Physiological and Metabolic Background of Speed Training

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DISCLAIMER

- I am not a scientist.
  - …but I have spent considerable time studying and trying to understand the sciences as applied to coaching
- I am a coach.
- Science helps with coaching; but coaching is not a science. Jeremy Fischer

Much Appreciation

» Gunter Lange

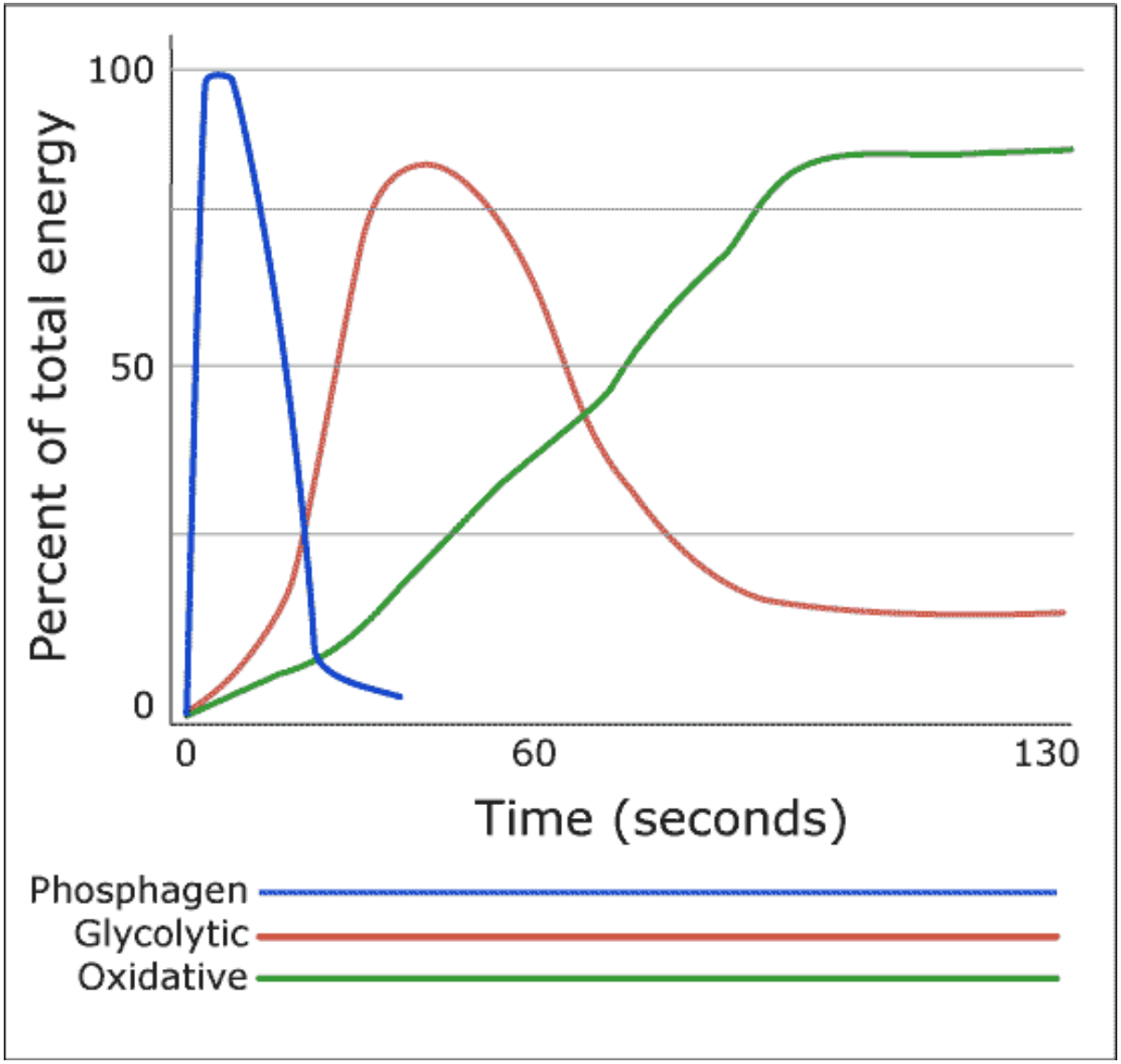
- For the Invitation to Participate in the World Coaches Conference

» Prof. Dr. Ulrich Hartmann

- For The Collaboration to Help Better Understand Energy System Dynamics and Openly Sharing

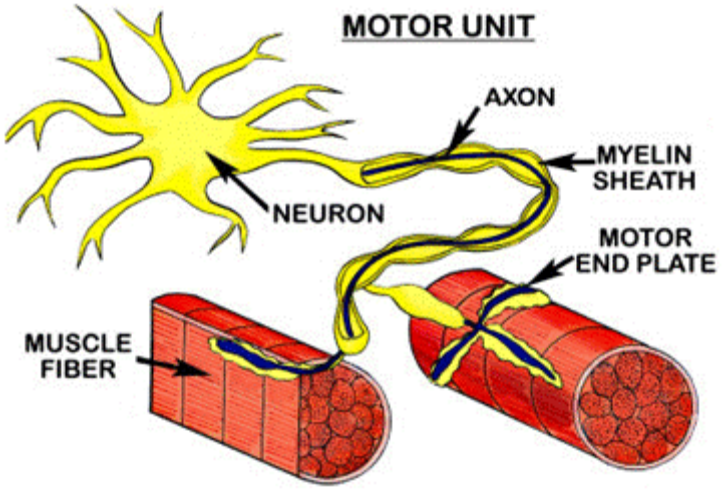
» Coaches, Scientist and Athletes Who Have Chosen to Invest your Valuable Time to Attend the Conference

Phospagen/Glycolytic/Oxidative Share



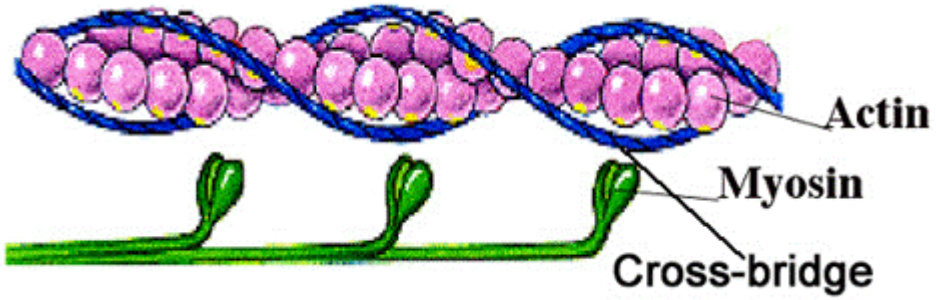
Mechanism of Volitional Muscle Contraction

» Action Potential Arrives at Neuro-Muscular Junction Causing Release of Calcium from Sarcoplasmic Reticulum



