Biology from an EE Perspective
Lecture 3

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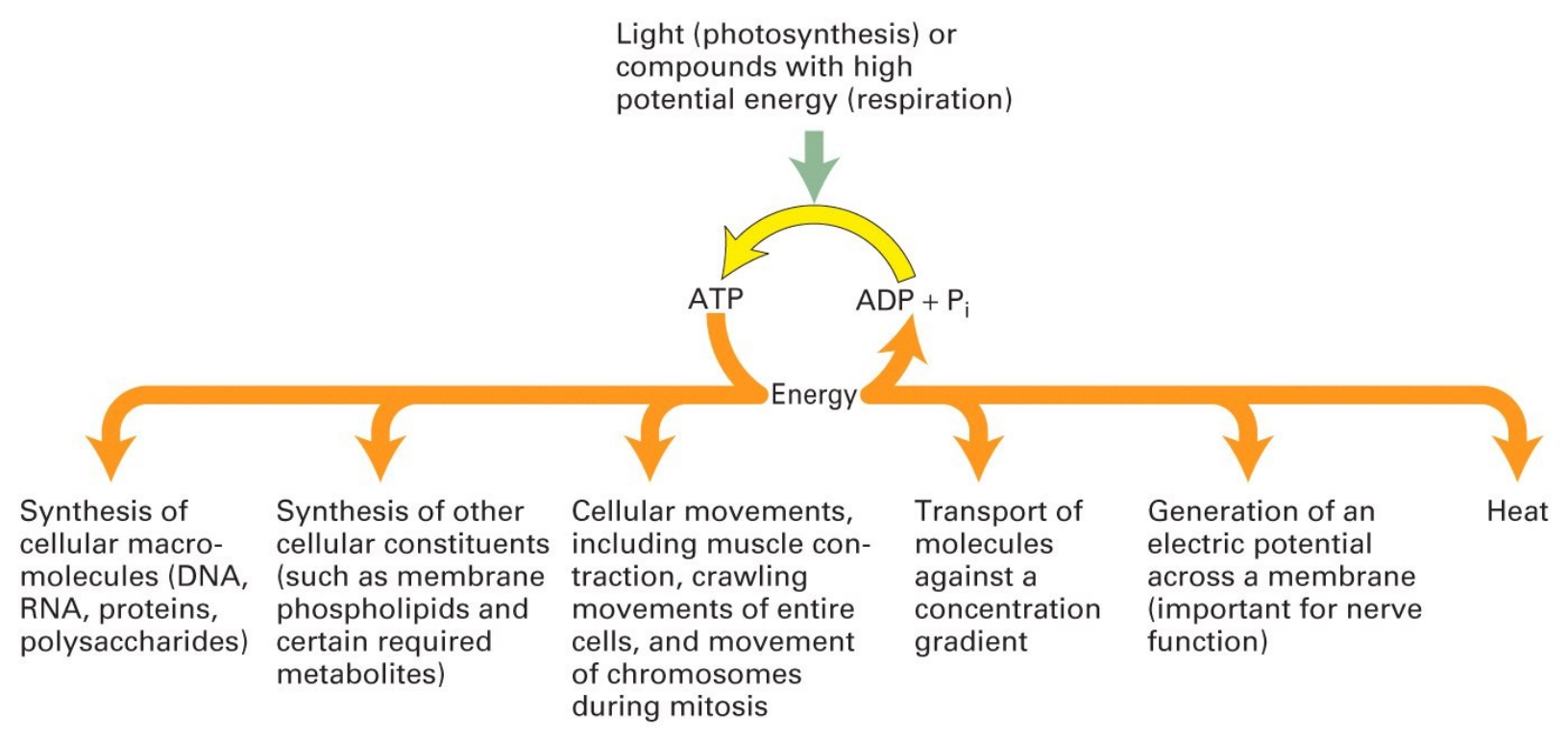
Cells ⇨ Tissues ⇨ Organs ⇨ Organism

Overview

- A first pass broad look at structure and function at the organism level for a multi-cellular organism -- would take examples from mammalian physiology
- At the organ level it is easier to make hypotheses about how an organ could work and then check it out [would do that with some organs but would want each of you to also do that exercise with at least one organ and come up with a list of concepts you would want to check up on]
- Again try to identify what functions would benefit from engineering modeling – then study those sub-systems in greater detail

