MEAT SCIENCE

Topics covered

- Prospects of meat industry in India
- Structure and composition of muscle
- Nutritive value of meat
- Muscle to meat conversion
- Abattoir standards

Prospects of meat industry in India

NIN guidelines: 180 eggs and 11 kg of meat per capita

Availability: 101 eggs and 7.1 Kg of meat

Rank of India: 8th in meat production and 3rd in egg production

Top Producing states: Uttar Pradesh(meat) & Andhra Pradesh (Egg)

Contribution of Livestock to Gross value addition: 5.73% of total and 30.19% to agriculture sector

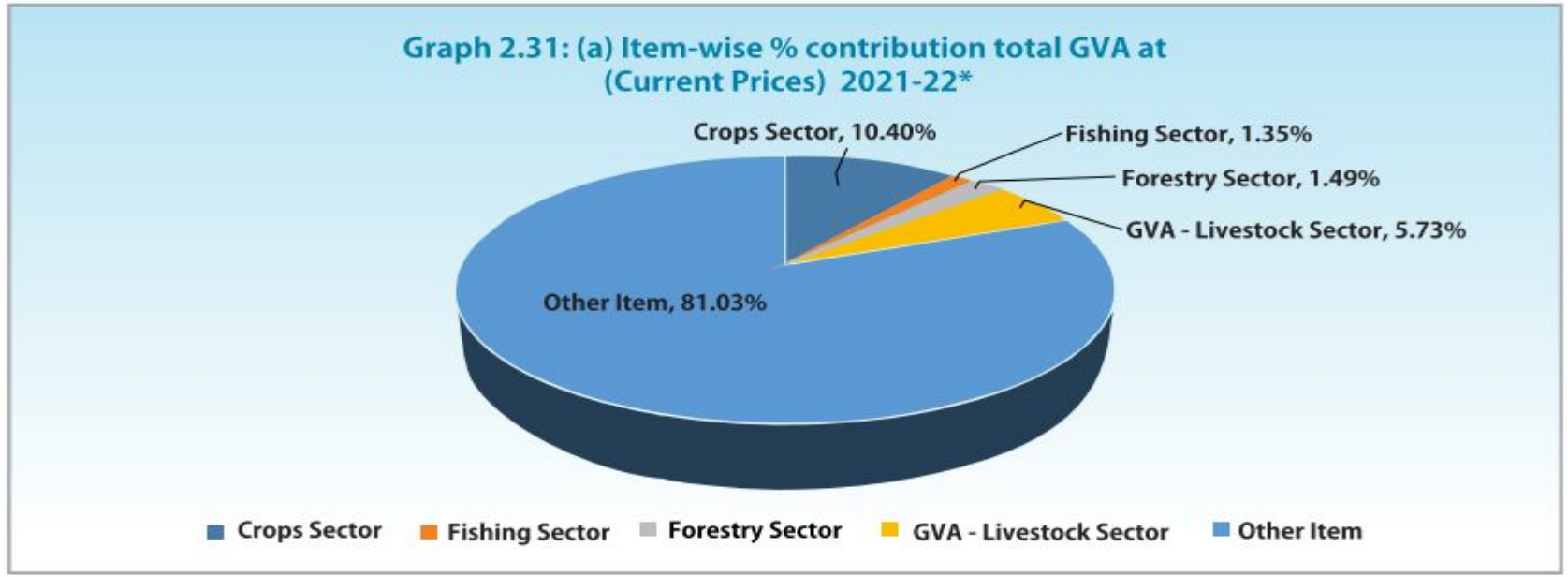
Poultry -main sector contributing to total meat production (51%)

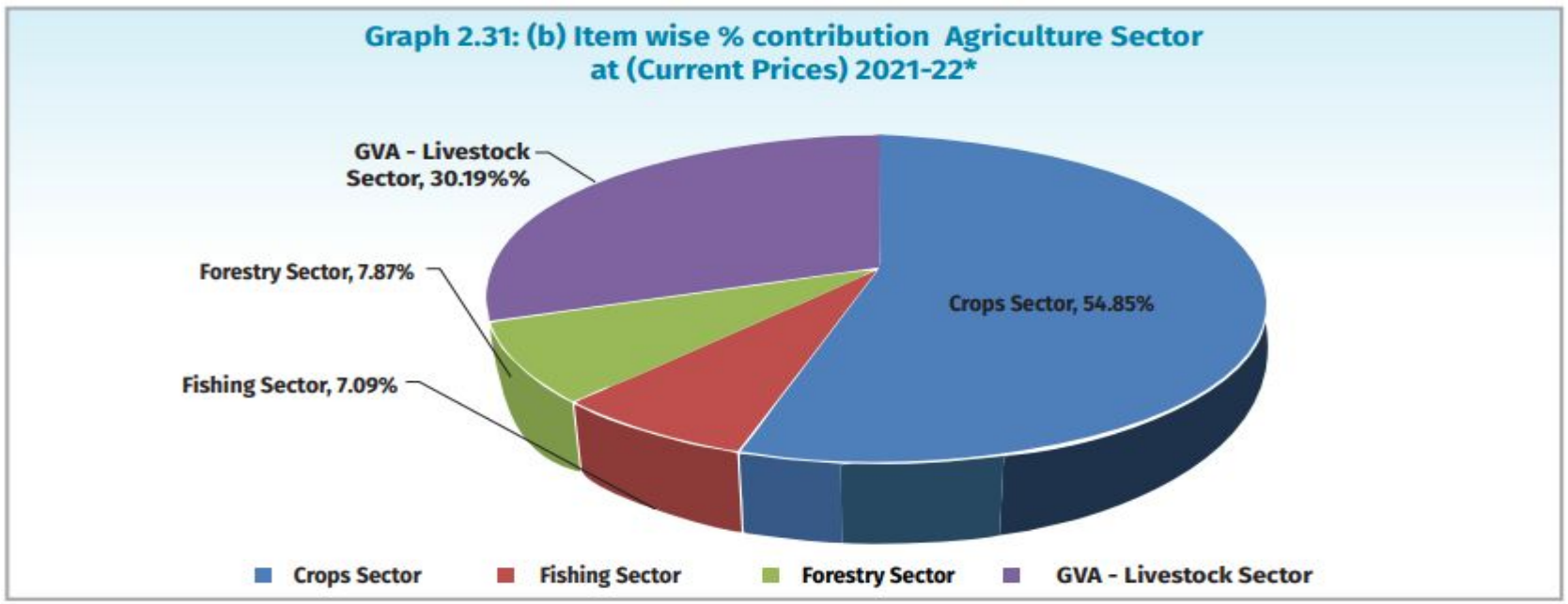
Buffalo meat share in total meat exports from India – 82%

3,900 licensed & authorized slaughter houses besides around 26,000 unauthorized slaughter houses

Registered Abattoirs cum meat processing plants with APEDA for export - 73

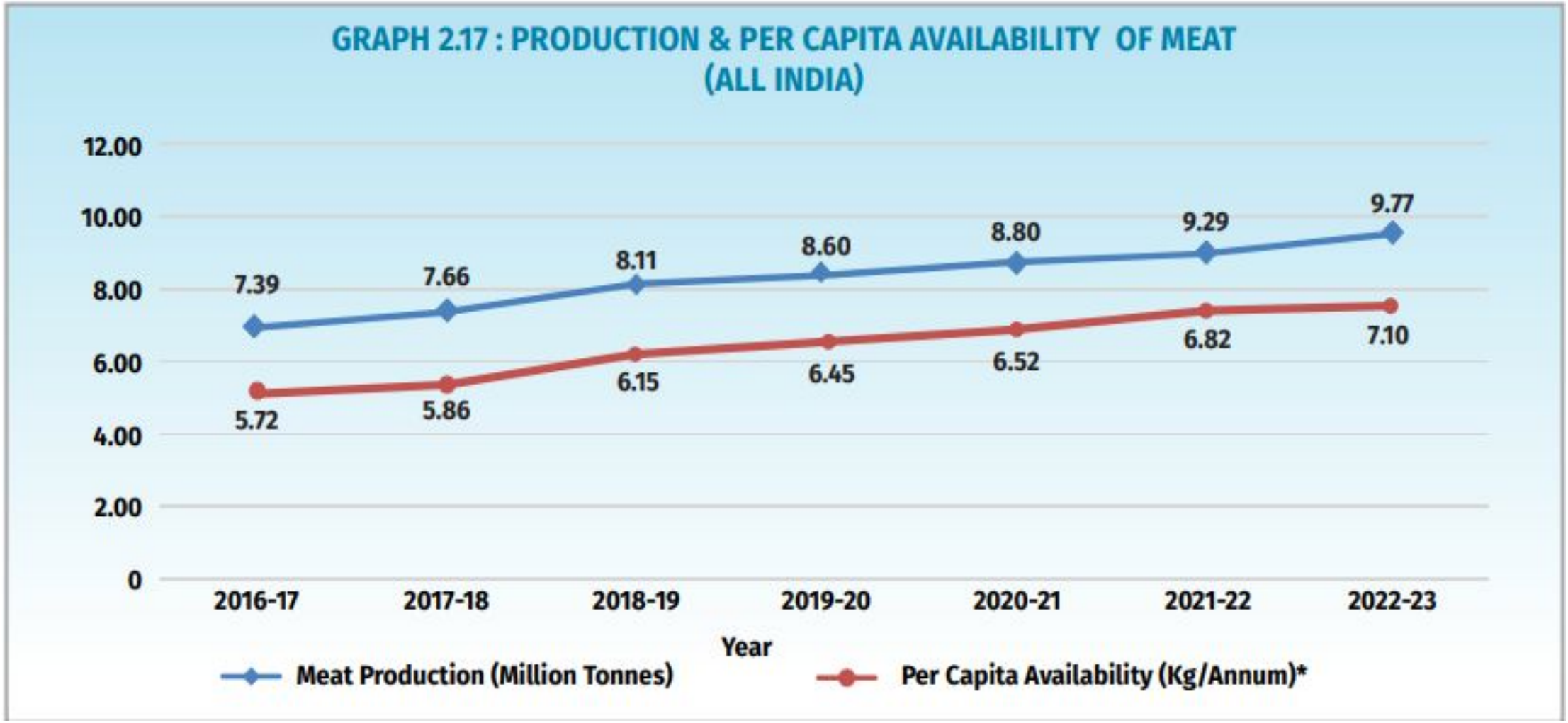
2.6.1 ITEM-WISE PERCENTAGE CONTRIBUTION IN AGRICULTURE & ALLIED SECTOR (A&AS) AND TOTAL GVA



