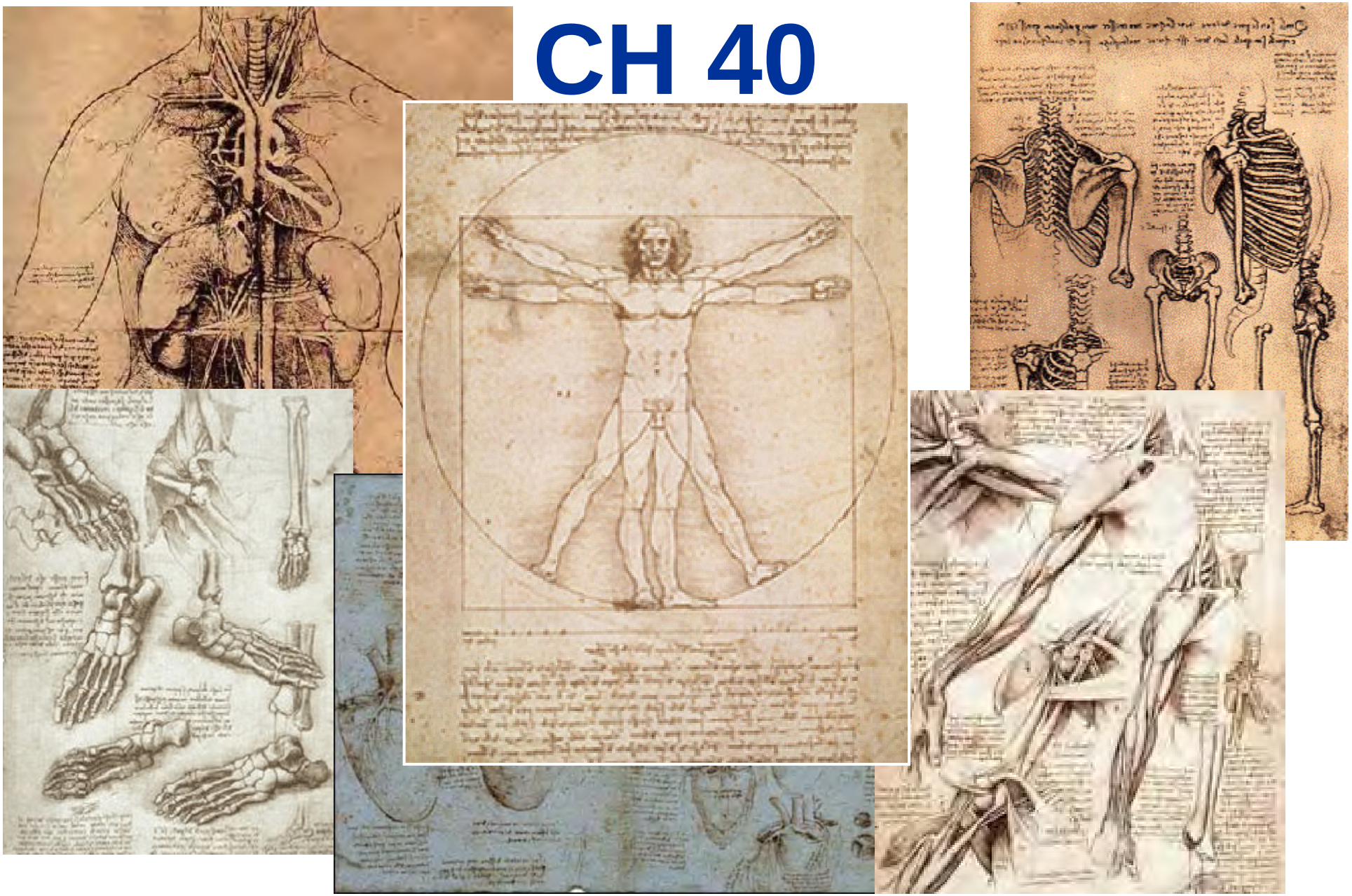
Animal Form and Function

CH 40



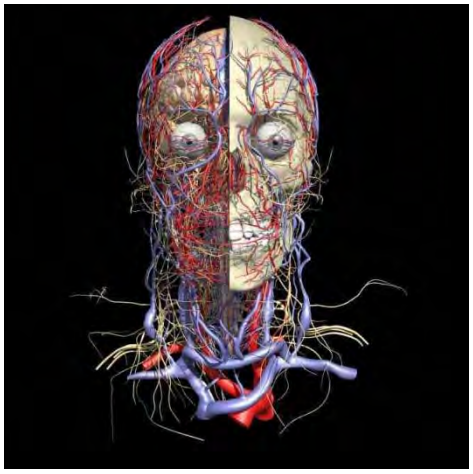
Anatomy

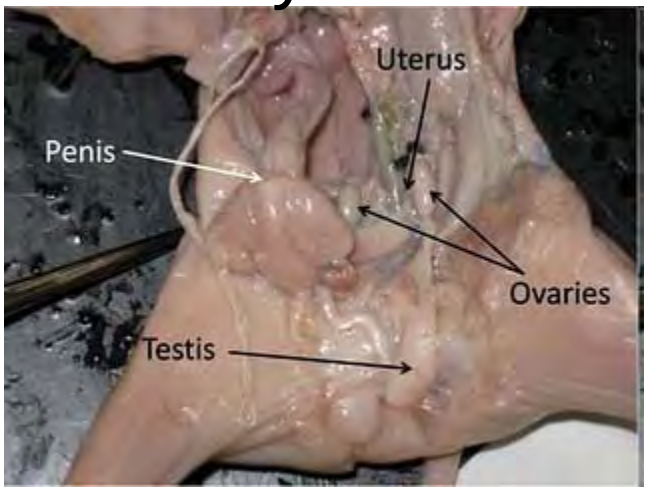
The structure (form) of an organism
(i.e. how its parts are organized and of what it's made)

The Anatomy Lesson of Dr. Nicolaes Tulp, 1632, Rembrandt

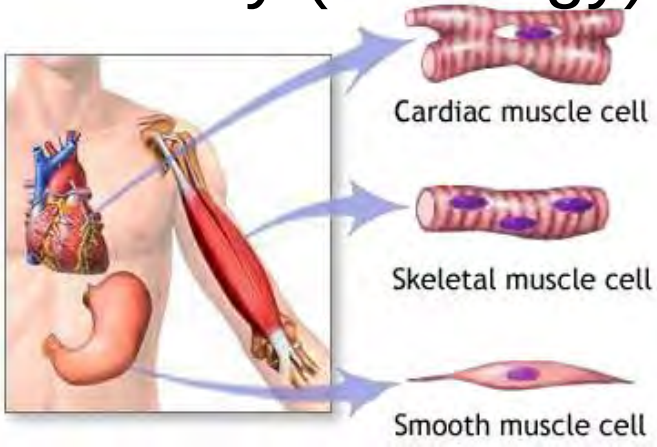
Anatomy

Gross anatomy





Microscopic anatomy (histology)

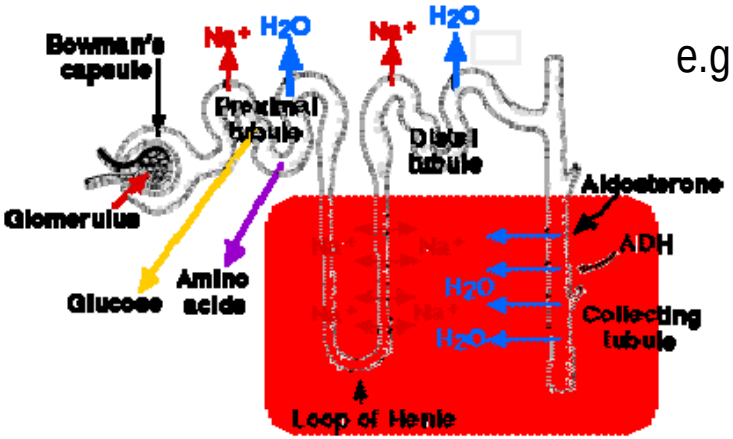


Physiology

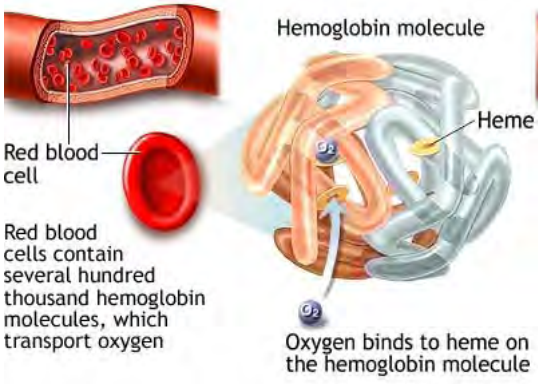
The physical and chemical processes (functions) of an organism (i.e. how the body works)

e.g. The mechanics of breathing

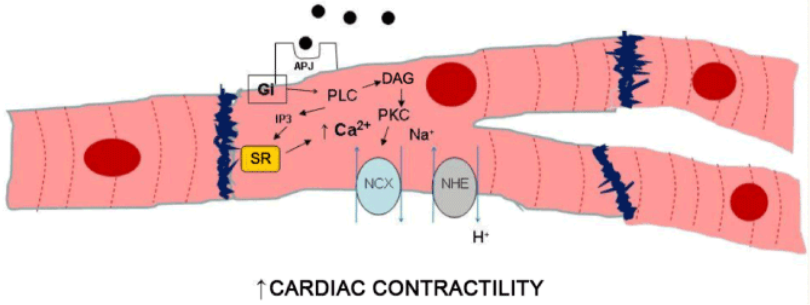
e.g. How does the kidney function?



e.g. How does the blood absorb O_2?



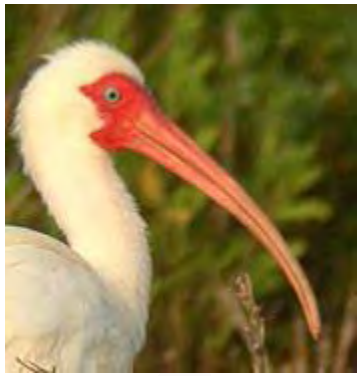
e.g. How does the heart contract?



Form Determines Function

Bird beak shape determines what they eat or how they obtain food









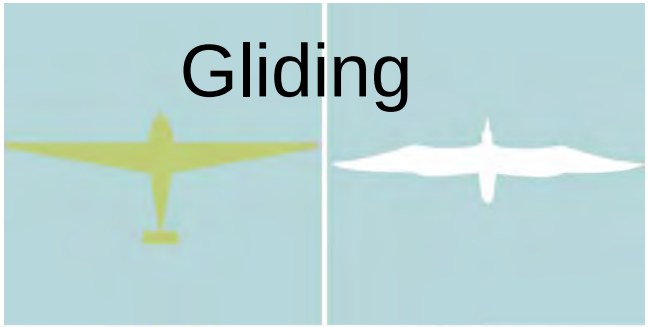




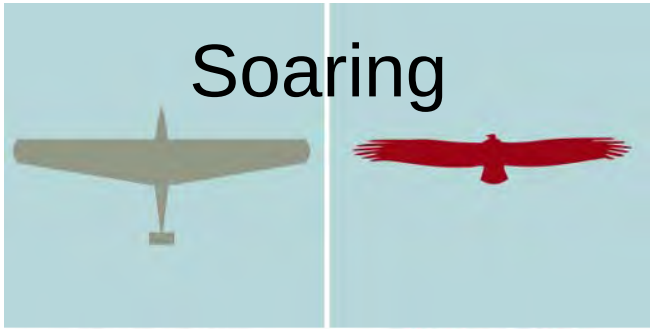
Form Determines Function

Like an airplane, a bird's body and wing shape determine how it flies and thus what/ how they eat

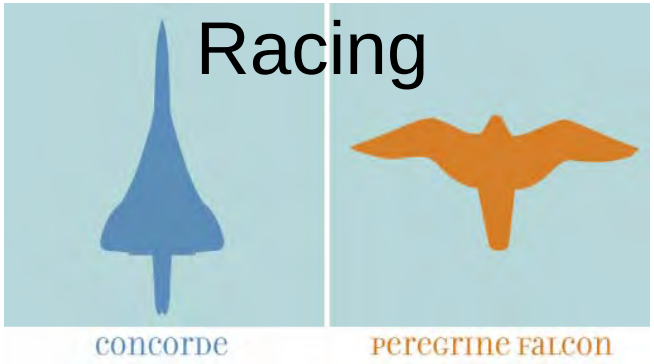
Gliding



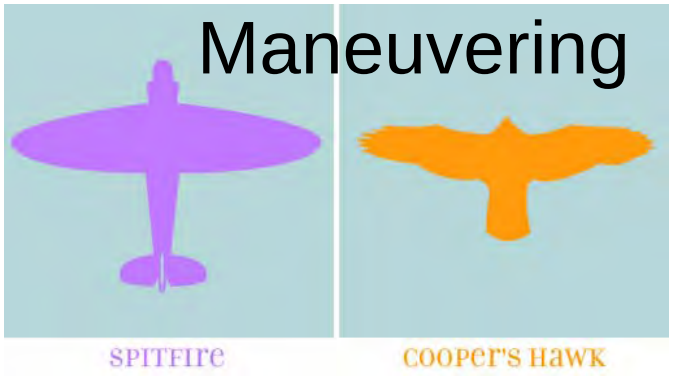
Soaring



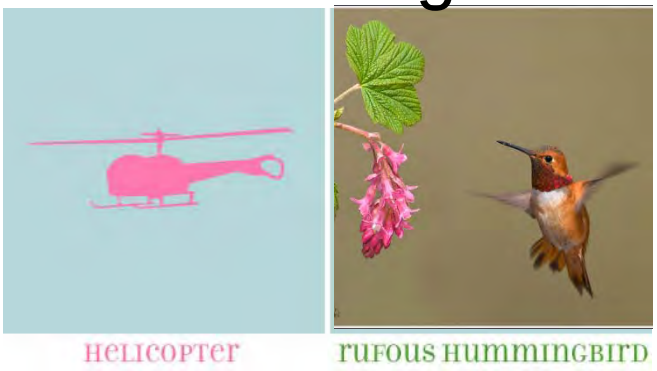
Racing



Maneuvering



Hovering

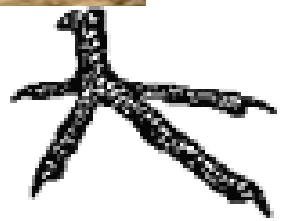


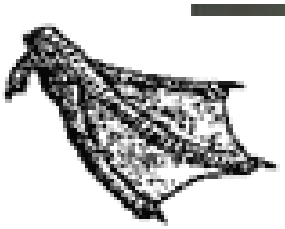
Form Determines Function

The shape of a bird's foot determines what it eats and how it searches for food

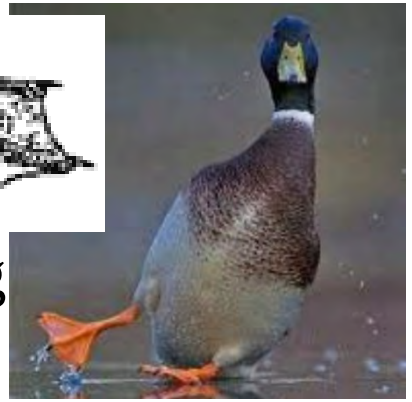
Grasping

Scratching



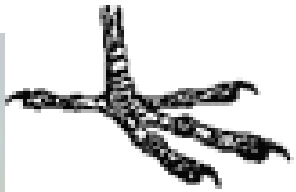


Swimming



Climbing

Perching



Running

Constraints on Form and Function

All is not possible!

(A) Evolutionary history and (B) physical laws place limits on form

10 (A) Evolutionary history (i.e. ancestry) constrains form

Even though whales spend all of their lives in water, due to their ancestry, whales don't have gills

Mammal Phylogeny

Lungs

(B) Physical laws constrain form - Speed

Body shape is constrained by need to hunt in water due to the drag imposed by water (46x viscosity of air).