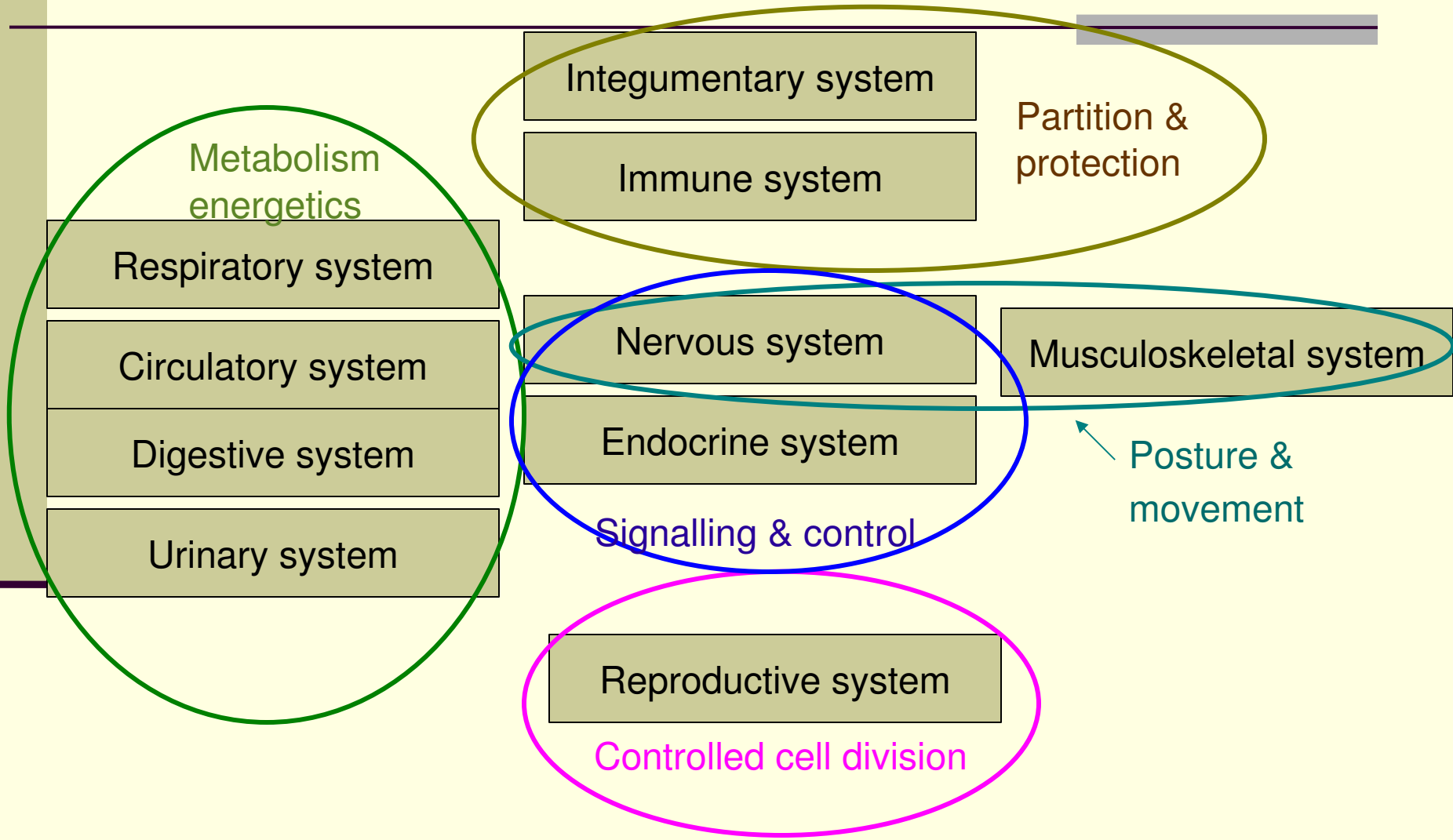
Important functions a cell needs to perform



How is function different at the organism level say for a mammal?

- Organism does not synthesize any food, needs to transforms nutrients for its metabolic activities
- Cells could have specialized functions
  - QQ: How many cell types does one have in a mammal?
- Does ATP remain the energy carrier?
- An additional set of molecules on the cell wall required to bind cells to form tissue for an organ plus new cell regulation mechanisms
- More complex signaling & regulation mechanisms for homeostasis & control

Block diagram of a mammal



Cells organized into tissues

- Specialization of cells allows them to carry a set of related functions more effectively
- Often a very high degree of interaction between different organ systems but many organ systems can handle various levels of failure in an organ
- Various levels of repair and regeneration possible for different organ systems

