Organs and Organ Systems

ChemEng 590B: Tissue Engineering

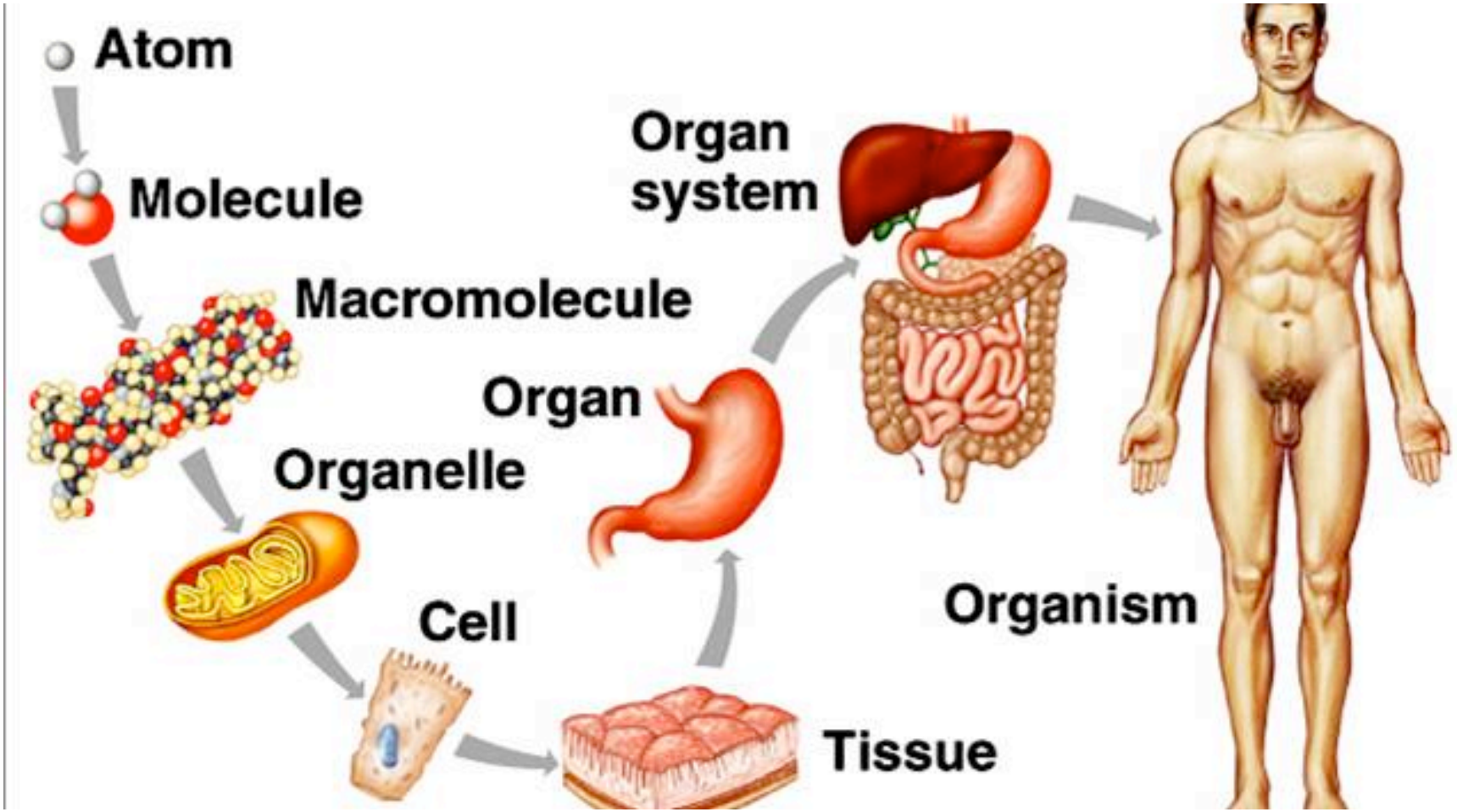
Lecture 3

January 29th, 2013

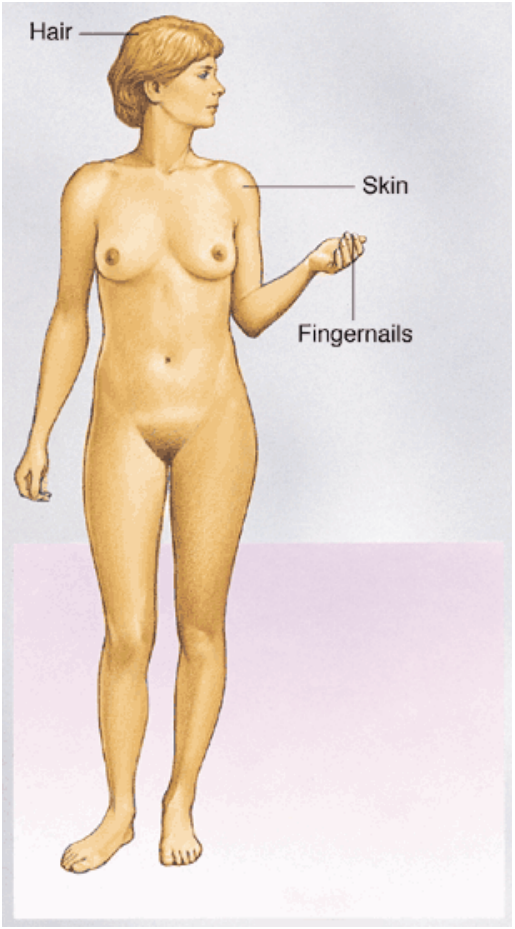
Definitions, top down

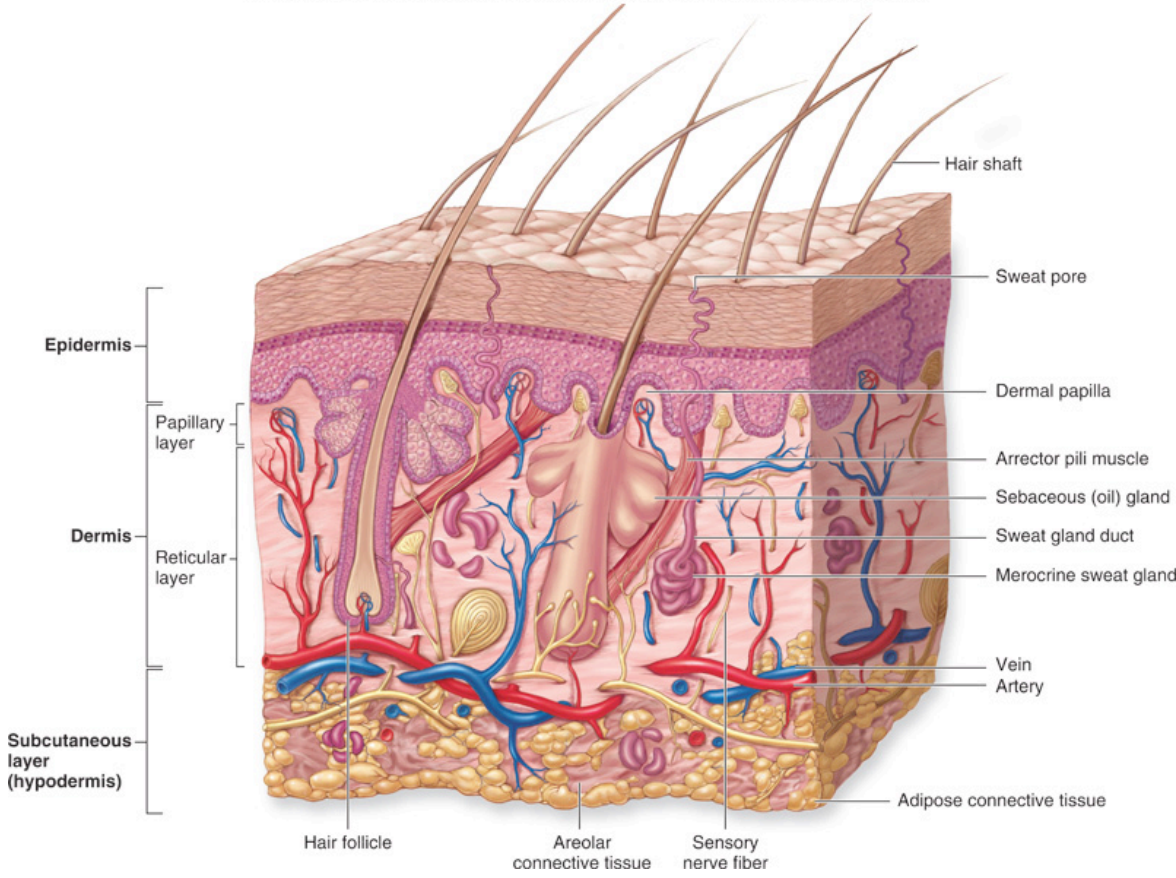
- Organism: any living thing considered as a whole.
  - E.g. Human. Bacterium.
- Organ system: group of organs that have a common function or set of functions and are therefore viewed as a unit. Humans have 11 major organ systems
  - E.g. respiratory, digestive.
- Organ: composed of two or more tissue types that perform one or more common functions.
  - E.g. bladder, heart, skin
- Tissue: group of similar cells and the materials surrounding them.
  - E.g. epithelial, connective, muscle
- Cell: the basic unit of all living things.
- Organelles: combined of molecules, and make up the small structures that make up cells.

Levels of Organization



Integumentary System

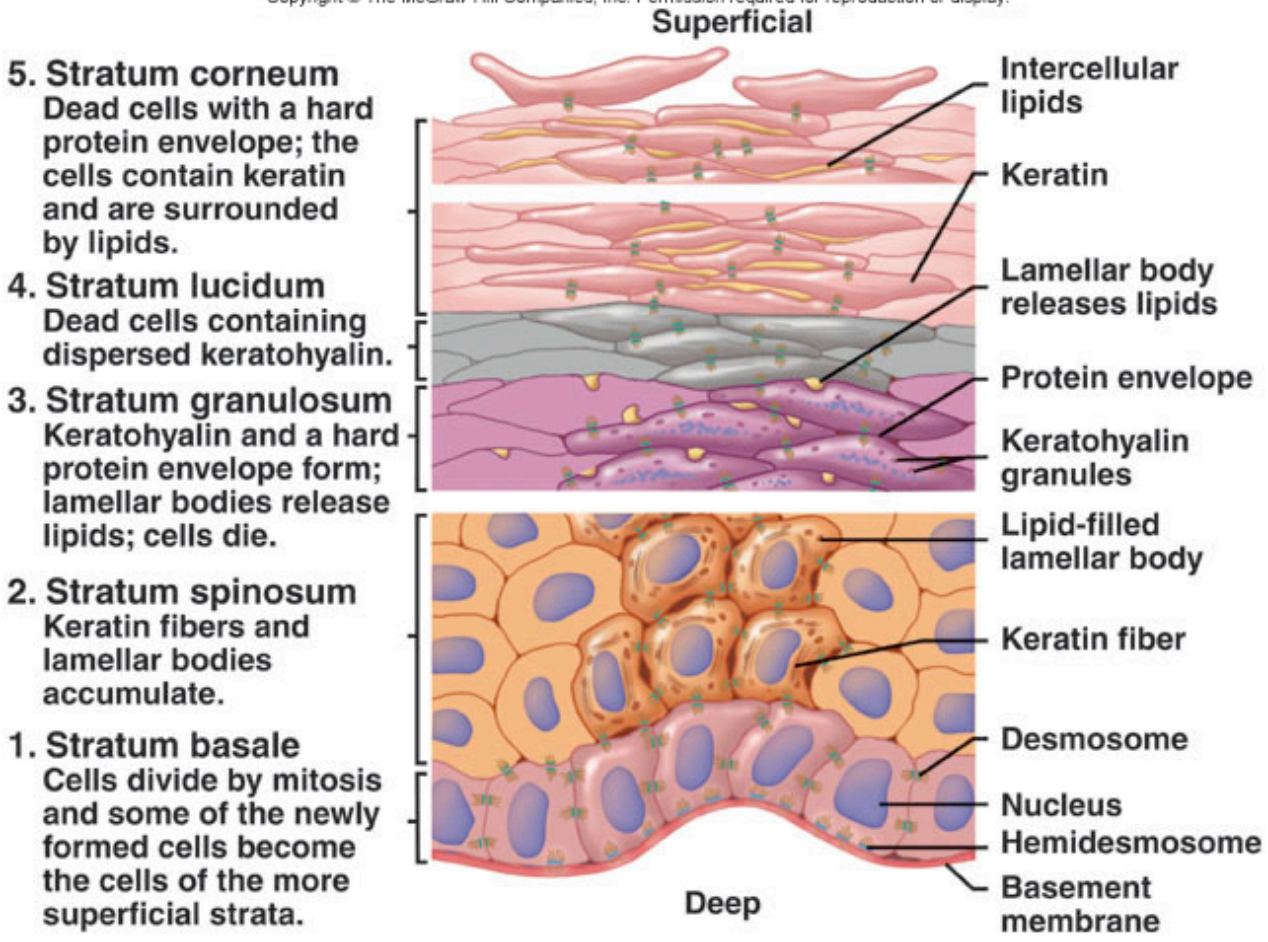




Provides protection, regulates temperature, prevents water loss, and produces Vitamin D precursors

