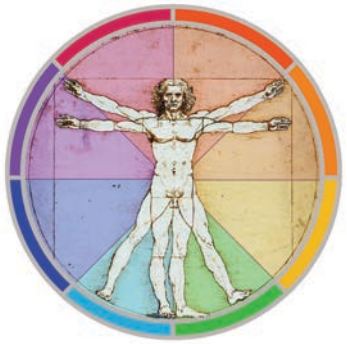
HUBS191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,

it is NOT a substitute for the lecture !



Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

HUBS191

Physiological
Principles of Human Movement and Sensation

Dr Regis Lamberts

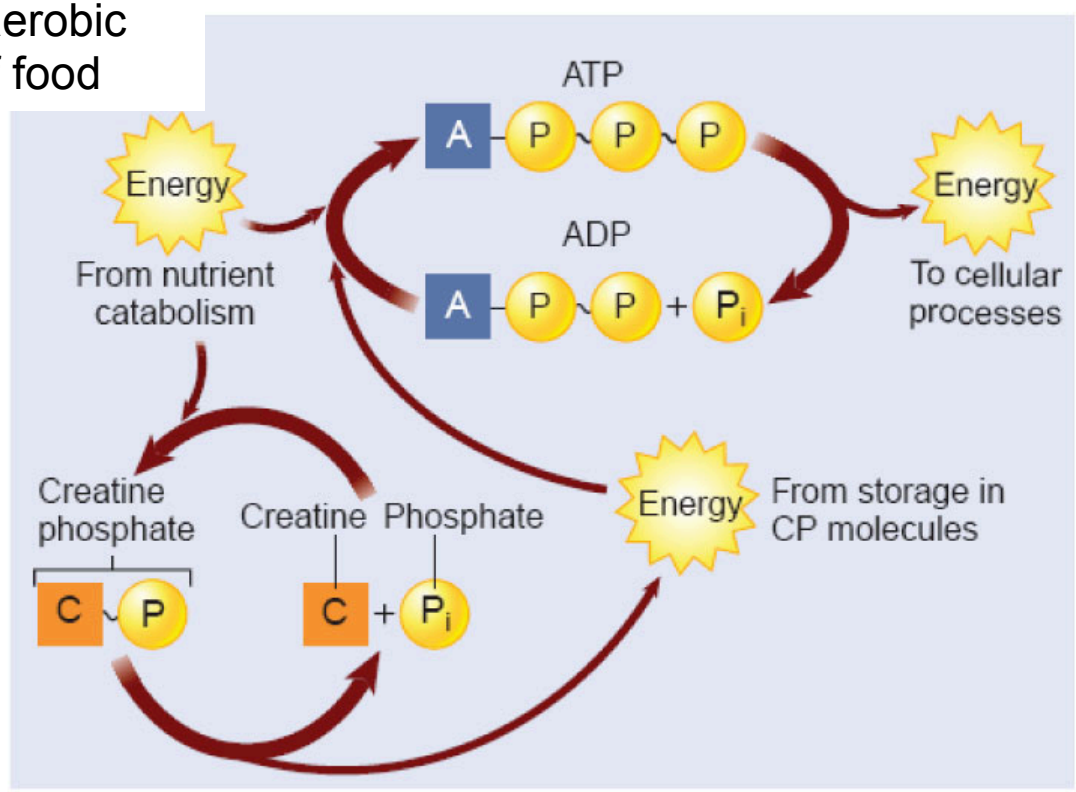
Lecture 26 – Skeletal Muscle Energy, Types and Function

Topics of Today's Lecture

1. Energy Sources for Muscle Contraction
2. Skeletal Muscle Fibre Types
3. Skeletal Muscle Function (Twitch and Tetanus)
4. Exercise & Fatigue

1. Energy Sources for Contraction

Aerobic & anaerobic metabolism of food



Limited stores of ATP in muscle
≈ 2-4 s contraction

CP stored in muscle

CP breakdown can resynthesis ATP
≈ 20 s contraction

ATP = adenosine triphosphate
ADP = adenosine diphosphate
P_i = inorganic phosphate
CP= creatine phosphate

