Lecture 6. Endothermy and thermoregulation

Class Business

- THIS CLASS HAS MOVED TO ROOM 106 IN THE BUSINESS BUILDING!!!

Reading for this lecture

Required. Gill: Chapter 6, p. 150-164.

1. Some definitions

A) BIRDS ARE BOTH HOMEOTHERMIC AND ENDOTHERMIC

i) **Homeothermic** means that they can maintain a constant (high) body temperature.

ii) **Endothermic** means that they can maintain their (high) body temperature by creating heat through metabolic means.

iii) Note that the terms "warm-blooded" and "cold-blooded" should be avoided (DO NOT USE THEM IN EXAMS!) because they are rather misleading – e.g., ectothermic (so called "cold-blooded") reptiles can be very warm, they just lack the ability to use their metabolism to stay warm all the time.

iv) And, just to complicate matters, some birds are not always homeothermic and do allow their body temperatures to fluctuate. See section 4 below.

2. Endothermy in birds

A) BIRDS ARE REALLY HOT

i) Birds have body temperatures that range from about 40-44°C (104-111°F).

ii) 80% of all bird species are warmer than the warmest 10% of mammal species.

B) ADVANTAGES

i) A primary reason for endothermy is that it allows an animal to maintain high activity levels at all times. Consequently, birds are able to remain active throughout the day, throughout the year, and throughout the world. This is not true for ectothermic animals.

ii) High body temperatures also confer important advantages to birds. At higher temperatures, nerve impulses travel faster, muscle strength is increased, and physical endurance is greater. These advantages are very important for flight and allow birds to live the lives that they have.

C) DISADVANTAGES

i) The price of endothermy is that it requires a high metabolic rate and is energetically very expensive. Consequently, birds need to eat at a far higher rate than similar-sized reptiles.

ii) Very high body temperatures also have their problems. Temperatures as high as those of birds are very close to the temperature above which proteins begin to denature and cells begin to die (~46°C). Consequently, birds need to be able to avoid overheating or they will cook their brains!

3. Defending body temperature

A) HEAT FLUX

i) Heat is produced by metabolic activity within the body. In addition, birds can obtain extra heat in the same way that their ectothermic ancestors did, by basking in the sun and absorbing solar radiation.

ii) Heat is lost from the body through both **conduction** (heat exchange with a substrate: loss is due to contact with a cooler substrate) and **convection** (heat exchange with the air: loss is due to warming of the surrounding colder air; this form of heat loss increases if the air is moving).

B) METHODS FOR ALTERING BODY TEMPERATURE

i) Change location. This can take many forms, ranging from moving to somewhere with a more favorable microclimate (e.g., a position that is out of the wind) to migrating thousands of miles (e.g., between the Arctic and the tropics).

ii) Change position. By increasing its functional surface area (e.g., by spreading its wings) a bird can alter the rate of heat exchange between its body and the environment. Also, birds can alter their position relative to the sun or the wind and adjust the amount of heat gain (through solar radiation) or heat loss (through convection).

iii) Manipulate feathers. Feathers are a key source of insulation for birds, and they are extremely well suited for allowing birds to adjust their level of insulation. Birds can erect their feathers to increase the amount of air that they trap (improves insulation in cool weather) or they can compress them against the body (to reduce insulation in hot weather) If it is very hot then the feathers can be raised high enough to expose skin and increase convective heat loss. Birds also can increase the amount of feathering seasonally to help deal with

winter weather. Feather color also influences heat exchange. In general, pale feathers reflect heat, while dark feathers absorb heat (though see the text book for complications that are caused by wind).

iv) Alter breathing. By slowing their breathing rate birds can reduce heat loss (because heat is lost in the air that they breathe out). Panting can be used to offload heat because it raises ventilation rate and increases the amount of evaporative cooling from the upper respiratory tract. Also, birds can reduce heat loss to the air that they breathe in by tucking their bills inside their plumage. This allows them to breathe warm air that is trapped among their feathers and thus avoid breathing colder air at ambient temperatures.

v) Use extremities. Some birds – especially waterbirds – can adjust their heat loss using their legs and feet. Much heat can be lost through the legs, thus reducing the risk of overheating. When the temperature is cold, birds can largely eliminate this heat loss, by altering the blood flow into the legs and using a "countercurrent" heat exchange system.

vi) Expend energy. If other methods fail, then birds can use energy (increase their metabolism) to defend their body temperature, e.g., by shivering.

C) TEMPERATURE REGULATION (see – and make sure you understand – Fig 6-11 in Gill)

i) When birds are in the **thermoneutral zone** their metabolic rate is constant. If temperatures drop below the **lower critical temperature (LCT)** energy expenditure (metabolism) needs to increase in order for birds to maintain their body temperature. Similarly, if temperatures rise above the **upper critical temperature (UCT)**, birds need to expend extra energy to off-load excess heat.

ii) Note that the LCT and UCT vary among species.

4. Hypothermia and torpor

i) In order to save energy (e.g., overnight), some birds will simply allow their body temperatures to drop a few degrees. This physiological state is referred to as **hypothermia** and appears to be quite normal in some birds.

ii) In some extreme cases, certain birds will allow their body temperature to drop considerably. Common Poorwills for example can reduce their body temperature to below 10°C. Under these conditions many physiological processes largely shut down and the birds become unresponsive. But, these birds do not become ectothermic and dependent on the environment to determine their body temperatures. They are still able to maintain their body temperatures in a controlled way and to raise it back to a normal level when they need to. Most species that use torpor are very small (e.g., chickadees, hummingbirds).