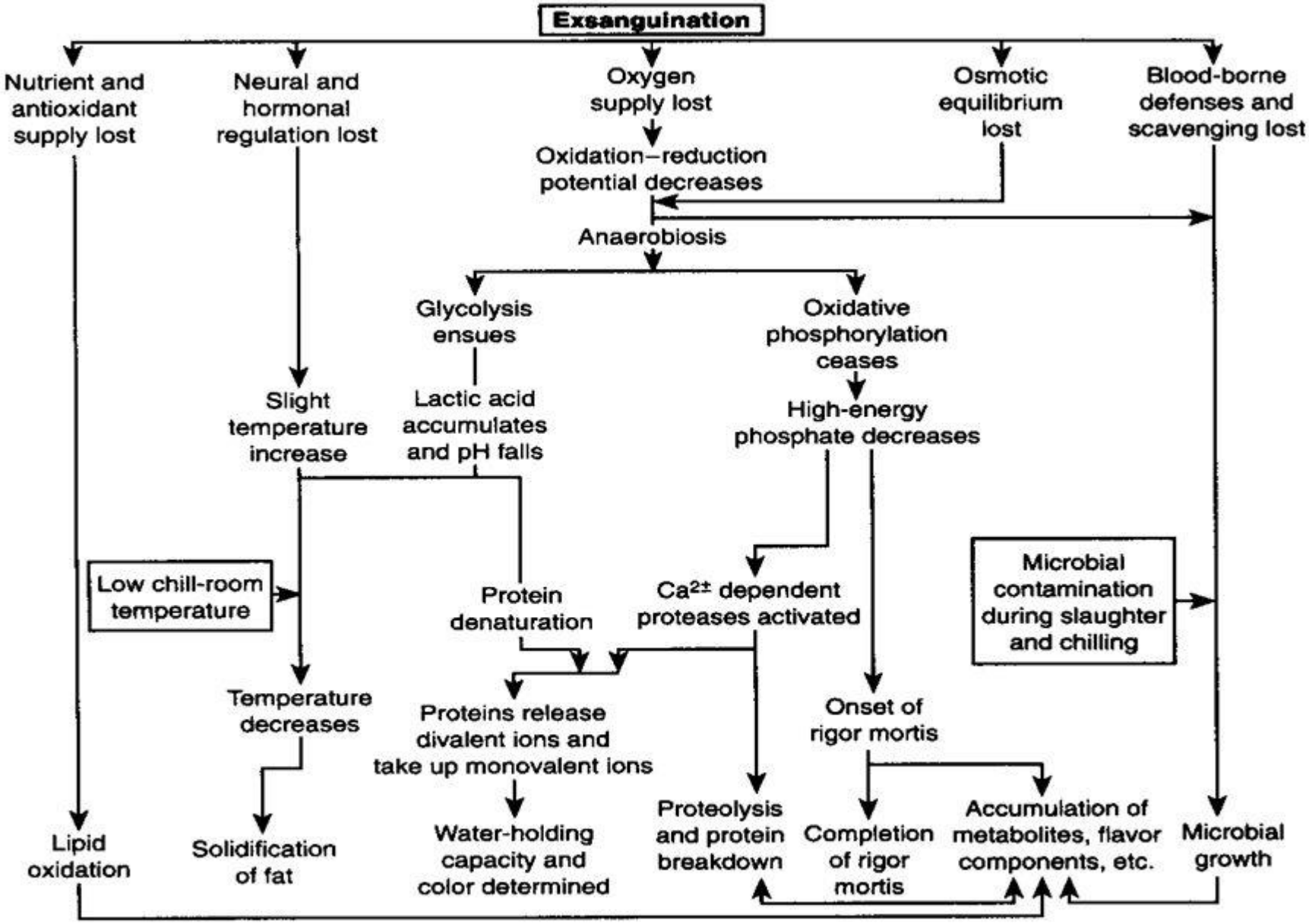


Changes in postmortem muscle

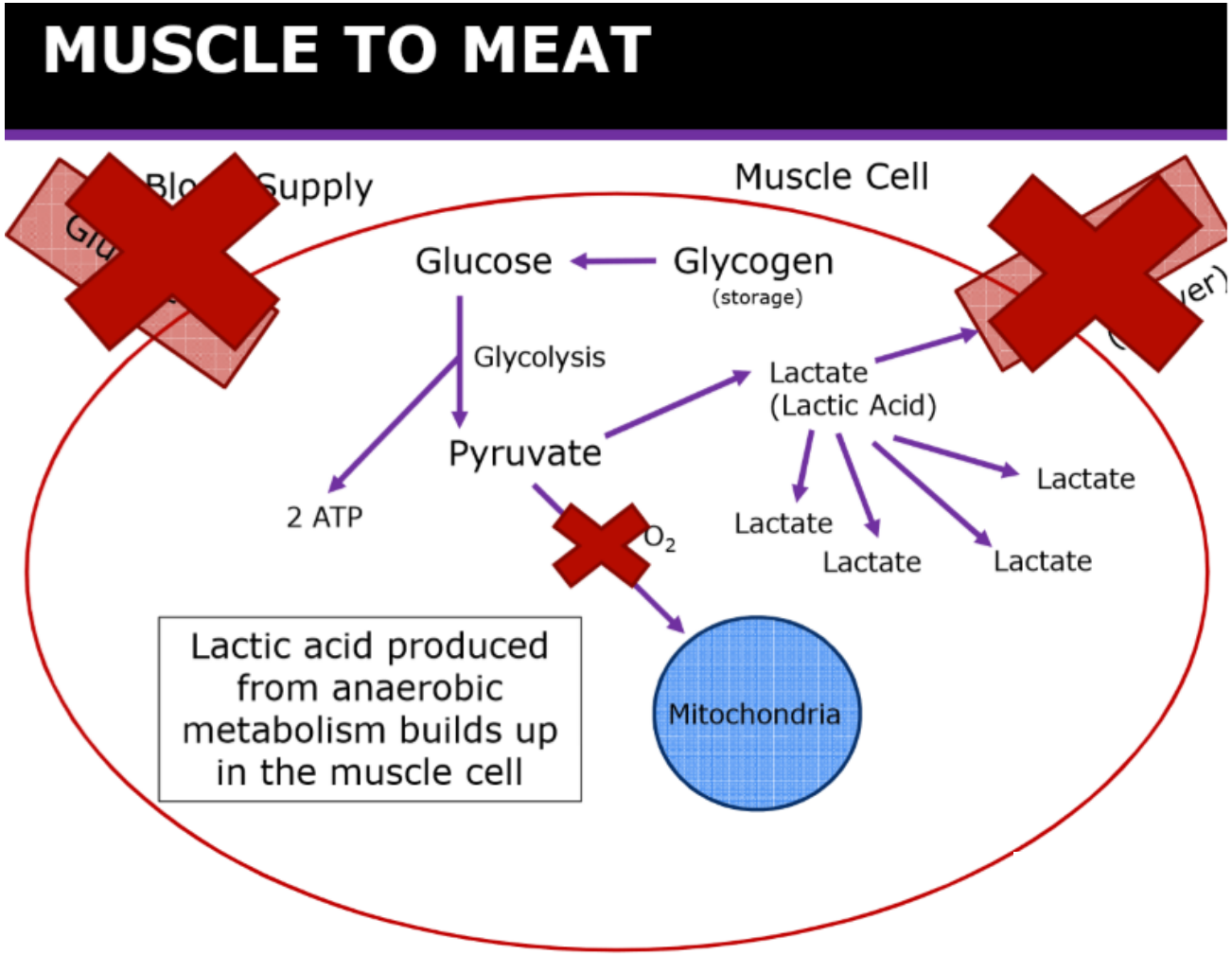
Following an animal's slaughter:

- Its circulation ceases.
- The oxygen supply falls resulting in a reduction of the 'oxidation-reduction‘ potential; the supply of vitamins and antioxidants cease resulting in a slow development of rancidity.
- Nervous and hormonal regulations cease; thereby causing the temperature of
- the animal to .fall and fat to solidity;
- Respiration ceases which stops ATP synthesis;
- Glycolysis begins resulting in the conversion of most of glycogen to lactic acid. Conversion of Muscle which reduces pH from about 7.4 to its ultimate level of about 5.6. to Meat

Following an animal's slaughter: (cont.)