The four types of tissues

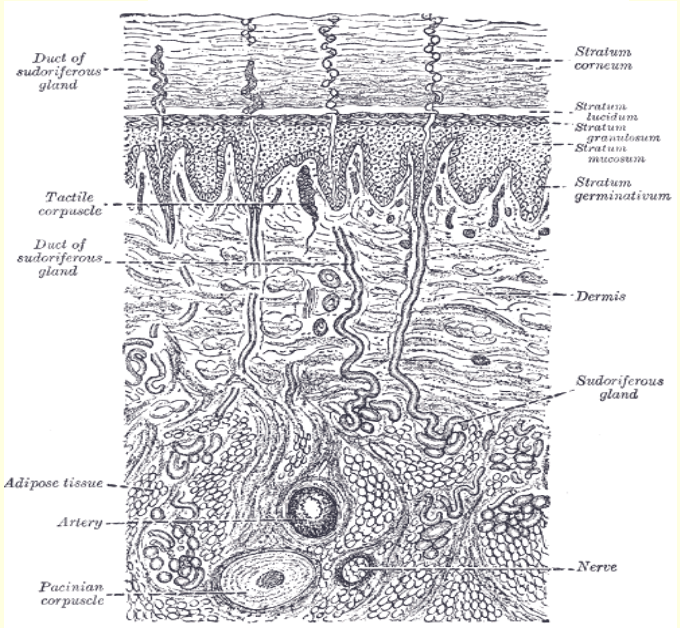
- Epithelial tissue:
  - Tightly packed cells forming continuous sheets – skin, covering of organs, ..
- Connective tissue:
  - Many types of tissue for support and structure – tendons, ligament, cartilage, bone, ..
- Muscle tissue:
  - Tissue that can contract – smooth and striated
- Nerve tissue:
  - Generate & conduct bioelectrical signals

Organs made from tissues

- Organs have at least two types of tissues
  - So bone not an organ, but cartilage+bones+ tendons+ligaments form the skeletal system
- Tissues structured in an organ to help perform/optimize a set of operation

Integumentary system

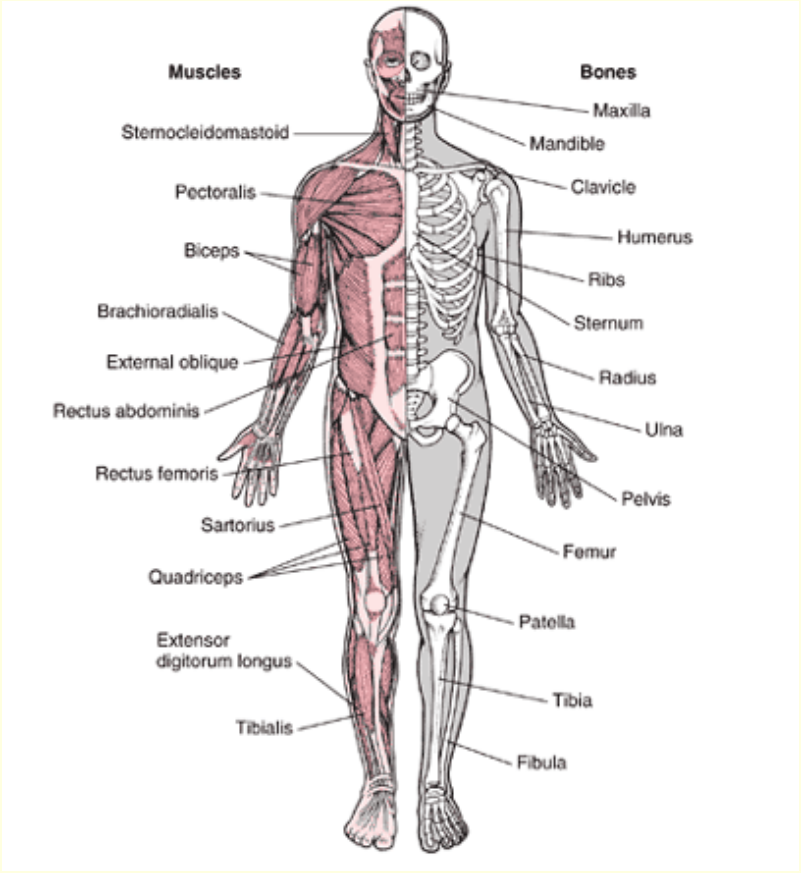
- Largest organ
- External and internal surfaces with different function
- Skin cells evolved with better adaptability to environmental factors
  - Protects from UV
  - Synthesizes Vitamin D
- Important for homeostasis
- Sensory receptors for pain, pressure, temperature