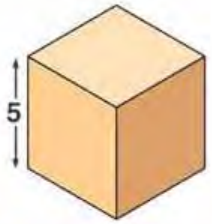
i.e. aquatic predators must be hairless and sleek

IOW natural selection results in similar features in independent evolutionary lineages (i.e. convergent evolution)

Physical laws constrain form – Heat & H_2O exchange

Surface Area to volume ratio (SA:V) affects rate of H_2O or heat loss or gain thus body size and shape is constrained by environment

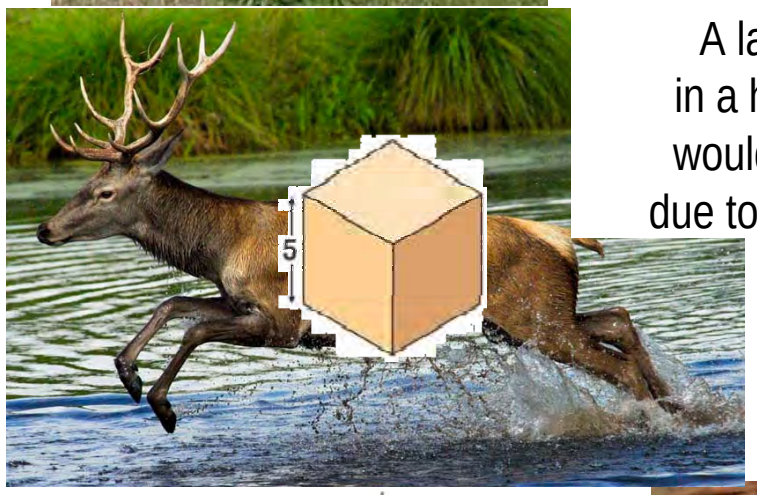
Small animals loose or gain heat & H_2O faster than large animals due to higher SA:V



Total surface area (height × width × number of sides × number of boxes)	6 1x1x6x1	150 5x5x6x1
Total volume (height × width × length × number of boxes)	1	125
Surface-to-volume ratio (surface area / volume)	6	1.2

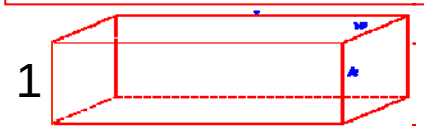
Figure 6.7 (Campbell 9th ed)

A small deer in a cold climate would freeze due to a large SA:V



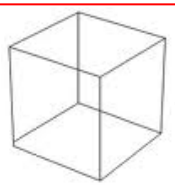
A large deer in a hot climate would overheat due to a low SA:V

Both size AND shape affect SA:V



8

SA/V 34/8 = 4.25



24/8 = 3

Animals with a long body or limbs loose heat & H_2O faster than compact animals due to higher SA:V

Physical laws constrain form – Cell size

Surface Area to volume ratio affects
rate of H_2O, gas, nutrient and waste exchange

Thus: Cell size and shape affects rate of exchange
with larger cells having more difficulty moving substances in and out

Thus: Cell size is limited since if too large can't maintain cell

So: Organism size is constrained in that to be bigger
they must have <u>more</u> cells (i.e. multicellular) <u>not larger</u> cells

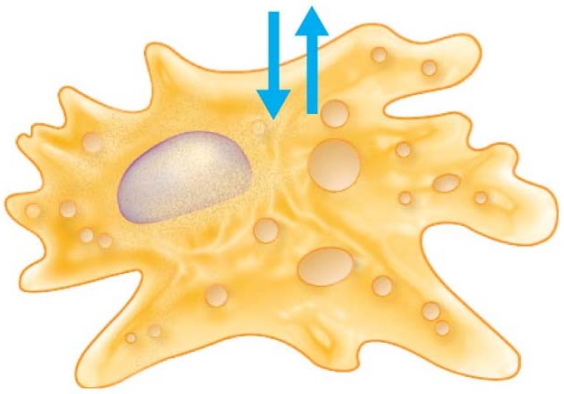


Figure 40.3 (Campbell 9th ed)

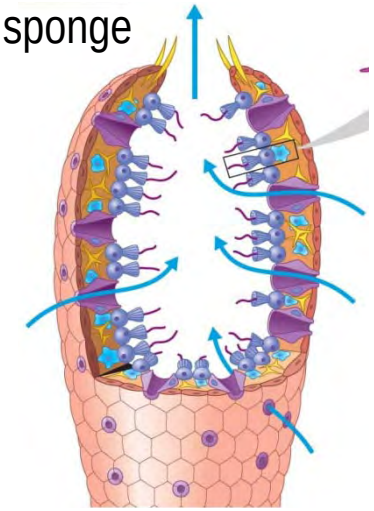
Physical laws constrain form - Complexity

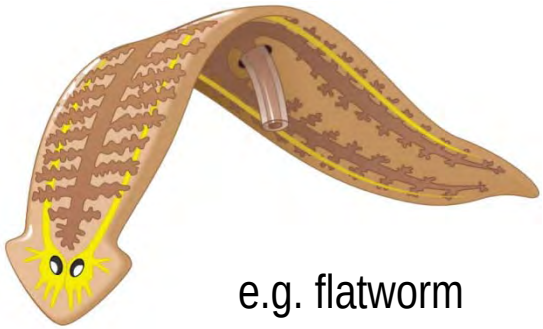
- Since: ALL cells must exchange materials with the environment
- Then: If an organism gets thicker then inner cells can't exchange nutrients/wastes with environment
- Thus: Thickness is constrained.

BUT this constraint be circumvented…

(A) Many simple animals are flat or designed so that most cells are in contact with external environment

e.g. sponge





e.g. flatworm

Figures 33.4 and 33.10 (Campbell 9th ed)

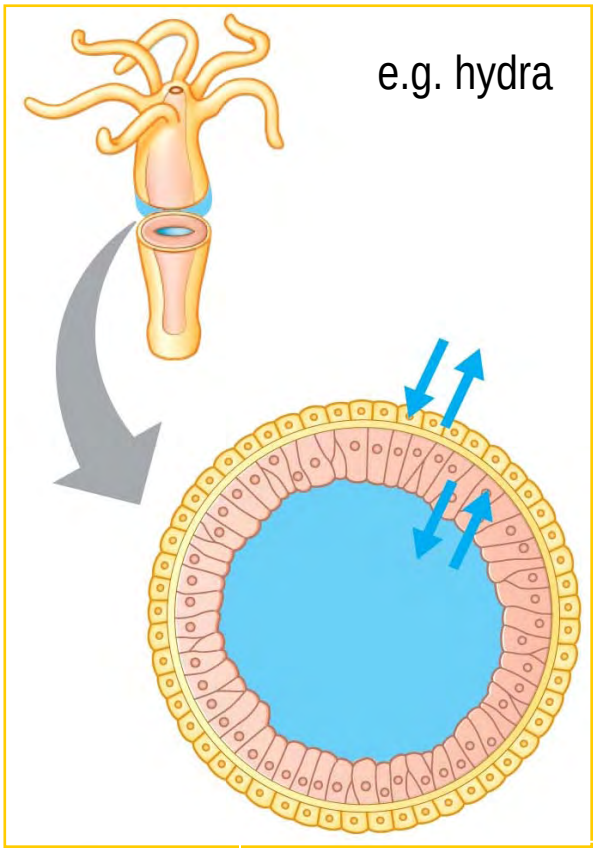


Figure 40.3 (Campbell 9th ed)

Physical laws constrain form - Complexity

- Since: ALL cells must exchange materials with the environment

(B) Complex organisms have:

2. Folded internal surfaces to increase SA:V

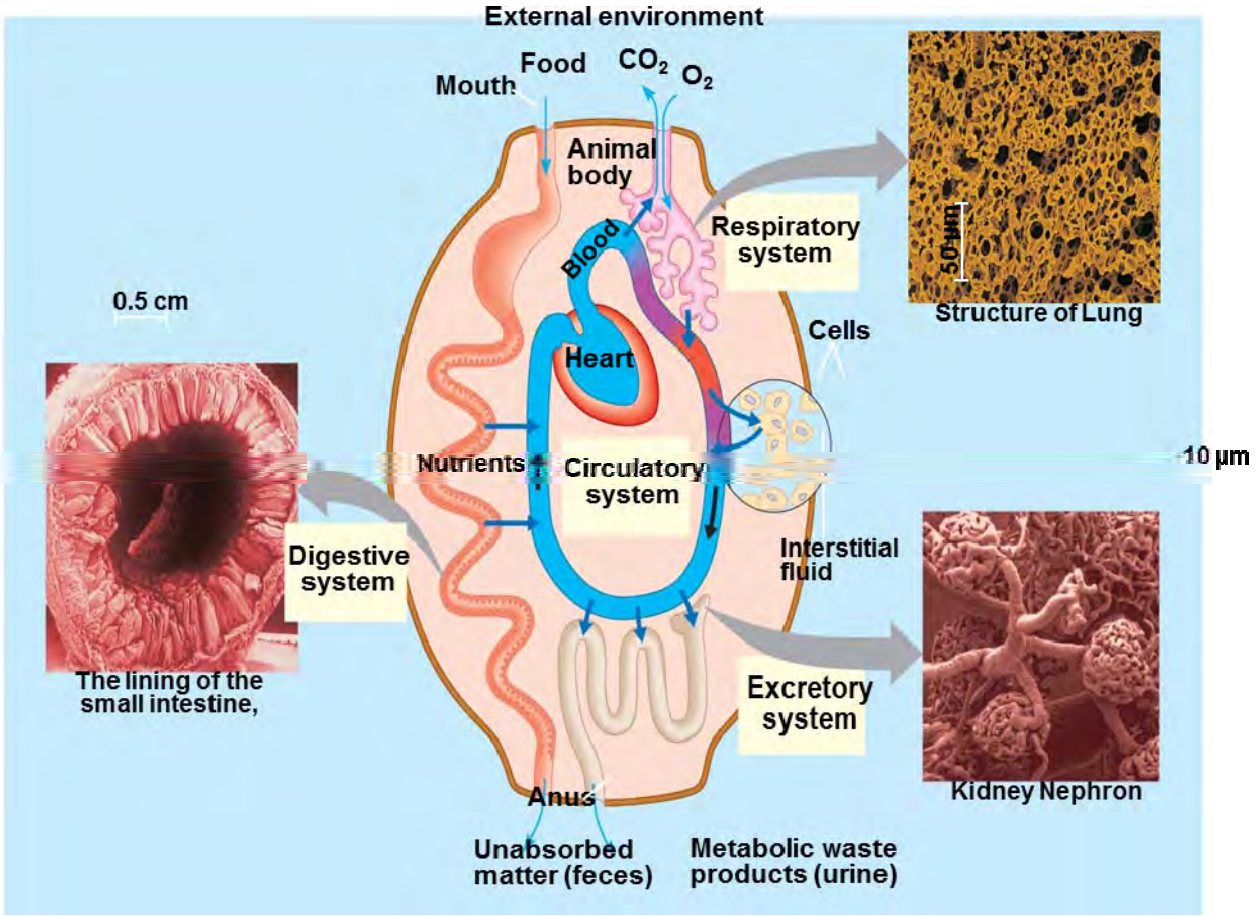


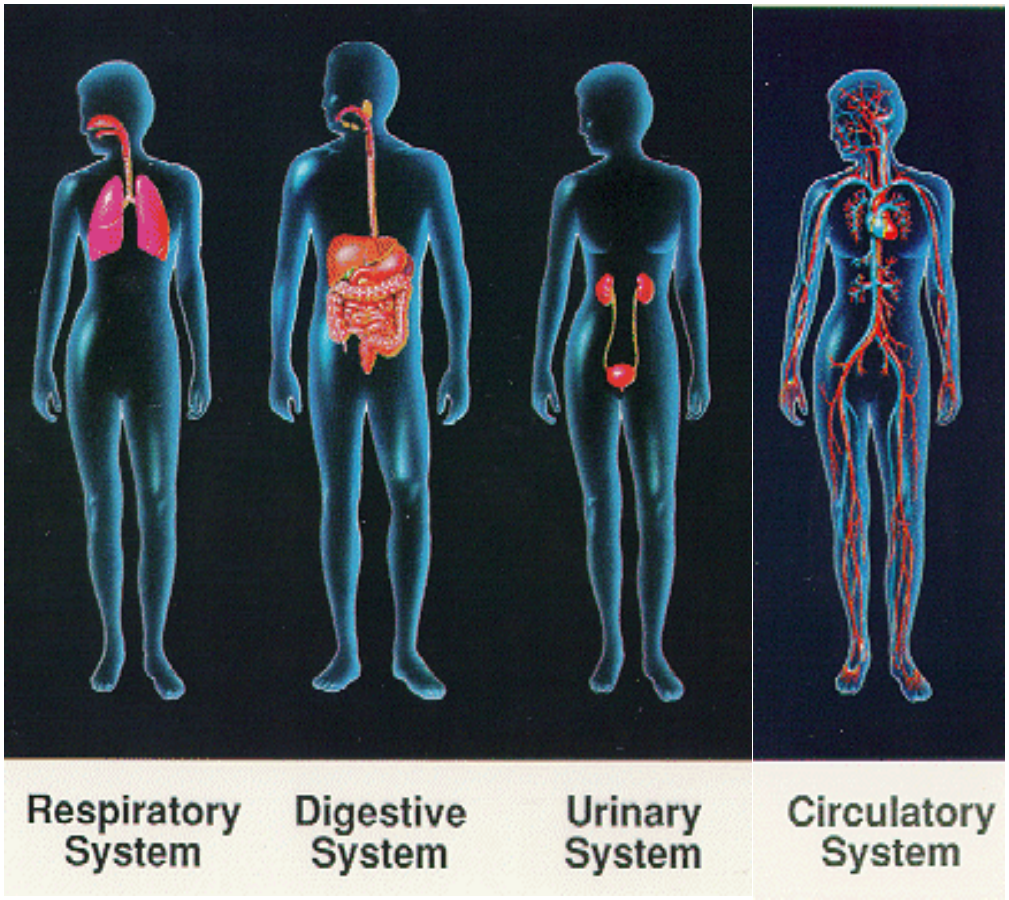
Figure 40.4 (Campbell 9th ed)

Physical laws constrain form - Complexity

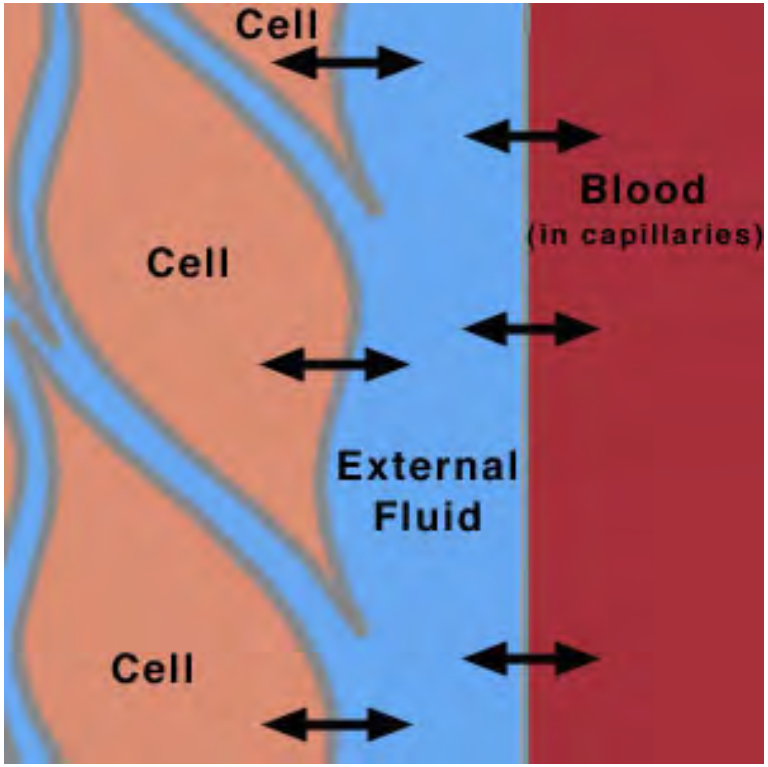
- Since: ALL cells must exchange materials with the environment

