Thermoregulation

Thermoregulator

Adaptations

Physiological Changes

Thermoregulation

- Regulation of internal body temperature
- Maintenance of body temperature within an acceptable range
- Example: humans live in climates of varying temperature but able to maintain constant body temperature

Cold & Warm blooded

- Why are the terms for classifying organisms into cold-blooded and warm-blooded inaccurate?
- What are the correct terms?
- What is the advantage of being able to regulate body temperature?
- What is the disadvantage of regulating body temperature?

Thermoregulation

	Ectotherm	Endotherm
Metabolic rate	Low	High
Heat generation	Too little to warm body	Enough to keep body warm
Internal body temperature	Determined by environment	Stable, regardless of external fluctuations
Example organisms	fish, reptiles, amphibians	mammals, birds

Advantage of Endothermic Regulation

1. High levels of aerobic metabolism
   - Perform vigorous activity for longer periods
   - E.g. flight
2. Enable terrestrial living and environments with largest fluctuations in temperature
   - Extreme temperature fluctuation on land (opposed to aquatic)

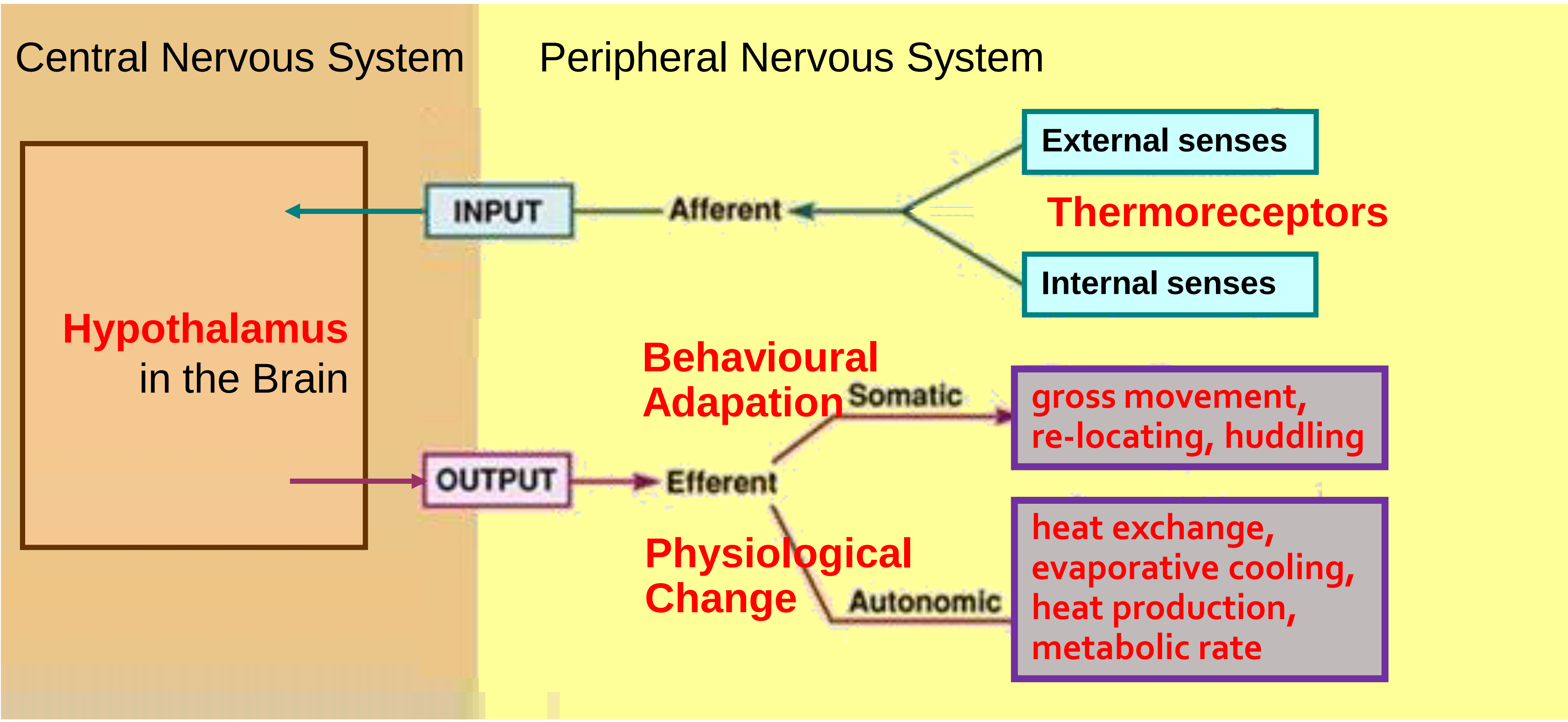
Disadvantage of Endothermic Regulation

1. Energetically expensive
   - Example: at rest, body temperature 20°C
   - humans: 1300-1800 kcal/day
   - alligator: 60kcal/day
2. Need to consume more food

Methods of Thermoregulation

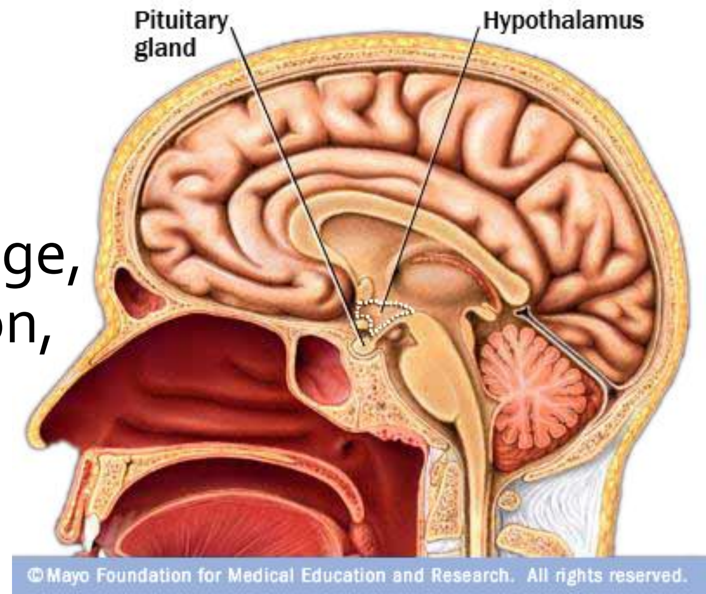
- Adaptations:
  - Physical adaptations
  - Behavioral adaptations
  - Circulatory adaptations
- Physiological changes:
  - Rate of heat exchange
  - Evaporative heat loss (cooling)
  - Rate of heat production
  - Rate of metabolic heat production

Nervous System Controls Thermoregulation



Brain: The body's thermostat

- Sensory receptor (input):
  - Thermoreceptors on skin sense temperature
- Integration: hypothalamus
  - Contains neurons that respond to changes in body temperature above and below the normal range
- Effector (output):
  - Behavioural changes
  - Physiological changes (heat exchange, evaporative cooling, heat production, metabolic rate)



