Physiology

- The internal systems of metabolism and excretion, which sustain daily activities and adapt individuals to their environment, are collectively called physiology.

Birds are high performance vertebrates

- The power and endurance for flight are made possible by high metabolic rates.
- High metabolic rates are costly:
  - High constant body temp
  - High energy consumption
  - High water consumption
- Many unique adaptations:
  - Temperature regulation
  - Water conservation
  - Respiratory system
  - Circulatory system

Why high temperature?

- Birds average 41°C:
  - Cost = energy, O₂, waste
  - 20 – 30X > reptiles
  - Proteins break down at 46°C

Why?

- Rates of physiological processes increase:
  - Nerve impulses 1.8X/10°C
  - Muscle contraction 3X/10°C

Adaptations of the respiratory system

- Air sacs:
  - Throughout body, even wing and leg bones
  - 1-2 cells thick
  - Allows unidirectional air flow
Flow-through lungs

- Two full in/out respirations required before air is exhaled
- Fresh air passes over the lungs continuously

Adaptations of the circulatory system

- 4-chambered heart
- Compared to mammals
  - 50 – 100% larger
  - Heart rates slower but blood flow similar due to larger stroke volume
  - Blood pressure 2X higher

Metabolic adaptations

- Metabolic rate is inversely related to mass
- The primary cause is the relationship between surface area and volume

Temperature regulation

- TNZ – metabolic rate does not change with temp
- <LCT – metabolic rate increases to raise temp, shivering
- >UCT metabolic rate increases to lower temp, evaporative cooling
Response to cold stress

- Acclimatization
- Behavior
- Hypothermia and torpor

Response to heat stress

- Adaptations
  - Evolutionary
  - Behavioral
  - Anatomical
- Evolutionary
  - Downy Woodpecker: body size increases with latitude, but birds in hot humid Mississippi Valley are smaller than birds at similar latitudes to the east or west

Response to heat stress

- Behavioral
  - Exposing bend of wing
  - Panting
  - Wetting abdomen
  - Exposing legs
  - Raising or lowering feathers

Response to heat stress

- Anatomical Adaptations
  - Gular fluttering
  - Shunt and counter-current blood flow to feet
Water economy

- High body temperature and reliance on evaporative cooling require water
  - Small species lose >35% of body weight/day due to evaporative cooling
  - Rates of water loss increase dramatically when temperature increases

Excretory system aids water economy

- Birds excrete nitrogen as uric acid vs urea (mammals)
  - Uric acid is a paste with 2X concentration of nitrogen and 20X savings in water vs urea
  - Cloaca reabsorbs water to yield concentrations of uric acid 3000X that found in blood

Salt glands conserve water