Strategies to improve cattle performance during heat stress

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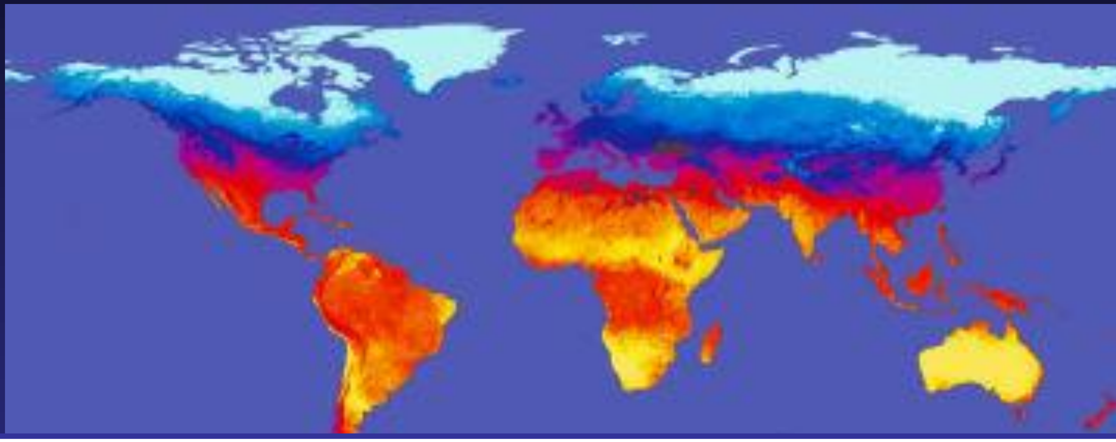
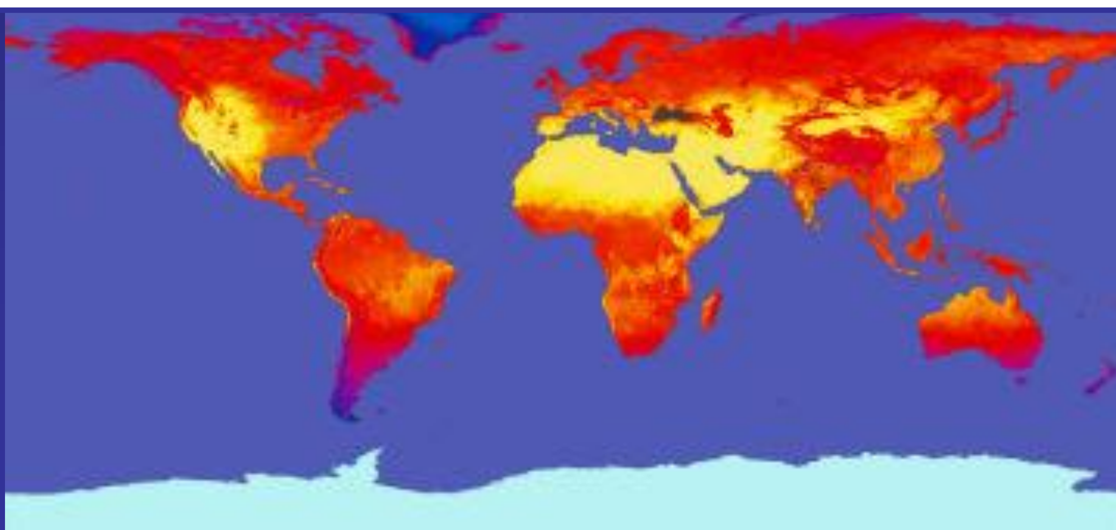
Heat Stress is a Global Problem



January 2003, NASA

40% of W. Canadian summer days THI > 72

Ominski et al., 2002



July 2003, NASA

Heat Stress: Economics and Food Security

- Cost: (lost productivity, mortality, product quality, health care etc.)
  - American Agriculture: > $4 billion/year
  - Global Agriculture: > $100 billion/year
- Heat abatement is the primary strategy to mitigate heat stress
  - But most developing countries and small stake-holders lack the resources to afford cooling technology
- Heat stress is the largest impediment to efficient animal agriculture (even in developed countries)
- Threatens global food security
- Regionalizes animal agriculture

St. Pierre et al., 2003; Baumgard and Rhoads, 2013

Heat Stress will Become More an Issue in the Future if:

- Climate change continues as predicted
- Genetic selection continues to emphasis lean tissue accretion, milk synthesis, etc..
  - Heat producing processes
- Developing countries become more affluent
- Human population continues to migrate towards the equator
  - Animal agriculture will migrate with the consumer

Baumgard & Rhoads, 2013

Temperature Humidity Index (THI)

- Easy way to measure and evaluate heat stress
- Based on cows only under shade..solar radiation is incredibly potent
- 72 thought to be when cows become susceptible
- Based on 60 year old data when cows were producing 10-15 kg/d

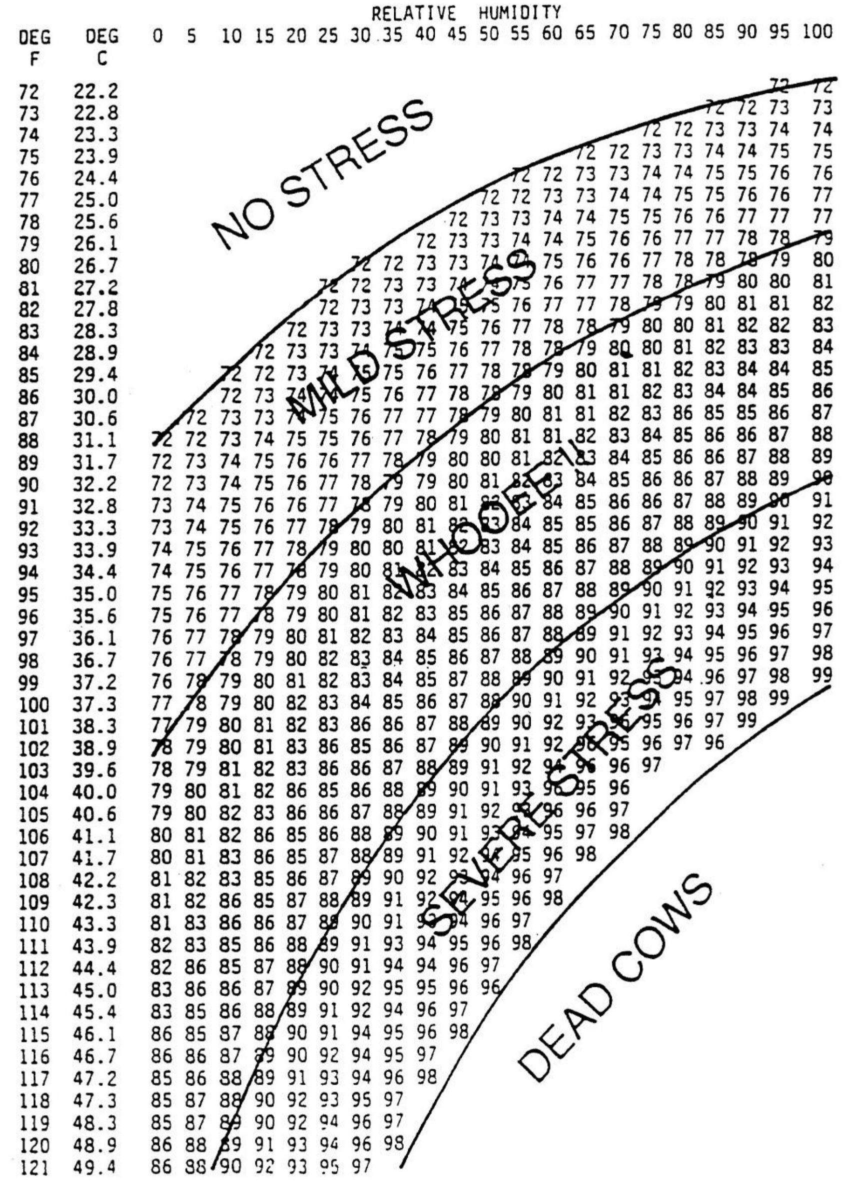


Figure 1. Temperature-humidity index table for dairy producer to estimate heat stress for dairy cows. Deg = Degrees. Relative humidity expressed as percentage. (From Frank Wiersma, 1990, Department of Agricultural Engineering, The University of Arizona, Tucson.)

Time to Re-Evaluate THI?

- When do modern dairy cows begin to experience heat stress?
- When should dairymen initiate cooling systems?
- Is it peak daily heat, average daily THI or minimum daily THI that is most indicative of heat stress?

