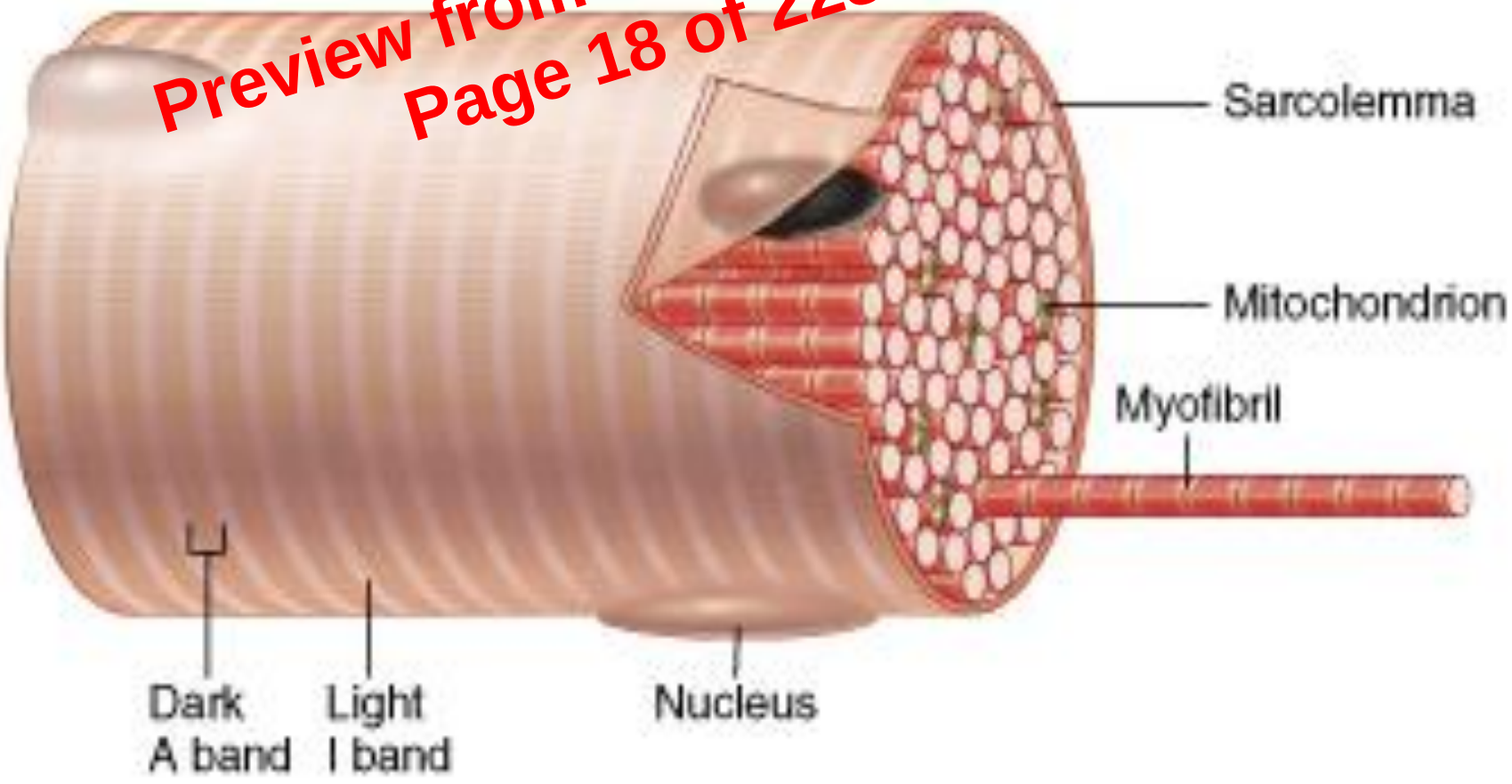
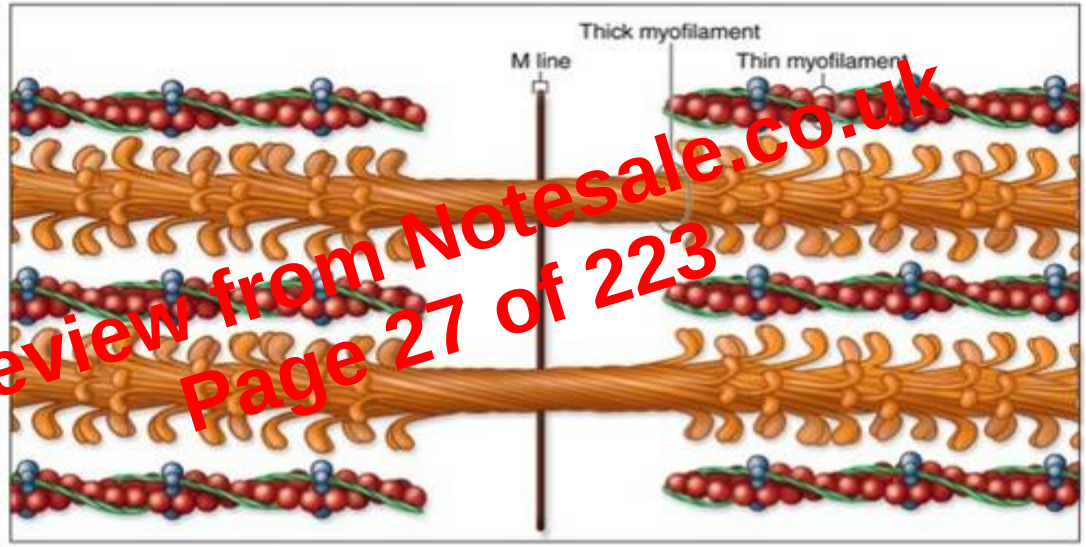
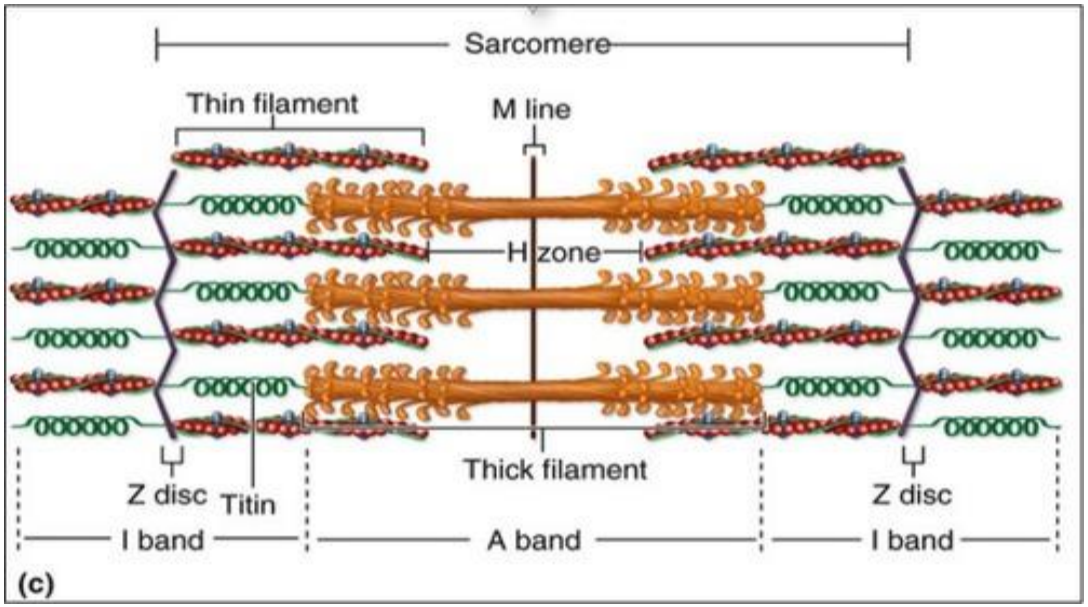
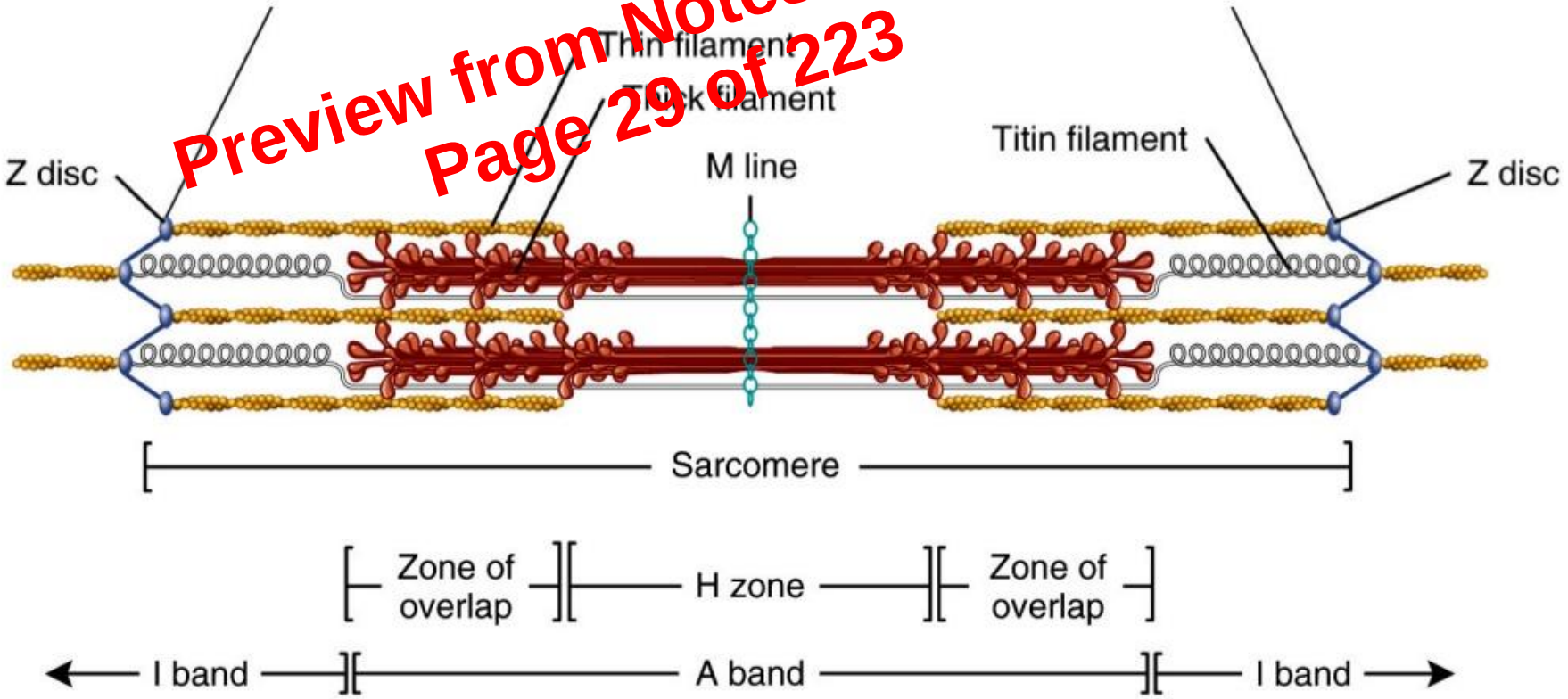
SKELETAL MUSCLE CELL