Mechanism of Muscle Contraction

- Calcium Binds with Troponin which allows Actin and Myosin to Bind and Contract using energy from ATP
- Magnesium Must be Available to Optimize this Step



Anaerobic Energy Share

The three primary enzymatic reactions that occur in the ATP-PC system

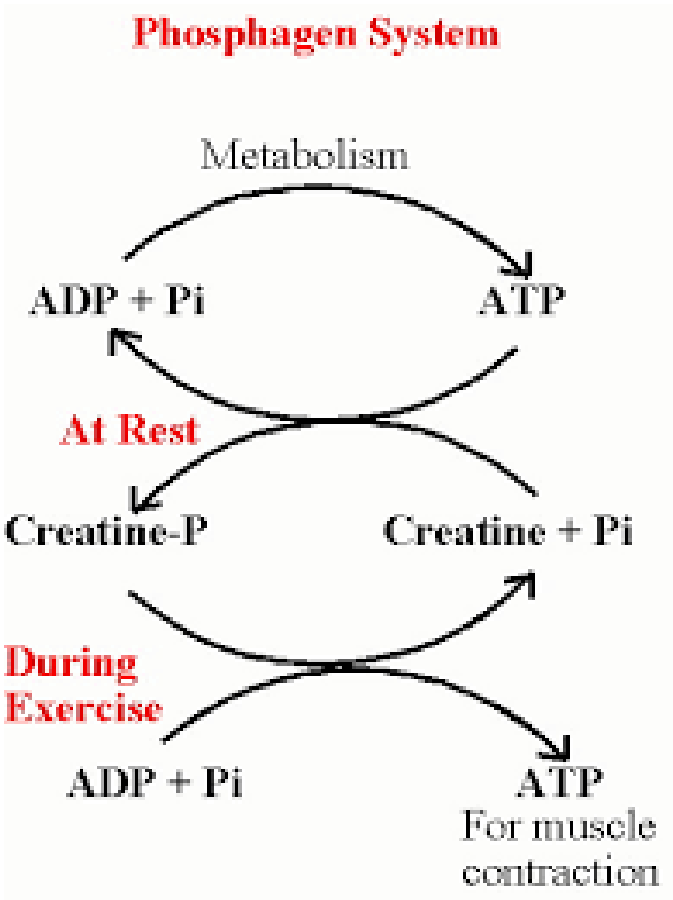
1. $ATP \xrightarrow[ATPase]{Myosin} ADP + inorganic\ phosphate\ (Pi) + energy$

2. $PC + ADP \xrightarrow[Kinase\ (CK)]{Creatine} ATP + C$

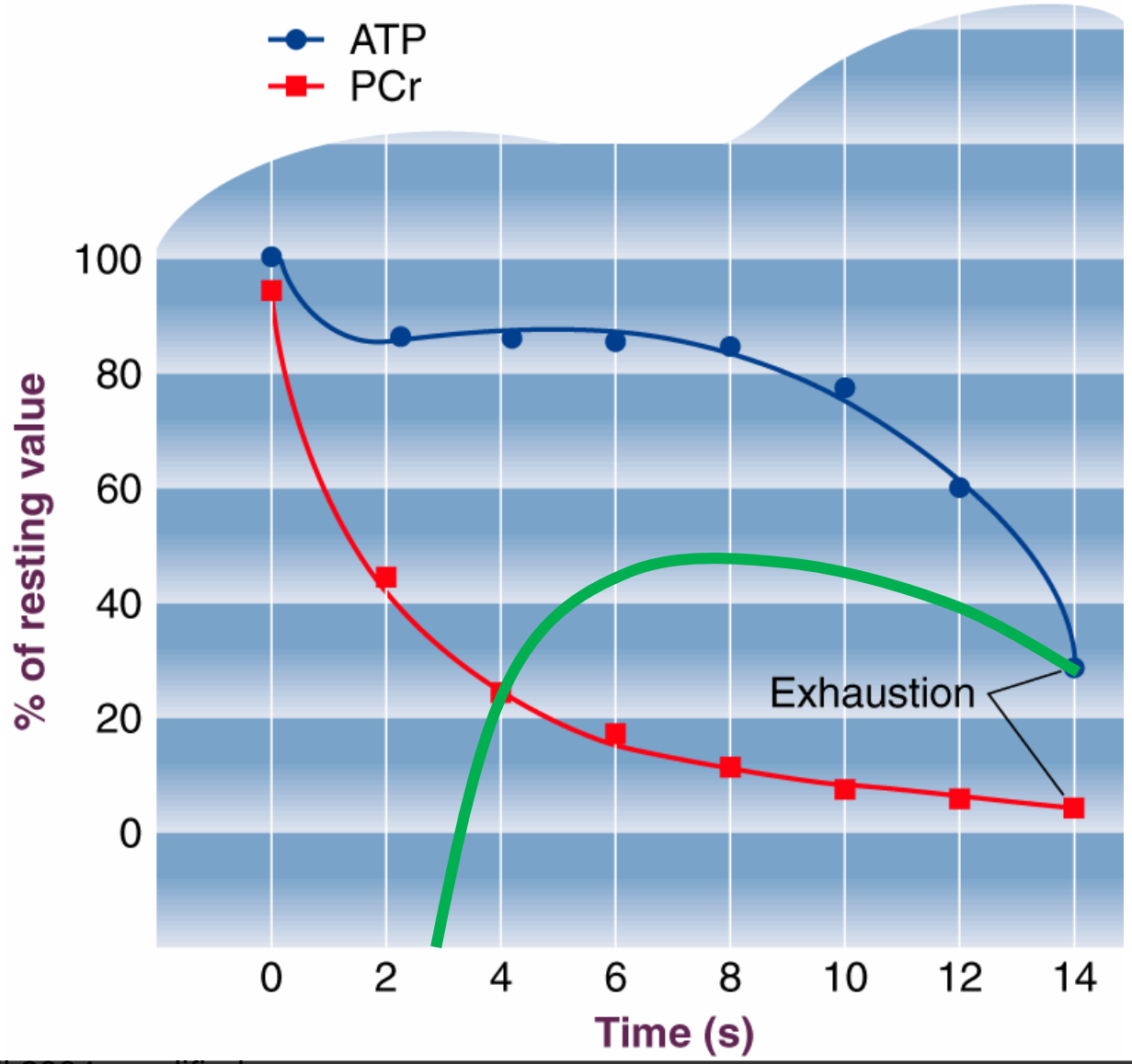
3. $2ADP \xrightarrow[Kinase\ (AK)]{Adenylate} ATP + AMP$

ATP Resynthesis (Anerobic alactic)