THI Summary

- Modern high producing cows begin to experience heat stress at a THI of 65-68
  - Much lower than the traditional 72

- As milk production continues to increase, the THI at which cows become “stressed” will continue to decrease

- Pasture based cows will become heat-stressed sooner than those under shades…….solar radiation

Heat Stressed Cow

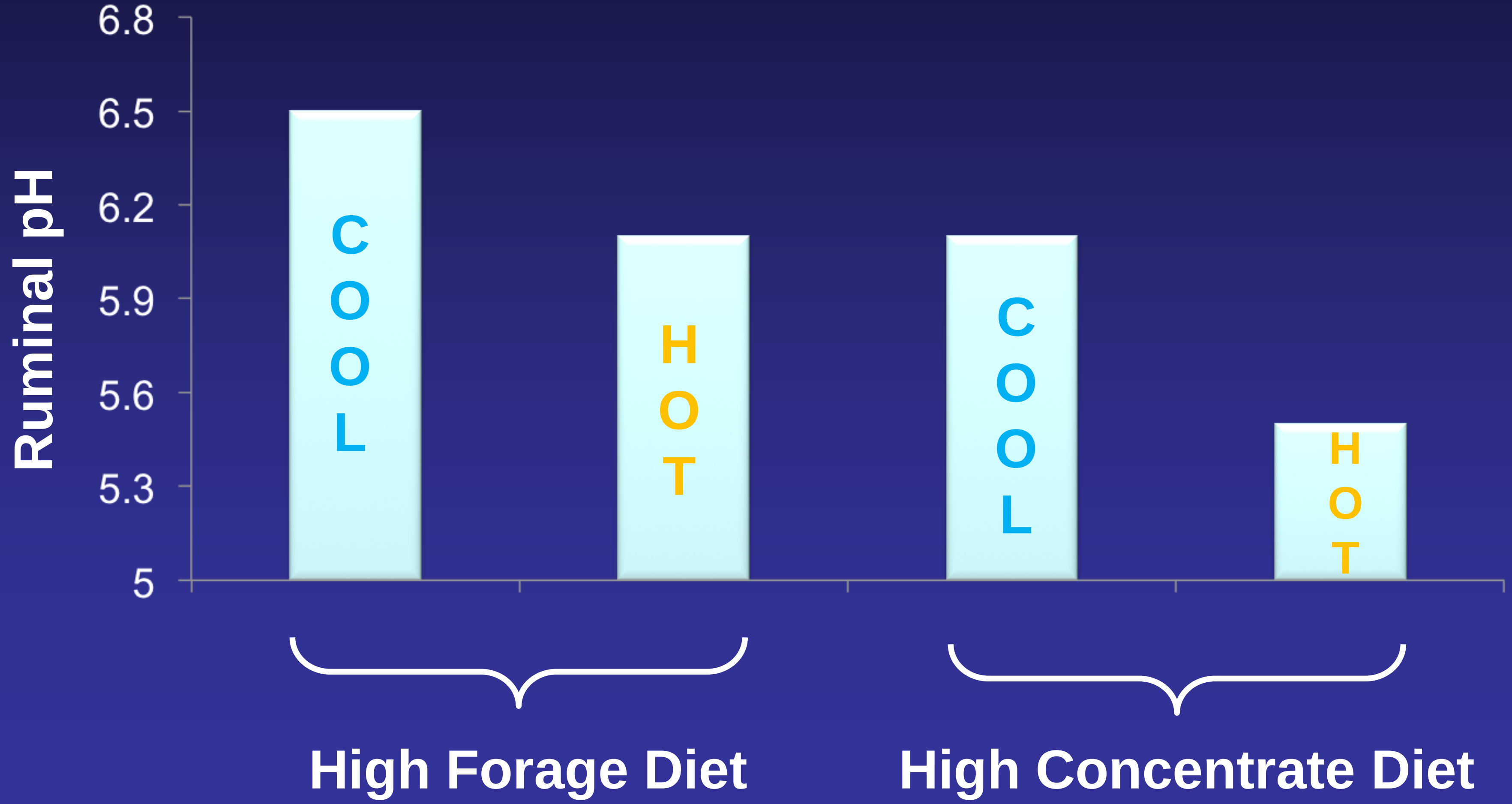
Results of Heat Stress

- Decrease in production (milk and growth)
- Reduced body condition
- Acute health problems
- **Rumen acidosis**
- Significant drop in pregnancy rate
- High incidence of abortions
- High death loss

Added all up … costly!

Effect of Heat Stress on Ruminal pH of Holstein Cows

(Mishra et al., JAS 30:1023)



Heat Stress Induced Rumen Acidosis

- Originates via:

  1) Altered respiration

    - Loss of systemic buffering capacity

2) Changes in feed and feeding behavior

  - Reduced feed intake
  - Increased concentrates
  - “sorting”
  - “bout/slug” feeding
  - Drooling
  - Less saliva production

Increased Respiration Rate

- Body requires 20:1 ratio of $HCO_3:CO_2$ in blood
- Increased expired CO_2
- To compensate, the kidney dumps HCO_3
- Therefore less HCO_3 to buffer the rumen

Summary

- ↑ Respiration = ↓ blood HCO_3 = ↓ saliva HCO_3
- ↓ Feeding = ↓ rumination = ↓ saliva production
- ↑ Drooling = wasted saliva
- Altered feeding habits and “hotter” rations

Metabolism Review

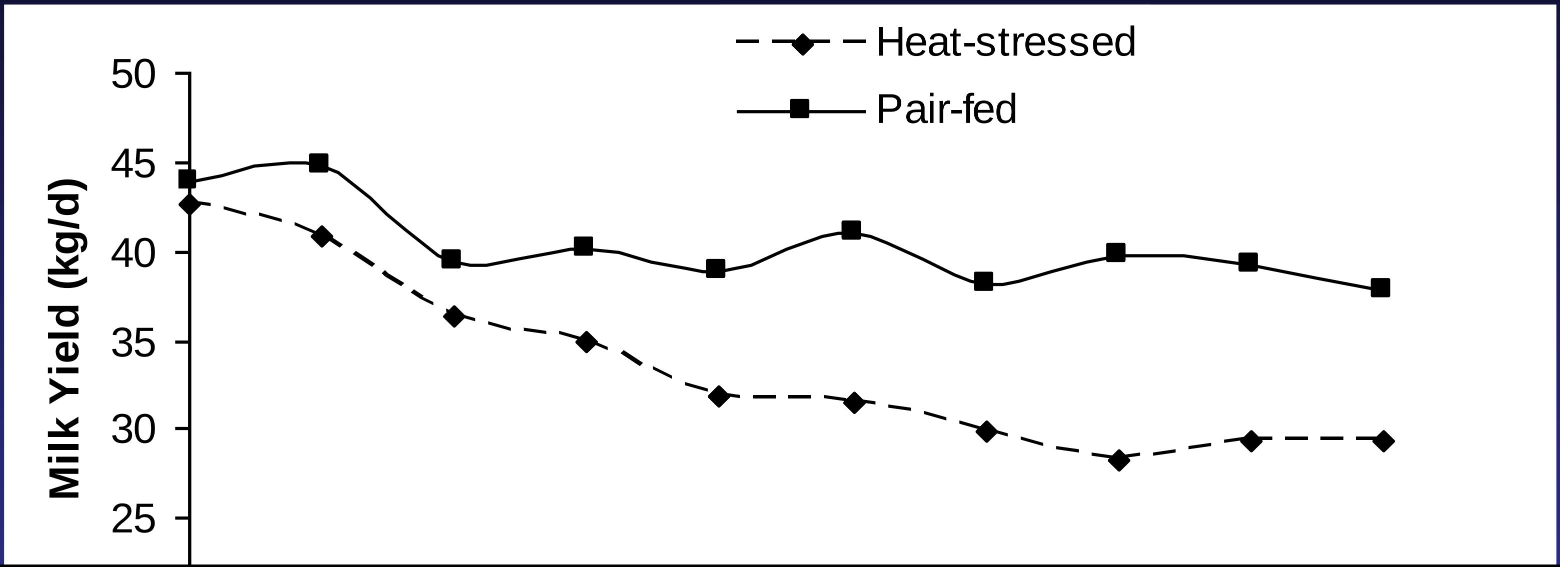
- Ad Libitum Intake
  - ↑ Insulin
  - ↓ NEFA
  - ↓ catabolic hormones
- Restricted Intake
  - ↓ Insulin
  - ↑ NEFA
  - ↑ catabolic hormones

Heat Stress Questions??

What is the basis for the reduced performance during heat stress?