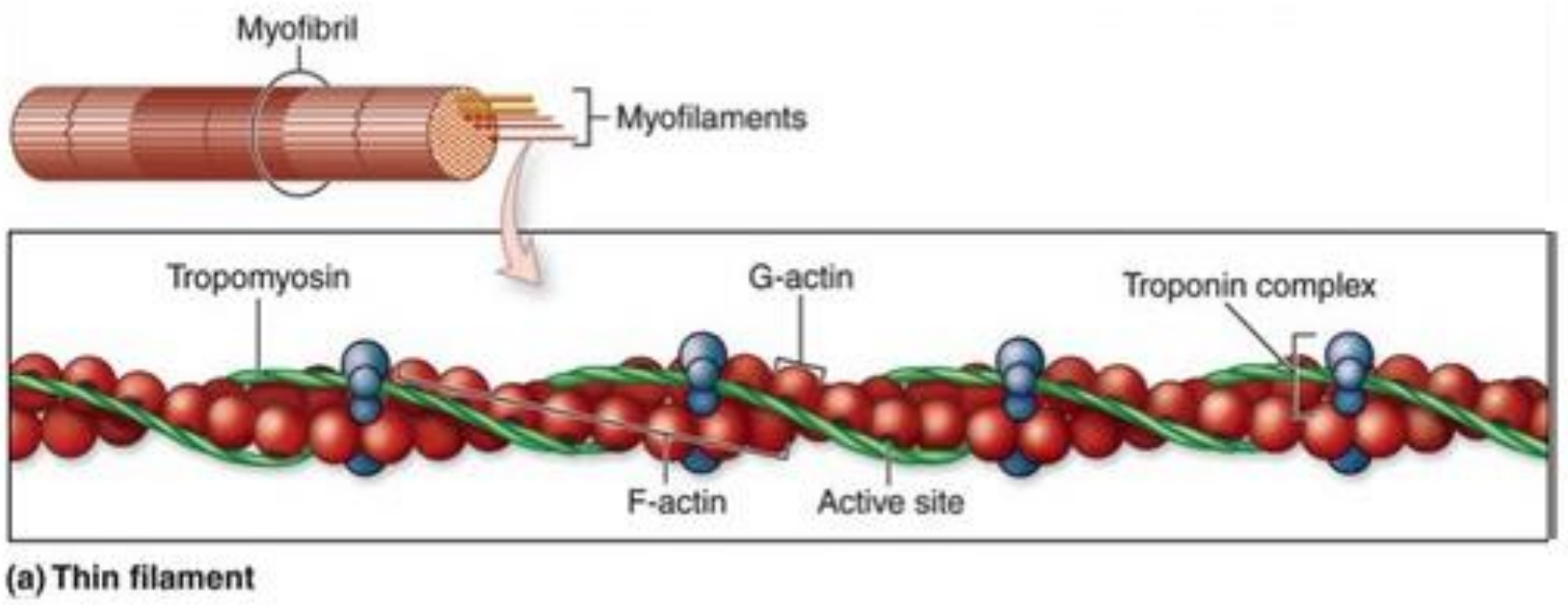


Comparison of thick and thin filaments





- **Actin** – the main component of thin filaments.
- Connects to the myosin for the sliding together of the filaments.
- Individual actin molecules *(G (Globular) actin)* join to form an actin filament *(F (Filamentous) actin)* that is twisted into a helix.
- **Function**: Binding site for myosin to shorten sarcomere.

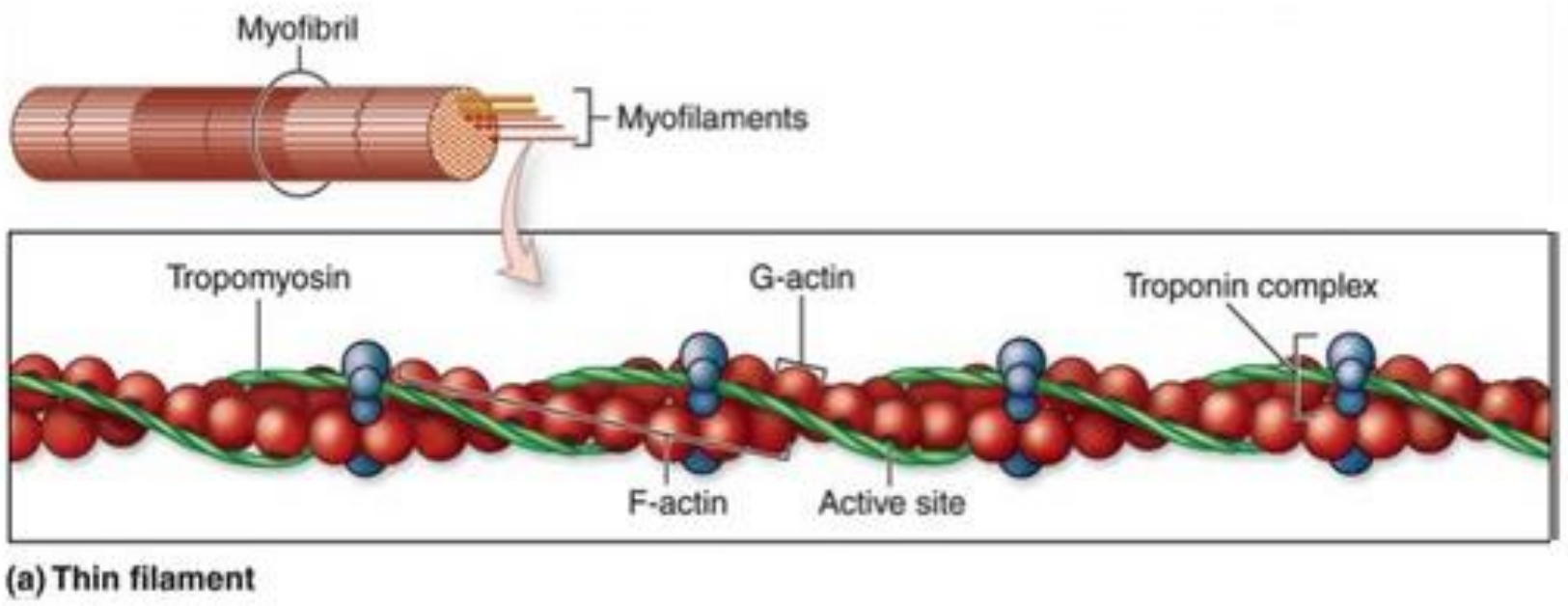


(a) Thin filament

Regulatory proteins

- They assist in switching contractions on and off
- **Tropomyosin** and **Troponin** – are part of the thin filament

Relaxed muscle – Tropomyosim, which is held in place by troponin blocks the myosin-binding sites on actin, preventing myosin from binding to actin.