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Physical Adaptations

- Insulation
  - hair, fur, feathers
  - fat located just beneath the skin

http://www.freakingnews.com/Fat-Cat-Pics-24390.asp

Behavioral Adaptations

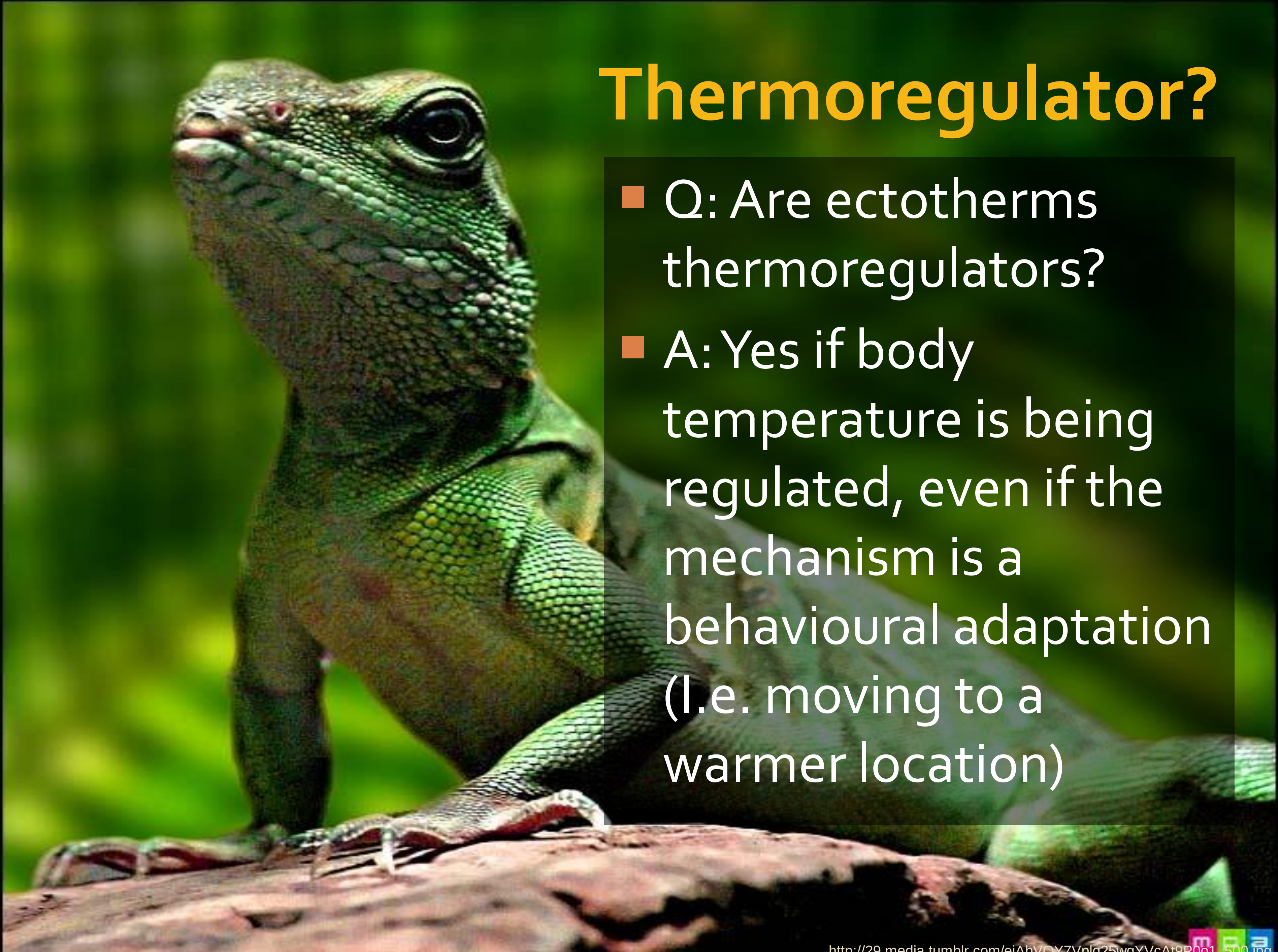
- Gross Movement
- Huddling:
  - decrease surface area & heat loss
- Re-locating:
  - Finding shaded areas
  - Basking in sun
  - Migration

Marine Iguana (*Amblyrhynchus cristatus*). Basking in the sun.

http://life-sea.blogspot.ca/2011/08/life-of-marine-iguana.html

Thermoregulator?

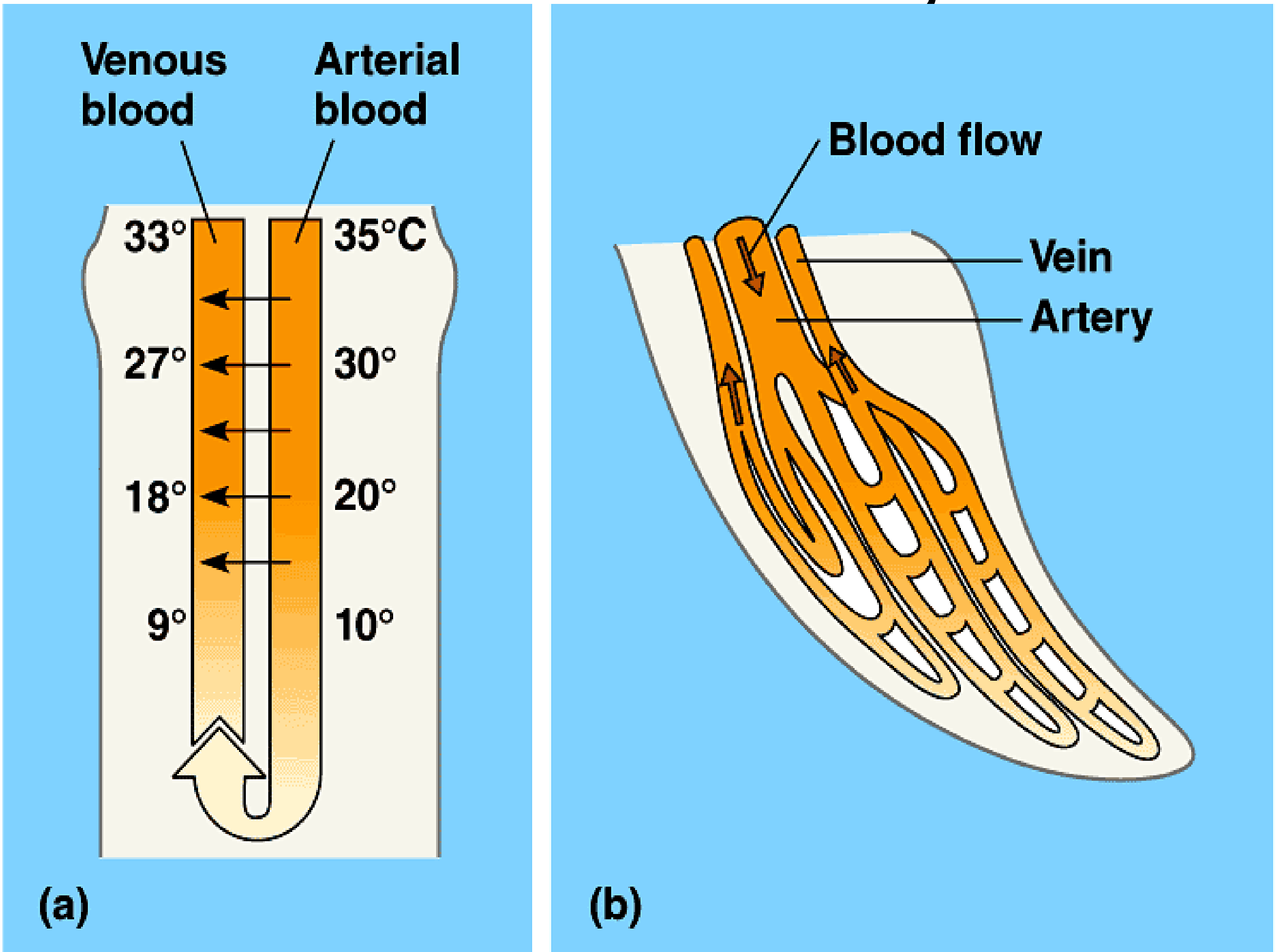
- Q: Are ectotherms thermoregulators?
- A: Yes if body temperature is being regulated, even if the mechanism is a behavioural adaptation (I.e. moving to a warmer location)



