

The Physiology of Fatigue

Can Fatigue be Measured?

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Animal Health Trust*

What is Fatigue?

- Temporary loss of strength and energy resulting from hard physical or mental work; "growing fatigue was apparent from the decline in the execution of their athletic skills"
- Feeling of tiredness or weariness usually associated with performance decrement

What is Fatigue?

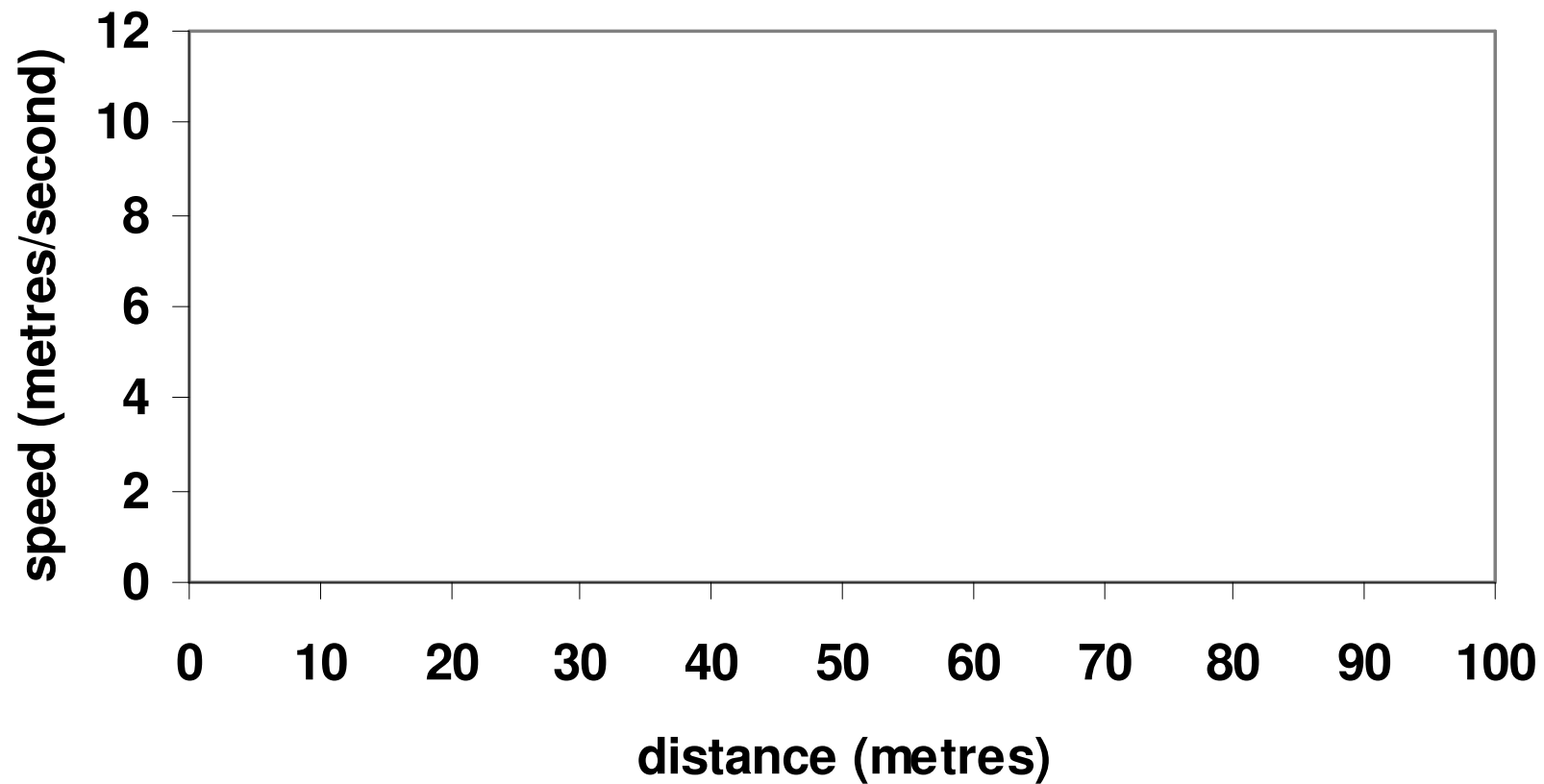
- A feeling of tiredness or weariness resulting in a decreased capacity for physical and mental work
- A condition that results when the body cannot provide enough energy for the muscles to perform a task
- Physical weariness resulting from exertion

What is Fatigue?



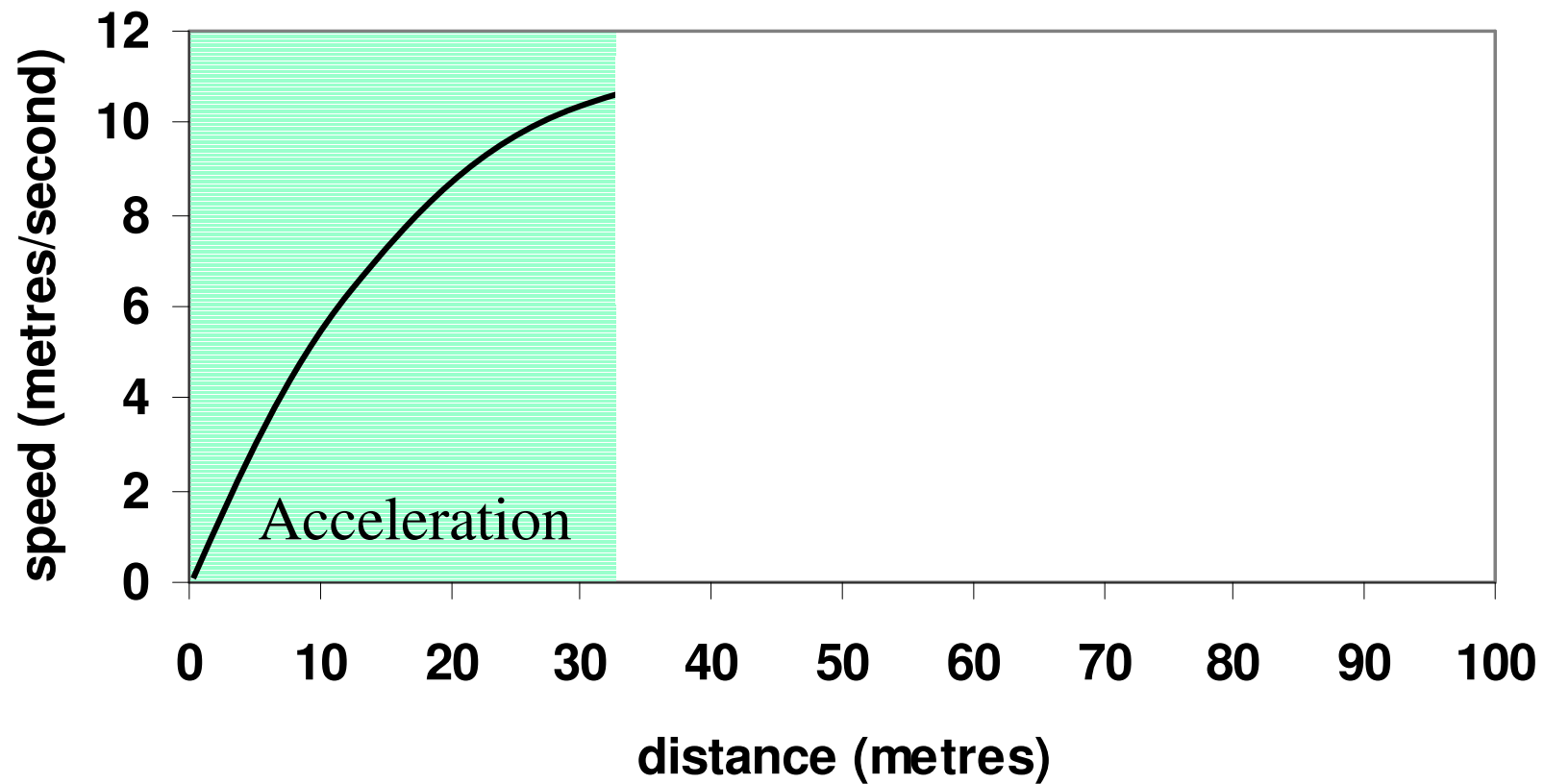
What is Fatigue?