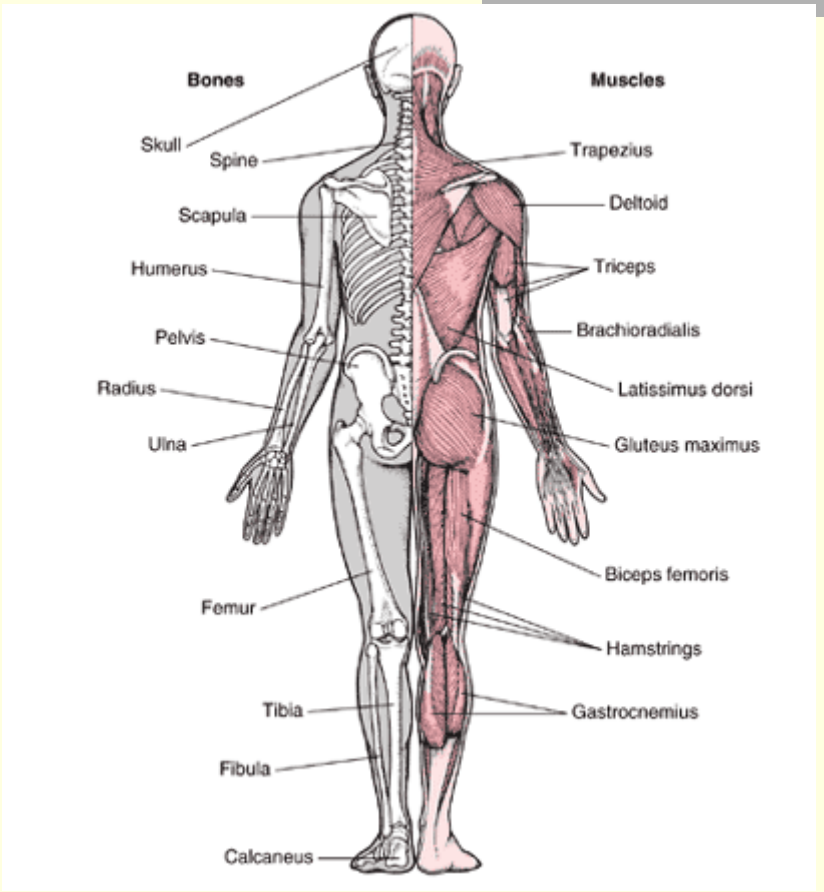


Some teasers about the skin

- Not as passive an organ as we think it to be, for example has muscles called arrector pili!
  - How is skin coloration controlled to adapt to UV exposure & vitamin D synthesis?
  - How do sweat glands operate – essentially how is the effective permeability modified with body temperature
- What are the molecular physiological processes that enable sensing temperature, pressure, texture, slip, ..?

Musculoskeletal System





http://www.merck.com/mmhe/sec05/ch058/ch058c.html

Musculoskeletal system function

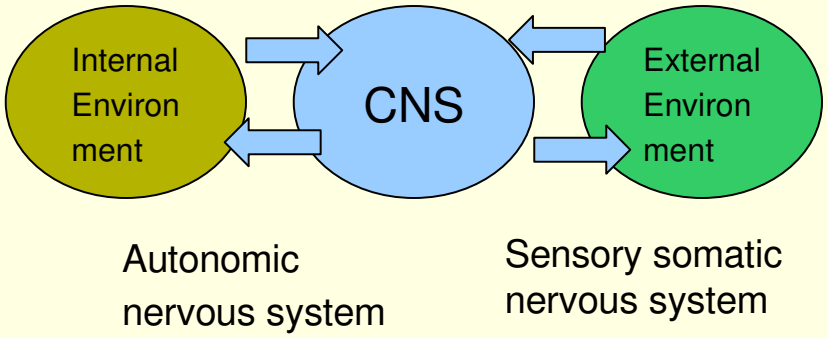
- Gives structure and acts as a scaffold for organs
- Protection for critical organs
- Enables posture, action and locomotion
- Red & white blood cells produced in the bone marrow
- Fairly well studied from the biomechanics angle for control of prosthetic devices

Some teasers on the musculoskeletal system

- Is bone a living tissue? If yes in what ways? How do the metabolic rates of living cells in bone compare to those with that of muscle cells? What form of circulatory system is there inside the bone for metabolite transfer?
- How are muscles controlled and how is biochemical energy actually converted into motion?
- How is bone repair controlled?

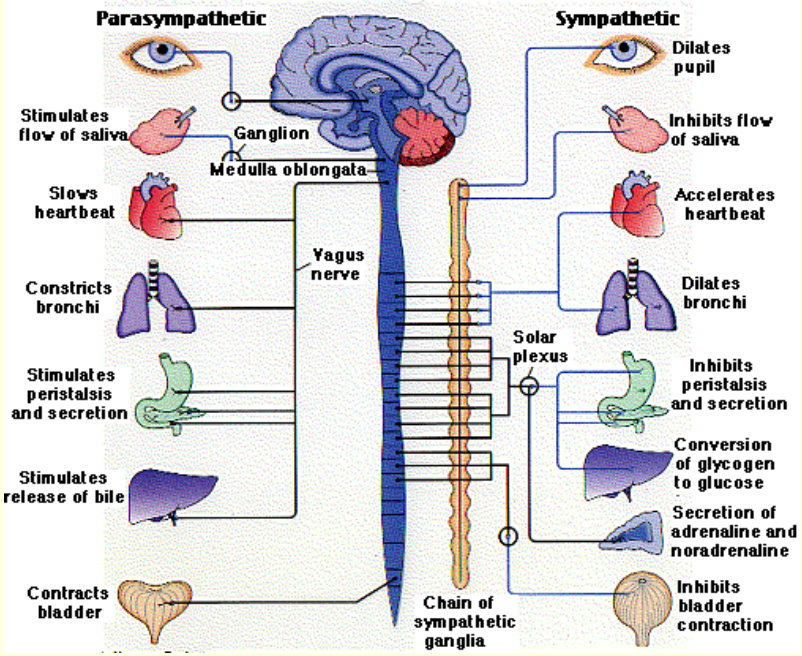
Nervous system

- Central nervous system (CNS)
  - Brain
  - Spinal cord
- Peripheral nervous system
  - Sensory somatic nervous system
  - Autonomic nervous system



