Basic Principles of Animal Form & Function

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Animal form and function are correlated at all levels of organization

- Physical Constraints on Animal Size and Shape
- Exchange with the Environment
- Hierarchical Organization of Body Plans
- Tissue Structure and Function
- Coordination and Control
- Regulating and Conforming
- Homeostasis

Physical Constraints on Animal Size and Shape

- Physical laws constrain evolution
  - An example of this would be water
    - Water is denser than air therefore any bump on the surface of a water animal can slow the animal down
- Animal body plans with regard to size
  - As body dimensions increase, thicker skeletons are required to maintain strength
  - As bodies increase in size, the muscles required for movement have to increase in size as well

Exchange with the Environment

- Exchanges occur when a substance is dissolved in an aqueous medium move across the plasma membrane of the cell
- The opportunity for exchange is strongly influenced by cell number
- Animals with a simple internal organization have a body plan that enables direct exchange between external environment and nearly all cells
- Animals with a more complexed body system adapted to sufficient exchange with the environment
- Internal body fluids link exchange surfaces to body cells
- Interstitial Fluid: the spaces between cells are filled with fluid
- Complex body plans have distinct benefits over simple ones

Hierarchical Organization of Body Plans

- Tissues: groups of cells of similar appearance and a common function
- Organs: different tissues are further organized into functional units
- Organ System: groups of organs that work together provide an additional level of organization and coordination
- Organs often contain tissues with distinct physiological roles
- Sometimes the roles are different enough that they are considered to be in more than one organ system
- Looking at the hierarchy of the body's organization from top to bottom shows emergent properties that underlie organ systems
- The specialization characteristic of complex body plans is based on varied combinations of a limited set of cell and tissue types

Tissue Structure and Function

- Epithelial Tissue: covers the outside of the body and lines organs and cavities within the body
  - The close packing of these cells help with a barrier against mechanical injuries, pathogens, and fluid loss
  - Epithelium: the cells of an epithelial tissue
- Connective Tissue: to bind and support other tissues in the body
  - Consists of a sparse population of cells scattered through and extracellular matrix
  - 6 major types of connective tissue
    - Loose connective tissue
    - Cartilage
    - Fibrous connective tissue
    - Adipose tissue
    - Blood
    - Bone
  - 3 connective tissue fibers
    - Collagenous: provide strength combined with flexibility
    - Elastic: easily stretched but are resilient
    - Reticular: very thin and branched
  - 2 predominate connective tissue cells
    - Fibroblasts: secrete the protein ingredients of the extracellular fibers
    - Macrophages: cells that roam the maze of fibers, engulfing foreign particles and the debris of dead cells by phagocytosis
- Muscle Tissue: the tissue responsible for nearly all types of body movement
  - Consist of filaments containing the proteins of actin and myosin, which enable muscle cells to contract
  - 3 types of muscle tissue
    - Skeletal
    - Cardiac
    - Smooth
- Nervous Tissue: to sense stimuli and transmit signals in the form of nerve impulses from one part of the animal to the other
  - Neurons: nerve cells
  - Glial Cells/Glia: help nourish, insulate, and replenish neurons

Coordination and Control

- 2 major systems
  - Endocrine System
    - Signaling molecules released into the bloodstream by endocrine cells reach all locations in the body
    - Hormones: signaling molecules broadcast throughout the body
      - Depending on which cells have receptors for that hormone, the hormone may have an effect in just a single location or in sites throughout the body
  - Nervous System
    - Neurons transmit information between specific locations
    - Each signal, called a nerve impulse, travels to a target cell along a dedicated communication line, consisting mainly of the neuron extensions called axons
    - 4 types of cells receive nerve impulses
      - Other neurons
      - Muscle cells
      - Endocrine cells
      - Exocrine cells
    - Involves more than one type of signal

Feedback control loops maintain the internal environment in many animals

- Regulating and Conforming
  - Regulator: uses internal control mechanisms to regulate internal change in the face of external fluctuation
  - Conformer: allows its internal condition to conform to external changes in the variable
- Homeostasis: “steady state” or internal balance
  - Mechanisms of Homeostasis
    - Set Point: maintaining a variable, such as body temperature or solute concentration, at or near a particular value
    - Stimulus: fluctuations in the variable above or below the set point
    - Sensor: receptor
    - Response: physiological activity that helps return the variable to the set point
  - Feedback Loops in Homeostasis
    - Negative Feedback: a response that reduces the stimulus
    - Normal Range: upper and lower limit
    - Positive Feedback: triggers mechanisms that amplify rather than diminish the stimulus
  - Alterations in Homeostasis
    - The set points and normal ranges can change under various circumstances
    - Some changes are associated with a particular stage of life
    - Acclimatization: the process by which an animal adjusts to changes in its external environment