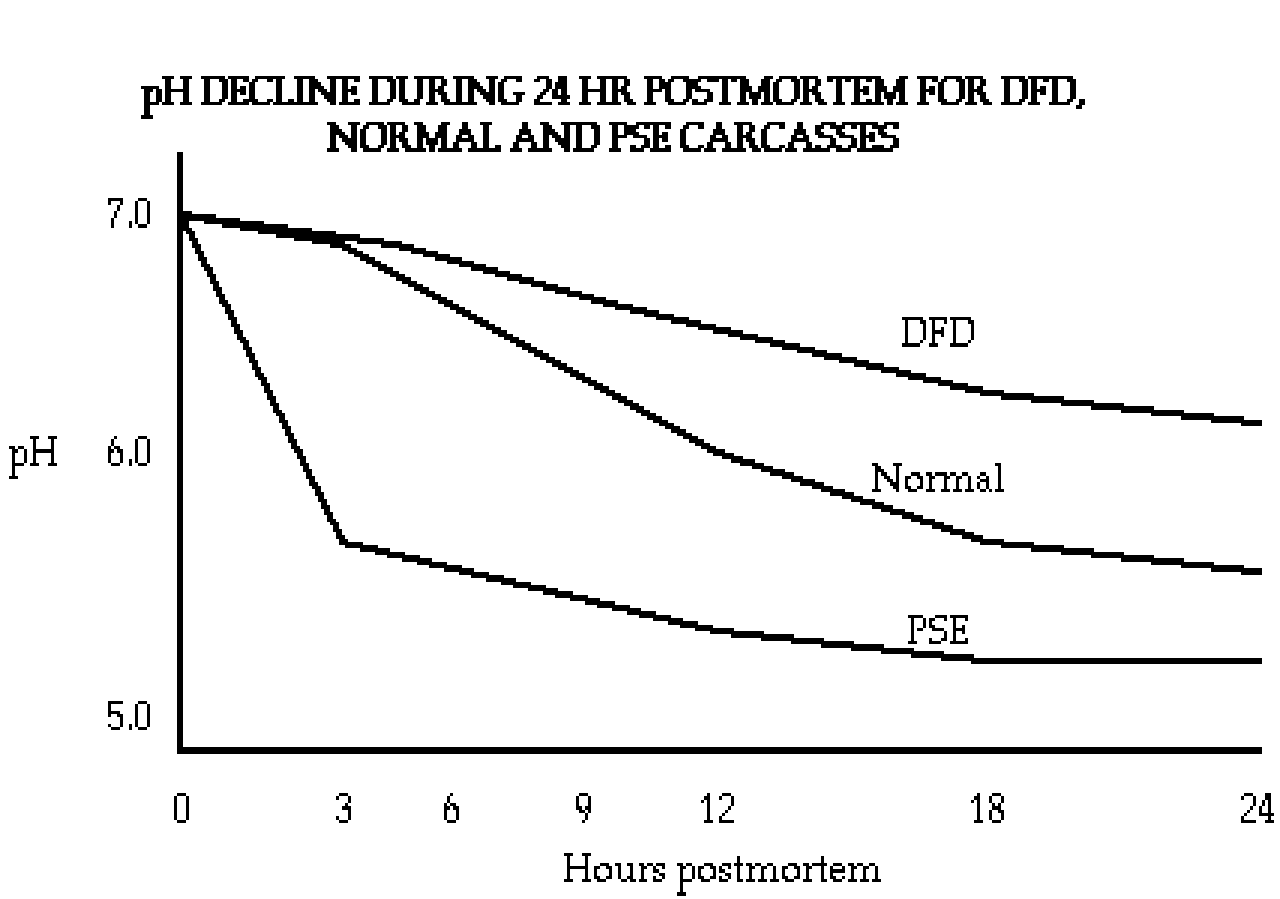
- The ability to resynthesize ATP is lost, lack of ATPcauses actin and myosin to combine to form actomyosin which leads to a stiffening of muscles;
- pH depression initiates protein denaturation, liberates and activates cathepsins and calpains.
- The defence mechanism ceases, thus allowing microorganisms to grow unchecked;
- Accumulation of various metabolites denatures muscle proteins.