Consists of skin, hair, nails, and sweat glands

Epidermal Layers of the Skin

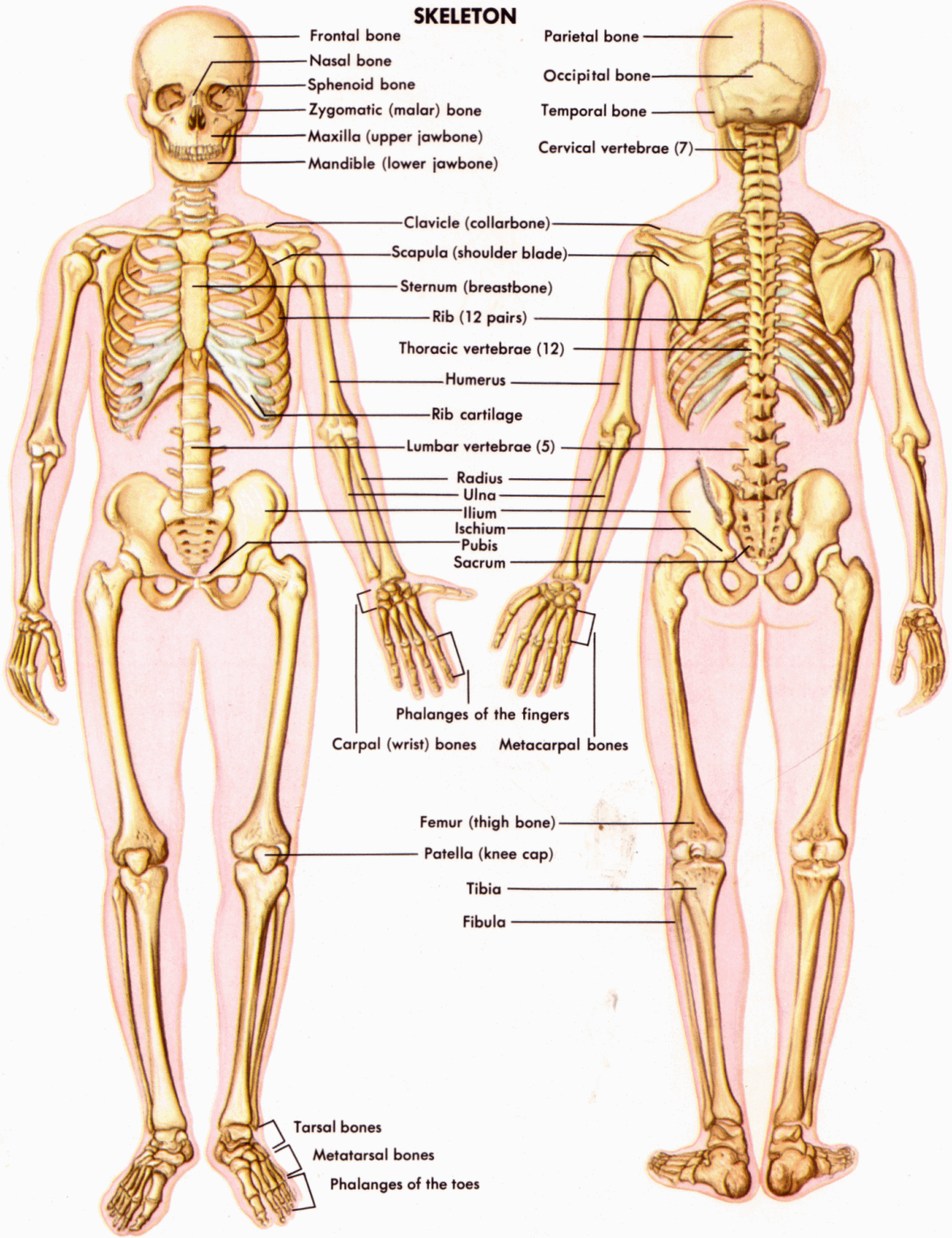


It takes 40-56 days for a cell to reach the epidermal surface

Grant thought:

Some drugs are administered by applying them to the skin. The drug diffuses through the epidermis to blood vessels in the dermis. What kind of substances can pass easily through diffusion? What kind have difficulty? Can drugs be *engineered* to pass through more easily??

*On your own: Look online for skin grafts



Skeletal System

Provides protection and support, allows body movements, produces blood cells, and stores minerals and fat. Consists of bones, associated cartilages, ligaments and joints

206 total bones

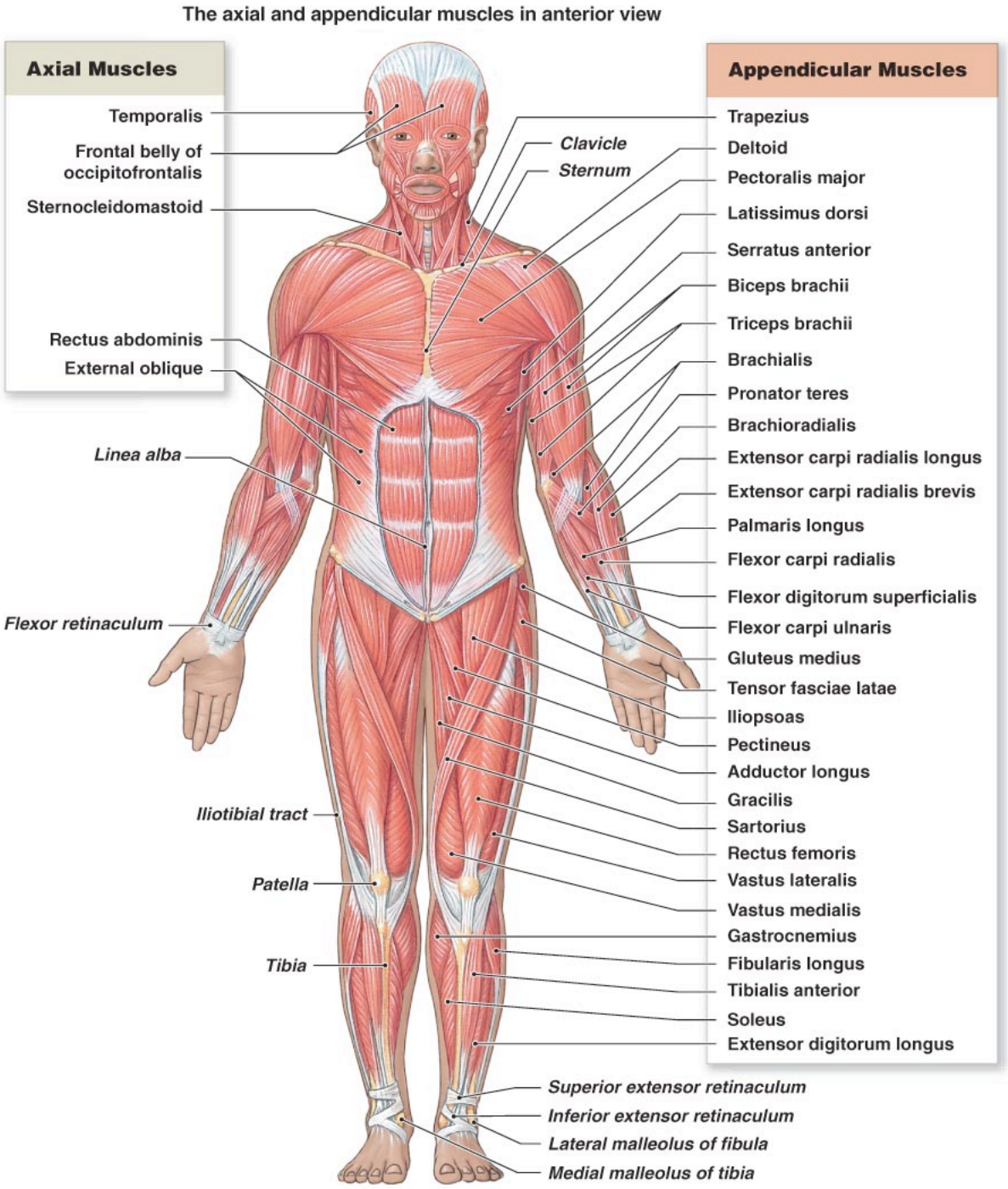
Skeletal System first to be "engineered"

Traditional route for skeletal system engineering: Bio-inert materials
Purposes:

1. Replace tissue *structure* and *function*, not *bio-activity*
2. do not entice an immune response once implanted into the body.
3. Have incredible mechanical toughness withstand physiological loading
4. Long lasting in the body (won't degrade over time)

Metals	Ceramics	Polymers
316L stainless steel Co-Cr Alloys Titanium Ti6Al4V	Alumina Zirconia Carbon Hydroxyapatite	Ultra high molecular weight polyethylene Polyurethane

Applications:
Skeletal tissue prosthesis (hip, knee replacement)