Homeostatic processes for thermoregulation involve form, function, and behavior

- Thermoregulation: the process by which animals maintain an internal temperature within a tolerable range
- Endothermy and Ectothermy
- Variation in Body Temperature
  - Animals can have a variable or constant temperature
- Balancing Heat Loss and Gain
- Acclimatization in Thermoregulation
  - Cells may produce variants of enzymes that have the same function but different optimal temperatures
- Physiological Thermostats and Fever

Endothermy and Ectothermy

- Endothermic: they are warmed mostly by heat generated by metabolism
- Ectothermic: they gain most of their heat from external sources
- Endothermic animals can maintain stable body temperatures even in the face of large environmental temperature fluctuations

Balancing Heat Loss and Gain

- 4 physical processes
  - Conduction
  - Convection
  - Radiation
  - Evaporation
- Heat is always transferred from an object of higher temperature to one of lower temperature
- Integumentary System: the outer covering of the body, consisting of the skin, hair, and nails
- Insulation
  - Reduces the flow of heat between animal and its environment
- Circulatory Adaptations
- Cooling by Evaporative Heat Loss
- Behavioral Responses
  - Hibernation and migration
- Adjusting Metabolic Heat Production

Circulatory Adaptations

- Circulatory systems provide a major route for heat flow between the interior and exterior of the body
- Many animals alter the amount of blood flowing between their body core and their skin
- Countercurrent Exchange: the flow of adjacent fluids in opposing directions that maximizes transfer rates of heat or solutes

Physiological Thermostats and Fever

- Hypothalamus: sensors for thermoregulation are concentrated in a brain region
- Nerve cells act as a thermostat and respond to either cool the body or heat it

Energy requirements are related to animal size, activity, and environment

- Bioenergetics: overall flow and transformation of energy in an animal
- Energy Allocation and Use
- Quantifying Energy Use
  - Metabolic Rate: the amount of energy an animal uses in a unit of time
- Minimum Metabolic Rate and Thermoregulation
- Influences on Metabolic Rate
- Energy Budgets
- Torpor and Energy Conservation

Minimum Metabolic Rate and Thermoregulation

- Animals must maintain a minimum metabolic rate for basic functions such as cell maintenance, breathing, and heartbeat
- Basal Metabolic Rate: minimum metabolic rate of a non growing endotherm that is at rest, has an empty stomach, and is not experiencing stress
- Standard Metabolic Rate: the metabolic rate of a fasting, non stressed ectotherm at rest at a particular temperature

Influences on Metabolic Rate

- Key factors
  - Age
  - Sex
  - Size
  - Activity
  - Temperature
  - Nutrition
- Size and Metabolic Rate
  - The relationship between overall metabolic rate and body mass is constant across a wide range of sizes and forms
  - The relationship of metabolic rate to size profoundly affects energy consumption by body cells and tissues
  - As body size becomes smaller, each gram of tissue increases in energy cost
  - As body size increases, energy costs per gram of tissue lessen, but an ever-larger fraction of body tissue is required for exchange, support, and locomotion

Torpor and Energy Conservation

- Torpor: a physiological state in which activity is low and metabolism decreases
- Hibernation: long-term torpor that is an adaptation to winter cold and food scarcity

Work Cited

- https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-animal-body-basic-form-and-function-33/
- http://medtropolis.com/virtual-body/
- http://www.innerbody.com/
- http://www.ucmp.berkeley.edu/alllife/eukaryota.html
- http://www.bioedonline.org/slides/content-slides/evolution/modes-of-speciation/
- http://www.bioedonline.org/slides/content-slides/evolution/species-concepts-and-reproductive-isolating-barriers/
- http://learn.visiblebody.com/
- http://www.bbc.co.uk/science/humanbody/
- http://science.nationalgeographic.com/science/health-and-human-body/human-body/
- http://science.jrank.org/pages/1307/Cell-Cell-size-numbers.html
- https://controls.engin.umich.edu/wiki/index.php/Feedback_control
- http://people.seas.harvard.edu/~jones/cscie129/pages/health/thermreg.htm
- http://www.healthline.com/health/autoimmune-disorders#Overview1
- http://www.neuroanatomy.wisc.edu/coursebook/neuro2(2).pdf
- http://www.nlm.nih.gov/medlineplus/ency/article/001202.htm
- Textbook