Autonomic nervous system

- Monitors internal environment & provides appropriate control signals
- Handle control in an involuntary fashion of
  - heart
  - lungs
  - viscera
  - glands



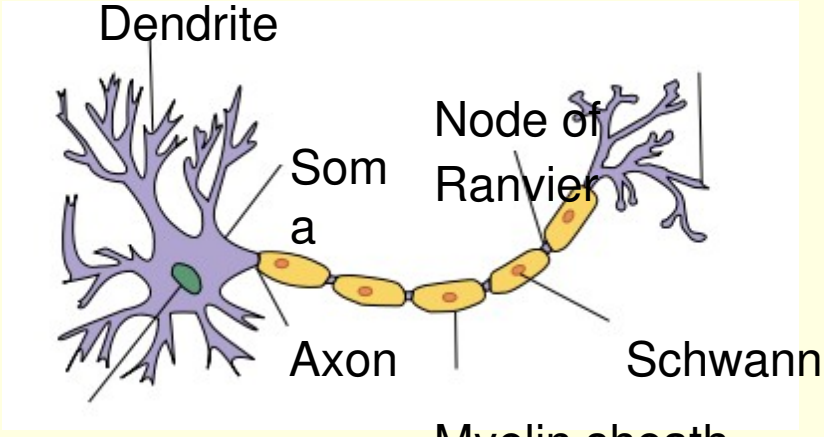
The parasympathetic & sympathetic nervous subsystems perform complementary control

Some teasers about nerves and nerve impulses

What is the signal?

- Biochemical
- Bioelectrical

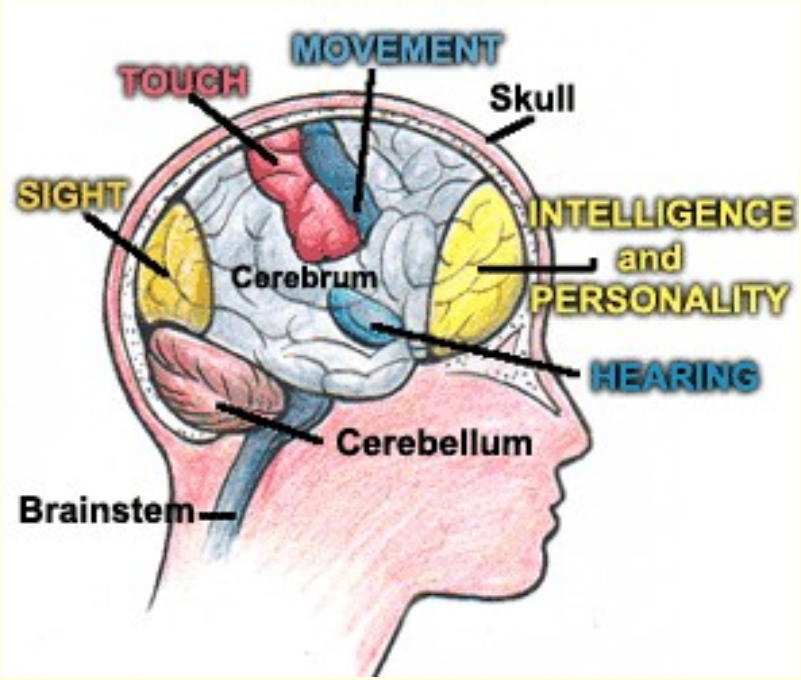
- For what types of function would one use what?
- How are chemical and physical parameters sensed?
- Is signal amplification necessary? How?



Broach the idea of cell potential, equivalent circuit of a neuron, ..

