Anatomy and Physiology for Engineers

Course Description:
- Introduction to the subject of human anatomy and physiology.
- Concentration on physiology and bioengineering.
- Springboard for exploring bioengineering in greater detail.
- Class lectures will complement the textbook material.
- HW assignments are intended to expand student’s knowledge and illustrate engineering approach toward understanding function.
- FAST-PACED course (Do not fall behind!)

Prerequisites:
- Graduate/senior student in engineering.
- Knowledge of basic biology and chemistry will be helpful.
- May need to supplement certain knowledge areas for homework.

Textbook and Objectives

Required Textbook
- *Human Physiology: From Cells to Systems*, by Lauralee Sherwood
  - 3rd or 4th edition is fine.
- Study Guide

Optional books:

Course Objectives:
- Learn basic aspects of human physiology.
- Develop an understanding of the engineering approach toward understanding biological function.
- Search the scientific literature, retrieve information and succinctly report on specific topics.
Homework, tests, and other inconveniences...

- Three examinations during semester.
- Final Report (Review Article - for graduate students or anyone taking the class as a graduate class).
- ~ 6 homework assignments.
- Comprehensive Final.
- Grading (undergraduate)
  - 3 tests: 15 % each; highest score at 20%; (total of 50%)
  - HW: 20 %
  - Final Exam: 30%
- Grading (graduate)
  - 3 tests: 15% each (total of 45%)
  - HW: 15%
  - Final Exam: 20 %
  - Final Paper: 20 %.

Office hours, etc.

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Let us get started…

Reading Assignment: Chapters 1,2; Appendix: B,C

Look, it’s moving. It’s alive, it’s alive, it’s alive. It’s moving. It’s alive, it’s alive, it’s alive, it’s alive, it’s alive!

Functions of Living Things

- **Responsiveness**
  - Living organisms respond to changes in their environment (irritability).
  - Also have capability to make long term changes to adjust to their environment (adaptability).

You are waking along the beach and come across a starfish. How do you determine whether it is dead or alive?
Functions of Living Things

- **Growth**
  - Increase in size over life of the organism.
  - This occurs increases in cell size and/or number.
  - Cell: Basic unit of life.

- **Reproduction**
  - Ability to create new generations of similar organisms.

- **Movement**
  - Internal and external movement.

- **Metabolism**
  - Chemical operations within the organism.
  - Used to provide energy for other functions.

So, is your car alive?

- It responds: stops when you push the brake pedal; accelerates when you push accelerator.
- It moves.
- It consumes food: metabolic processes take place in conversion of gasoline to energy and waste products.
Biology: The Study of Life

Anatomy - “cutting open”

Study of internal and external structures and physical relationship among various body parts

Physiology - “study of nature”

Study of function, i.e., how the body works.

Mitochondria from skeletal muscle cell

Anatomy & Physiology are highly linked:
Form follows function; function determines form

Which bike would you pick for a road race?

- 20 lbs
- Wide wheels
- 10 gears
- Deep tread
- 4 lbs
- Narrow wheels
- 24 gears
- Aerodynamic design
Anatomical Perspectives

Microscopic anatomy

- Study of structures that cannot be seen without magnification.
- **Cytology**: Study of individual cells.
- **Histology**: Study of groups of cells - tissue.

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Anatomical Perspectives

Microscopic anatomy
- Study of structures that cannot be seen without magnification.
- **Cytology**: Study of individual cells (ex: cardiac cell).
- **Histology**: Study of groups of cells - tissue (ex: heart muscle).

Gross anatomy
- Examination of structures visible to the eye.
- **Surface**: General form and superficial markings.

Regional: Superficial and internal features of a specific region.
Anatomical Perspectives

- Microscopic anatomy
  - Study of structures that cannot be seen without magnification.
  - **Cytology**: Study of individual cells.
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- Gross anatomy
  - Examination of structures visible to the eye.
  - **Surface**: General form and superficial markings.
  - **Regional**: Superficial and internal features of a specific region.
  - **Systemic**: Features of a group of organ systems that work in coordination.
Physiology

- **Cell physiology**
  - Study of the functioning of a cell.

- **Special physiology**
  - Study of how an organ functions (ex: kidney, liver, etc.).

- **System physiology**
  - Study of whole organ systems (ex: respiratory physiology).

- **Pathological physiology or pathology**
  - Study of the effects of disease on organs and organ systems.

Levels of organization

**Cells:** Basic unit (Cytology).

**Tissue:** Groups of cells (Histology)
- **Muscle** tissue: Generation of force.
- **Nervous** tissue: Facilitate conduction of electrical impulses.
- **Epithelial** tissue: Promote exchange of materials between cells and environment.
- **Connective** tissue: Connects and anchors various body parts.