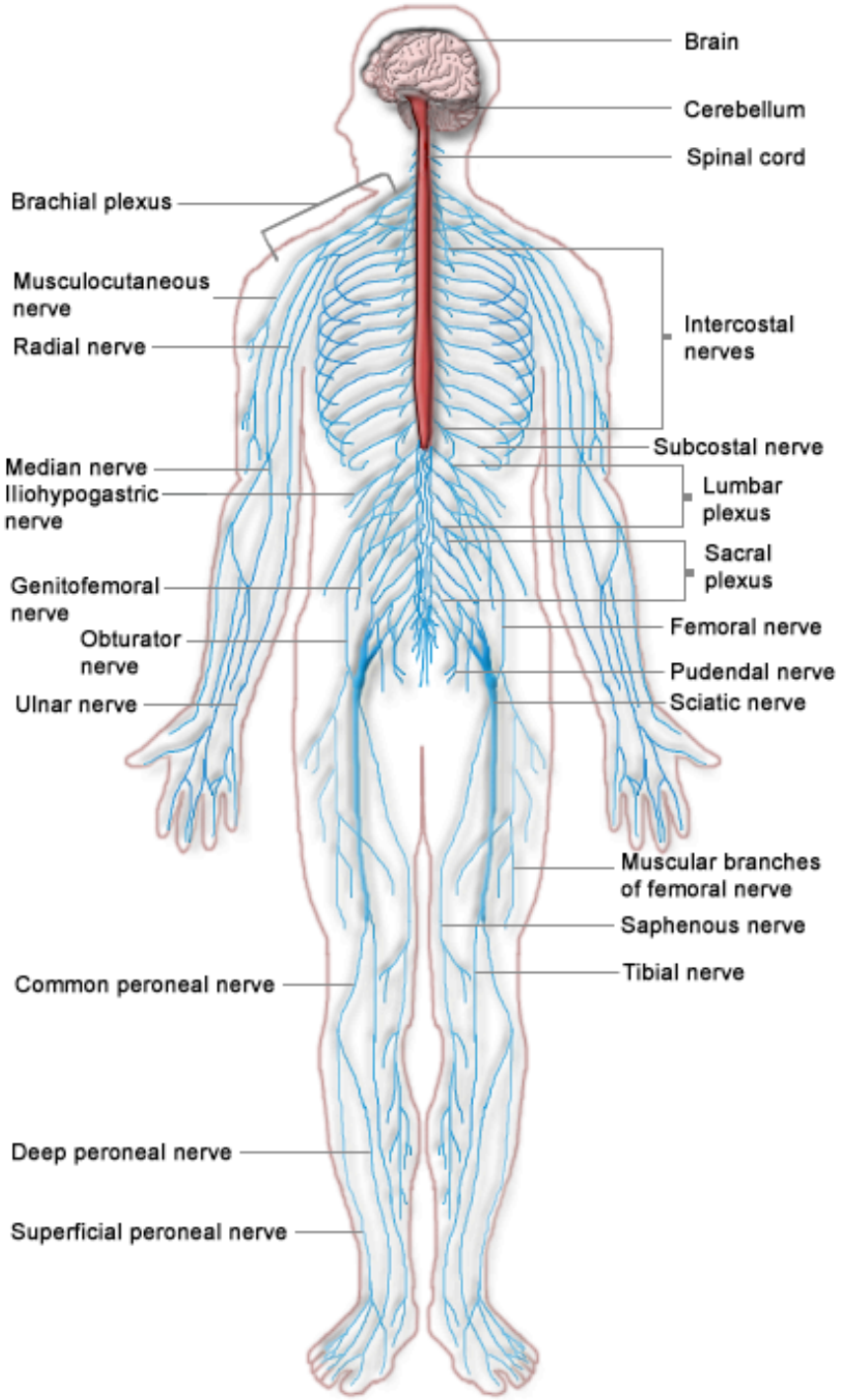


Muscular System

Produces body movements, maintains posture, and produces body heat. Consists of muscles attached to the skeleton by tendons

GRANT THOUGHT

Not truly engineered yet. Many working on stem cell-to-muscle cell differentiation techniques.

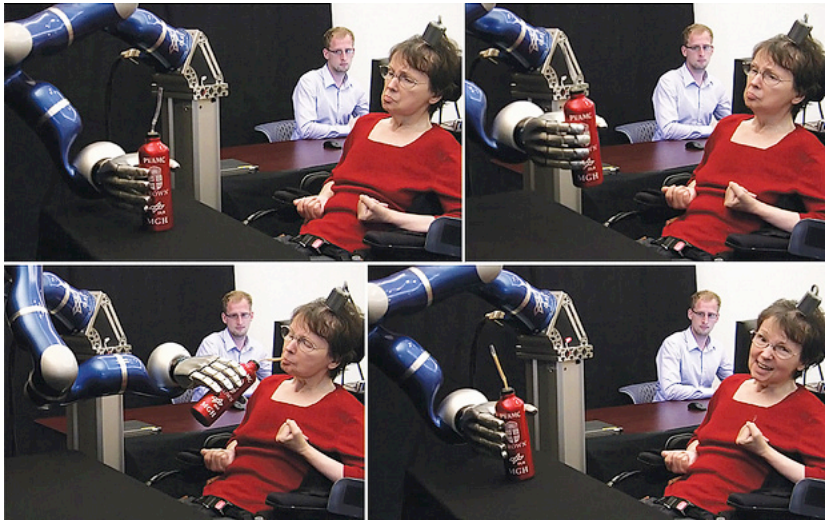


Nervous System

A major regulatory system that detects sensations and controls movements, physiologic processes, and intellectual functions. Consists of the brain, spinal cord, nerves, and sensory receptors.

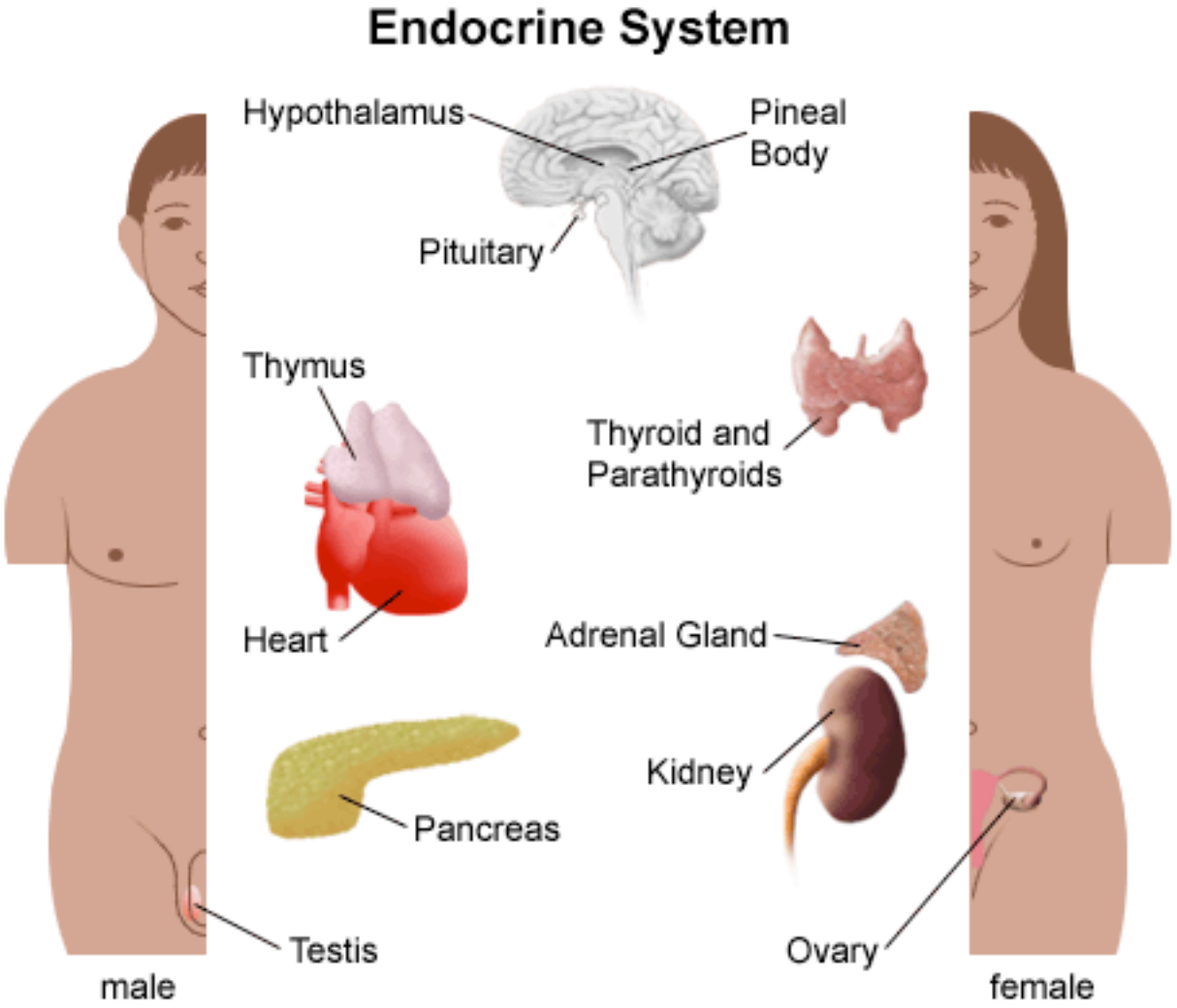
Engineering advances:

1. Functional electrical stimulation: use outside or implanted devices to stimulate otherwise inactive nerves.



BrainGate Neural Interface

Endocrine System

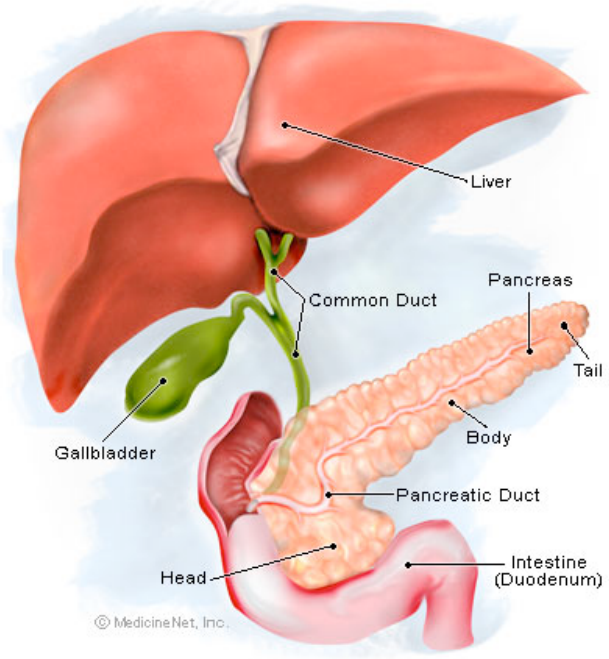


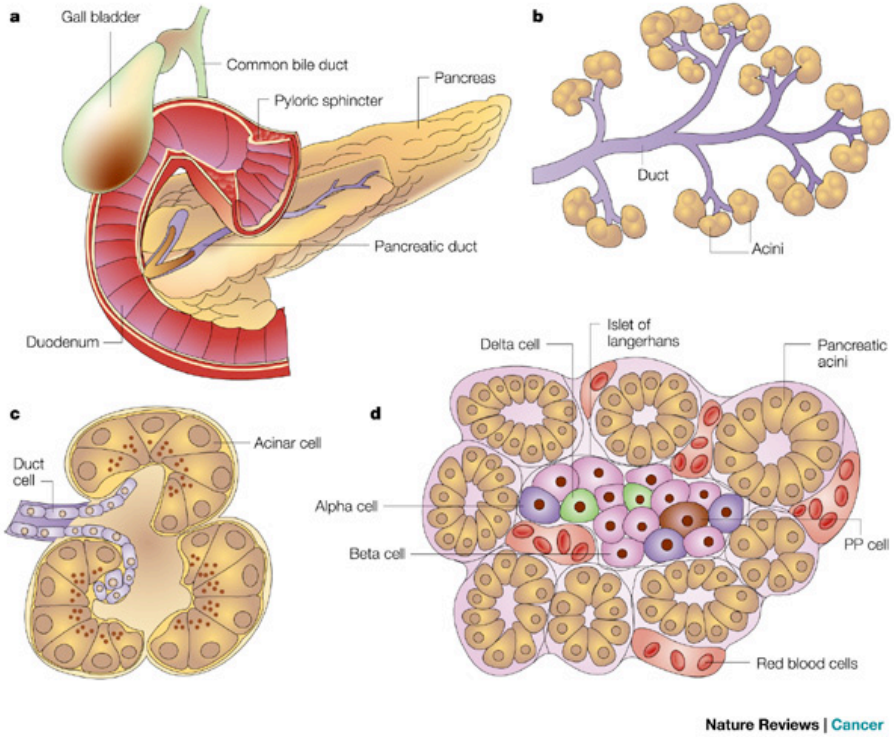
GRANT THOUGHT

Not truly engineered yet. Typically treated with repeated injections of hormones or daily pills. Can be adapted to a patch or implanted, permanent device?