Fig 12-14, p. 357 Thibodeau & Patton 8th edition

1. Energy Sources for Contraction

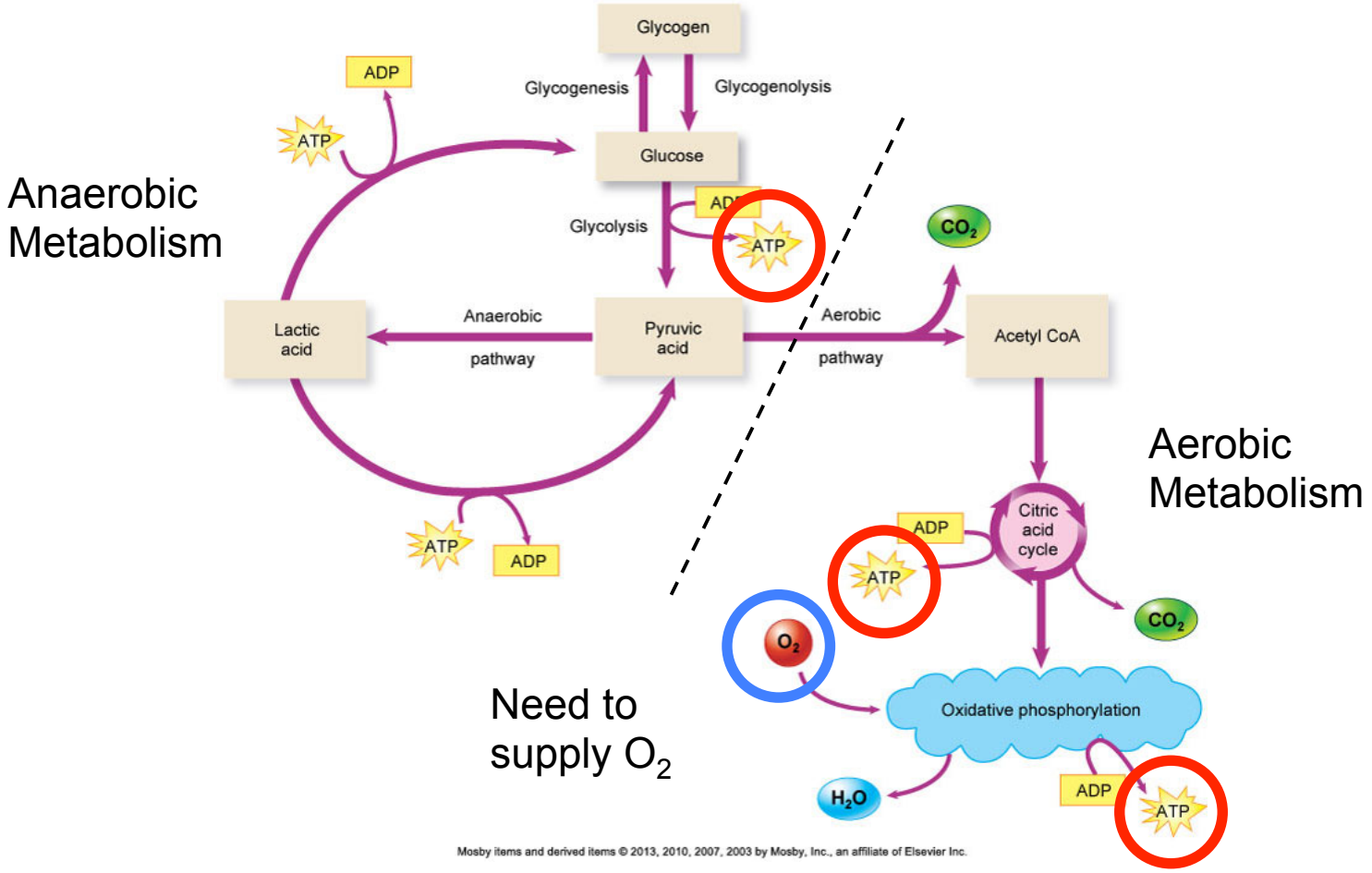


Fig 30-12, p. 941 Thibodeau & Patton 8th edition

1. Energy Sources for Contraction

1. Anaerobic
- short term
- fast energy production
- no O_2 required
- ATP, CP, glycolysis

2. Aerobic
- long term, steady
- slower energy production
- O_2 required
- Oxidative phosphorylation

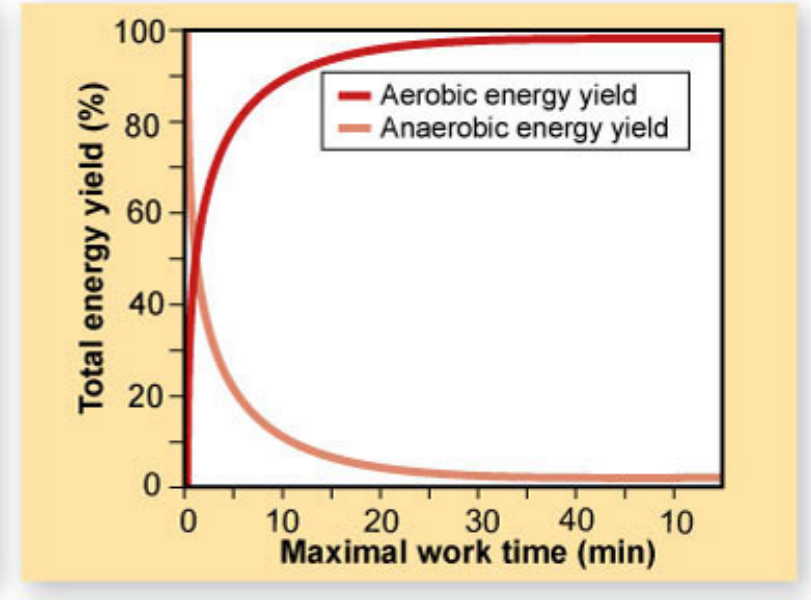


Fig 12-16, p. 359 Thibodeau & Patton 8th edition

Skeletal Muscle Mechanism of Contraction

1. Excitation
   - Neuronal Action Potential (AP)
   - Acetylcholine (Ach) release from nerve terminal
   - AP on Muscle Fibre

2. Contraction
   - Ca^{2+} release from the internal Ca^{2+} store
   - Crossbridge formation of myofilaments
   - Contraction – Sliding filaments

3. Relaxation
   - Ca^{2+} re-uptake into internal Ca^{2+} store
   - Uncoupling crossbridge

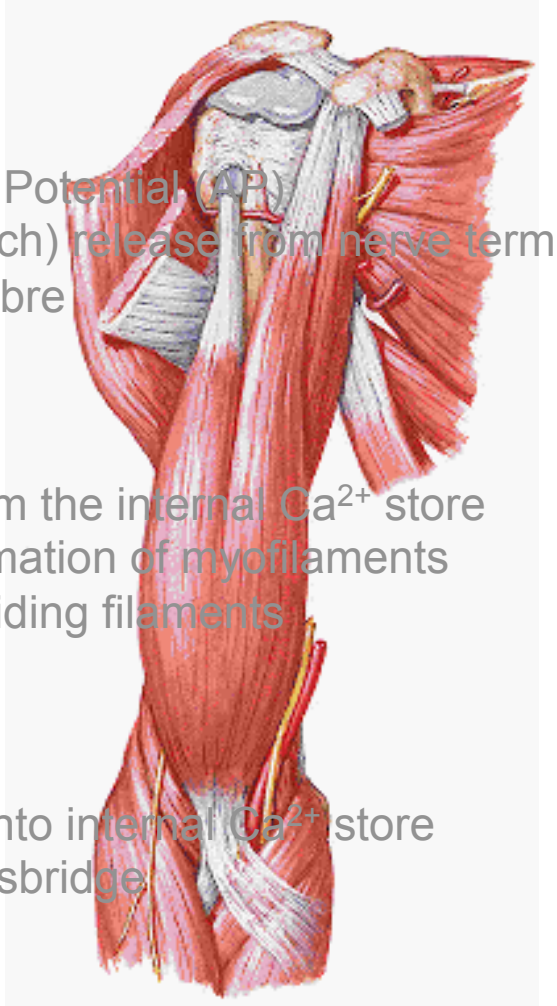
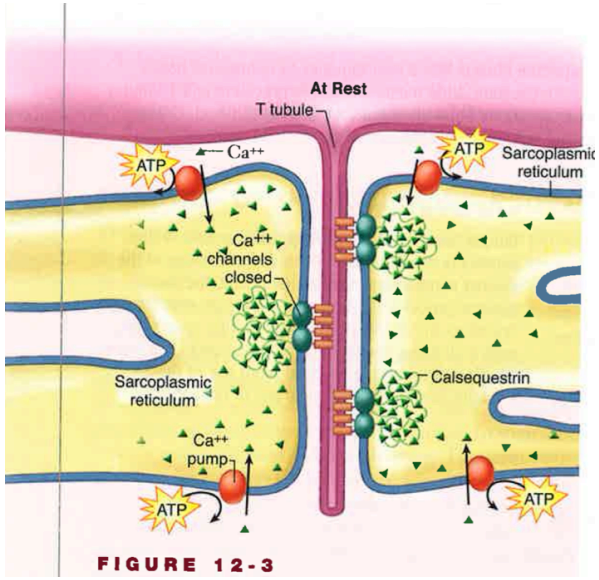