(B) Complex organisms have:

2. Delivery/ removal systems



Interface w/ cells
via interstitial fluids



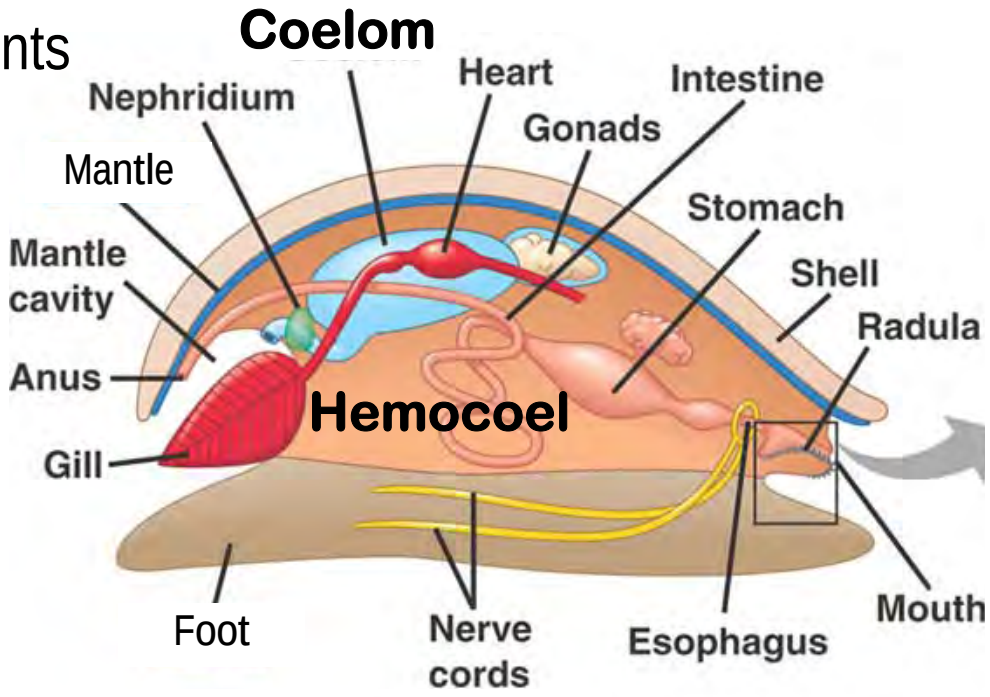
Physical laws constrain form - Complexity

- Since: ALL cells must exchange materials with the environment

(B) Complex organisms have:

3. Fluid-filled compartments

e.g. Snail



Bathe organs in fluid
to exchange substances

A. Coelom or pseudocoelom
B. Hemocoel
- In open circulatory system

e.g. Nematode

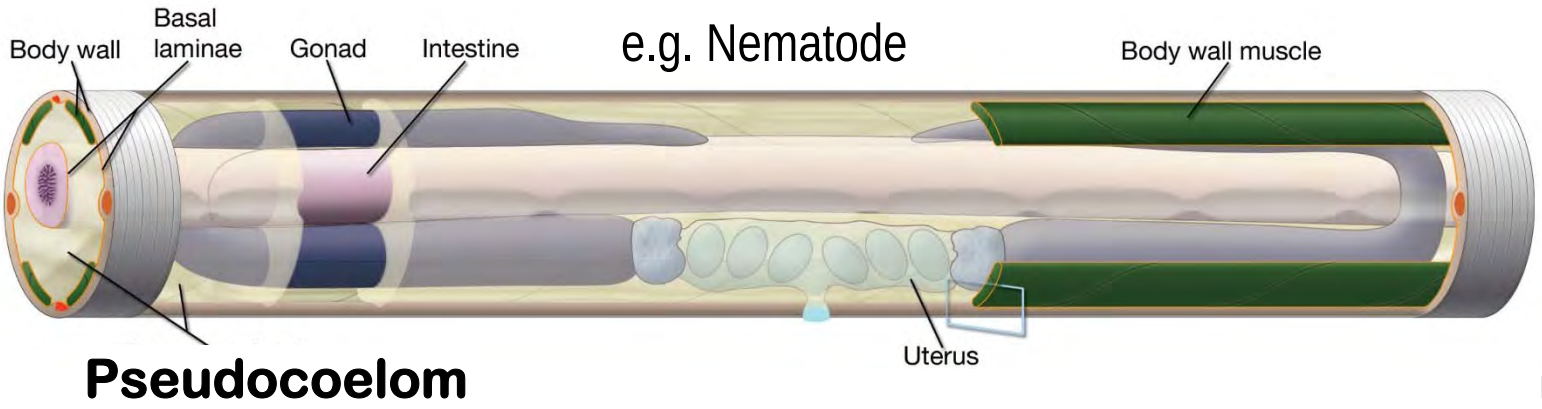


Figure 33.15 (Campbell 9th ed)

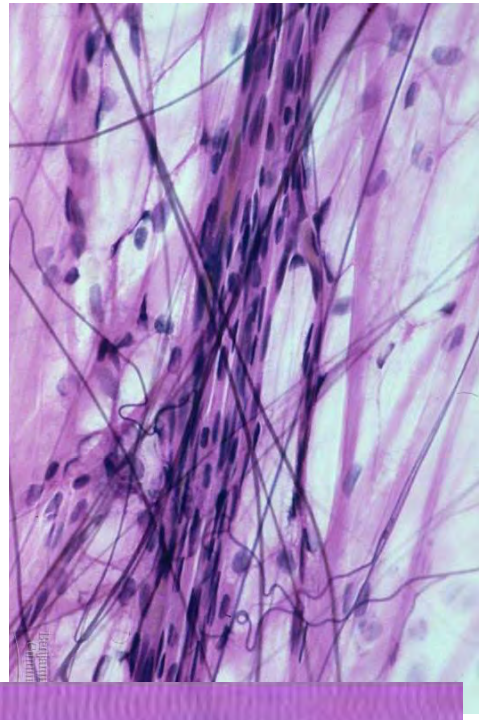
Hierarchy of Form and Function

Greater size allows/necessitates
greater complexity / specialization

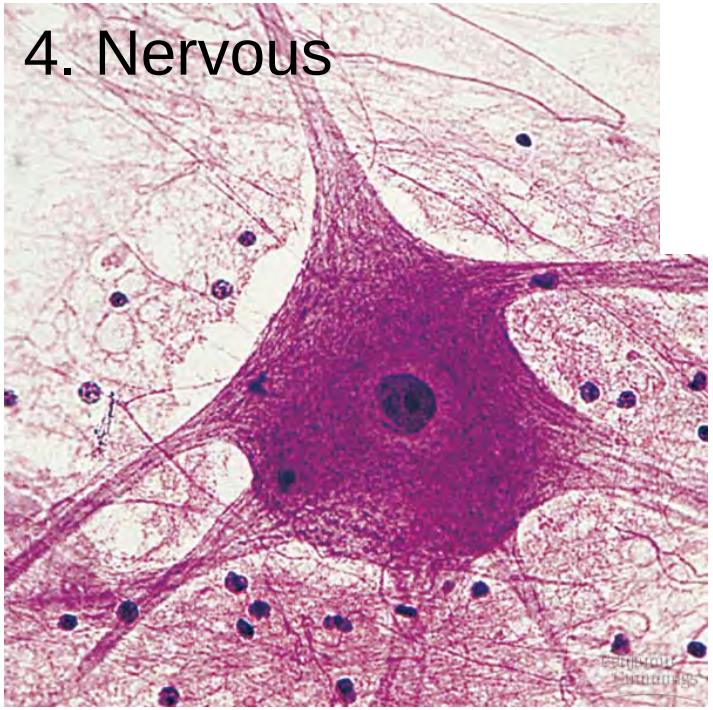
- **Cells** – many types
  - **Tissues** – aggregation of specialized cells
    - **Organs** – aggregation of multiple tissues
      - **Organ systems** – aggregation multiple organs

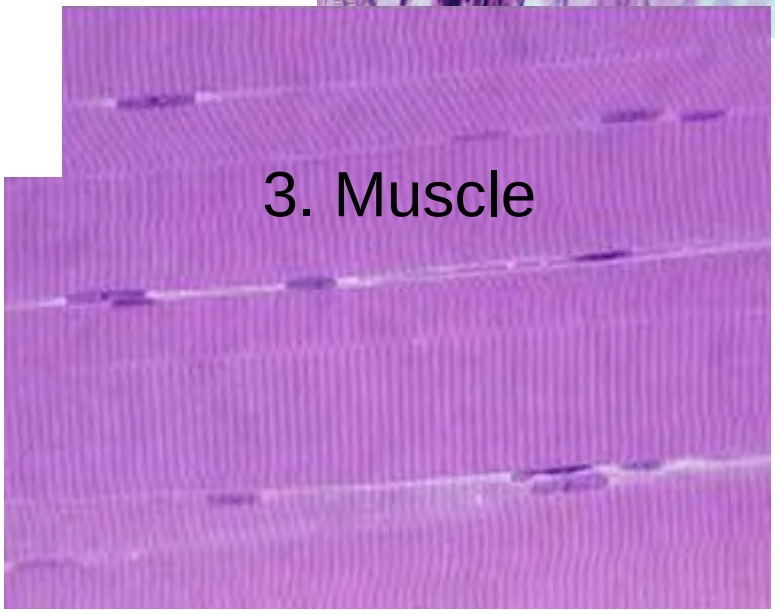
Tissue: A group of similar specialized cells that function as a unit

2. Connective



4 types of Animal Tissues



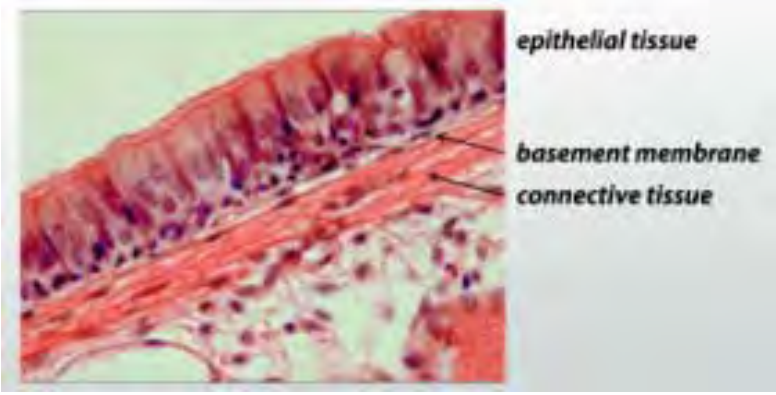


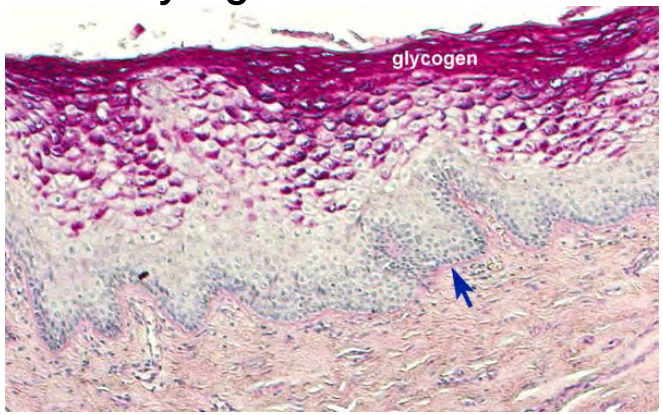
Epithelial Tissue

Membranous tissue covering nearly all external and internal body surfaces

Morphology

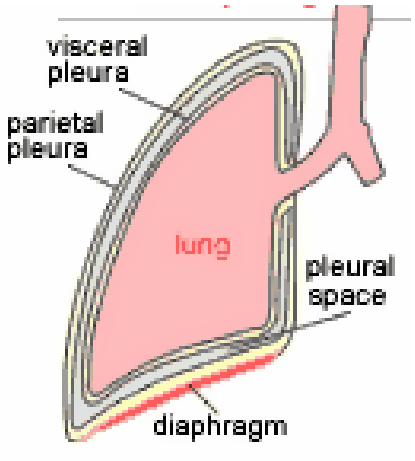
1. Tightly packed cells
   - Joined together laterally via tight junctions
   - Very little interstitial fluid between cells
2. Top & bottom ends differ (i.e. it is polarized)
   - Free surface exposed to outside or inside (lumen) of organ or duct
   - Attached surface resting on underlying connective tissue
3. Separated from the underlying tissue by a basement membrane
   - Thin sheet of collagen and proteins
   - Produced by epithelial cells and partly by underlying connective tissue cells.

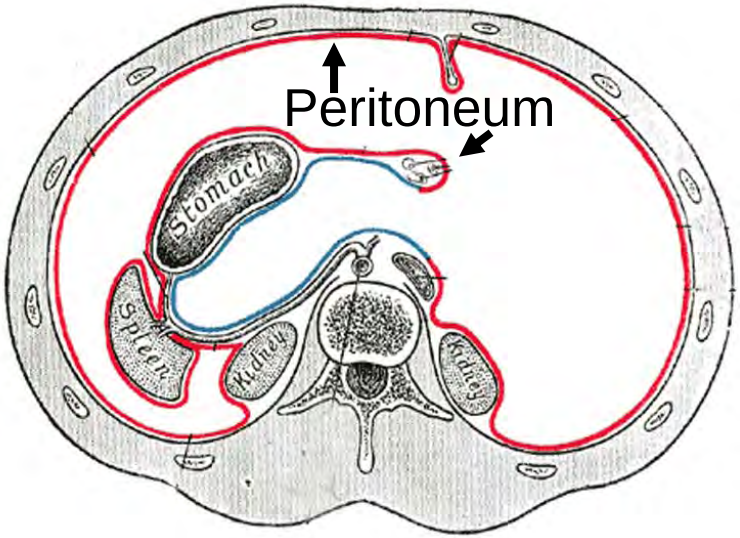




Epithelial Tissue

Membranous tissue covering covers nearly all external and internal body surfaces





Where does it occur?

1. Surfaces that interface w/ outside
   - epidermis, cornea, mouth, rectum
   - digestive, respiratory, reproductive, and urinary tracts
2. Lines vessels & ducts
3. Glands (skin, liver etc.)
4. Membranes (peritoneal, pericardial, pleural etc.)

