Anatomy Basics

Presentation by Laurie Wang, Slides by Slidesgo

01

Body Plans

Role of Evolution in Shaping Body Plans

Fusiform body plan – popular in swimming animals

Trade-offs of bigger body plans: thicker skeletons, more muscle mass percentage, limited mobility

Exchange with Environment

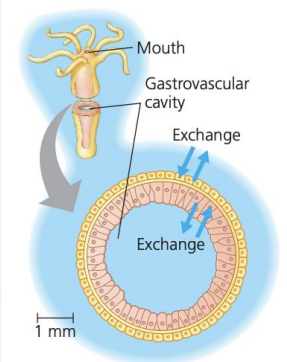
- Rate of exchange is proportional to membrane surface area
- Amount of material exchanged is proportional to total body volume
- Every cell in an animal must have access to a suitable aqueous environment
    - Really easy for single-celled animals!

Exchange with the Environment

Simple

Hydra
- Sac-like body
- 2 cell thick walls
- Both interior + exterior exposed to water

Tapeworm
- Flat body
- Most cells in direct contact with intestinal fluid



Complex

- Lots of folding and branching increases surface area
- Exchange surfaces are inside the body
  - Protects delicate tissues
  - Allows for streamlined body contours
  - Human digestive system has 25x the surface area of skin
- Exchange between **interstitial fluid** and **circulatory fluid** to obtain nutrients and get rid of wastes
- Good for highly variable environments

Hierarchical Organization of Body Plans

- Cells make a working body through emergent properties
  - Tissues – a group of similar cells with a common function
  - Organs – functional units of tissues
  - Organ system – a group of organs that work together
  - Porifera (sponges) don’t have any of these!
- Types of analysis
  - “Bottom-up” (cells to organ systems) – reveals emergent properties
  - “Top-down” (organ systems to cells) – reveals multilayered specialization

4 main types of tissues

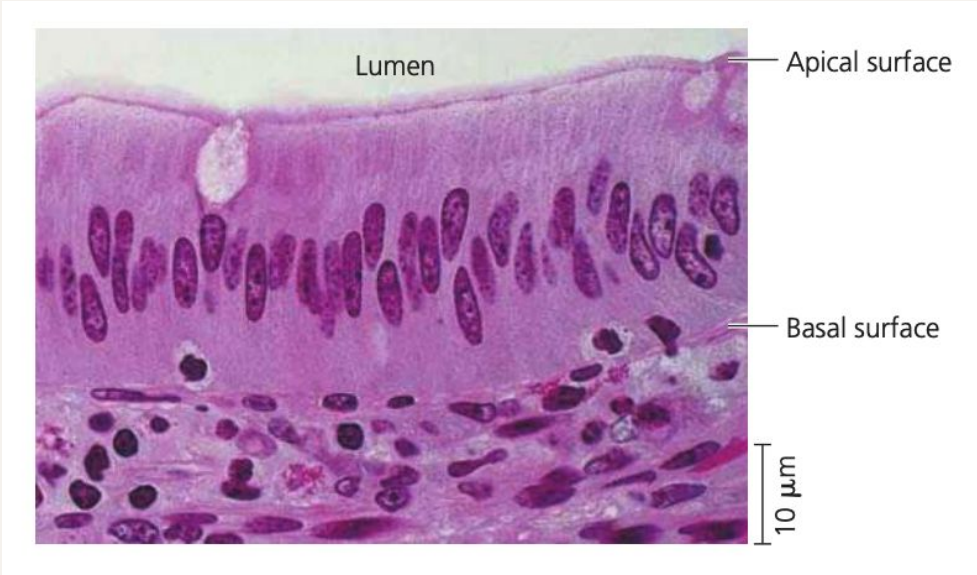
- Epithelial
- Connective
- Muscular
- Nervous

CarMEN

Epithelial tissue

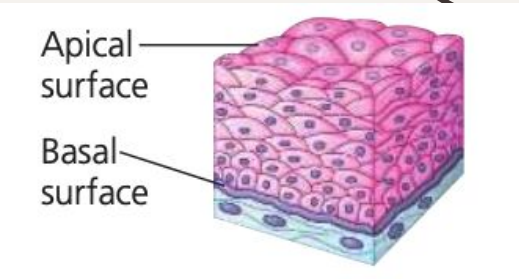
- **Apical surface**–faces lumen/outside, usually has specialized projections