A major regulatory system that influences metabolism, growth, reproduction, and many other functions. Consists of glands, such as the pituitary, that secrete hormones

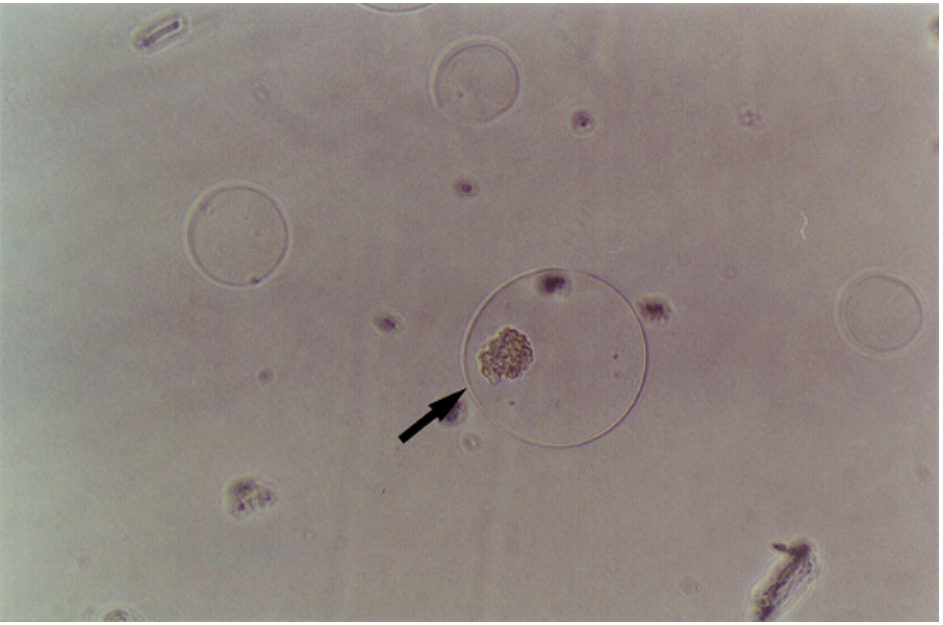
Pancreas Function



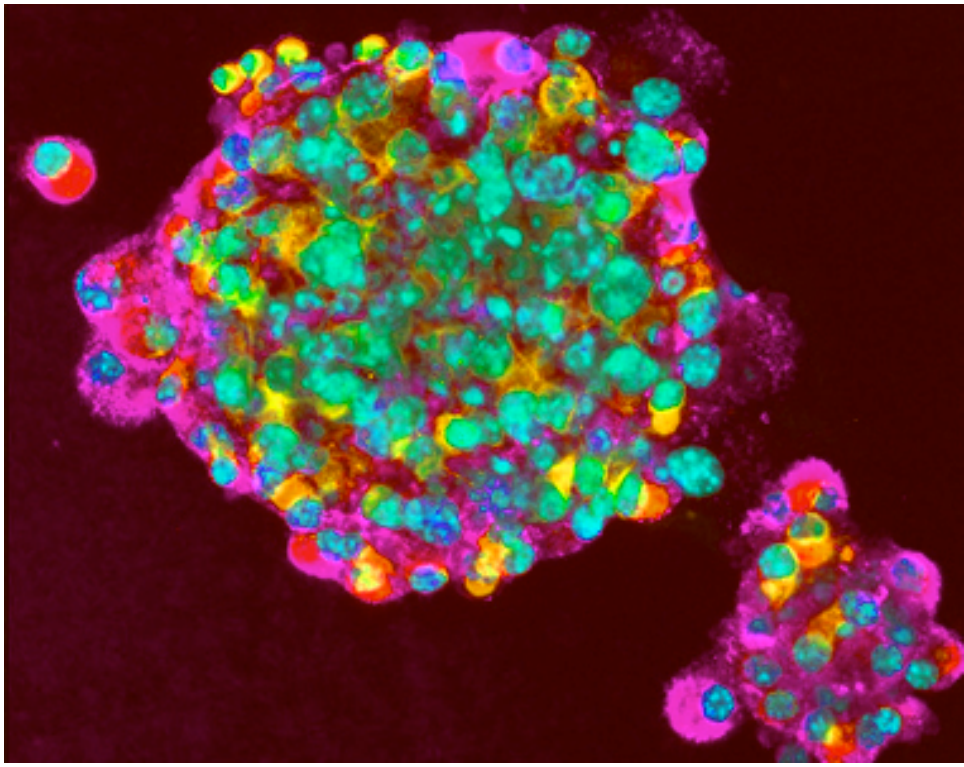


Produces many enzymes (including insulin) to break down food (carbohydrates)
Secretes enzymes into the small intestine after measuring carbohydrate levels.
Different islet cells produce different enzymes.

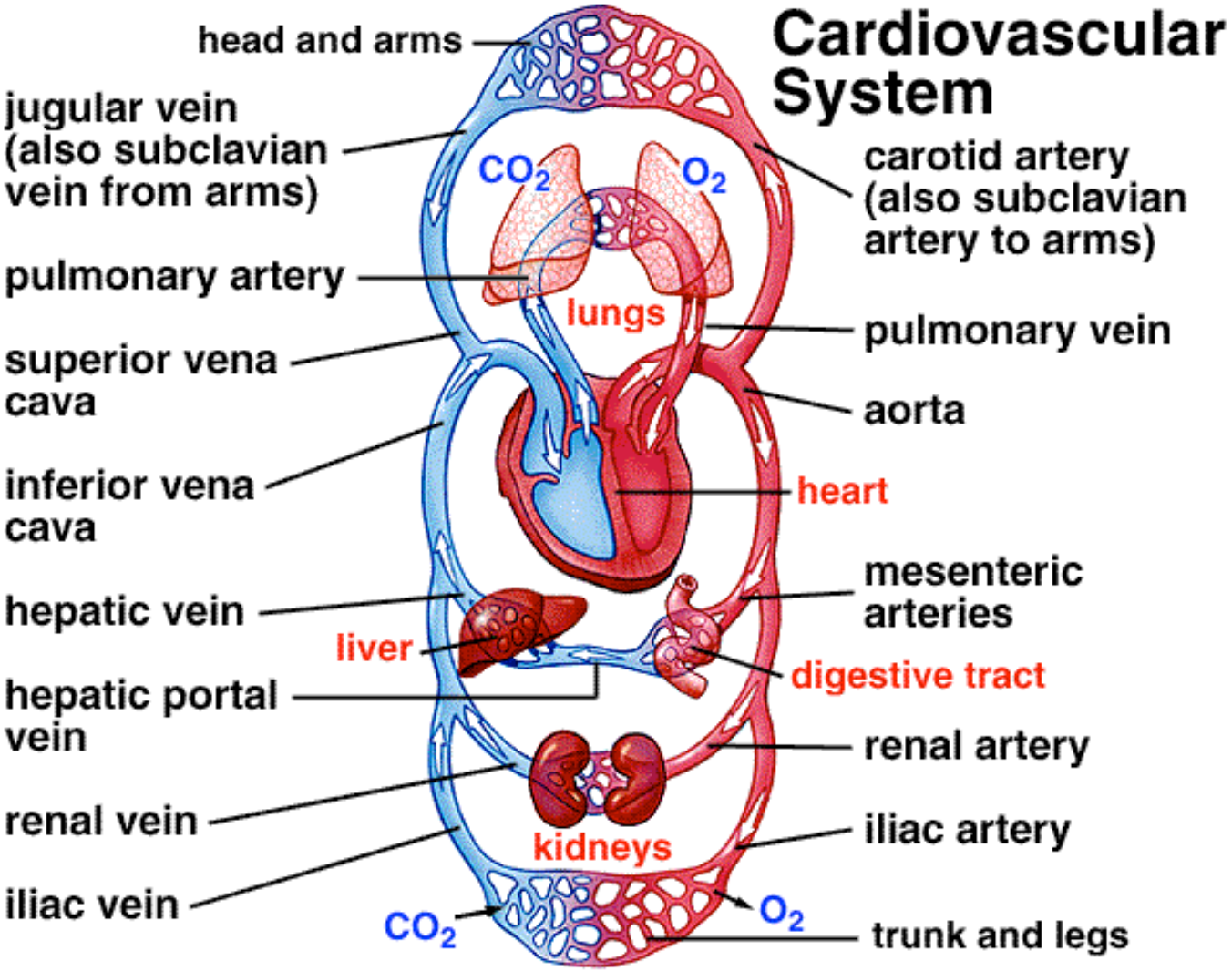
Hydrogel culture of islet cells



Stem cell differentiation to islet cells

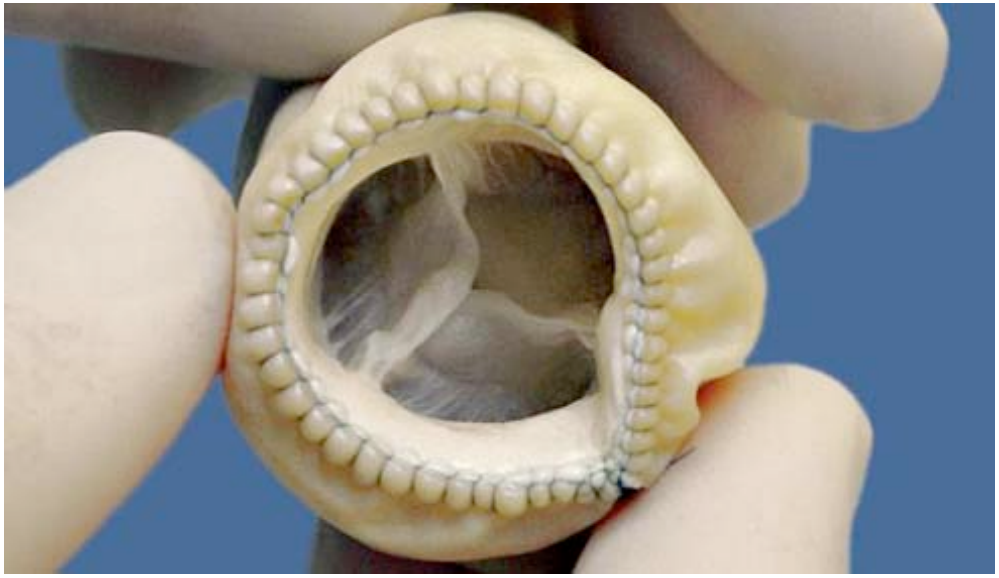


Cardiovascular System



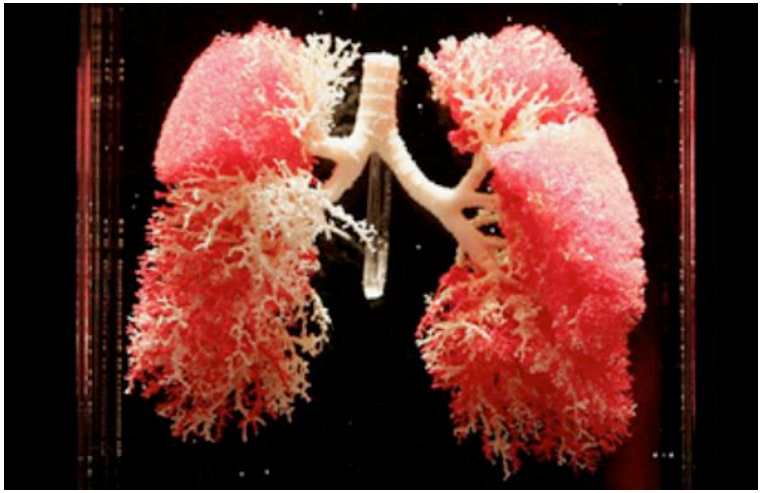
Transports nutrients, waste products, gases, and hormones throughout the body; plays a role in the immune response and the regulation of body temperature. Consists of the heart, blood vessels, and blood.

Lots of active TE in cardiovascular area!