Indirect vs. direct effects of heat

Effects of Environment on Milk Yield

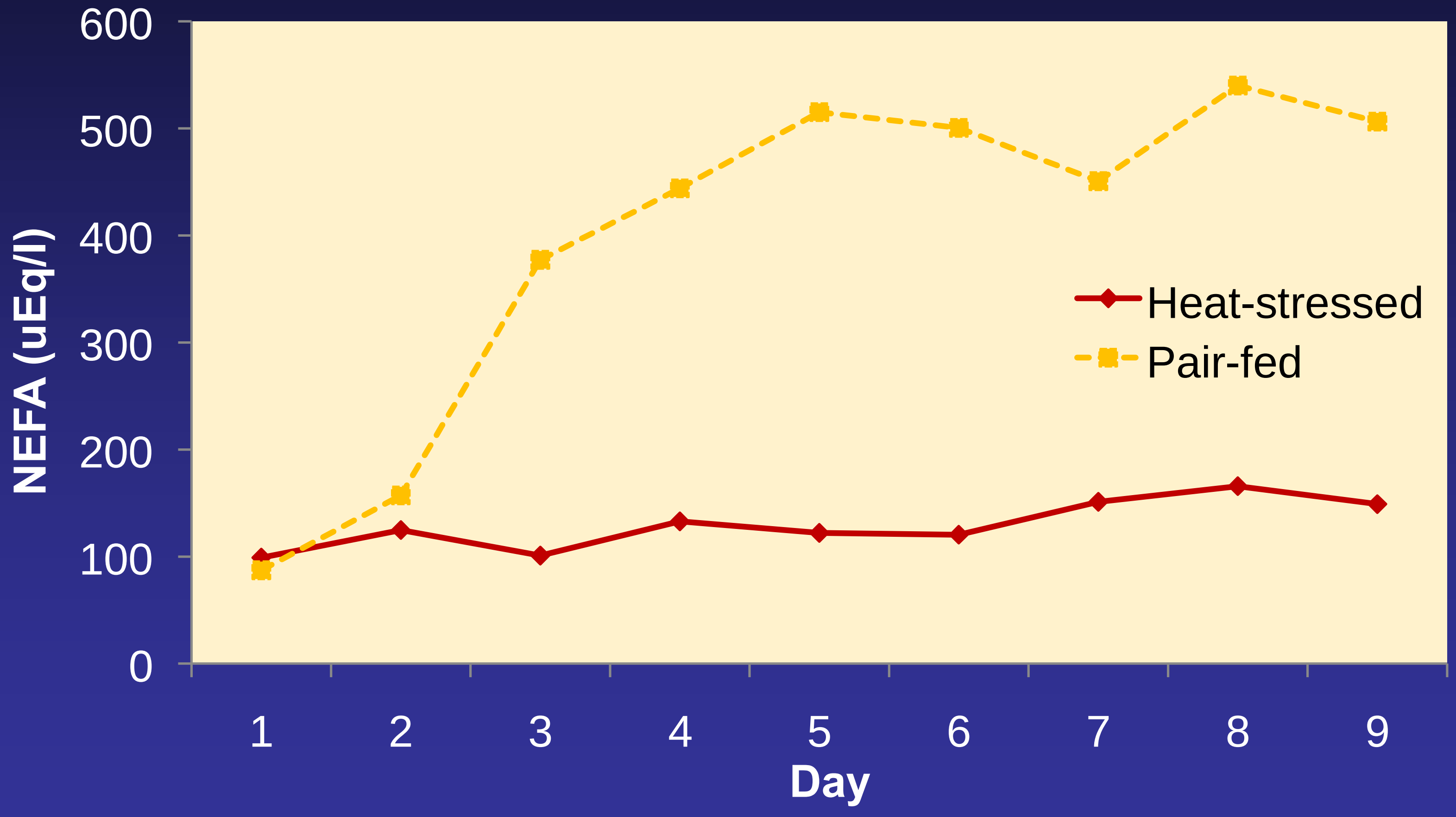


Heat stress ↓ yield ~45%
Pair-feeding ↓ yield by ~19%

Thus, ↓ feed intake only accounts for ~50% of the reductions in milk yield

Rhoads et al., 2007
Wheelock et al., 2008
Wheelock et al., 2010
Baumgard and Rhoads, unpublished

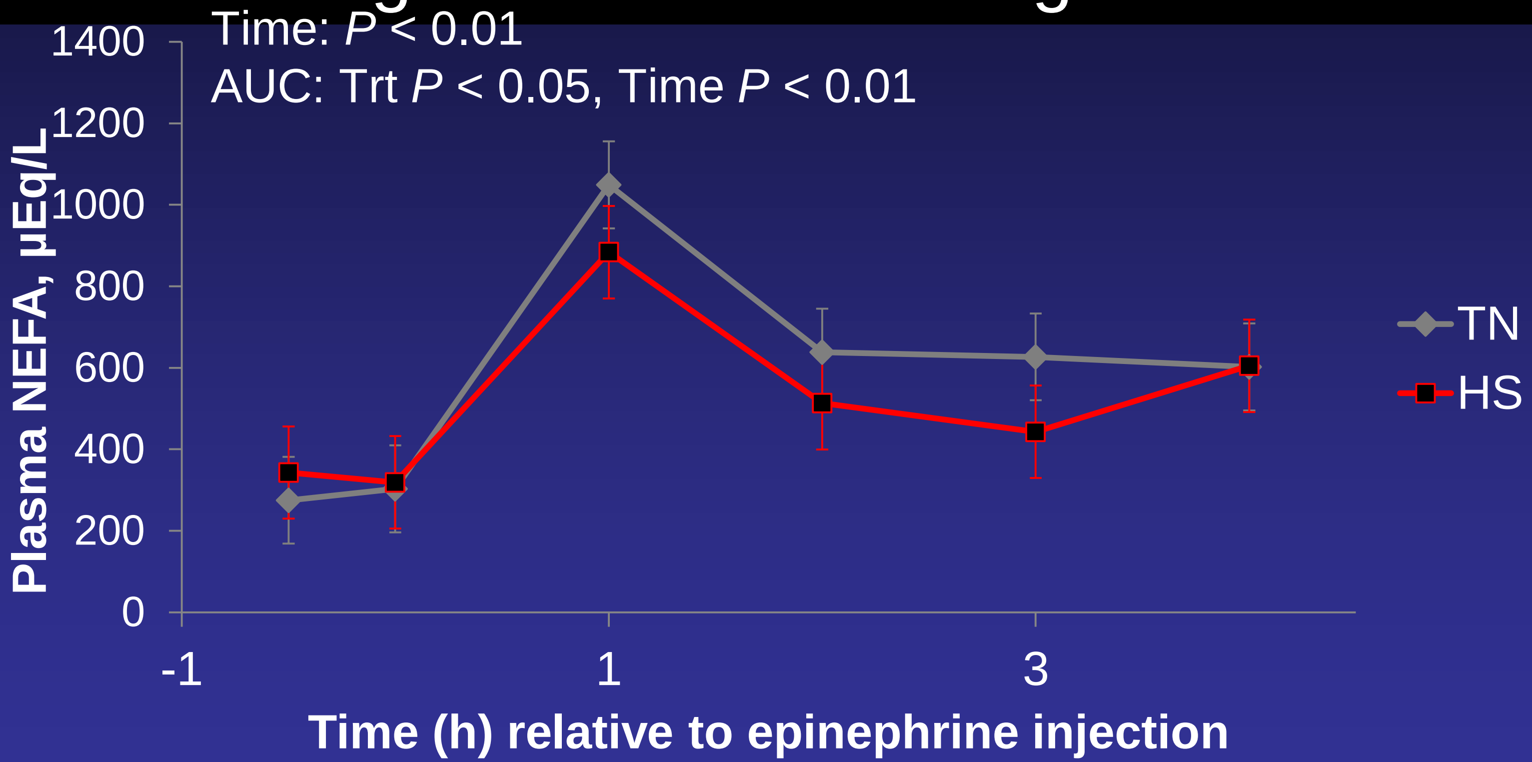
Effects of Heat Stress on Adipose Tissue Mobilization



Rhoads et al., 2009

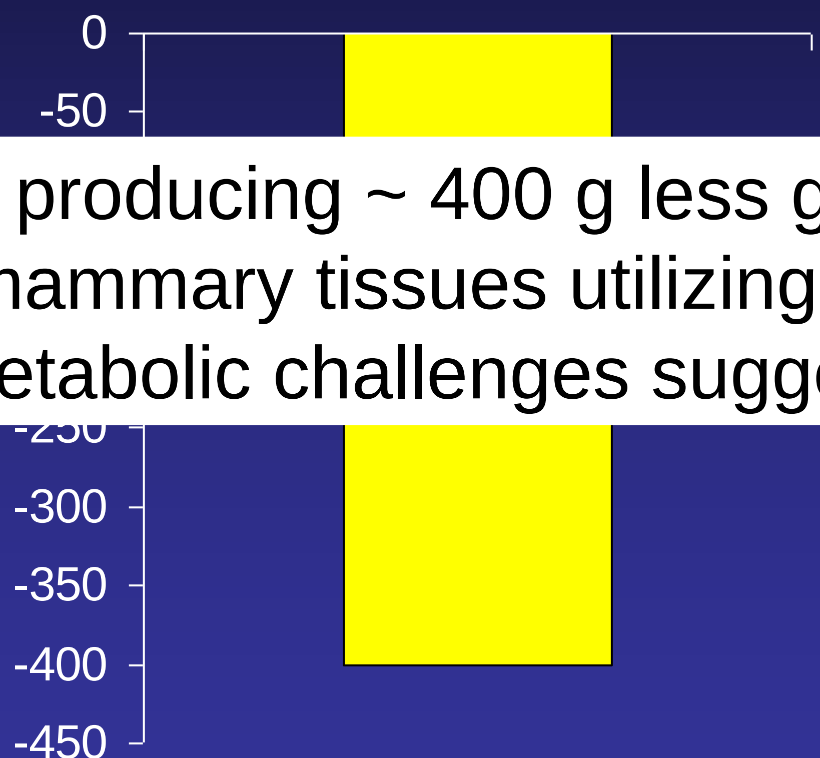
NEFA Response to Adrenergic Signal

Adipose tissue is less sensitive
to adrenergic stimulation during heat stress



Xie et al., 2014

Heat Stress Cows Secrete ~400 g less lactose/d than Pair-Fed Thermal Neutral Controls