(a) Thin filament

Other structural proteins in skeletal muscle fibers

- They keep the thick and thin filaments in proper alignment, gives myofibril elasticity and extensibility and link the myofibril to sarcolemma and extracellular matrix
- **Titin** – stabilizes the position of thick filament. Because it can stretch and then spring back unharmed, it accounts for much of the elasticity and extensibility of myofibrils.
- **Myomesin** – forms the M line of sarcomere; binds to titin molecules and connects adjacent thick filaments to one another.
- **Nebulin** – wraps around entire length of each thin filament. Anchors thin filaments to Z discs and regulates the length of this filaments during development.

MUSCLE CELL TYPES

1. SKELETAL MUSCLE CELL

STRUCTURE: - **Striated, long, cylindrical**, not branched
- **Many peripheral nuclei**

NERVOUS CONTROL: - **Voluntary** ("conscious control" by somatic nervous system)

LOCATION: - attached to bones

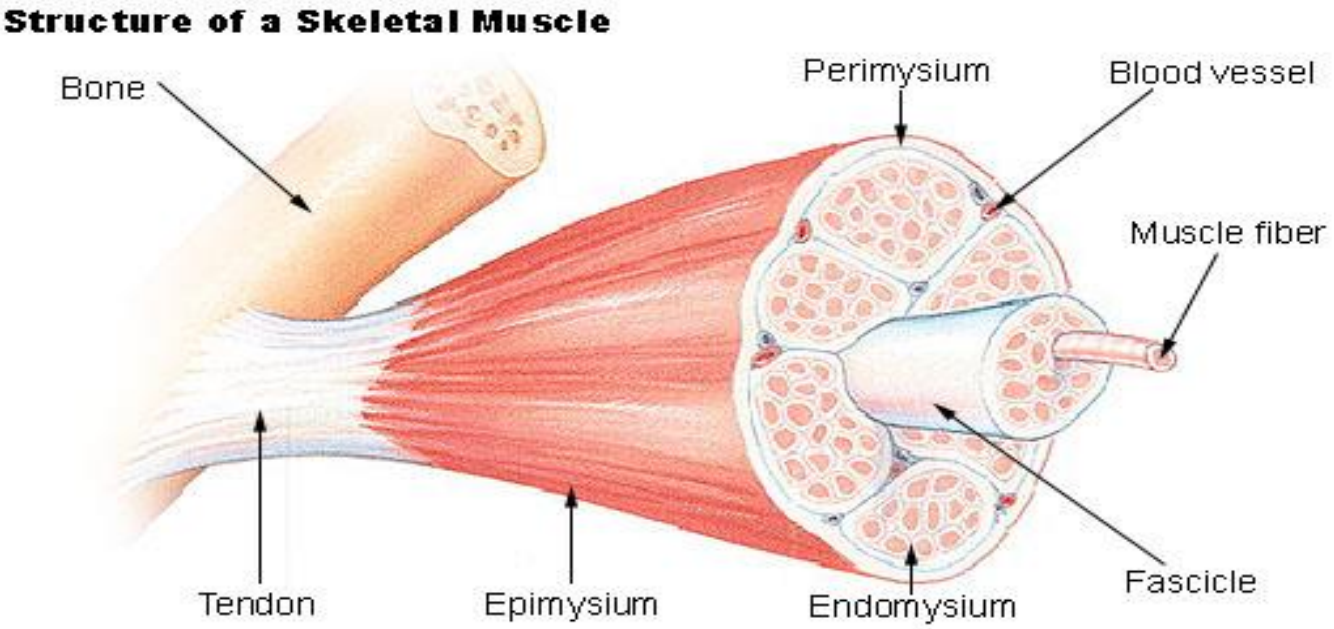


TABLE 9.3 Comparison of Skeletal, Cardiac, and Smooth Muscle

CHARACTERISTIC	SKELETAL	CARDIAC	SMOOTH
Body location	Attached to bones or (some facial muscles) to skin	Wall of the heart	Single-unit muscle in walls of hollow visceral organs (other than the heart); multiunit muscle in intrinsic eye muscles, airways, large arteries
Cell shape and appearance	Single, very long, cylindrical, multinucleate cells with obvious striations	Branching chains of cells; uni- or binucleate; striations	Single, fusiform, uninucleate; no striations



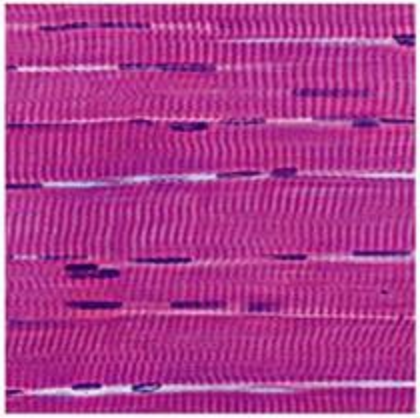
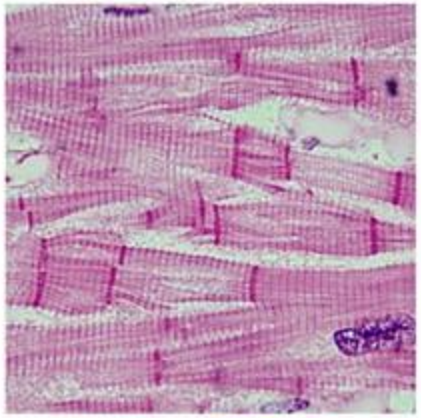
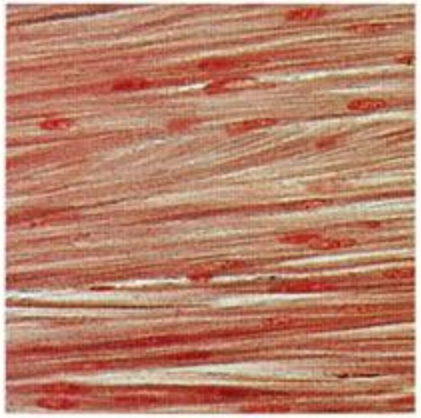
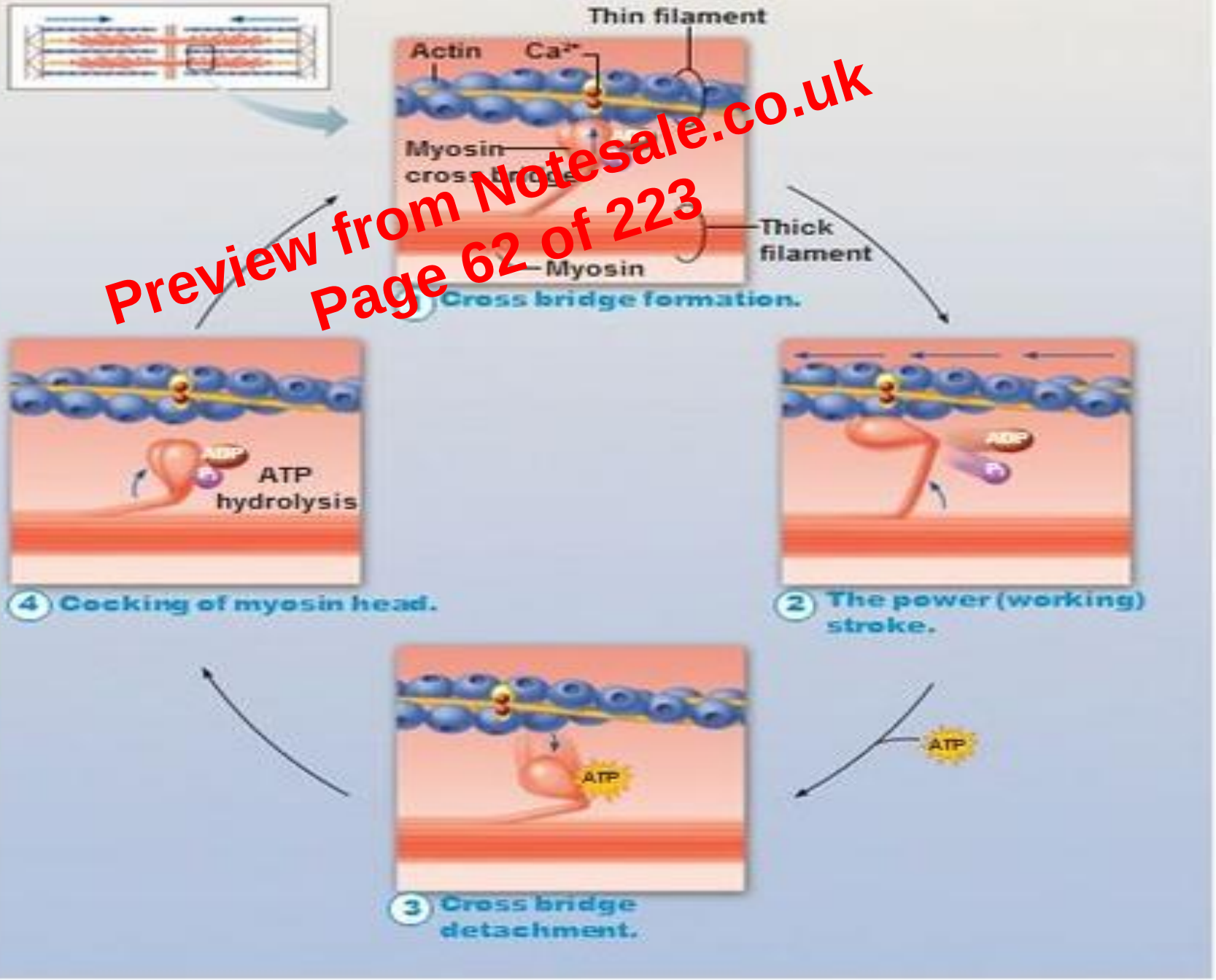





