Temperature Regulation

WEEK 9, LECTURE 1

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Welcome back! Let’s jump right into our topic for today – Internal Regulation

This lecture series will cover…

Temperature regulation

Thirst

Hunger

This week’s lectures are fairly simple, although we’ll definitely go into the detail behind each process. Here’s what’s on the agenda (see above).

Temperature Regulation

Temperature affects many aspects of behavior

Temperature regulation is vital to the normal functioning of many behavioral processes

Homeostasis refers to temperature regulation and other biological processes that keep certain body variables within a fixed range

- Some birds stand on one foot to keep the foot closer to their body warm
- Toucans' large beaks radiate heat to keep their bodies from overheating

Let's start with temperature regulation, which affects a wide variety of behaviors and is actually really important with regards to other physiological and behavioral processes.

Temperature and many other biological processes are regulated through something called homeostasis, which is a process that keeps certain body variables within a fixed range. This can be accomplished behaviorally – so, for instance, some birds stand on one foot to keep warm – or physiologically – for example, toucans have these really massive beaks that radiate heat and help keep them from overheating.

Homeostasis

Any biological process that keeps body variables within a fixed range

- Examples: temperature, levels of water, oxygen, glucose, calcium, protein, fat, and acidity in the body

Set point: a single value that the body works to maintain

Negative feedback: processes that reduce discrepancies from the set point

- i.e., Negative feedback brings any changes from the set point back up to the set point
- Much of motivated behavior can be described as negative feedback

Homeostasis doesn't just refer to temperature regulation – it can encompass any biological process that keeps specific body variables within a fixed range. Other examples are listed above.

Sometimes this range is so narrow that it's actually just a single value. This is referred to as a "set point".

This set point can vary according to environmental changes and the like, and so we need a process that helps us return to that point: this is known as negative feedback. Your bones help store calcium, and if your body's calcium levels fall below their set point the body will borrow from that storage. If your calcium levels are too high, some excess calcium is stored in the bones, while the remainder is excreted. Both of these methods are examples of negative feedback, which helps return your calcium levels to their set point.

Allostasis

Refers to the adaptive way in which the body anticipates needs depending on the situation

- Helps the body avoid errors instead of just correcting them

Homeostasis is a very *reactive* system, in that it reacts to changes in the body or environment. Something changes and your body reacts – sometimes by generating behavior – to counter that change.

There's also a process that's more *proactive* – it anticipates changes before they occur and makes adjustments accordingly. This is called allostasis, and it helps the body avoid making errors, rather than correcting for them after they've already occurred. A fantastic example of allostasis would be the fight or flight response – it triggers a number of physiological changes in your body that help prepare it for vigorous activity. Both allostasis and homeostasis are important for internal regulation – one isn't necessarily better than the other.

Example: Controlling Body Temperature

Temperature regulation is one of the body's top biological priorities

Maintaining temperature requires twice as much energy as all other homeostatic activities combined

Basal metabolism describes the energy used to maintain a constant body temperature while at rest

So let's tie that all back to temperature regulation. It's one of the body's top biological priorities, and it's actually *incredibly* costly from an energetic standpoint. As stated above, maintaining temperature requires twice as much energy as all other homeostatic activities combined!

In order to maintain a constant temperature, our bodies rely on something called basal metabolism, which is the amount of energy used to maintain a constant temperature *at rest* ("basal" means "base" or "floor"). The average young adult burns around 2000-2600 kilocalories per day on this process alone. This is largely accomplished by burning brown adipose cells (i.e., fat cells), which release energy directly as heat.