Epithelial Tissue

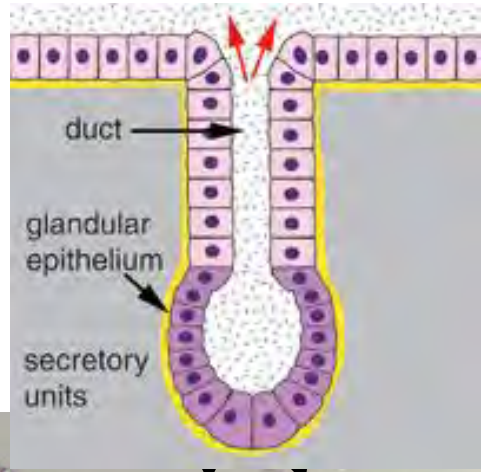
Main functions:

A. <u>Protection</u>

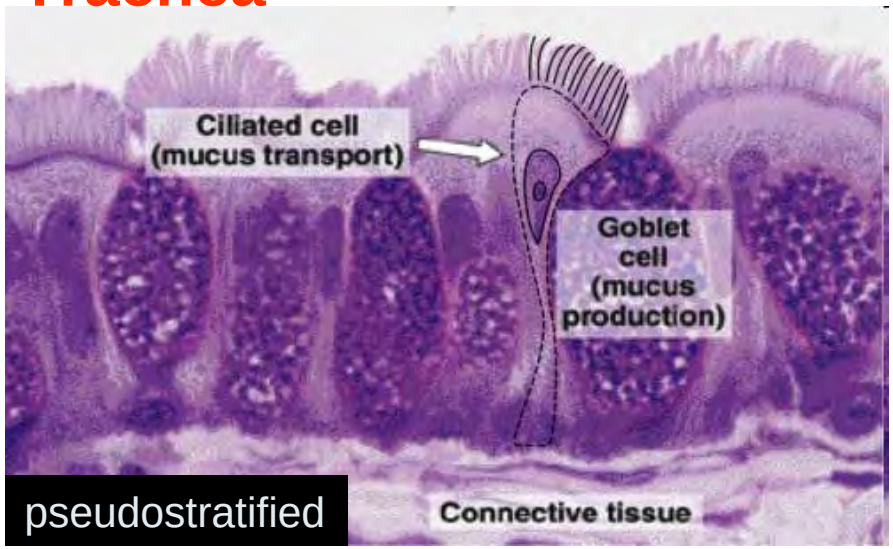
- mechanical damage
- chemical damage
- desiccation
- infection
- cleaning (cilia, mucus)

B. <u>Metabolic</u>

- absorption
- secretion (glands)

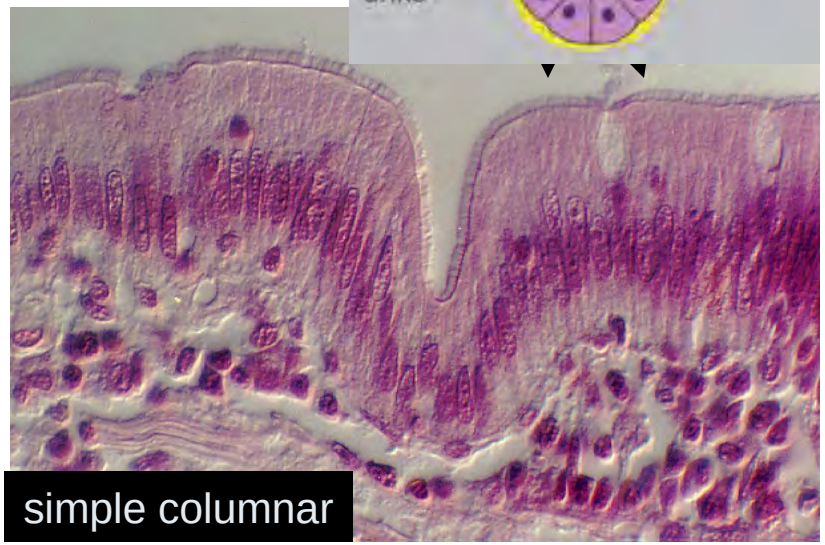


Trachea



pseudostratified

Intestine



simple columnar

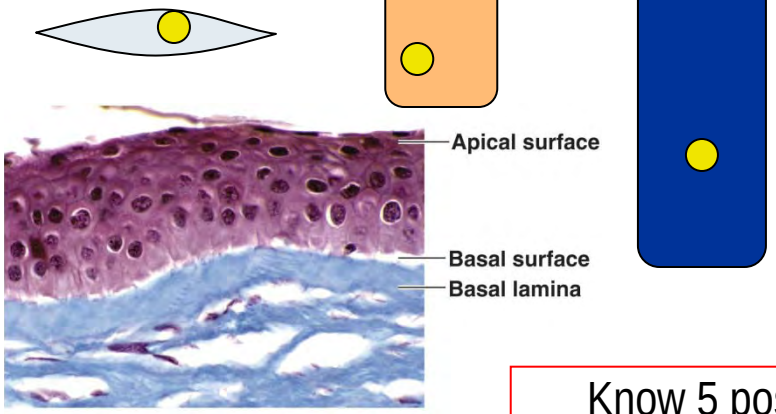
Epithelial Tissue

Classified based on:

1. # of layers:
   - simple = 1 layer
   - stratified = > 1 layer
   - Pseudostratified = 1 layer but…

2. cell shape:

squamous | apical layer cuboidal | columnar

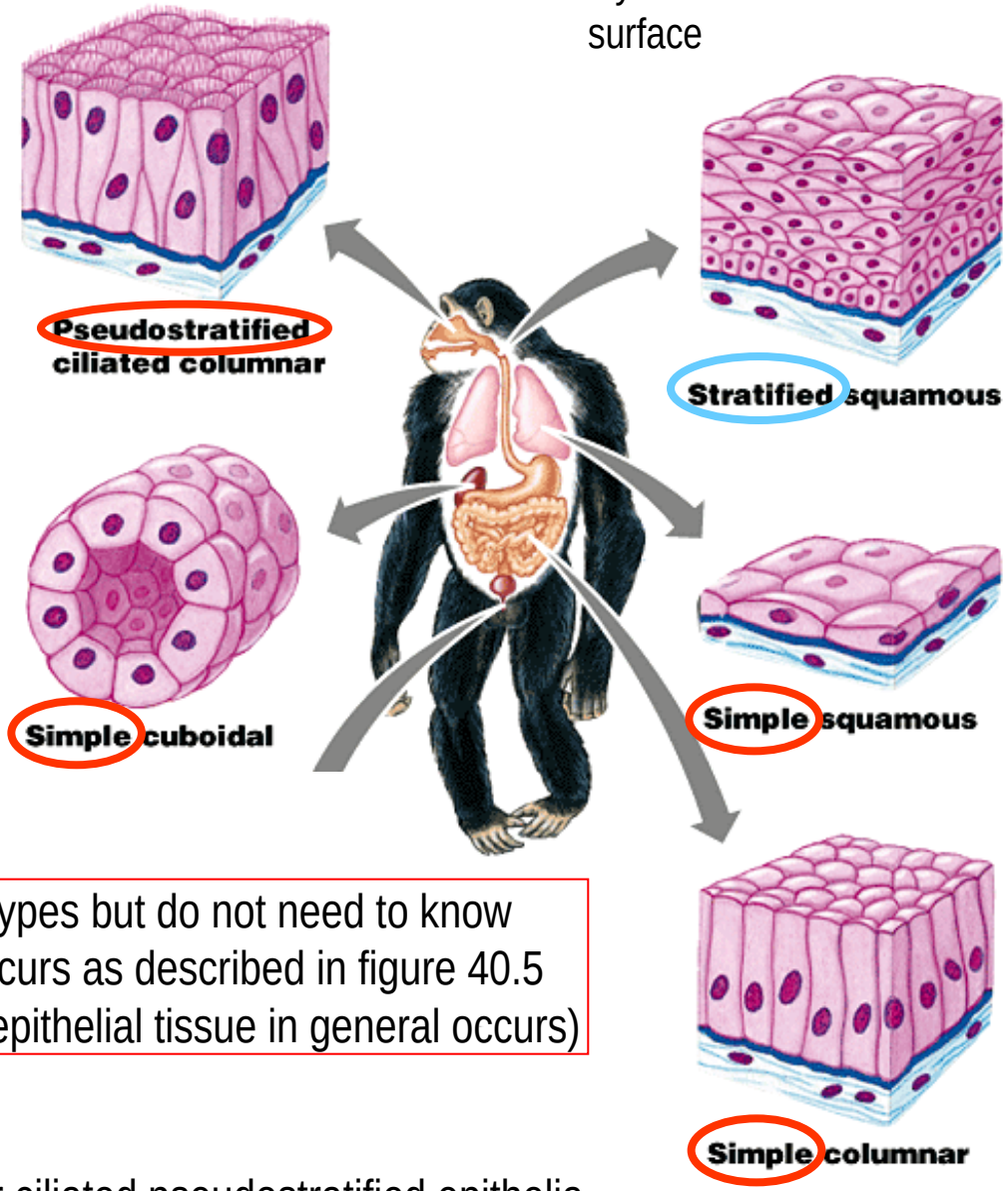


3. Specialization
   - ciliated
   - glandular
   - keratinized

e.g. keratinized stratified squamous or ciliated pseudostratified epithelia

In pseudostratified, all cells contact basal lamina but not all reach surface

In stratified, the basal cell layer does not reach the surface



Know 5 possible types but do not need to know where each type occurs as described in figure 40.5 (but DO know where epithelial tissue in general occurs)

Connective Tissue

Sparse populations of cells scattered throughout an extracellular matrix

Function

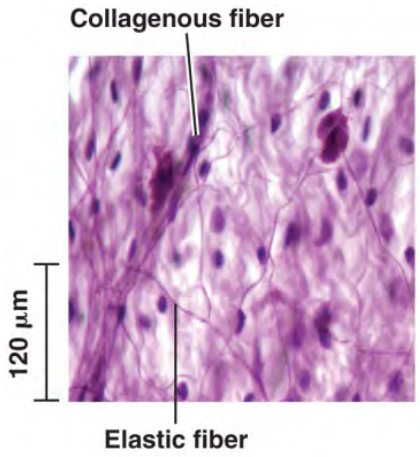
- Holds tissues and organs together and in place

General Morphology:

- Abundant Extracellular Matrix (ECM)
  - 2 main components that differ in type and proportion in different connective tissues:
    - A. ground substance (GS) - can be 1) liquid; 2) gelatinous: or 3) solid
    - B. fibers (not in blood)
      - 3 types
        1. Collagenous: strength & flexibility
        2. Reticular: join to other tissues
        3. Elastic: resume normal shape spontaneously
- Few & loosely associated cells located within the ECM

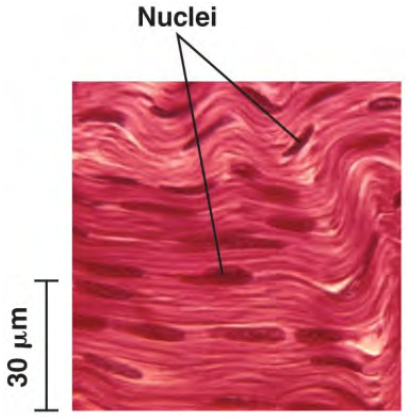
  (vs. epithelial or muscle w/ tightly associated cells)
  - Most cells produce ECM (Fibroblasts, chondrocytes, osteoblasts)
  - Other cells (Macrophages) engulf foreign particles
  - Tissue specific cells: osteoclasts, adipocytes, blood cells,etc.

28 6 types of connective tissues



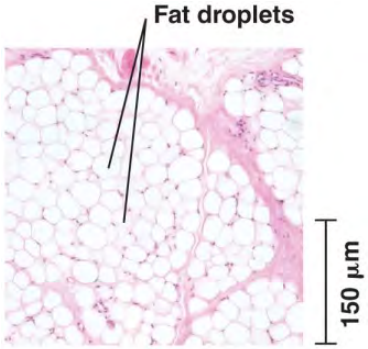
Loose connective tissue

- ECM: Liquid or gelatenous GS
- Fibers: Loose weave of all 3 types
- Holds skin & most organs in place



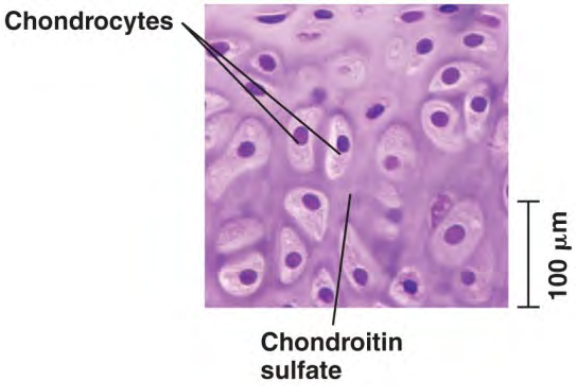
Fibrous connective tissue

- ECM: Very little ground substance
- Fibers: Mainly dense collagen fibers
- In tendons (muscle to bone) and ligaments (bone to bone)



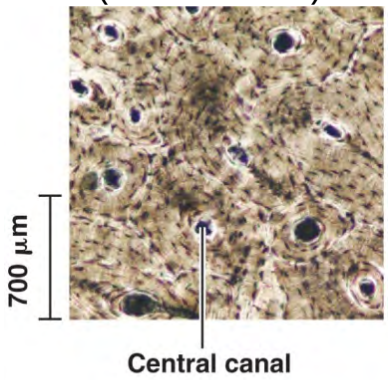
Adipose tissue

- Mainly large storage cells
- Very little ECM w/ collagen that binds cells together & in place
- Cushions, insulates and stores fuel



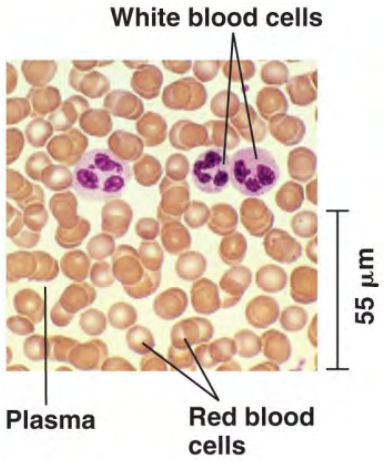
Cartilage

- ECM: Abundant and rubbery
- Fibers: mainly collagen
- Fibers/ECM secreted by cells (chondrocytes)
- Strong yet flexible and cushions (vert disks)



Bone

- ECM: Abundant and solid
- Fibers: Mainly collagen
- Fibers/ECM secreted by cells (osteoblasts)



Blood

- Fibers: none
- ECM: liquid (plasma)
- Various mobile cell types

Figure 40.5 (Campbell 9th ed)

Connective Tissue:
Diseases

- Vitamin C deficiency
- Prevents collagen synthesis
- In primates, guinea pigs etc

Muscle Tissue

Contractile tissue responsible for most body movement

Types: 3 main types

Morphology:

- Tightly packed cells
- Elongated cells (aka fibers)
  - Unbranched or branched
  - Single or multiple nuclei

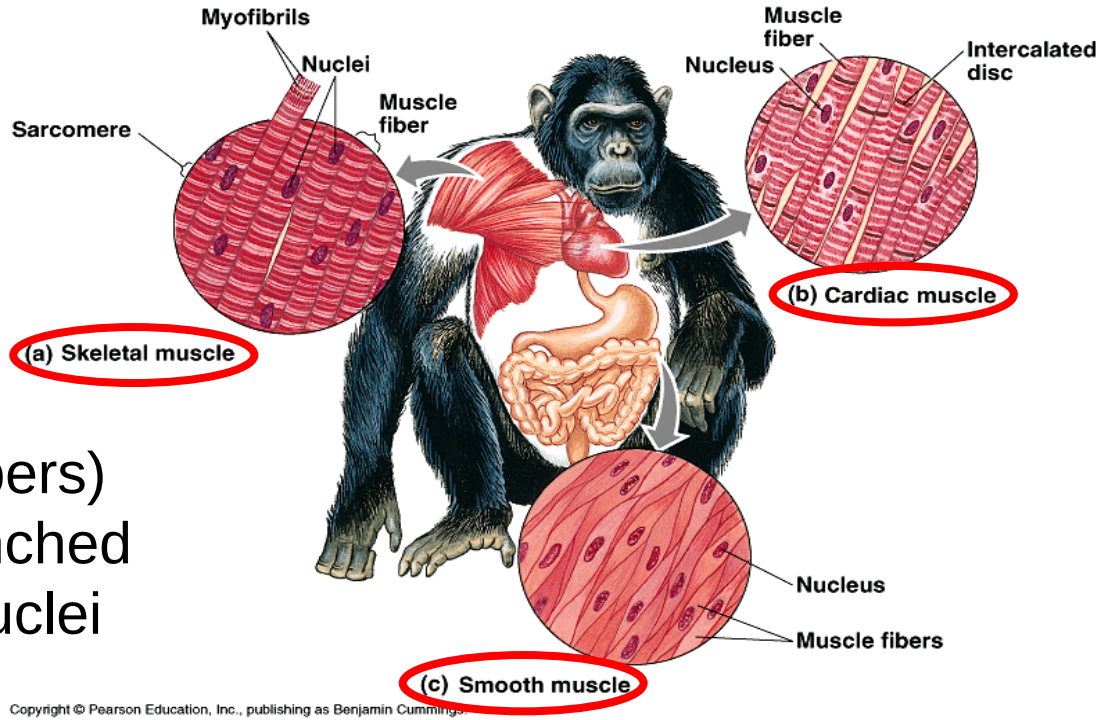


Figure 40.5 (Campbell 9th ed)