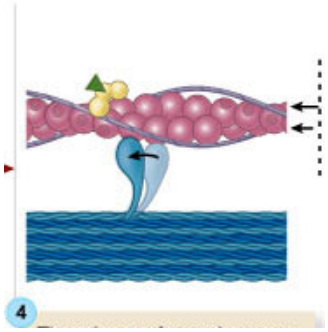
Fig 12-8, p. 354 Thibodeau & Patton 8th edition

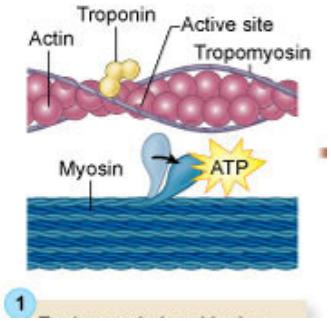
1. Energy for "Relaxation"

- Ca^{2+} re-uptake into the SR



- Uncoupling of Crossbridge

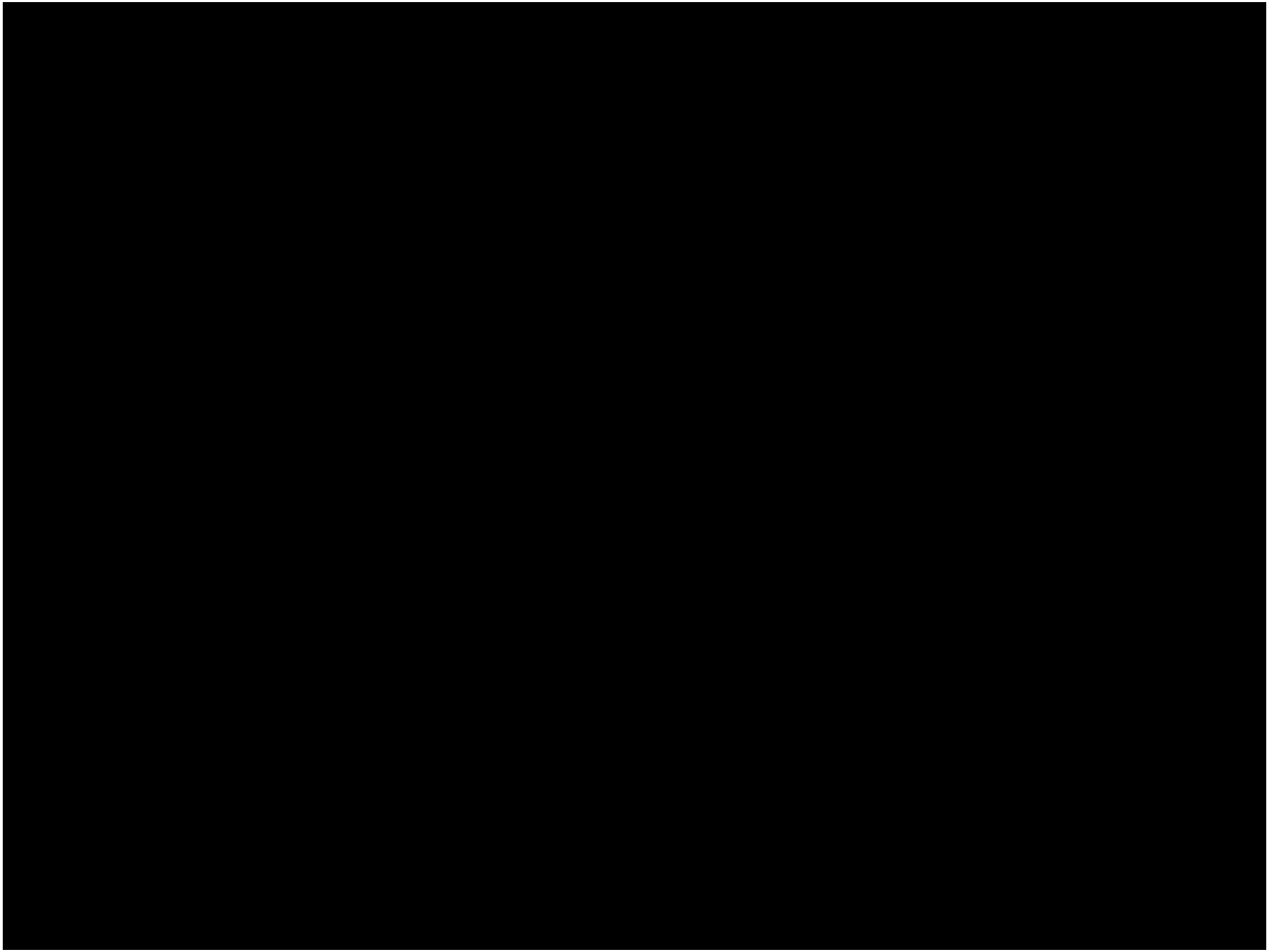




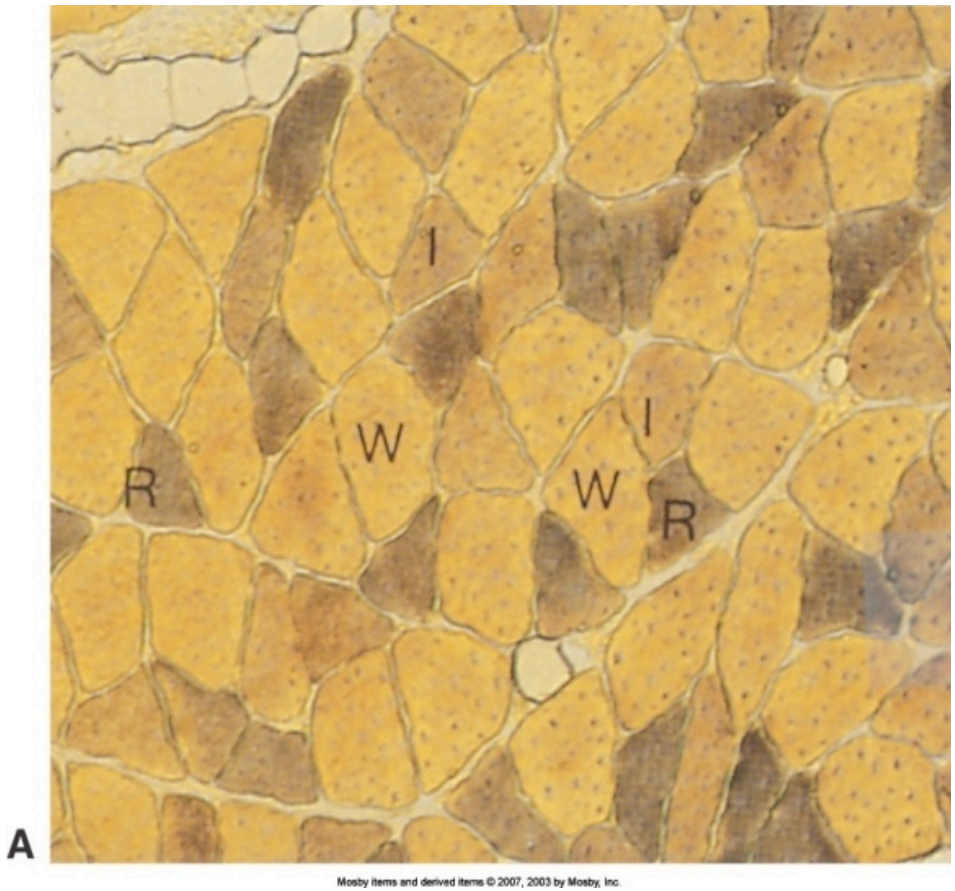
What happens if you run out of energy (ATP)?

Fig 12-9, p. 354 Thibodeau & Patton 8th edition