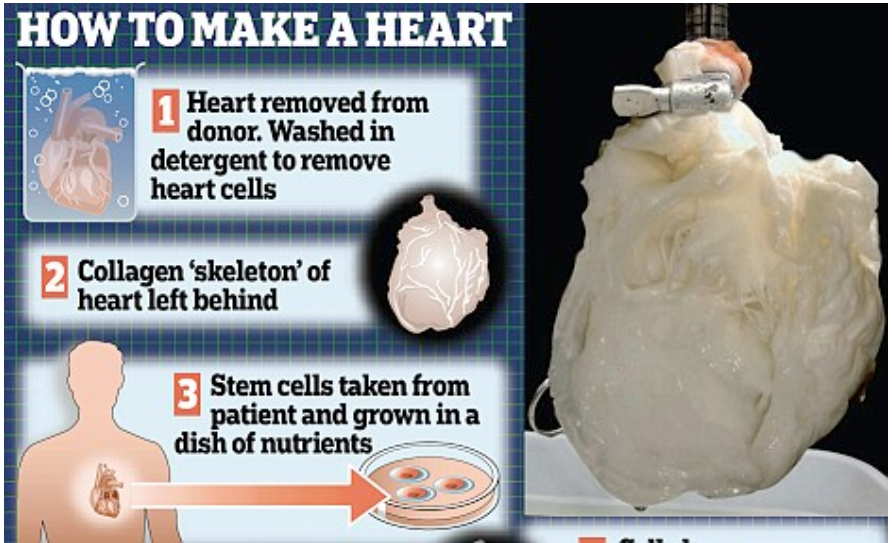


Heart Valves, from cadavers or animals

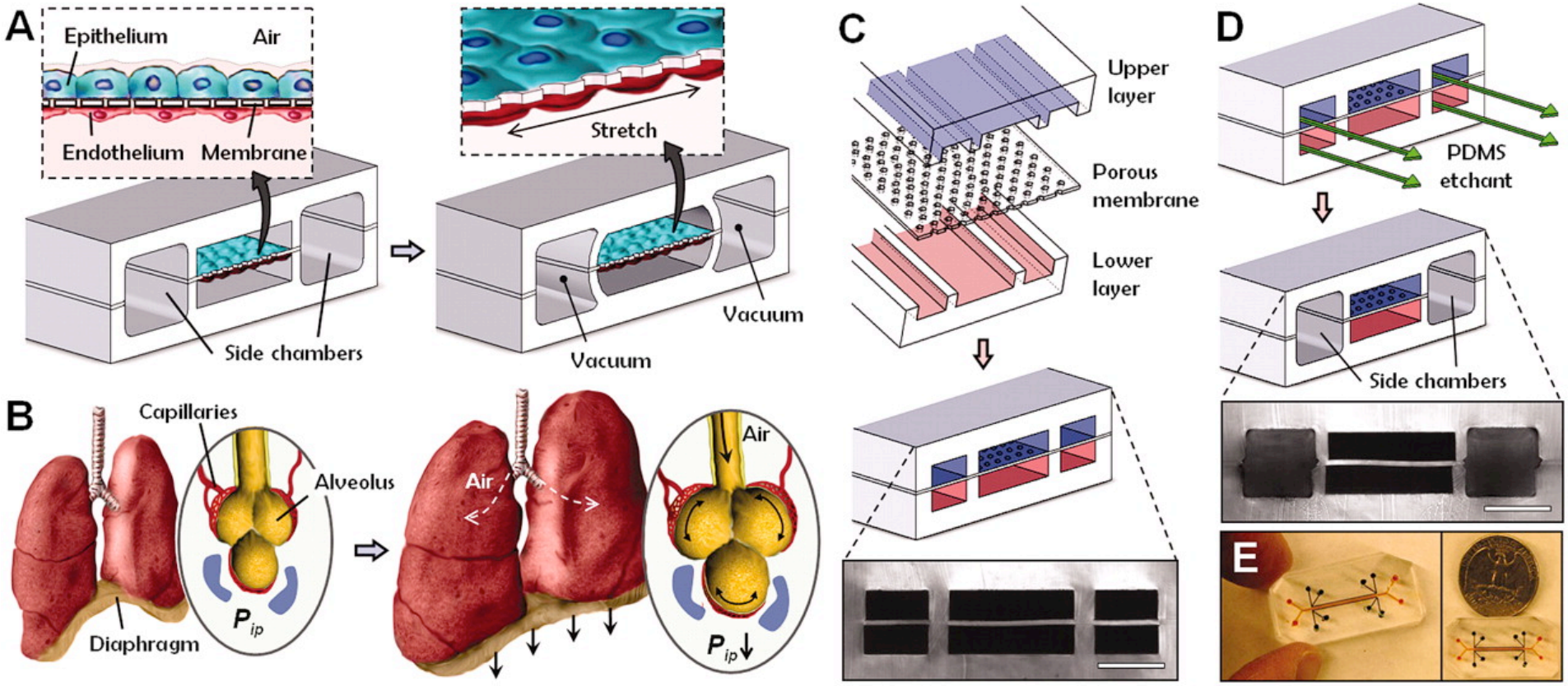
Rat heart



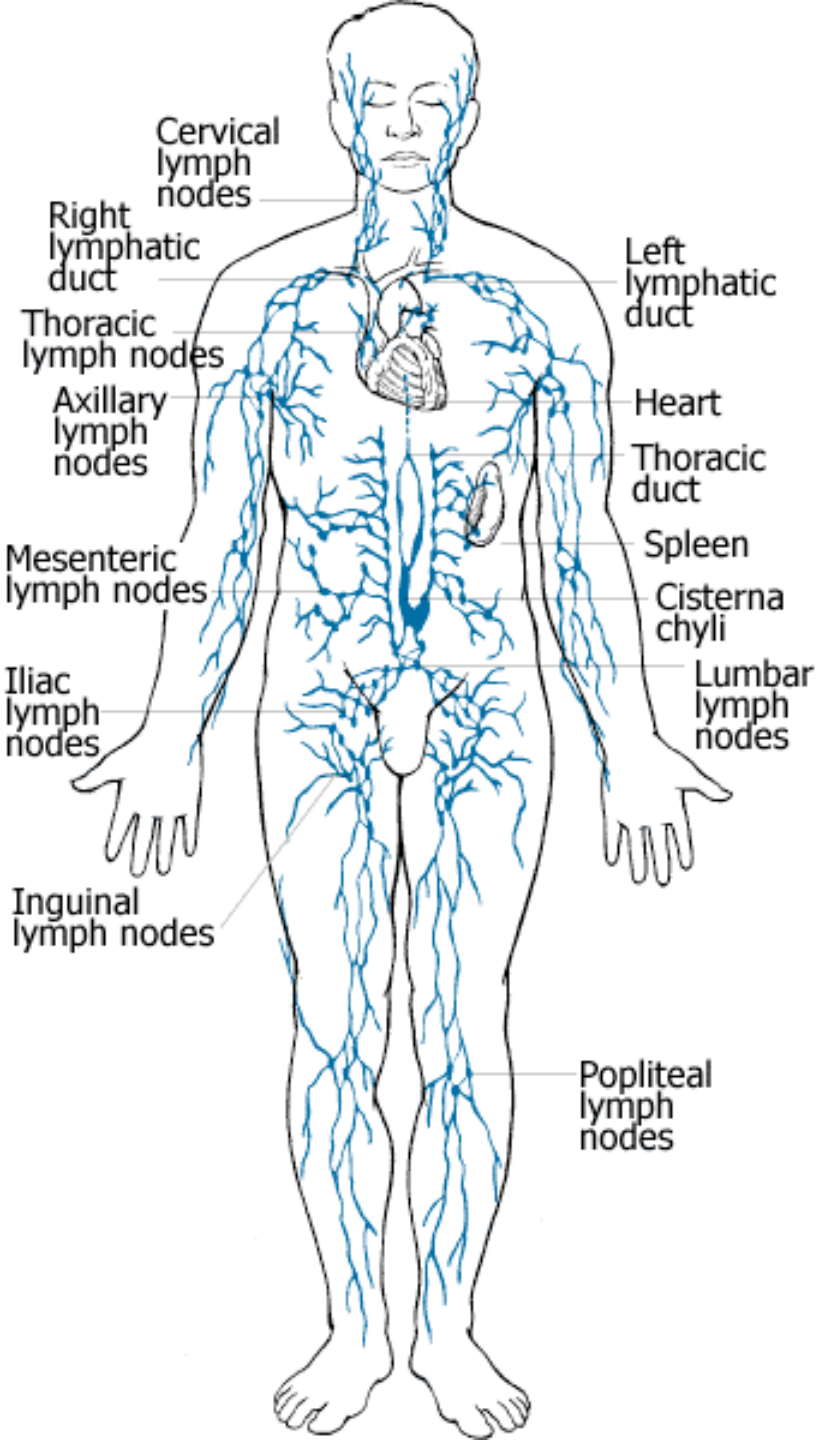
lungs



Preview to wiki? Organs on a chip



Lung on a chip
Weiss Institute, Harvard

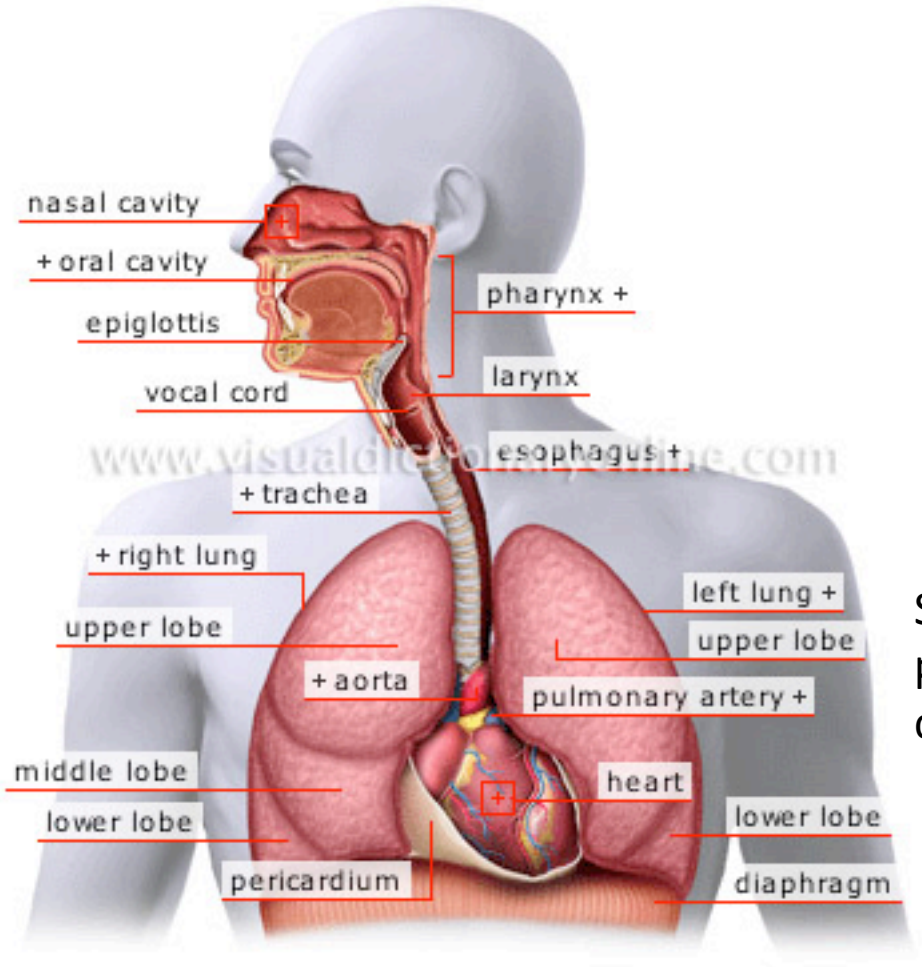


Lymphatic System

Removes foreign substances from the blood and lymph, combats disease, maintains tissue fluid balance, and absorbs fats from the digestive tract. Consists of the lymphatic vesssels, lymph nodes, and other lymphatic organs.

Only bioengineer (Chemical Engineer) working on this is Melody Swartz, EPFL. She studies flow patterns to the lymph using principles of fluid dynamics.