http://29.media.tumblr.com/eiAbVQY7Vplg25wgYVcAt9P0o1_500.jpg

Circulatory Adaptation

- Counter current heat exchange



(Fig. 44.5)

Countercurrent Heat Exchange

- Arteries carrying warm blood in limbs (and wings) are in close contact with veins conveying cool blood back toward the trunk
- Venus blood approaching torso will be almost as warm as the body core

Methods of Thermoregulation

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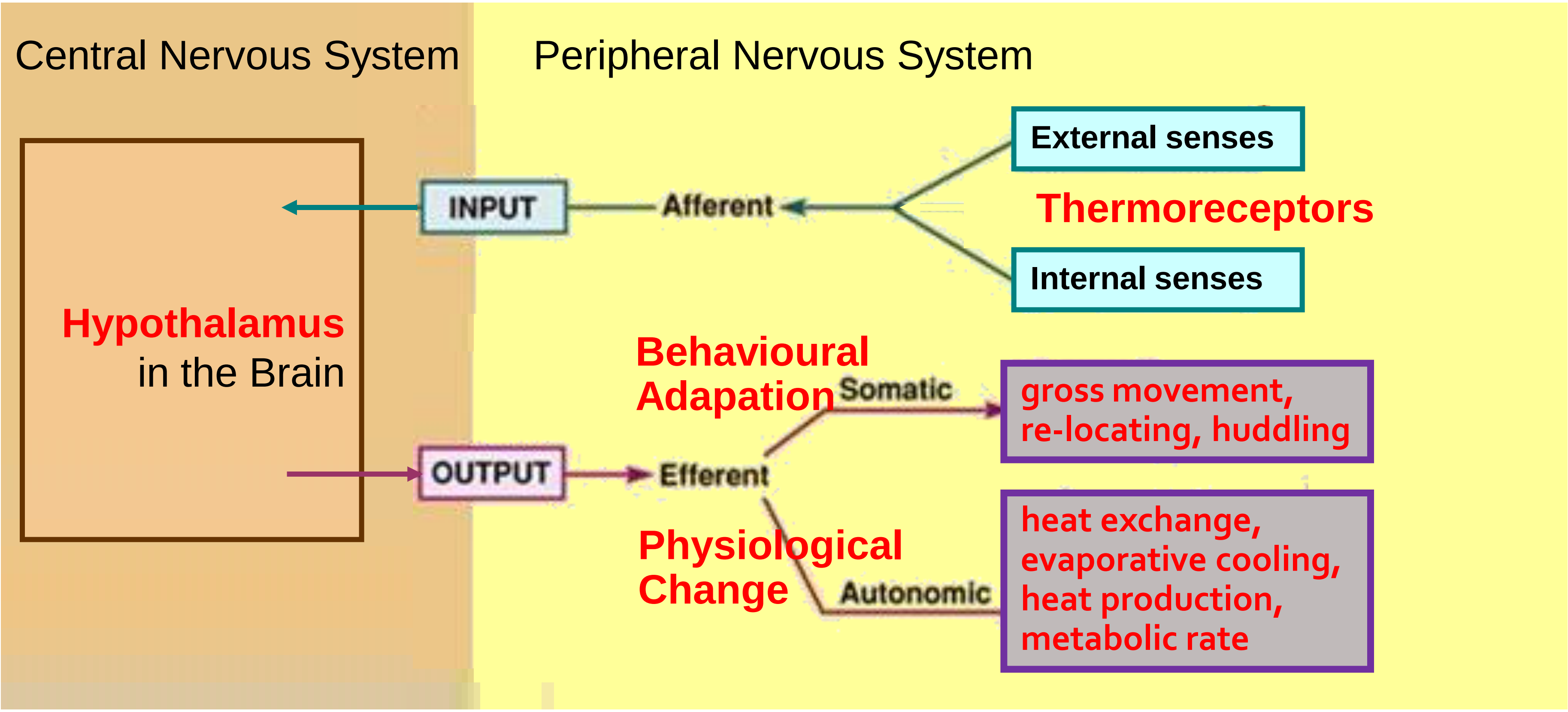


Rate of Heat Exchange

- Regulated by blood vessel size
  - Vasoconstriction: cold response
  - Vasodilation: heat stress

Rate of Heat Exchange

Vasoconstriction

- Decrease:
  - superficial blood vessel diameter
  - blood flow to surface of extremities
- Result:
  - Reduce heat loss from body
  - Blood redirected to torso (organs)

Vasodilation

- Increase:
  - diameter of blood vessels near body surface
  - blood flow to surface
- Result:
  - transfer body heat to environment

Extreme Cold

- Why does your body allow you to get frost bite?
- What happens to body temperature with hypothermia? Why is hypothermia such a concern but frost bites aren't?