Fig 12-3, p. 350 Thibodeau & Patton 8th edition



2. Muscle Fibre Types – Metabolic



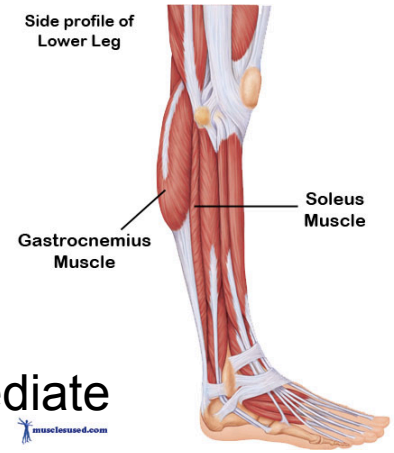
- "**Red**"
  - High myoglobin
  - High aerobic enzymes
- "White"
  - Low myoglobin
  - Low aerobic enzymes
- "Intermediate"

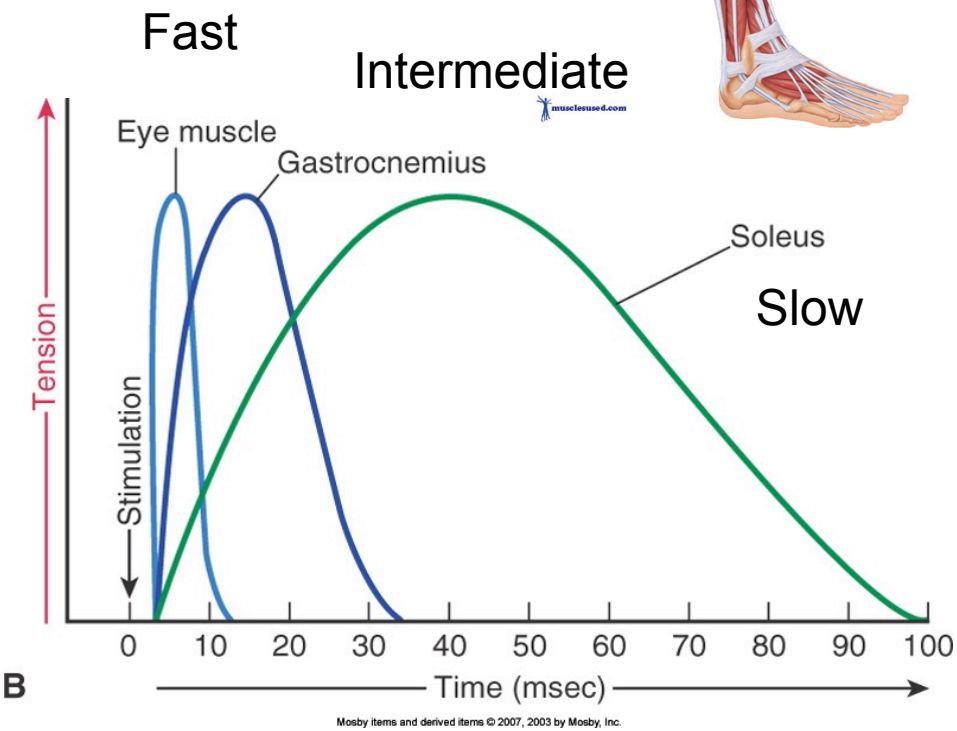
- Oxygen binds to hemoglobin in blood, ….and to myoglobin in muscle
- Both pigments colour red due to oxygen iron (Fe) binding