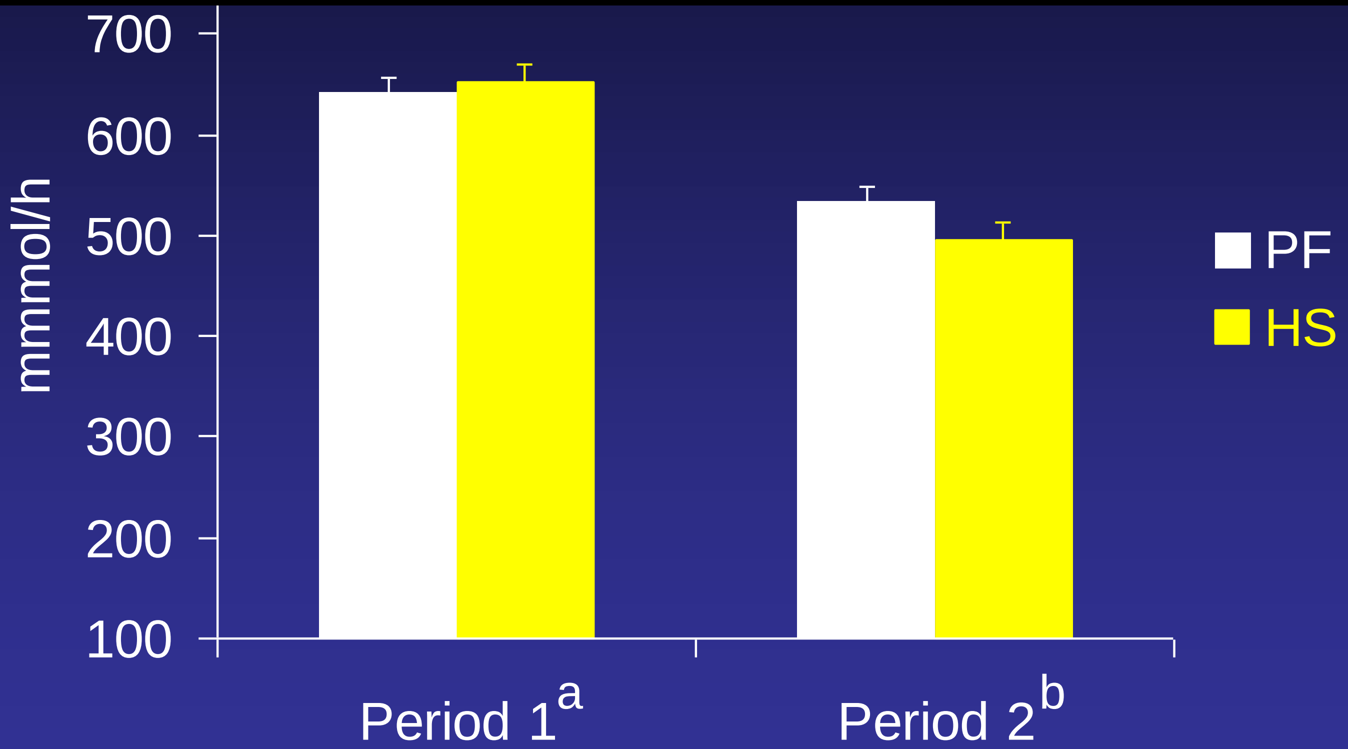


Is the liver producing ~ 400 g less glucose/day????
or is extra-mammary tissues utilizing ~400 g more/day
Our metabolic challenges suggest the latter

Rhoads et al., 2007
Wheelock et al., 2008

Whole Body Glucose Production

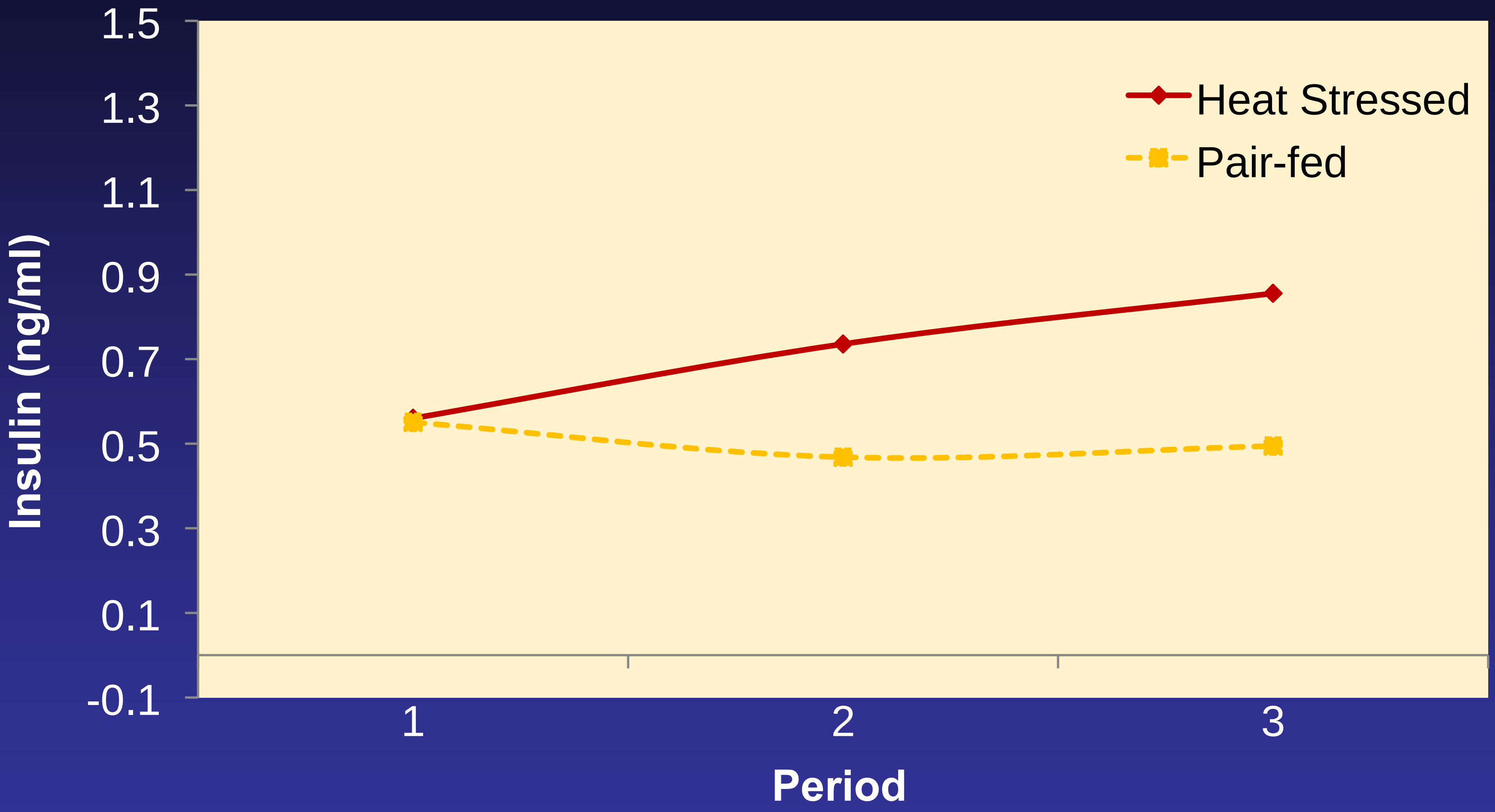
Extra mammary tissues utilize ~ 400 g more glucose/d during heat stress