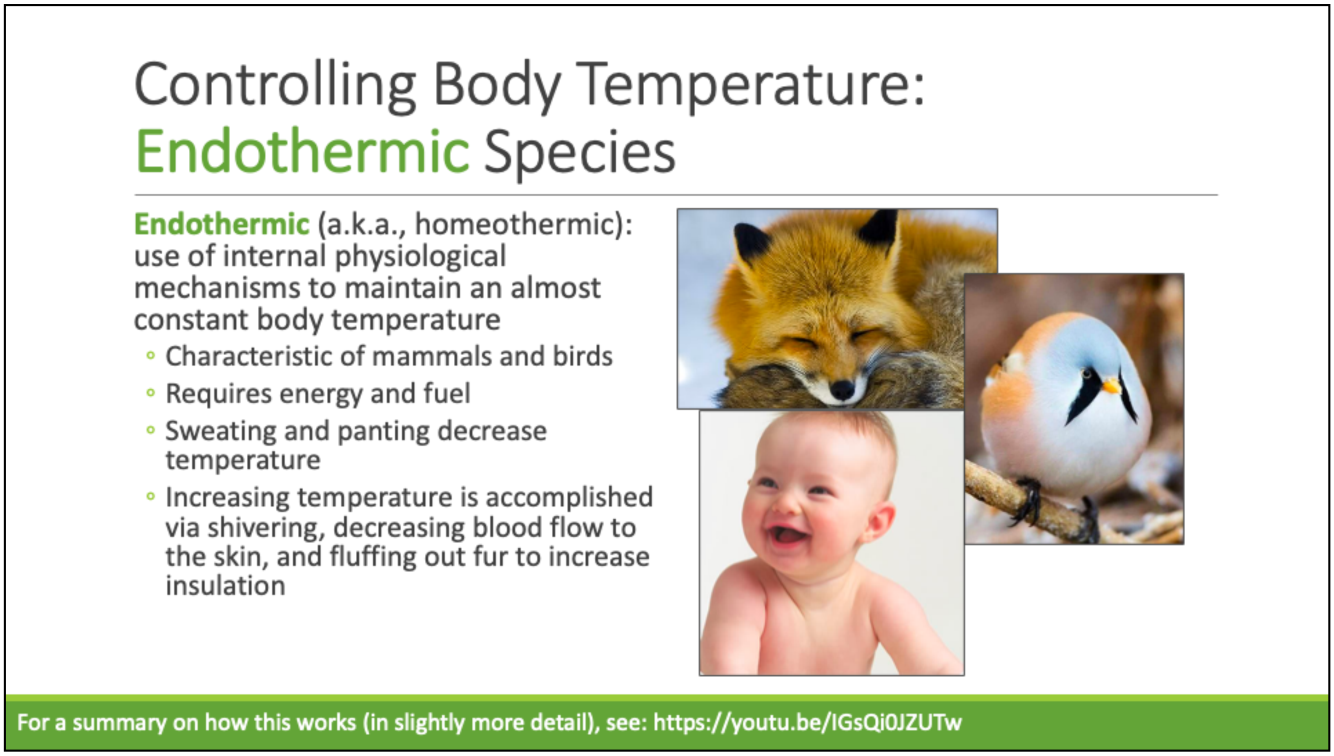
Controlling Body Temperature: Ectothermic Species

Ectothermic (a.k.a., poikilothermic): occurs when the body temperature matches that of the environment

- Includes amphibians, reptiles, and most fish
- Ectotherms lacks the internal, physiological mechanisms of temperature regulation
- Temperature regulation is accomplished via choosing locations in the environment
  - Although known as "cold-blooded," organism is cold only if environment is cold

Snake seeking warmth from an external source

Broadly speaking, there are two ways that organisms maintain a constant temperature. The first type we'll talk about are ectothermic (or "poikilothermic" – be happy you don't have to hear me stumble over this word in a live lecture!) species, which depend on external sources for body heat instead of generating it themselves. You can read more about ectothermic species above.



On the other hand, some species are *endothermic* (or "homeothermic," which is much easier to pronounce), meaning they use internal physiological mechanisms to maintain a constant body temperature.

Most mammals and birds are endothermic. In contrast to ectothermic processes, endothermic processes require more energy to produce. You can read through some examples of endothermic processes above. I'd like you to think about how each of these processes are generated internally (i.e., they don't require an organism to move to a warm or cold spot), and the fact that internal processes use energy.

