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Beyond the Symptom: The Biology of Fatigue
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The Role of Temperature in Athletic Fatigue

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Disclaimer and Disclosures

Disclaimer
This certifies that the views expressed in this presentation are those of the author and do not reflect the official policy of the NIH.

Disclosure
I, H. Craig Heller, have a relationship that is relevant to the subject matter of this presentation.

I am associated with a company – Arteria – that has licensed our body heat extraction technology from Stanford University. I am not employed by Arteria.

Credits
Dennis Grahn, Vinh Cao, DARPA, Pac12, and Many Stanford undergraduates

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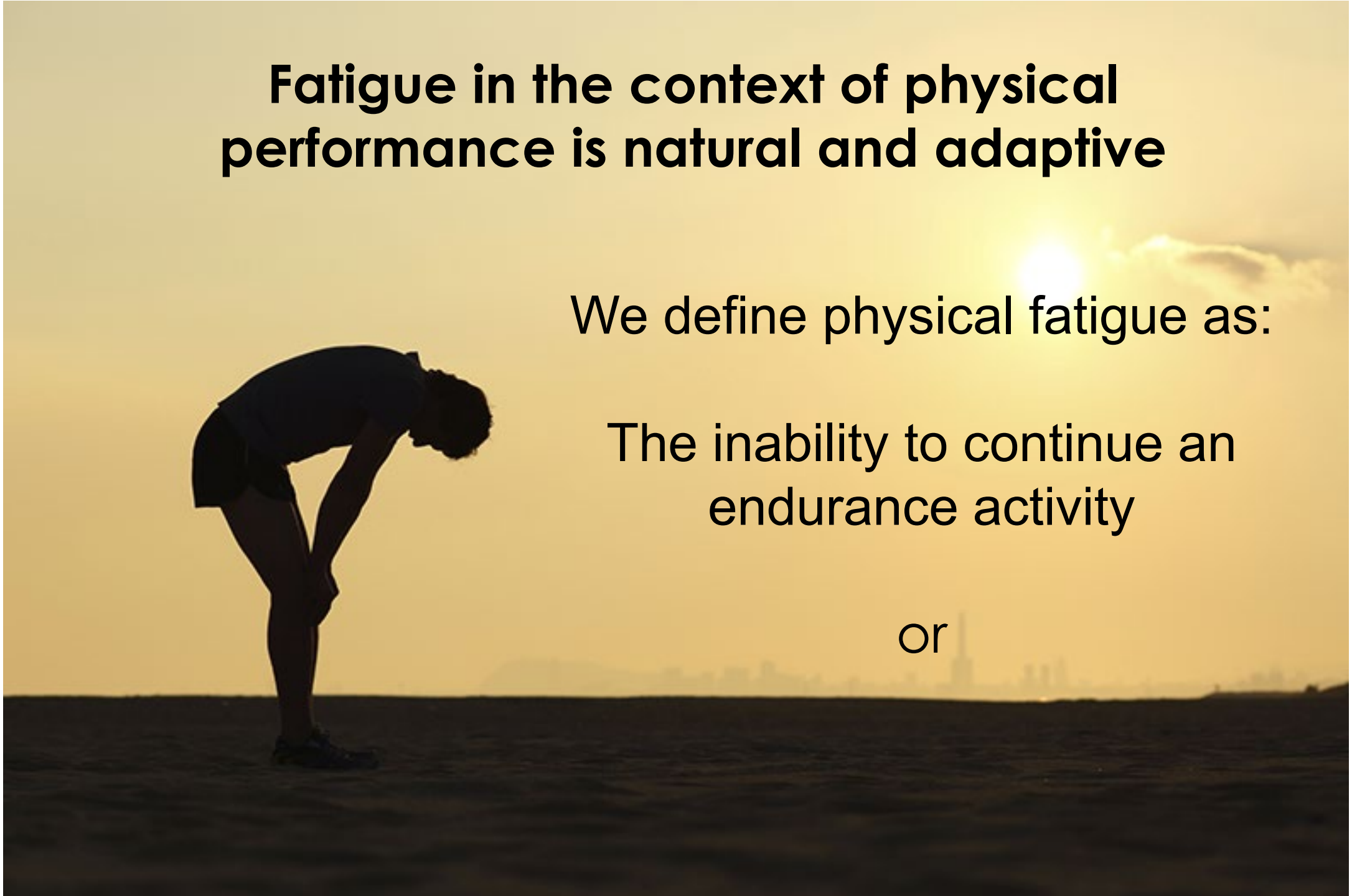
Fatigue in the context of physical performance is natural and adaptive



We define physical fatigue as:

The inability to continue an endurance activity

or

The inability to produce or sustain a maximal muscle contraction

COMPONENTS OF PHYSICAL PERFORMANCE

STRENGTH

ENDURANCE

SKILL

MAXIMUM POWER OUTPUT

COGNITIVE CAPACITY

ALL ARE SUBJECT TO FATIGUE
ALL ARE AFFECTED BY TEMPERATURE

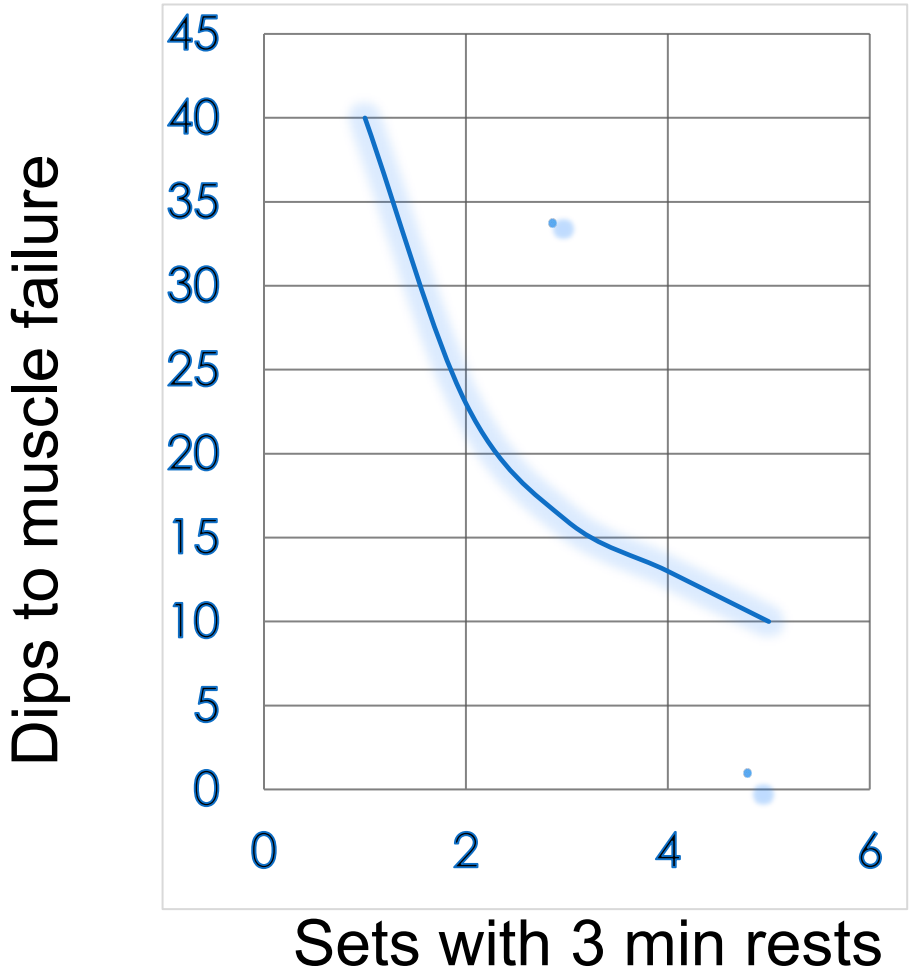
Hyperthermia limits endurance activities

Paula Radcliffe
Women's marathon
Athens Olympics 2004

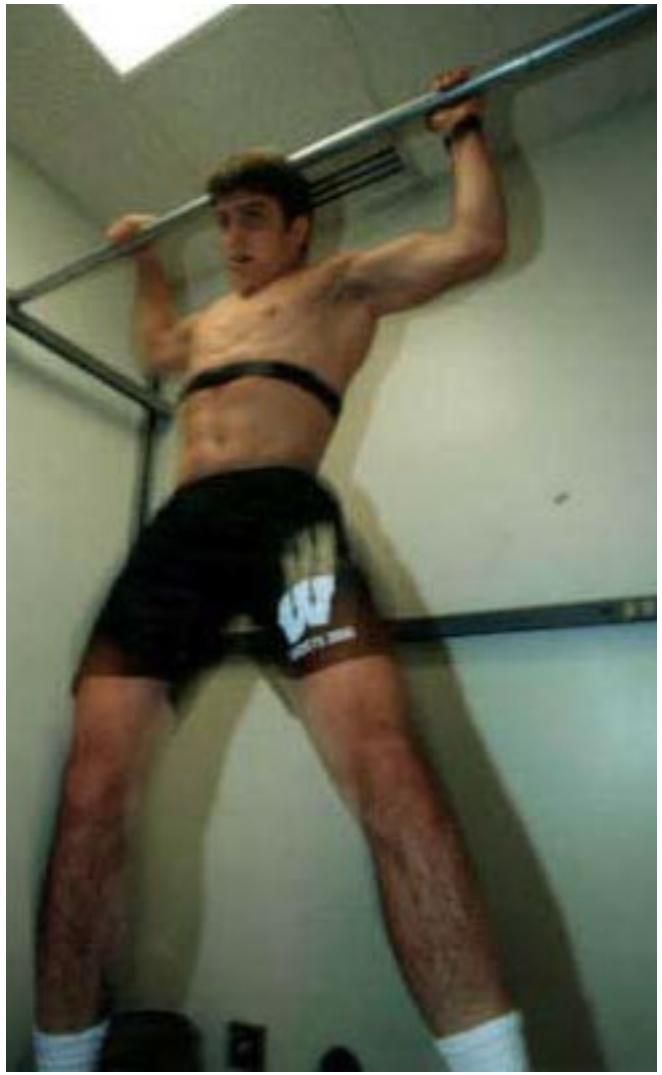
Subsequent NY Marathons: 2:23:10, 2:23:9, 2:23:56