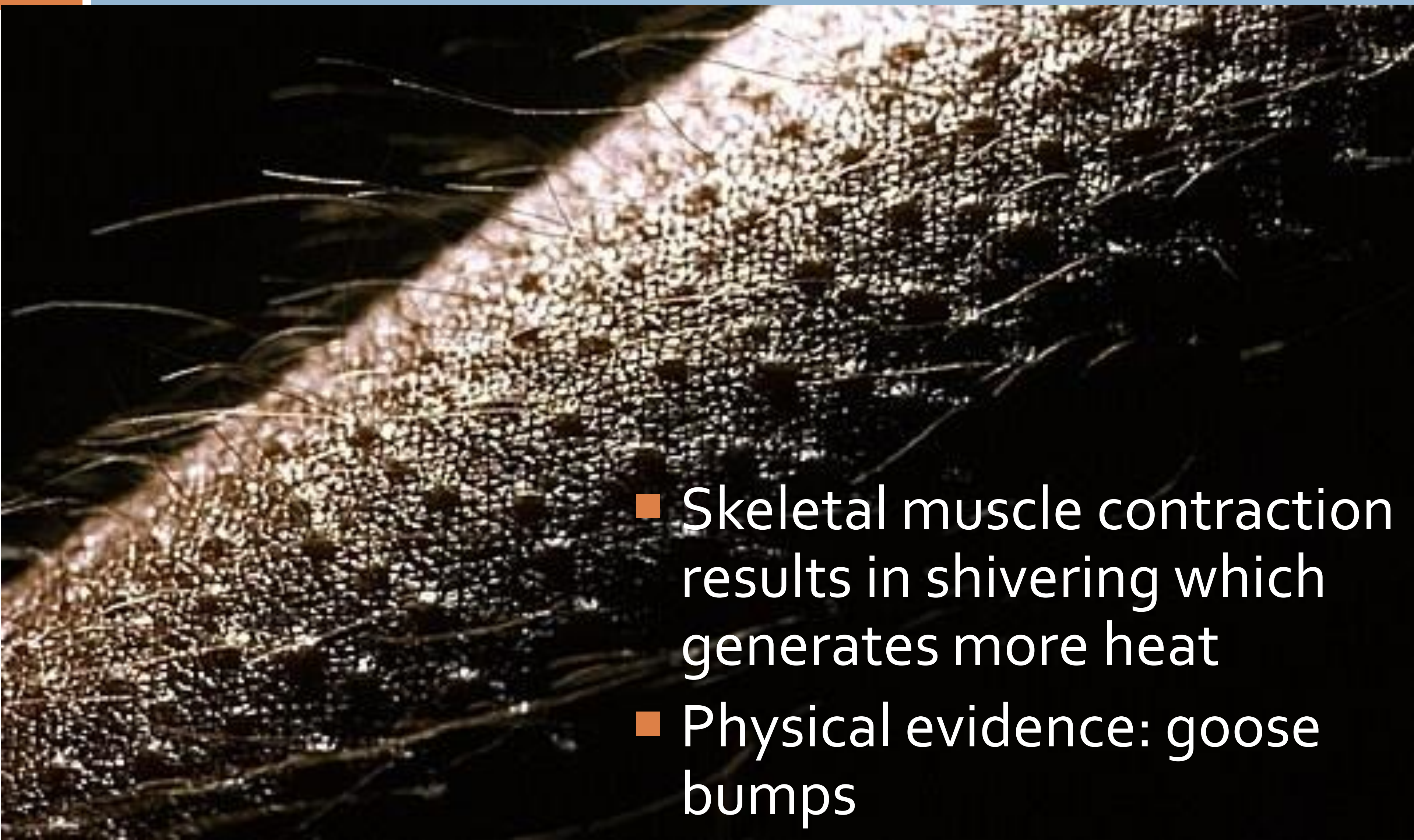
Cryopreservation

- Suspending life due to freezing
  - frozen cytosol can expand to break the cell membrane
  - Need to dehydrate cells before freezing
- Only certain cell types can be cryopreserved
  - Semen
  - Blood (special cells for transfusion, or stem cells)
  - Tissue samples like tumors and histological cross sections
  - Human eggs
  - Human embryos that are 2, 4 or 8 cells
- Example: Frozen Wood Frog
  - Kenneth B. Storey – Carleton University
  - Video: http://www.youtube.com/watch?v=UvCdOXG2rPo (1:56)

Evaporative Heat Loss (cooling)

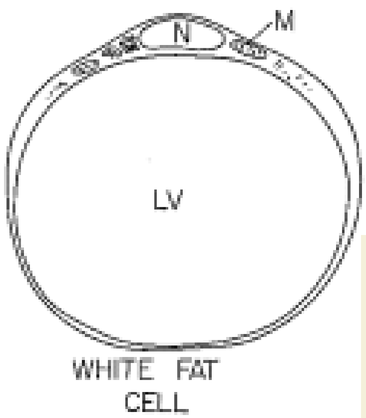
- Water absorbs heat when it evaporate
- Sweating evaporates water across skin thus removing heat from body

Rate of Heat Production

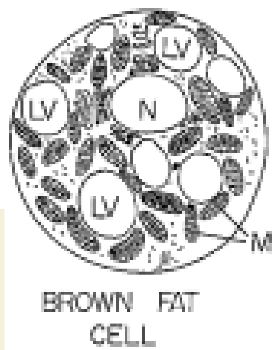


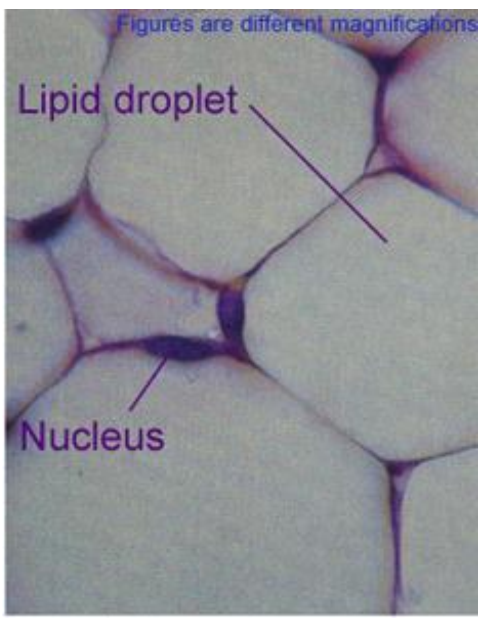
- Skeletal muscle contraction results in shivering which generates more heat
- Physical evidence: goose bumps

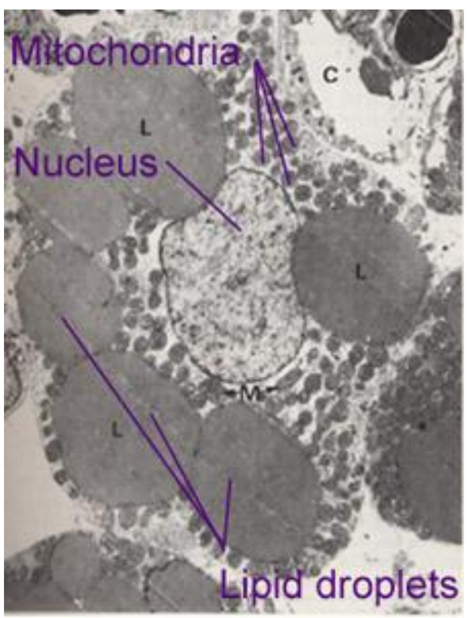
Rate of Metabolic Heat Production: Fat Cell Structure



LV: lipid vacuole;
M: mitochondria;
N: nucleus.
Artwork courtesy of Dr. John Horwitz, U.C. Davis.