THE PROCESS THAT HAPPENS IN A MUSCLE CELL AFTER EXSANGUINATION:



Postmortem pH decline

- As the stored oxygen supply becomes depleted, the aerobic pathway of metabolic process must stop functioning. Then,
- Metabolic process is shifted from aerobic pathway to anaerobic pathway for the production of energy in the form of ATP.
- The lactic acid is produced from anaerobic metabolism and gets accumulated in the muscle instead of going to liver for further metabolism because the circulatory system is no longer available for this transportation.
- Until all the stored muscle glycogen is depleted and the conditions are reached that slow or stop anaerobic glycolysis, lactic acid will continue to accumulate in the muscle.
- This will result in a lowering of pH in the muscle.



• Animal flesh pH 7.1

Slaughtered

Meat pH 5.4-5.7

In dying muscle, lactic acid accumulates and lowers pH.
Within 24 hours after death
(1) glycogen ——-> lactic acid
(2) muscle pH: 7.0 ——-> 5.6 (because of lactic acid)
(3) muscle color: purple changes to bright red or pink
(pH 7.0 ——-> 5.6)

THE PROCESS CONVERSION OF MUSCLE TO MEAT IN TERMS OF THREE PHASES (1. PRE RIGOR MORTIS 2. RIGOR MORTIS 3. TENDERIZATION)

Pre rigor mortis

Vital functions stop

Deprivation of oxygen

Residual O_2 into haemoglobin and myoglobin

Presence of ATP and phosphocreatine

↓

Aerobic metabolism

Actomyosin and myosin dissociation

Rigor Mortis

Start of muscle to meat

↓

ATP and phosphocreatine reservoir exhausting

↓

Anearobic metabolism

No actomyosin and myosin dissociation

Highest toughness

Tenderization phase

Toughness deceases

Activation of proteolitic enzymes

↓

Calpains

Cathepsins

Caspeses

Proteosomes

Introducing proteolytic enzymes externally

Rigor mortis

- Literal translation is “death stiffening.”

- In conversion of muscle to meat, rigor mortis is the most important event.
- The muscles become inextensible or contracted and joints become stiffened after death and this condition is called as '**rigor mortis**'.
- This stiffening results from the permanent cross bridges between actin and myosin filaments in the muscle.
- Again these cross bridges are result of accumulation of lactic acid in the muscle, decline in muscle pH and coagulation of muscle protein.