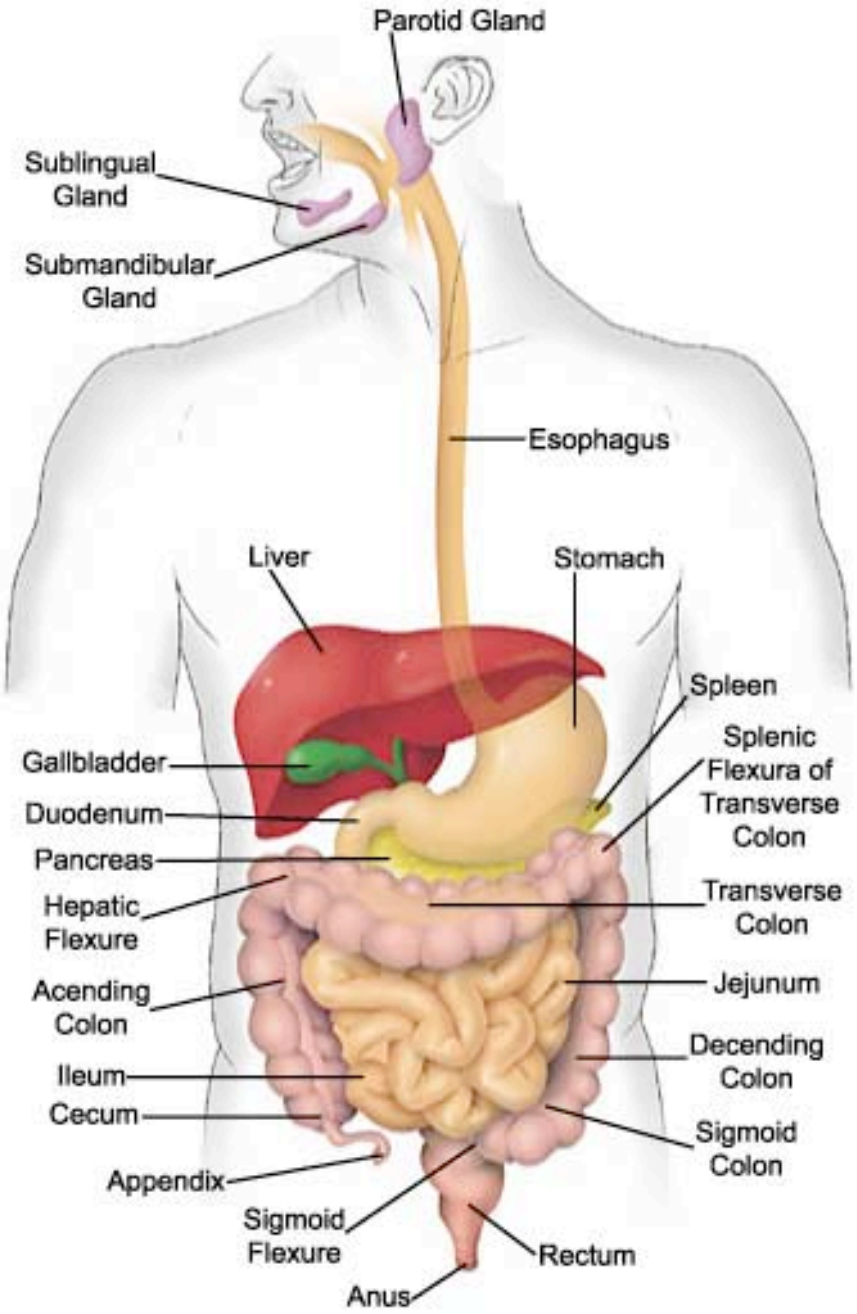
Respiratory System



Same engineering principles as cardiovascular system

Exchanges oxygen and carbon dioxide between the blood and air and regulates blood pH. Consists of the lungs and respiratory passages.

Digestive System



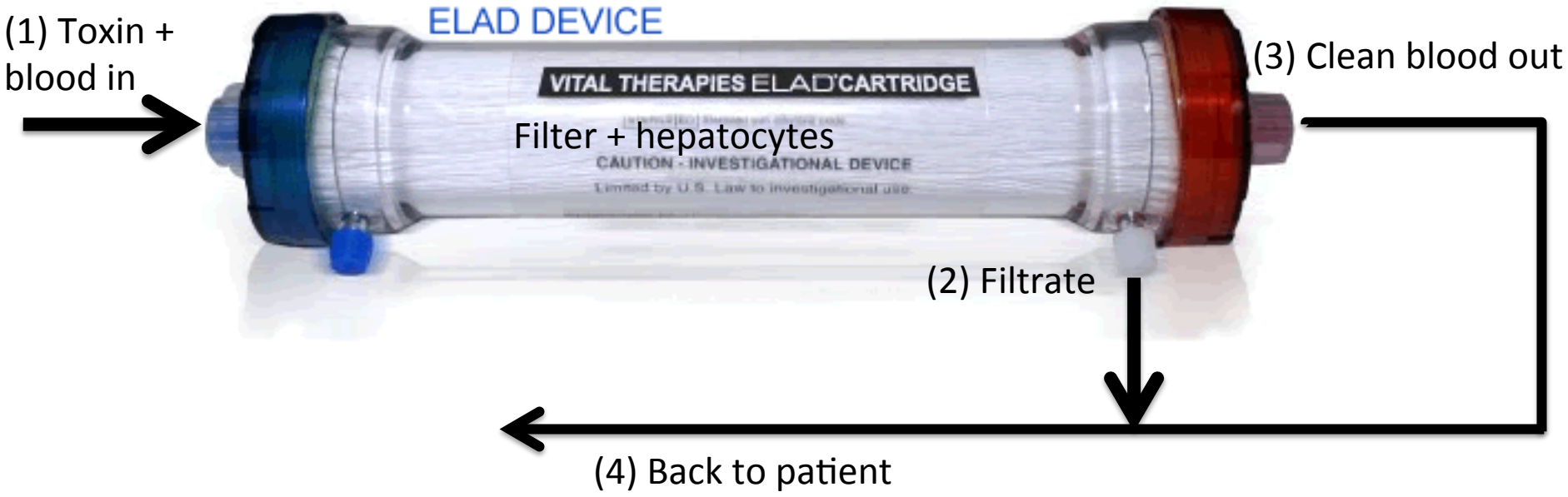
Performs the mechanical and chemical processes of digestion, absorption of nutrients, and elimination of wastes. Consists of the mouth, esophagus, stomach, intestines, and accessory organs.

Teeth are part of the digestive system – lots of obvious TE activity w.r.t dental implants.

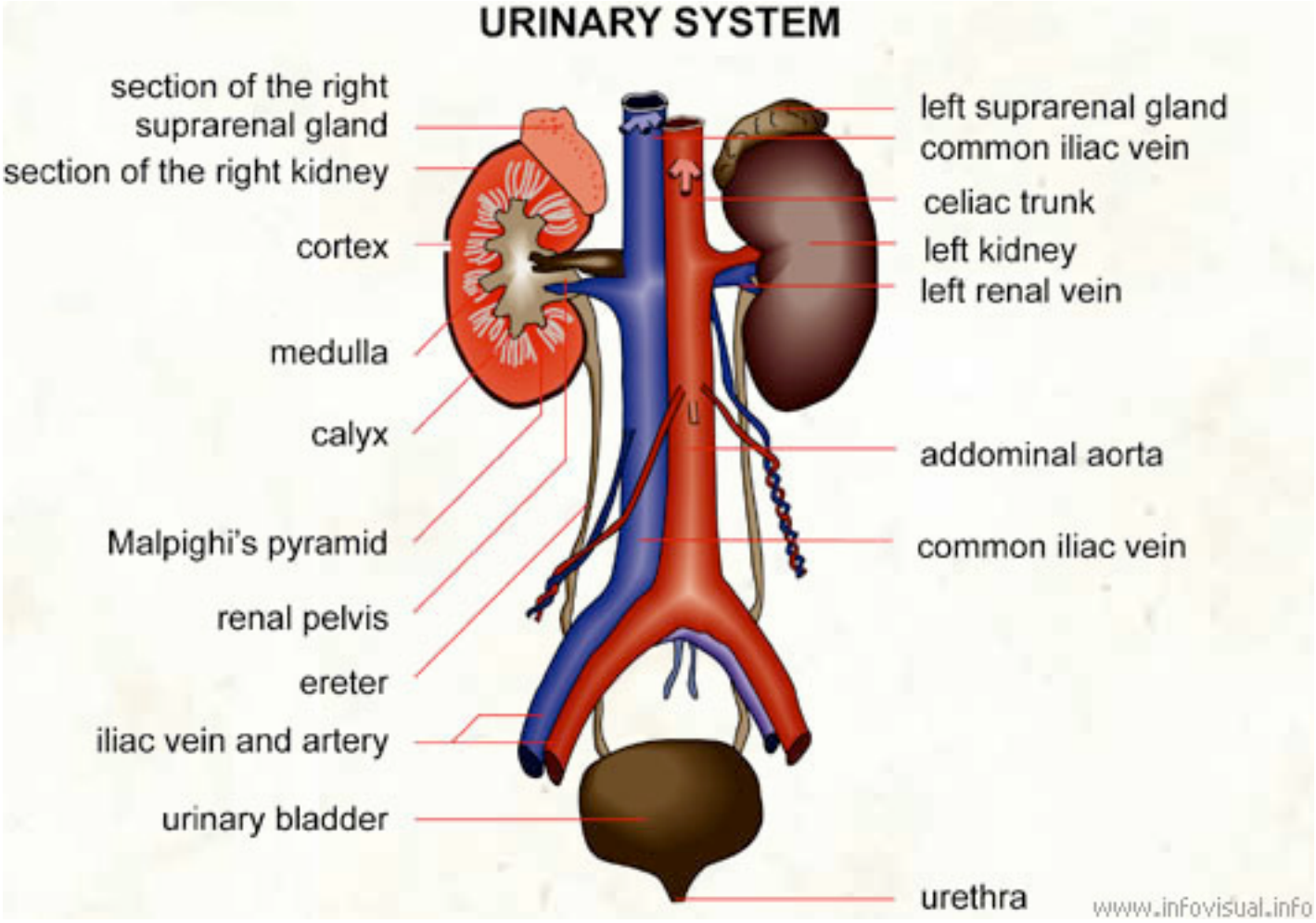
Some work in liver. Check out Linda Griffith and Sangeeta Bhatia (both at MIT).

Artificial Liver Device

Synthetic Filter: retains very large compounds (>100,000 g/mol)
+ Hepatocytes: process bilirubin (reaction)