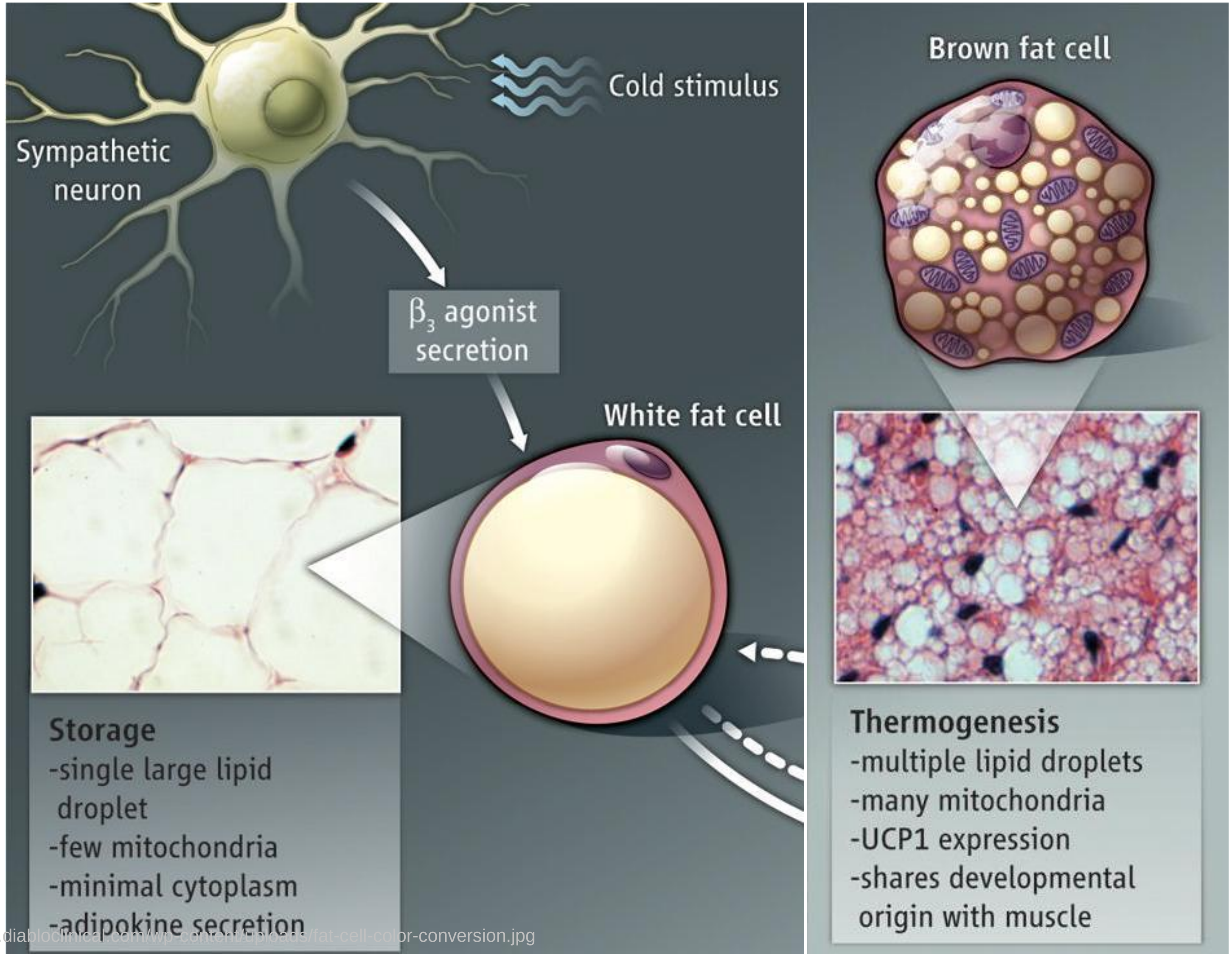


http://www.sportsci.org/encyc/adipose/Image1.gif

http://researchonmedical.com/wp-content/uploads/2013/03/Brown-Fat-Versus-White-Fat.jpg

- White fat cells:
  - Single large lipid vacuole
- Brown fat cells:
  - Numerous small lipid vacuole
  - High concentration of mitochondria
  - Only applies to endotherms
  - Prevalent in newborns (babies don't shiver)

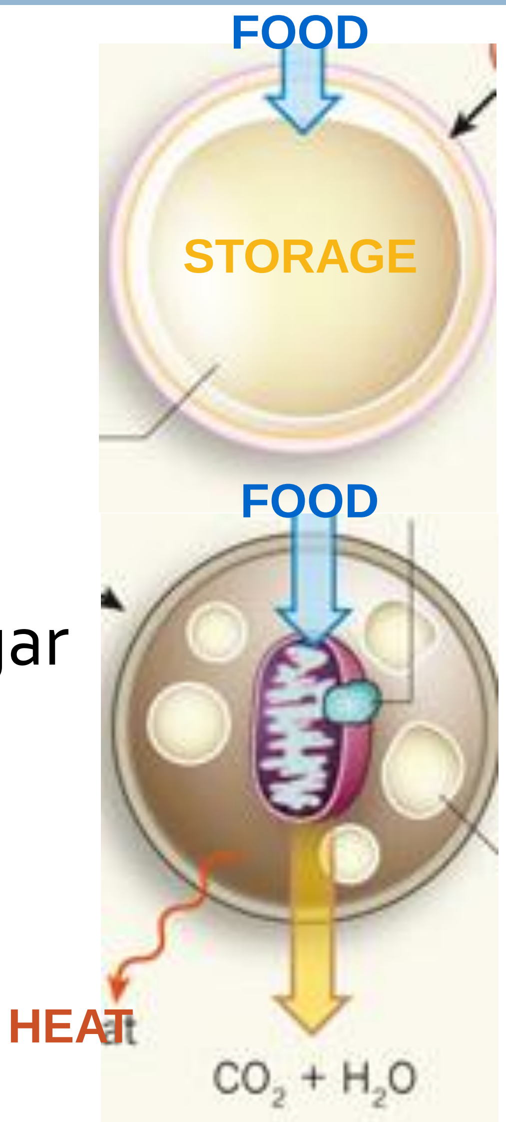
Rate of Metabolic Heat Production: Fat Cell Structure



http://www.diabloclinical.com/wp-content/uploads/fat-cell-color-conversion.jpg

Rate of Metabolic Heat Production: Fat Cell Function

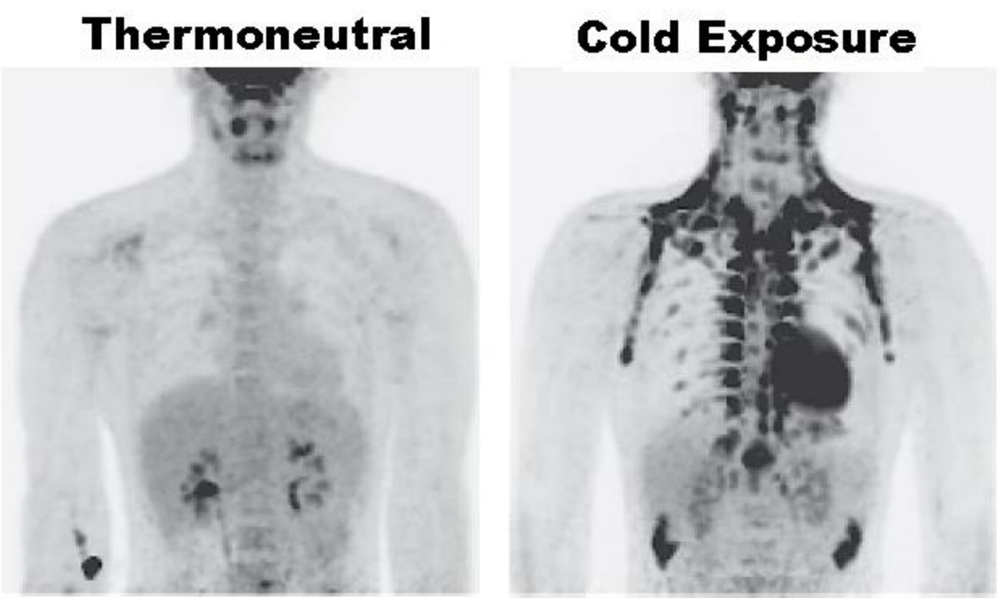
- Normal (white) fat cells:
  - Convert sugar into fat for storage
- Brown fat cells:
  - Mitochondria undergo metabolism converting sugar to ATP and heat
  - Doesn't require insulin to bring sugar to cells