Function:

- Movement
- Contract due to nerve signals

Muscle tissue + connective tissue + nerves + blood vessels
= an organ called a “muscle”

3 types of muscle tissue:
A. Skeletal

- Long, wide, || cells
  - Multiple nuclei on edges
  - Striated
- Voluntary
- Location:
  - Attached to bones by tendons
- Function:
  - Primarily used for movement

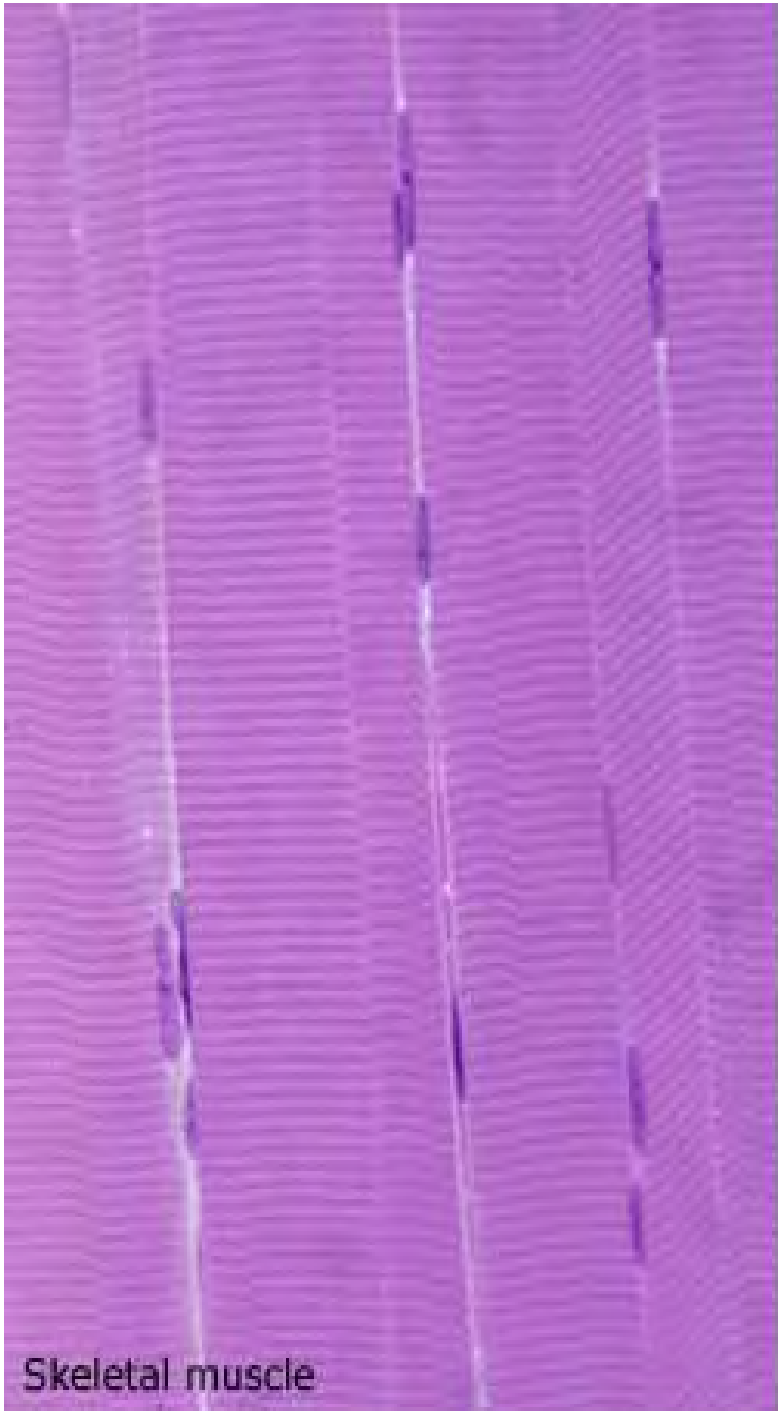
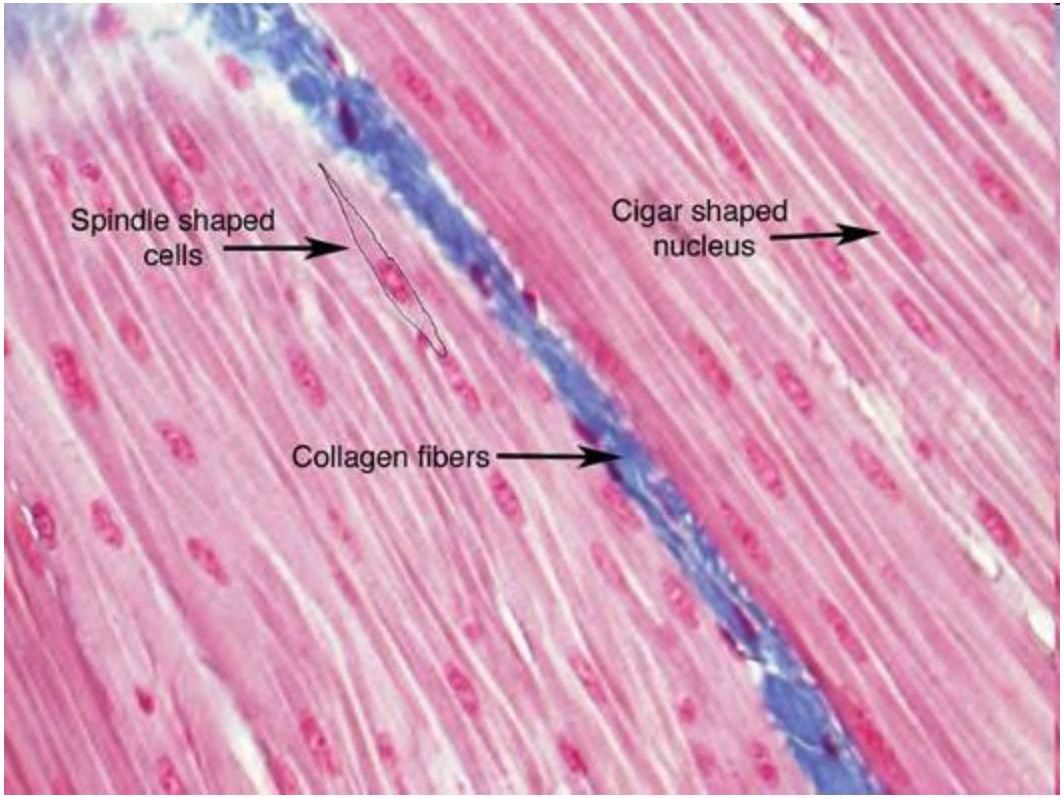


Figure 40.5 (Campbell 9th ed)

3 types of muscle tissue:

B. Smooth



- Small tapered cells
  - 1 nucleus
  - Not striated;
- involuntary
- Location:
  - In walls of blood vessels digestive tract, urinary bladder, reproductive tract
- Function: digestion, circulation, reproduction

Is the diaphragm controlled by skeletal or smooth muscle?

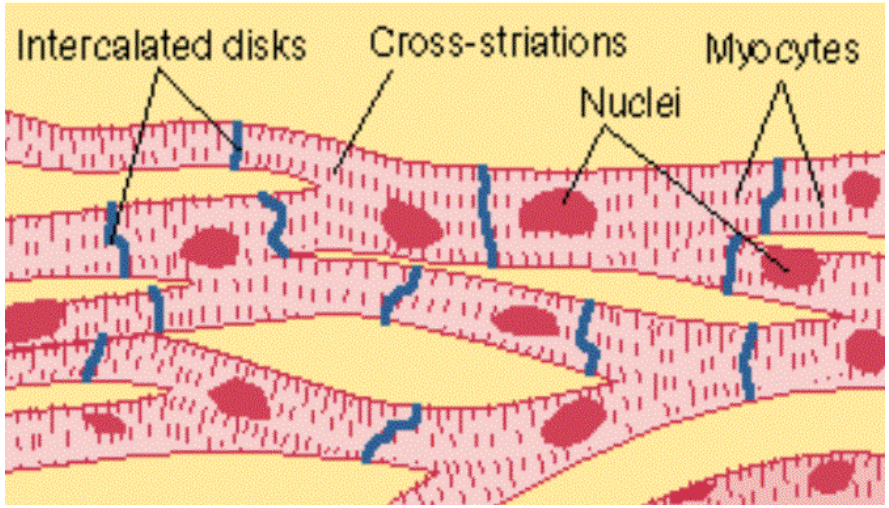
What about the urinary bladder?

Figure 40.5 (Campbell 9th ed)

3 types of muscle tissue:

C. Cardiac

- Long, branched cells
- 1 nucleus
- Striated
- involuntary
- *Intercalated disks*
  - faster communication



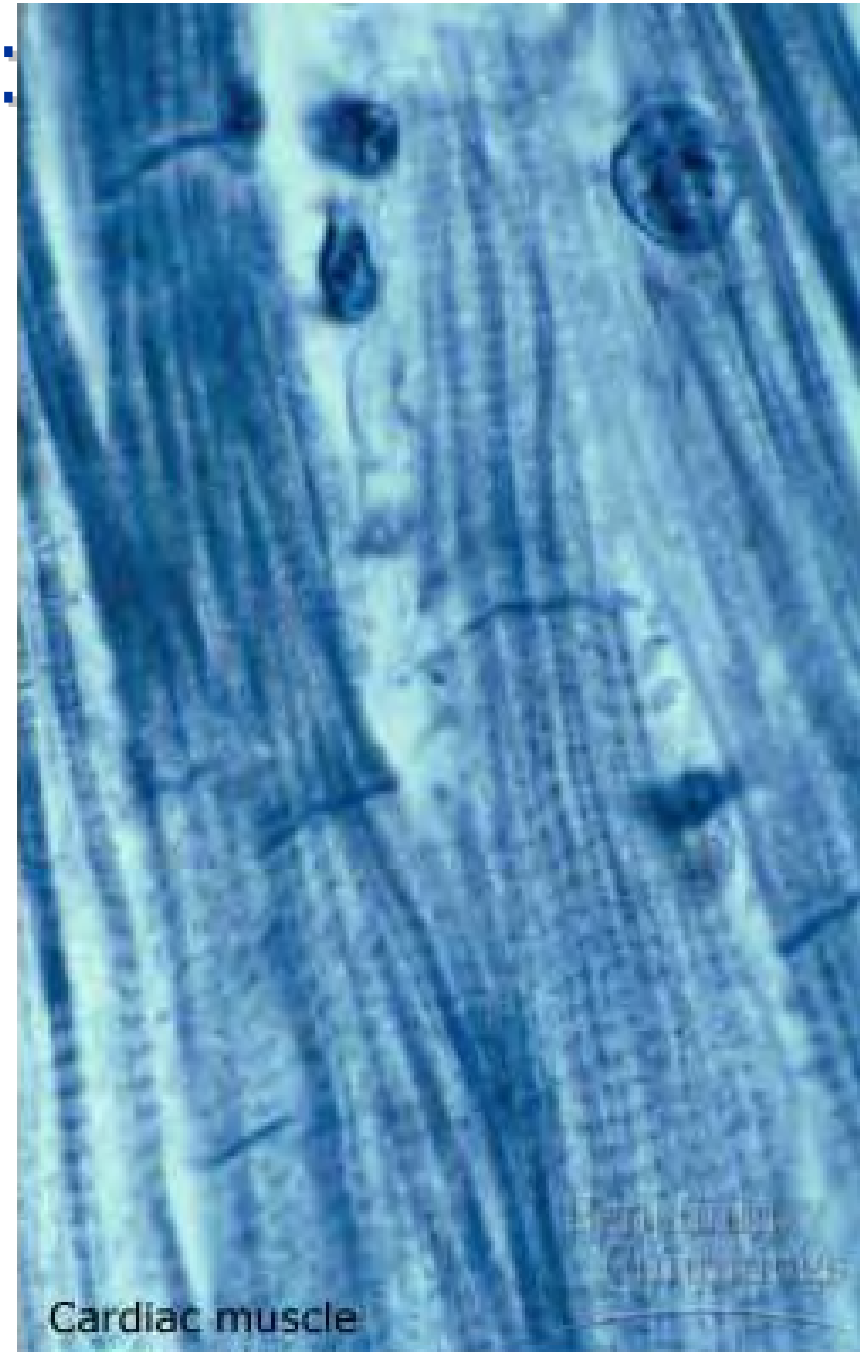


Figure 40.5 (Campbell 9th ed)

Nervous Tissue

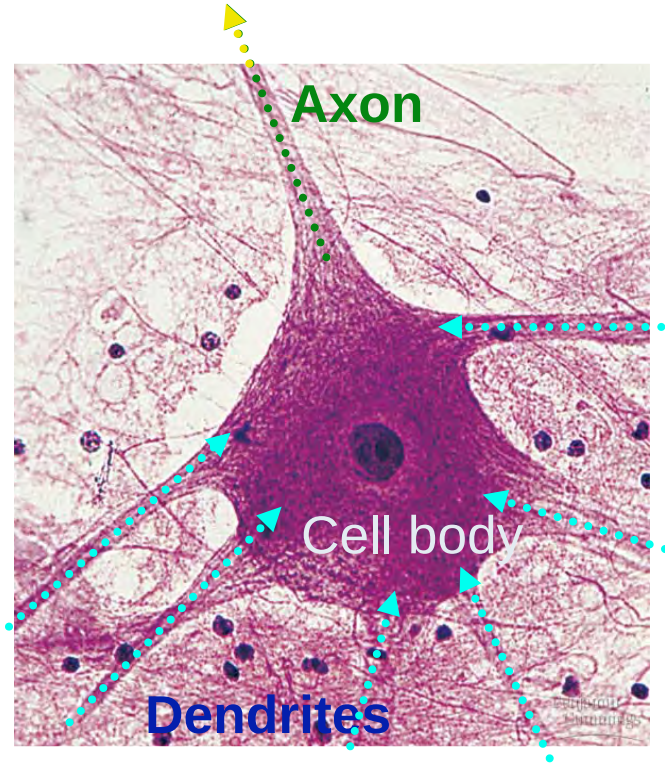
Types: discussed later

Morphology

- 2 general classes of cells:
  - Neurons
    - Transmit electrochemical signals
      - Cell body, axon, dendrite
  - Glia
    - Various types which function in:
      - anchoring neurons
      - provide nutrients for neurons
      - remove dead cells
      - form myelin sheath
    - 10x more abundant than neurons

Function:

- Sense stimuli
- Transmit signals btwn body parts
- Process signals



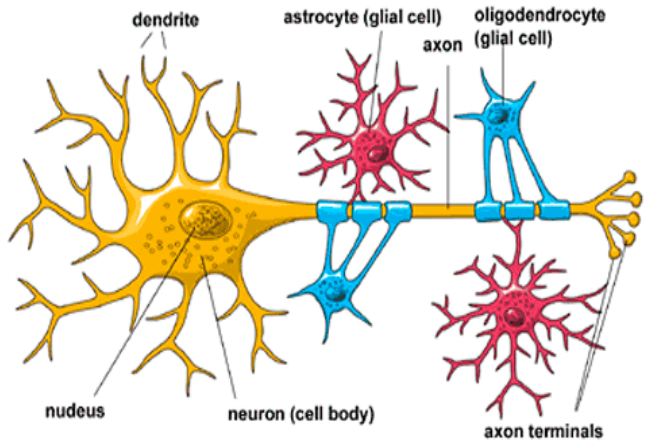


Figure 40.5 (Campbell 9th ed)

Coordination and Control

- Nervous system
  - Transmit signals btwn specific locations
  - Better for rapid response
    - Locomotion and behavior
- Endocrine system
  - Transmit molecules via the blood stream
  - Better for gradual changes that affect the entire body
    - Growth, development, reproduction, digestion etc.