Difference ? Athens 95F Ave. NY 45F

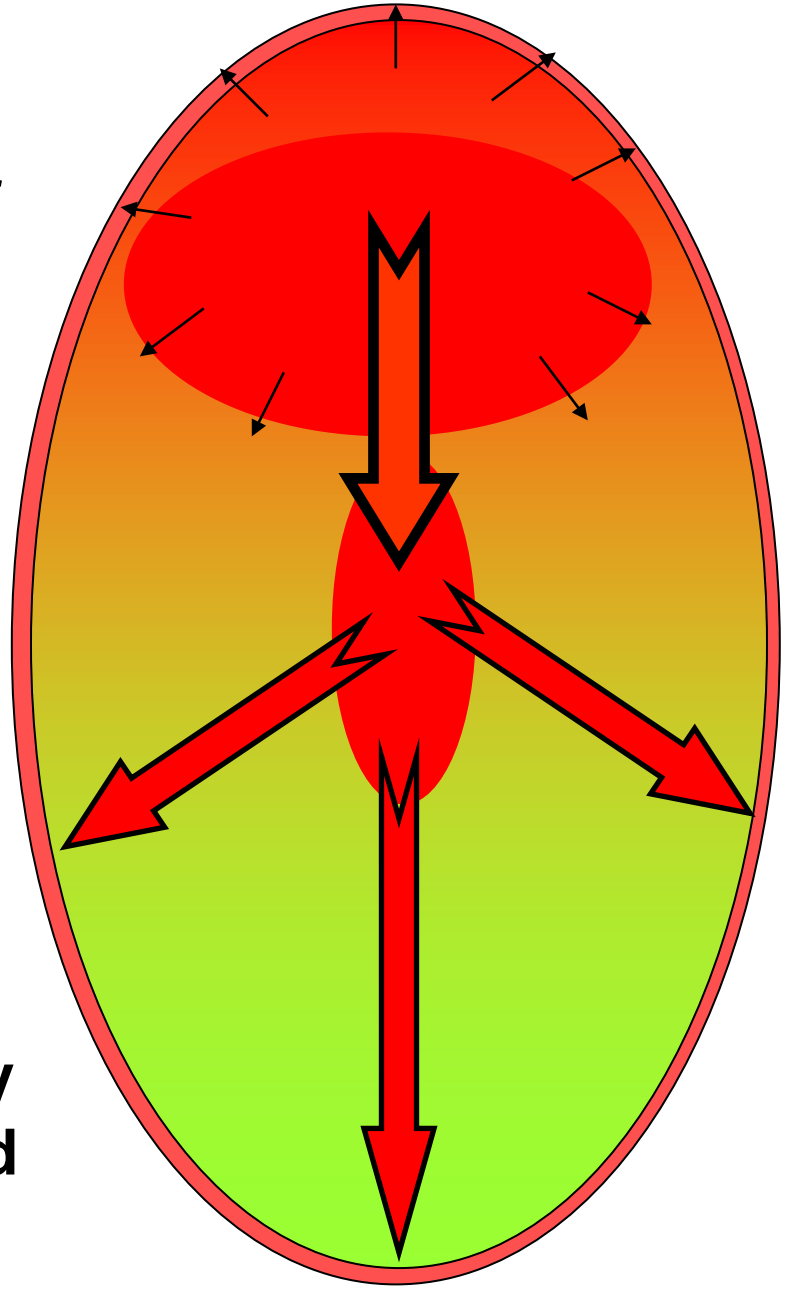
Could anaerobic performance also be temperature limited?



Baseline:
"By the fifth set I was completely exhausted. This is a typical pattern of exhaustion."



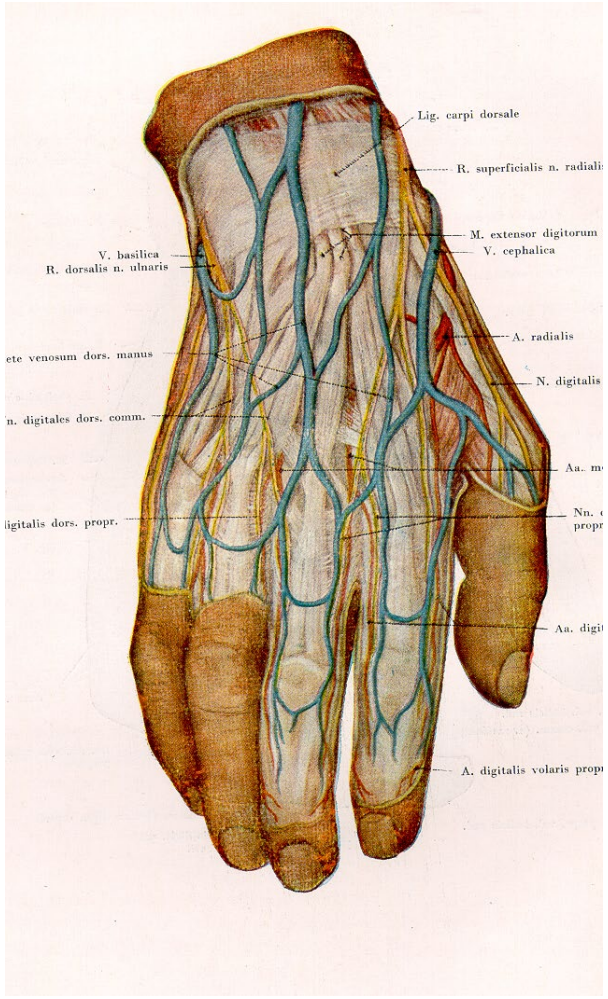
Metabolic heat from exercising muscles gets out of the muscles in the blood and enters the general circulation before being lost to the environment

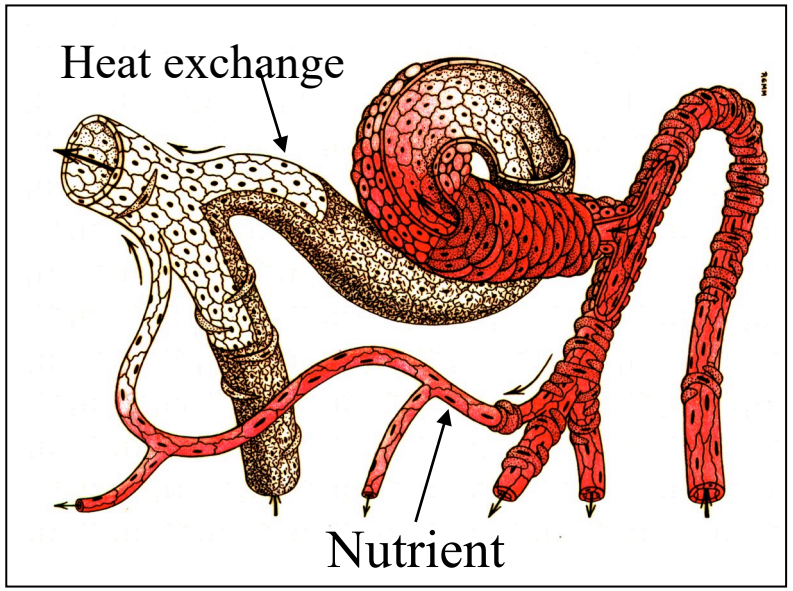


Body heat is lost to the environment over the body surface, but all body surfaces are not equally good for heat exchange.