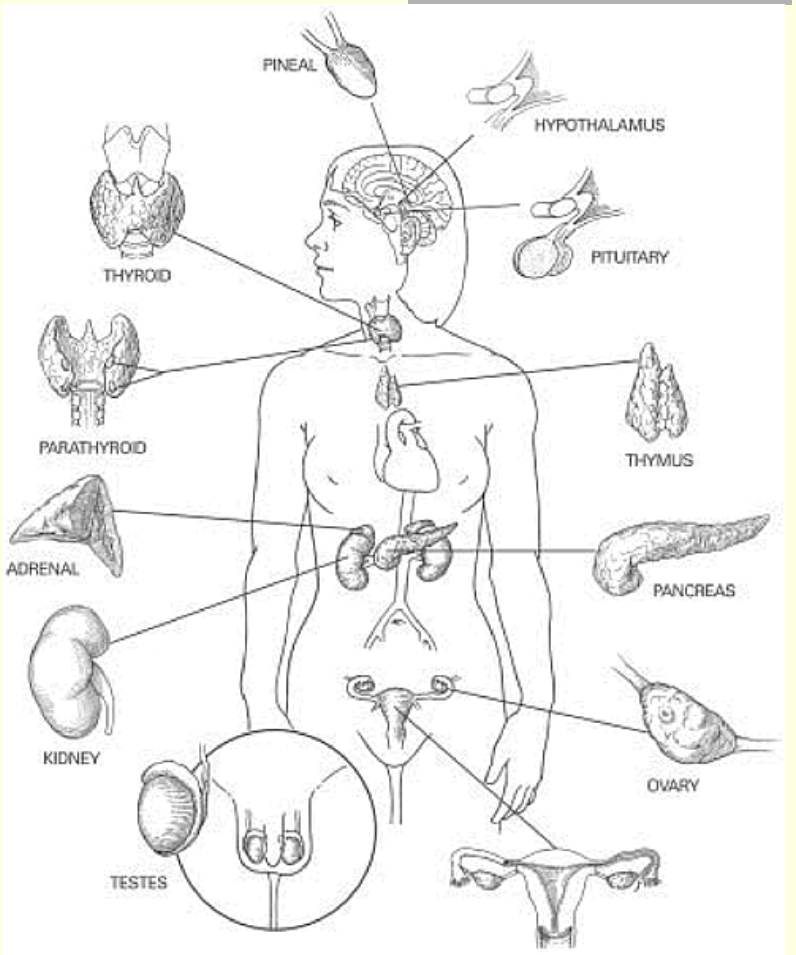
Brain & the CNS

- Won't attempt to even address it
- Some idea of localization of function
- Might address some issues when looking at an organ system?
- ECEs often interested in issues of memory & cognition



Endocrine system

- Biochemical signaling and control system for:
  - Body energy levels
  - Growth and development
  - Homeostasis – internal balance of body systems
  - Response to environmental stress & injury
  - Reproduction

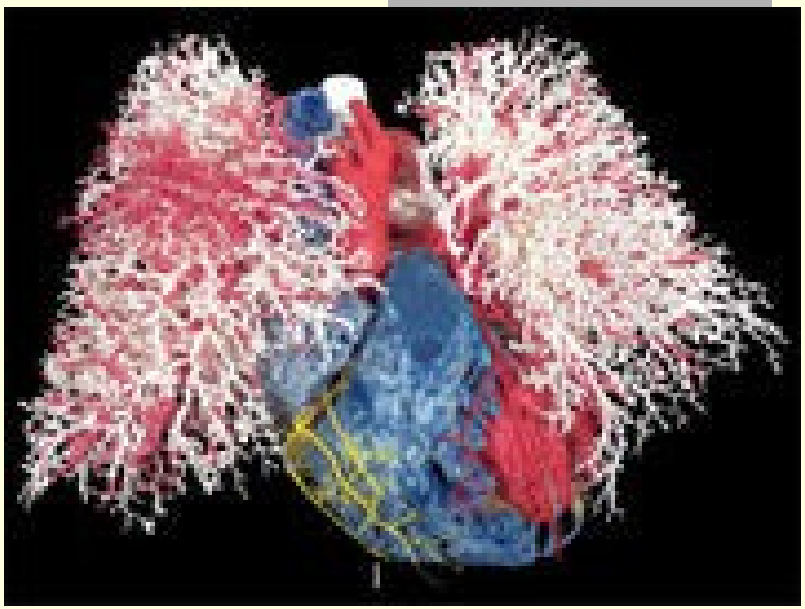


Endocrine system teasers

- How is homeostasis sensed?
- How are control loops formed?
- What is done for effecting a control?

Circulatory system

- Needed for supply of nutrition and oxygen and transport of metabolic products for excretion
- Components: heart, blood, blood vessels



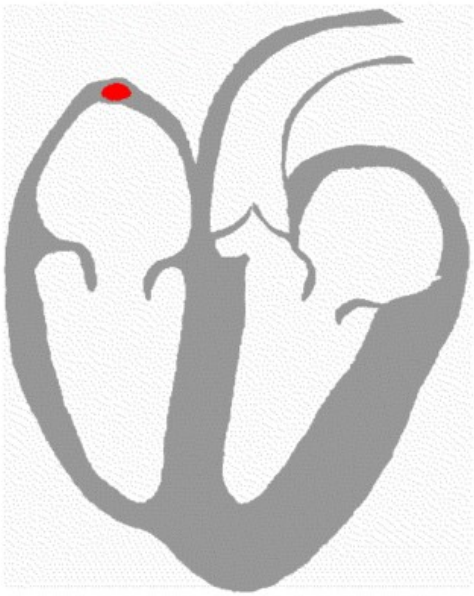
Do a hypothetical quick architectural design and compare!