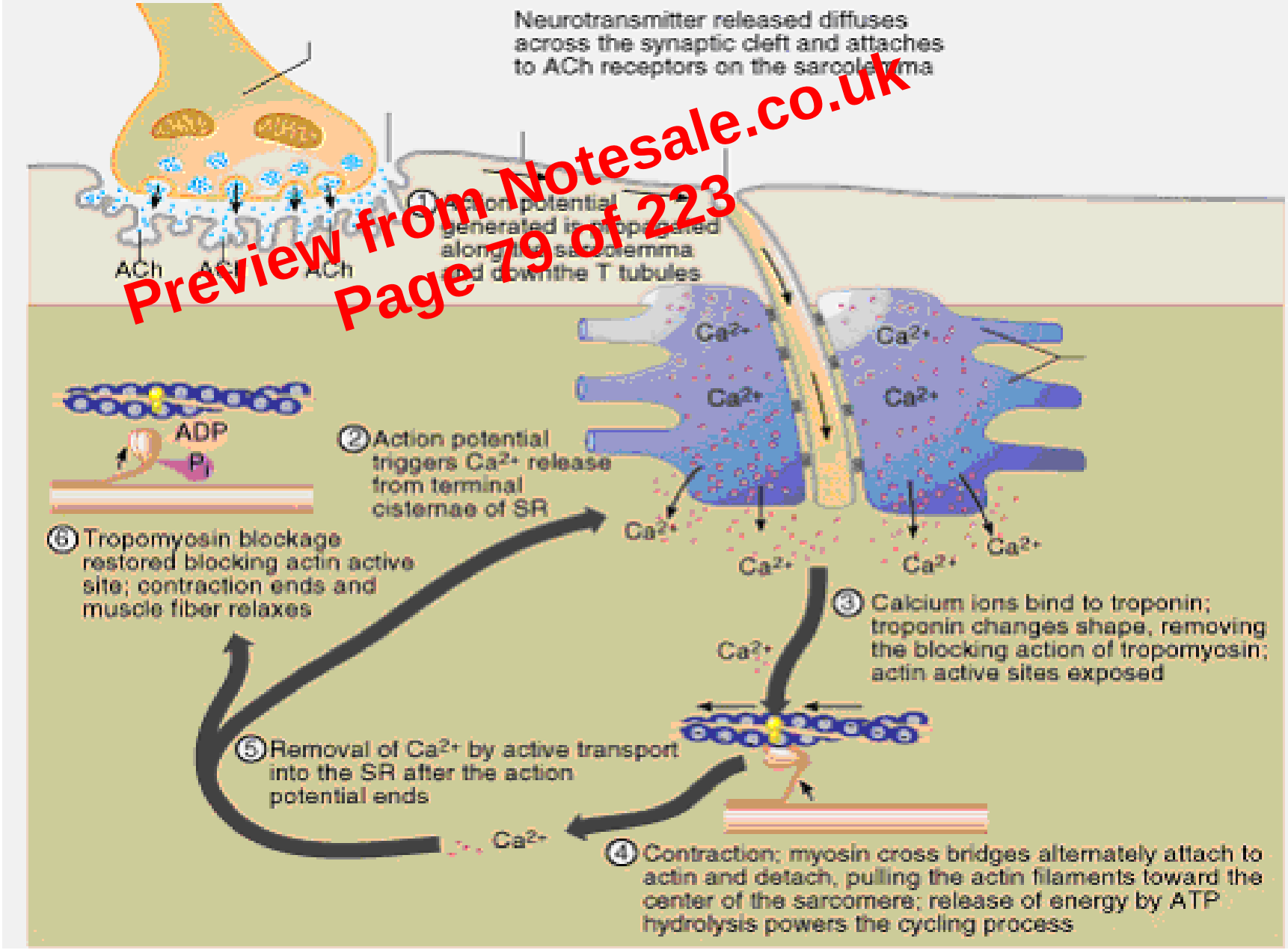

Table 9.3.1

Skeletal muscle

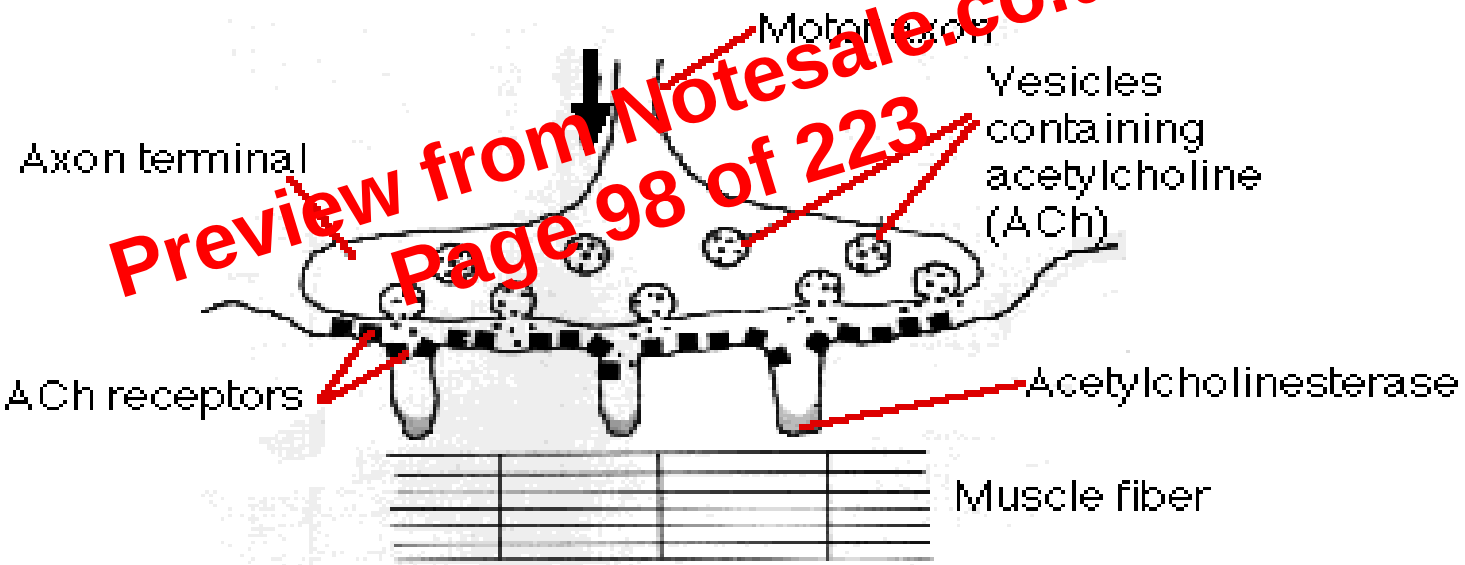
Formation of cross bridge

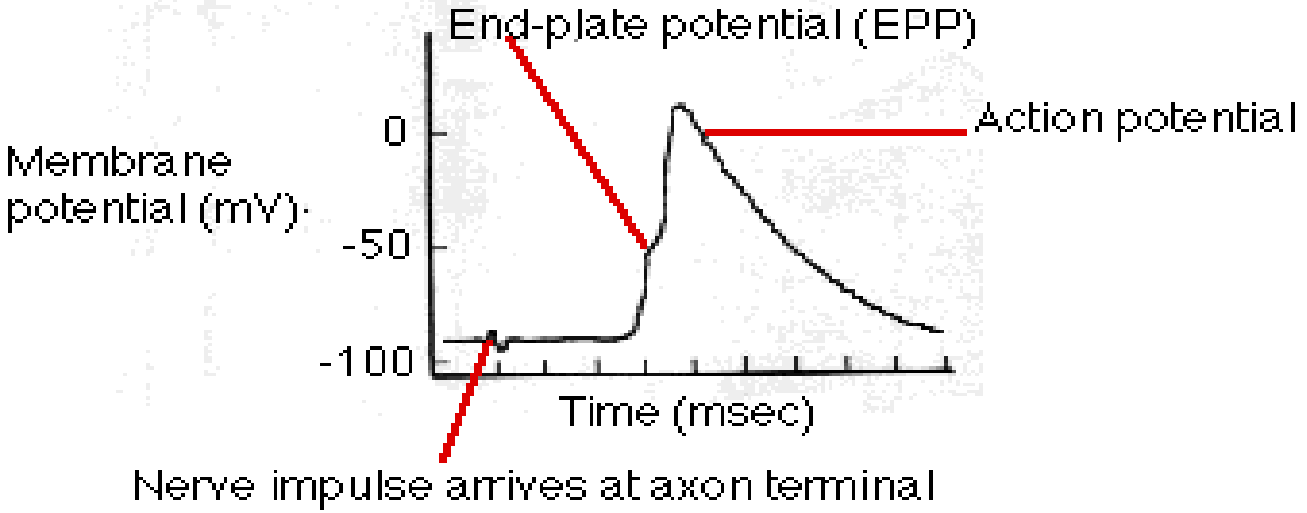
- Initiated when calcium ions released from SR bind to troponin (This causes troponin to change shape);
- Tropomyosin moves away from myosin binding sites on actin allowing myosin head to bind actin and form a cross bridge;
- Myosin head has to be activated before a cross bridge cycle can begin;
- ATP combines with myosin head and is hydrolyzed to ADP and inorganic phosphate (Energy from hydrolyzed ATP activates myosin head forcing it to be in cocked position)