ATP is Resynthesized which allows Actin and Myosin to maintain a Strong Bond



ATP and CRPH during 100m sprint



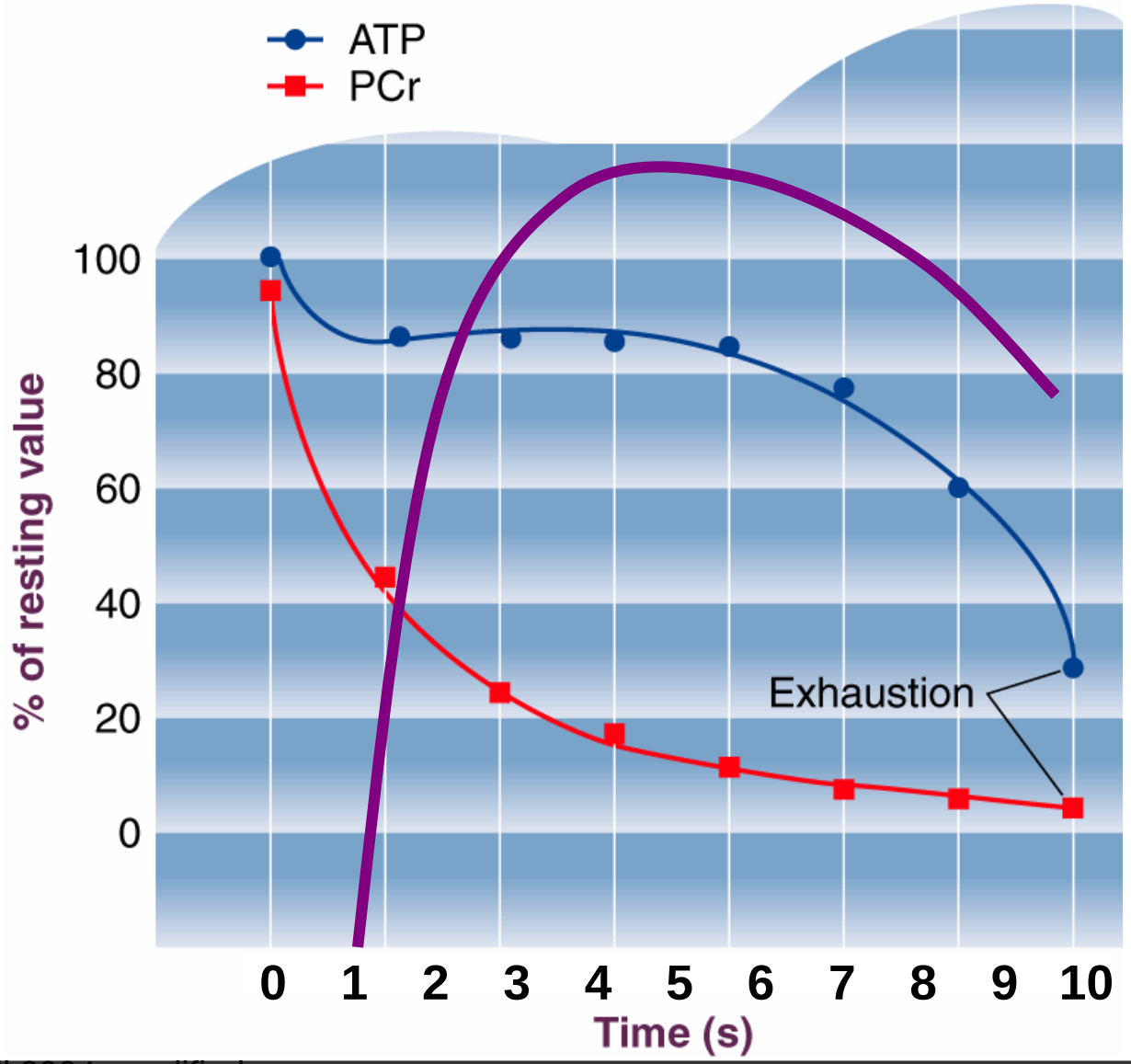
VLAmax

untrained subject;

VLAmax 1,2 mmol/l/s; 30-40% of the VLAmax of a top sprinter

Wilmore & Costill 2004, modified

ATP and CRPH during 100m sprint



VLAmax

High trained sprinter;