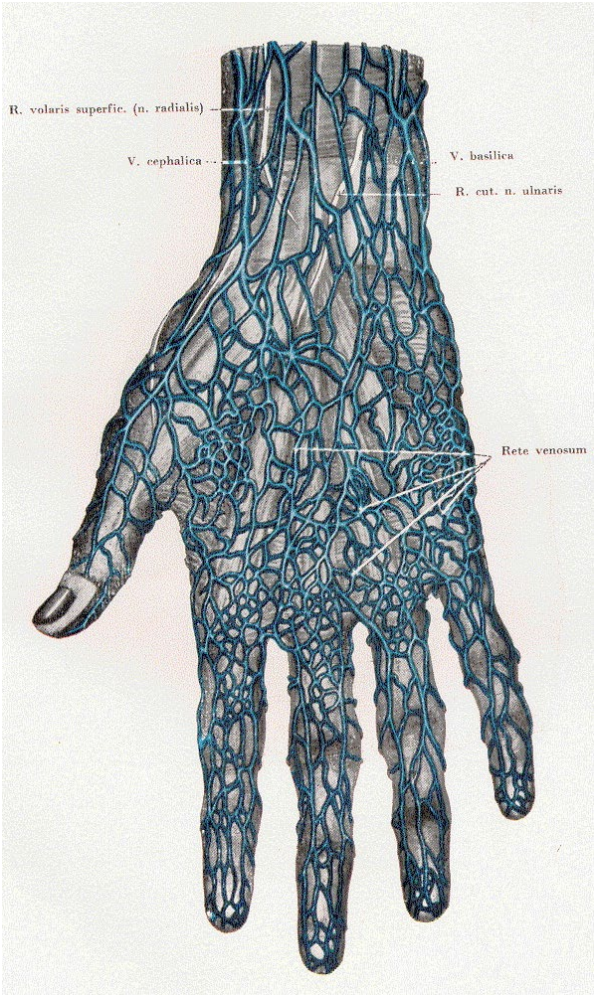
How to extract heat from the body core efficiently?

Cooling of the glabrous skin:

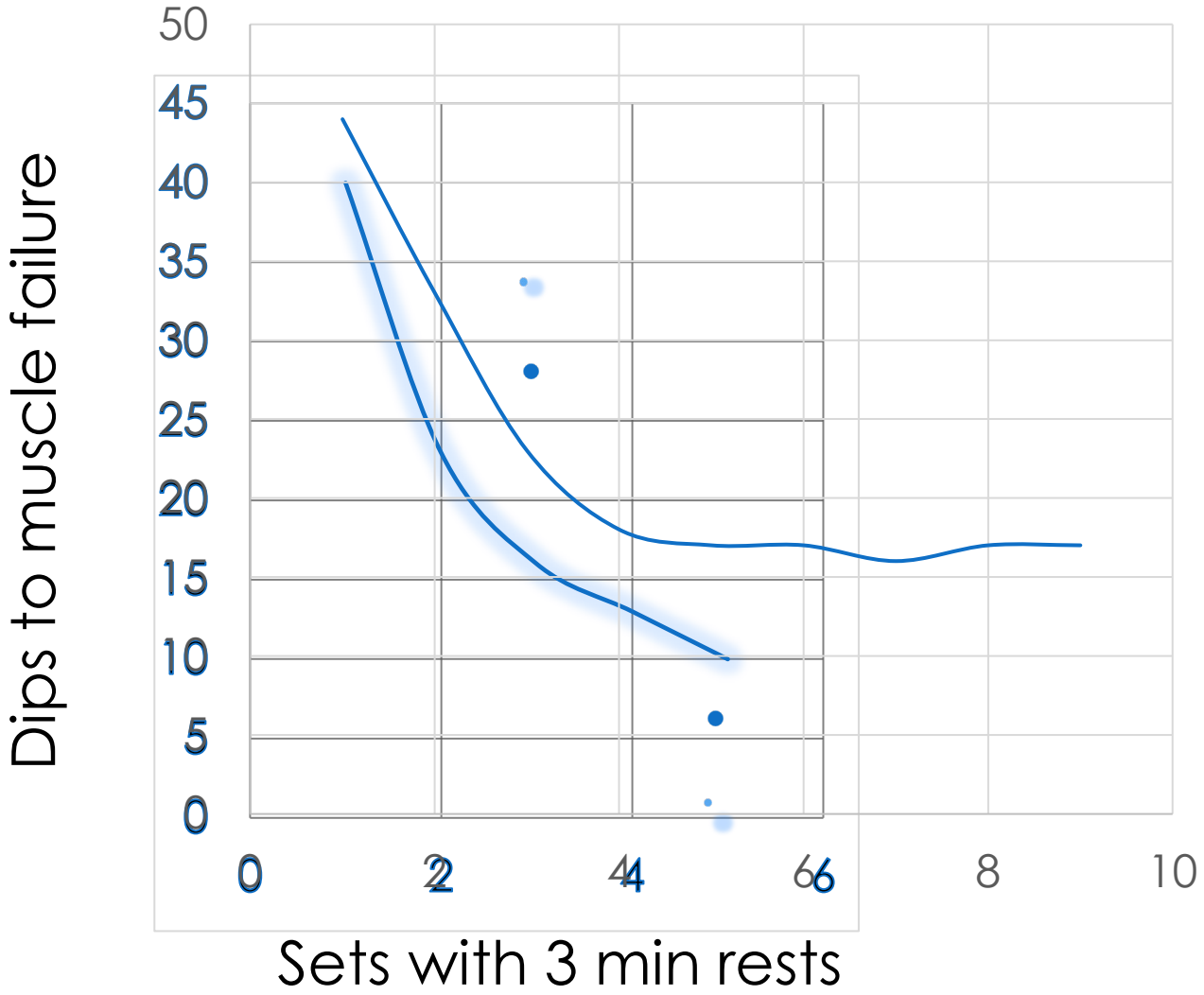




Arteriovenosal anastomoses and retia venosa are mammalian adaptations for heat loss.



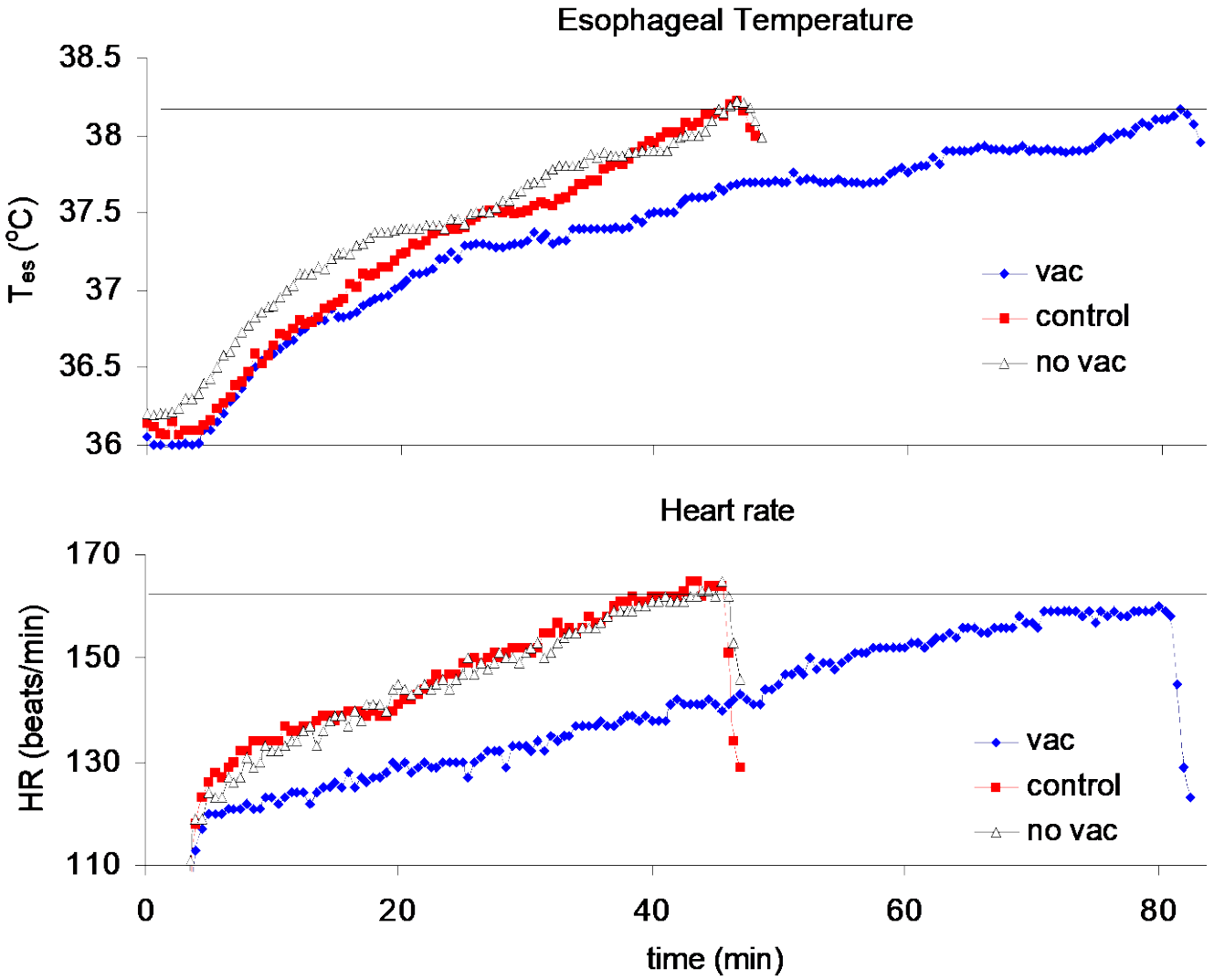
Extracting heat by palmar cooling delays muscle fatigue and increases work volume



4 days later with palmar cooling
"This is not a typical pattern of exhaustion. I was able to produce in my ninth set today what I did in my third set on Saturday"