Period: $P < 0.05$

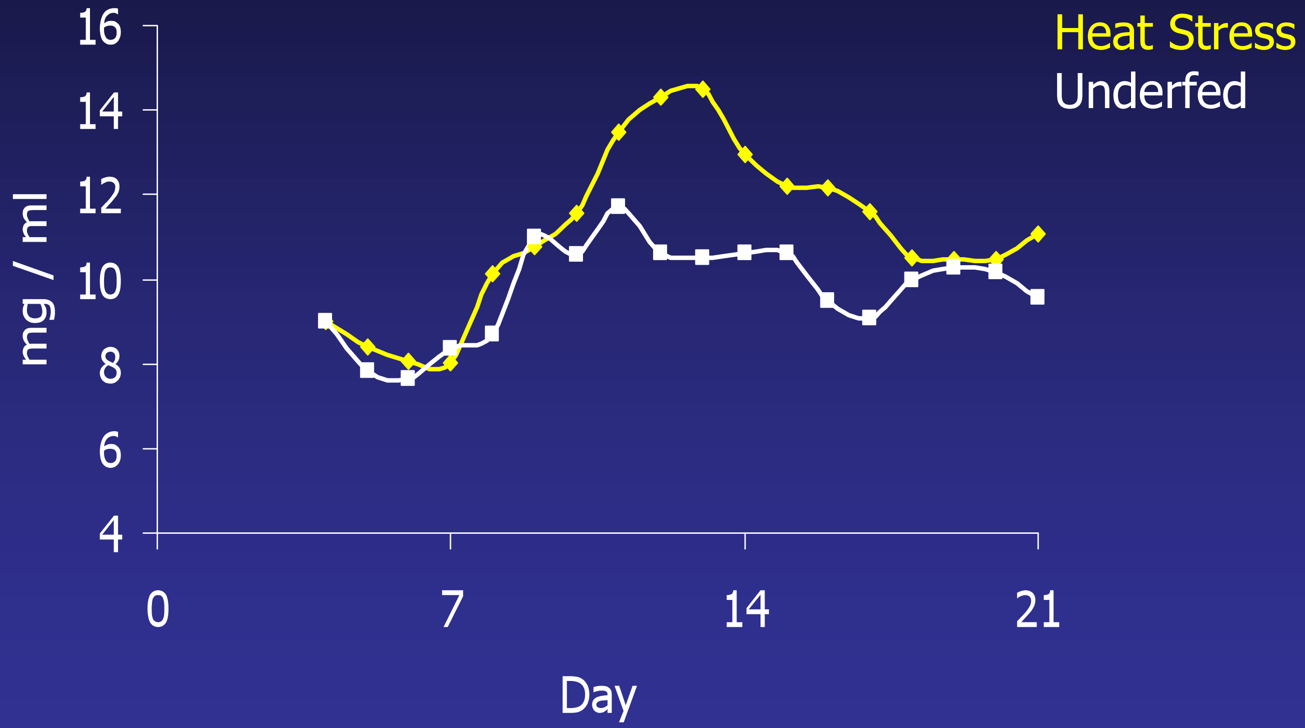
Baumgard, Rhoads and Waldron, unpublished

Circulating Insulin in Cattle



Wheelock et al., 2010

Heat Stress and PUN



Wheelock et al., 2010

Energetic Summary

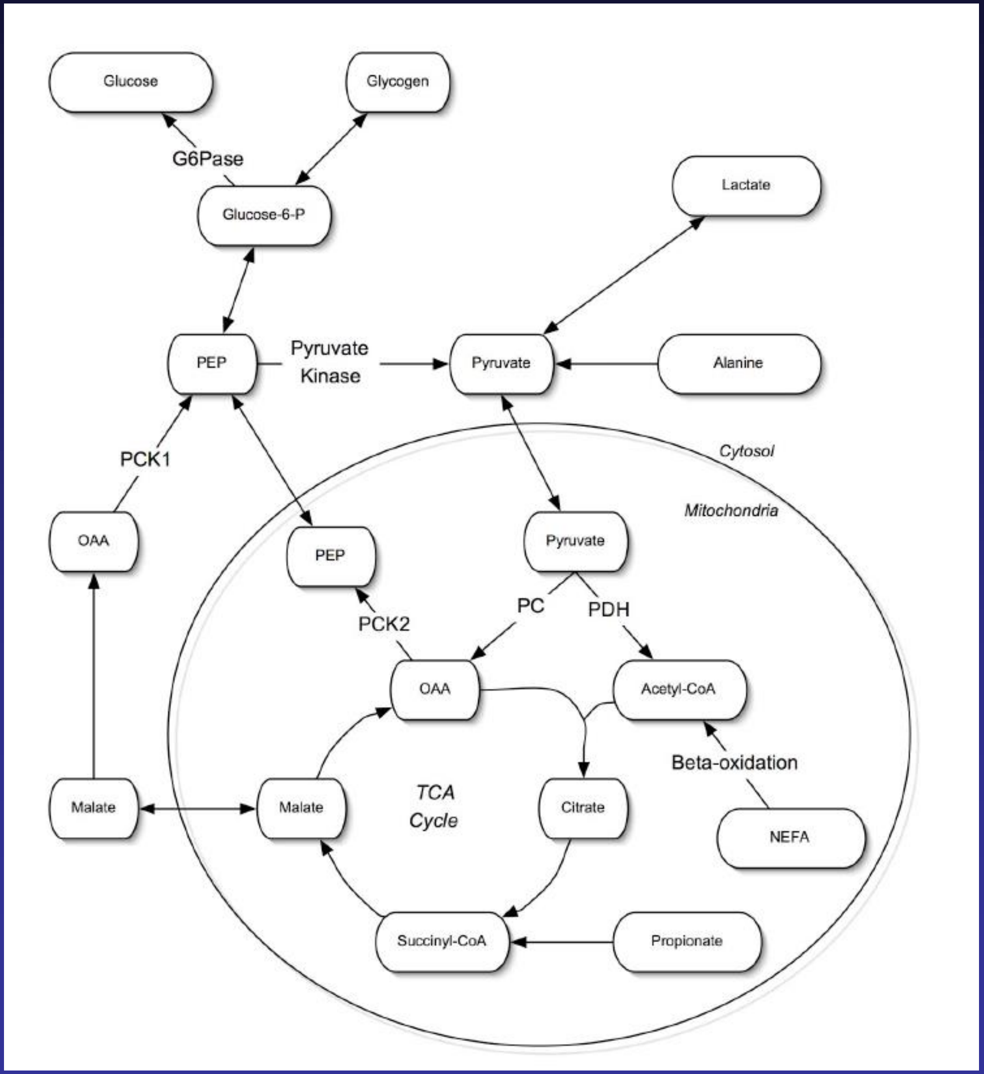
- Decreased feed intake only accounts for ~50% of the reductions in milk yield
- Tissue differences in sensitivity to catabolic and anabolic signals
- Heat-stressed cows have increased insulin action
  - Decreased NEFA
  - Increased glucose disposal
- Heat-stressed cows require extra energy
  - Especially glucose

Potential Fuels for Energy

- VFA (acetate)
  - Contribution is presumably decreased b/c DMI is reduced
- NEFA
  - Do not increase during heat stress
- Glucose
  - Elevated basal and stimulated plasma insulin
  - Increased disposal
- Amino Acids
  - Elevated PUN may indicate some catabolism
  - Source for gluconeogenesis?