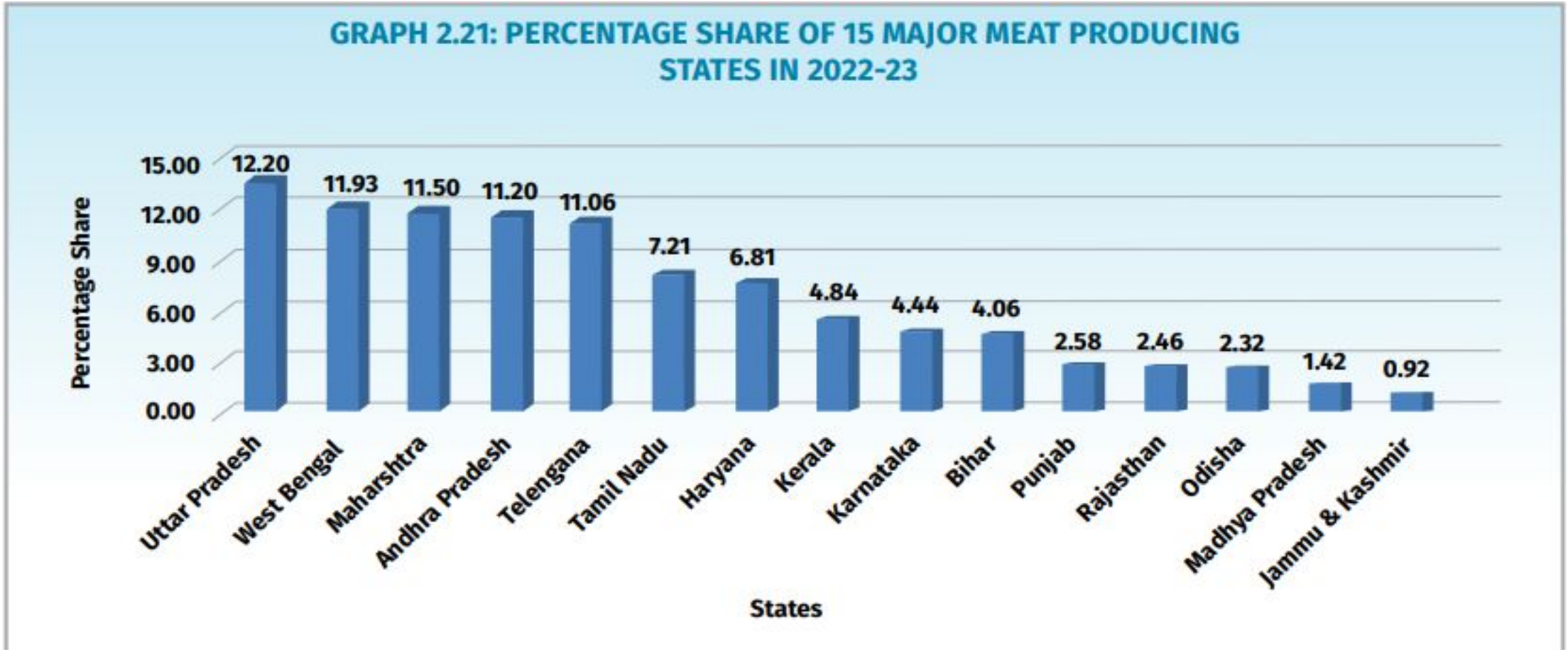


- The total meat production in the country is 9.77 million tonnes during 2022-23.
- India ranks 8th in the world in terms of total Meat production (Source: FAO).
- The meat production has increased by 5.13% as compared to previous year (2021-22).
- The meat production from poultry is 4.995 million tonnes, contributing about 51.14% of total meat production. The growth of poultry meat production has increased by 4.52% over previous year.
- The top 5 meat producing States are Uttar Pradesh (12.20%), West Bengal (11.93%), Maharashtra (11.50%), Andhra Pradesh (11.20%) and Telangana (11.06%). They together contribute 57.90% of total meat production in the country.