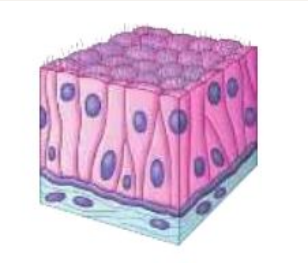
- **Basal surface**



Types of Epithelial Tissue

- **Stratified squamous**
  - Multilayered
  - Regenerates rapidly
    - New cells dividing from the basal surface push out
  - Found in places with abrasion
    - Skin, mouth lining
- **Pseudostratified columnar**
  - Single layer
  - Heights and nucleus position vary
  - Ciliated cells in mucous membranes – participate in **cilial beat**
- **Simple squamous**
  - Good for diffusion
  - Thin and leaky
  - Found in places with a lot of exchange
    - Blood vessels
    - Air sacs





Types of Epithelial Tissue

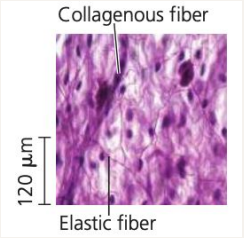
- Simple columnar
  - Found in places with secretion or active absorption
    - Intestines – secrete digestive juices, absorb nutrients
- Cuboidal
  - Found in places with secretion
    - Epithelium of kidney tubules
    - Glands
      - Thyroid gland
      - Salivary glands

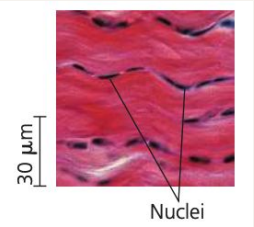
Connective tissue

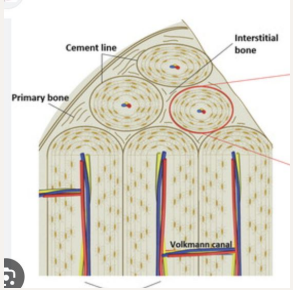
- Made up of sparse cells in an extracellular matrix, which has a web of fibers in a liquid, jelly, or solid
  - Contains:
    - Fibroblasts, which secrete fiber proteins
    - Macrophages, which engulf foreign particles and cellular debris through phagocytosis
- 3 types of fibers
  - **Collagenous** – provide strength and flexibility
  - **Reticular** – join connective tissues with other tissues
  - **Elastic** – make tissues elastic

Types of Connective Tissue

- Loose
  - Most widespread
  - Binds epithelia to underlying tissues and holds organs in place
  - Loose weave of all 3 fibers
  - Found in skin and throughout the body
- Fibrous
  - Dense with collagenous fibers
  - Found in tendons (connect muscles to bones) and ligaments (connect bones to bones)
- Bone
  - Mineralized connective tissue
  - Osteoblasts deposit collagen, Ca^{2+}, Mg^{2+}, and phosphate ions, which combine into minerals
  - Osteons – concentric layers of mineralized matrix around central canal