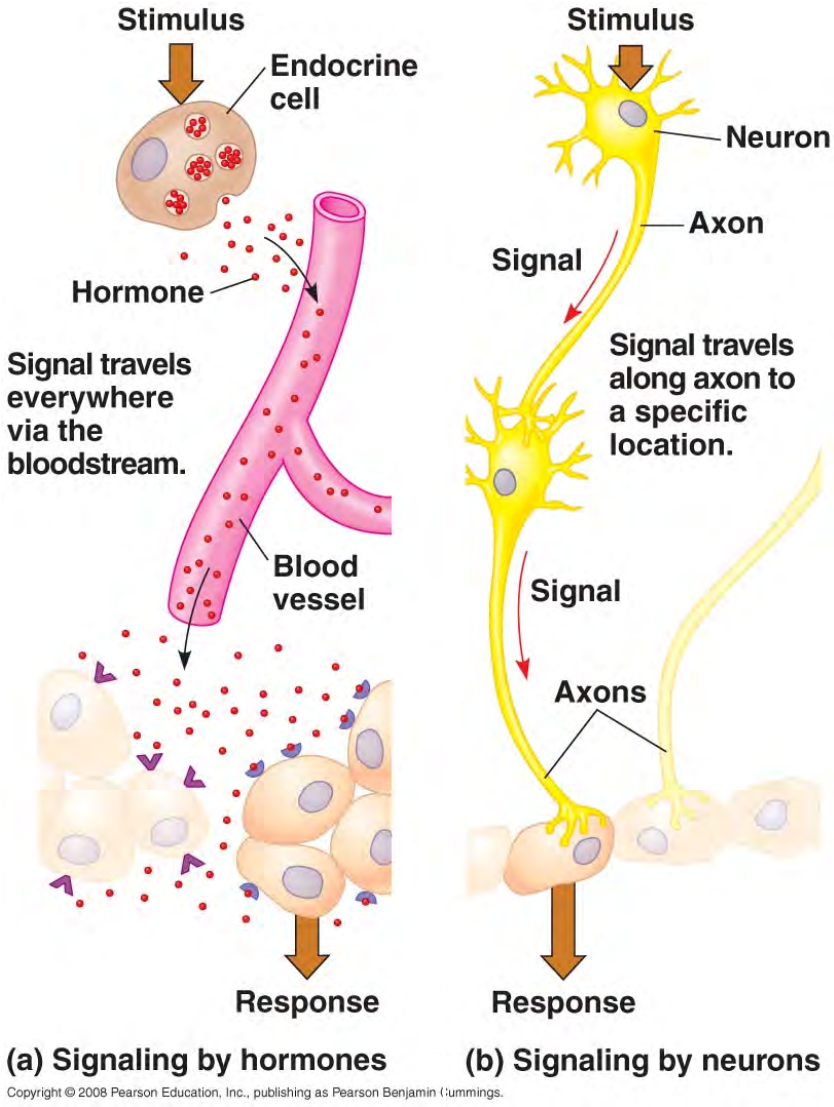
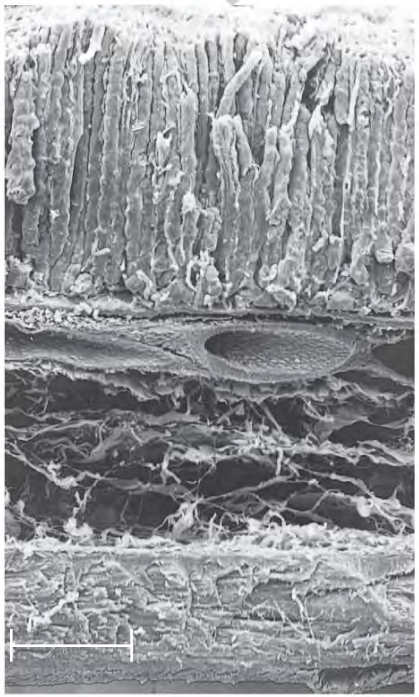


Figure 40.6 (Campbell 9th ed)

Organs

- In most animals, tissues organized into organs
- Tissues may be:
  - intermingled or
  - arranged in distinct layers

Lumen of stomach

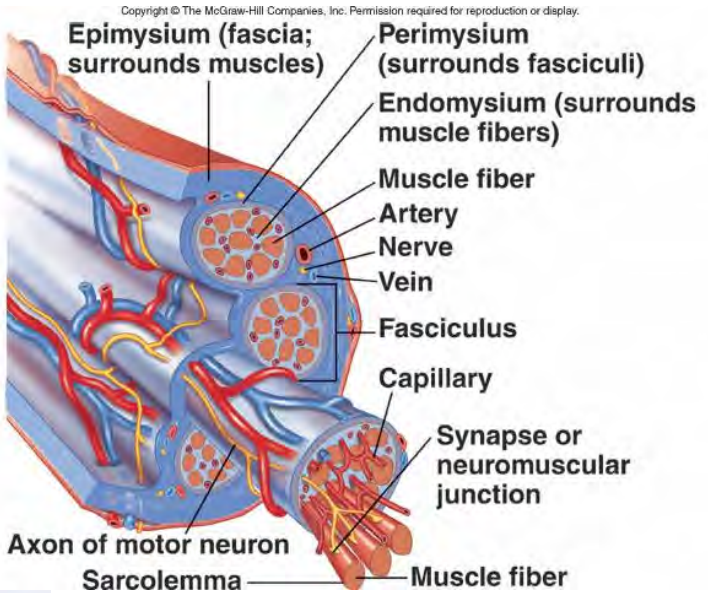


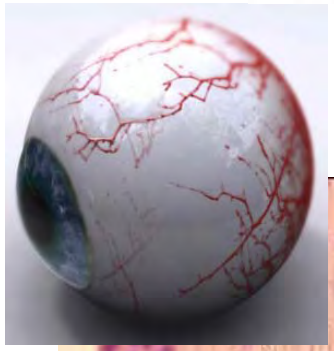
Mucosa: Epithelial layer

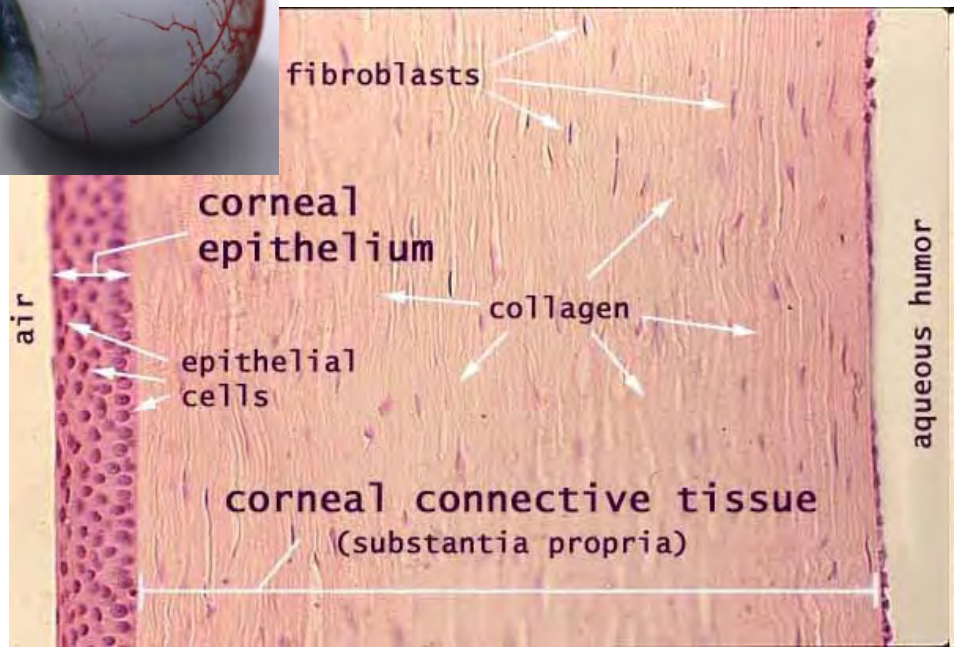
Submucosa: connective tissue

Muscularis: smooth muscle

Serosa: connective and epithelial tissues







Organ Systems

We will discuss many of these in subsequent lectures…

Table 40.1 Organ Systems: Their Main Components and Functions in Mammals

Organ System	Main Components	Main Functions
Digestive	Mouth, pharynx, esophagus, stomach, intestines, liver, pancreas, anus	Food processing (ingestion, digestion, absorption, elimination)
Circulatory	Heart, blood vessels, blood	Internal distribution of materials
Respiratory	Lungs, trachea, other breathing tubes	Gas exchange (uptake of oxygen; disposal of carbon dioxide)
Immune and lymphatic	Bone marrow, lymph nodes, thymus, spleen, lymph vessels, white blood cells	Body defense (fighting infections and cancer)
Excretory	Kidneys, ureters, urinary bladder, urethra	Disposal of metabolic wastes; regulation of osmotic balance of blood
Endocrine	Pituitary, thyroid, pancreas, other hormone-secreting glands	Coordination of body activities (such as digestion, metabolism)
Reproductive	Ovaries, testes, and associated organs	Reproduction
Nervous	Brain, spinal cord, nerves, sensory organs	Coordination of body activities; detection of stimuli and formulation of responses to them
Integumentary	Skin and its derivatives (such as hair, claws, skin glands)	Protection against mechanical injury, infection, drying out; thermoregulation
Skeletal	Skeleton (bones, tendons, ligaments, cartilage)	Body support, protection of internal organs, movement
Muscular	Skeletal muscles	Movement, locomotion

Table 40.1 Campbell et al. 9th ed

Animal Function

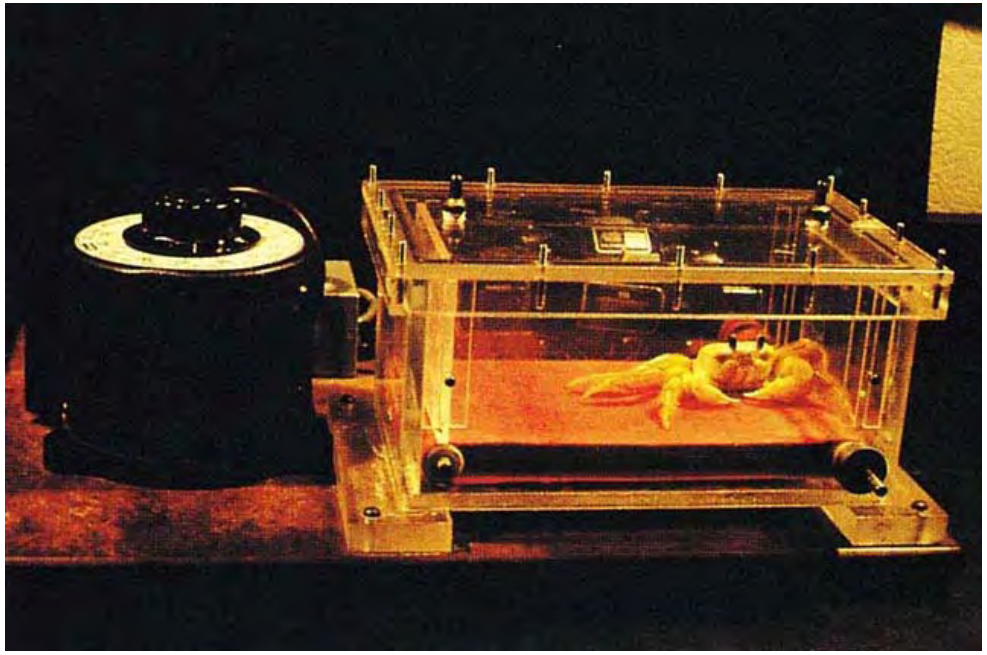
Two Basic Questions

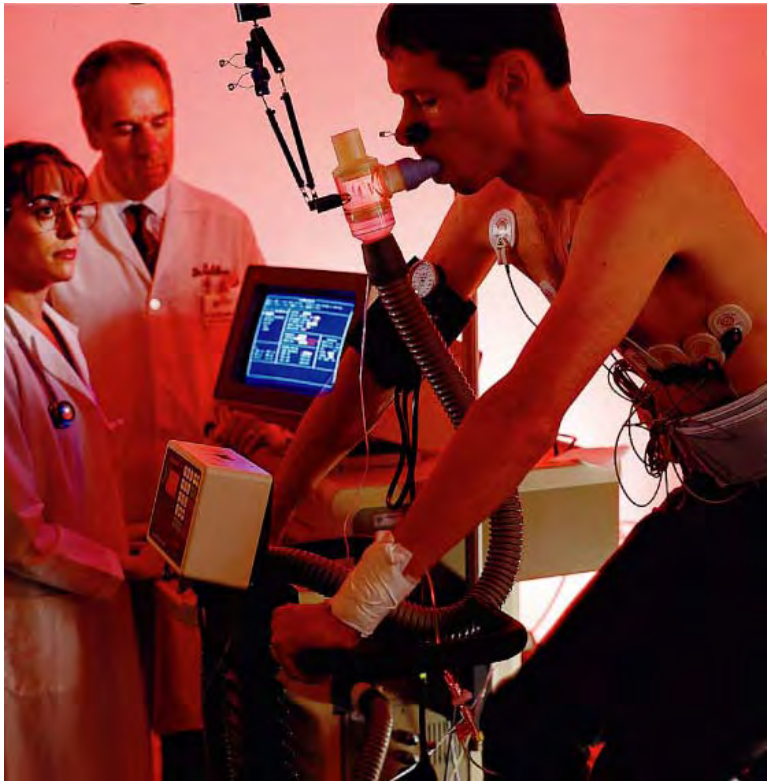
(1) How do organisms use energy?

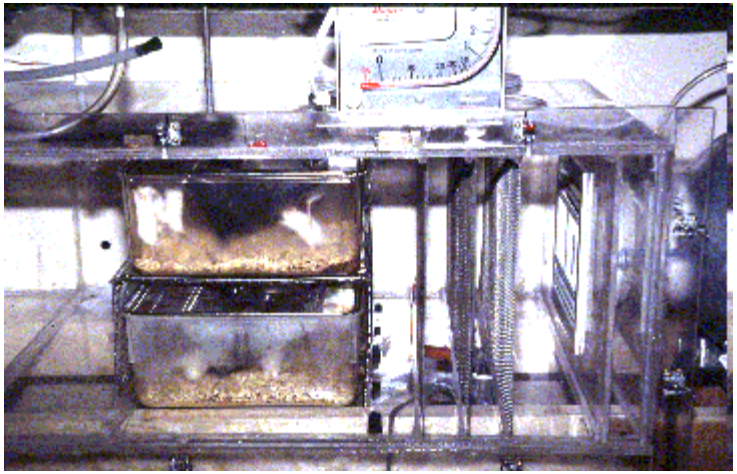
(2) How do organisms cope with changing environment?

(1) How do organisms use energy?

Metabolic rate - amount of energy used per unit time



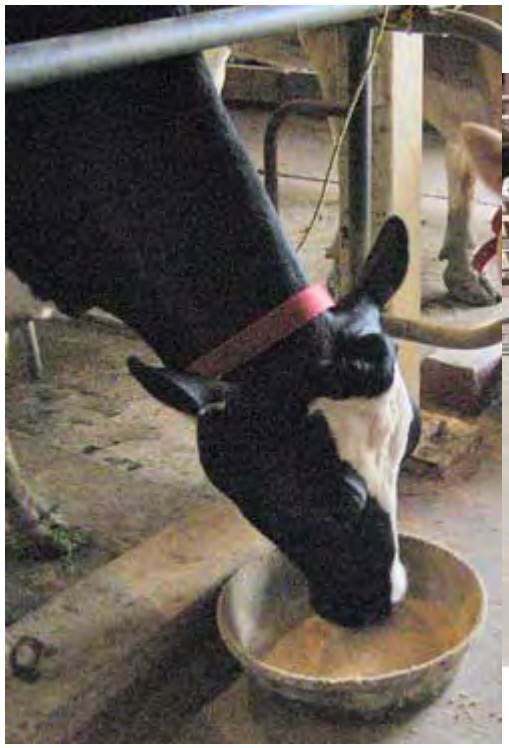




Measured by amount of O_2 consumed or CO_2 or heat produced

(1) How do organisms use energy?