Rigor mortis

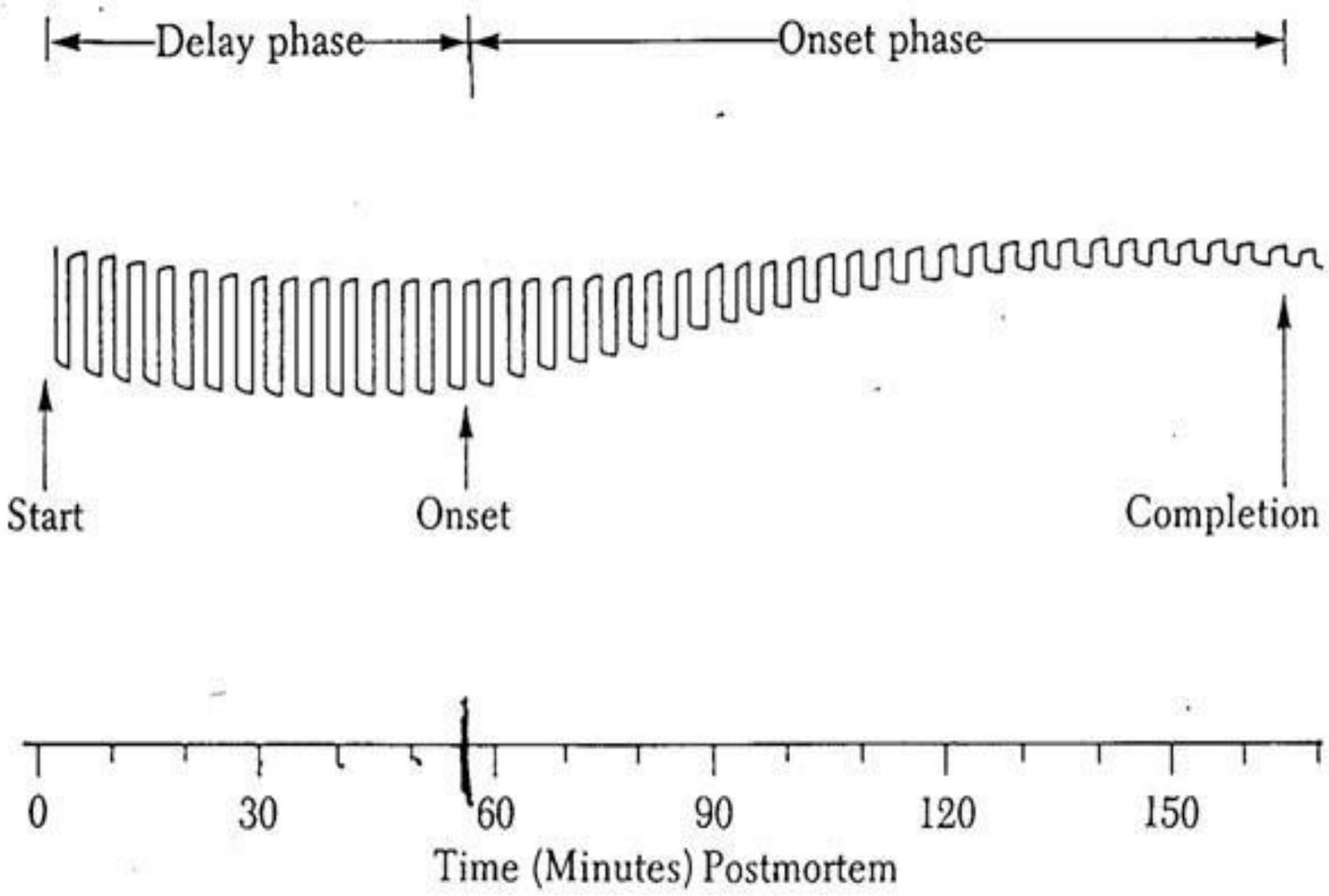
Rigor has four phases:

- **Delay phase**
- **Onset phase**
- **Completion**
- **Resolution**

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

EXTENSIBITILY OF MUSCLE DURING RIGOR DEVELOPMENT



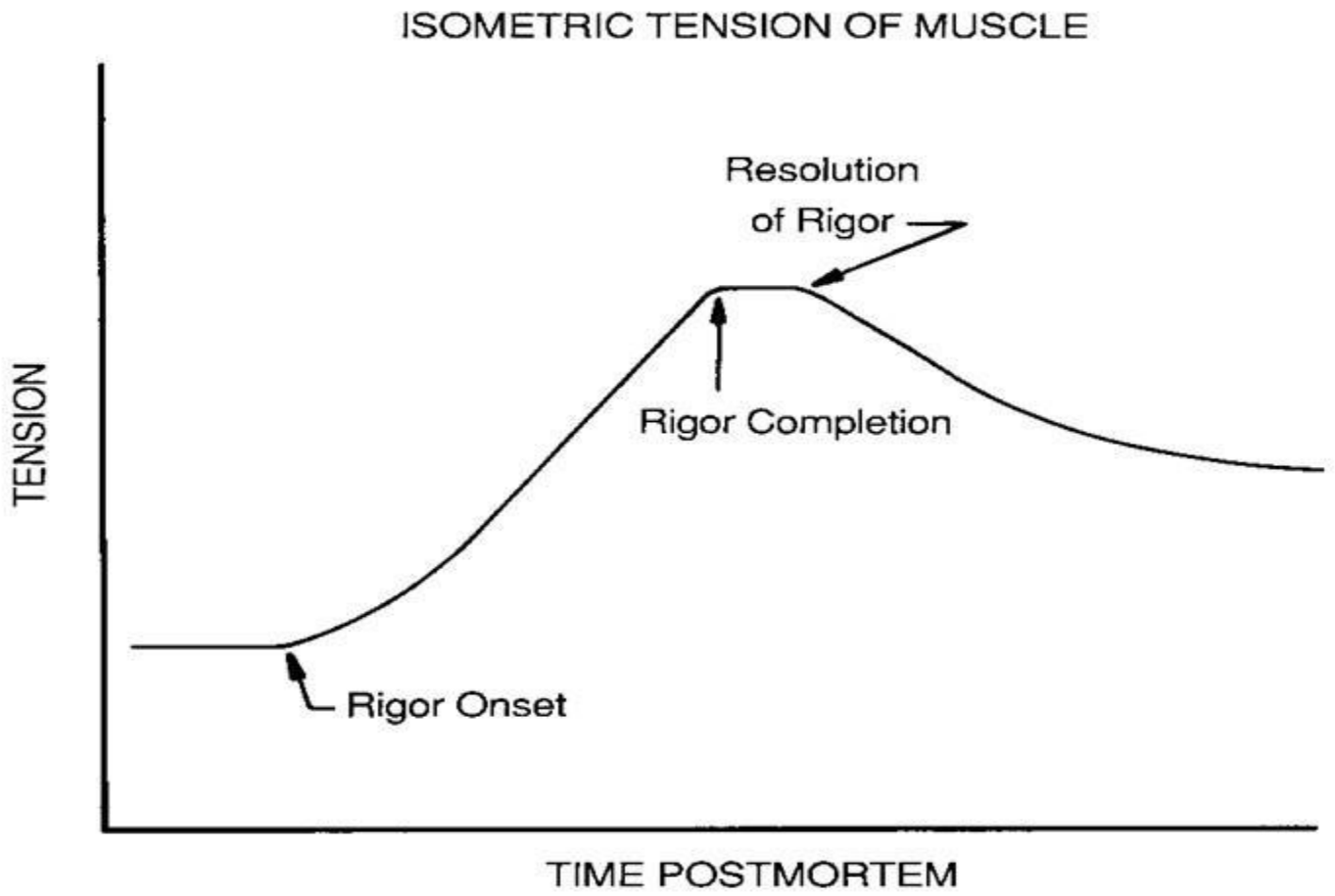
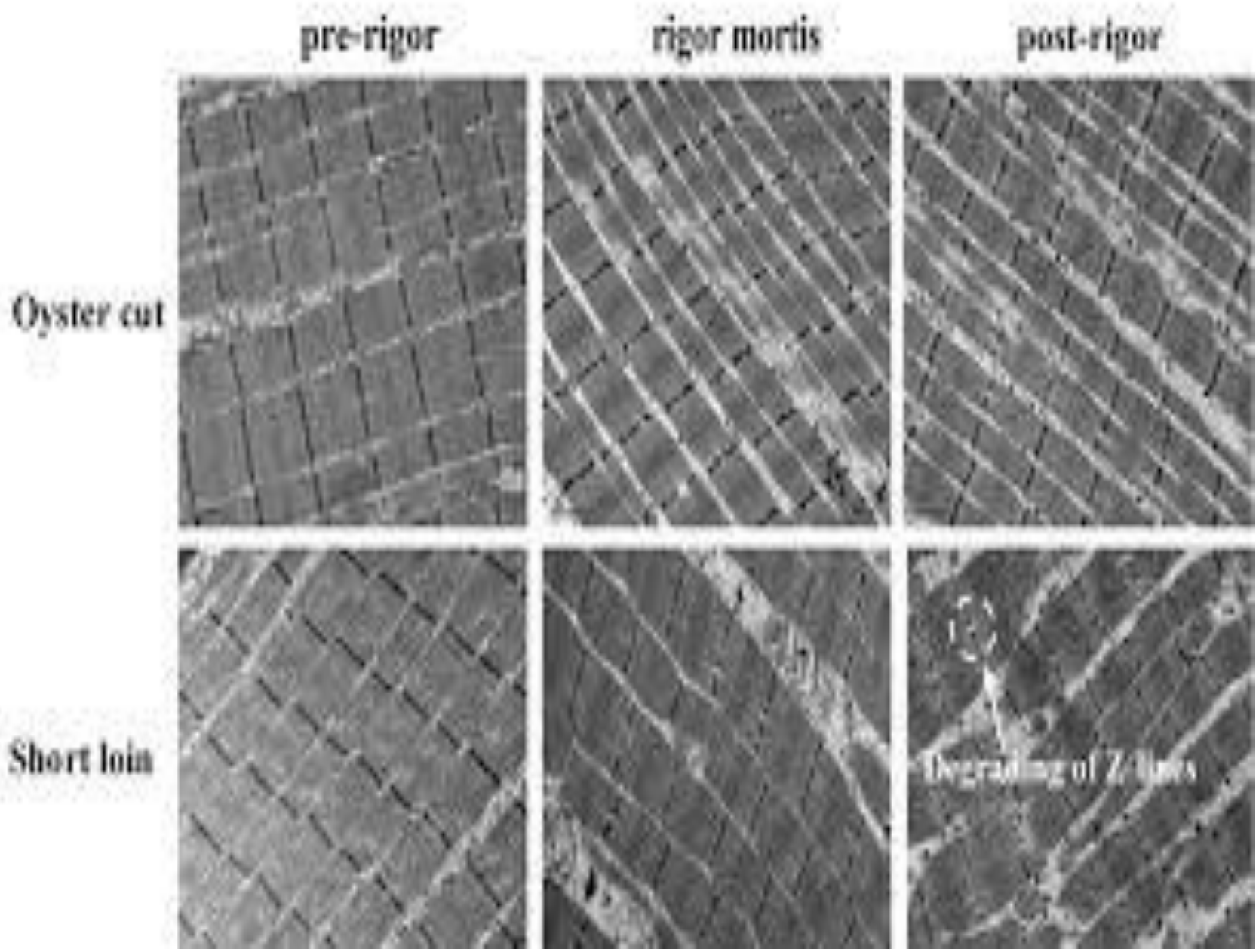