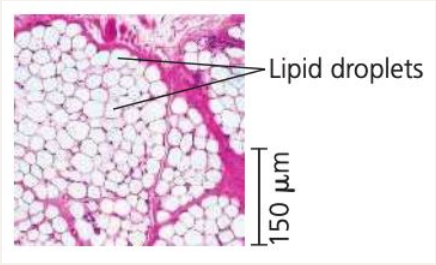


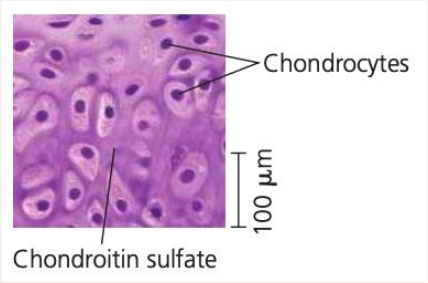


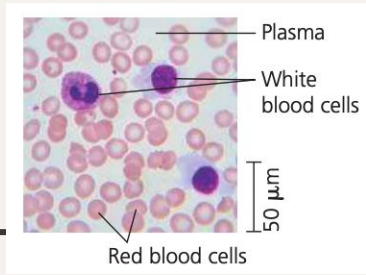


Types of Connective Tissue

- Adipose tissue
  - Specialized loose connective tissue
  - Fat is stored in adipose cells within the matrix – each cell has a large fat droplet
  - Pads and insulates the body; stores fuel
- Cartilage
  - Collagenous fibers embedded in a rubbery, protein-carbohydrate complex called chondroitin sulfate
  - Chondrocytes secrete collagen and chondroitin sulfate
  - Strong, yet flexible
  - Embryonic skeletons often have cartilage, which is replaced with bone
- Blood
  - Plasma is the matrix – water, salts, dissolved proteins
  - Contains erythrocytes, leukocytes, and platelets





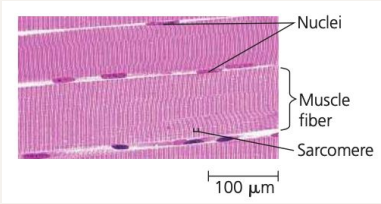


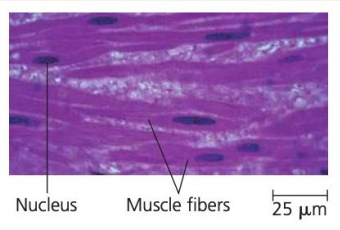
Muscular tissue

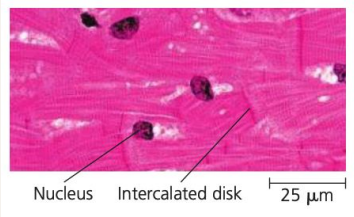
- Made of filaments with **actin** and **myosin**

Types of Muscular Tissue

- Skeletal/striated
  - Responsible for voluntary movements
  - Contains bundles of long cells fused together called muscle fibers
  - Organized in **sarcomeres**, which are contractile units among fibers
    - Responsible for striated look
  - Building muscle increases the size of the fibers, but not number
- Smooth
  - Lacks striations
  - Involuntary body activities
  - Found in digestive tract, bladder, arteries, other internal organs
  - Spindle-shaped cells
- Cardiac
  - Striated, somewhat similar to skeletal muscle
  - Forms the contractile walls of the heart
  - Branched fibers connect via **intercalated disks** to relay signals and synchronize heart contraction





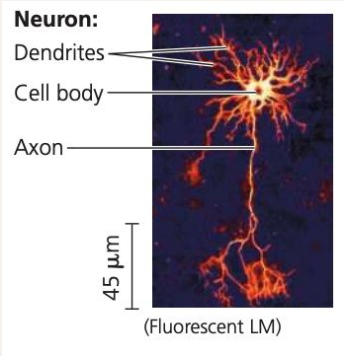


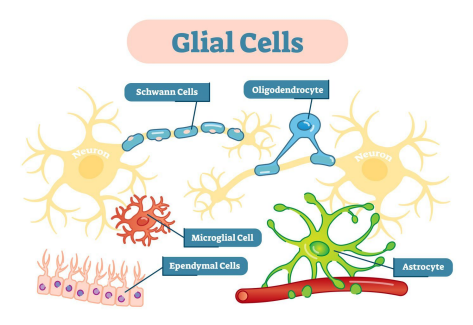
Nervous tissue

- May form a brain

Types

- Neurons
  - Receive impulses from other neurons from the soma and dendrites
  - Transmit impulses to neurons, muscles, or other cells via axons
  - Axons are often bundled into nerves
- Glia
  - Nourish, insulate, and replenish neurons, modulate neuron function





Coordination and Control of the Body

- Endocrine system
  - Releases signaling molecules (hormones) into the bloodstream
  - Causes gradual changes
- Nervous system
  - Neurons transmit signals throughout the body
  - Causes more immediate and rapid changes

02

Maintaining the Body

Maintaining a good internal environment

- Regulator – internal mechanisms control internal change
- Conformer – internal conditions change with variable conditions

Homeostasis – maintaining internal balance

- Mechanism
  - You have a set point where everything is happy
  - The stimulus, which is a fluctuation, is detected by some kind of sensor
  - Sensor signals the control center to trigger a response
- Feedback control
  - Negative feedback dampens the stimulus
  - Positive feedback amplifies stimulus