100 metres sprint



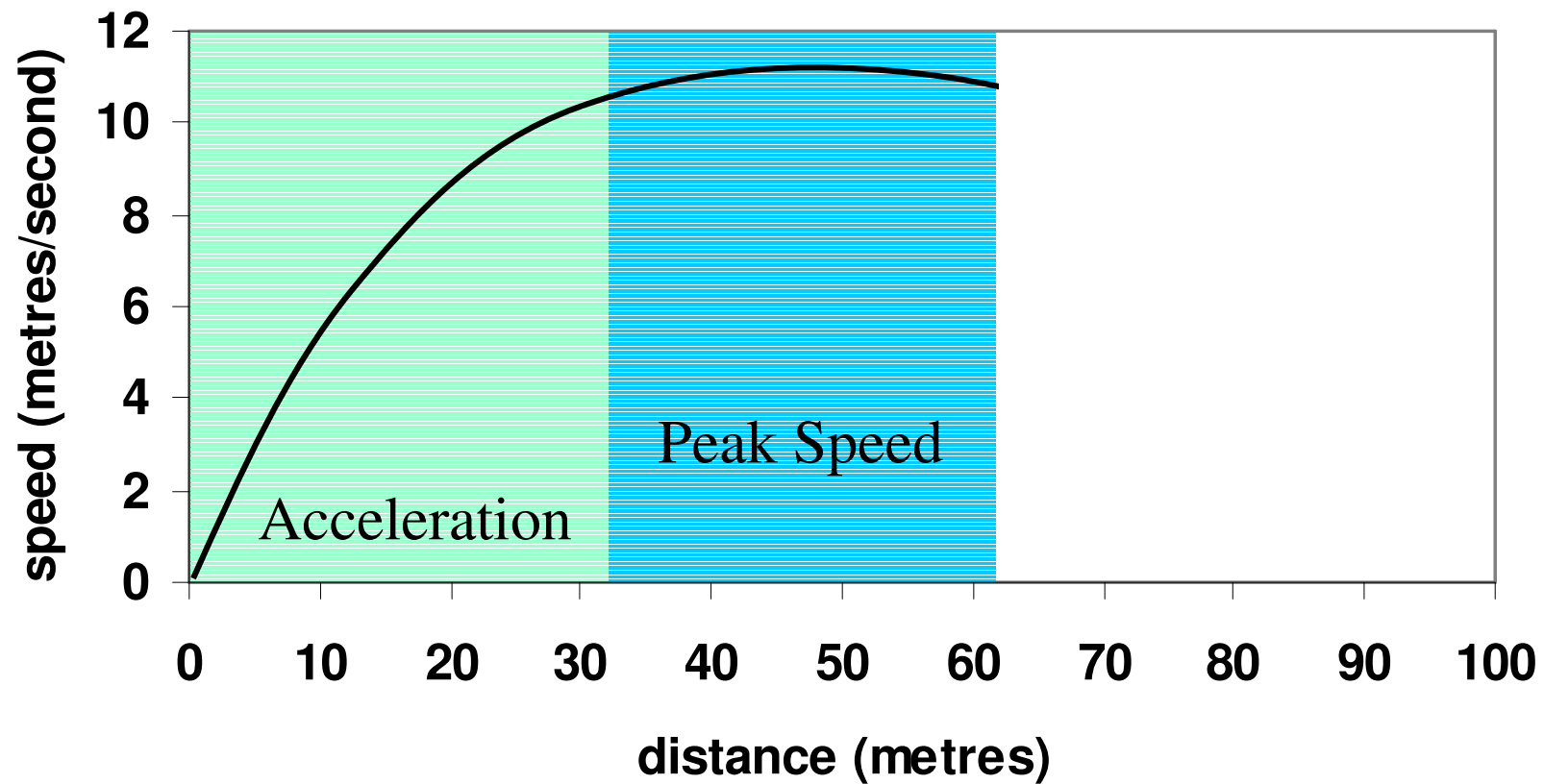
What is Fatigue?

100 metres sprint



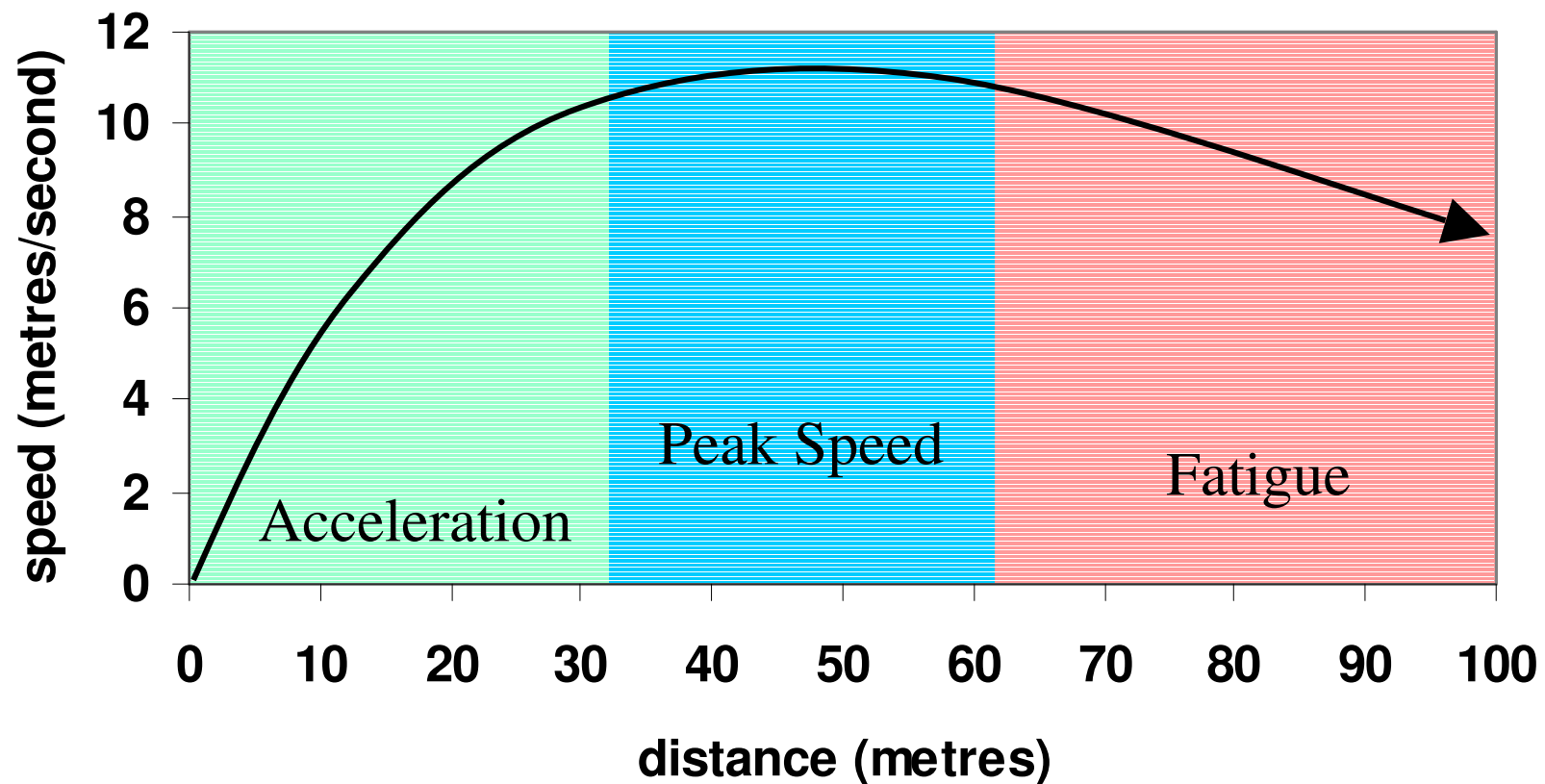
What is Fatigue?

100 metres sprint



What is Fatigue?

100 metres sprint

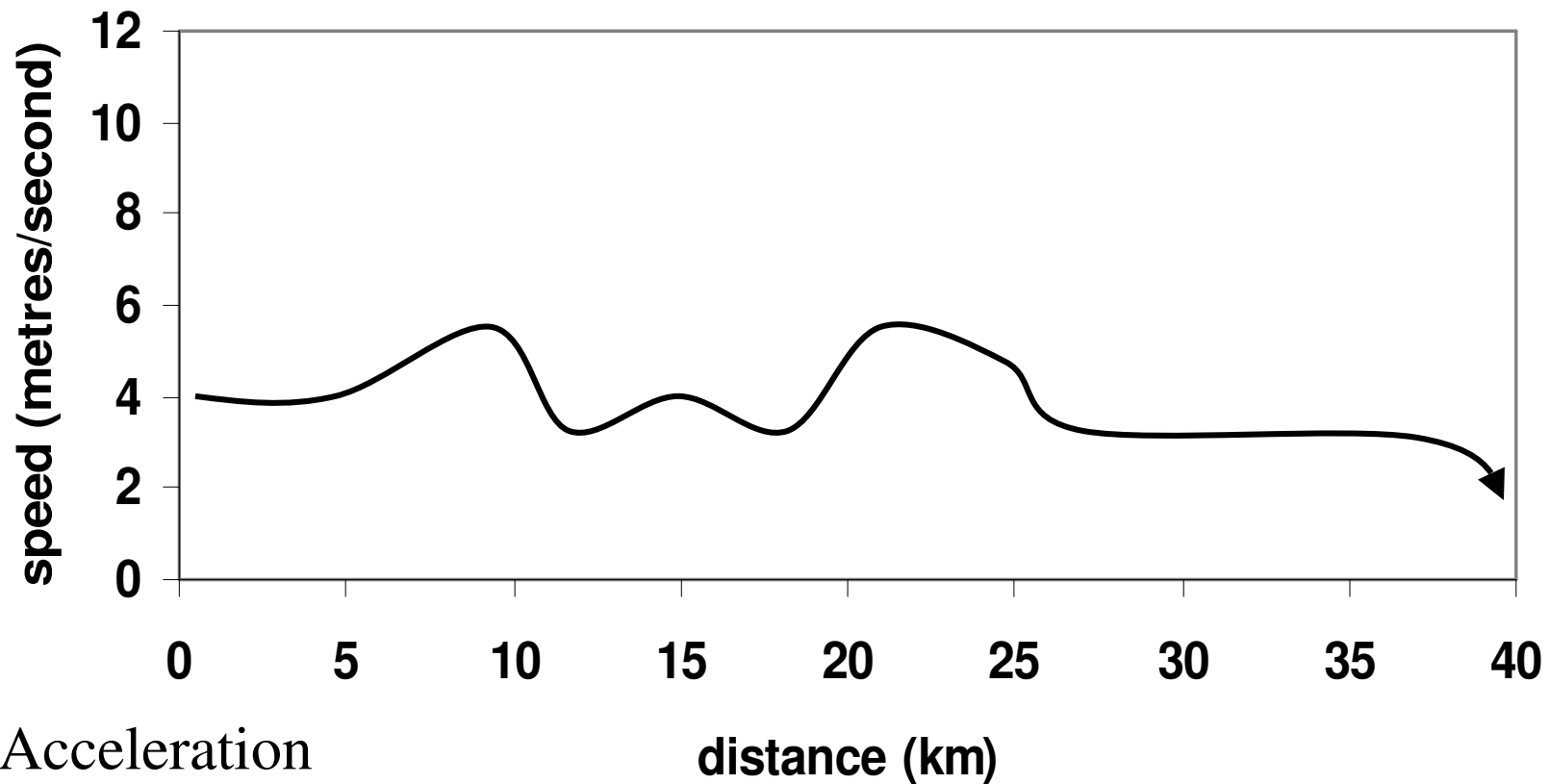


What is Fatigue?