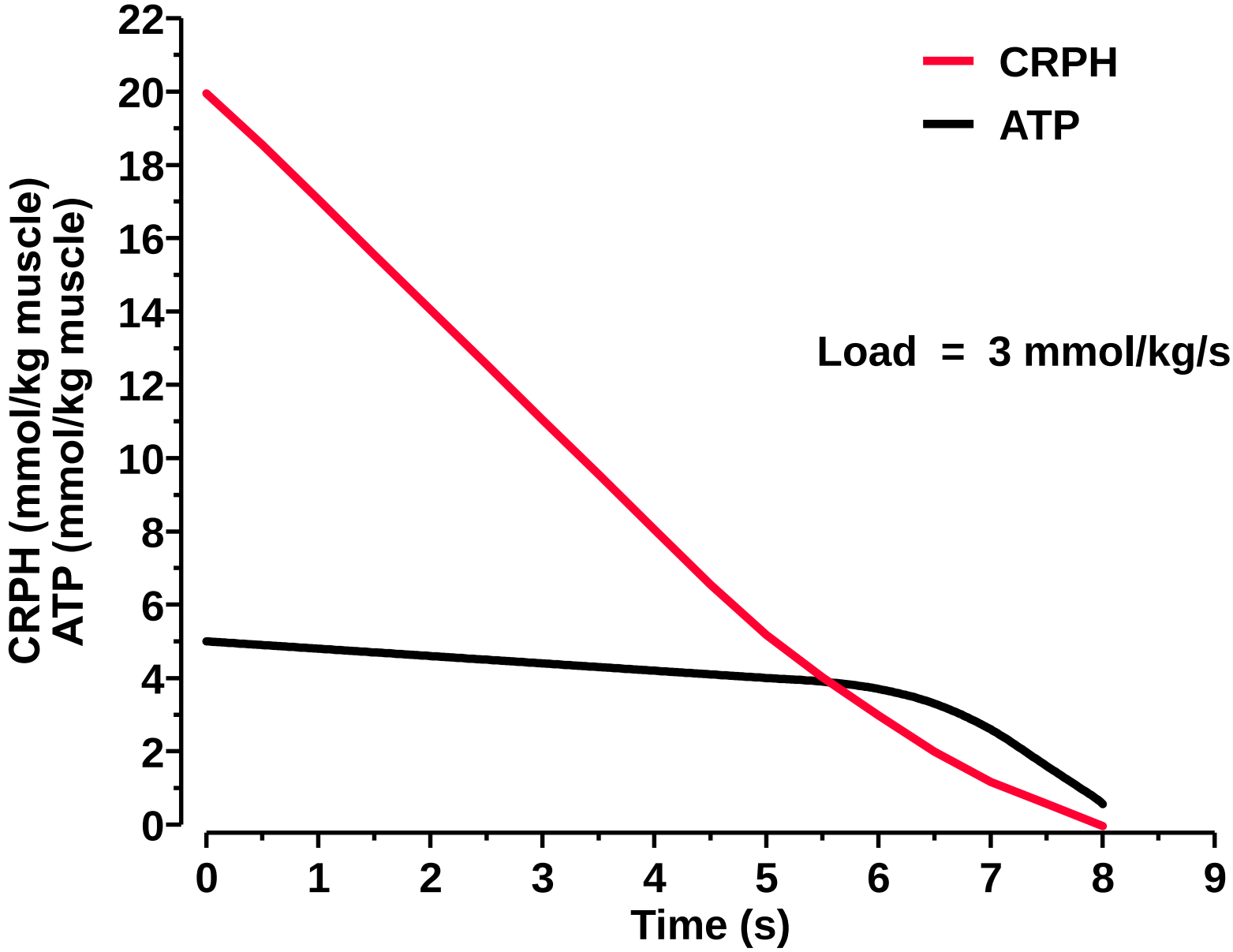
VLAmax > 3,0 mmol/l/s

Wilmore & Costill 2004, modified

Delta Lactate

- The Rate of Change for Lactate

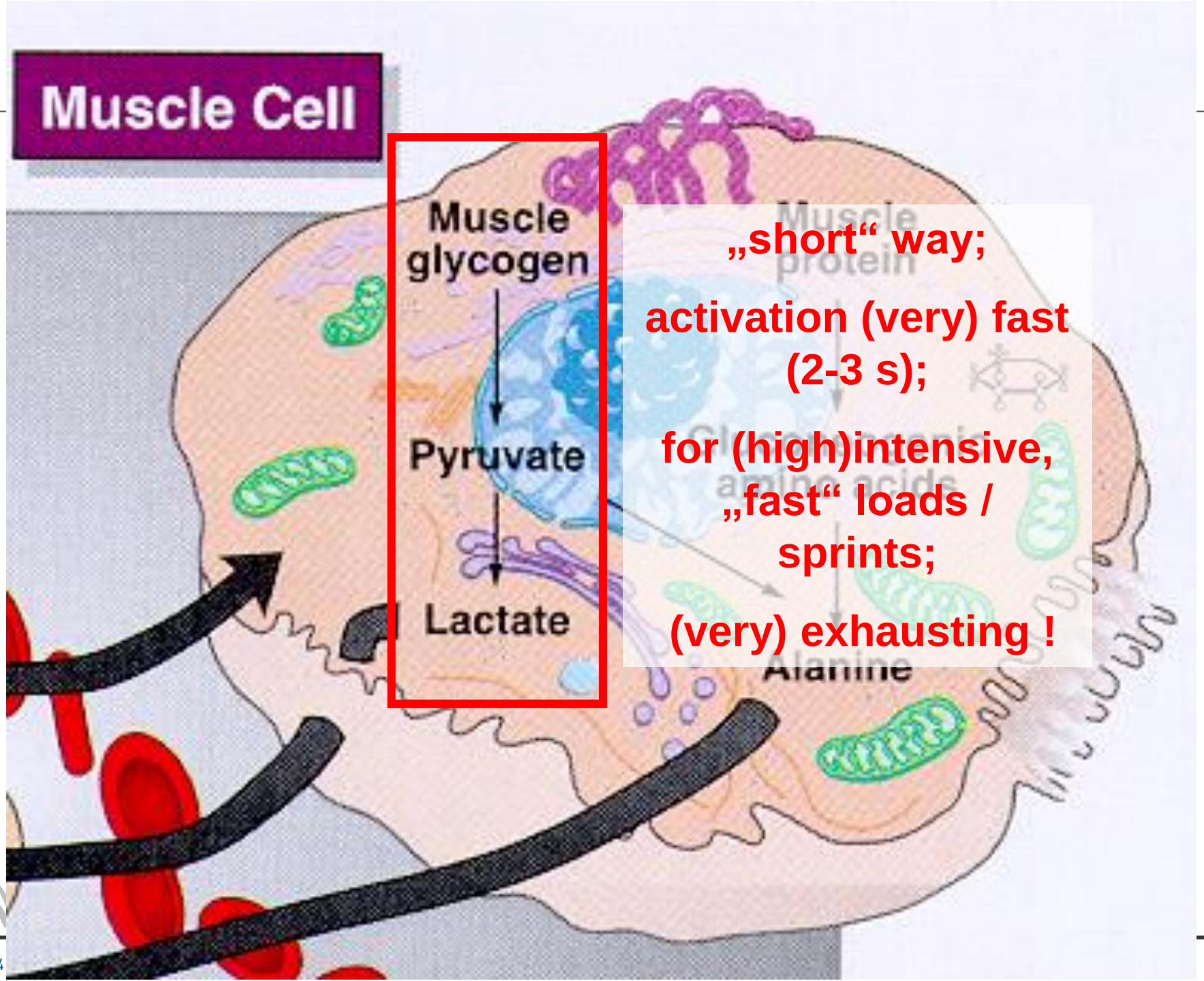
Stored ATP and CrPh in Skeletal Muscle



Anaerobic/Aerobic Contribution to Running

Anaerobic/Aerobic Contributions to Running		
From Astrand, 1971	Anaerobic %	Aerobic %
400-meters	81.5	18.5
800-meters	65.0	35.0
1500-meters	47.5	52.5
5K	20.0	80.0
10K	10.0	90.0
Marathon	2.5	97.5

Anaerobic/Aerobic Contributions to Running		
From Gaston, 2001	Anaerobic %	Aerobic %
200-meters	82.0	18.0
400-meters	56.5	43.5
800-meters	39.5	60.5
1500-meters	23.0	77.0
5K	6.0	94.0
10K	3.0	97.0
Marathon	1.0	99.0



„short“ way;

activation (very) fast (2-3 s);

for (high)intensive, „fast“ loads / sprints;

(very) exhausting !