Endothermic species do not rely solely on internal processes to regulate temperature – they also use behavioral strategies. Examples include putting on or taking off clothes or moving more when it's cold and less when it's hot. These types of behavior help regulate temperature, and as a bonus are much less energetically costly to perform.

Surviving in Extreme Cold

Ectothermic animals

- Death will occur if body temperature drops below freezing
  - Ice crystals form in cells and blood
- Amphibians and reptiles burrow underground to avoid the cold
- Some insects and fish stock blood with antifreeze compounds in winter
  - Extraordinary blood-clotting ability quickly repairs ruptured blood vessels

An alligator in a state of “brumation”

Survival is at a high risk if the external temperature drops below freezing. Humans and other mammals have internal processes to help cope, but what about ectothermic animals? For many of them, the danger is in their blood freezing, which would cause an expansion of blood vessels to the point of bursting.

Ectotherms have evolved some really cool strategies to combat this, which you can read about above.

The alligator shown above, for example, essentially goes into a state of suspended animation – referred to formally as “brumation” – during the winter. It does not engage in any bodily processes besides drinking and breathing, and it moves very little during this time to conserve energy.

The Advantages of Constant High Body Temperature

Mammals evolved to have a constant temperature of ~37˚C (98˚F)

- Muscle activity benefits from being as warm as possible
  - Readies muscles for vigorous activity

If warmer is better, why not have higher baseline temperatures?

- There are costs to having temperatures that are too high!
- Requires even more energy
- Proteins in the body break their bonds and lose their useful properties at higher temperatures
- Reproductive cells require cooler temperatures

Mammals have a relatively high internal body temperature, compared to other types of organisms. This has a particularly strong benefit: it keeps slow-twitch muscles active, which keeps us from relying on short bursts of vigorous activity from fast-twitch muscles. We can run away more easily than ectothermic animals, even in cold temperatures.

However, maintaining a high internal body temperature also comes with several costs, which you can read about above. As with many, *many* evolved processes, there is a trade-off with having a high baseline body temperature.

Brain Mechanisms: POA/AH

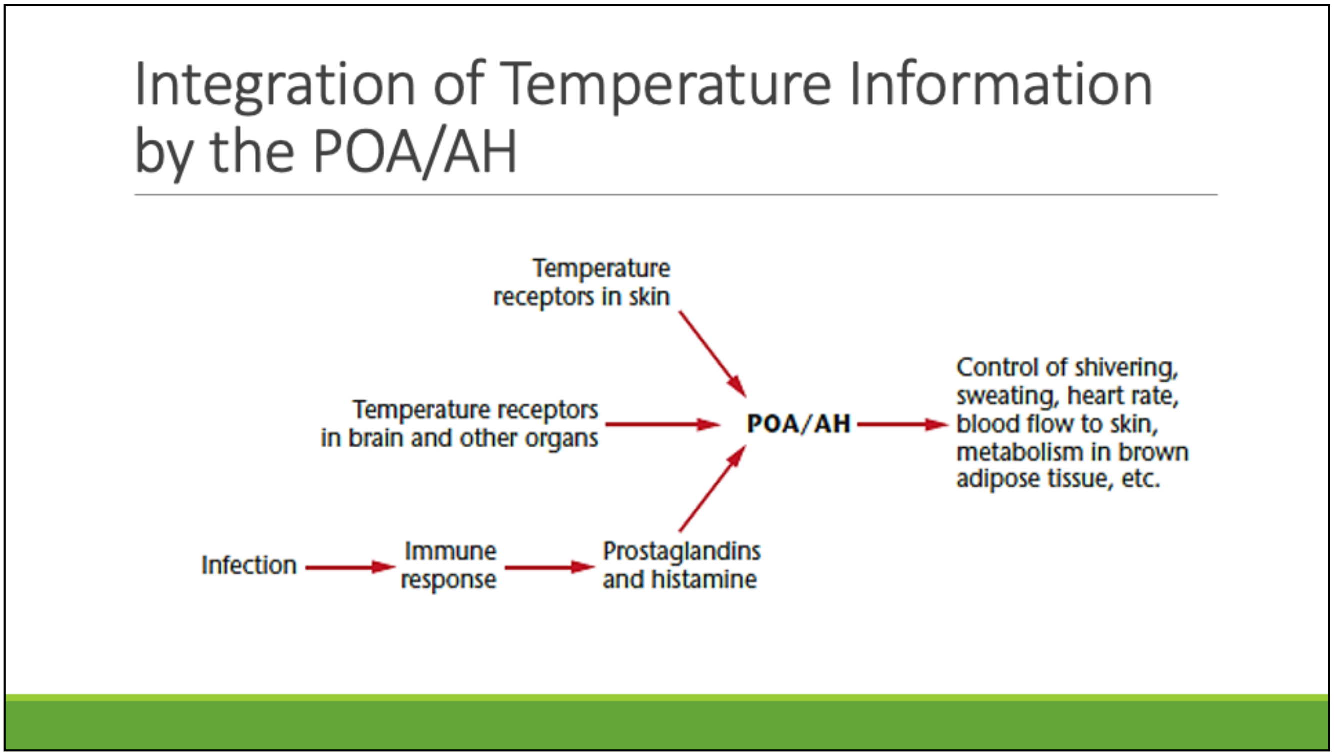
Body temperature regulation is predominantly dependent upon areas in the **preoptic area**/**anterior hypothalamus** (POA/AH)