Metabolic rate - amount of energy used per unit time



Or by calories consumed and energy lost in feces and urine.

(1) How do organisms use energy?

Energy requirements are related to size, activity and environment

Basal metabolic rate (BMR)

= energy needed for basic functions
(e.g. cell maintenance, breathing, heartbeat)

- BMR is positively related to body mass
  - i,.e. The amount of energy needed for basic maintenance is proportional to size.

Liters O_2/hr

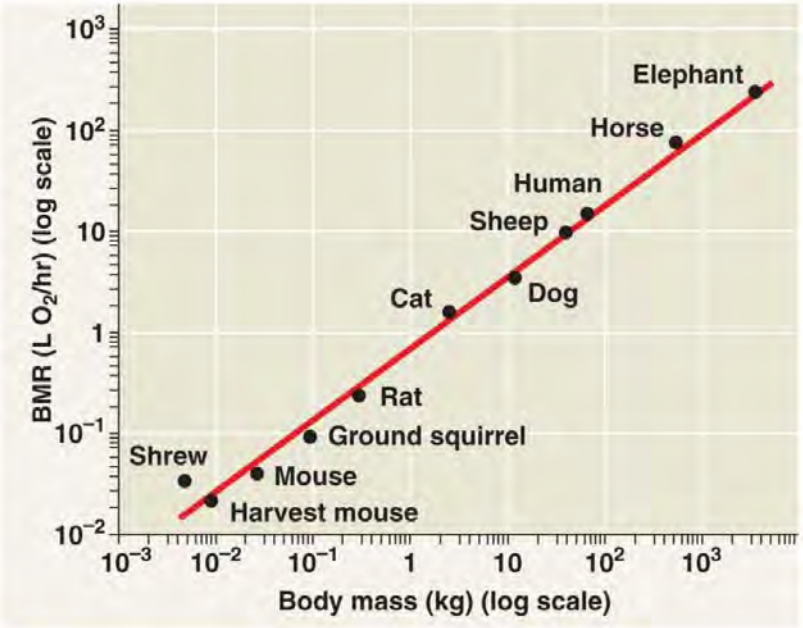
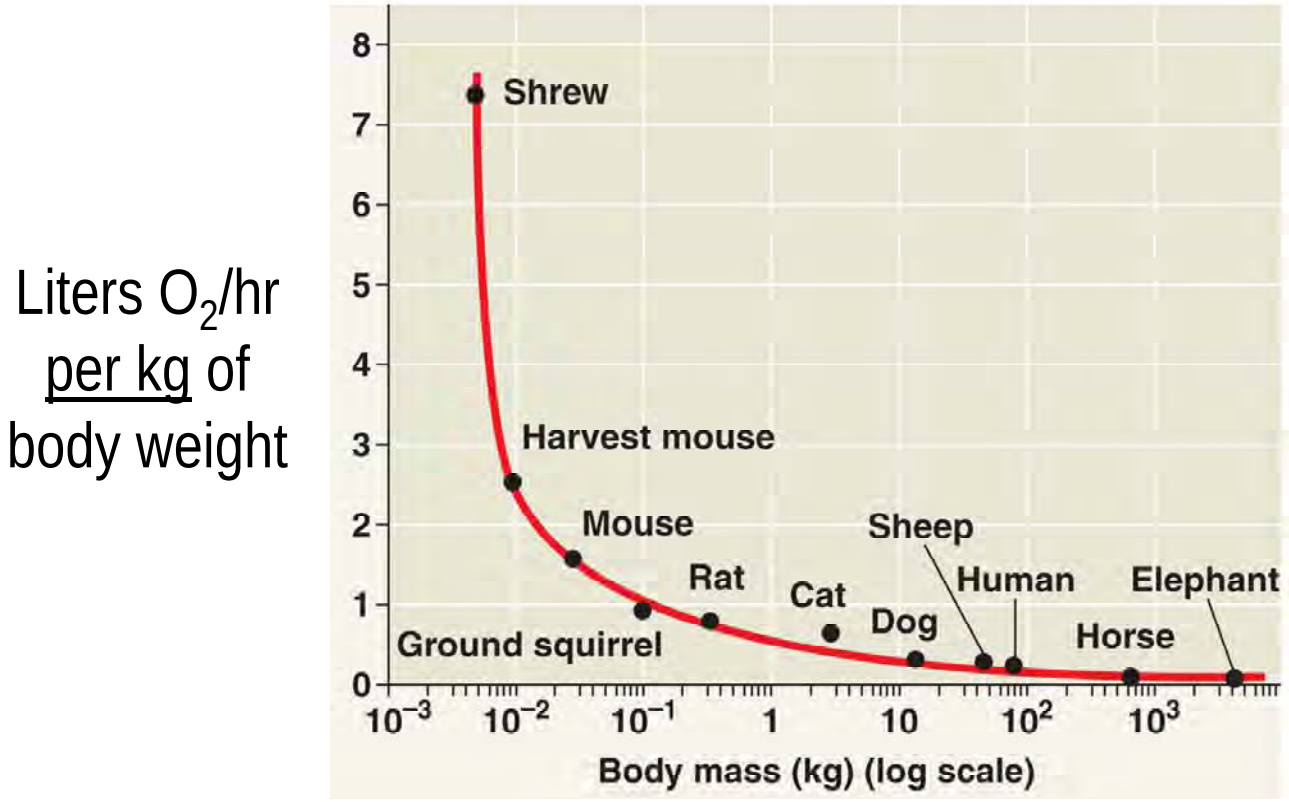


Figure 40.19 (Campbell 9th ed)

(1) How do organisms use energy?

- BMR <u>per kg</u> is negatively related to body mass
  - i.e. Smaller animals require more energy per kg of body weight



(b) Relationship of BMR per kilogram of body mass to body size

Figure 40.19 (Campbell 8th ed)

Energy Budgets

= Energy used for
BMR, activity, growth, reproduction, & temperature regulation

Proportion used for each varies among:
(A) endotherms; (B) endotherms & ectotherms
depending on:
(1) activity level, (2) ambient temperature, (3) body size, (4) reproductive state

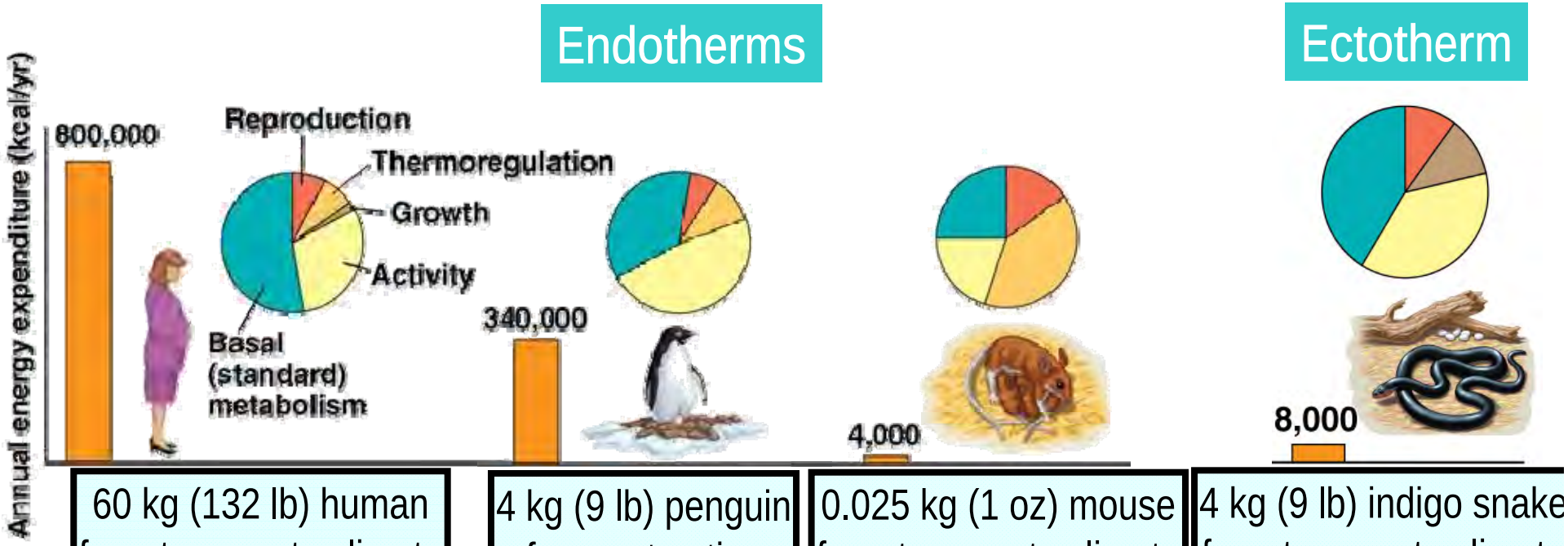


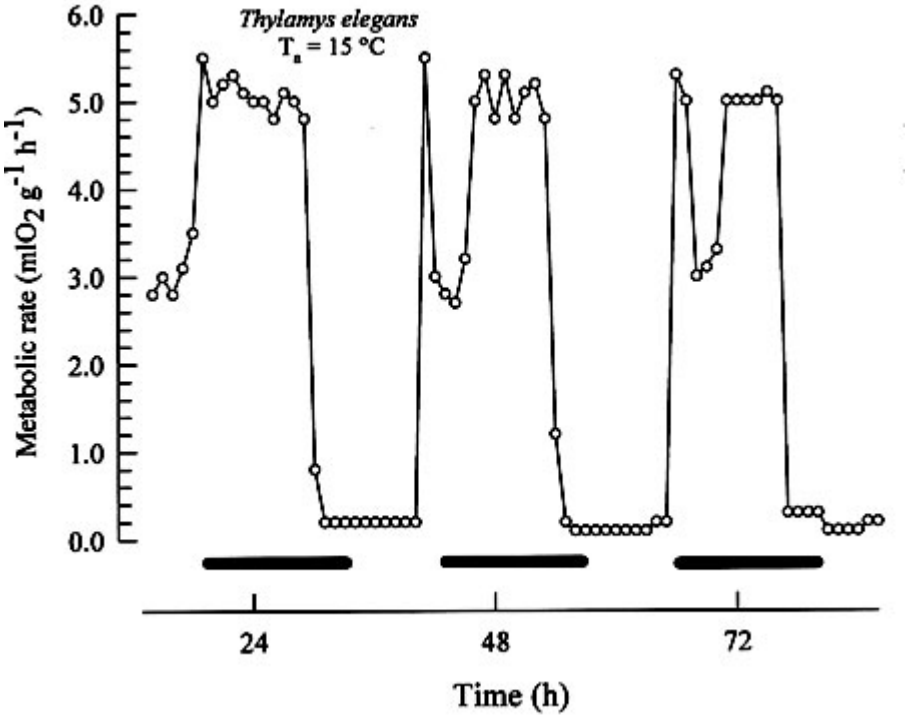
Figure 40.20 (Campbell 9th ed)

Energy Conservation

Torper - reduced state of activity and metabolic rate
- may occur over **short or long** periods of time

A. Daily Torper – short-term torper seen in small animals with high BMR/kg

Chilean mouse-opossum
(*Thylamys elegans*)



Daily torpor in a Chilean mouse-opossum over 3 days
[Bars indicated dark hours.]

Bozinovic, F, G RuÍz, A Cortes and M Rosenmann. 2005. Energetics, thermoregulation and torpor in the Chilean mouse-opossum *Thylamys elegans* (Didelphidae). Revista Chilena de Historia Natural 78: 199-206.

Energy Conservation

B. Long-term Torper

1. Hibernation - long term torper
   in response to <u>cold and food scarcity</u>

Belding's Ground squirrel (*Spermophilus beldingi*)

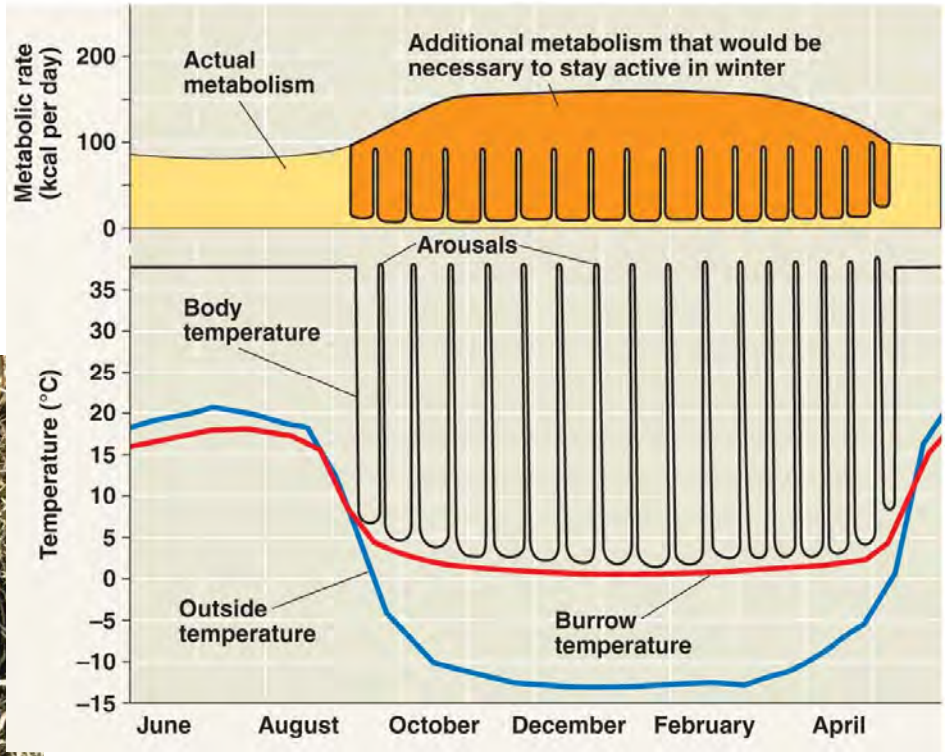


Figure 40.21 (Campbell 8th ed)

Energy Conservation

B. Long-term Torper

2. Estivation - long term torper

in response to heat and H_2O scarcity

Caimen

Lungfish fossil

Animal Function

Two Basic Questions

(1) How do organisms use energy?

(2) How do organisms cope with changing environment?