Box 12-4, p. 358 Thibodeau & Patton 8th edition

2. Muscle Fibre Types – Function

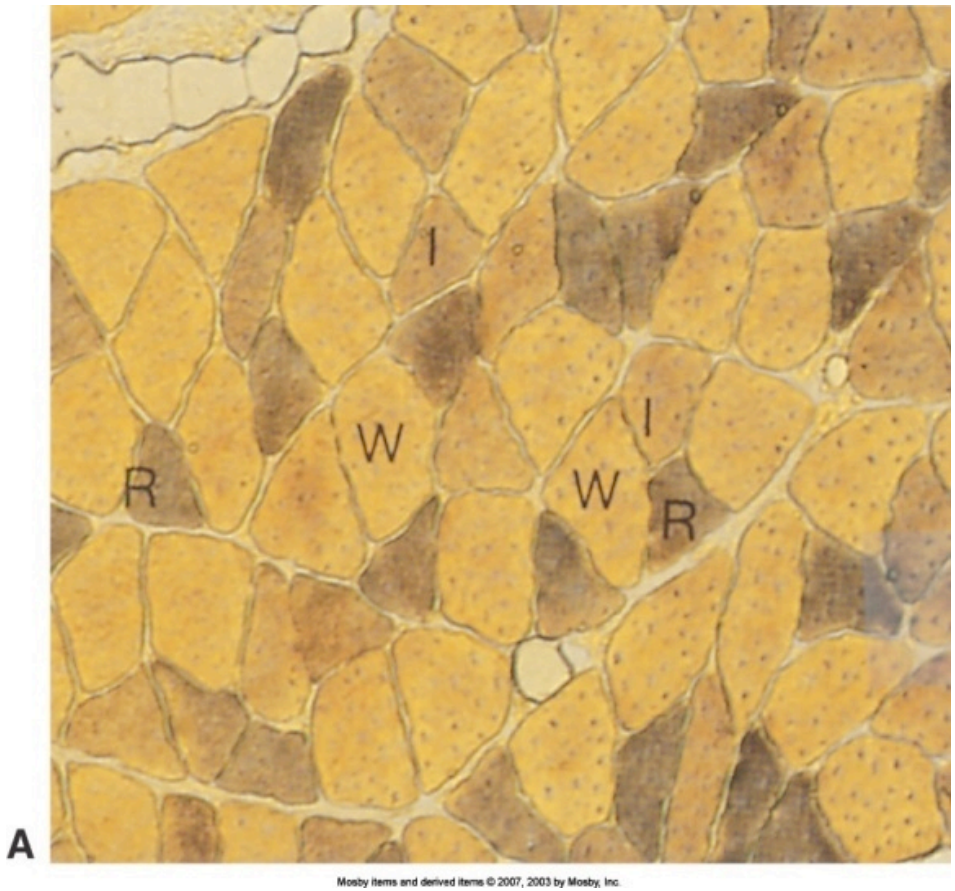
- Slow (Myosin type I) "Red"
  - Slow rate interaction with actin
  - Slow force production
  - Slow energy consumption
  - Sustained by aerobic metabolism
- Fast (Myosin type IIx) "White"
  - Fast rate interaction with actin
  - Fast force production
  - Fast energy consumption
  - Use anaerobic metabolism
- Intermediate (Myosin type IIa) "Intermediate"





Box 12-4, p. 358 Thibodeau & Patton 8th edition

2. Muscle Fibre Types – Metabolic



- "Red" / Slow
- "White" / Fast
- "Intermediate"

Depending on their function muscles are dominated by one fibre type or a **mix of fibre types**

Box 12-4, p. 358 Thibodeau & Patton 8th edition

2. Muscle Fibre Types – Function

Track Cycling World Championship Men Team Sprint 2016

3 laps – 43 seconds - 60 km/h average

World Class Sprinters

Need explosive power
Short duration
Anaerobic metabolism
Need relative less oxygen

Leg muscles develop higher proportion of FAST/WHITE and INTERMEDIATE fibres

2. Muscle Fibre Types – Function

World Speed Skating Championships
Bronze at Men's 5000 meters on 9th of Feb 2017
6 min 11.67 sec (12 ½ round)

World Class "Endurance" Athlete

Needs fatigue resistance
Pace slower – needs endurance
Uses aerobic metabolism

Leg muscles develop higher proportion of SLOW/RED and INTERMEDIATE **fibres**
(+ adaptations for supply of O_2)

Question!

The energy required for muscle contraction is obtained by hydrolysis of ATP. Which statement related to maximal muscle contraction is correct?

A. ATP stores provide energy for 2-4 minutes, and creatine phosphate (CP) provides energy for ATP resynthesis for 20 minutes.

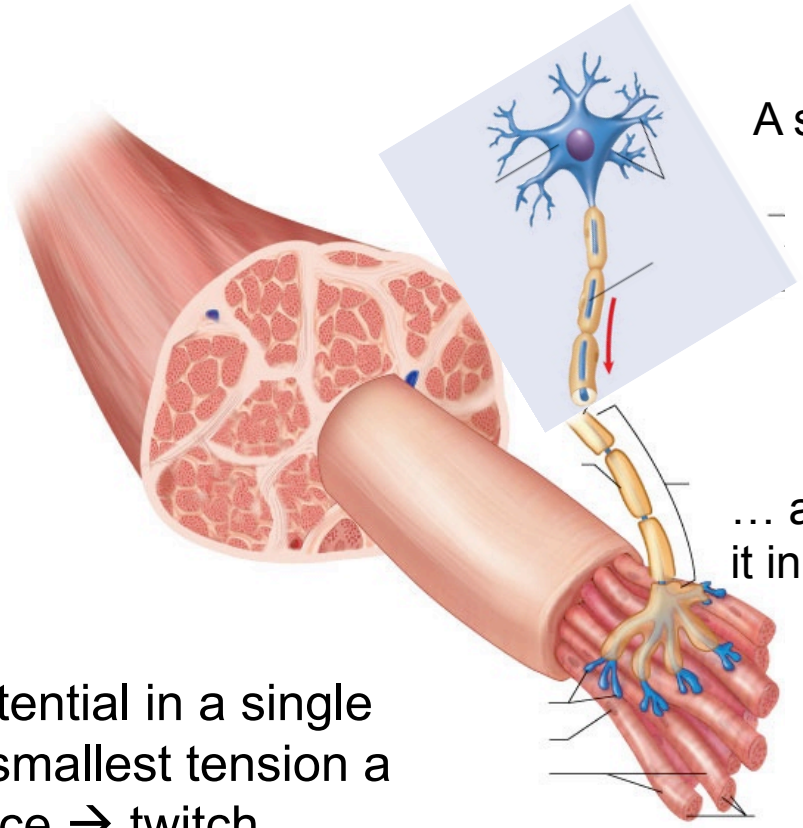
B. ATP stores provide energy for 2-4 seconds, and CP provides energy for ATP resynthesis for 20 seconds.