Process of Glycolysis

- **Hexokinase Reaction (Glucose Phosphorylation)**
  - Requires one ATP to donate Phosphate Group
  - Enzyme Hexokinase in the Presence of Magnesium
  - Yields Glucose-6-Phosphate, ADP and H+
- **Phosphoglucose Isomerase**
  - Yields Fructose-6-Phosphate
- **Phosphofructokinase (PFK)**
  - Addition of second Phosphate from ATP with Magnesium
  - Yields fructo-1,6-bisphospate (FBP), ADP and H+
  - Rate Limiting Enzyme
- **Aldolase**
  - Cleaving FBP to glyceraldehyde-3-phosphate (GAP) & dihydroxyacetone phosphate (DHAP) reorganized to GAP

Process of Glycolysis

- **Glyceraldehyde-3-phosphate Dehydrogenase**
  - Oxidation by coenzyme nicotinamide adenine dinucleotide (NAD)
  - Phosphorylated by addition of free phosphate group by glyceraldehyde-3-phosphate dehydrogenase (GAPDH)
  - Yields 1,3 bisphoglycerate, NADH and H+
- **Phosphoglycerate Kinase**
  - Yields 3-phosphoglycerate & ATP by phosphoglycerate kinase (PGK) plus ADP in presence of Magnesium
- **Phosphoglycerate Mutase**
  - Rearrangement of the Position of the Phosphate Group
- **Enolase**
  - Yields phosphoenolpyruvate plus water
- **Pyruvate Kinase**
  - Converts phosphoenolpyruvate, ADP and H+ into pyruvate and ATP

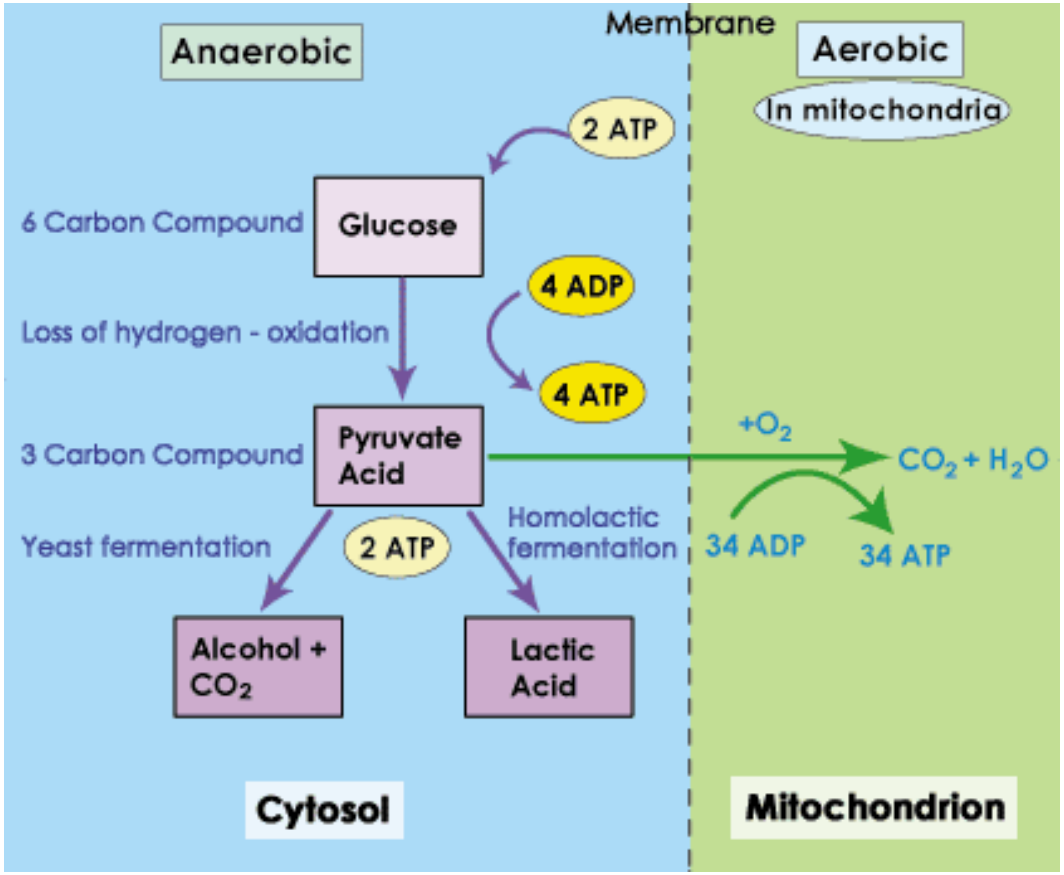
Glycolysis: Keeping Score

- Process has consumed two ATP but Yields four ATP
  - Net Yield is Two ATP
- Process has generated four H+ but utilized two H+
  - Net Yield is Two H+

The Fate of Pyruvate

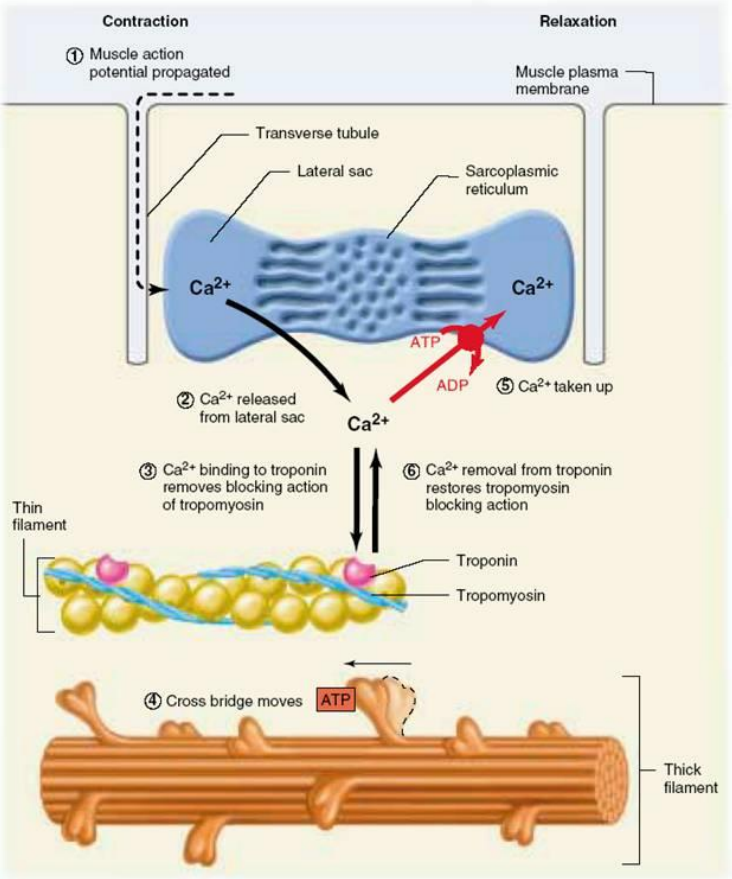
» Pyruvate and NADH Yield Lactate and NAD

- In Oxygen Deficient Environment Lactic Acid is Produced
- Lactate Dehydrogenase