Rate of Metabolic Heat Production

- Non-shivering (adaptive) thermogenesis
- Increased brown fat numbers and brown fat activity
- Hormones can cause mitochondria to increase metabolic activity to produce heat instead of ATP

(Wijers, S. L., Schrauwen, P., Saris, W. H., Lichtenbelt, W. D., & Bartolomucci, A. (2008 March 12). **Human Skeletal Muscle Mitochondrial Uncoupling Is Associated with Cold Induced Adaptive Thermogenesis.** *PLoS ONE*, *3*(3), e1777. http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0001777&representation=PDF)



van Marken Lichtenbelt, W. D., Vanhommerig, J. W., Smulders, N. M., Drossaerts, J. M., Kemerink, G. J., Bouvy, N. D., et al. (2009). **Cold-Activated Brown Adipose Tissue In Healthy Men.** *New England Journal of Medicine*, *360*(15), 1500-1508. http://www.nejm.org/doi/pdf/10.1056/NEJMoa0808718
Studied 10 healthy lean men. They rested in a supine position for one hour at 72°F and then for two hours at 61°F. The activity of their brown adipose tissue was assessed by PET-CT scanning that measured the uptake of a glucose isotope, ^{18}F-fluorodeoxygluxose (^{18}F-FDG). Under the thermoneutral condition of 72°F, very little of the ^{18}F-FDG was taken up by brown fat, as shown by the subject on the left. However, when the temperature was decreased to 61°, brown fat activity was significantly increased (right).

Rate of Metabolic Heat Production

- Torpor: state of low metabolic activity
  - Applied during environmental extremes
  - Conserves energy
- Hibernation: long-term torpor
  - Survive long periods of cold temperatures on limited supplies of energy
  - Body temperature declines
- Estivation: summer torpor
  - Survive long periods of high temperatures or when water is scarce
  - Example: Lung Fish (http://www.youtube.com/watch?v=ZUsARF-CBcI)

Summary of Physiological Thermoregulatory Response

- Cold responses
- Heat stress responses

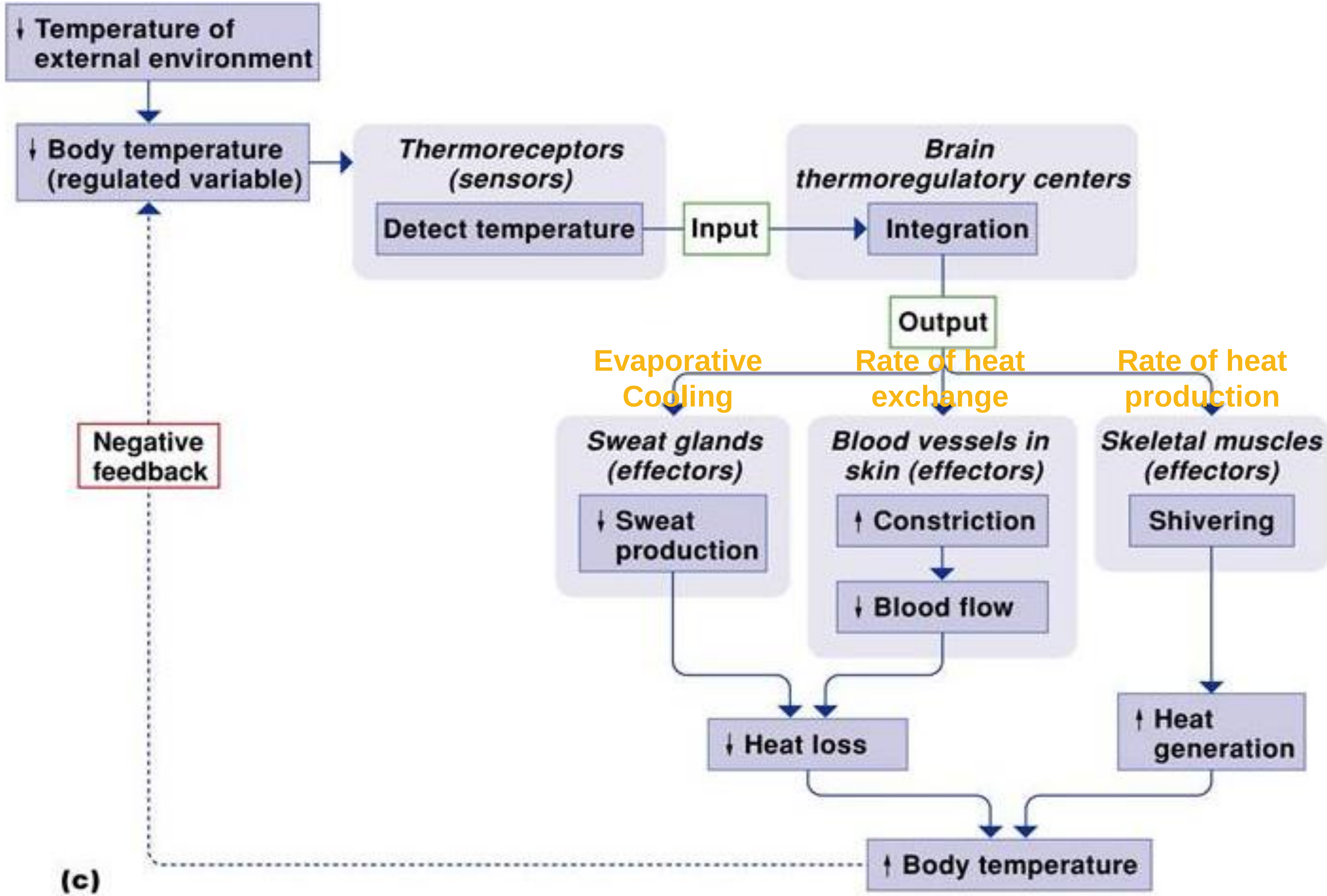
HW: Complete this chart

	Cold Response	Heat Stress Response
Physical adaptations		
Behavioral adaptations		
Circulatory adaptation		
Rate of heat exchange		
Evaporative heat loss		
Rate of heat production		
Rate of metabolic heat production		

Cold Response: Physiological Changes

- Rate of heat exchange decreases
- Evaporative cooling decreases
- Rate of heat production increases
- Rate of metabolic heat production increases