Circulatory system hypothetical design

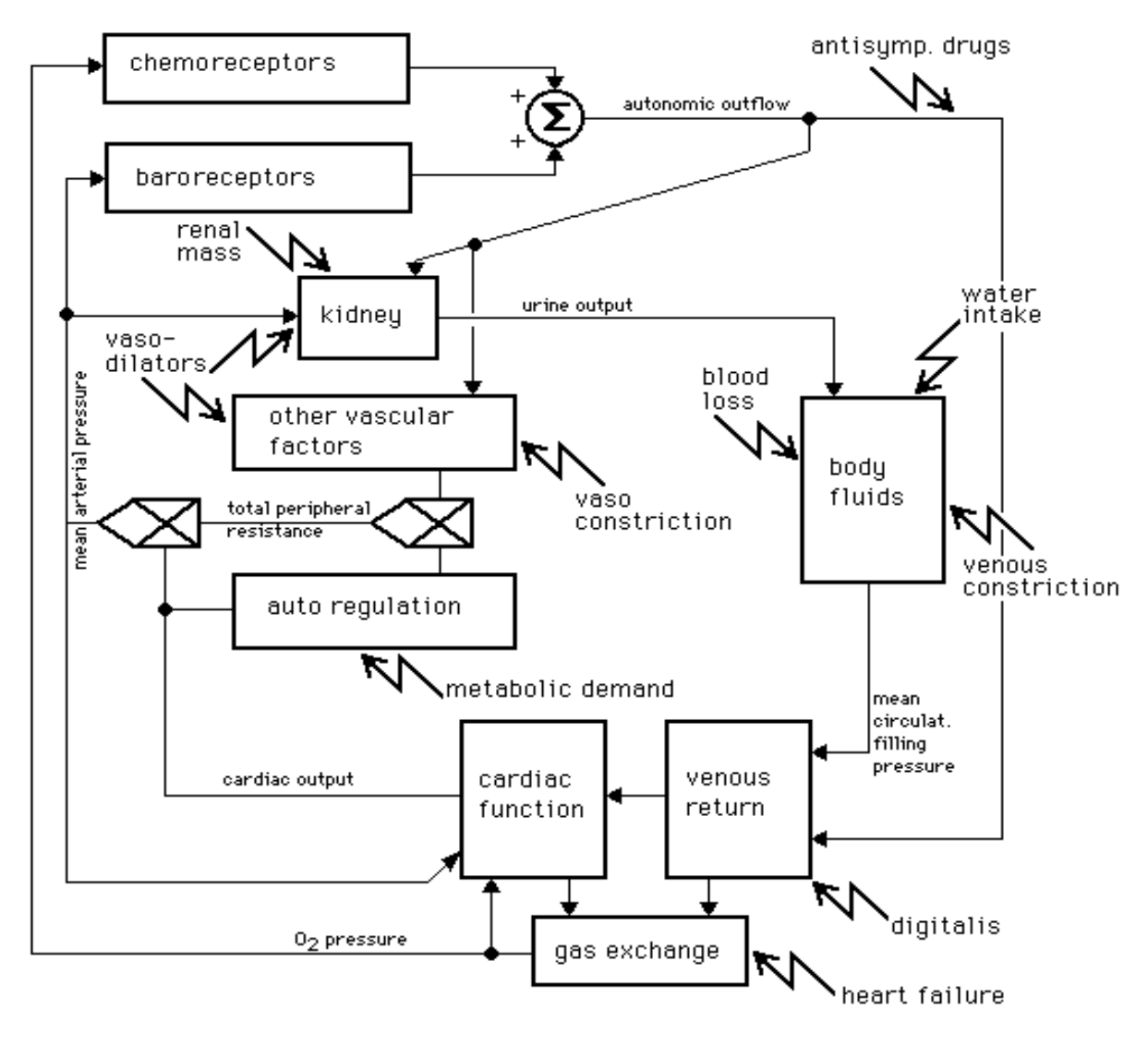
- One or more chambers & pump action?
- How does oxygen get absorbed in hemoglobin & then how does it get released? What is the role of carbon dioxide – is it just dissolved in plasma or does it play a more active role?
- Role of red blood cell change of shape in capillaries?
- Pumping rate control and homeostasis?