C. ATP stores provide energy for 2-4 minutes, and can only be resynthesised in the presence of oxygen.

D. ATP stores provide energy for 2-4 seconds, and can only be resynthesised in the presence of oxygen.

E. None of the above is correct.

3. Skeletal Muscle Function



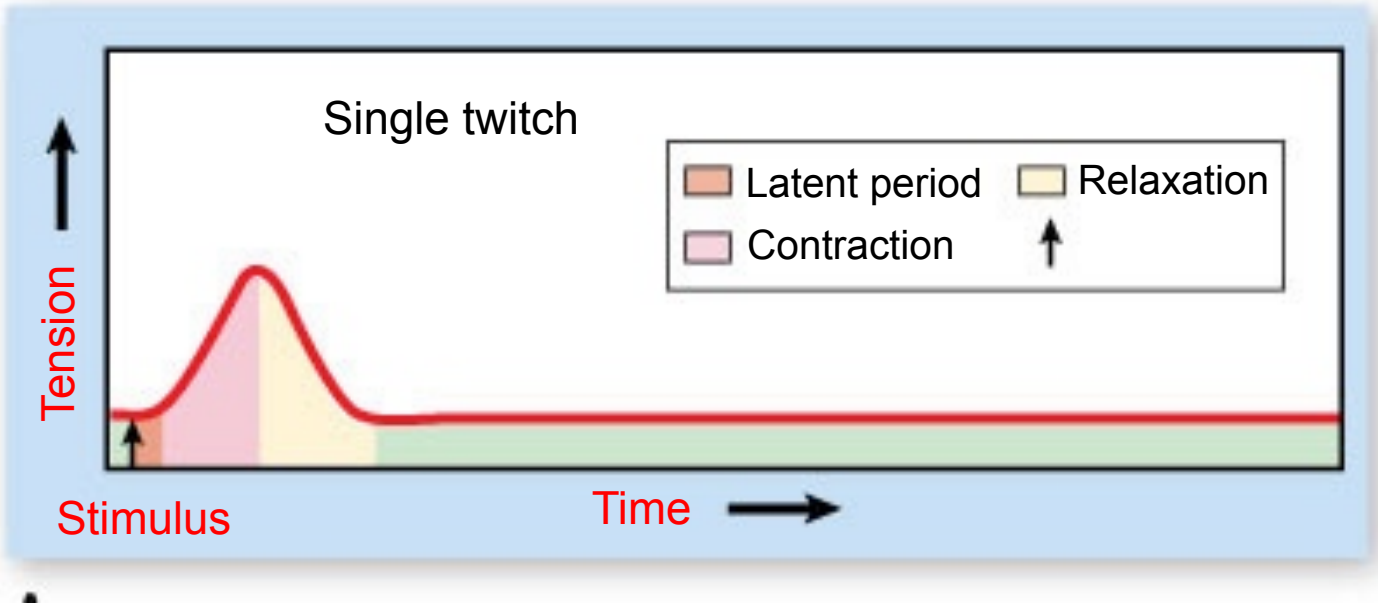
A single motor neuron ….

… and all the muscle fibres it innervates.

A single action potential in a single motor unit → the smallest tension a muscle can produce → twitch

Fig 12-18, p. 360 Thibodeau & Patton 8th edition

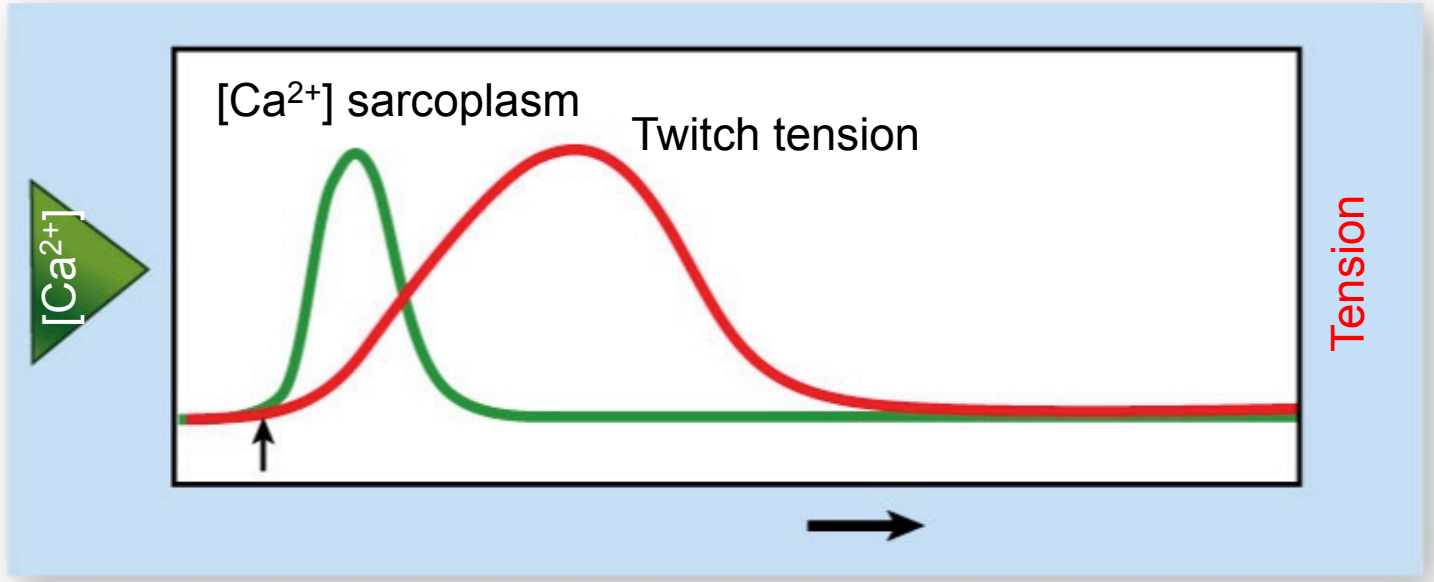
3. Skeletal Muscle Function - Twitch



- A single electrical stimulation of a muscle → a single activation of many motor units = a twitch of the muscle