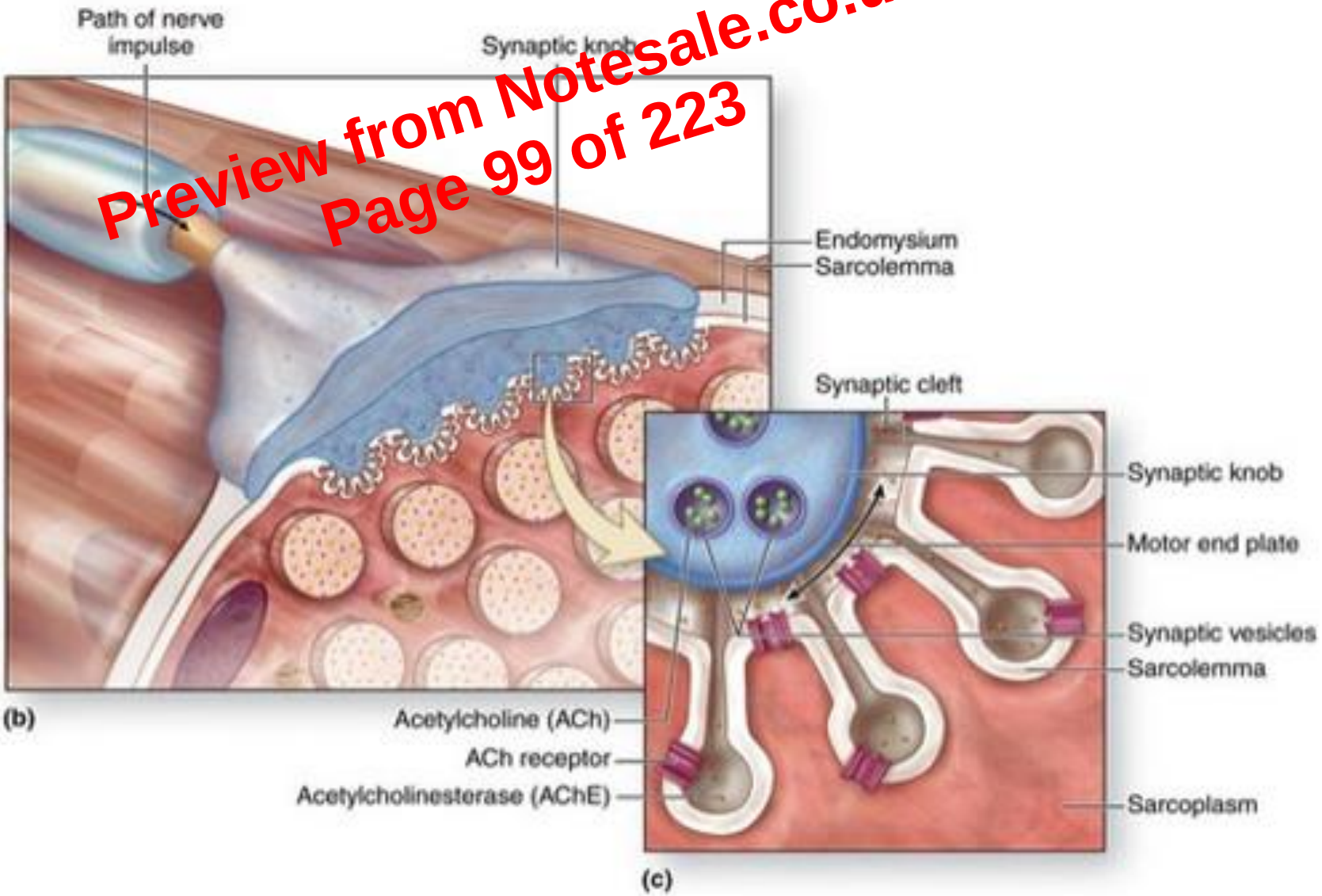


NEUROMUSCULAR JUNCTION



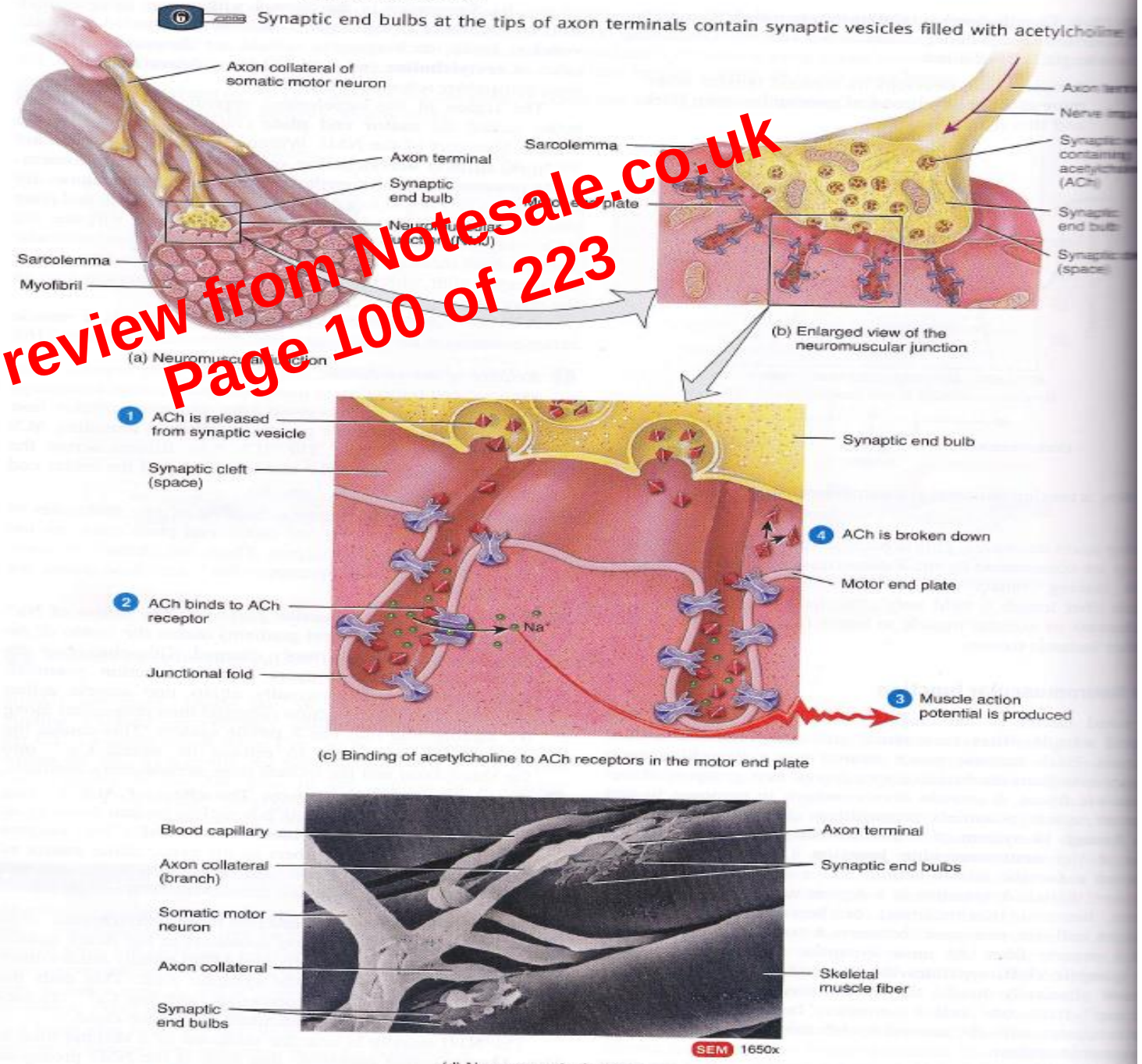


NEUROMUSCULAR JUNCTION



skeletal muscle fiber.

6 Synaptic end bulbs at the tips of axon terminals contain synaptic vesicles filled with acetylcholine.



? What part of the sarcolemma contains acetylcholine receptors?

MOTOR UNIT

DEFINITION – This is a motor neuron plus all skeletal muscle fiber it stimulates.

- So one skeletal muscle can have many motor units.

- We generally see 2 patterns;

1. MUSCLES CONTROLLING PRECISE (fine) MOVEMENTS

2. MUSCLES CONTROLLING POWERFUL GROSS MOVEMENTS

MUSCLE PHYSIOLOGY

- TWITCH CONTRACTIONS
- A brief contraction of all muscle fibers in a motor unit of a muscle in response to a single action potential in its motor neuron.