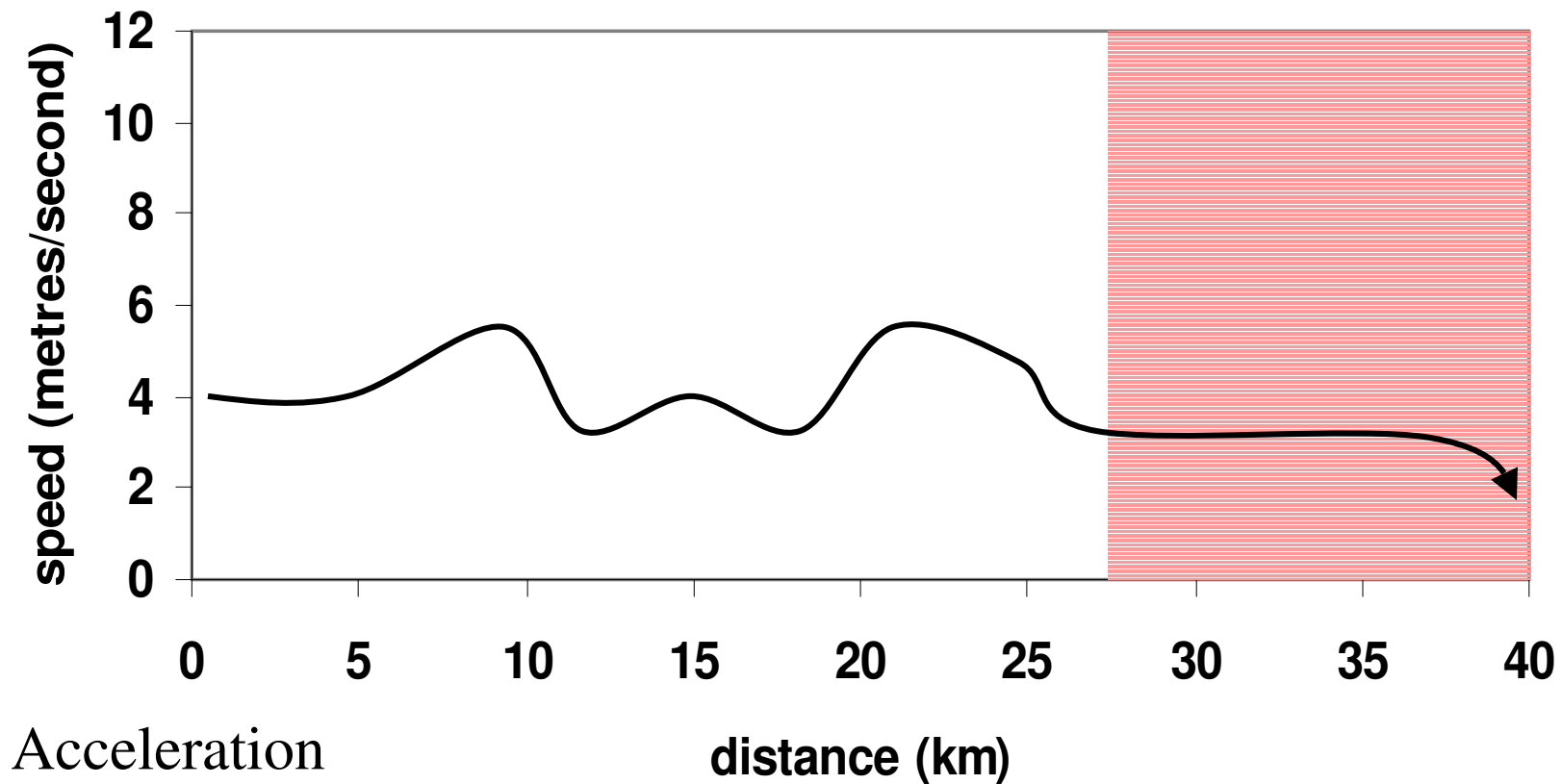
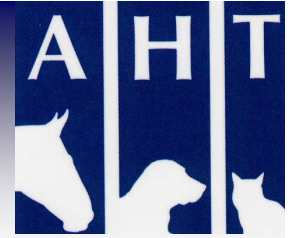
What is Fatigue?

The Marathon



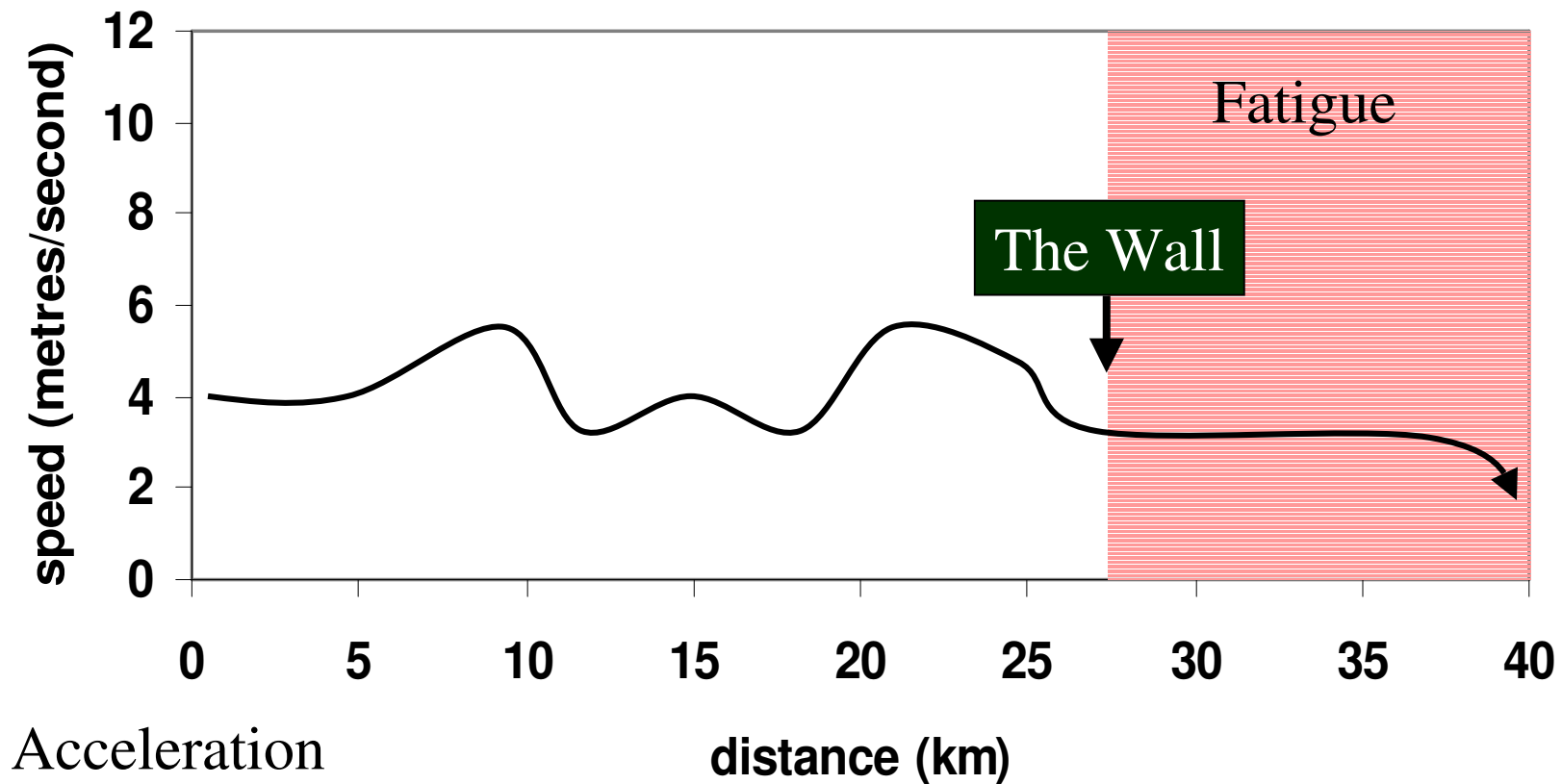
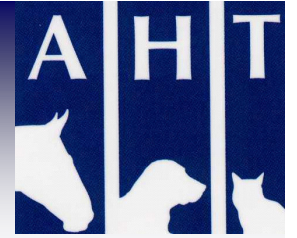
What is Fatigue?