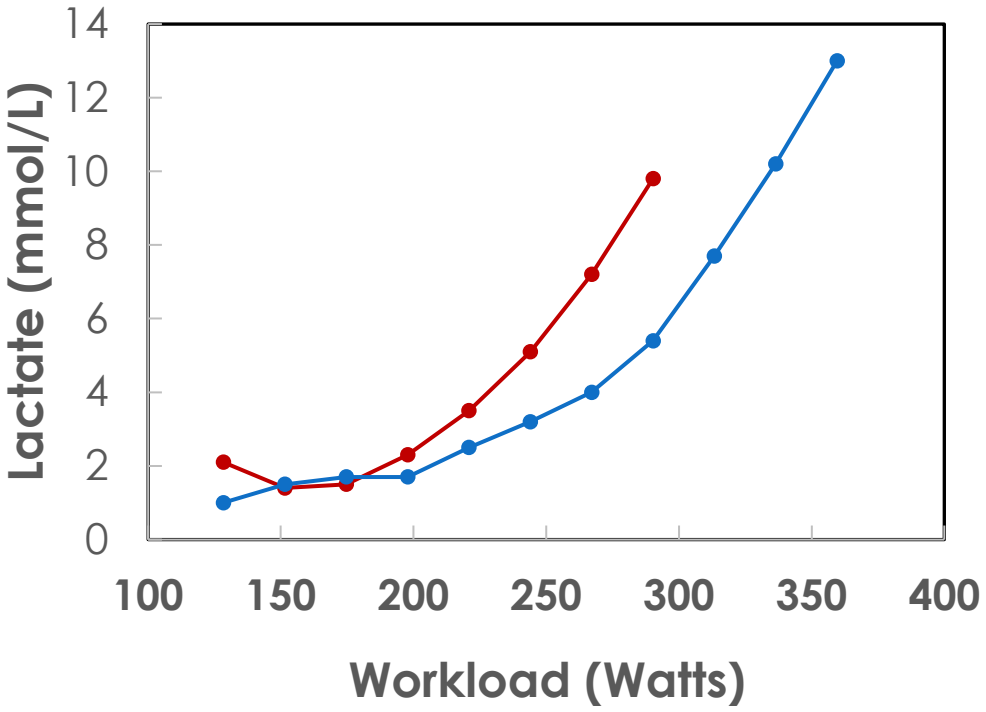
Endurance tests and use of cardiac drift as a marker for fatigue.

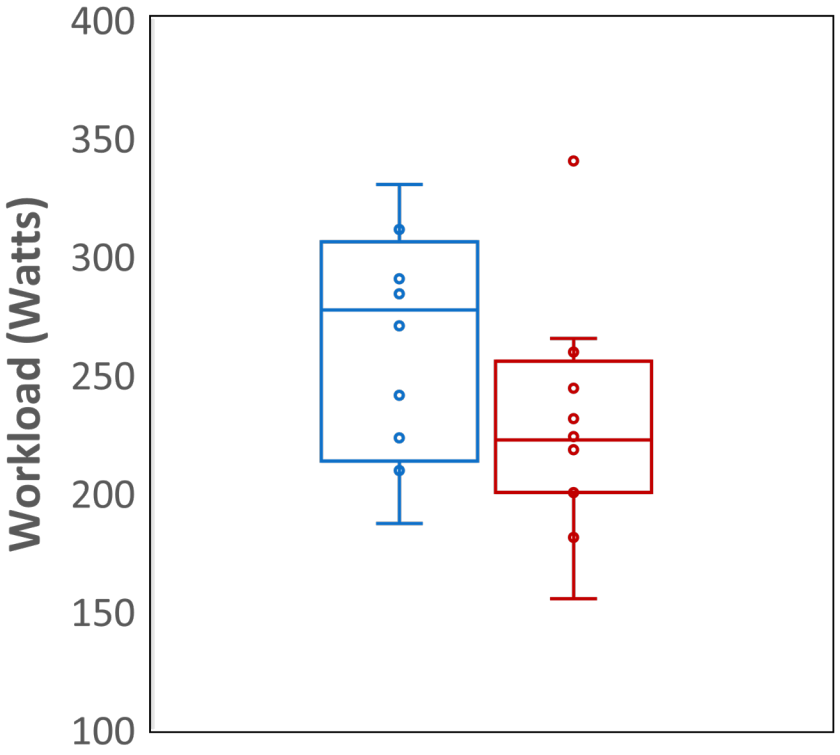
Uphill hike 3.5mph, 39ºC.



How does increased temperature cause muscle fatigue?
Compromise of ATP production signaled by rise in blood lactate.
Lactate threshold is temperature sensitive.

Red – subjects began Bruce test at a core temp. Of 38°C
Blue – subjects began Bruce test at a core temp of 37°C