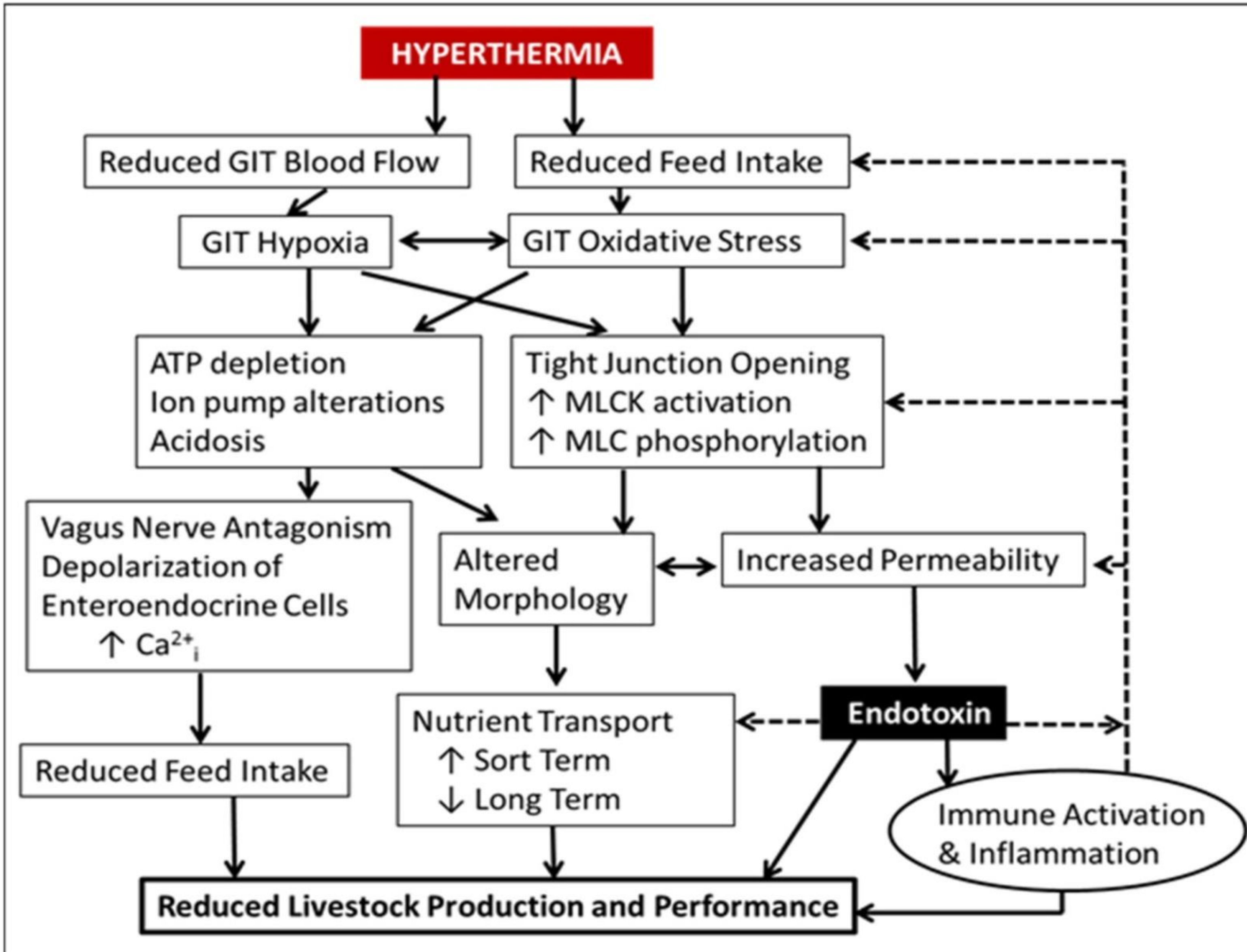
Gluconeogenesis

- Less than 10% of the glucose requirement is met by dietary glucose
- Example: Dairy cow producing 90 kg milk requires 7.4 kg glucose, 6.6 kg of which must come from gluconeogenesis



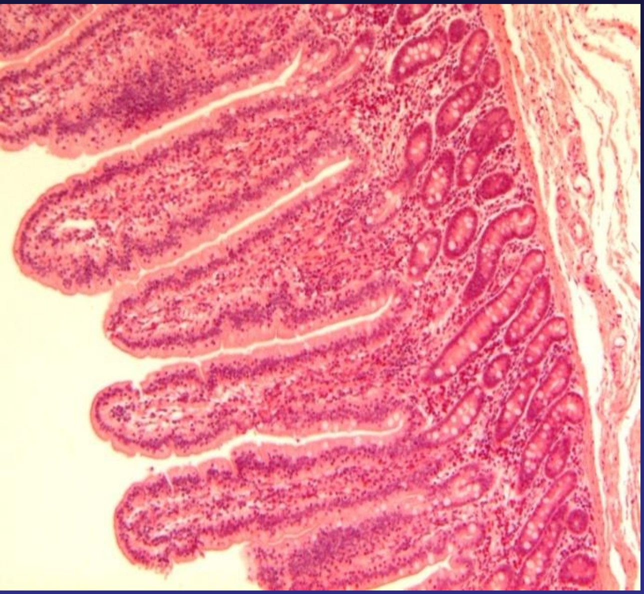
Heat Stress and Gut Health

- Massive diversion of blood flow to skin and extremities
- Coordinated vasoconstriction in intestinal tissues
  - Reduced nutrient and oxygen delivery to enterocytes
  - Hypoxia increases reactive oxygen species (ROS)
- Reduced nutrient uptake increases rumen and intestinal osmolarity in the intestinal lumen
  - Multiple reasons for increased osmotic stress