The Marathon



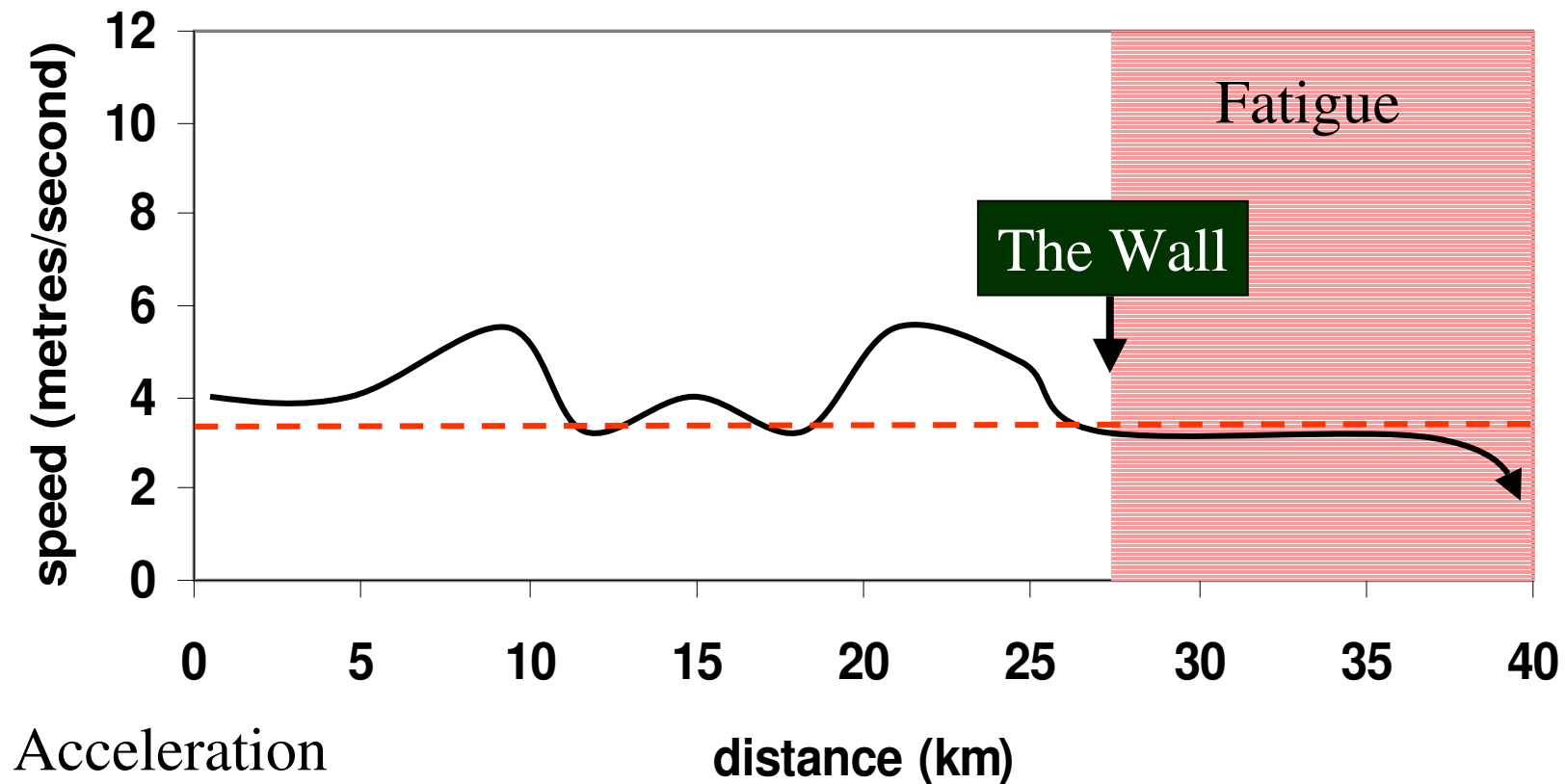
What is Fatigue?

The Marathon



What is Fatigue?

The Marathon



When does Fatigue become Exhaustion?



Los Angeles Olympics
The Women's Marathon
5 August 1984
Gabrielle Andersen-Scheiss
Switzerland

When does Fatigue become Exhaustion?



Twenty minutes after the winner crossed the finish line, Andersen-Scheiss (39) staggered into the stadium, suffering from heat prostration. Her right leg was stiff and her left arm was hanging limply by her side.

While spectators gasped in horror, doctors noted that she was perspiring and they let her continue. For 5 min and 44 s, she lurched along the final lap around the track, occasionally stopping and holding her head.

Finally she fell across the finish line and into the arms of waiting medics. Andersen-Scheiss finished 37th.

Remarkably, she recovered rapidly and was released by medical personnel only two hours later.

When does Fatigue become Exhaustion?



Valya Tsybulskaya, exhausted after completing the 10km walk

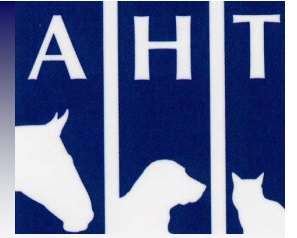
When does Fatigue become Exhaustion?



When does Fatigue become Exhaustion?



When does Fatigue become Exhaustion?



Wednesday



Saturday

Fatigue *versus* Exhaustion

FATIGUE

- Able to restart exercise after a short rest
- Physiologically normal
- Risk of pathology low

EXHAUSTION

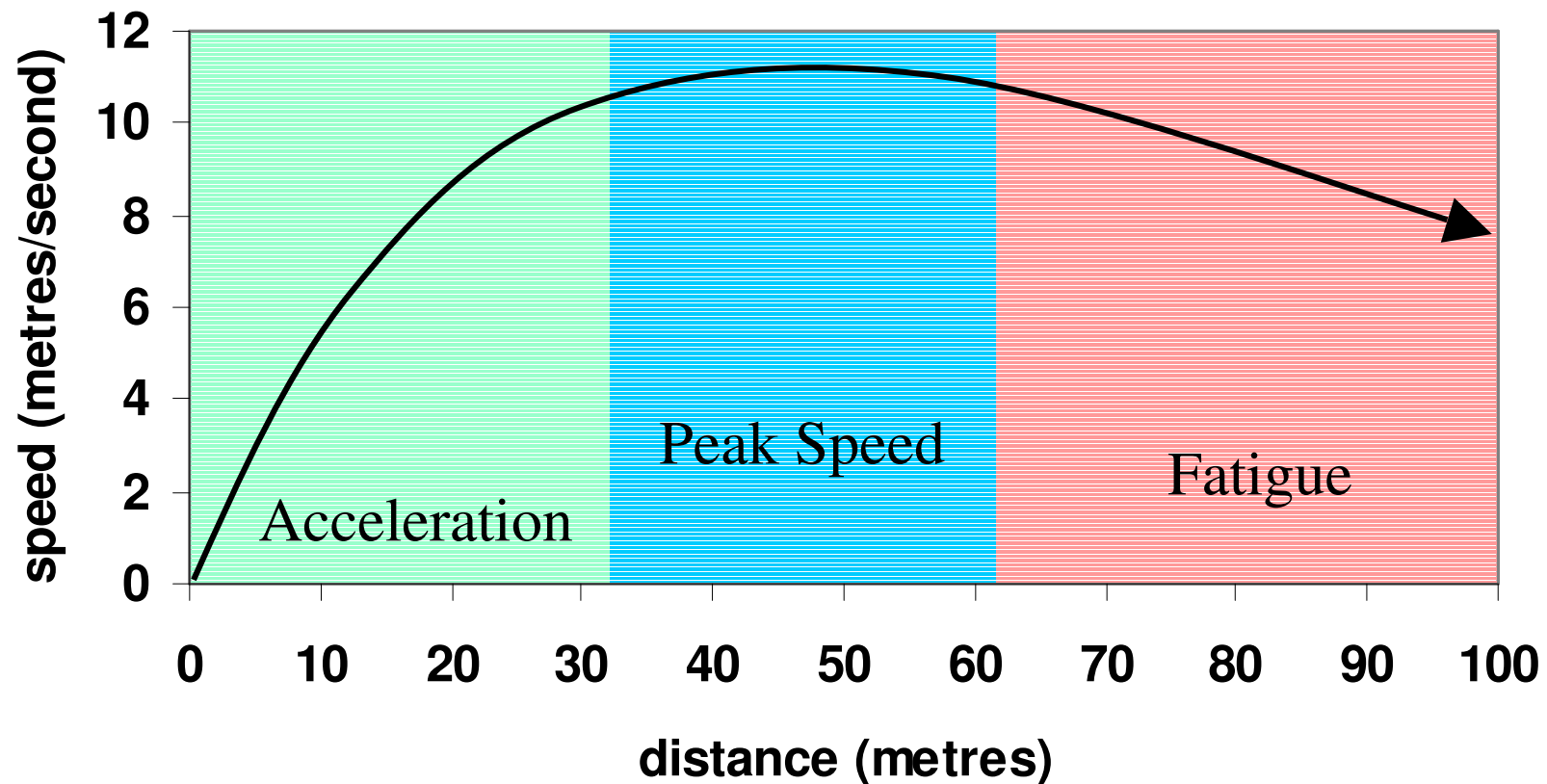
- Not able to continue to exercise
- Physiological extremes
- Pathological changes

Definitions of Exhaustion

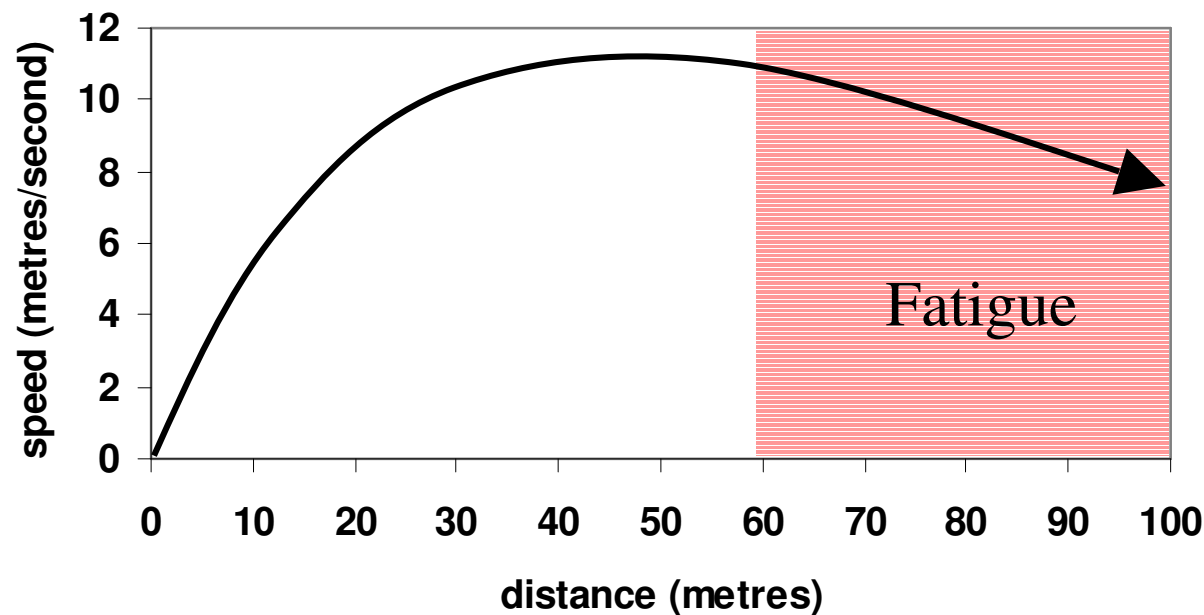
- Extreme fatigue
- Serious weakening and loss of energy
- The act of exhausting something entirely
- See *Fatigue*
- The depletion of energy stores resulting in muscle fatigue to the point where physical activity cannot be performed

What is Fatigue?