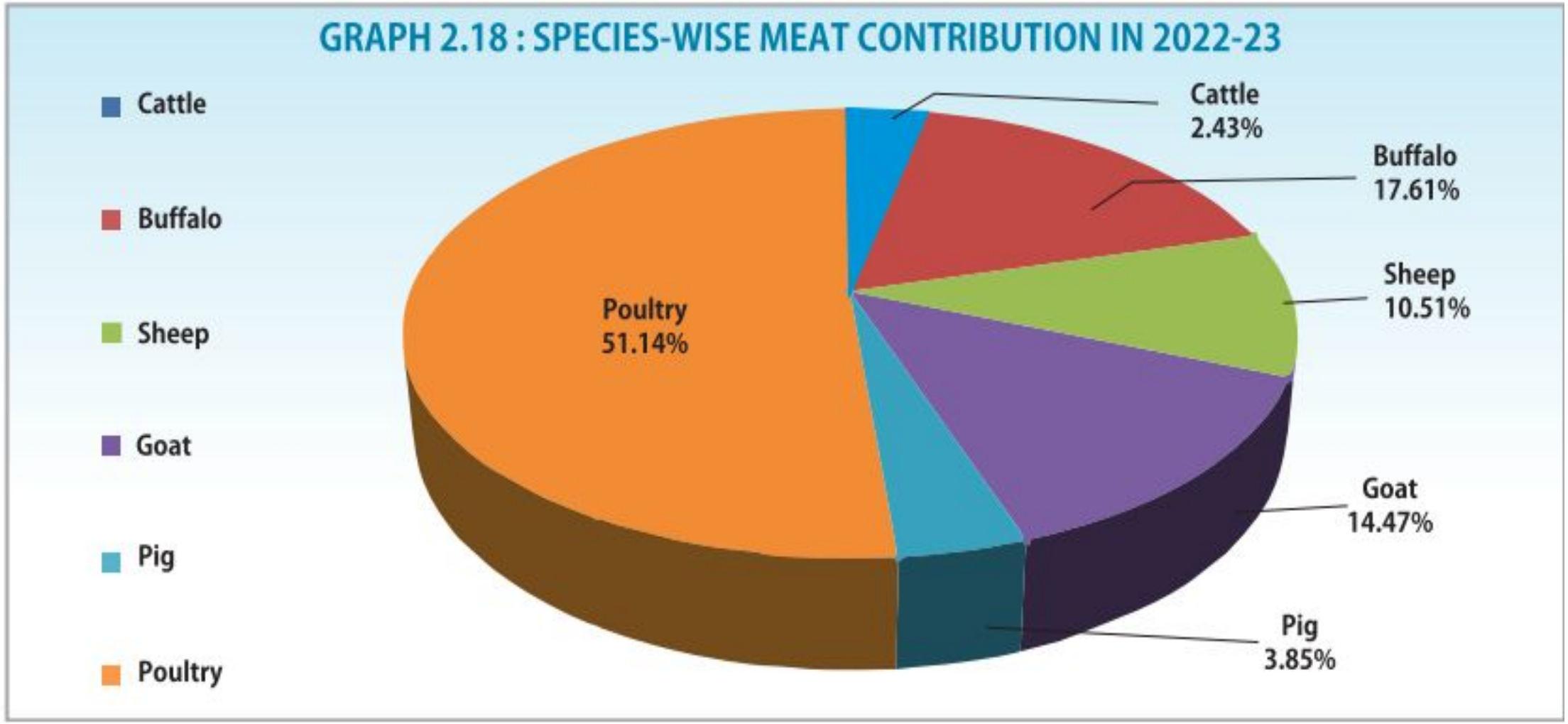
Production and availability



State wise Contribution



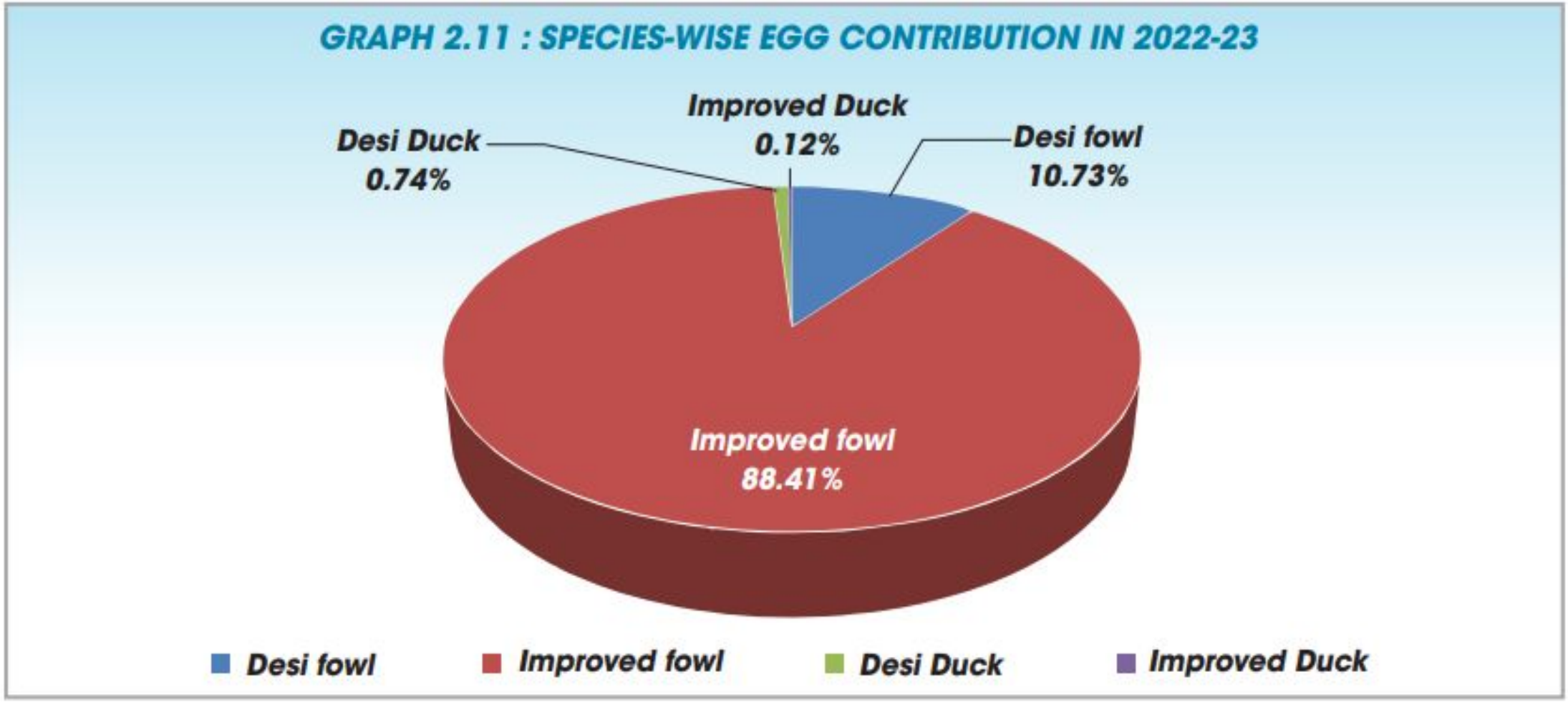
Species Wise Contribution



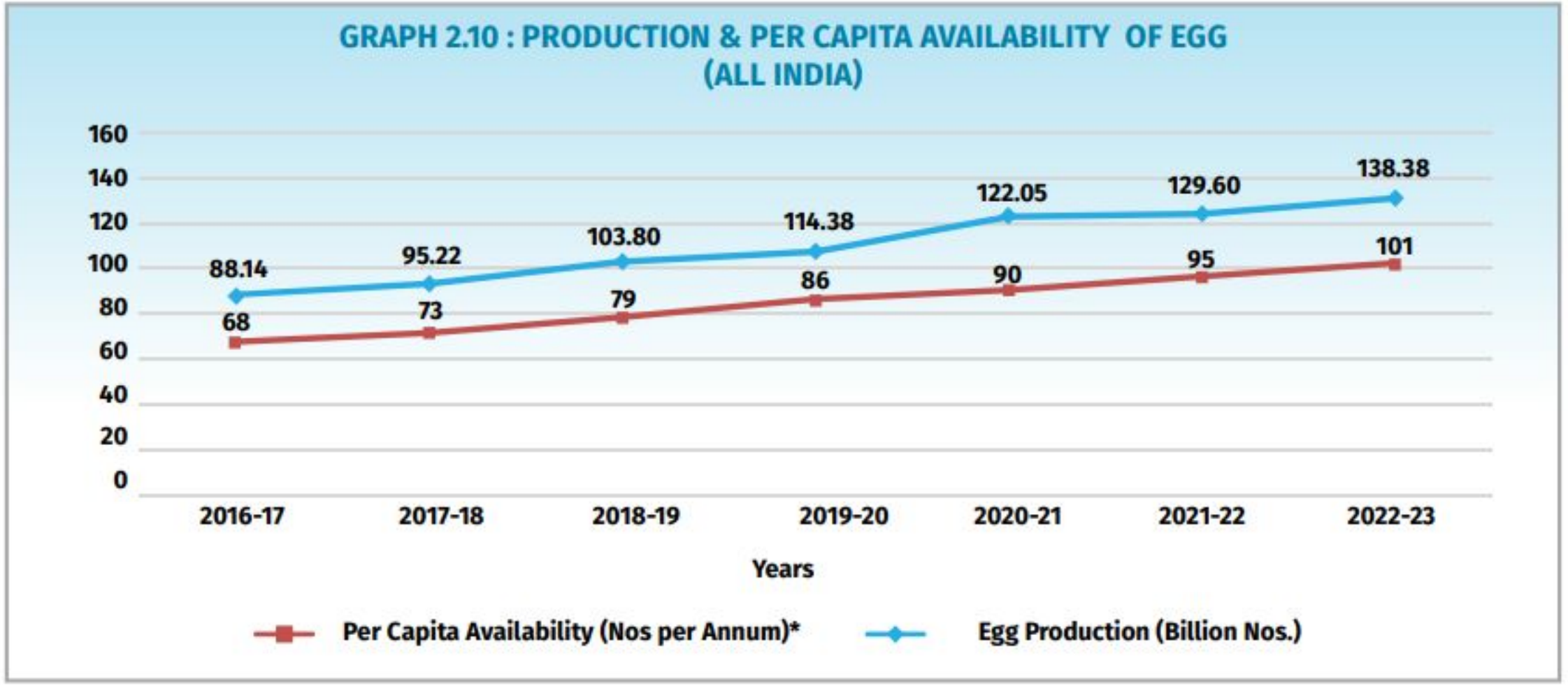
MAJOR HIGHLIGHTS OF EGG PRODUCTION

- The total egg production in the country is 138.38 billion numbers during 2022-23.
- India ranks 3rd in the world in terms of total Egg production (Source: FAO).
- The egg production has increased by 6.77% as compared to previous year (2021-22).
- The per-capita availability of egg is 101 eggs per annum.
- Top 5 egg producing States are Andhra Pradesh (20.13%), Tamil Nadu (15.58%), Telangana (12.77%), West Bengal (9.93%) and Karnataka (6.51%) They together contribute 64.93% of total egg production in the country.
- The total egg production from commercial poultry is 118.16 billion numbers and backyard poultry are 20.20 billion numbers contributing 85.40% and 14.60% of total production of egg respectively.