Figure 5.3. Isometric tension development in muscle during phases of rigor mortis.

Resolution of rigor

- After a period of completion of rigor mortis, rigors 'passes off' i.e., the muscles do not remain stiff indefinitely. The muscles again soften during this progressive 'resolution‘ of rigor.
- This 'resolution' of rigor occurs due to physical changes in muscle structure.
- Z-line structure of the muscle fibre becomes disintegrated.
- The degradation of muscle structure can be estimated from the myofibrillar fragmentation index (mfi).
- After death of the animal, mfi increases with advancement of ageing time and the meat becomes more tender on cooking.


pre-rigor
rigor mortis
post-rigor
Oyster cut
Short loin

Conditioning of meat

- Conditioning of meat is also known as ripening or ageing of meat.
- Two types of changes:

  (i) weakening of the myofibrils and

  (ii) Structural changes in intramuscular connective tissue.
- The main causative factor for conditioning is the myofibrillar change which is associated with breakdown of attachments of the thin (actin) filaments to Z-discs.
- Neither actomyosin complex dissociates nor the muscle becomes extensible during conditioning.

Conditioning of meat

- very small change in the connective tissue component like collagen where some cleavages of cross-links are seen.

Two main sorts of proteolytic enzymes responsible for tenderization:

  - calpains and
  - cathepsins

- **Cathepsins** occur in the lysosomes and generally act at acidic pH.
- They tenderized meat by degrading troponin-T, some collagen cross-links and mucopolysaccharides of the connective tissue ground substances.

CONDITIONING OF MEAT

- **Calpains** are located in the region of Z-lines and activated by calcium ions, higher pH, and temperature and reduced calpastatin activity.

- **Calpastatin** is the inhibitor of calpains.
- Calpain is otherwise known as CASF i.e., calcium activated sarcoplasmic factor.

Two forms of calpains:

- m-calpain and
- μ-calpain.

Loss of structural integrity

- Resolution of rigor mortis results in disintegration of Z-line structure and conditioning leads to breakdown of myofibrillar structure and denaturation of collagenous connective tissue.

- Thereby the membrane properties are altered and the microscopic muscle structure does not remain same after all these postmortem events as they were in the living muscle.

Loss of protection from bacterial invasion

- Due to altered membrane properties muscles become susceptible to invasion of microorganisms.
- We know that the lymphatic system and white blood cells of circulatory system prevent the spread of microorganisms.
- After exsanguinations of the animal, these two systems do not work and microorganisms can spread throughout the muscles very easily.
- Most of the postmortem changes favour the growth of the microorganisms except the lowered pH of the muscle which inhibits the microbial proliferation.