MYOGRAM

- i.e. is a graph record of a twitch muscle contraction.
- A **myogram** has 3 parts;
  - i) LATENT PERIOD
  - ii) CONTRACTION PERIOD
  - iii) RELAXATION PERIOD

MUSCLE PHYSIOLOGY

- **MYOGRAM**

REFRACTORY PERIOD of a Twitch

- i.e. if 2 stimuli applied one immediately after the other, the muscle fibers responds only to the 1rst stimulus but not to the 2nd stimulus.
- For the first stimulation, the muscle fiber contracts and temporarily loses its excitability and can not respond again until it regains its responsiveness.
- Varies with different muscle type

E.g. Skeletal muscle ~ 5 msec
Cardiac muscle ~ 300 msec

MUSCLE PHYSIOLOGY

- TETANUS

a) INCOMPLETE (unfused) TETANUS

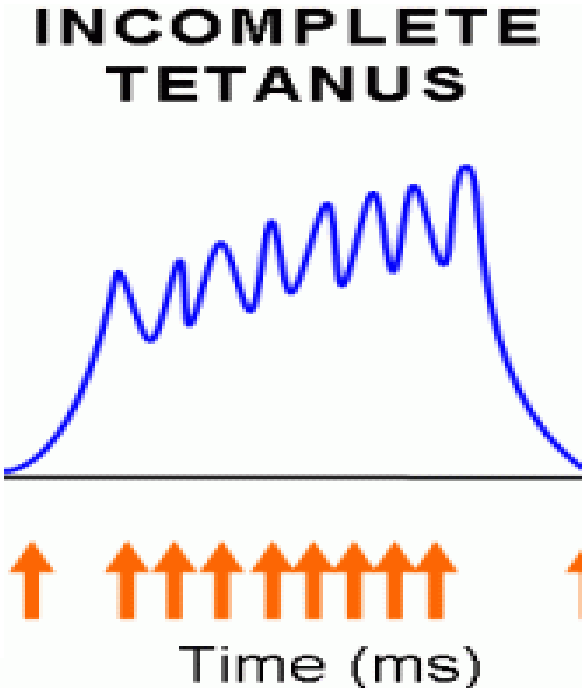
DESCRIBE – Skeletal muscle is stimulated at a rate 20 -30 times per second.

↓

Skeletal muscle **partly relax between stimuli**

↓

RESULT: INCOMPLETE (unfused) TETANUS



MUSCLE PHYSIOLOGY

- TETANUS

b) COMPLETE (fused) TETANUS

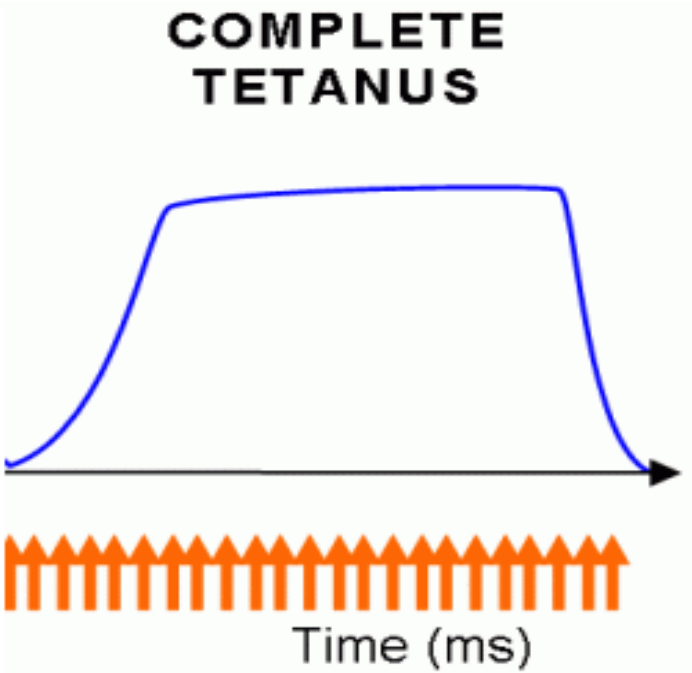
DESCRIBE – Skeletal muscle is stimulated at a rate of 80 – 100 stimuli per second.

↓

- **Sustained contraction**
- **Lacks partial relaxation** between stimuli

↓

RESULT: COMPLETE (fused) TETANUS



MUSCLE PHYSIOLOGY

- **STAIRCASE EFFECT (TREPPE)**

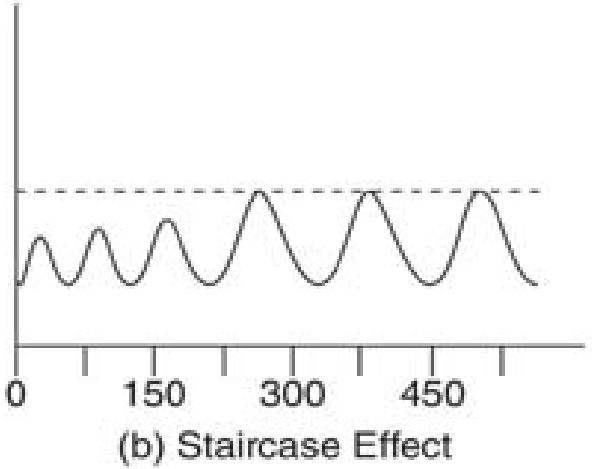
DESCRIBE: - Muscle is relaxed for some time

And is stimulated by:

i) Several **identical stimuli**

ii) The **stimuli are far apart**

for wave summation to occur



(b) Staircase Effect

RESULT: Each of the first few contractions is a little stronger than the last called staircase effect or treppe.

After first few contractions, muscle reaches peak performance → undergoes its strongest contractions.

MUSCLE RELAXATION

2. Closing of Ca^{2+} release channels in SR

LOCATION: - SR

ACTION: - By **active pump activity** , they rapidly.

i) Remove Ca^{2+} from sarcoplasm into SR

ii) In SR, CALSEQUESTRIN, a calcium-binding protein binds to Ca^{2+}.

* This reaction takes Ca^{2+} out of sarcoplasm and also allows more Ca^{2+} to be sequested with SR.
(E.g. Ca^{2+} level is 10 000 times lower in sarcoplasm of relaxed muscle than inside SR)

iii) ↓ Ca^{2+} levels in sarcoplasm

↓

Tropomyosin-troponin complex moves back over myosin-binding sites on actin.

↓

Prevents further binding of myosin head to actin

↓

Thin filaments slips back to relaxed position

MUSCLE PHYSIOLOGY

- ISOTONIC AND ISOMETRIC CONTRACTION

2) ISOMETRIC CONTRACTION

DESCRIBE: Muscle contractions are characterized by;

- muscle tension
- NO change in muscle length

IMPORTANCE: Stabilizes some joints as others are moved.

EXAMPLE: - Holding a book in a steady position
- The book pulls arm downwards → stretching shoulder and arm muscles

↓

Isometric contractions of shoulder and arm muscles counteracts the stretch

↓

2 forces; 1. Contractions
2. Stretching

} applied opposite direction → creates tension

MUSCLE METABOLISM

2) GLYCOGEN – LACTIC ACID SYSTEM

(2 OPTIONS)

FATE OF PYRUVATE?