Fig 12-21, p. 362 Thibodeau & Patton 8th edition

3. Skeletal Muscle Function - Twitch



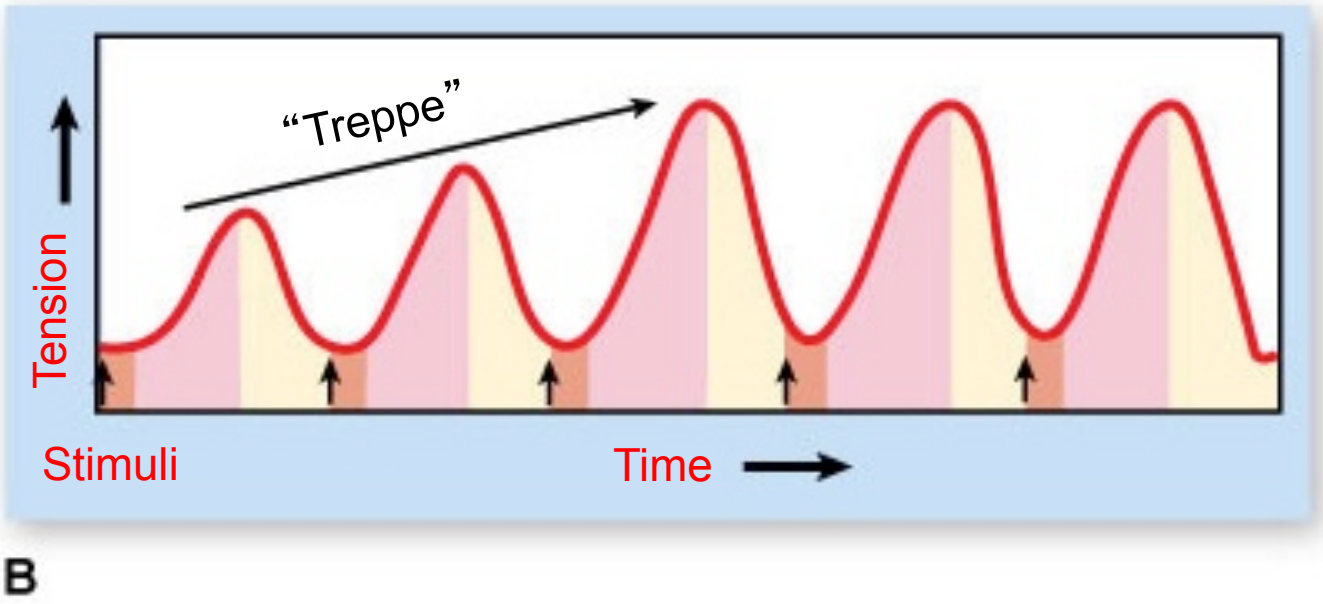
A

- A twitch is a mechanical event
- To build up and decline tension in a muscle takes longer than the underlying biochemical processes (Ca^{2+} cycling)
- **Single twitches can occur spontaneously, but usually do not**
- Electrically-evoked twitches are used to study muscle function

Fig 12-22, p. 363 Thibodeau & Patton 8th edition

3. Skeletal Muscle Function - Twitches

Series of spaced twitches



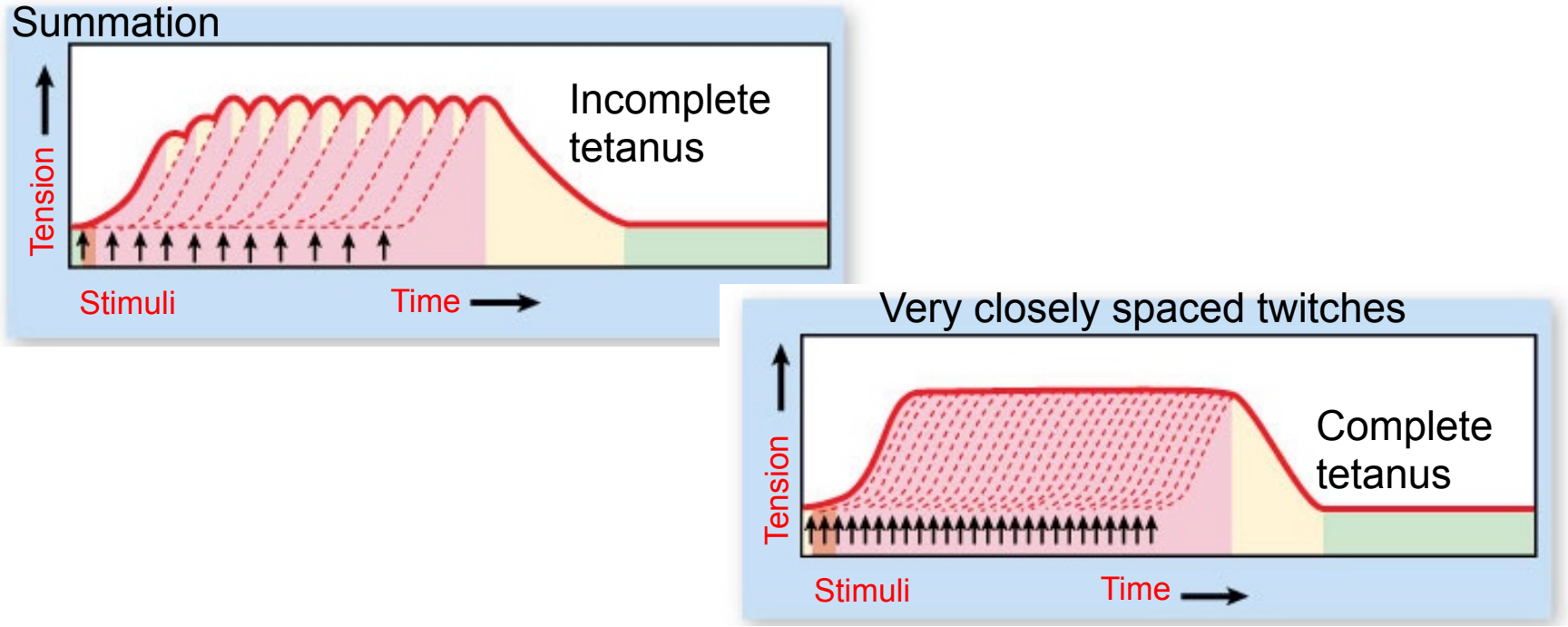
B

- Repeated stimuli cause increasing levels of tension, due to:
  - Sustained higher levels of sarcoplasmic Ca^{2+}
  - Actin-myosin interactions become more sensitive to Ca^{2+}
  - Heat (at higher temperature it can produce more tension)