100 metres sprint



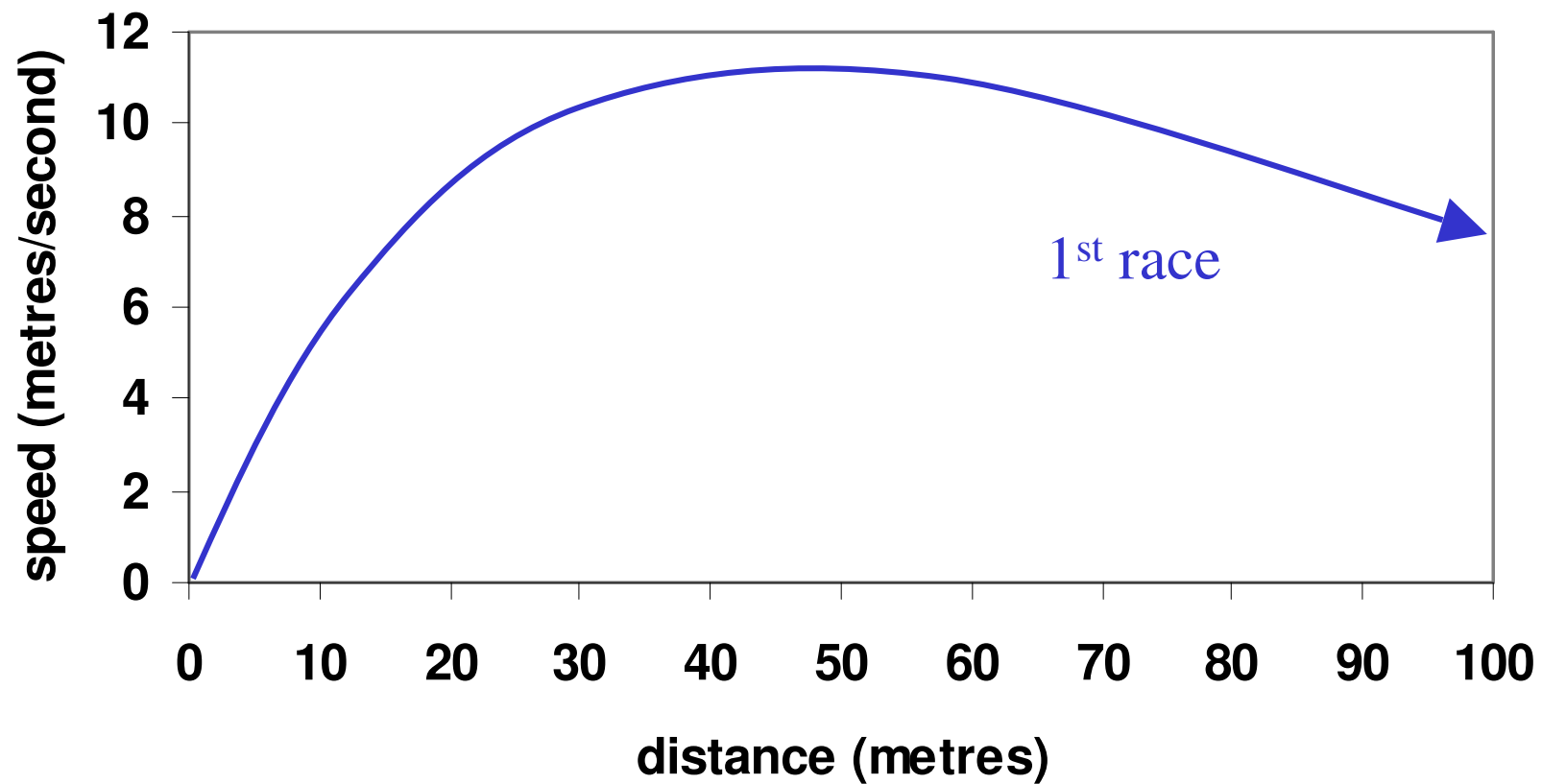
What is Fatigue?