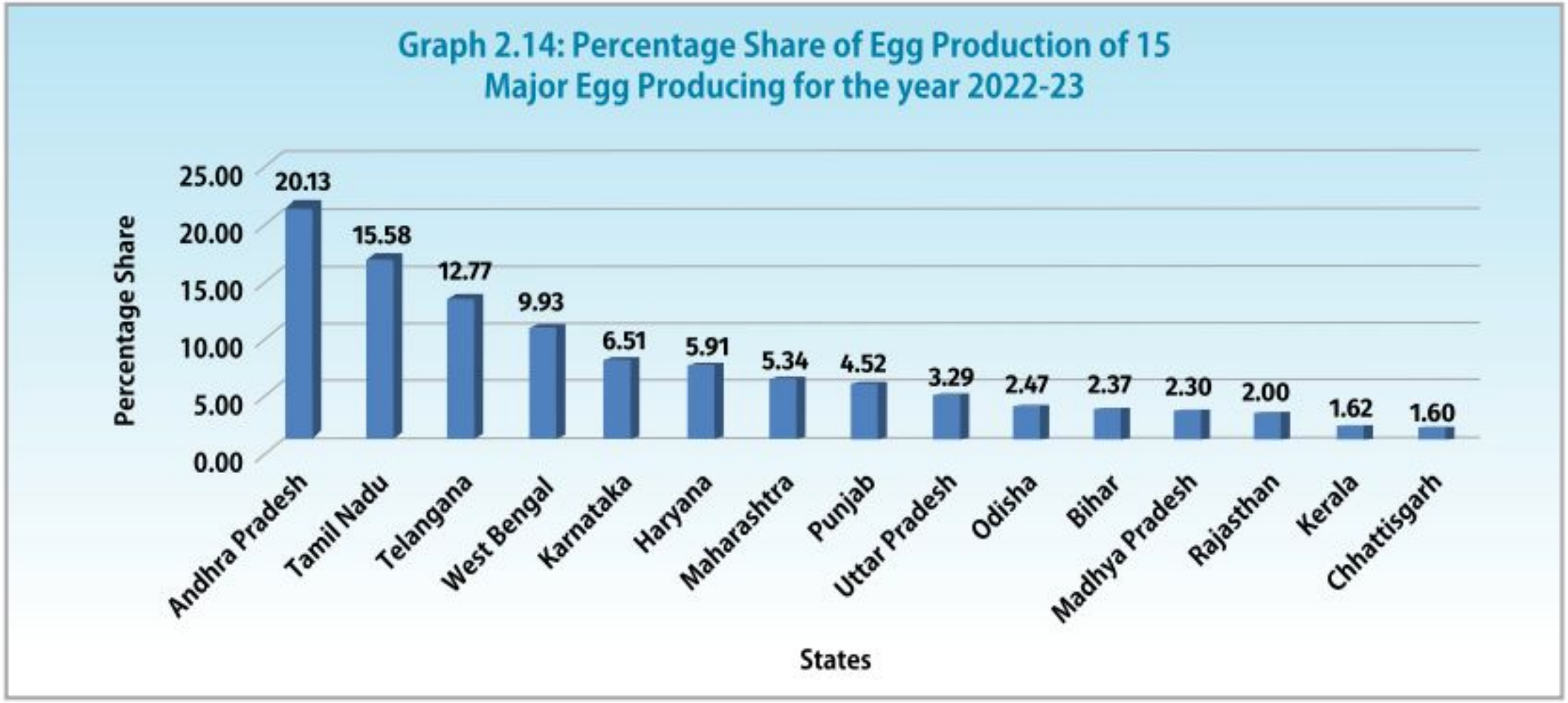
Species Wise Contribution



Production and availability



State wise contribution



20th Livestock Census (DAHD, 2019)

Category	2012	**2019**	% Change (2012 to 2019)
Cattle	190.9	**192.52**	**0.85**
Buffalo	108.7	**109.85**	**1.06**
Yak	0.08	**0.06**	-25.00
Mithun	0.30	**0.38**	26.66
Bovines	299.98	**302.82**	1.00
Sheep	65.07	**74.26**	**14.13**
Goat	135.17	**148.88**	**10.14**
Horses & Ponies	0.63	**0.34**	-45.24
Mules	0.20	**0.08**	-57.09
Donkeys	0.32	**0.12**	-61.23
Camels	0.4	**0.25**	-37.05
Pigs	10.29	**9.06**	-12.03
Total livestock	**512.06**	**535.82**	**4.64**

Export of Animal Products for 2023-24 APEDA: Agricultural and Processed Food Export Development Authority

CATEGORY	Value (in crores Rs.)
Buffalo Meat	31010.10
Sheep/ Goat Meat	643.55
Poultry Products	1530.20
Dairy Products	2260.94
Animal Casing	399.21
Processed Meat	20.55
Albumin (Eggs & Milk)	173.06
Natural Honey	1470.84
TOTAL	37,665.51

Meat of different animals

- Goat: Chevon
- Sheep: Mutton
- Deer (game animals): Venison
- Pig: Pork
- Cattle: Beef
- Horse: Chevaline
- Buffalo: Carabeef
- Calf: Veal
- Bobby calves: calves slaughtered within a few days of birth

Nutritive value of meat and poultry

- high quantity as well as quality of proteins, available supply of vitamin B complex, some minerals (Fe) and some essential fatty acids.
- **Water:** 75%
- **Protein:16-22% (18.5%). Meat contains all essential amino acids among which highest is lysine.**
- **Fat:** 3%

  Lipids: Most abundant fatty acid in meat is oleic acid> palmitic> Stearic acid

  Saturated fatty acids: stearic acid and palmitic acid.

  Cholesterol: lean meat 70-75mg/100g (liver and brain300-2000mg/ 100g)
- **CHO:** 1% or less (major glycogen)

Energy supplied by broiler: 151 cal/100 g

Inorganic substance: 1% minerals

- **Meat:** good source of all minerals except calcium. Max is K followed by P.
- **Vitamins:** good source of B complex but poor source of vitamin C (absent in lean meat)
- Lean pork has 5-10 times more thiamine than other meats

100 g serving of meat supplies:

- 10% of RDA of calories
- 50% of RDA of proteins (RDA of proteins is 56 g @ 0.8 grams/ kg BW).
- 35% of iron demand (**100% if serving is liver**)
- 25-60% of B complex vitamins

Skeletal muscles

- Water- 75% & Solids 25%
- Protein- 19%
- Lipids- 2.5%
- Carbohydrates- 1.2%
- Nitrogenous Subst.- 1.65%
- Inorganic Subst.- 0.65%
- Vitamins- traces

Water 75%	Protein 19%		Lipids 2.5%	Carb. 2.5%	Miscellaneous 2.3%		Vitamins Minute qu.	
	Myofibrillar 11.5%	**Sarcoplasmic 5.5%**	**Connective tissue 2.0%**	Neutral lipids	Glycogen	Nitrogenous subst.	Inorganic subst.	Water sol.	Fat Sol
	Myosin 50-55%	Haeme pigment (Myolobin)	Collagen			Creatinine	Macro Elements	Vitamin B complex	Vitamin A
	Actin 20-25%			Phospholipids	Glucose-6-phosphate				
	Tropomyosin 8-10%	Oxidative enzymes				Ionosine Phosphate	Micro Elements		Vitamin D
	Troponin 8-10%	Mitochindrial oxidative enzymes	Reticulin	Cerebrosides	Glucose				
	C protein 2-2.5%								
	M protein 4.0%	Lysosomal enzymes				Nucleostides	Trace Elements		Vitamin E
	Alpha actinin 2-2.5%	Nucleo-proteins	Elastin	Cholesterol	Lactic Acid	Carnosine			
	Beta Actinin 1-1.5%					Anserine etc.			Vitamin K

Structure and composition of muscle tissue

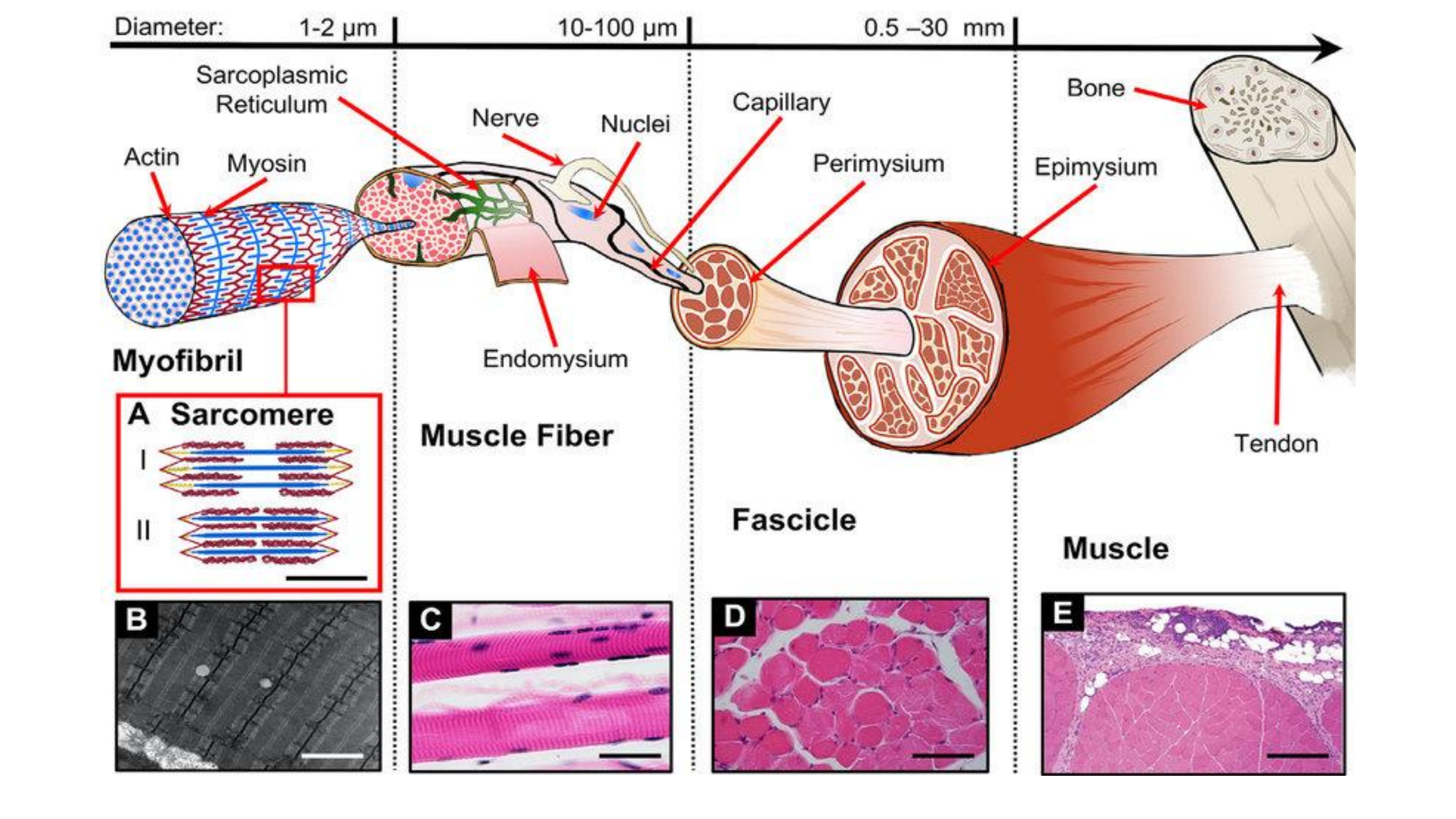
- Meat: animal tissue which are suitable for use as food.