Thermoregulation

- Why thermoregulate?
  - Enzyme efficiency
  - Membrane fluidity
  - Temperature-sensitive biochemical processes
- Types of regulation
  - **Endothermy** – use heat generated by metabolism
    - Mammals, birds, some fishes and insects, a few reptiles
  - **Ectothermy** – use heat from external sources
    - Many reptiles and fishes
    - Eat less
    - Tend to tolerate larger fluctuations in internal temperature
- Variation in body temperature
  - **Poikilotherm** – body temperature varies with environment
  - **Homeotherm** – body temperature stays constant

Balancing Heat Loss and Gain

- Ways of exchanging heat from high to low
  - Radiation
  - Evaporation
  - Convection
  - Conduction
- Adaptations
  - Insulation – reduces heat flow between animal and environment
    - On body surface – hair and feathers
      - Goosebumps are because mammals/birds raise hair/feathers in response to cold, trapping a thicker layer of air
    - Beneath body surface – adipose tissue
      - Marine mammals use blubber
  - Circulatory adaptations
    - **Vasodilation** and **vasoconstriction**
    - **Countercurrent exchange**
  - Evaporative cooling
    - Sweat glands
    - Panting

Balancing Heat Loss and Gain

- Behavioral responses
  - Mostly in ectotherms
  - If cold – seek warmth, orient body towards heat, expand surface area exposed to heat
  - If hot – bathe, seek coolness, reduce surface area exposed to heat
    - Dragonflies use the obelisk posture
  - Social behavior
    - Endotherms
      - Penguins huddle
    - Ectotherms
      - Honeybees
        - Huddle if cold
        - Transport water to hive and fan wings if hot

Balancing Heat Loss and Gain

- Adjusting metabolic heat production
  - In endotherms
  - Thermogenesis
    - Muscle activity → moving, shivering
  - Non-shivering thermogenesis
    - Mitochondria are signaled to increase energy production to make heat, not ATP
    - Brown fat is specialized for rapid heat production
  - Found in some reptiles
    - Female Burmese pythons incubate eggs through shivering
- Acclimatization
  - Birds and mammals have thicker feathers/fur in the winter and shed during summer

Physiological thermostats + Fever

- Hypothalamus
- Fever in mammals and birds
- Behavioral fever in certain ectotherms

03

Energy Use

Quantifying Energy Use

- Metabolic rate is the amount of energy and animal uses in a given time interval
- How to determine metabolic rate
  - Monitor rate of heat loss with a calorimeter
  - Measure the amount of oxygen consumed and carbon dioxide produced
  - Measure rate of food consumption, amount of energy in food, and chemical energy lost in waste products (long-term)
- **Basal metabolic rate (BMR)** – resting metabolic rate for endotherms
- **Standard metabolic rate (SMR)** – resting metabolic rate for ectotherms
- Metabolic rate is directly proportional to mass to the ¾ power
- The amount of energy needed per gram of body weight is inversely proportional to body size
- Hibernation and estivation reduce energy use

04

Practice!

Which of the following physiological processes generates most of the heat needed to keep an infant warm:

W) digestion of food in the gut
X) oxidative metabolism
Y) inspiration of air
Z) bacterial activity in the gut

An example of a negative feedback mechanism is thermoregulation in animals. When an ectotherm begins to feel cold, which of the following typically happens?

W) It sits in the Sun until it gets warm
X) It uses metabolic energy to warm
Y) It goes into torpor
Z) Its body temperature cools to match the environment

Students are given an organism and asked to create an experiment to determine whether it is ectothermic. They vary room temperature and record whether the body temperature of the organism changes. Which result would be consistent with an ectothermic organism?

W) The organism's body temperature would not vary with room temperature
X) The organism's body temperature would vary inversely with room temperature
Y) The organism's body temperature would vary with room temperature
Z) The organism's body temperature would only vary when the room temperature increased

Which of the following organisms would use the highest percentage of its energy budget for homeostatic regulation?

W) Marine hydra
X) Desert bird
Y) Desert insect
Z) Marine jellyfish

Thanks!