Fatigue refers to the inability to continue exercise at a given intensity

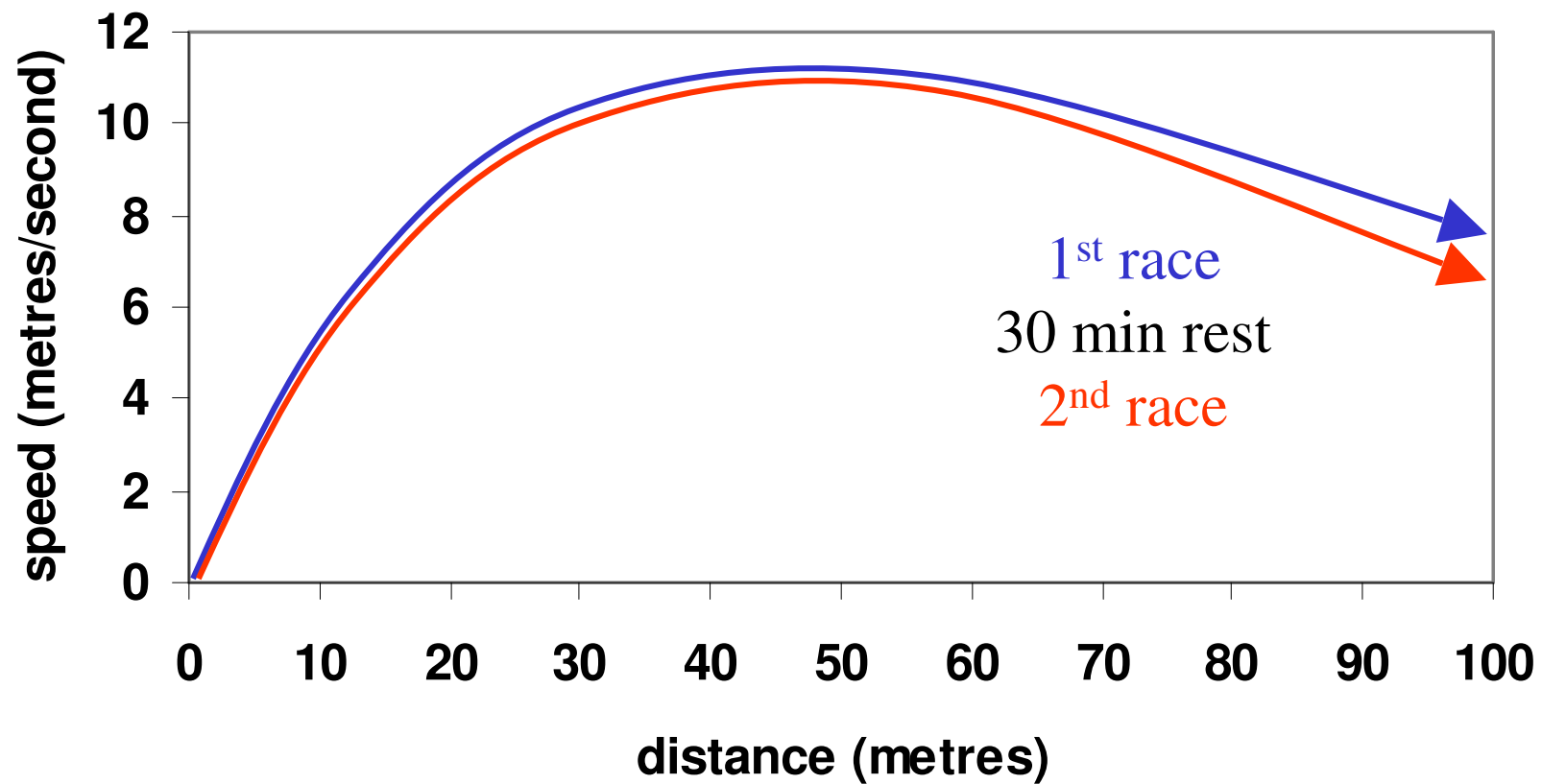
Fatigue

100 metres sprint



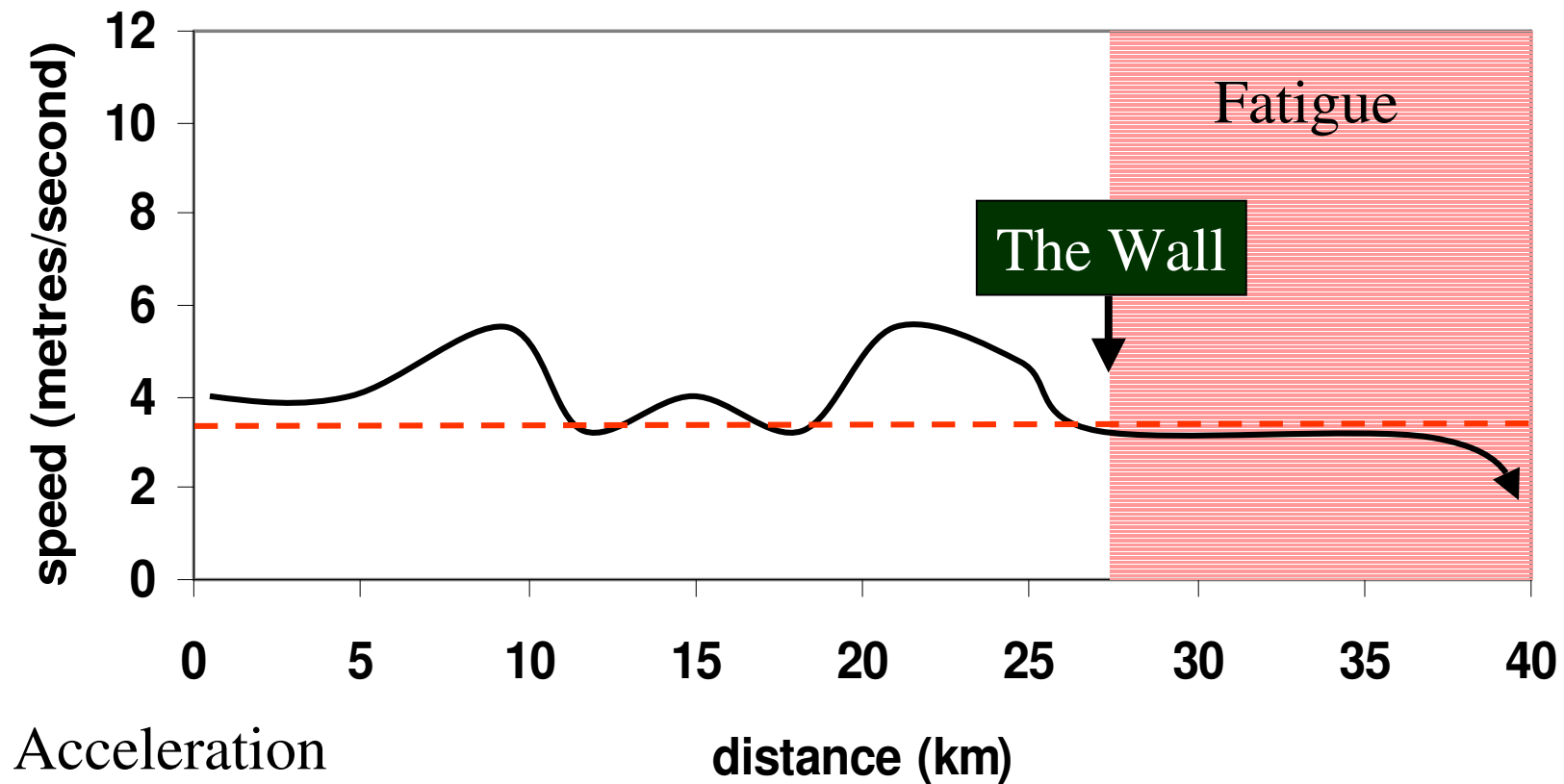
Fatigue

100 metres sprint



What is Fatigue?

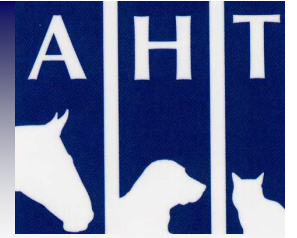
The Marathon





Development of Fatigue & Exhaustion



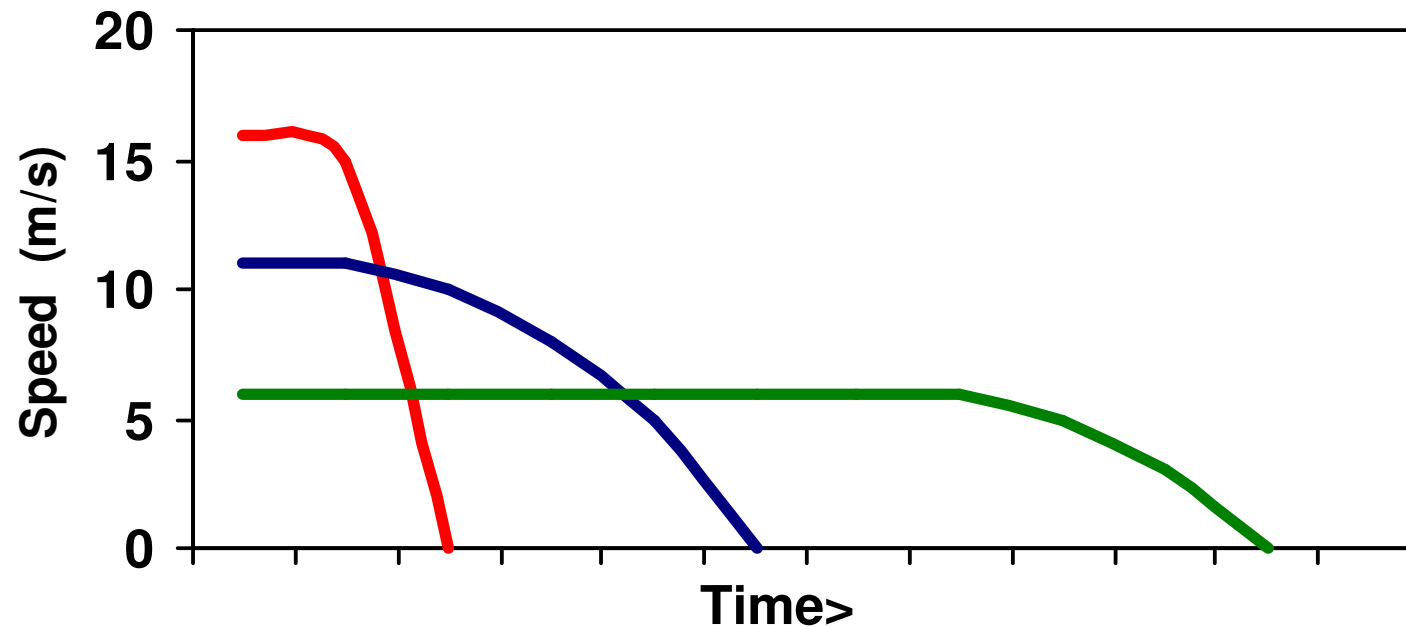


Development of Fatigue & Exhaustion

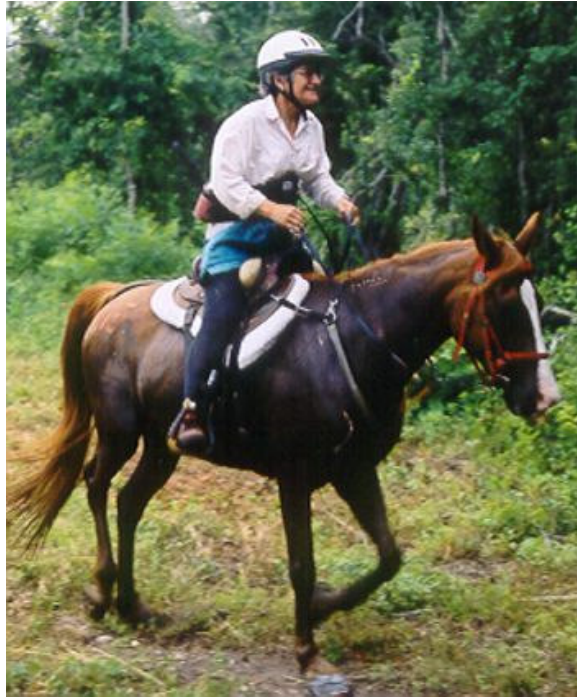


Fatigue & Intensity

The higher the intensity, the earlier the onset of fatigue



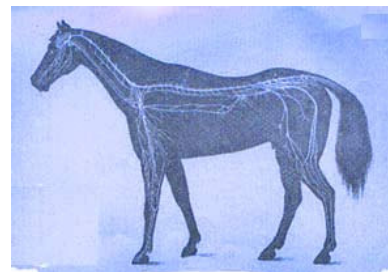
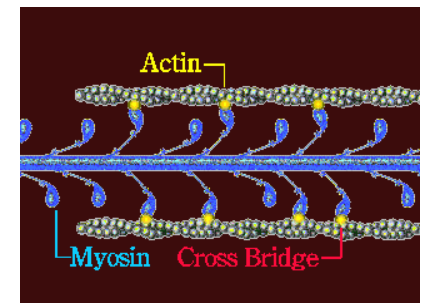
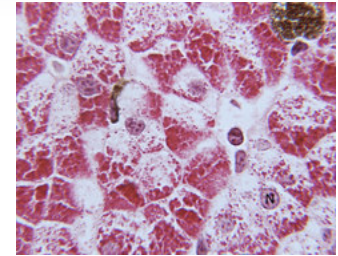
Fatigue



Same effect, different mechanisms

Causes of Fatigue

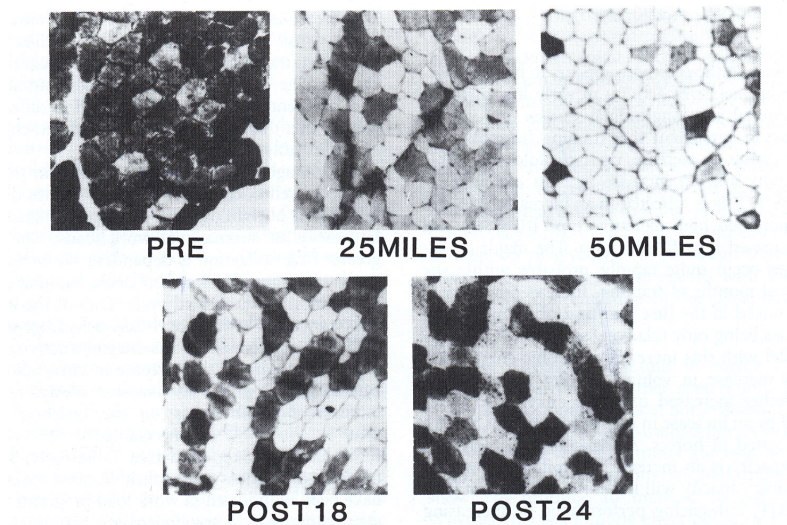
1. Fatigue of energy generating systems within and external to muscle
2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism
3. Disturbances to homeostasis
4. Central or peripheral nervous system dysfunction