Composition:

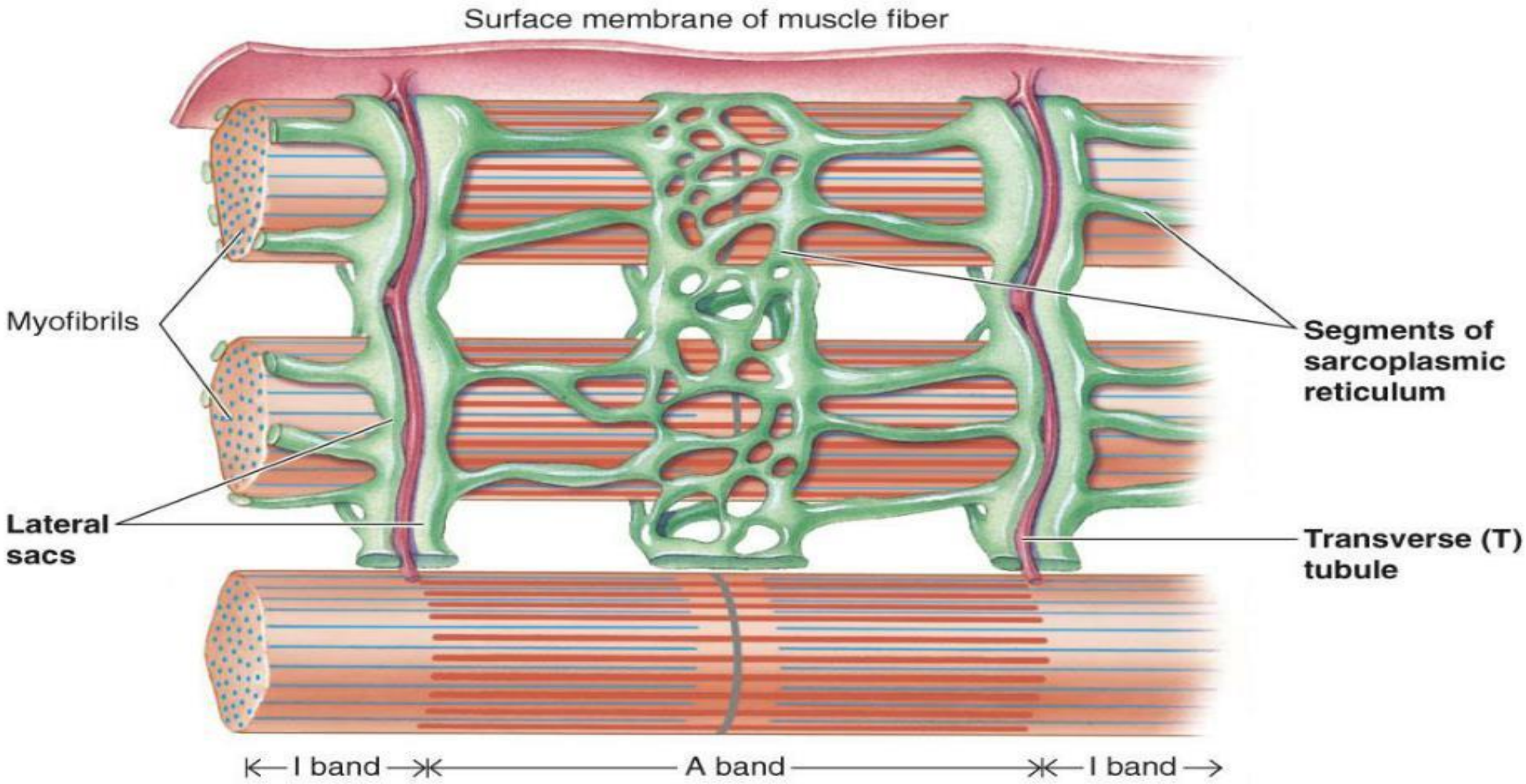
1. Muscle- skeletal muscles, smooth muscles and cardiac muscles
2. Connective tissue - adipose tissue, cartilage, bone, connective tissue proper.
3. Nervous tissue
4. Epithelial tissue

Skeletal muscles:

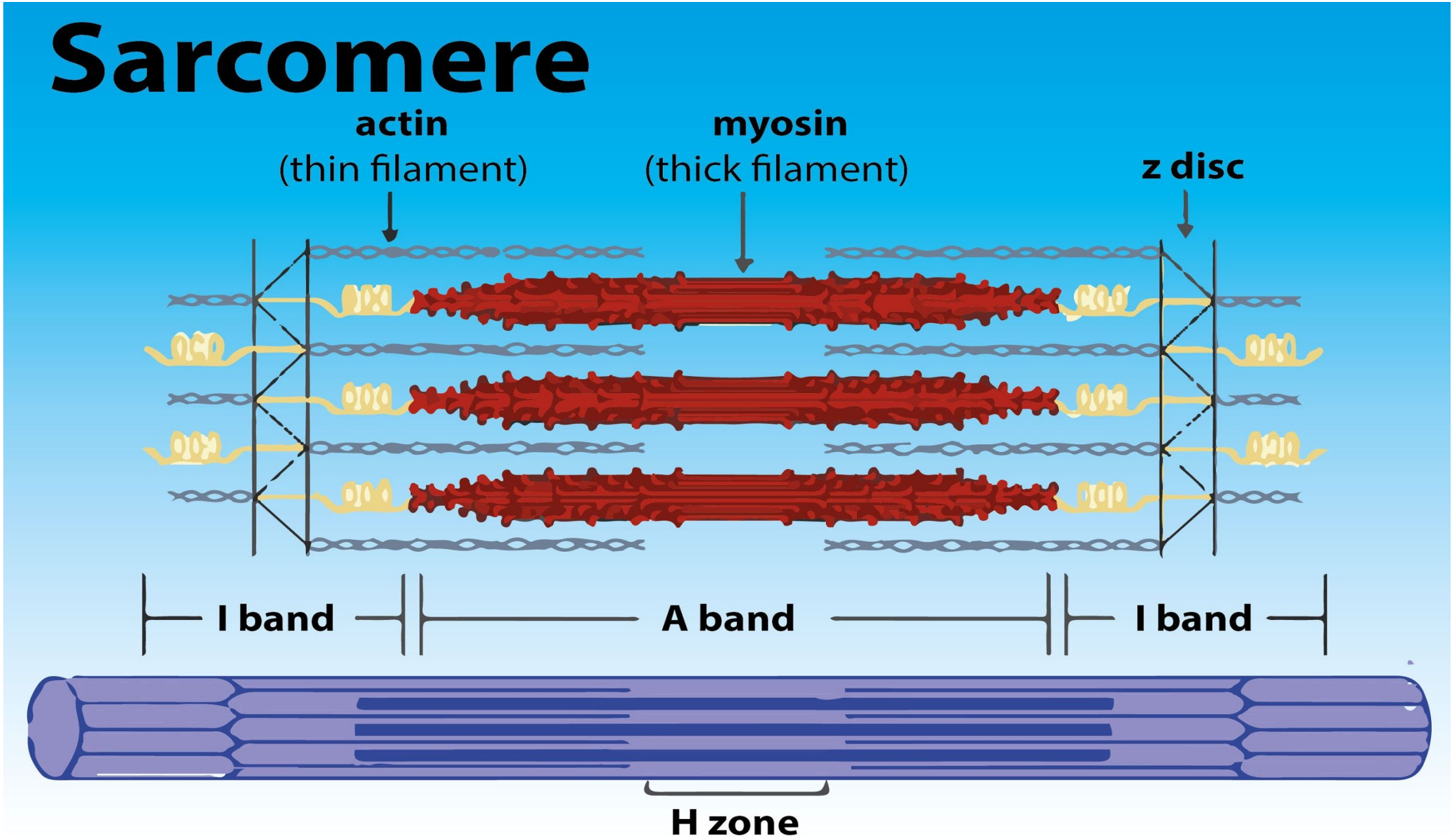
- Constitute bulk of carcass (35 to 65%)
- Covered with connective tissue
- **Epimysium:** Outermost covering of connective tissue surrounding a muscle.
- **Perimysium:** covering of Muscle bundles
- **Endomysium:** CT covering the muscle fibre.
- **Muscle fibre:** specialized cell structural unit of muscle & form 75-92% of total muscle volume. Have Diameter of 10 to 100 microns.
- **Sarcolemma:** membrane surrounding the muscle fibre.
- **Sarcomere:** basic contractile unit of muscle fibre.