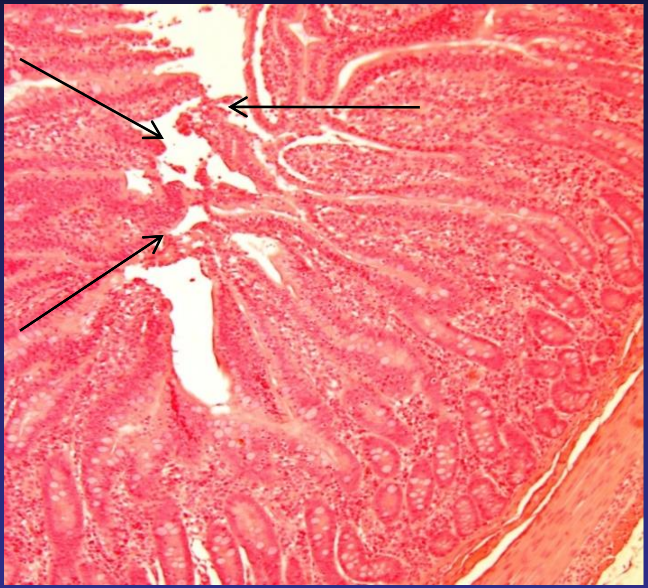


Baumgard et al., 2011

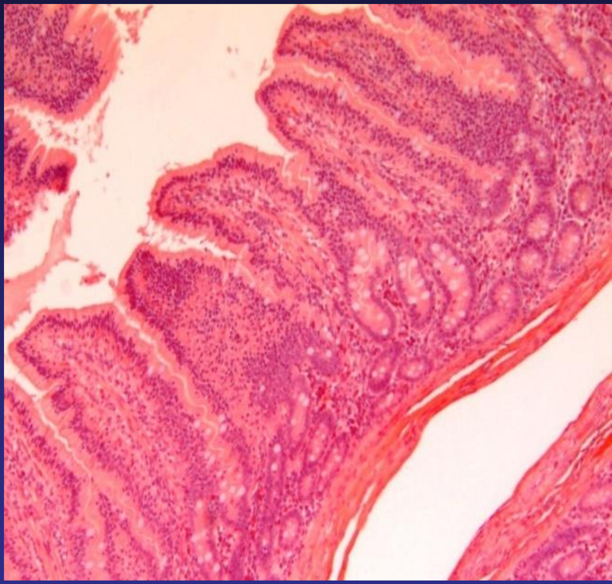
Intestinal Morphology



Thermal Neutral



Heat Stress



Pair-fed

Pearce et al., 2011

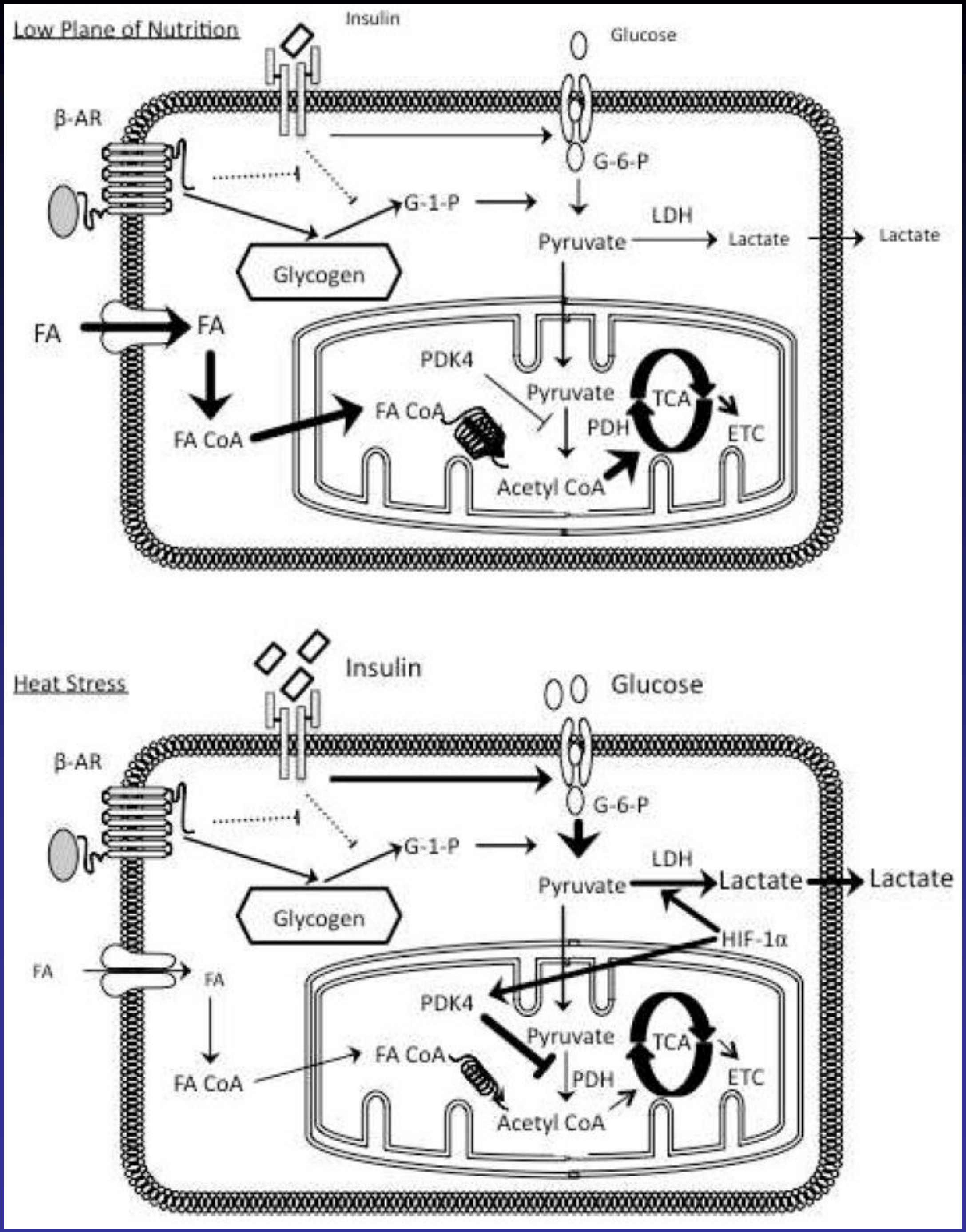
Heat Stress and Gut Integrity

- Endotoxin (aka. Lipopolysaccharide: LPS)
- Component of bacteria cell wall
- When bacteria die, LPS is released into intestine
- Normally LPS is prevented from entering through GIT tight junctions
- During HS some LPS enters blood stream

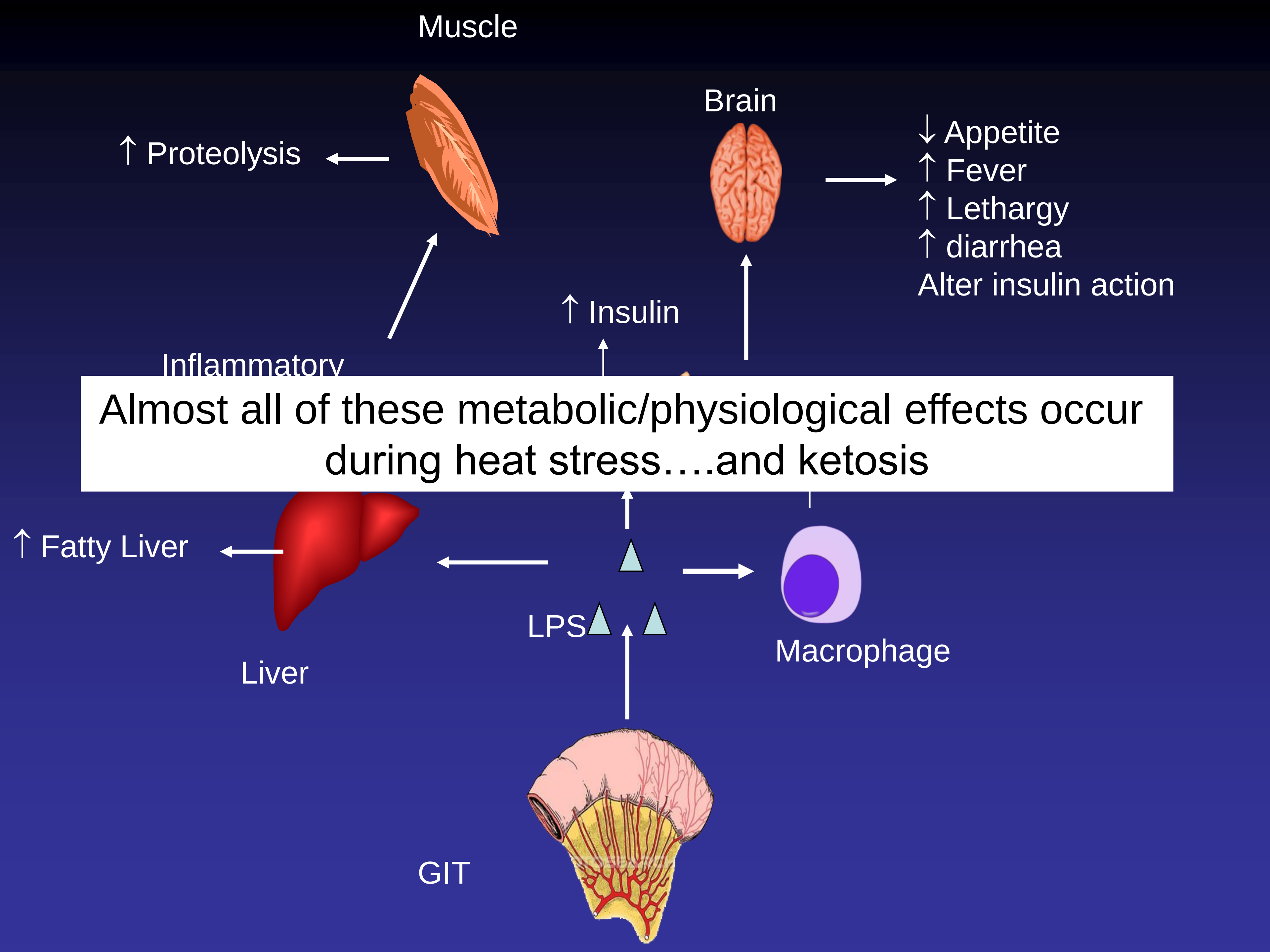
Heat Stress and Gut Health

- LPS can cause liver damage
  - May impair gluconeogenesis capability
  - May impair ability to export VLDL (fatty liver)
  - May impair ability to secrete anabolic hormones
- LPS stimulates inflammatory cytokine production….catabolic condition
  - TNFα, IL-1 etc..
    - Reduced appetite
    - Stimulates fever
    - Causes muscle breakdown
    - Induces lethargy
    - ....reduces productivity

Skeletal Muscle Metabolism



Rhoads et al., 2013

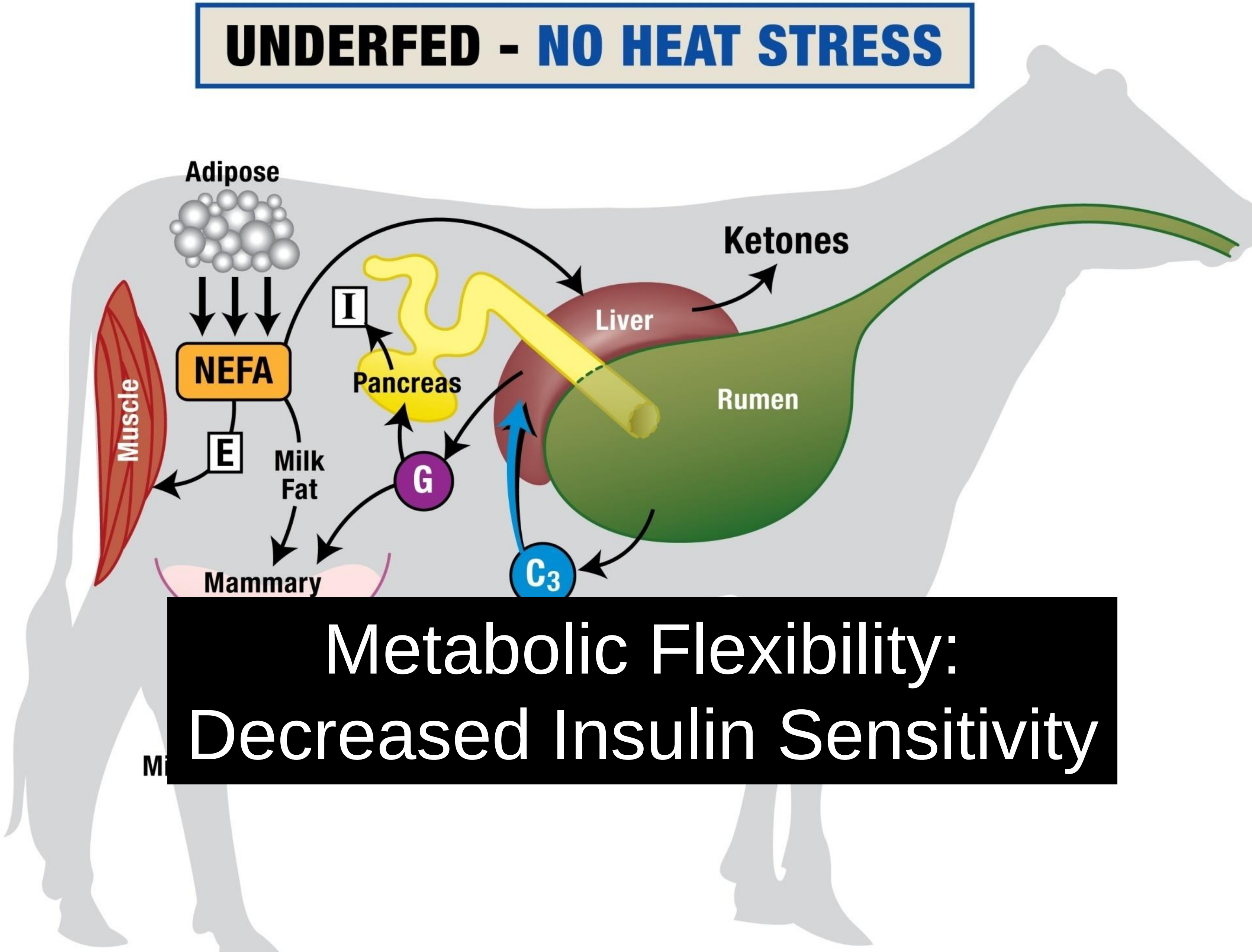


Almost all of these metabolic/physiological effects occur during heat stress….and ketosis