Heat stress alone does not raise lactate levels,

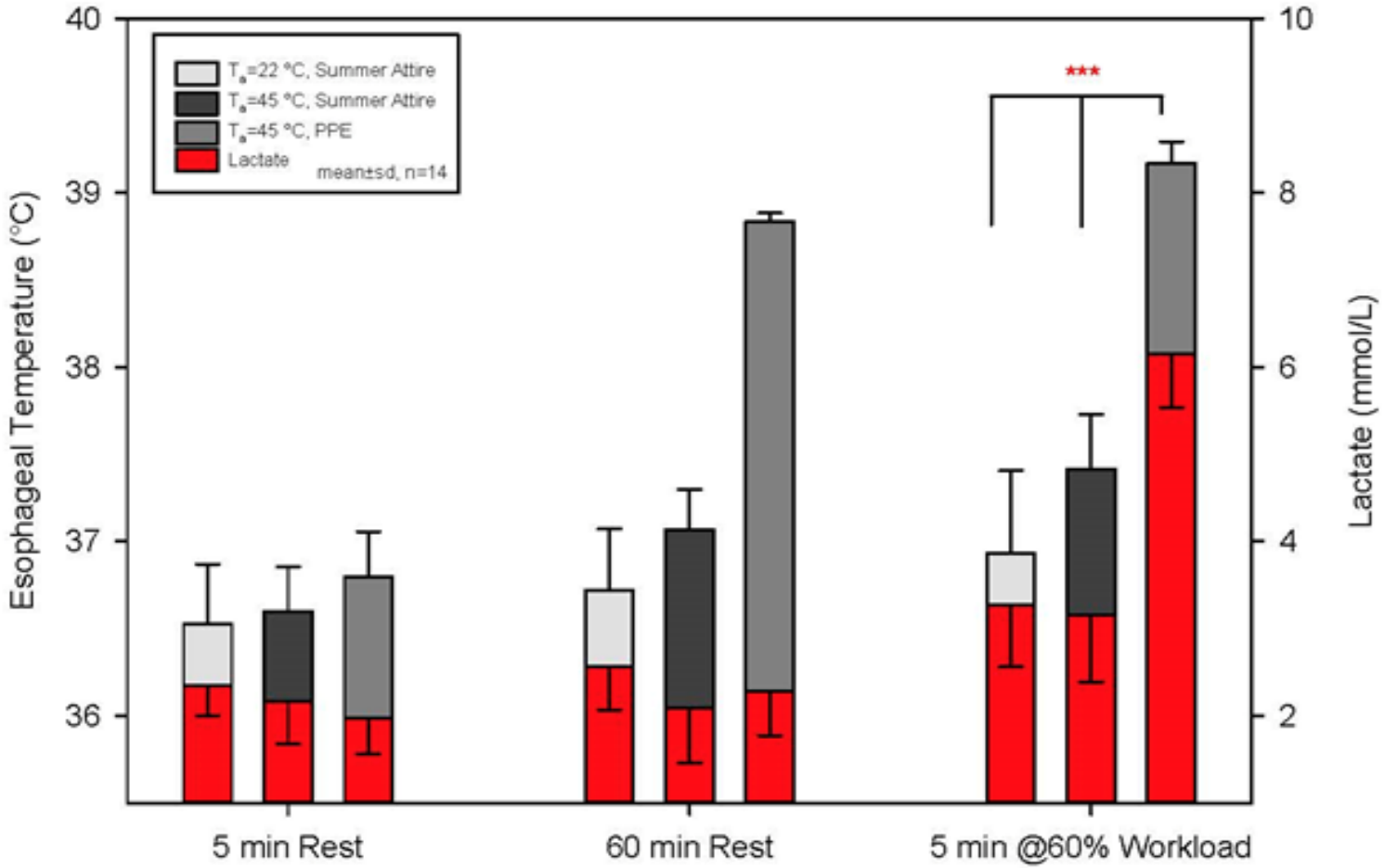
Heat plus work raises lactate levels.

Subjects dressed in exercise attire with or without PPE.

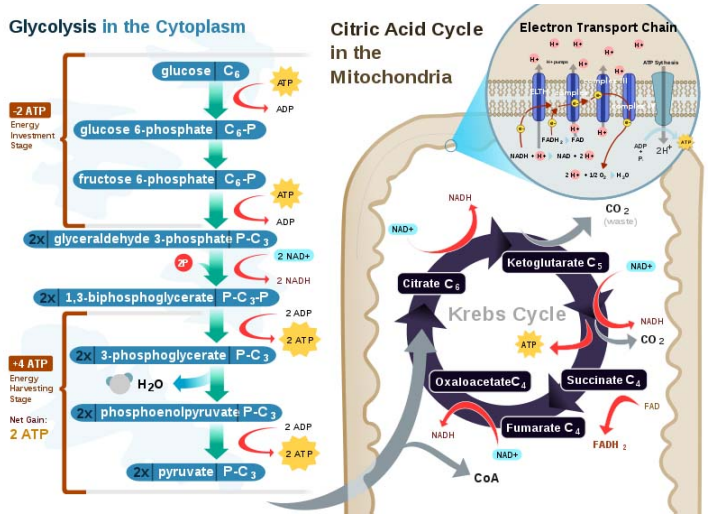
Spend 60 min. at 22°C or 45 °C

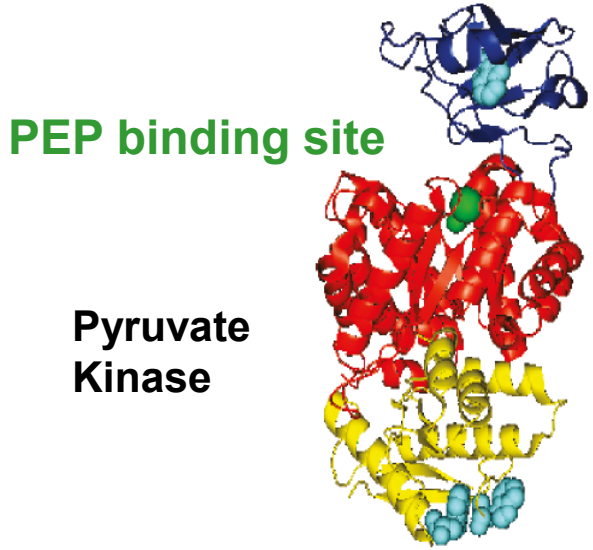
Then exercise at 60% VO2max for 5 min.

Lactate rise seen after exercise challenge to overheated muscles.