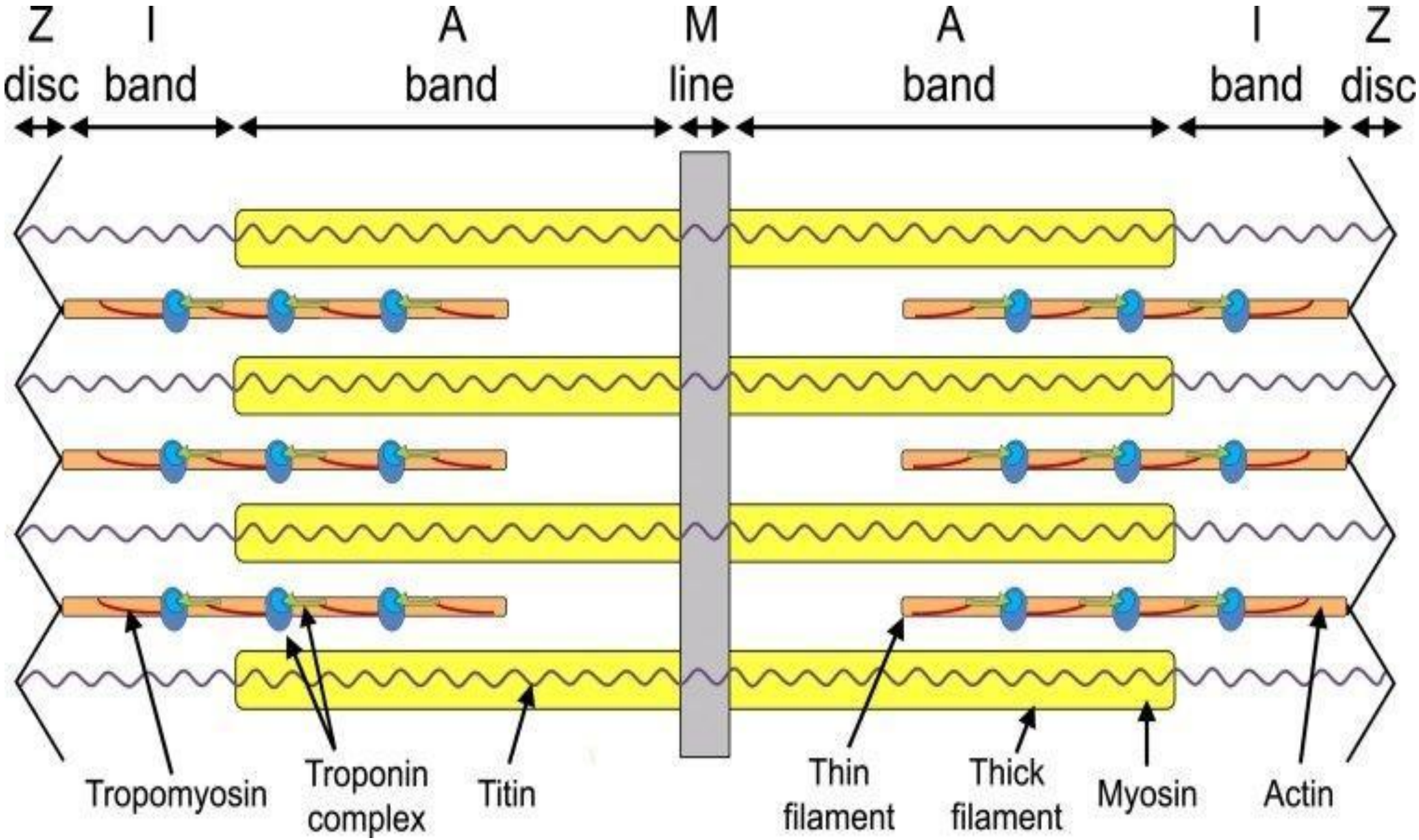

Diameter:
1-2 µm
10-100 µm
0.5 –30 mm
Sarcoplasmic Reticulum
Actin
Myosin
Nerve
Nuclei
Capillary
Perimysium
Bone
Epimysium
Myofibril
Endomysium
Tendon
A Sarcomere
I
II
Muscle Fiber
Fascicle
Muscle
B
C
D
E

T Tubules and Sarcoplasmic Reticulum

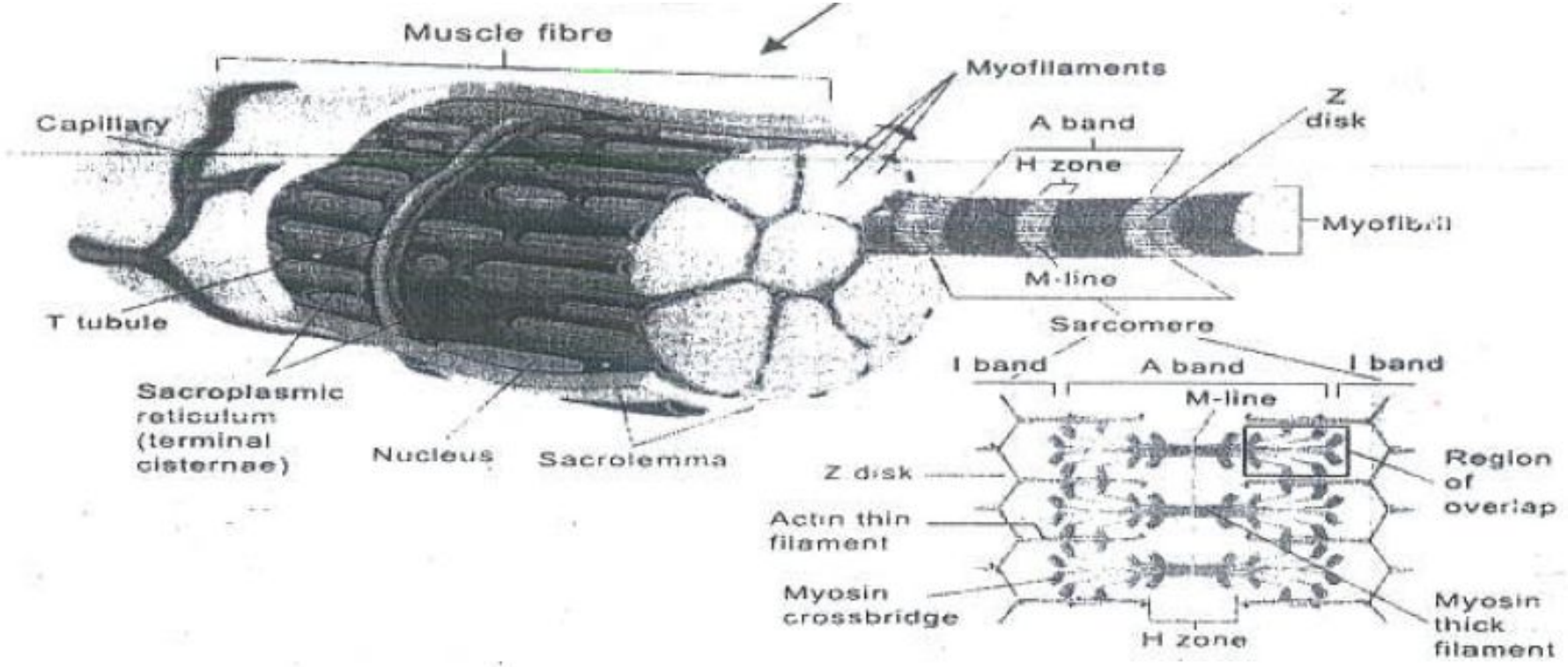


Sarcomere


actin
(thin filament)
myosin
(thick filament)
z disc
I band
A band
I band
H zone


Z disc
I band
A band
M line
A band
I band
Z disc
Tropomyosin
Troponin complex
Titin
Thin filament
Thick filament
Myosin
Actin

- T- tubules/T systems/transverse tubules: These are deep invaginations of sarcolemma. In skeletal muscle T tubule invaginations are typically located at the junction of A-I band of sarcomere. Thus a sarcomere has two T tubules.
- Sarcoplasm: It is the cytoplasm of muscle fibre. Sarcoplasmic reticulum (SR)- as reservoir for calcium ions



- **Nuclei:** Muscle fibres are multinucleated.

- **Myofibrils:** These are long, thin, cylindrical rods with diameter of 1 to 2 microns. They contain some filaments known as myofilaments which are called thick and thin myofilaments (striated appearance).

- **Thick filaments** (myosin): form A band which is broad dark band and bisected by M line.
- **Thin filaments** (actin): forms I band which is bisected by Z line.
- H zone: Contains only myosin filaments.

- Sarcomere: unit of myofibril between two adjacent Z-lines. Include A band and 2 half I bands.

- In transverse section, each myosin filament is surrounded by six actin filaments in hexagonal arrangement.

- **Proteins of myofilaments:**
  a. **Contractile-** action and myosin (75 to 80%)
  b. **Regulatory-** Z line proteins, tropomyosin, troponin.