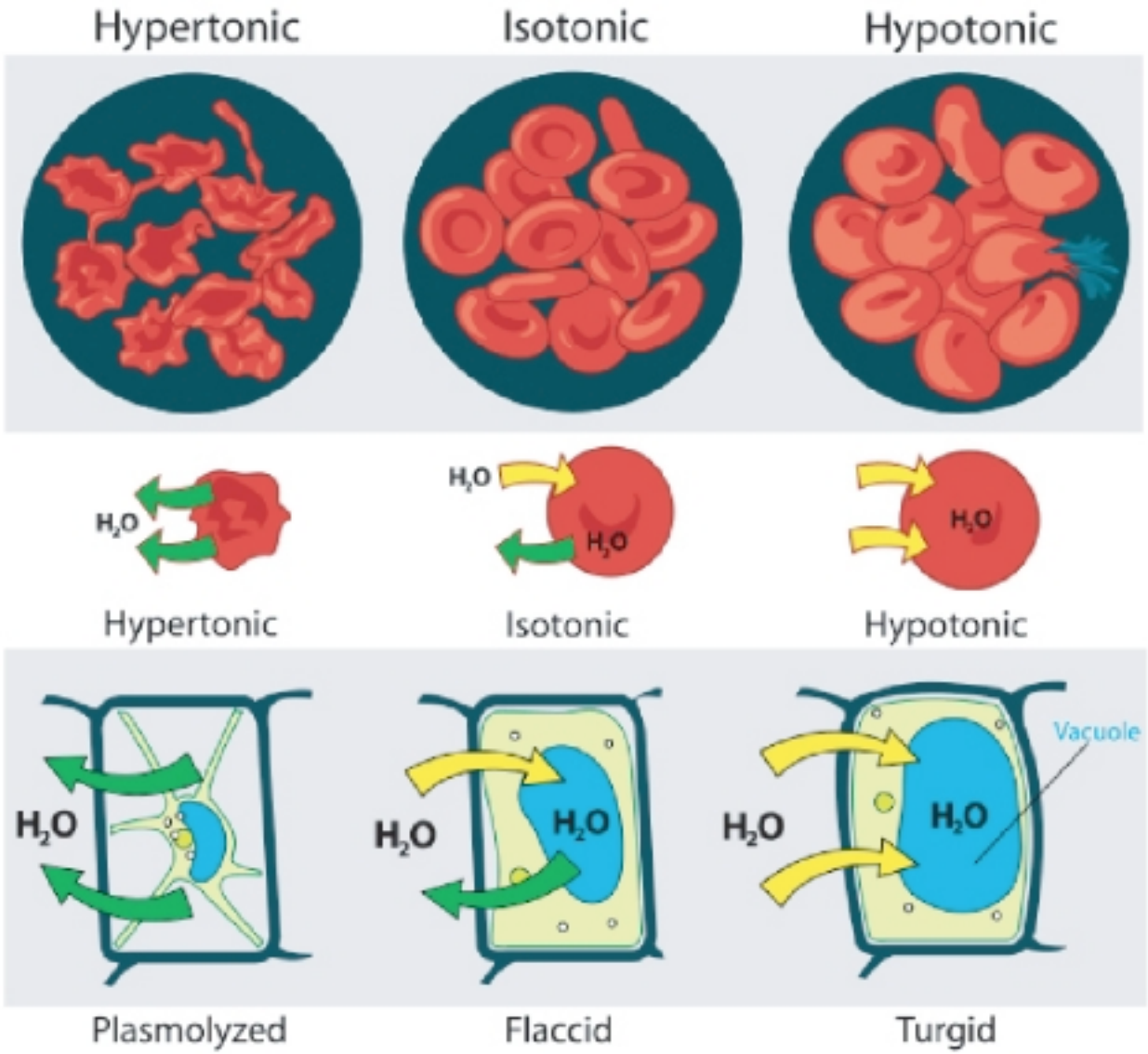
Urinary System



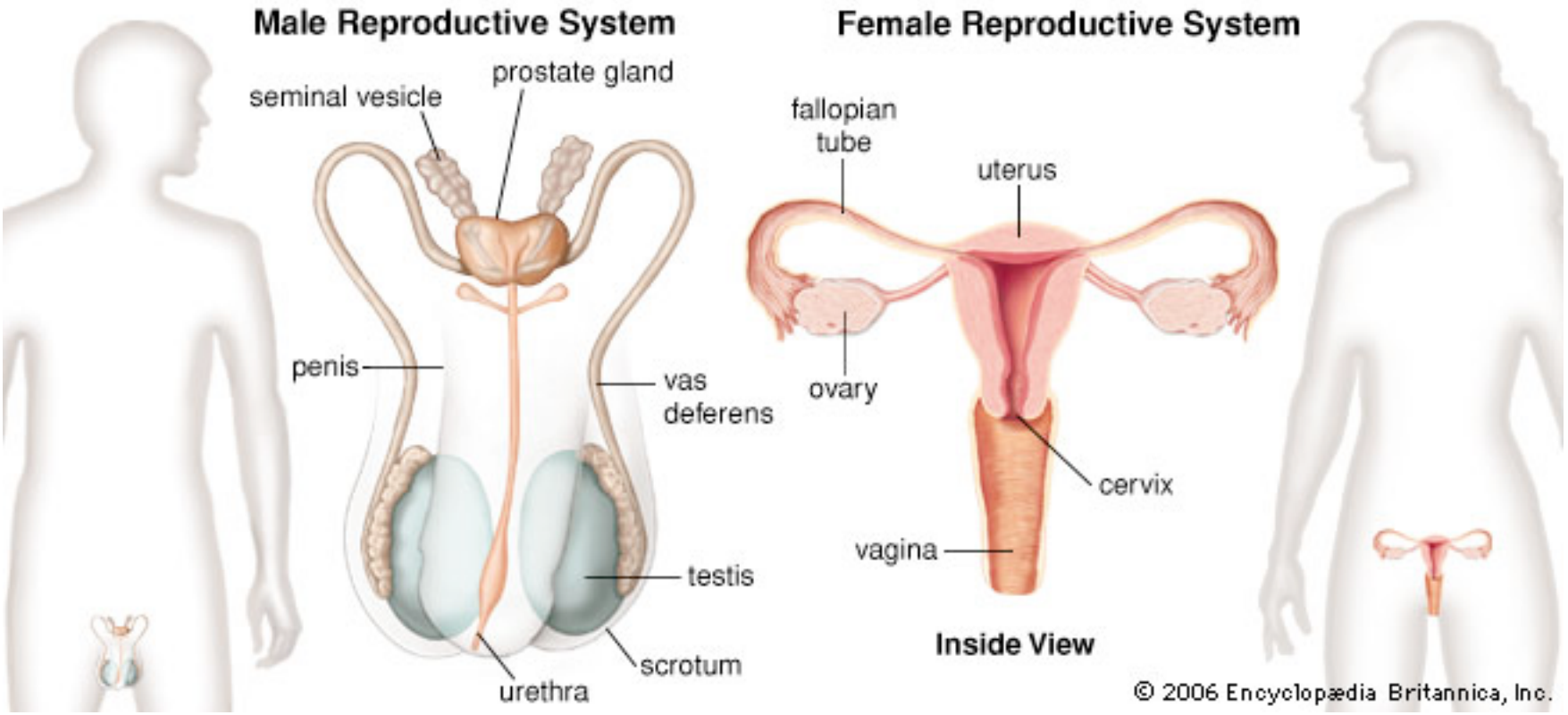
Removes waste products from the blood and regulates blood pH, ion balance, and water balance. Consists of the kidneys, urinary bladder, and ducts that carry urine.

Tony Atala (wiki option) – has built replacement bladders.

Why is the salt balance important?



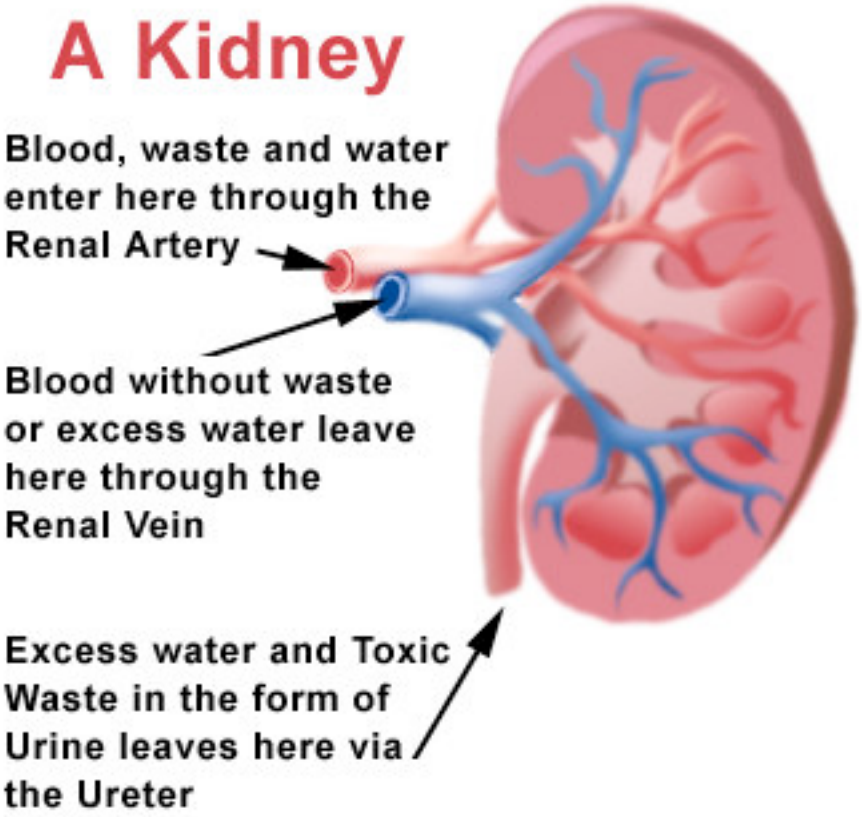
Reproductive System

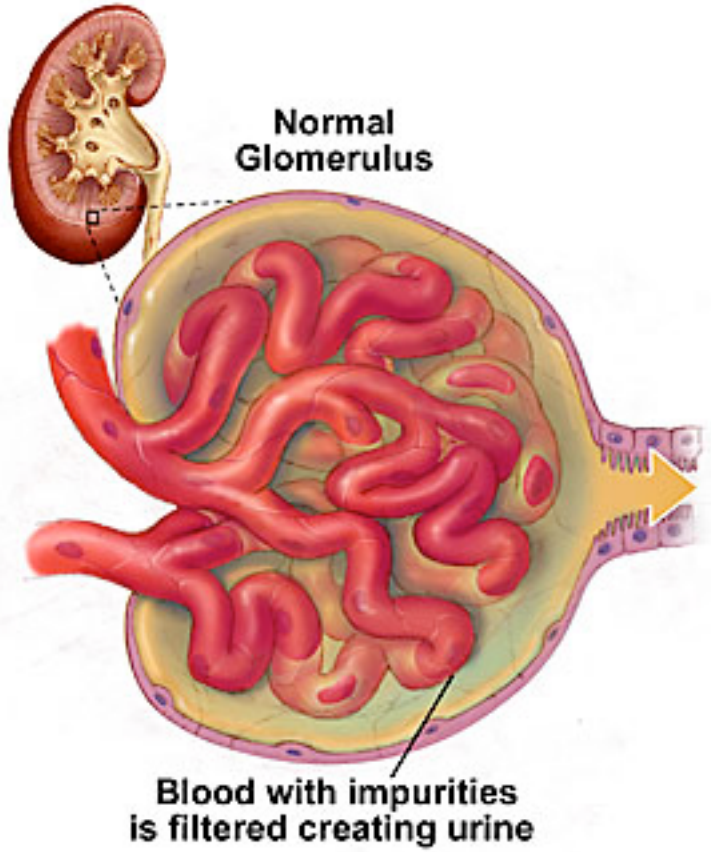


F: Produces oocytes and is the cite of fertilization and fetal development; produces milk
M: Produces and transfers sperm cells
Both: produces hormones that influence sexual functions and behaviors.

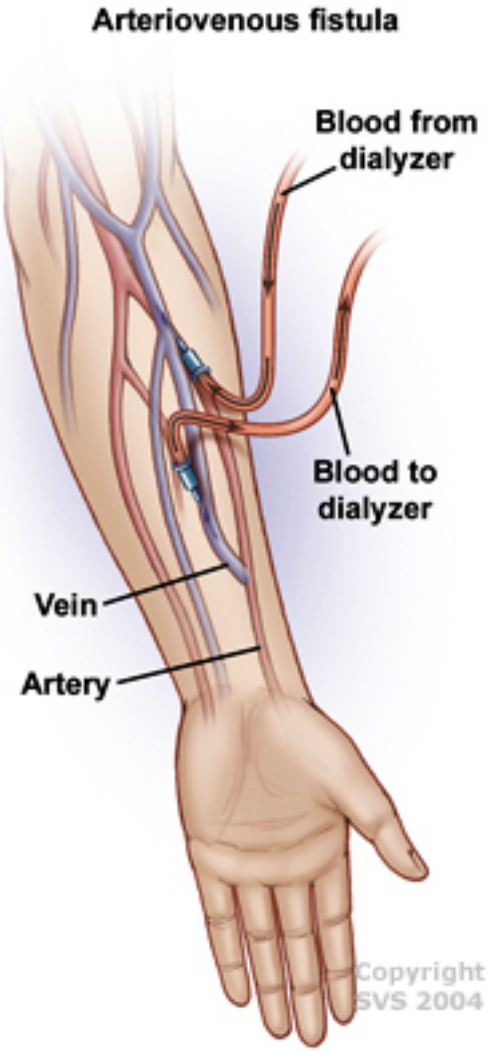
Tony Atala: lots of tissue engineering of reproductive system organs.