Causes of Fatigue

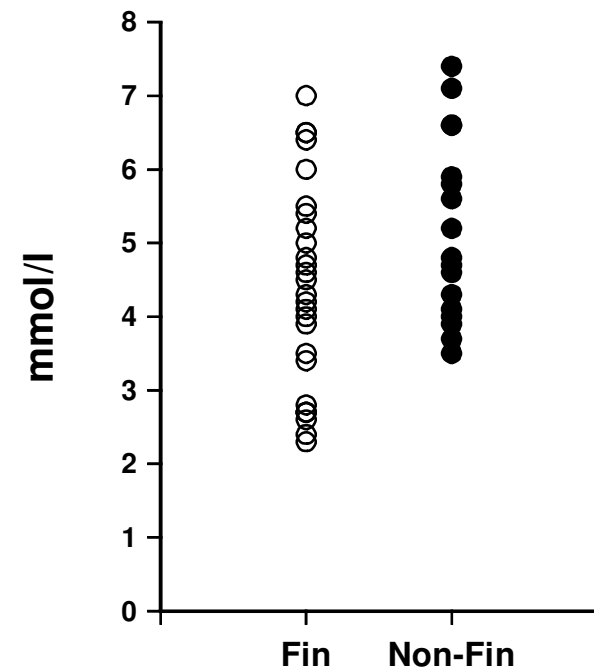
1. Fatigue of energy generating systems within and external to muscle

- Muscle glycogen depletion
- Liver glycogen depletion



Snow *et al.* (1981)

Plasma glucose at the end of a 140km race ride



Marlin *et al.* (2002)

Causes of Fatigue

1. Fatigue of energy generating systems within and external to muscle
 - Muscle glycogen depletion
 - Liver glycogen depletion
 - Depletion of fat stores



Causes of Fatigue

2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism
 - Lactic acid accumulation
 - Phosphocreatine depletion and phosphate accumulation
 - Hypoxia/impaired of oxygen delivery

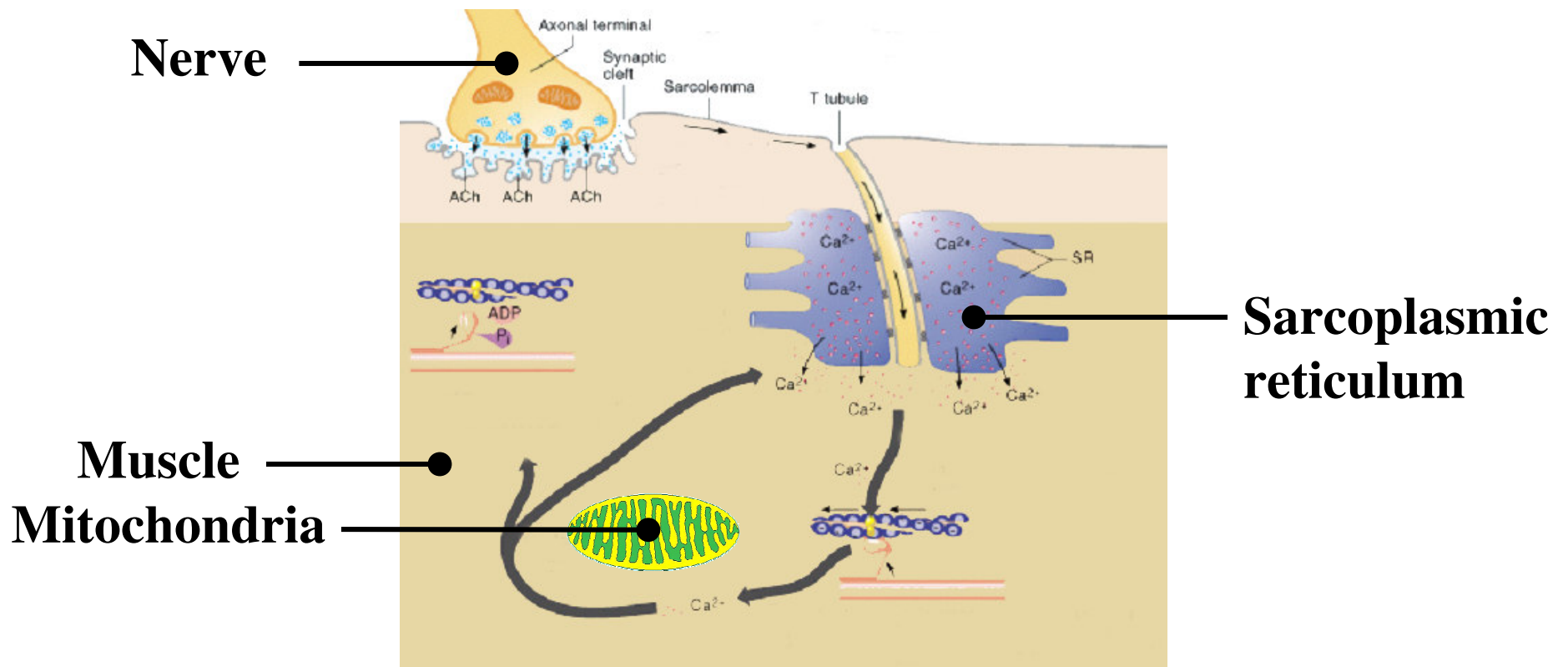


Causes of Fatigue

2. Accumulation of metabolic by-products & failure of the muscular contractile mechanism
 - Lactic acid accumulation
 - Phosphocreatine depletion and phosphate accumulation
 - Hypoxia/impaired of oxygen delivery
 - Disturbance to calcium metabolism

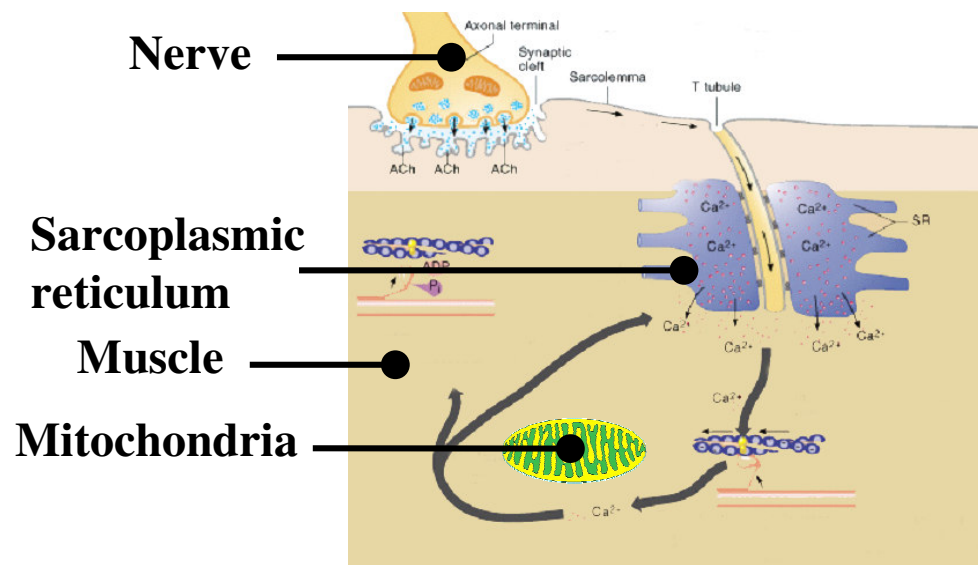
Causes of Fatigue

Disturbance to calcium metabolism



Causes of Fatigue

Disturbance to calcium metabolism



- Mitochondrial dysfunction due to Ca^{++} uptake
- Reduction in Ca^{++} release from SR
- Both mechanisms thought to be important in development of fatigue during prolonged exercise

Causes of Fatigue

3. Disturbances to homeostasis

- Electrolyte concentrations and their compartmentalisation
- Concentrations of glucose in blood, muscle and other tissues (e.g. brain)
- Muscle and systemic pH and osmolality
- Temperature (especially muscle and brain)
- Concentrations of FFA
- Blood and plasma volume
- Hormone concentrations



Causes of Fatigue

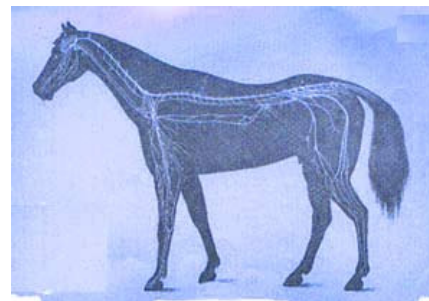
4. Central or peripheral fatigue

Negative inputs

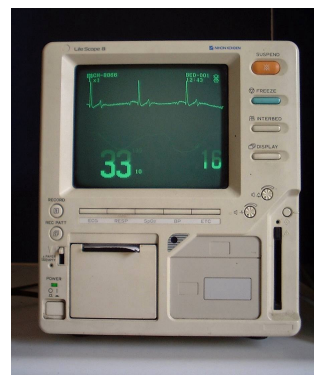
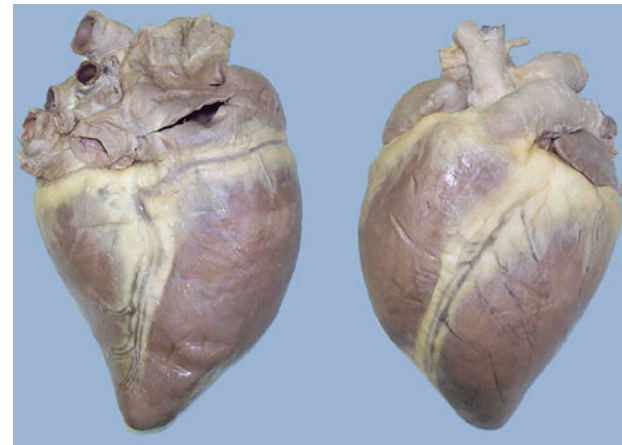
- Pain (e.g. muscles, joints)
- Sensations of breathlessness
- “Fatigue”
- Low brain glucose

Positive inputs

- External stimulation
 - Crowd
 - Riders voice
 - Whip
 - Other horses



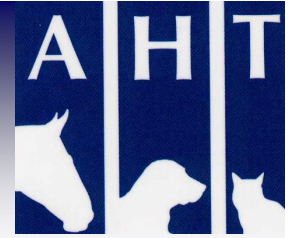
Cardiac Causes of Fatigue?