- **Myosin:** most abundant myofibrillar protein (50-55%)
- Ratio of length to diameter is 190:1.
- Strong affinity for Ca and Mg ions – ATPase activity stimulated by Ca and inhibited by Mg
- **Actin:** 20-25%. G(globular) and F(fibrous) actin
- **Tropomyosin:** 8-10% of myofibrillar proteins.
- **Troponin:** 3 subunits

  Troponin T: binds to tropomyosin and troponin C

  Troponin C: binds with Ca ions

  Troponin I: inhibits actino-myosin ATPase complex
- **Connective tissue protein:** collagen (rich in hydroxyproline & Proline but poor in lysine), elastin (desmosine & iso-desmosine) and reticulin.

Muscle proteins

- **Myofibrillar proteins**: 11.5% - soluble in concentrated salt solution

  E.g. Myosin, Actin, Tropomyosin

- **Sarcoplasmic Proteins**: soluble in water and dilute salt solutions

  E.g. myoglobin, glycolytic enzymes

- **Connective tissue proteins**: Insoluble

  E.g. collagen, elastin, reticulin

Muscle proteins- (19.0%)

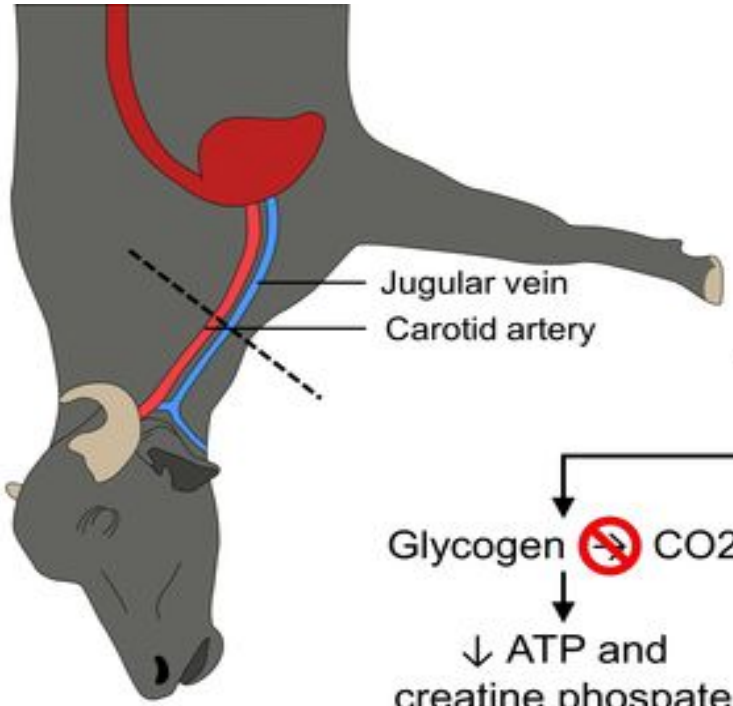
Myofibrillar (11.50%)	**Sarcoplasmic (5.50%)**	**Connective Tissue (2.0%)**
Myosin (5.5%)	Glyceraldehyde Phosphate Dehydrogenase (1.2%)	Collagen (1.0%)
Actin (2.5%)	Creatine Kinase(0.5%)	Elastin (0.05%)
Troponin (0.6%)	Aldose (0.6%)	Organelles(0.95%)
Tropomyosin (0.6%)	Glycolytic Enzymes (2.2%)	
Actinins (0.5%)	Myoglobin (0.2%)	
Nebulin (0.3%)	Hb and extracellular proteins (0.6%)	
Connectin (0.9%)		
M-line & C Proteins (0.2%)		
Miscellaneous (0.4%)		

Myoglobin

- Sarcoplasmic protein
- Gives red colour to muscle
- Content will be higher in red muscle fibre and low in white
- Carrier of oxygen to muscle fibre
- Oxymyoglobin: cherry red colour
- Metmyoglobin: Brownish red colour

Conversion of Muscle to Meat

- Post-mortem glycolysis and pH decline
- Rigor Mortis
- Loss of Protection from Invading Microorganisms
- Degradation due to proteolytic enzymes
- Loss of Structural Integrity
- resolution of rigor mortis.



Exsanguination

↓

Blood circulation stops

↓

↓ Oxygen supply

↓

↓ Oxidation-reduction potential

↓

Anaerobiosis

Glycogen → CO2

↓

↓ ATP and creatine phospate

↓

Ca2+ dependent proteases activate

↓

Onset of rigor mortis

↓

Accumulation of metabolites, flavour, components

Glycogen → lactic acid

↓

↓ pH

↓

Activation of cathepsins

↓

Protein denaturation

↓

Exudation of fluid and discoloration

Water-holding capacity and color determined

Bacterial growth

↓ Nutrient and antioxidant supply

↓

Lipid oxidation

Meat yield of 58%

* **Loss of Homeostasis:** The homeostasis is controlled by nervous system, which ceases to function within 4-6 minutes after bleeding.

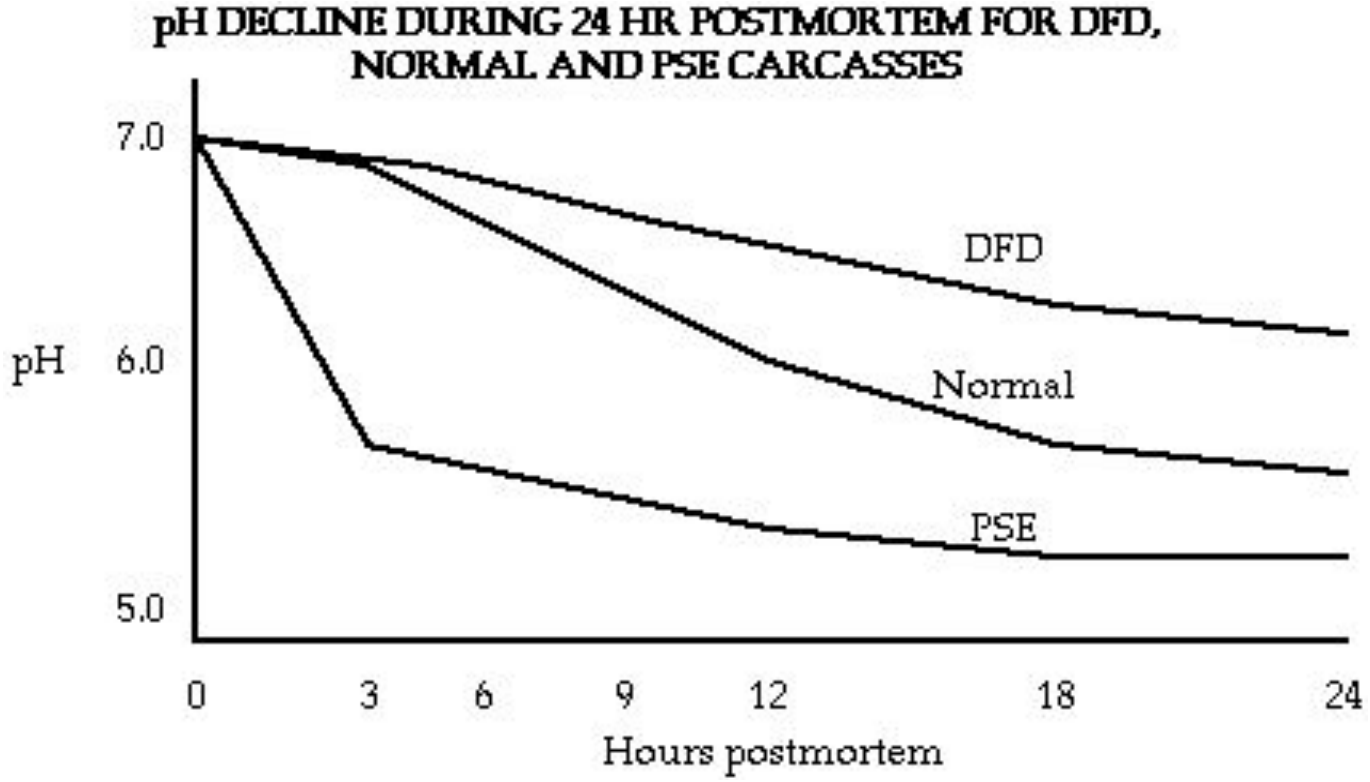
✔In the absence of blood supply, there is loss of body heat and temperature starts declining.

✔**Decline in pH:** In the absence of oxygen, anaerobic glycolysis leads to the formation of lactic acid, and thus decrease in pH.

✔pH drop steady in the first 5-7 hours, followed by little decrease in the next 15-20 hours to ultimate ph. (5.5 - 5.7 from 6.8 -7.2)

✔ A low ultimate pH is desired to have a check on the proliferating micro-organisms during storage.