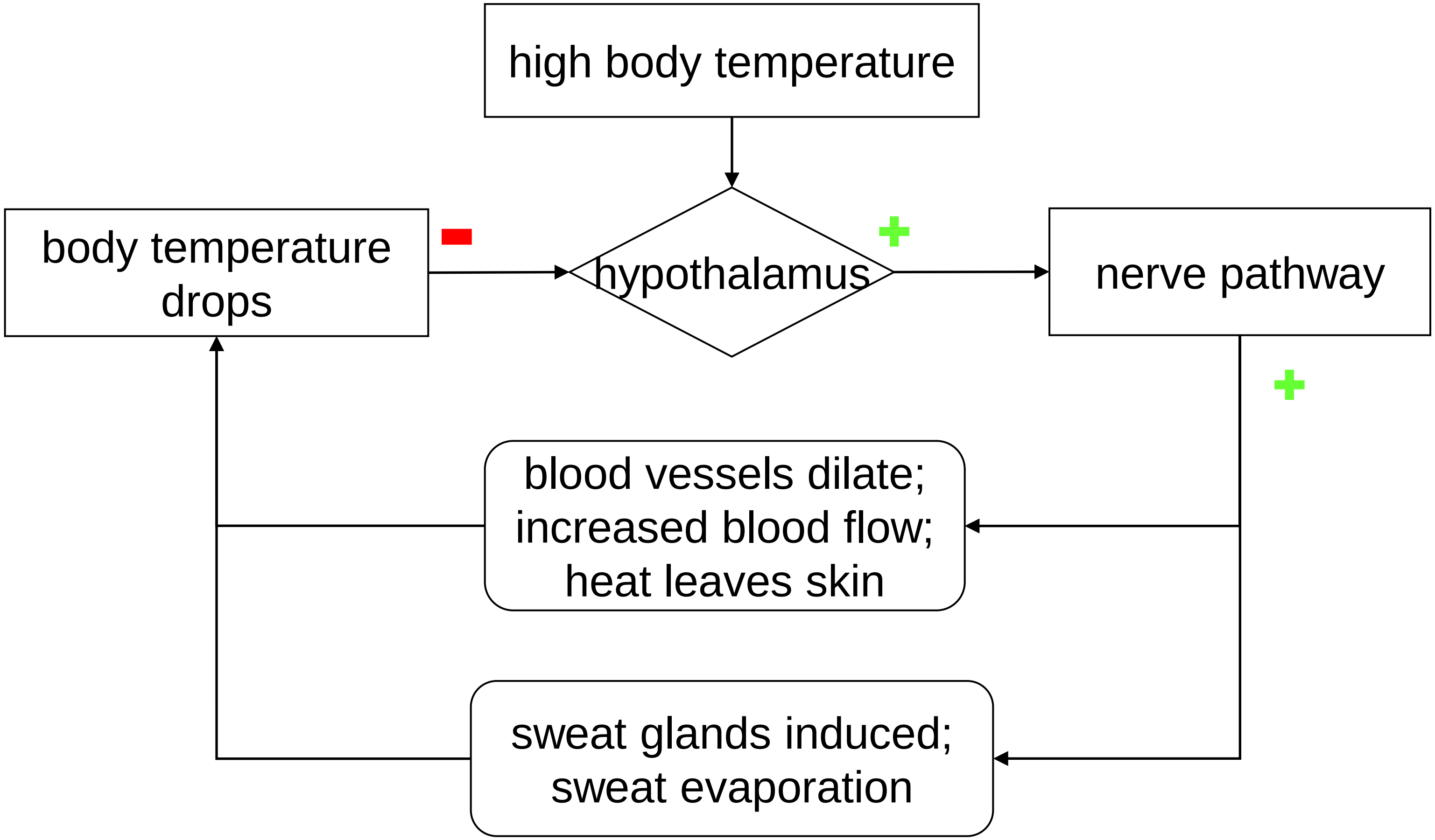
Cold Response: Physiological Changes



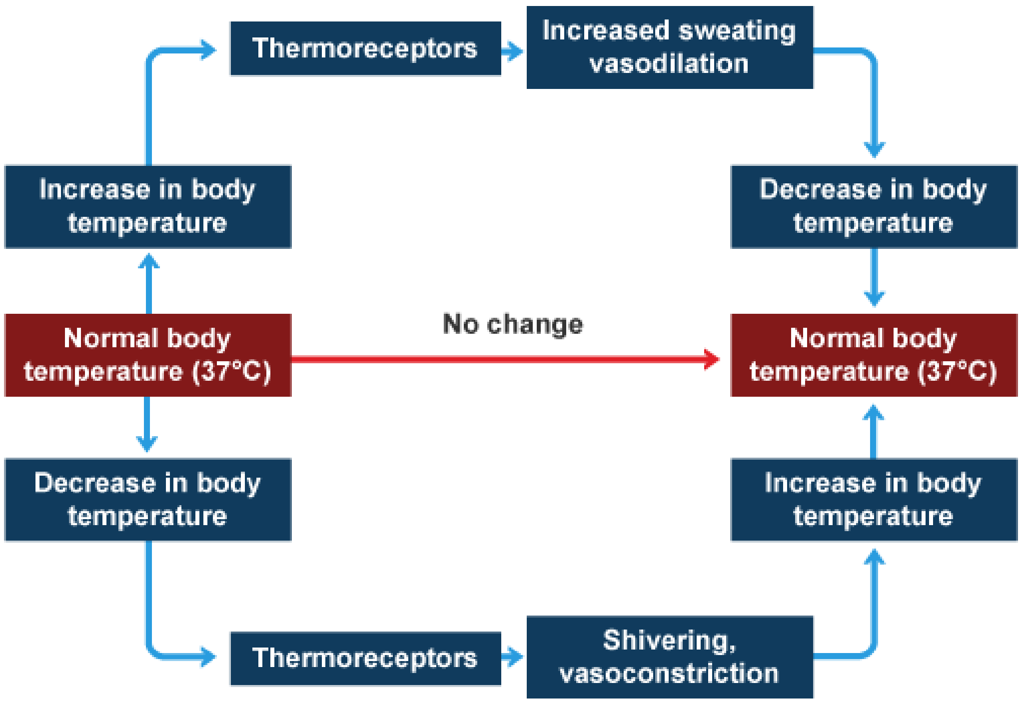
Heat Stress Response: Physiological Changes