What factors affect the time to onset of fatigue?

- Intensity, duration and pattern of exercise
- Fitness
- Age
- Body Condition
- Environmental conditions
 - Heat, heat & humidity or cold
 - Altitude
 - Pollution





What is fatigue in an endurance horse?

- The horse that stops eating & drinking?
- The horse that will not canter?
- The horse that is reluctant to trot?
- The horse that will not walk?

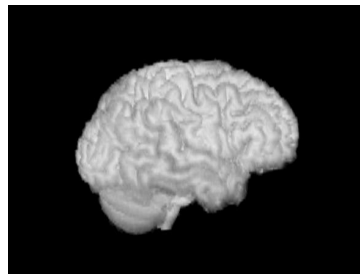
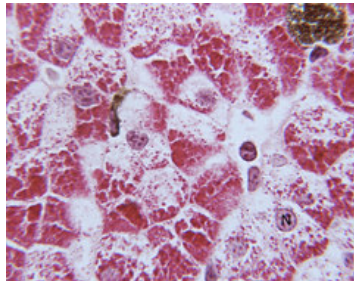
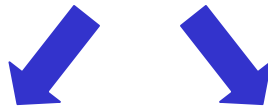
Indicators of fatigue

- Ataxia, stumbling, unwillingness to exercise
 - Pain
 - Weakness
 - Hyperthermia
 - Low blood glucose
 - Hypovolaemia
 - Low BP
 - Nerve dysfunction

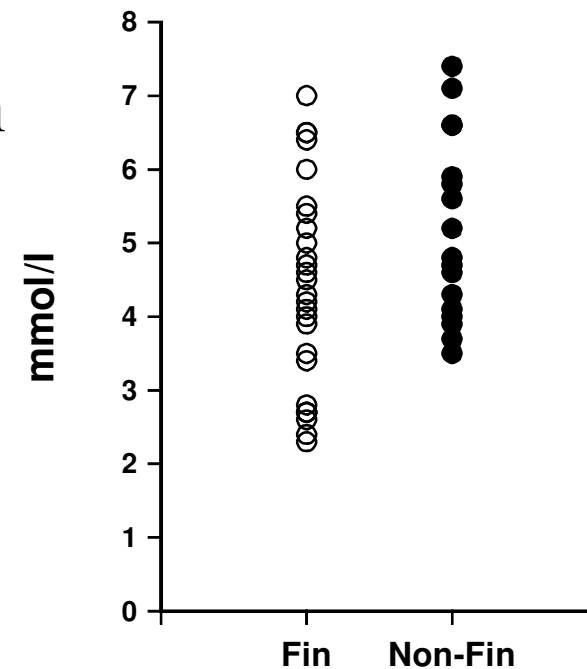


Indicators of fatigue

- Hypoglycaemia
 - Muscle glycogen depletion
 - Liver glycogen depletion



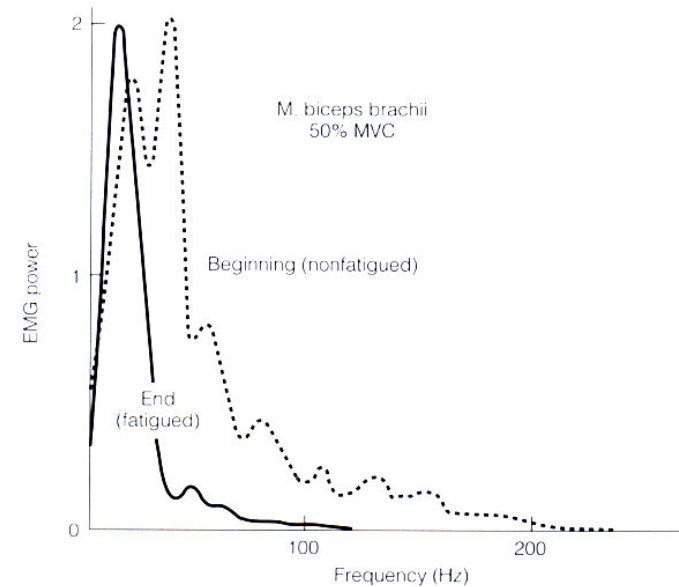
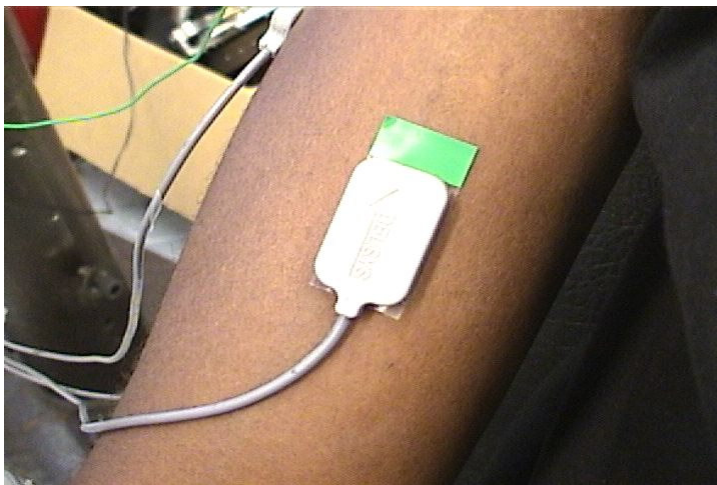
Plasma glucose at the end of a 140km race ride



Marlin *et al.* (2002)

Indicators of fatigue

- Changes in muscle EMG output

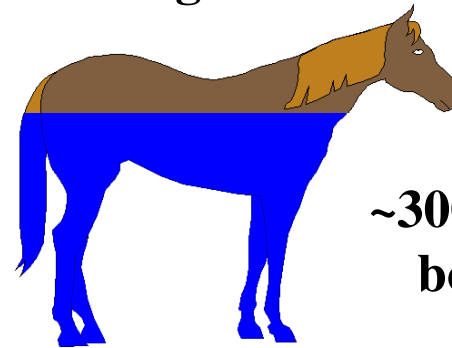


Naeije & Zorn (1982)

Indicators of fatigue

- Dehydration
 - Hypovolaemia
 - Electrolyte loss
 - Acid-base disturbance

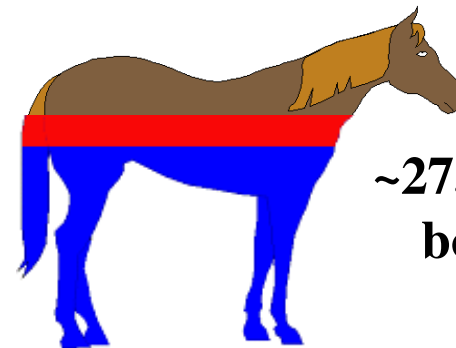
500kg horse



~300 litres total
body water



5% dehydration

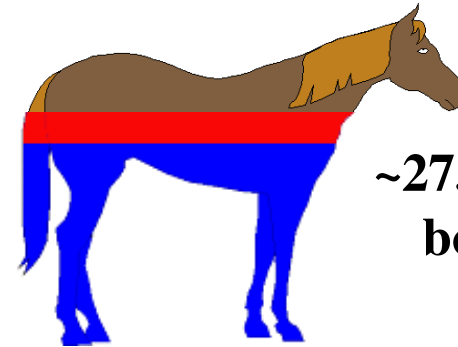


~275 litres total
body water

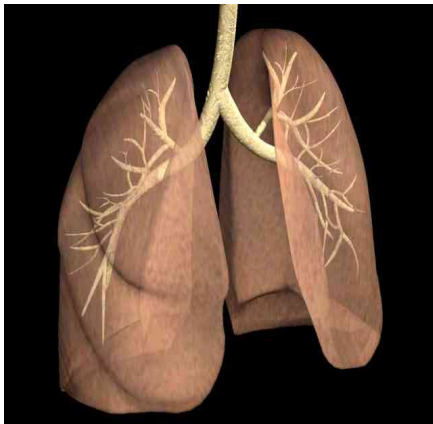
Indicators of fatigue

- Dehydration

5% dehydration



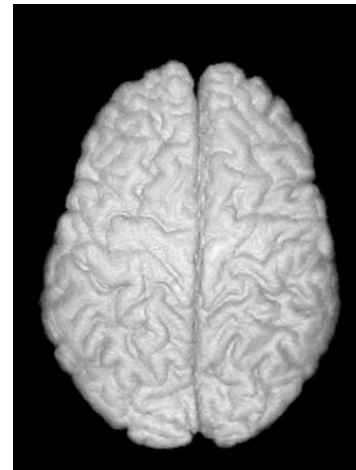
~275 litres total
body water



Lungs ~90%>



Blood~80%>



Brain ~70%>

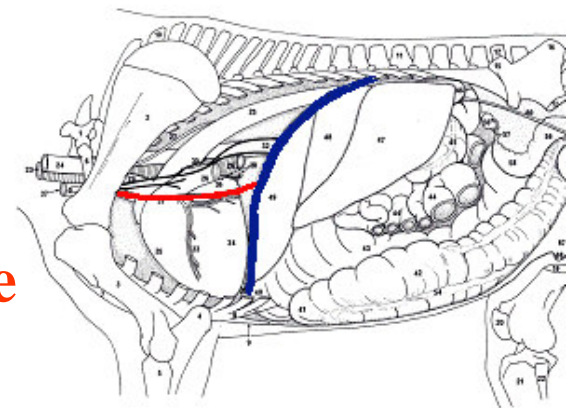


Bone

Indicators of fatigue

- Synchronous diaphragmatic flutter (SDF)
“Thumps”
 - Indicative of moderate to marked:
 - Dehydration
 - Electrolyte disturbance
 - Acid-base disturbance
 - Failure to maintain homeostasis

Phrenic nerve



Diaphragm

Indicators of fatigue

- Changes in the ECG
 - May be indicative of electrolyte and acid-base disturbance
 - Little or no published data on changes in equine ECG following endurance exercise



Indicators of fatigue

Worsening Clinical Picture