a) Enough Oxygen

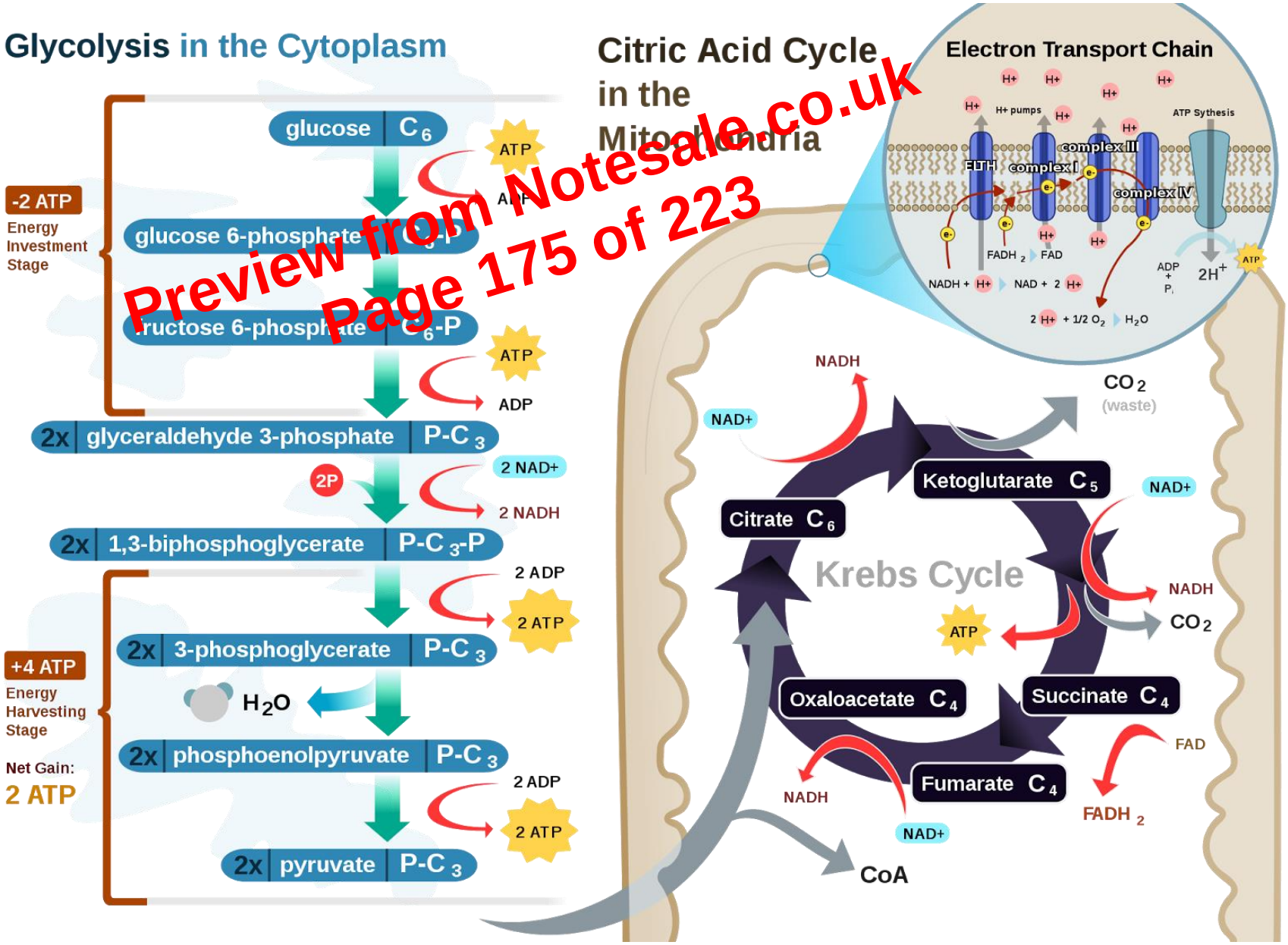
- Each pyruvate enters mitochondria → goes through oxidative respiration → ATP (more ATP produced)

i.e. 1 glucose → GLYCOLYSIS → 2 pyruvate → OXIDATIVE RESPIRATION

GLYCOLYSIS:
- cytoplasm
- anaerobic
- 2 ATP

OXIDATIVE RESPIRATION:
- mitochondria
- aerobic
- 34 ATP

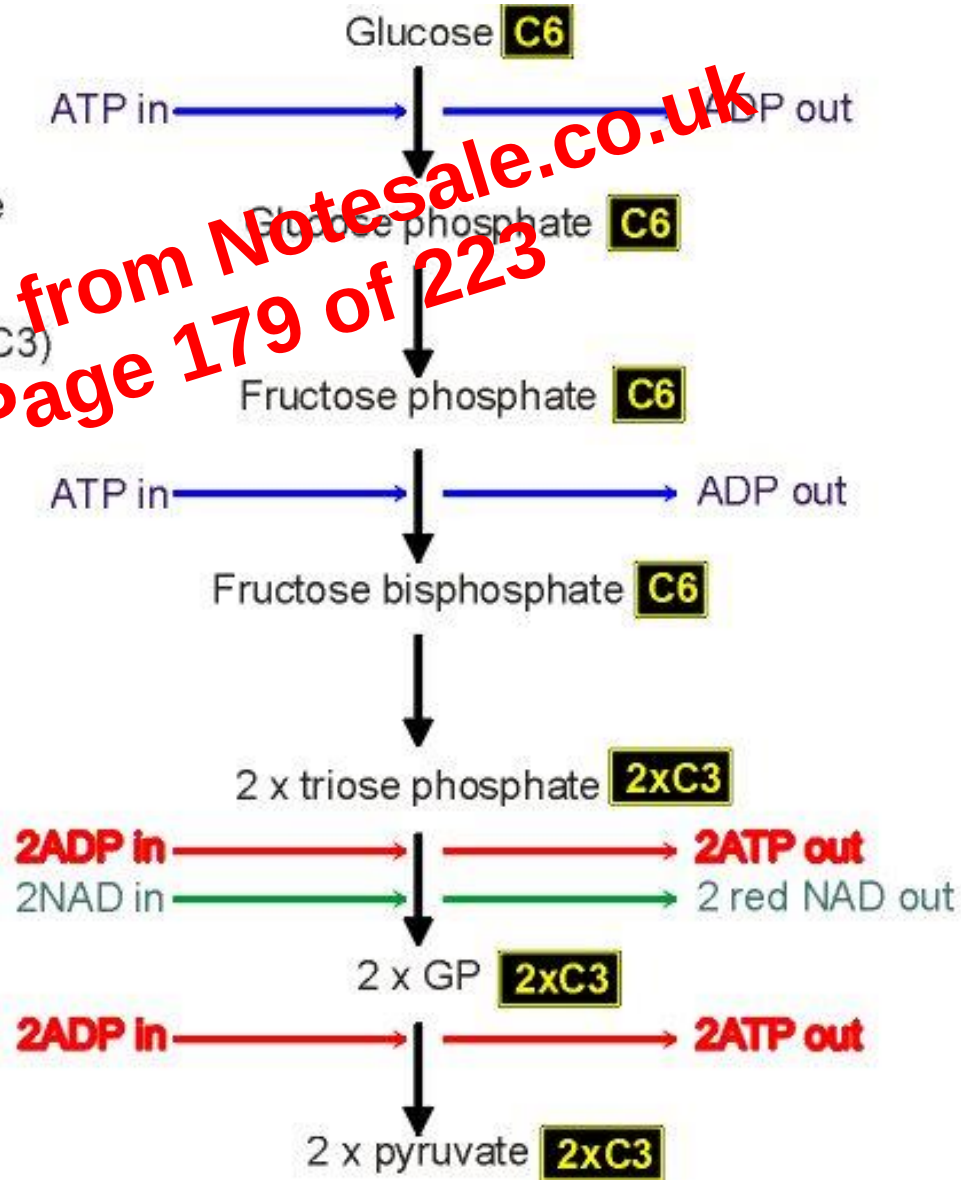
1 glucose → GLYCOLYSIS → KREBBS → CYTOCHROME ELECTRON PATHWAY → 36 ATP



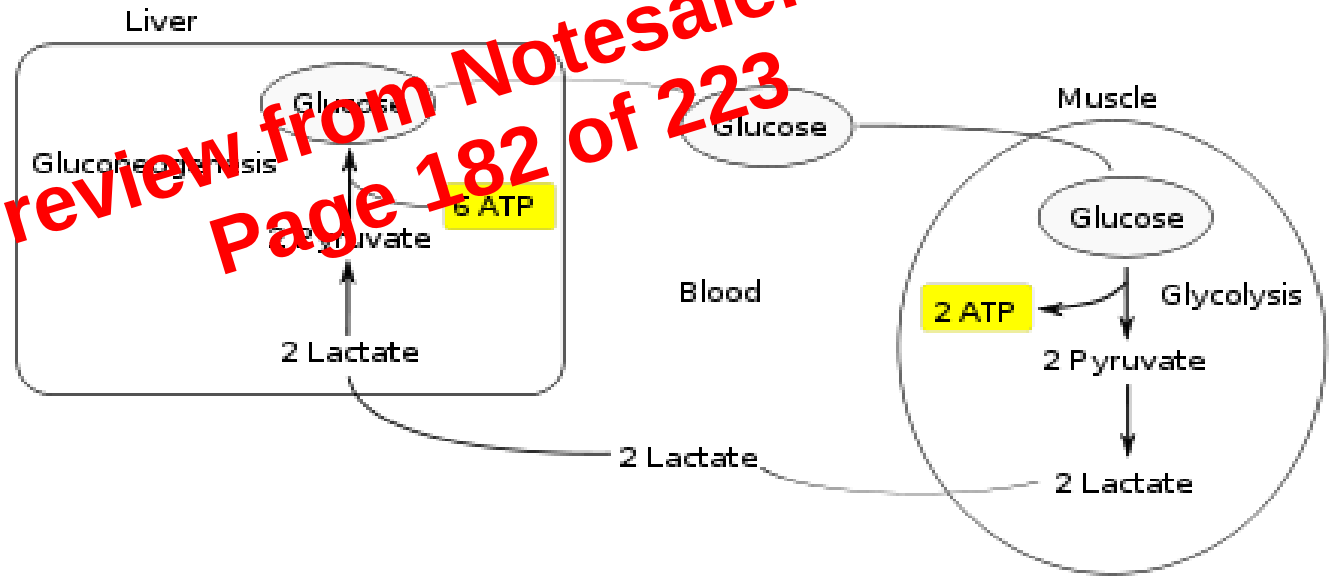
Oxidation	reduction
Oxidation is gain of oxygen. - Oxidising agents <u>give oxygen</u> to another substance.	***Reduction is loss of oxygen.*** - Reducing agents <u>remove oxygen</u> from another substance.
Oxidation is loss of hydrogen. - Oxidising agents give oxygen to another substance or <u>remove hydrogen from it.</u>	***Reduction is gain of hydrogen.*** - Reducing agents remove oxygen from another substance or <u>give hydrogen to it.</u>
Oxidation is loss of electrons. *An oxidising agent oxidises something else.* *Oxidation is loss of electrons (OIL RIG).* *That means that an oxidising agent takes electrons from that other substance.* *So an oxidising agent <u>must gain electrons</u>.* *Or you could think it out like this:* *An oxidising agent oxidises something else.* *That means that the oxidising agent must be being reduced.* *Reduction is gain of electrons (OIL RIG).* *So an oxidising agent must gain electrons.*	***Reduction is gain of electrons.*** • Oxidation Is Loss - OIL • Reduction Is Gain – RIG

GLYCOLYSIS
stage by stage

Yield:
2xpyruvates (C3)
2ATP (net)
2redNAD



Lactic acid cycle (Cori cycle)



- The **Cori cycle** (also known as Lactic acid cycle), refers to the metabolic pathway in which lactate produced by anaerobic glycolysis in the muscles moves to the liver and is converted to glucose, which then returns to the muscles and is metabolized back to lactate.