- Regulation

Thermoregulation

Maintenance of internal temperature within tolerable range

Does temp vary? → / Where is heat from? ↓	**Poikilotherm** Body heat varies w/ ambient temp	**Homeotherm** Body heat remains constant
Ectotherm Body heat derived from environment	Most μorganisms, invertabrates, fish, amphibs, reptiles	Many smaller oceanic fish
Endotherm Body heat derived from own metabolism	Many subterranean rodents	Most birds & mammals

***None of these terms indicate what the internal temperature of the organism is.

Thermoregulation

Organisms exchange (+/-) heat with environment by : conduction, convection, radiation, and evaporation

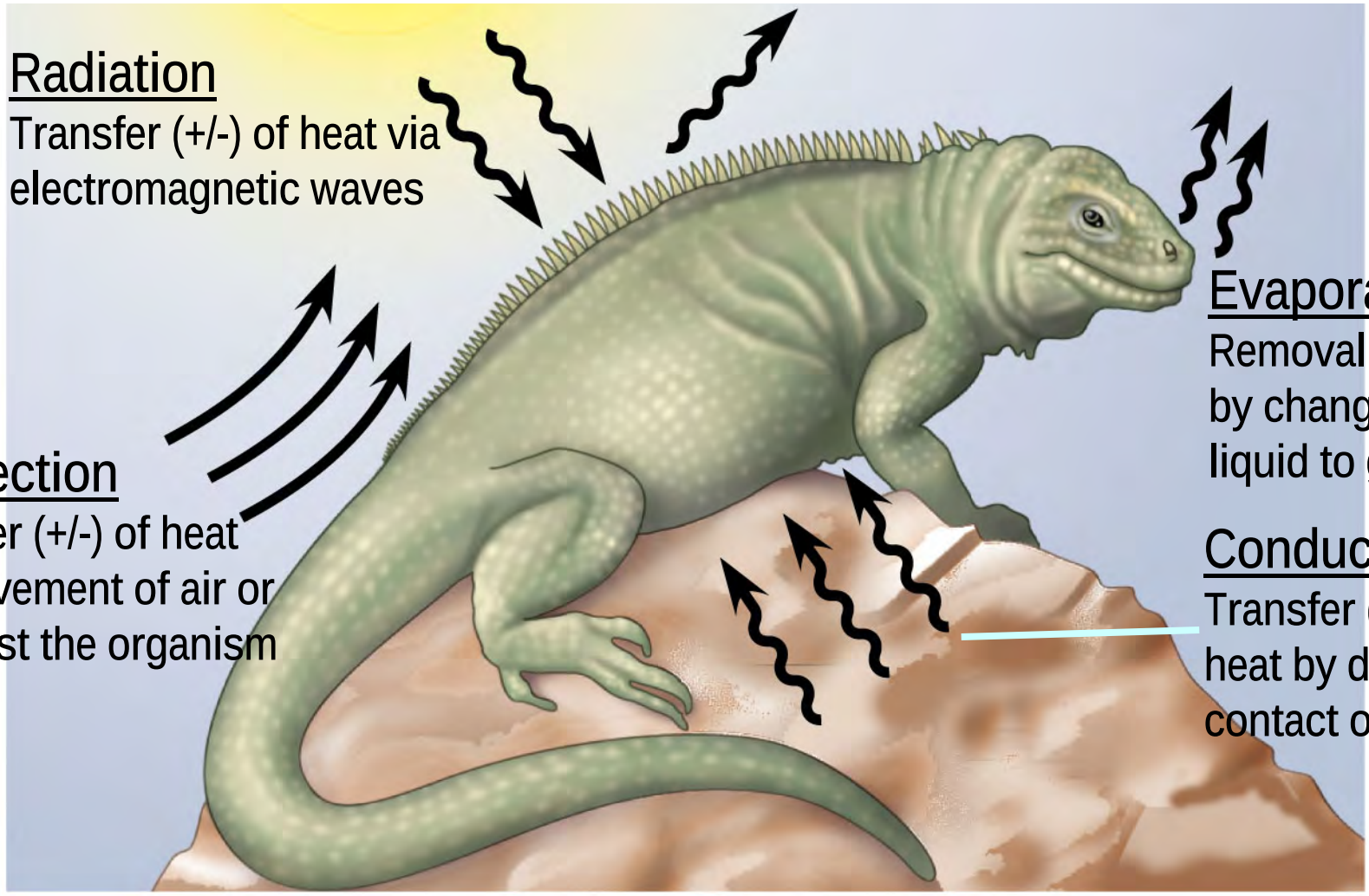
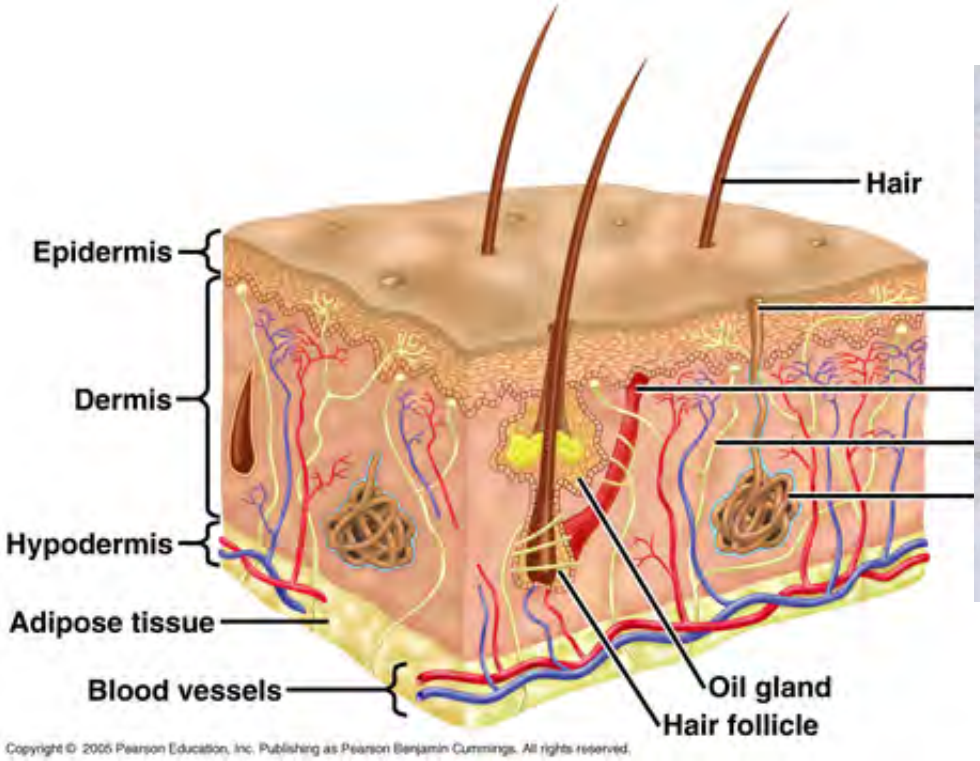


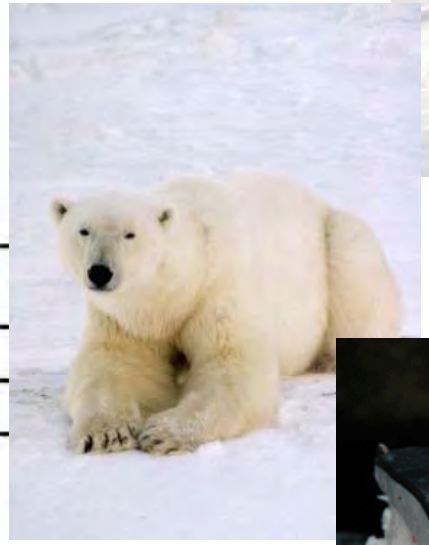
Figure 40.11 (Campbell 9th ed)

How to thermoregulate:

Insulation

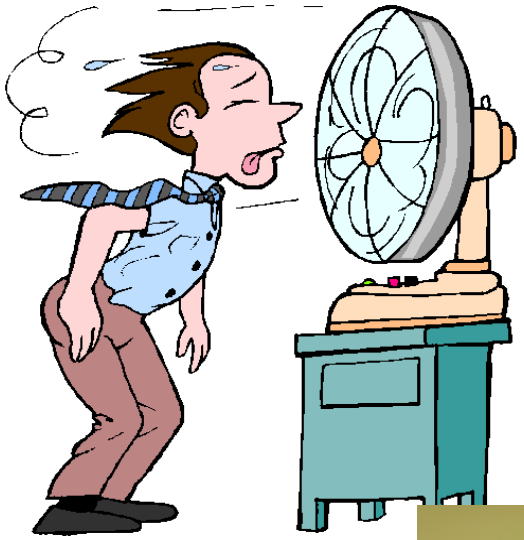
Fat, fur, feathers





How to thermoregulate:

Evaporative cooling



How to thermoregulate:

Behavior

Figure 40.13 (Campbell 9th ed)

How to thermoregulate:

Circulatory adaptation

Vasodilation vs. vasoconstriction

Alteration of amount of blood flowing btwn body core and skin

Countercurrent exchange

Transfer of heat (or solutes) btwn fluids flowing in opposite directions

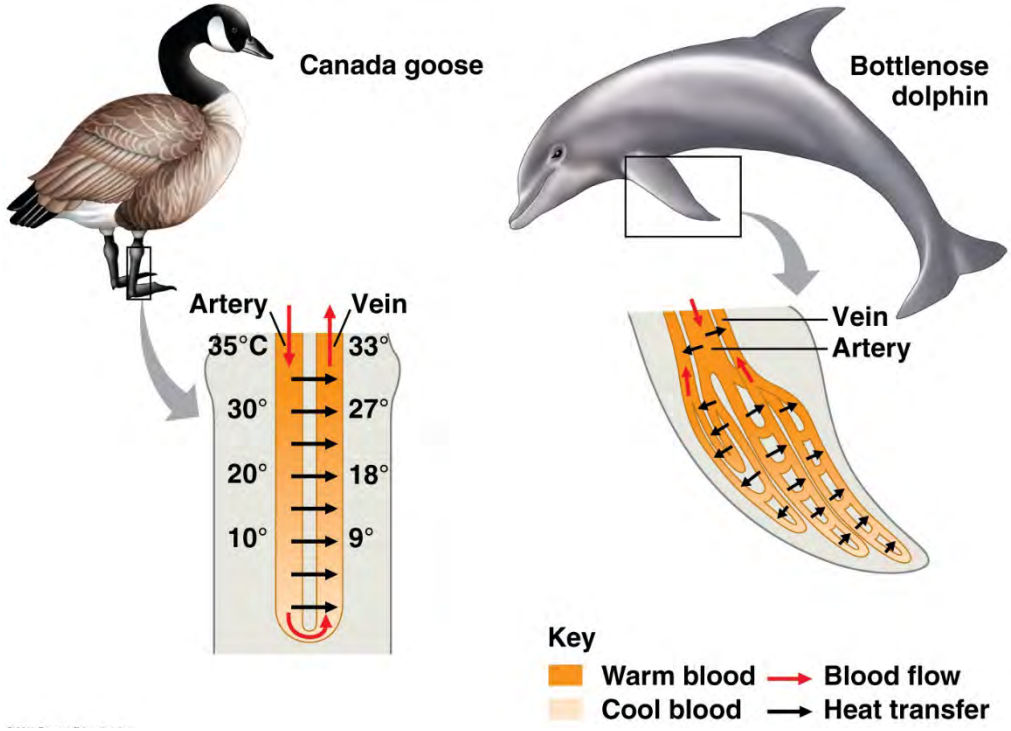


Figure 40.12 (Campbell 9th ed)

How to thermoregulate:

Adjust heat production

- Increase metabolic rate
- Alter mitochondria (via hormones) to produce heat instead of ATP
- Muscle shivering helps endotherms and some ectotherms

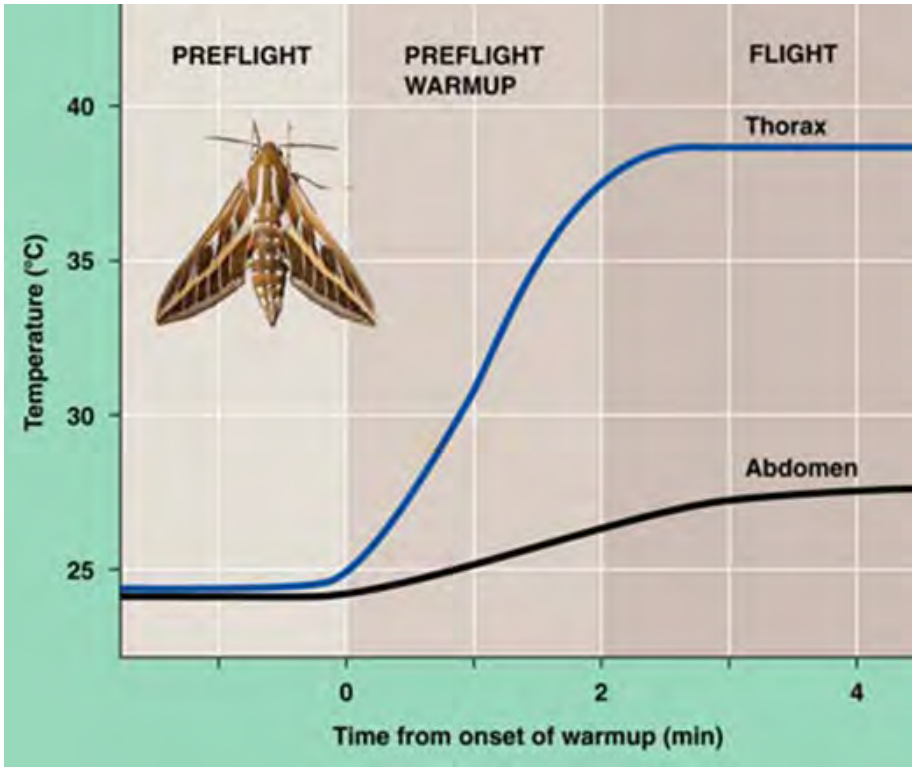


Figure 40.15 (Campbell 9th ed)

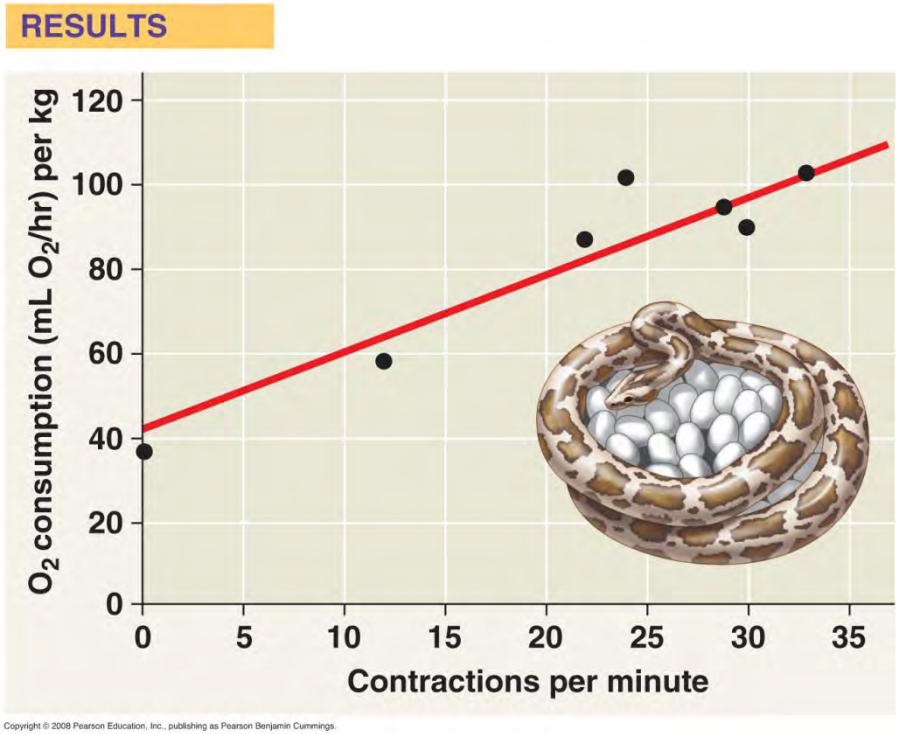


Figure 40.14 (Campbell 9th ed)

Readings on which you will NOT be tested

Table 40.1

Section 40.2 (860-862)

Physiological Thermostats and Figure 40.16 (867-868)

Energy Allocation & Quantifying Energy Use and Figure 40.17 (868-869)

Figure 40.21

In general:

- You are NOT responsible for definitions of terms or sections included in the text but which were not discussed in lecture
- You are not responsible for the details of examples used in the text but not discussed in lecture. HOWEVER, these additional examples will help your understanding of concepts discussed and may be used on exams to test if you understand the general concepts.
- You ARE responsible for material covered in lecture but not included in the readings

Next Chapter

Chapter 41 - Nutrition