Heart

- Very well studied and a wealth of biochemical, mechanical & electrical properties available
- Electrically simple (!), robust, more than 100 years of study, does not have fine grained functionality & interconnect

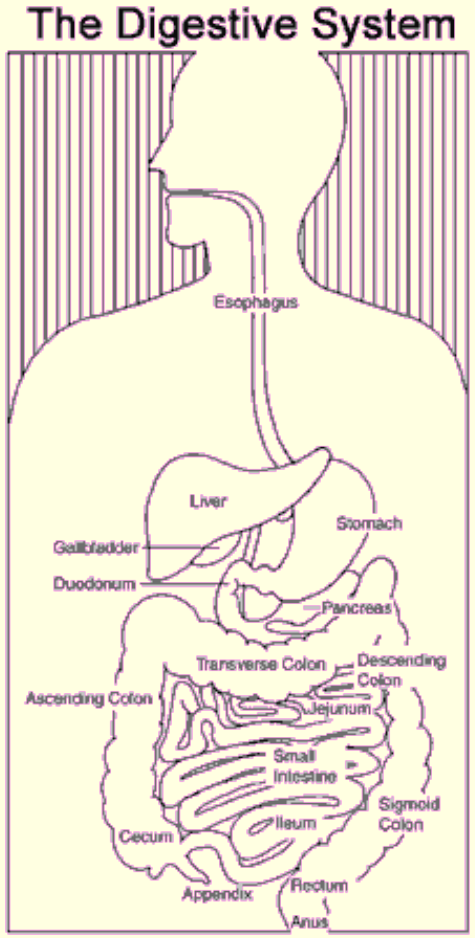


Cardiovascular system modeling



Digestive system

- Helps absorb nutrients that power metabolic processes by
  - Physically breaking up food
  - Utilizing enzymes to further break up polymers of carbohydrates, protein and fat to molecules that can be absorbed
  - Absorbing nutrients & excreting waste



Teasers on the digestive system

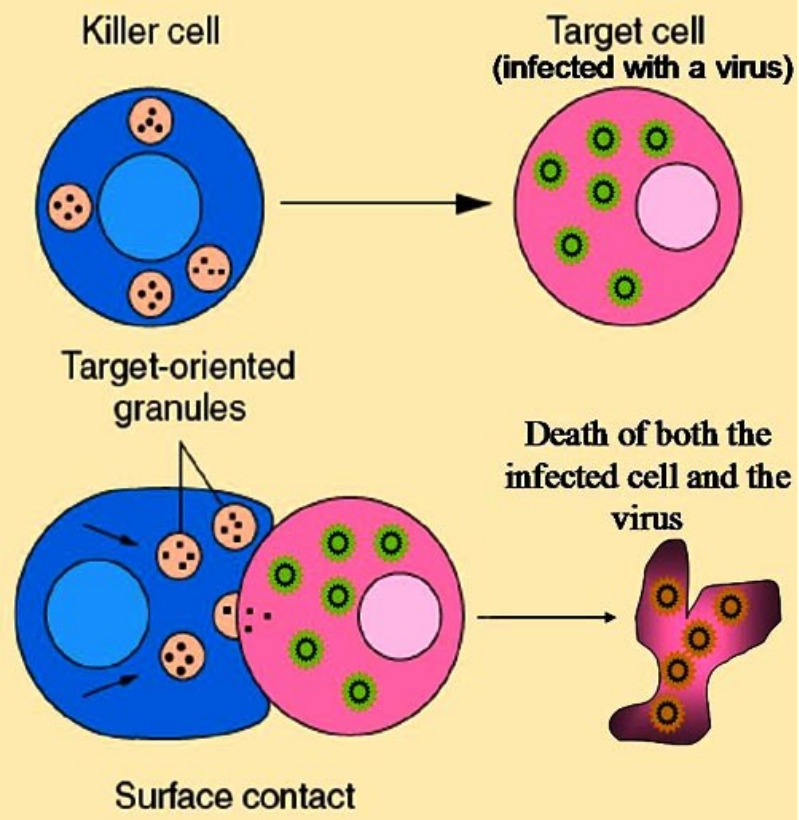
- The digestive system is very complex with a modestly complex neural system in the gut & here are some points you might wish to think about!
  - Acidity in the stomach can be quite low after a meal pH < 2. How is this acid produced and why does it not damage cells in the stomach?
  - How are pathogens handled and how does the system distinguish them from friendly bacteria in the gut?
  - Does the system recognize poisonous substances & how are they processed?
  - How do molecules get absorbed from the small intestine, an internal surface, into the system?

Immune system

- Not localized
- A collection of processes for protecting an organism against infection by identifying & killing pathogens
- Complex pathogen recognition receptors plus complement system
- Immunodeficiency or auto immune disease

Immune system

- How is a pathogen detected?
- What processes are triggered to specifically target pathogens?
- How does the immune system handle a virus infection?



Reproductive system

- At the mammalian level, reproduction involves many other organ systems than the male & female reproductive systems
- Some questions that remain unanswered take us to the bleeding edge of modern biology:
  - Why do genes have dominant & regressive traits?
  - How is cell multiplication and differentiation controlled?
  - How is homoestasis in the embryo controlled?
  - ... this list like that for the CNS is very large!!

Rounding up

- The goal of giving you a real bird's eye view (or rather an astronaut's view!) of physiology was really to raise questions about how organ systems carry out physiological functions
- You would go from an astronaut's view to a bird's eye view by reading the the links suggested
- And we should identify one or two organ systems we should do in more detail from both an engineering and a molecular perspective