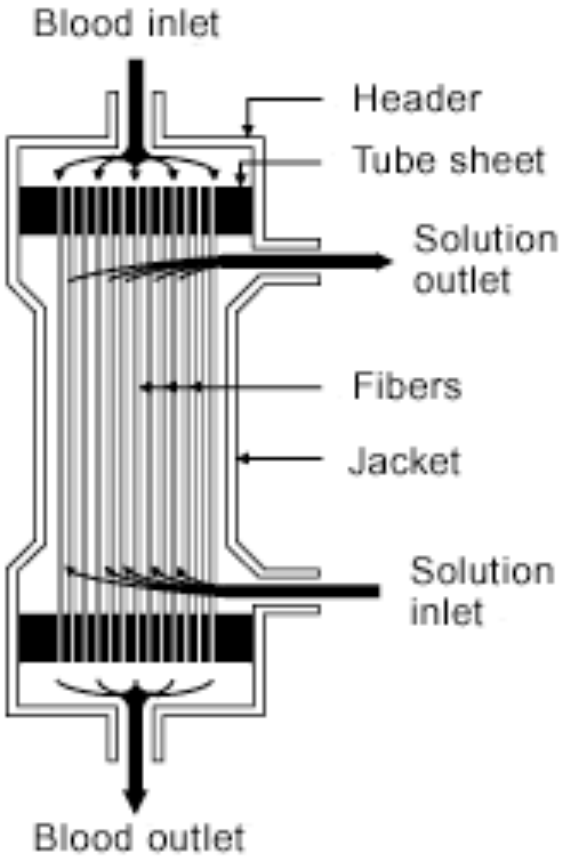
Kidney Function



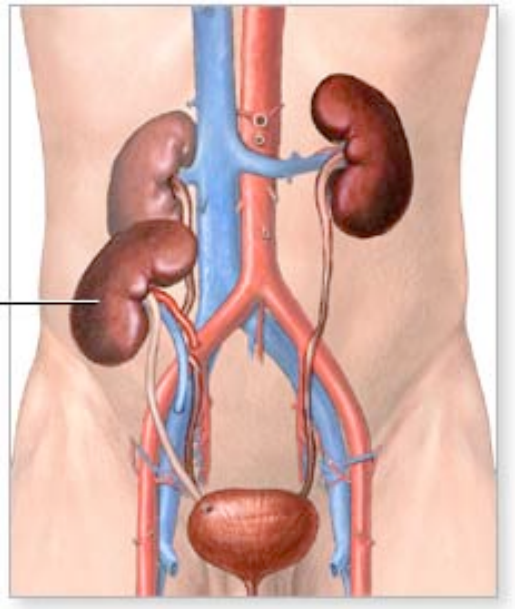


Dialysis given to patients with kidney failure



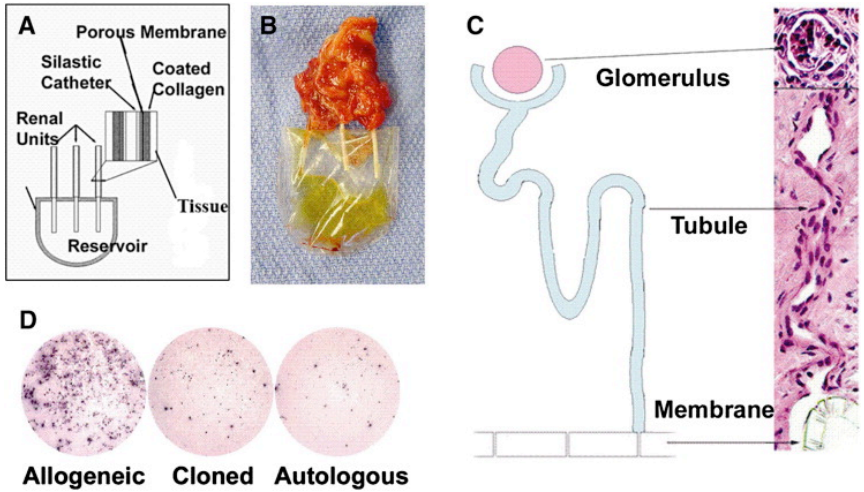


Permanent solutions to kidney failure



Decellularized kidney

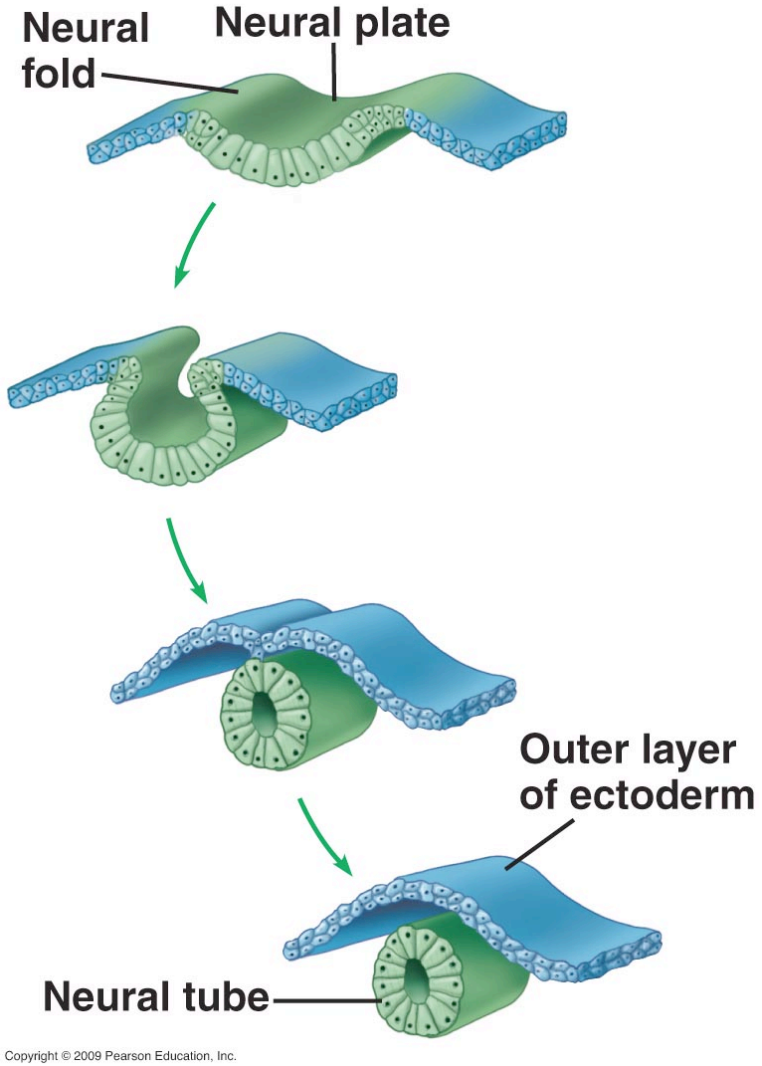
Tissue engineering bio-hybrids?



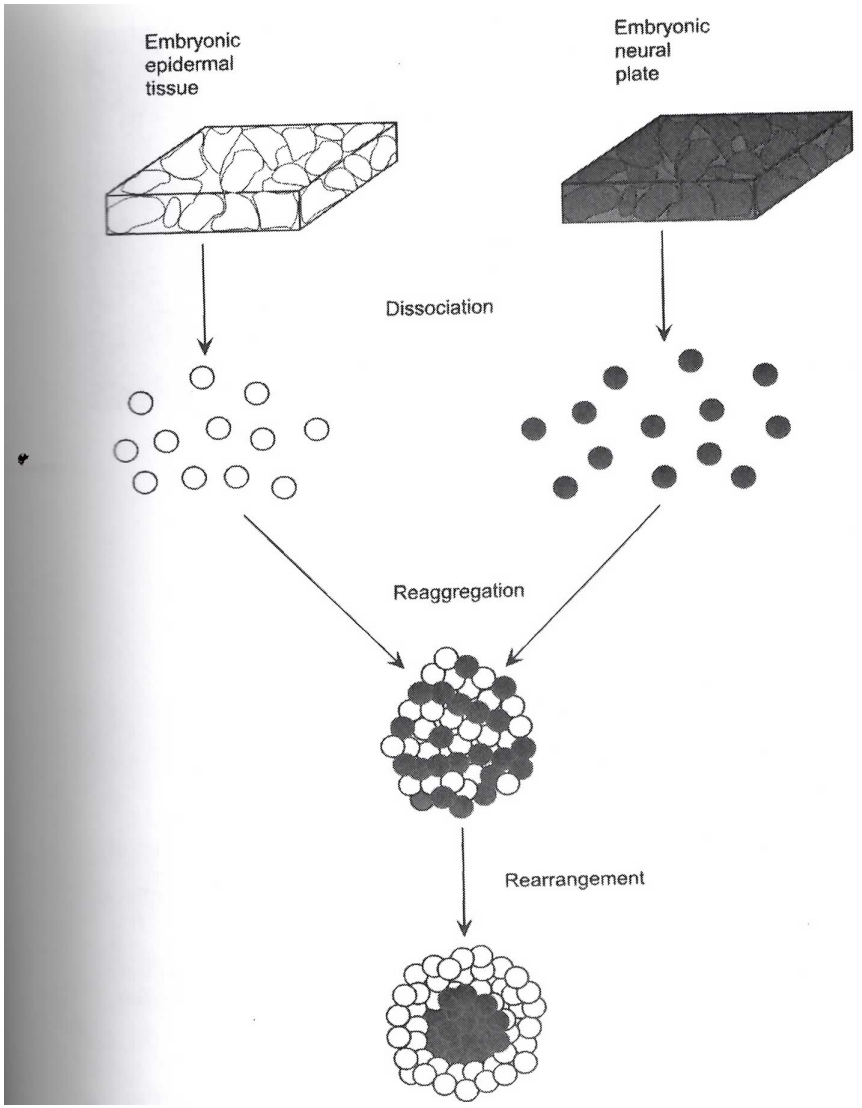
How do all these organ systems develop?

MBOC: xenopous egg

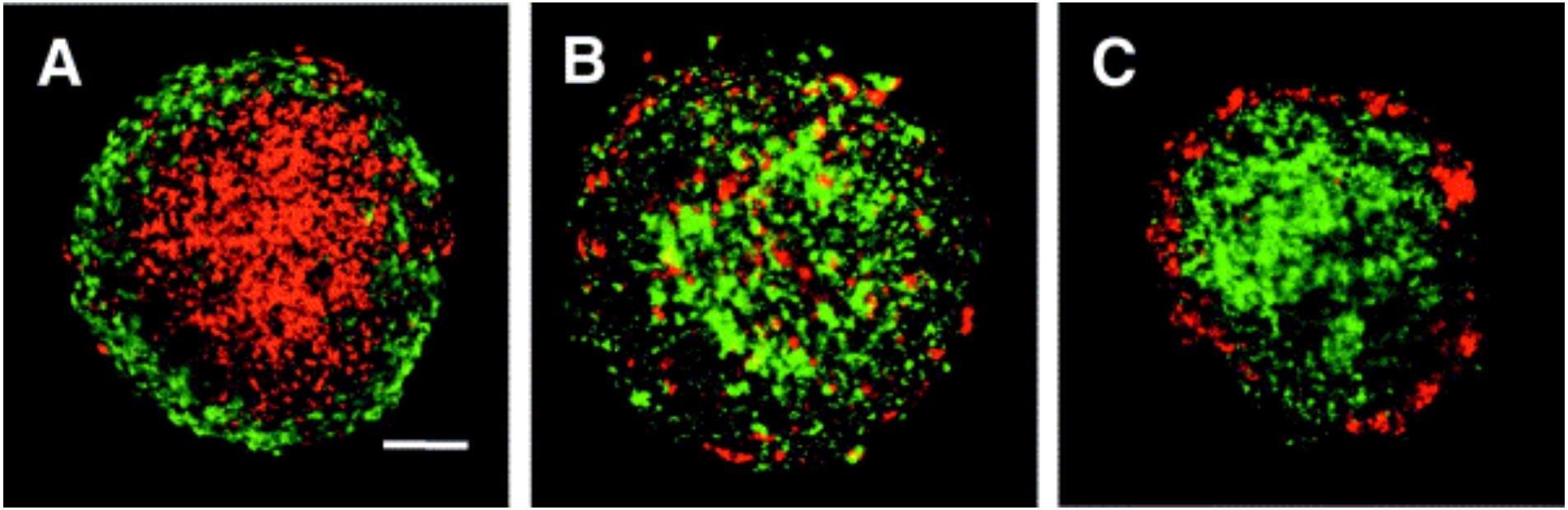
Self-sorting in embryonic cells captures some of developmental process



Neural plate formation in frog embryo development



Chemical Equilibria of Cell Sorting



From Duguay et. al., *Developmental Biology*

This type of approach can sometimes get an engineered tissue "started" – to capture tissue function naturally.

Grant thought: manipulate cell surface receptors to get them to self sort??