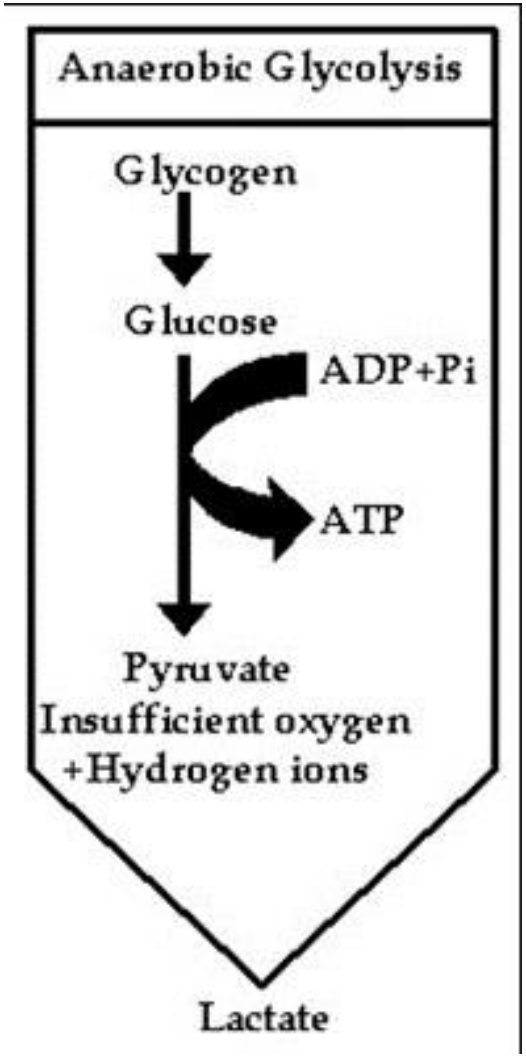
Muscle Relaxation

» When Nerve Stimulation Stops the Muscle Relaxes as a Result of Reuptake of Calcium by the SR through the Calcium Pump



Lactate versus Lactic Acid (pH+)

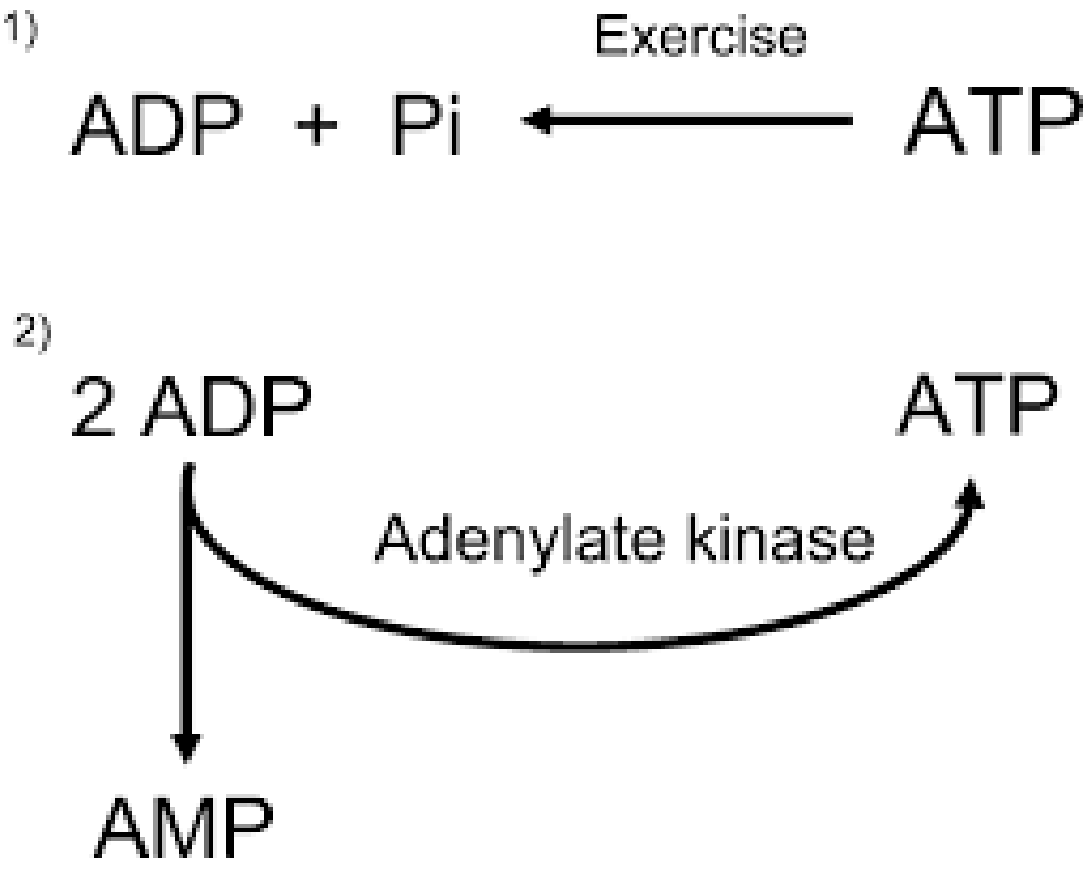
- When Pyruvate Accumulates Due To Insufficient Oxidative Capacity
- Decrease in Intracellular pH+ Shuts Down Muscle Functions



Managing Intracellular Acidity

- Diffusion of Lactate from the Cell into the Blood
- Buffering Intracellular H+ Accumulation
- Active Transport: Monocarboxylate Transporter-4 (MCT-4)
  - Protein encoded by SLC16A3 Gene
  - Expressed in White Skeletal Muscle Fiber
  - Proposed Export of Lactate out of Cells

Adenylate Kinase Reaction

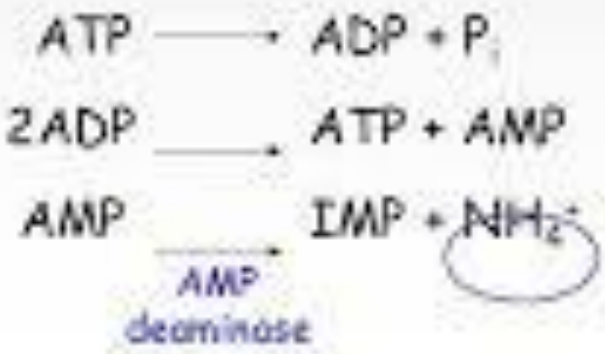


Adenylate Kinase Reaction

Free ammonia is also produced in muscle

Amino groups can be liberated:

- ☐ during normal muscle turnover
- ☐ during starvation
- ☐ during severe muscle activity



Cessation of Muscle Contraction

- Energy System Fatigue
  - Reduction in Available ATP
- Nervous System Fatigue
- Voluntary Neural Control
  - Conscious and Unconscious Mechanisms
- Sensory Neural Control
  - Reality versus Perception

Adaptation to Aerobic Training

- Maximizing Metabolic Stress at Key levels of Structural Stress

- Primary Factors that Lead to Adaptation to Training
  - Intracellular Calcium
  - Heat Stress
  - Decrease in ATP:ADP Ratio
  - Glycogen Depletion
  - Caloric Restriction
  - Oxidative Stress