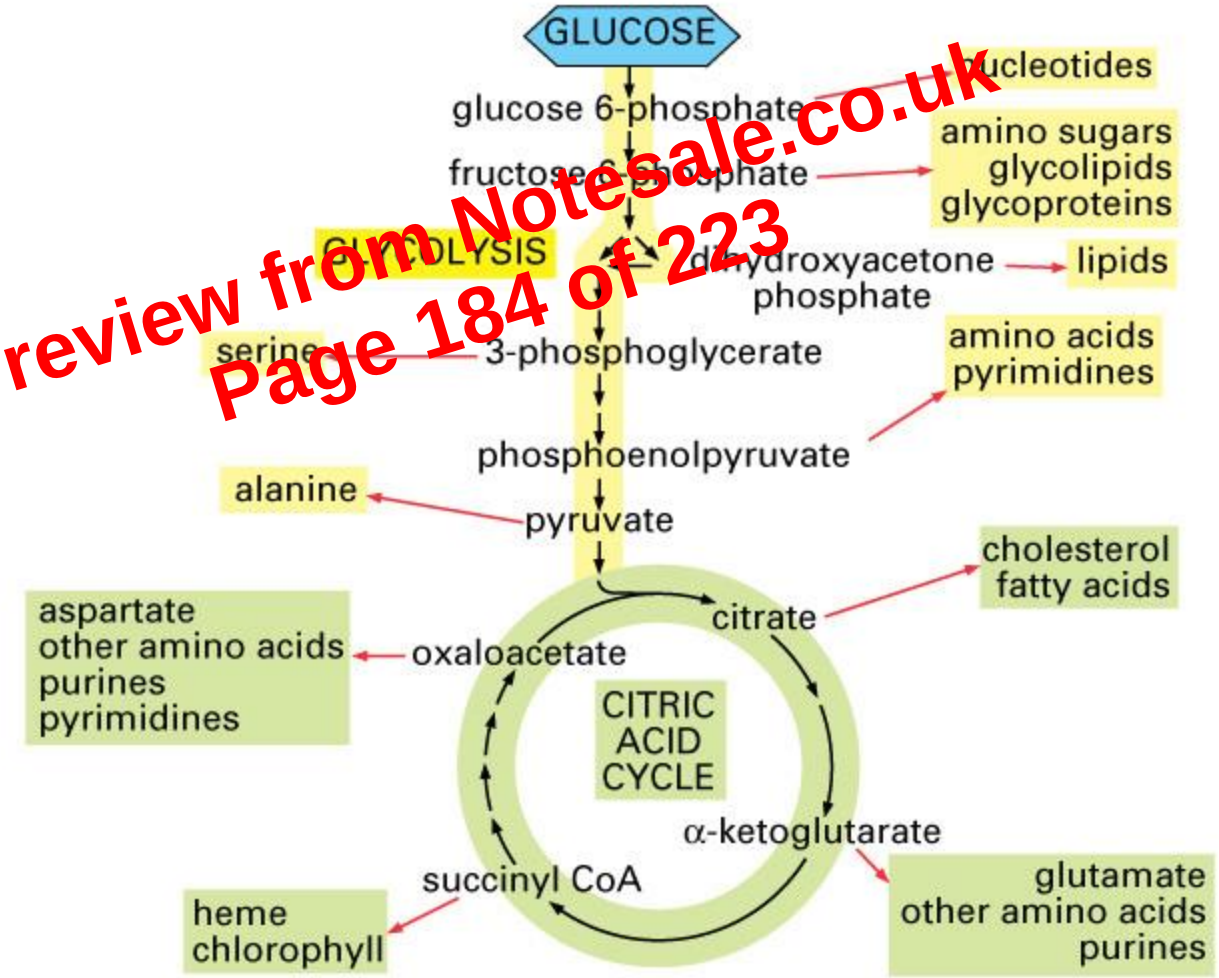


Figure 13-23 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Beta oxidation

E.g.
Oxidation of **palmitic acid, $CH_3(CH_2)_{14}COOH$ (C16 fatty acid)** yields the 131 ATP

i.e. 7 NADH + 7 FADH2 + 8 acetyl-CoA in 7 cycles of mitochondrial beta oxidation.

- 1 Acetyl-CoA = 3 NADH + 1 FADH2 + 1 GTP (=ATP) during Krebs cycle.
- Respiratory chain = 3 ATP/NADH and 2 ATP/FADH2

-Palmitic acid ATP yield is 131 ATP molecules.
-However 2 ATP molecules were used for the initial activation of every fatty acid that is going to be oxidized in the mitochondria. So net ATP is 131 -2 = 129 ATP

MUSCLE METABOLISM

- **MAXIMAL OXYGEN UPTAKE**

- Is the maximal rate that oxygen is used at anaerobic catabolism of pyruvate.

FACTORS THAT INFLUENCE IT;

i) Gender (> for males)

ii) Age (Highest at ~ 20 years)

iii)Size (body size)

E.g. Highly trained athletes

- Maximal Oxygen uptake is 2 times greater

- Because of i) Training

  - ii) Heredity

MUSCEL FATIGUE

DEFINE: Is when muscle is unable to maintain its strength of contraction or tension

WHAT HAPPENS AT CELL LEVEL?

- Muscle can not produce enough ATP to meet its needs

FACTORS CONTRIBUTING TO MUSCLE FATIGUE

i) Insufficient oxygen
ii) Depleted glycogen
iii) Build-up lactic acid
iv) Failure for action potential in motor neuron to release enough ATP

Variations in Skeletal Muscle Fibers

- Differ in amount of myoglobin, mitochondria, capillaries
- **Red muscle** (darker)
- **White muscle** (lighter)
- Range of contraction speeds & fatigue resistance

TYPES OF SKELETAL MUSCLE FIBERS

2) FAST OXIDATIVE (type IIA) fibers

FEATURES :

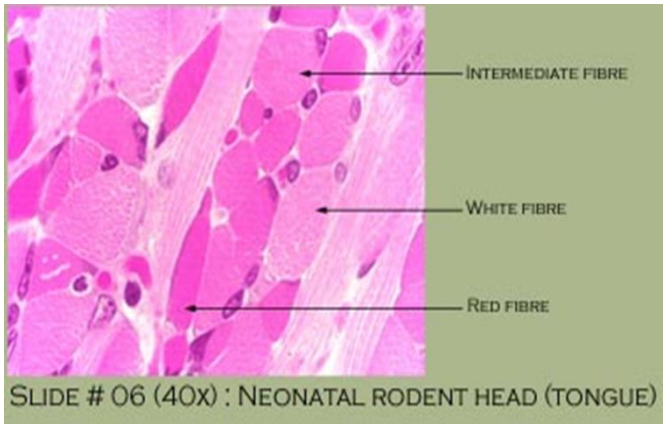
- Another name is "**fast-twitch A, fatigue resistant**"
- Has large amount of myoglobin – give sit red color
- Has many mitochondria
- Has many blood capillaries

METABOLISM – Aerobic oxidative process to produce ATP. (It is fatigue resistant but not as much as slow oxidative fibers)

CONTRACTION VELOCITY – Fast (= fast- twitch) i.e. splits ATP rapidly

DISTRIBUTION

E.g. Sprinters – a large proportion is in the leg muscles



SLIDE # 06 (40X) : NEONATAL RODENT HEAD (TONGUE)

TYPES OF SKELETAL MUSCLE FIBERS

3) FAST GLYCOLYTIC (type IIB) fiber

FEATURES:

- Another name is "**fast-twitch B and fatigue resistant fibers**"
- Has low amount of myoglobin (Gives its **white colour**)
- Has few mitochondria
- Has few blood capillaries

METABOLISM – Anaerobic process (glycolysis) to produce ATP. It fatigues easily ("fatigable fibers")

CONTRACTION VELOCITY – Fast (= Fast twitch)

i.e. It splits ATP rapidly

SIGNIFICANCE – Largest diameter fiber contracts strongly and rapidly.

DISTRIBUTION

E.g. Muscles of arms