The POA/AH receives input from temperature receptors throughout the body

- Sends output to the raphe nucleus (in the hindbrain), which controls responses to heat/cold
- Heating the POA/AH leads to panting or sweating; cooling leads to shivering
  - This is the primary area for controlling sweating and shivering
- Also receives input from the immune system → receiving increased prostaglandins and histamines and causes shivering, increased metabolism and fever

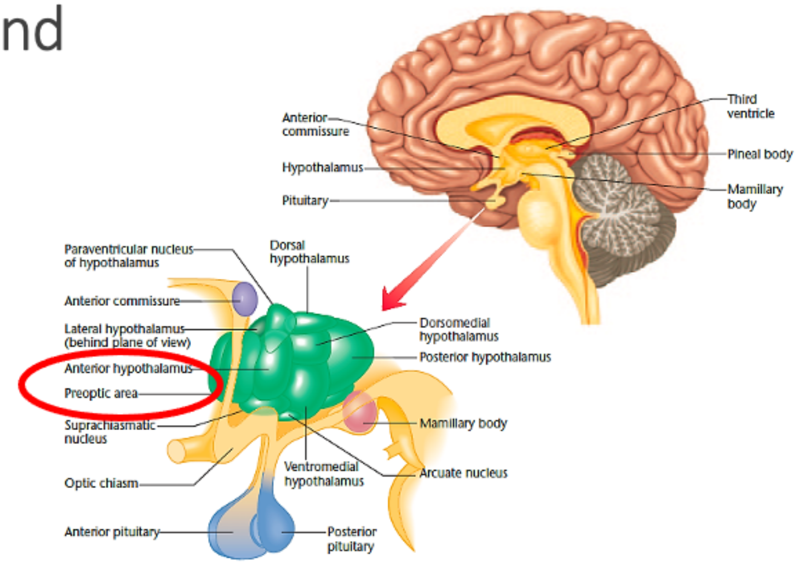
So that was a bit of an introduction to different methods of temperature regulation. Let’s talk about the brain mechanism that actually control these processes.

The main area involved here is a complex known as the POA/AH, which you can read about above. You can see how it triggers internal process like sweating or shivering in response to external changes in temperature. And, as stated above, it can also regulate temperature based on signals from the immune system – meaning it can control things like a fever response.