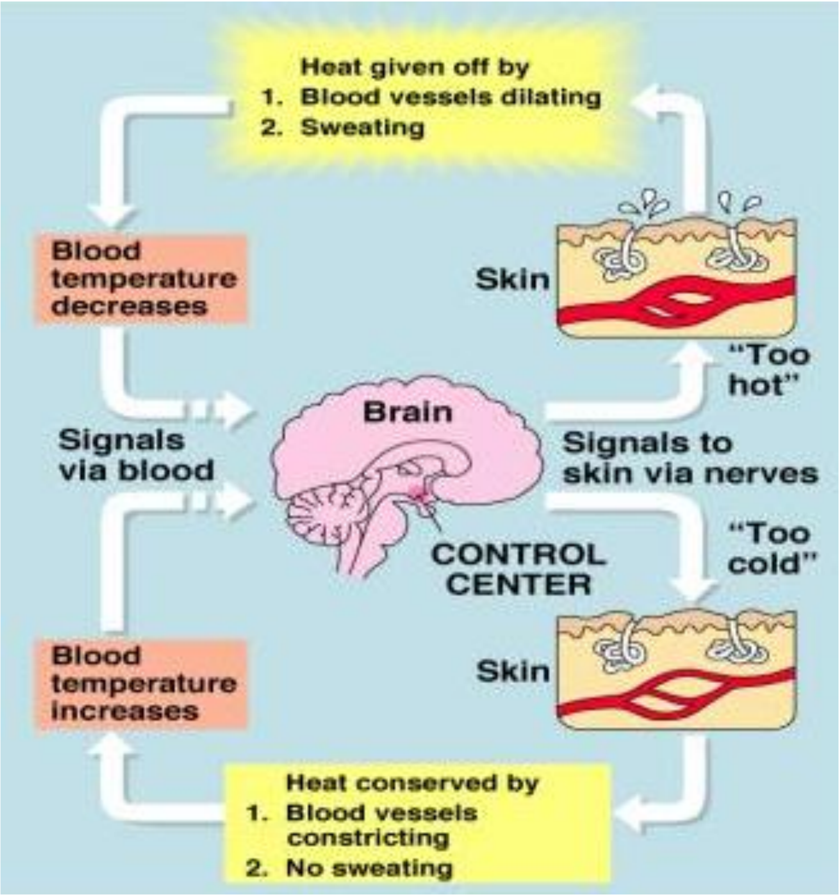
- Rate of heat exchange increases
- Evaporative cooling increases
- Rate of heat production decreases
- Rate of metabolic heat production decreases

Heat Stress Response: Physiological Changes



Physiological Thermoregulatory Response





http://www.bbc.co.uk/bitesize/intermediate2/biology/images/200/113_bitesize_intermediate2_biology_subunit5_metabolic_rate.png

http://bioserv.fiu.edu/~walterm/B/homeostasis/lectur33.jpg

Physiological Thermoregulatory Response Summary

Stimulus	Decrease temperature	Increase temperature
Blood vessels		
Skeletal muscles		
Sweat glands		

Physiological Thermoregulatory Response Summary

Stimulus	Decrease temperature	Increase temperature
Blood vessels	Vasoconstriction: decrease blood flow	Vasodilation: increase blood flow
Skeletal muscles	Shivering	
Sweat glands	Decrease production of sweat	Evaporative cooling: increase sweat

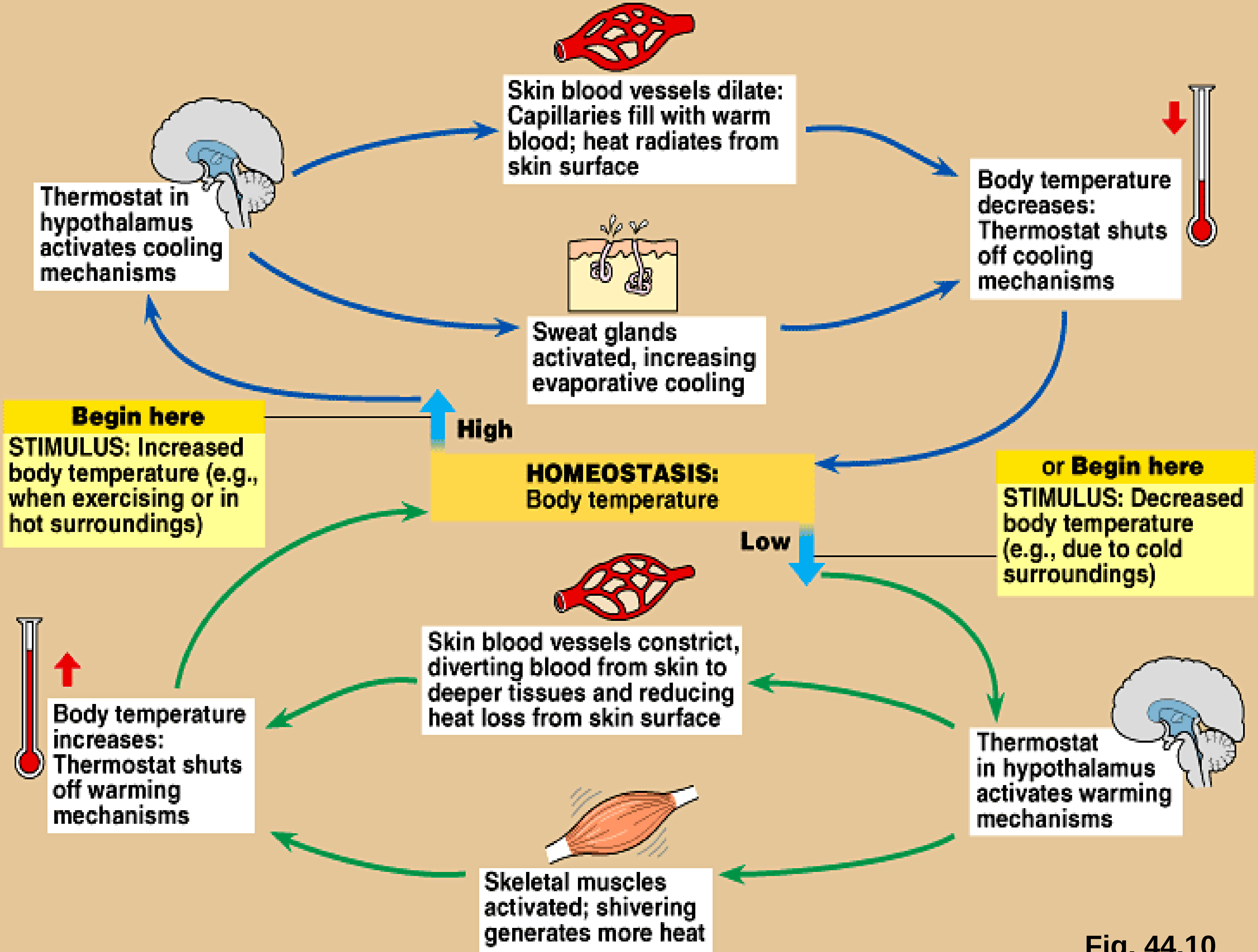

Skin blood vessels dilate: Capillaries fill with warm blood; heat radiates from skin surface
Thermostat in hypothalamus activates cooling mechanisms
Body temperature decreases: Thermostat shuts off cooling mechanisms
Sweat glands activated, increasing evaporative cooling
Begin here
STIMULUS: Increased body temperature (e.g., when exercising or in hot surroundings)
High
HOMEOSTASIS: Body temperature
Low
or Begin here
STIMULUS: Decreased body temperature (e.g., due to cold surroundings)
Skin blood vessels constrict, diverting blood from skin to deeper tissues and reducing heat loss from skin surface
Body temperature increases: Thermostat shuts off warming mechanisms
Thermostat in hypothalamus activates warming mechanisms
Skeletal muscles activated; shivering generates more heat

Fig. 44.10