Lactating Dairy Cow
Metabolic Adaptation to Heat Stress

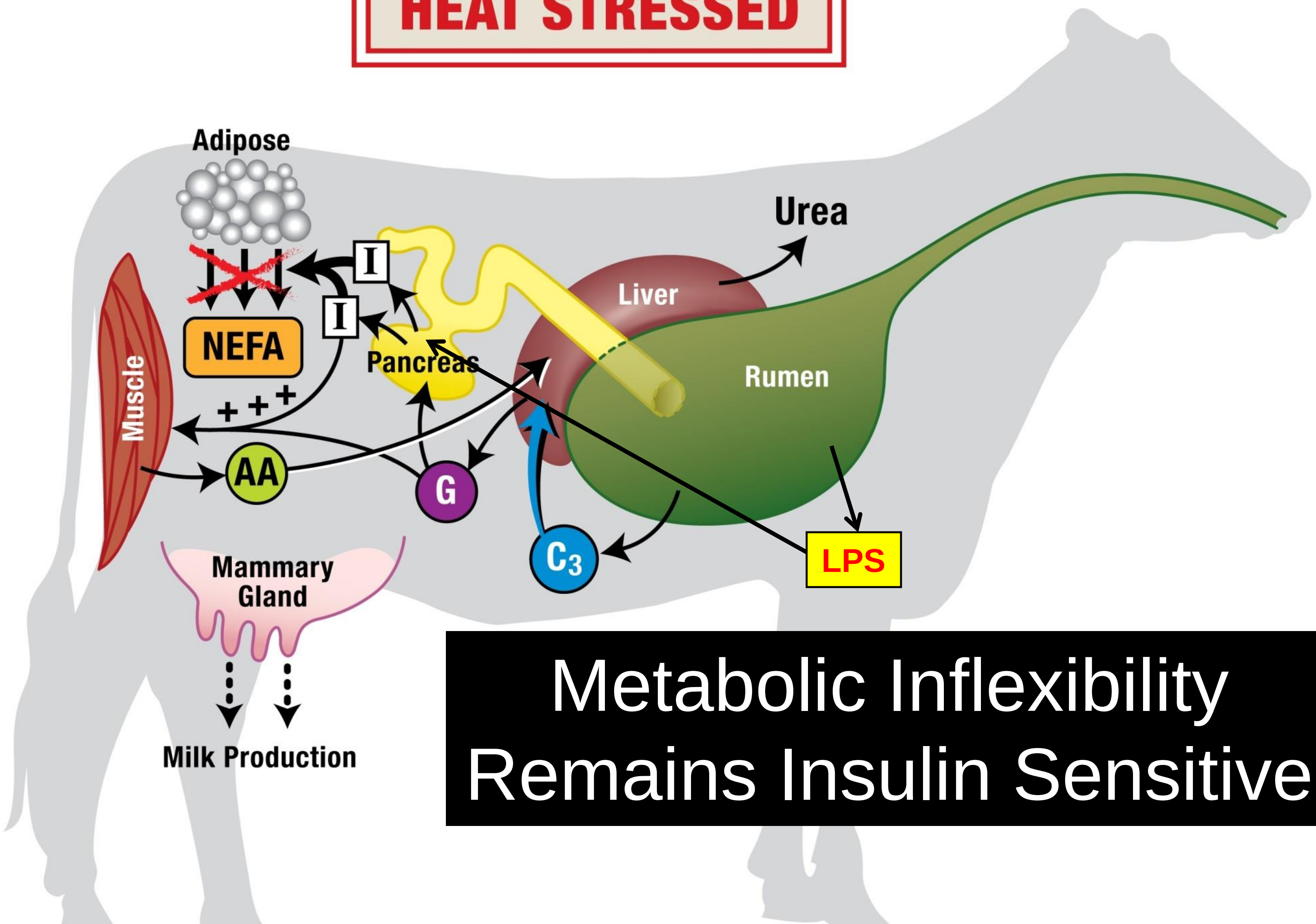
Summary

Metabolic Flexibility: Decreased Insulin Sensitivity



Baumgard and Rhoads, 2013

HEAT STRESSED



Metabolic Inflexibility
Remains Insulin Sensitive

Baumgard and Rhoads, 2013

Conclusions

- Heat-stressed animals fail to enlist glucose sparing mechanisms (i.e. they do not mobilize adipose tissue)
  - May begin to explain the "direct" effects of heat on production
- Reasons why glucose appears to be a primary fuel source is currently unknown but may relate to reduced NEFA via lipolysis
- One possibility may relate to impaired cellular metabolism and mitochondrial dysfunction as exhibited by skeletal muscle

Dietary and Management Options?

- Strategies recently evaluated by our group
  - Rumensin
    - Increases rumen propionate production
  - rbST
    - Partitions nutrients towards mammary gland
- <u>BUT</u> Heat Stress Abatement is the Key

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Reduce walking distance
- Reduce time in holding pen
  - Ventilate and cool
- Exit lane cooling
- Don’t “lock up or work” during mid day
- Feed early in the morning and late in the night
  - Push up often
  - Remove old feed
- Avoid vaccinations during the middle of the day
- <u>At least</u> provide shade for dry cows

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Feed more frequently
  - Especially during the cooler parts of the day
- Fiber:
  - Avoid the temptation to reduce fiber content
  - Rumen acidosis
  - Production data
- Protein
  - Currently unknown if protein requirements change during heat stress
  - RDP about 10% of CP

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Clean water tanks daily
  - Consider re-hydration therapies, especially in transition cows
    - Decreased rumen content of Na^+ and K^+ (Beede &Collier, 1982)
    - Electrolyte supplementation may be effective
  - Increased opportunity for dehydration
  - Medicate/supplement the water?
- Dietary HCO3
  - Helps prevent rumen acidosis
    - Heat stress cows are already prone to rumen acidosis
    - Can increase to 300-400 g/head/d during the summer

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Dietary Fat (by-pass)
  - Additional energy without the heat increment of fermentation
    - Heat stressed cows are in negative energy balance dietary fat should help maintain milk yield and body condition
    - Can go up to 7-8% of dietary dry matter
- Potassium
  - Cows use potassium to sweat, thus there is an increased potassium need during heat stress
  - Can increase to 1.7% of ration dry matter
  - Consider K^+HC0^3……consider the costs
  - – Be careful of a positive DCAD in dry cows

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Betaine:
  - Not for methyl donor reasons
  - But for GIT integrity reasons
  - Used extensively in the Asian poultry and swine industries during heat stress
- Niacin
  - Increases skin vasodilatation and decreases body temperature: Whether small decreases in rectal temperature translates into improved production remains to be determined

Dietary and Management Strategies to Reduce the Negative Effects of Heat Stress

- Chromium
  - Appears to improve productivity, likely due to increased DMI
- DCAD:
  - Keep in 30-40 meq/100 g of DM
  - No apparent improvements of going higher
- Direct fed microbials/yeast
  - Products that increases rumen digestion, stabilizes pH, increases propionate and increases DMI should benefit a heat stressed cow
    - The inconsistencies in the literature regarding these variables is of interest

Summary

- Concentrate on maintaining healthy rumen pH
  - It will pay dividends during late Summer and Fall
- Heat stress markedly affects metabolism independent of reduced nutrient intake
  - Can in large-part be explained by increased insulin action
  - Maximizing glucose synthesis will improve production
- There is no dietary magic pill
- Dietary and management modifications
  - Ionophores, rbST etc…
  - Fat feeding makes sense
  - Consult with your nutritionist

Acknowledgments

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Questions?