Topic 13: Energetics & Performance

- How are gas exchange, circulation & metabolism inter-related?

Gas Exchange
- How is it done in air and water?
- What organs are involved in each case?
- How does ventilation differ among taxa?

Circulation
- What are the main components of circulation?
- How does circulation work?
- How does the anatomy of the heart differ among taxa?

Metabolism
- What are the different types of metabolic rates?
- What are the two types of metabolism?
- How is performance influenced by temperature?

How are gas exchange, circulation & metabolism inter-related?

- What are the components of the gas exchange system?
- What are the components of the circulatory system?
- How are gas exchange, circulation & metabolism interrelated?

Mammalian circulation – ignore the details
How are gas exchange, circulation & metabolism inter-related?

Mammalian circulation – ignore the details

© McGraw-Hill
Gas Exchange

- Two main purposes
  - From environment to tissues
  - From tissues
- Gas exchange occurs in both air and water
  - Amphibians do this in both air and water

Gas Exchange

- Two types of structures for respiration
  - Lungs
  - Gills, skin, pharynx, cloaca
- Amphibians have many non-pulmonary gas exchange structures (also often lungs)
- Reptiles have predominantly pulmonary gas exchange

Gas Exchange

- Non-pulmonary: Amphibians
- Gas exchange and water balance are related through same structures
- Gas exchange structures:
  - Plethodontids (cutaneous respiration)
  - All amphibians
  - Especially hellbender, hairy frog
  - All larval amphibians
  - Paedomorphic adults

Gas Exchange

- Non-pulmonary: “Reptiles”
- Not prevalent because of keratinized skin
- Hydrophiinae (sea snakes)
  - Some Testudines
    - Has _________ lined with villi
    - Pump water in and out of bursae ~80 times/minute

Gas Exchange

- Pulmonary – using lungs
- Widespread (obviously)
- Requires _________ of the lungs
  - Exhalation of O₂ poor, CO₂ rich air
  - Inhalation of O₂ rich, CO₂ poor air
- Most amphibians use _________

Gas Exchange

- Pulmonary ventilation
- Lepidosaur use _________
  - Expansion of thoracic cavity creates negative pressure
  - Inhalation
  - In lizards, air moves between lungs during locomotion
  - In snakes, pressure changes
    - In ___________ lung where gas exchange occurs
    - Not much in _________ part, where air is stored
Gas Exchange

- Pulmonary ventilation
  - Testudines have a rigid shell
  - Tail is ventral size of visceral cavity, facilitating ventilation
  - Crocodilia use the liver
  - M. diaphragmaticus pulls liver anteriorly
  - This compresses lungs, leading to exhalation

Pough et al. 2004, Fig 7-7

Circulation

- Components of the circulatory system
  - Heart
  - Vessels (veins, arteries, capillaries)
  - Blood

- The heart pumps the blood through the vessels to:
  - Lungs/gills
  - Organs
  - Muscles

- Transports mammalian circulation — ignore the details

© McGraw-Hill

Circulation

- Circulation pattern depends on gas exchange structure

- Gills (larval amphibians)
  - Heart
  - O₂-poor blood goes to gills
  - O₂-rich blood goes to body
  - Same as fishes

www.universe-review.ca

Circulation

- Lungs (most others)
  - Heart
  - Pulmonary circuit has lower blood pressure than systemic circuit

- Variation in how heart is divided among taxa

www.universe-review.ca

Circulation

- Variations in heart morphology: Anura
  - 3 chambers
    - __________

- Oxygenated and deoxygenated blood mix in heart!

- Channels formed by trabeculae help keep O₂ rich and poor blood separate

- "Good enough" for slower metabolism

Photo © EJ Backman

Pough et al. 2004, Fig 7-8

© McGraw-Hill
**Circulation**

- Variation in heart morphology: Testudines & Squamata
- 3 chambers (2 atria, 1 ventricle)
- Ventricle subdivided into 3 chambers:
  - Abroventricular valve blocks interventricular canal between CA & CV
  - Muscular ridge divides CV & CP

**Circulation**

- What are shunts for?
  - Controlling pH
  - Can supply more oxygen to tissues when animal is not breathing
  - Controlling amount of blood in the systemic circuit affects heating and cooling rates
  - R-4-L shunt: Blood bypasses the lungs during diving, etc.

**Metabolism**

- The use of sugars to produce energy
  - This energy is used for:
    - Movement
    - Reproduction
    - Anything else the animal does

- Sugars are transported to cells by
- Sugars are metabolized in

**Metabolism**

- Maximum metabolic rate occurs at maximum aerobic speed (MAS)
  - During sustainable activity
    - Glucose is metabolized
    - Water and CO₂ are produced
  - During unsustainable activity
    - Glycogen is metabolized
    - Lactate is produced, leading to fatigue
Metabolism

- All metabolism produces ATP, which is used as energy.

**Aerobic**
- 1 sugar $\rightarrow$ 35 ATP + CO2 + H2O
- Efficient but slow
- Good for sustained activity

**Anaerobic**
- 1 sugar $\rightarrow$ 3 ATP + Lactic Acid
- Inefficient but fast
- Good for short term, high output activity

Sceloporus jarroviuse glycolytic metabolism during territorial defense

- Routine activity
  - Little _____ build up.
- Territorial defense
  - Intense
  - Includes running and biting other males
  - [Lactate] proportional to # bites/minute

Temperature affects performance in ectotherms

- Affects locomotion in Phelsuma dubia
- At high temps, they take ___________
- Stride duration is affected by how fast muscles can ___________
- Stride length is ___________

Post-meal metabolism in snakes

- Digestion uses a lot of energy, especially when meal is big
- Some pythons consume ~10X more oxygen at peak digestion

- Also, intestine of a fed snake:
  - More blood
  - More mucous
  - Thicker intestinal lining
Metabolism

- Calling in frogs is also energetically expensive

- The higher the calling rate, the higher the metabolic rate
  - Some call 1500X/hour
  - VO₂ increases 10X

?; Pough et al. 2004, Fig 7-18

---

Metabolism

- Calling in frogs is energetically expensive...

- ...but is it worth it?

Pough et al. 2004, Fig 7-19, 7-20