28 October 2005 **Temperature IV – Temperature regulation** ® R. B.Huey

I. How ectotherms can gain control over body temperature (SN 253-4)

A. To maintain a constant $\underline{T}_b$, an animal must balance (heat in + heat generated) minus (heat lost). Thus for temperature to be held constant (thermal homeostasis), animal must constantly vary many physiological and behavioral systems to gain balance.

B. Endotherms have a "normothermic" temperature, and ectotherms generally have a "preferred" body temperature (determined by placing the animal in a laboratory thermal gradient) that they attempt to achieve (usually) in nature.

C. <u>Behavioral</u> <u>adjustments</u> (chief method by ectotherms, but also used by endotherms) – exploit natural thermal heterogeneity (cold vs. warm spots) in the environment (see last lecture).

1. Adjust time of activity (time of year, time of day when conditions favorable)
2. Habitat selection (open habitats in mountains, shady where hot).
3. Microhabitat selection (top vs. bottom of leaf may have different temperatures.).
4. Sun-shuttling. Bask when $\underline{T}_b$ low, move to shade when $\underline{T}_b$ hot.
5. Posture. Dog curls in ball (reduces surface area). When $\underline{T}_b$ is cold, lizard orients perpendicular to rays of sun to heat quickly. (SN p. 261)
6. Humans control amount of clothing, posture, cuddling, etc.

D. <u>Physiological,</u> <u>morphological</u> <u>adjustments</u>

1. Color change. Dark lizard can achieve $\underline{T}_b$ 5°C warmer than light lizard.
2. **Vasodilation**. Increases cutaneous blood flow. Promotes either heat loss or heat gain. Helps increase convective heat transfer within body (SN 289-90)
3. **Vasoconstriction**. Peripheral flow reduced, reduced convective heat transfer. (In humans, blood flow to skin drops to near zero in cold temperatures)
4. Heart rate. Heart rate is often higher (for a given $\underline{T}_b$) during heating than during cooling, thus increasing convective heat transfer via the blood. This increases rate of heating (achieves optimal $\underline{T}_b$ sooner) and decreases rate of cooling.
5. Piloerection (raising fur, or "ptiloerection" for feathers). Increases insulation and slows heat exchange. Fur thickness changes seasonally. (DN 256-7)
6. Blubber. Fat is a poor conductor (conducts heat only 1/3 as fast as other tissues). Reduces heat loss to water in aquatic animals. (photo on p. 264)
7. Shivering (under central & peripheral control). Increases heat production when an animal's skin/body is cold.
8. Some insects "shiver" flight muscles, thereby warm up before flight.
9. "Non-shivering" thermogenesis. Increased heat production without muscular activity. Main heat producers are liver, kidney, and brain. [**"BAT"** (brown adipose tissue) is a special tissue – its sole function is to produce lots of heat in neonatal mammals and in hibernators during arousal.]
10. Evaporation, of course, from previous lecture

II. Where's the thermostat?

A. Thermoregulation requires ability to monitor $\underline{T}_b$ (<u>sensors</u>), compare it with a reference (set point $\underline{T}_{set}$), and to effect change in behavior and physiology (above) to **oppose** any "error" (e.g., if $\underline{T}_b > \underline{T}_{set}$, animal activates cooling mechanisms).

B. $\underline{T}_{set}$ is not fixed <u>even</u> in endotherms, but varies somewhat with time of day ("circadian rhythms"), fever, hibernation, torpor, food scarcity, etc.

C. Where are the sensors?

1. "Peripheral" (skin, abdomen, spinal cord). Skin has both heat (increase firing rate at high temperature) and cold (increase firing rate at low temperatures) sensitive neurons (may be anatomically distinct).
2. "Central" -- **hypothalamus** (except in birds), spinal cord. (Fig. 12.1)

D. Integration -- "traditional" view is that the primary integrator and activator is the hypothalamus in the base of the brain. If one locally heats this area with tiny "**thermodes"** (water-filled needles), a dog pants and its $\underline{T}_b$ drops. Do the same to a lizard, and it moves to the cool end of a thermal gradient.

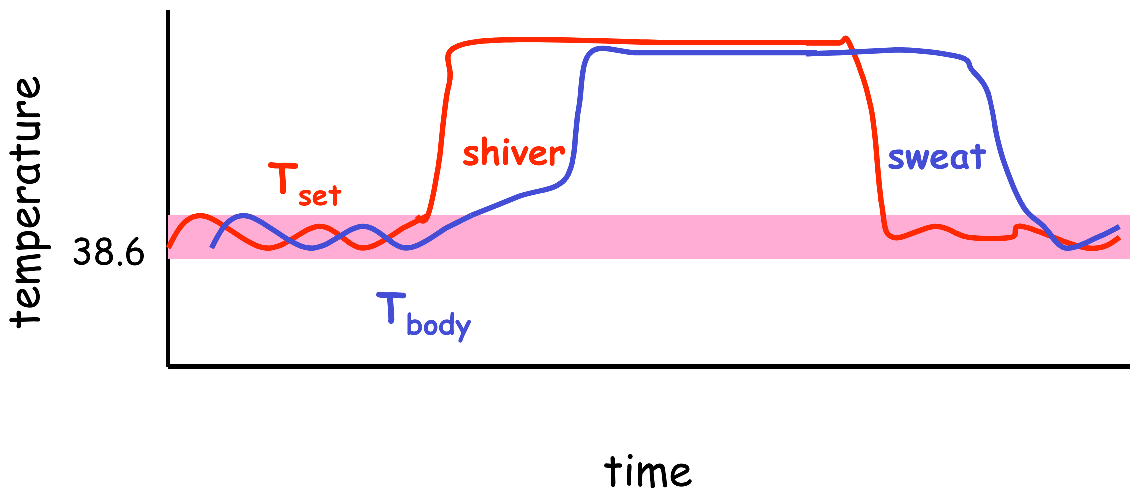
E. Nature of "set-point." Vertebrate hypothalamus has heat and cold sensitive neurons. If they fire in balance, no thermoregulatory response activated. If heat-sensitive neurons fire excessively, cooling effectors (e.g., panting or shade seeking) activated (converse for cold-sensitive neurons).

F. Peripheral sensors are important too. Multiple sensors and controllers may permit finer control of body temperature that would be possible if only the hypothalamus were involved.

III. Fever – is it bad for your health?

A. Fever has historically been considered by western medicine as a "pathological" condition that should be suppressed (e.g., with aspirin). (SN 246)

B. What happens during fever? Set-point temperature is raised. Because $\underline{T}_b$ is now below new $\underline{T}_{set}$, animal feels cold and activates heat-generating and conserving mechanisms (shivering). Conversely, when the fever is "breaking," $\underline{T}_{set}$ is below $\underline{T}_b$, animal feels hot and thus activates heat-loss mechanisms (sweating).



C. Remarkably, fever also occurs in many ectotherms. Inject ectotherm with pathogen, it has a higher preferred temperature. Thus causes a <u>behavioral</u> fever.

D. Fever (low-grade) seems to help fight infection in many ectotherms. Why?

1. Bacteria and circulating leukocytes inadvertently produce "pyrogens"-- polysaccharides that change the **host's** set-point temperature.
2. Higher temperatures increase nutrient requirements of bacteria. At same time, the host actively withdraws iron from its blood.
4. Bacteria are thus "starved" to death. **"Nutrient insufficiency hypothesis."**

E. Thus, **Low-grade** fevers appear adaptive for animals. If your iguana is sick, give it a heat lamp and don't give it iron supplements. **But if you (or especially a child) have a high fever, call a doctor. High-grade fevers can be dangerous.**