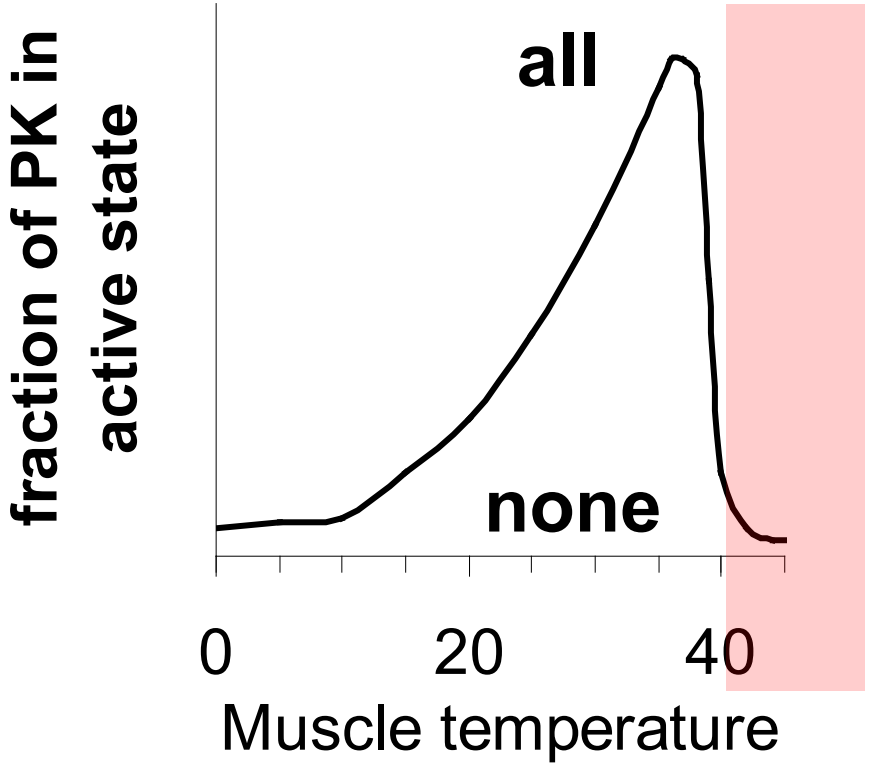


How does heat compromise energy metabolism?





Pyruvate Kinase is temperature sensitive.



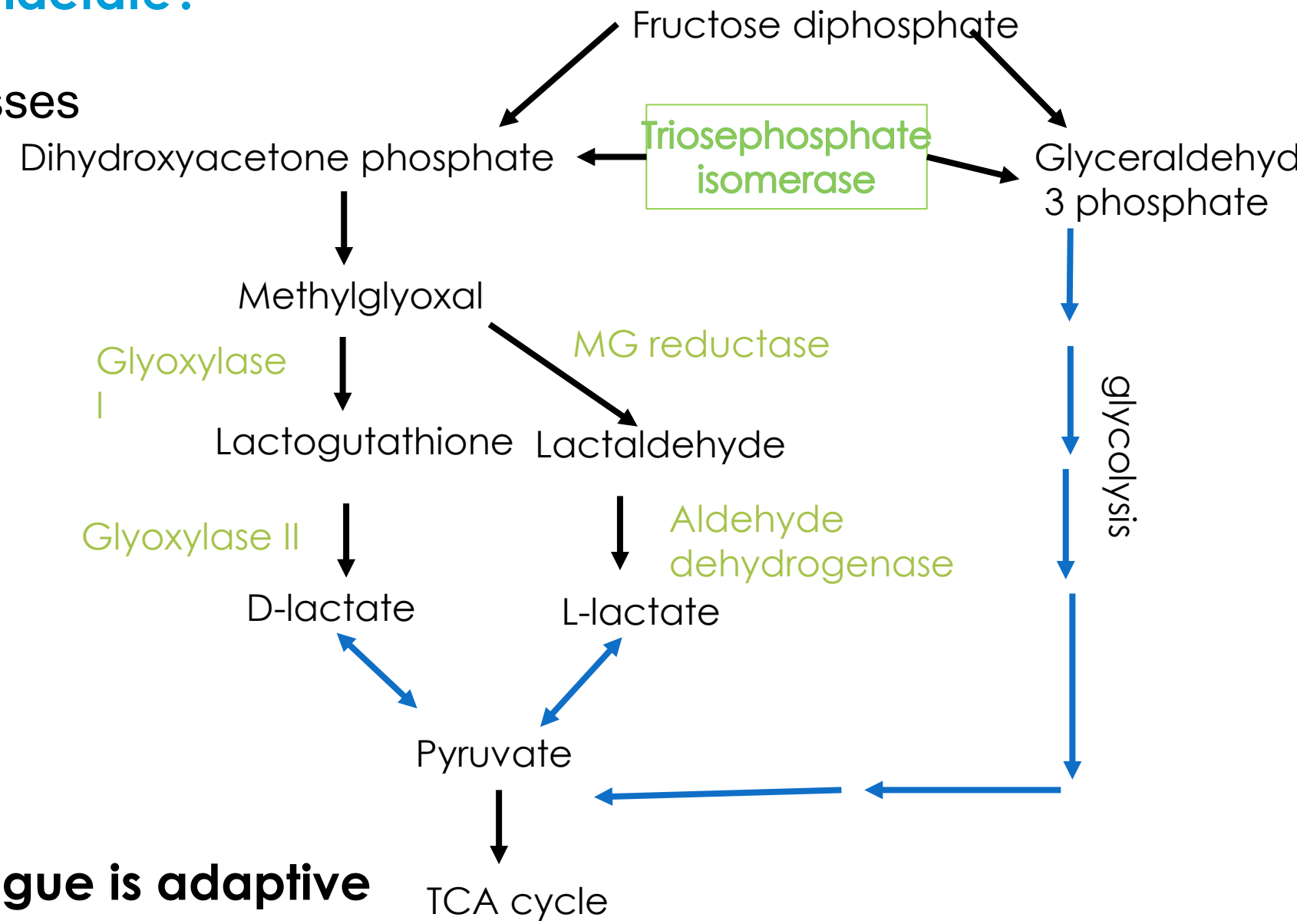
Biochemical auto-protection to prevent thermal self-destruction!!

Herman and Lee (2009) Biochemistry 48:9466-9470

If heat interferes with production of pyruvate, How can it cause a rise in lactate?

Methylglyoxal shunt bypasses glycolysis resulting in production of lactate

Suggestion: When looking for causes/mechanisms of fatigue associated with disease conditions, consider possible deficits in energy metabolism resulting in compromises of ability of cells to do work.



Keep in mind – normal fatigue is adaptive