Adaptation to Low Intensity Aerobic Training (Factors)

» Calcium from Myofibular Space Stimulates Binding Proteins

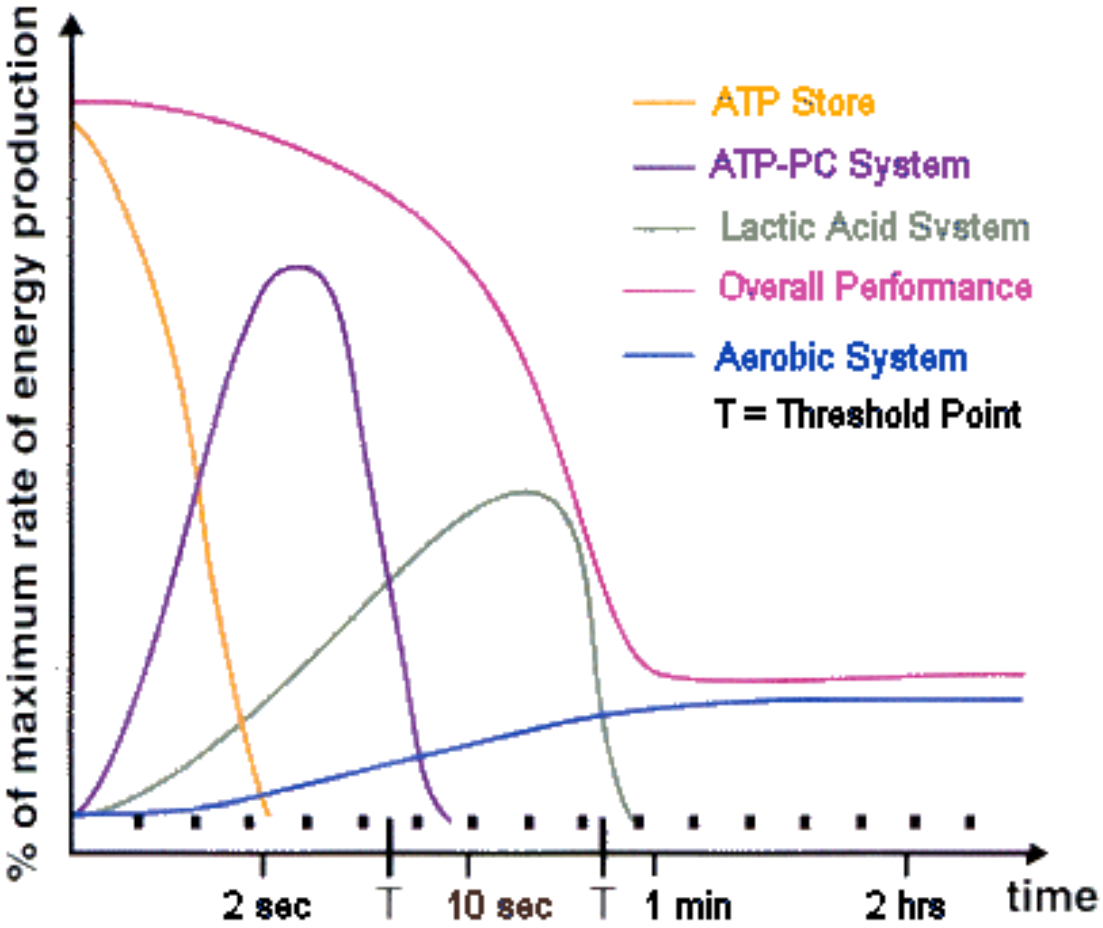
- Activator of PGC-1
- Prolonged Contraction Increases Intracellular Ca++
- Induces Mitochondrial Biogenisis
- Rationale for Long Slow Distance

…Initially Smaller Motor Units are Recruited, but Upon Fatique

…Larger, Mitochondria Poor, Units are Recruited to Maintain Output

…Increase in Mitochonria and Capillaries so Increase Power at Lactate Threshold

Training Stress Points



Adaptation to High Intensity (75-100% VO_2 Max) Aerobic Training (Factors)

» Events that Affect PGC-1 Activity

- Phosphocreatine Depletion

  …Increased Levels of ADP, AMP and Creatine Activate AMPK

- Muscle Glycogen Breaks Down

  …Triggers AMPK and another Activator p38

- Lactate and NAD+ Increase

  …Activates SIRT1 increases acetylation of PGC-1

  …SIRT1 also Activated by Caloric Restriction

  …Was thought Resveratrol Activates SIRT1

- Epinephrine Increase

  …Training in the Heat

  …Training while in Glycogen Depletion

  …Training at High Intensities

Reactive Oxidative Species (ROS)

- Oxygen Free Radicals Produced in Mitochondria during Aerobic Exercise
  - ROS Scavenged by antioxidants
  - Some Needed for Transcription of PGC-1
  - Indication Supplementation with Synthetic Antioxidants Blunt Response

Adaptation to Aerobic Training

- Aforementioned Factors Increase Quantity and Activity of a Protein that Increases Desired Adaptive Responses
  - peroxisome proliferator-activated receptor gamma coactivator 1 alpha (PGC-1a)

- Adaptive Responses: Aerobic (Endurance) Training
  - Mitochondial Biogenisis
  - Angiogenisis
  - Increased Fat Oxidation

Dietary Considerations: Affecting Mitochondrial Adaptation

- Consider Restricting CHO Intake Prior to Certain Sessions
  - Perceived Exertion Elevated and Performance Decreased
- Ingest zero CHO Drink with 200mg Caffeine and no Antioxidants
  - Increase Calcium Release
  - No Synthetic Antioxidants Promotes Mitochondrial Biogenisis
  - Increases Epinephrine Release During Training
- Sessions Performed at Low Intensity for Long Duration
- Excessive Use of These Strategies May Result in Reduced Immune System Function

Dietary Considerations Affecting Energy Share

- Inadequate CHO Intake or Suboptimal Timing and Poor Selection of CHO Intake
  - Compromised Stored CHO in Muscle that Negates Adequate Energy from Glycolysis.
- Implications of a strict Vegan Diet
  - No ingestion of Creatine in Food
  - Even with proper Amino Acids, Body Produces Insufficient Quantities to support High Intensity Performance
  - Exogenous Creatine Supplementation
- Insufficient Magnesium Intake
  - Reduced Levels of Strength and Power
  - Lack of Adequate Amounts Used in Enzymatic Reactions

What Is Work Capacity?