- ✔ A sharp decline in post-mortem pH even before the dissipation of body heat through carcass chilling – PSE
- ✔ Contrary to this, muscles which maintain a consistently high pH during post-mortem conversion to meat - DFD



Rigor Mortis

- ✔ Stiffening of muscles after death
- ✔ ATP complexed with Mg++ at certain concentration required for breaking the actomyosin bond for relaxation of muscle
- ✔ ATP concentration decreases, permanent actomyosin cross bridges begin to form.
- ✔ Muscle gradually becomes less and less extensible under an externally applied force. This is delayed phase of rigor mortis
- ✔ Then actomyosin formation picks up and the muscle begins to loose extensibility rapidly. This phase is called the fast or onset phase of rigor mortis.
- ✔ When all the creatine phosphate (CP) is depleted, ADP can no longer be phosphorylated to ATP, muscle becomes quite inextensible and stiff. This stage marks the completion of rigor mortis

Rigor is characterized by three stages

1. **Delayed phase:** plenty of ATP in the muscle (complexed with Mg2+), the muscle remains in the relaxed state
2. Onset phase: After the depletion of muscle glycogen, ATP level is maintained from rephosphorylation of adenosine diphosphate (ADP) by creatine phosphate (CP).
3. Completion phase: No remaining creatine phosphate or glycogen for energy development. Actomyosin bond is formed from the permanent cross bridges of actin and myosin

Pattern of Rigor Mortis

- Begins in muscles of jaw neck downwards body trunk and extremities
- Time duration: Depend upon species, animal, post slaughter condition, physiological conditions and muscle
- Temperature (rapid at high temperatures than at low);
- pH of meat

  DFD high pH minimal glycogen minimal re-synthesis of ATP

  PSE low pH LA rapid consumption of ATP
- **Beef and lamb:** 6-12 hr after slaughter
- **Pork:** 5 min – 3 hr
- **Poultry:** 5 min – 1 hr

Factors affecting Rigor

1. Species of animal: onset faster in active animals. It is faster in horses and cattle than pigs.

2. Type of muscle: Active and well nourished muscles undergo rigor first.

3. Glycogen content: Glycogen content is directly proportional to the fall in pH and the onset of rigor mortis. Higher glycogen content leads to more formation of lactic acid and a marked fall in pH.

4. Initial level of ATP and creatinine phosphate: In healthy animals the initial level of ATP is high therefore there is a delay in the onset of rigor.

5. Atmospheric temperature: High temperature is responsible for early onset and low temperature for delay in rigor.

Loss of Protection against Invading Micro-organisms

- During post-mortem period, body defense mechanism stops operating and membrane properties are altered.
- So, during conversion to meat, muscle is quite susceptible to invading micro-organisms.
- Except for low pH, most of the other post-mortem changes favour bacterial growth.
- Hence, utmost handling precautions are necessary to prevent contamination of meat.

Degradation due to proteolytic enzymes

- ✔ Several autolytic lysosomal enzymes called cathepsins, which remain inactive in a living muscle tissue, are activated as the muscle pH declines.
- ✔ These enzymes initiate the degradation of muscle protein structure.
- ✔ Cathepsin – B,D,H, L
- ✔ Calcium activated Sarcoplasmic factors (CASF)/ Calpains: enzymes activated by calcium and act above pH of 6 causing tenderization and important for tenderization
- ✔ Calstatin – antagonist of calpains

Loss of Structural Integrity

- Post-mortem alteration of membrane properties initiates the degradation of muscular proteins.
- There is a progressive disruption of myofibrillar structure.
- The resolution of rigor mortis is reported to occur due to disintegration of Z-line structure.
- A rapid decline in muscle pH also causes denaturation of collagenous connective tissue.

Ageing/ ripening/ Conditioning

- ✔ Ageing - the holding of carcasses just above its freezing point so as to obviate microbial spoilage and accompanied by an enhancement in tenderness and flavour of meat.
- ✔ The enhancement in flavour is mainly attributed to inosine (inosine monophosphate), a breakdown product of ATP(adenosine monophosphate).
- ✔ The improvement in tenderness is on account of the subtle proteolysis that take place in the cytoskeletal proteins.
- ✔ Ageing period in different species of food animals
  Cattle : 14 days
  Sheep and Goats : 7 days
  Pigs : 5 days
  Chicken : 2 days

1. Removal of blood exsanguination. If >50% retained less shelf life (excellent medium fro microbes) and meat is less appealing
2. Circulatory failure- anaerobic metabolism LA
3. Decline in pH: 7 (neutral) to 5.6-5.8 (acidic) in 8 hr
4. Stress condition: DFD or PSE
5. PM heat dissipation: depending on muscle location and fat covering
6. Loss of protection from microbes
7. Loss of structure: z-line protein degradation
8. Physical changes: color oxymyoglobin- bloom
9. Water holding capacity: 65-80% water tenderness/ juiciness

   High pH: DFD High WHC And Low pH: PSE Low WHC
10. Rigor mortis: stiffness due to permanent acto-myosin complex cross-bridge.

    Normal muscle contraction: 20% site cross-bridge but in rigor mortis 100% binding site involved.

    Normal relaxation ATP binding with Mg^{+2}. But in rigor mortis z-line protein breakdown.

Abattoir

- A place where animals are killed for their meat
- **Abattoir planning:** max. daily killing and disposal and treatment of edible and inedible byproducts.

1. **Selection of site:**

   Proper water and electricity supply should be there

   Sewerage

   Availability of rail and road transport.

   Availability of labor.

   No pollution from other industries

   Good availability of stock near by

   Isolated from local housing.

- In general urban sites are avoided and nominated industrial area should be chosen

2. Water

- Potable water must be distributed to all parts of plant under adequate pressure.
- Pressure should be at least 20 Psi in main pipe lines.
- Hot water of at least 82°C should be available in plant for cleaning and disinfection of machinery and for scalding.
- Recommended water requirement:

  454 liters /day/pig

  272 liters /day/bovine

  45 liters /day/sheep

3. Electricity:

industrial 3 phase electricity

Generator for emergency

4. Area size

- Small abattoir up to 30,000 units/year - 1-2 acres
- Medium abattoir up to 50,000 unit/year - 2-4 acres
- Large abattoir up to 10,00,00 units/year – 4-6 acres
- For calculating of area size: 1 adult bovine (ALU) = 2 pigs = 3 calves = 5 sheep.

5. Lighting

- Adequate natural or artificial lighting must be provided throughout the meat plant.
- Intensity of lights is usually taken at levels of 0.9 m from floor except in inspection area where height is 1.5 m

Overall intensity should not he less than:

✔ **540 lux (50 foot candle) - at all inspection points.**

✔ 220 lux (20 foot candle) - in work rooms/ slaughter hall

✔ 110 lux (10 foot candles) - in other areas

6. Ventilation:

Must be adequate to prevent excessive heat steam and condensation, accumulation of odour.

7. Floor and wall finishes:

- Easily cleaned.
- Non-absorbent.
- Floor: Non-slip material.
- General Gradient: Floor slope towards drains should be 1:50 (least 2 cm per 100 cm)
- Drainage valleys under the dressing rail where the blood tends to collect, the gradient should be 1:25.
- One drainage inlet for every 36 m^2 of floor space.
- Ceiling height should be at least 5 m.
- Walls: covered with smooth impervious material like (tiles) up to 3 m.
- Doors should be wide enough to allow passage of workers, trolleys and carcasses (4.5 ft). Self closing and double action doors are preferable.

Goat meat is known as

(A) Mutton

(B) Veal

(C) Chevon

(D) Pork

Fresh muscle (lean) tissue contains about percent of protein.

(A) 11

(B) 15

(C) 19

(D) 23

The intensity of light at all inspection points in an abattoir should not be less than

(A) 110 Lux

(B) 220 Lux

(C) 420 Lux

(D) 540 Lux

The characteristic and eye appealing bright red colour of the surface tissues of freshly cut meat is due to

a. Oxymyoglobin
b. Oxyhaemoglobin
c. Oxymyoglobin and oxyhaemoglobin
d. None

On slaughter of hunted animals, the onset of rigor mortis is usually:

(A) Very slow

(B) Very rapid

(C) Absent

(D) Not affected

Maximum fat present in which meat?

- (A) Carabeef
- (B) Beef
- (C) Pork
- (D) Rabbit

Protein content of white meat is:

- (A) Lesser than red meat
- (B) Higher than red meat
- (C) Equal than red meat
- (D) No comparison with red meat

- Brown colour of meat is due to:
- (A) Oxyhaemoglobin
- (B) Oxymyoglobin
- (C) Metmyoglobin
- (D) All of these

Carabeef is the meat which is obtained from:

- (A) Cattle
- (B) Sheep
- (C) Swamp Buffalo
- (D) Camel

Meat from sheep which is between the age of one month to one year is termed:

- (A) Mutton
- (B) Veal
- (C) Chevon
- (D) Lamb

Pork is rich in vitamin:

- (a) Niacin
- (b) Thiamine
- (c) Riboflavin
- (d) B2

- Rigor mortis in fowl is seen in hours.
- (a) 2-4
- (b) 4-8
- (c) 8-12
- (d) 12-24

- The unique amino acid present in elastin is:
- (a) Glycin
- (b) Proline
- (c) Demosine
- (d) Lysine

- Meat is poor source of:
- (a) Vitamin A
- (b) Vitamin B complex
- (c) Vitamin C
- (d) Vitamin D

- The freezing point of meat lies between----------°C.
- (A) 3 & 4
- (B) 1 & 1.5
- (C) 0 & 1
- (D) -1 &-1.5

- The recommended light intensity at work rooms in an abattoir is
- (A) 10 foot candles
- (B) 20 foot candles
- (C) 30 foot candles
- (D) 40 foot candles