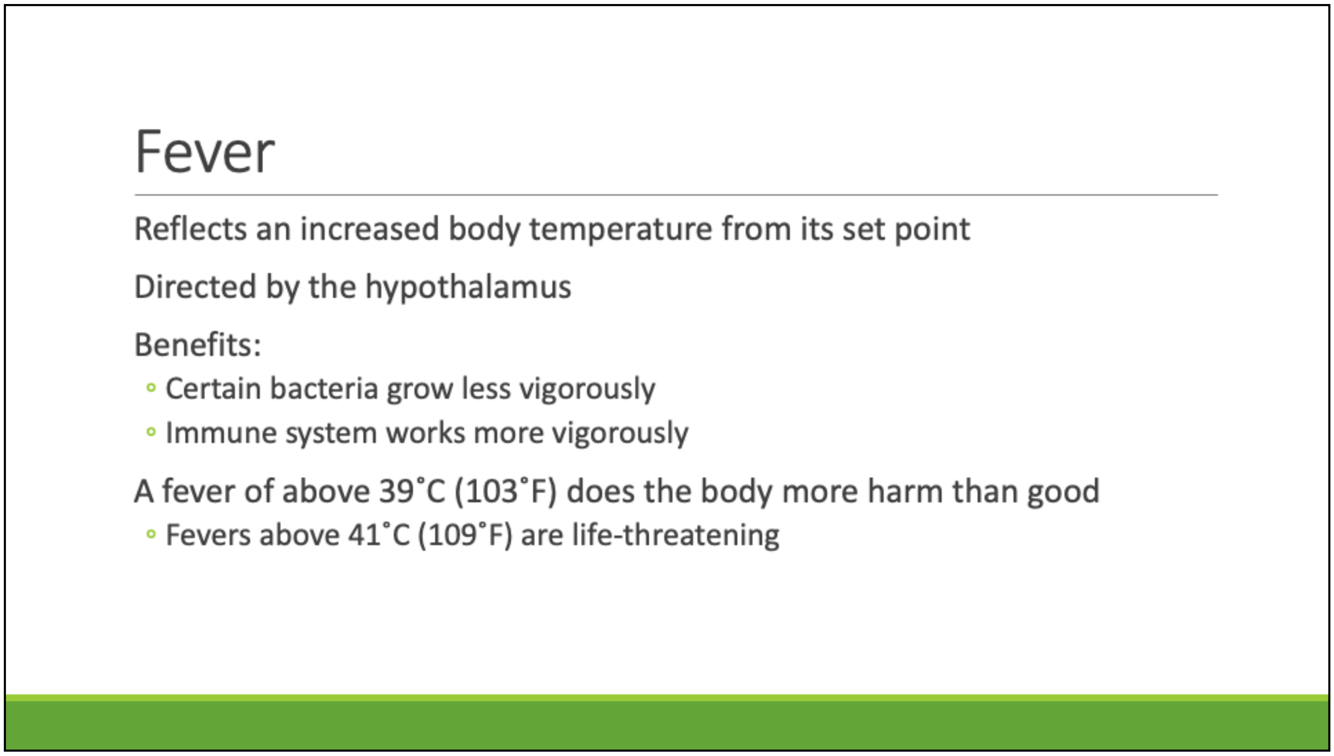
Here's a handy diagram of how this process plays out. If the brain and skin become too hot, the POA/AH sends signals that lead to sweating and other methods of heat loss. Conversely, if the brain and skin become too cold, or if the immune system indicates an infection, the POA/AH initiates shivering, increased heart rate, decreased blood flow to the skin, and increased metabolism via brown adipose tissue.