- Work Capacity is Often Used Synonymously with…
  - General Endurance Capacity / Aerobic Fitness

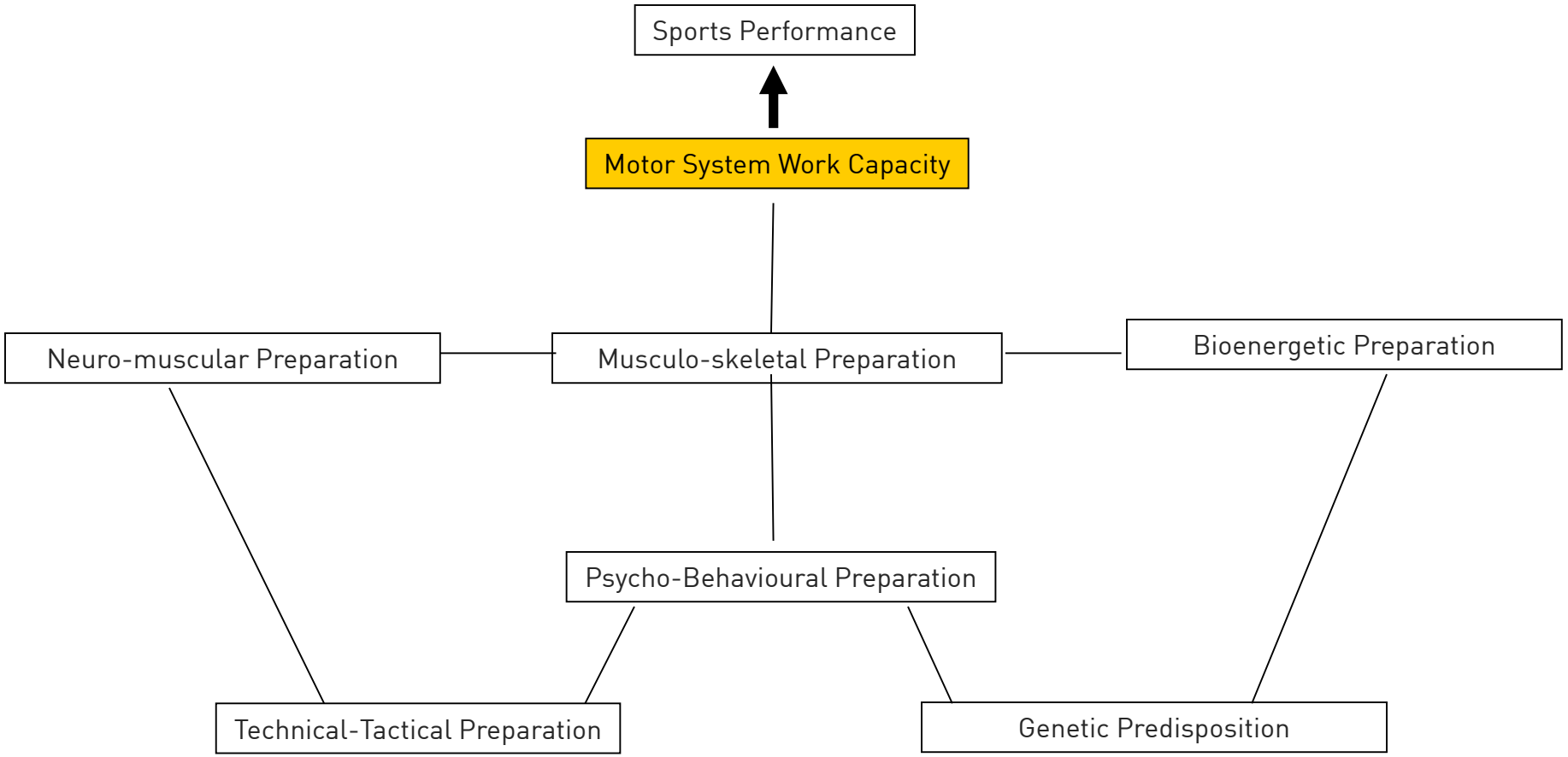
- Work Capacity is not Just the Ability to Withstand Large Training Loads.

What Is Work Capacity?

- Work Capacity is the Ability Maintain the Quality and Intensity of an Activity
  - under Ever Increasing Volumetric Loads
  - and Be Able to Return to Homeostasis in Both Short Term and Long Term

- Increases in Work Capacity is Realized by Increasing the Capacity in All the Bio-motor Abilities.

Preparing for Sports Performance
Adapted from Verkhoshansky (2006)



Work Capacity: An Important Focus of Long Term Athletic Development

- A Holistic Perspective of Developing Work Capacity
  - Gives the Athlete a Comprehensive Base Upon Which to Train and Recover
- Linking General Development of Bio-Motor Abilities with Movement Skill Development Enhances the Athleticism of the Individual

Work Capacity: An Important Focus of Long Term Athletic Development

- If Properly Addressed in Training…
  - Work Capacity is Additive Over the Career of the Athlete

- Reducing Restrictions, Imbalances and Instability through a Blend of Therapeutic Exercises…
  - Has a Positive Effect on Reducing Injury Likelihood
  - Don't Build Work Capacity on Dysfunction Gray Cook paraphrased

The Bio-Motor Abilities: Building Blocks of Training Goals

- The Qualities that an Individual Must Possess to Be Successful at Any Physical Endeavor
- Bio-motor Demands Vary with Nature of the Activity and Event
  - Which Determines the Direction of Training as The Athlete Increases Specialization
- Early Over-Emphasis on a Bio-motor Quality May Put the Body Out of Balance with Respect to Long Term Development

Sherrington's Law

- Reciprocal Innervation
  - When Agonist Contracts, Antagonist is inhibited
- Muscle Co-contraction for Joint Stabilization
- Pre-Activation (Anticipatory Firing)

Joint Position Dictates Muscle Recruitment

» Neuro-Biomechanical Facilitation

- General Endurance Capacity / Aerobic Fitness

» Neuro-Biomechanical Inhibition

Passive Versus Active Insufficiency

» In Single Joint Muscles (Passive)

- Maximum Force Generated at Length slightly Greater then Resting Length
- As Muscle Shortens it Can Produce Less Force
- Caveat for optimal Length-Tension Relationship

» In Two Joint Muscles (Active)

- To Produce Maximum Force at Superior Joint Inferior Joint must be Momentarily Fixed.
- Pulling a rope from the middle

Connective Tissue Dynamics

- Lengthening Connective Tissue
  - 6 minute of activation
  - Eccentric Loading
  - Gelatin (Proline and Glycine) + Vitamin C
  - 6 hour Refractory Period
- Increasing Tensile Strength
  - Short Bouts of Ballistic Exercises

Implication of Hypertophy Phase Strength Training and Muscle Contraction Characteristics

- Shifting the Contraction Characteristics from II-B to II-A
  - Heavy Chain Myosin to Light Chain Mysosin
- Hypertrophy through Increased Sarcopasmic Reticulum versus Increase in Intracellular Contractile Protein

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