Fig 12-21, p. 362 Thibodeau & Patton 8th edition

3. Skeletal Muscle Function - Tetanus

Series of closely spaced twitches

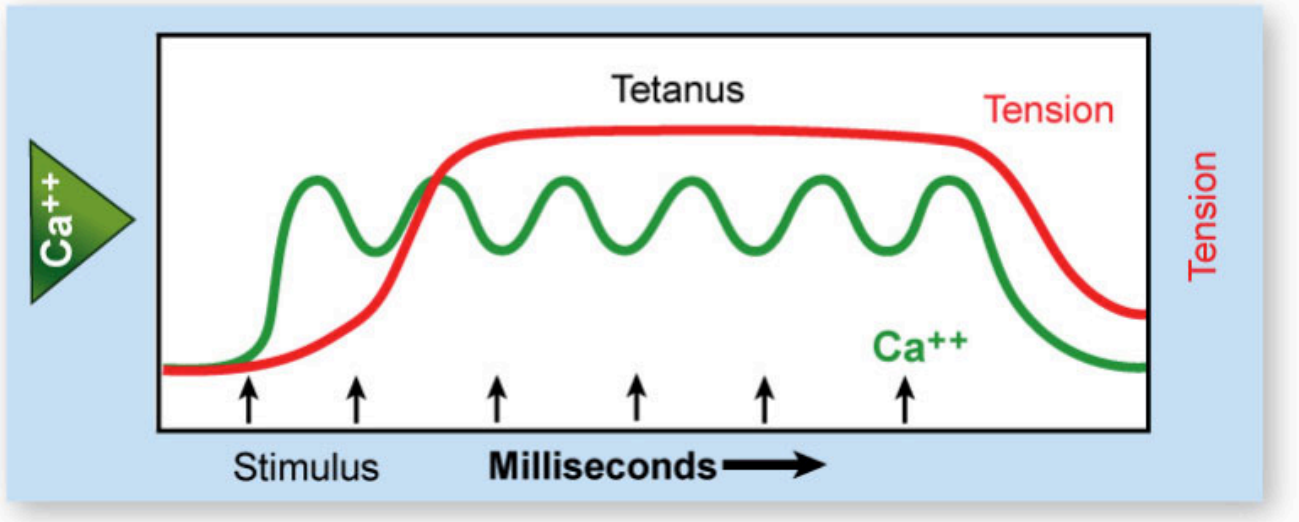


- Rapidly repeated stimuli cause even higher levels of tension = summation
- "Incomplete Tetanus" – fluctuations from individual twitches visible

- Physiological phenomenon is named after the disease (tetanus, bacterial infection) which produces uncontrollable sustained contractions

Fig 12-21, p. 362 Thibodeau & Patton 8th edition

3. Skeletal Muscle Function - Tetanus



- Main mechanism of summation = sustained higher level of [Ca^{2+}] in sarcoplasm
- Actin-myosin interactions become more sensitive to Ca^{2+}
- Heat

Tetanus is contractile state reached in most of the skeletal muscle fibres most of time

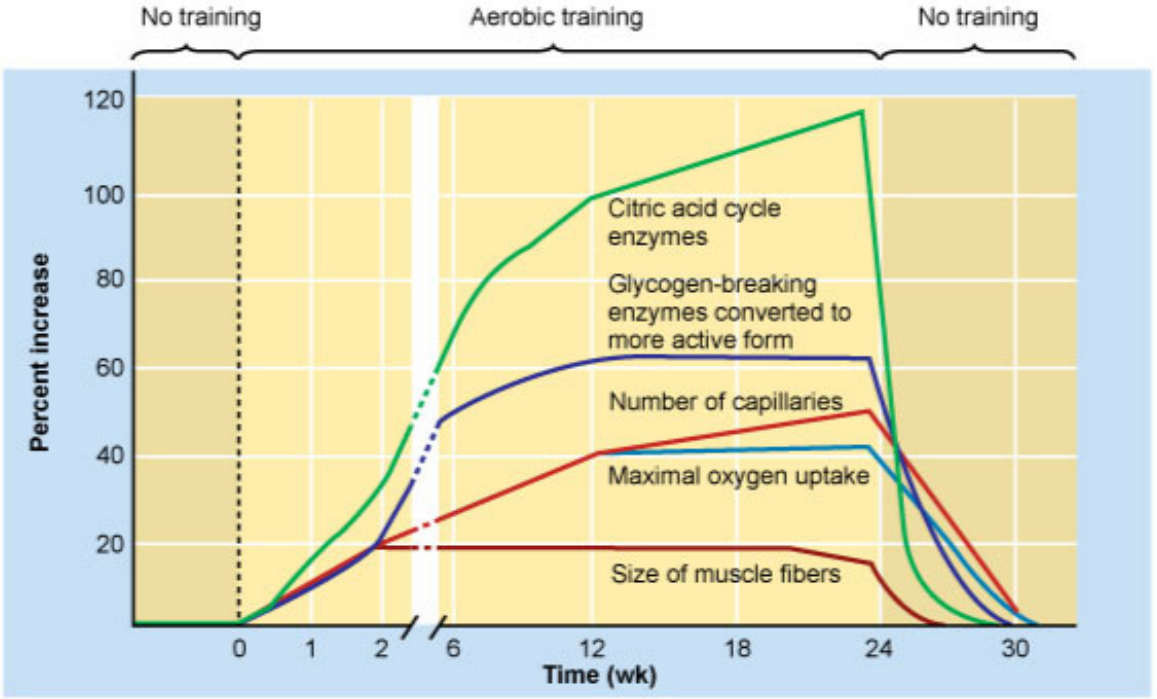
Fig 12-22, p. 363 Thibodeau & Patton 8th edition

4. Exercise and Fatigue: Training

Strength training
Increase # contractile filaments (hypertrophy)
More power
Improved anaerobic metabolism

Disuse
Loss # contractile filaments (atrophy)
Less power

Endurance training
Increase blood supply to muscle, more # blood vessels, more mitochondria, more aerobic enzymes
Improved aerobic metabolism



Box 12-6, p. 364 Thibodeau & Patton 8th edition

4. Exercise and Fatigue: Exhaustion

Suzanne Stokes said she gave Iron Man a go after her husband Ken was diagnosed with cancer last year. Source: 1 NEWS 08-03-2017

- A state of exhaustion (loss of strength or endurance) produced by strenuous muscle activity

Physiological fatigue

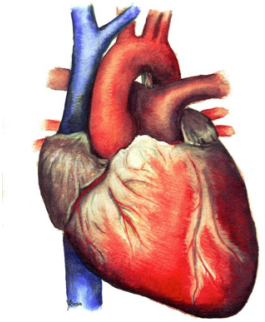
- ATP depletion, secondary to depletion of glucose, glycogen & O_2
- Build up of metabolic by-products: e.g. P_i and lactic acid

Psychological fatigue

- Feedback from working muscles to brain produces sensation of fatigue, even though muscle is still capable of contracting

Tomorrow!

Cardiac Muscle



Smooth Muscle

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