Major Subdivisions of the Hypothalamus and Pituitary Gland



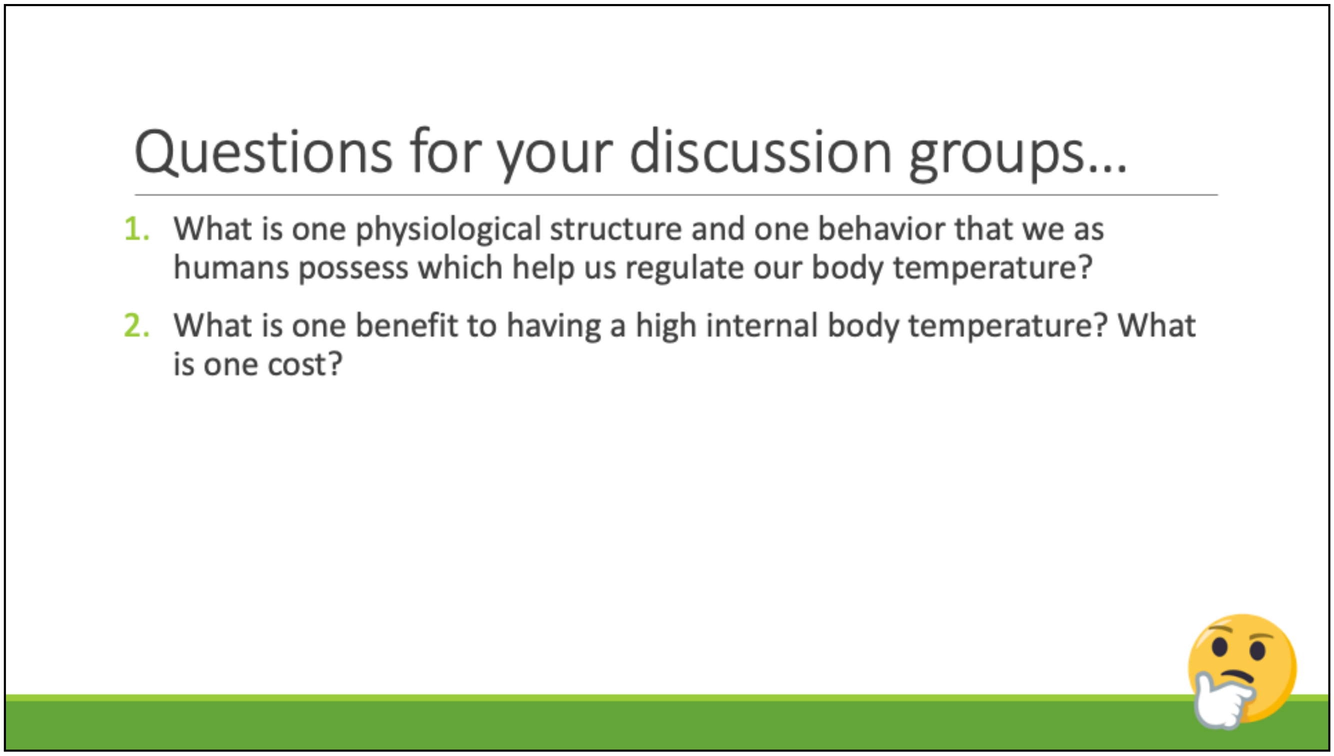
The book provides you with a diagram of the hypothalamus and pituitary mainly to provide you with some context as to where all of these structures are located. You don't need to memorize this diagram, but hopefully it'll help you place these areas when you're thinking about them. I've circled the relevant areas to help you place them.

I'd also like you to think about the broader functions of the hypothalamus as we discuss these processes. Remember, the hypothalamus is a structure mainly in charge of signaling the release of specific hormones to different areas of the body.



As I mentioned a few slides ago, the POA/AH complex can initiate a fever in response to signals from the immune system. You can read about it above.

I'd like to highlight that fevers are actually beneficial – they improve the functioning of the immune system while simultaneously inhibiting the growth of bacteria. However, this area of the brain will continue to raise body temperature as part of an immune response, and after a certain point a fever will actually do more harm than good. This is, I think, especially relevant to the circumstances we're all facing today – one of the major guidelines for Covid-19 is that you seek medical help if you have a fever of 104 degrees or more. At this point, the fever is actually working against you, and medical intervention can help fight off the disease and bring the fever down to a more manageable level.



Okay, short lecture to kick it off this week! Here are a couple of questions for your discussion group. I'll see you in the next lecture, on thirst!