**Organs:** Primary tissues grouped to perform a specific function.
- Stomach contains:
  - Muscle tissue to move food.
  - Epithelial tissue to protect blood vessels from acids.
  - Nervous tissue within the walls to control muscle contraction, gland secretion, etc.
  - Connective tissue to bind all the various other tissues.

**Organ systems**
- Collection of organs designed for particular function
  - Digestive system

**Organism:** Single, independently living individual that is separate from the external environment.
Importance of a cell

Consider the following sentence:

*I dropped my cap down the well.*

Overall image: Organism
Sentence: Organ system
Phrases: Organs
Words: Tissues
Letters: Cells

What happens if the ‘p’ in cap is replaced by ‘t’?

Levels of Organization

[Diagram of levels of organization in the human body, showing various levels from Organism to Atoms.]

Anatomy and Physiology for Engineers
**Homeostasis**

- **Homeo**: unchanging; **stasis**: standing
- Refers to the existence of a stable internal environment.
- Crucial to survival of an organism.
- For multi-cellular organisms, the cell cannot interact directly with the external environment.
- However, cells must interact with the ‘outside’
  - Obtain nutrition, generate energy, process and discard waste.
- Key is the aqueous internal environment within the body but outside the cells: extracellular fluid.
- **Extracellular** fluid is made up of:
  - **Plasma**: fluid portion of blood
  - **Interstitial fluid**: surrounds and bathes the cells.
- Each cell maintains a homeostatic balance with its extracellular fluid.
- This allows the entire organism to generate a stable internal environment.

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**Components of the Extracellular Fluid**

- **Cell**
- **Interstitial fluid**
- **Blood vessels**
- **Plasma**

Anatomy and Physiology for Engineers
**Diffusion across the cell membrane**

- **Fick’s law of mass transfer (simple diffusion):**

  \[ J = -D_A \frac{dC_A}{dx} \]

  - \( J \): Flux in axial direction (x);
  - \( dC_A/dx \): Concentration gradient
  - \( D_A \): Diffusivity or diffusion coefficient

- **Diffusion across pores and membranes:**

  \[ J = -A_p D_A \frac{dC_A}{dx} \]

  - \( A_p \): Porosity of membrane (pore area / total surface area)

**Regulation occurs via feedback**

Homeostatic regulation involves:

- **Receptor** sensitive to the environment change or stimulus.
- **Control center** to receive and process receptor information.
- **Effector** to respond to commands of the control center to oppose or enhance the stimulus.

Most physiological regulation involves **negative feedback**, which causes the effector to oppose the stimulus.
Negative Feedback

- Most common regulatory phenomenon in the body.

Positive Feedback

- Found in few natural processes
  - Ex: Cascade of reactions that lead to a blood clot.
  - Blood clot is required to close wounds and facilitate healing.
  - Therefore, a fast acting process is required.
- More common in disease conditions.
  - Ex: Development of atherosclerosis.
Back to anatomy...

- Language of anatomy is based on Greek and Latin roots
- Examples of root words (from Greek)
  - Kardia (heart) --> cardi
  - Gaster (stomach) --> gastr
  - Hepar (liver) --> hepat
  - Nephros (kidney) --> nephr
  - Osteon (bone) --> oste
- Combine root words with suffixes and/or prefixes for description
  - Cardio + logy = “Heart” + “study”
    - Study of the heart
  - Hyper + therm + ia = “Excessive” + “Heat” + “Condition”
    - Overheating
  - Osteo + arthr + itis = “Bone” + “Joint” + “Inflammation”
    - Inflammation of bones and joints
- Key to success is repetition and association.

Superficial Anatomy

- **Anatomical position:** Standing with hands at the side facing forward.
- **Supine:** Lying face up in anatomical position.
- **Prone:** Lying face down in anatomical position.
Directional References

Planes and Sections
Body Cavities

X-Ray Imaging

- What cut plane is this?
- Which body cavity does this image reveal?
Case Scenario

A.R. is a 40-year-old woman who presents to your office with the chief complaint of worsening abdominal pain for three days. She also complains of nausea, vomiting, and constipation, and has not had a bowel movement in almost a week. She denies fevers, chest pain, or shortness of breath.

She has no significant past medical or surgical history, takes no medications, and has no allergies. She does, however, smoke five cigarettes a day, and drinks alcohol socially.

She works for a sign and placard company.

On examination, she is in mild distress due to abdominal discomfort. Vitals are significant for a pulse of 110 and blood pressure of 150/70. Lungs are clear, and heart exam is normal. Abdominal exam is significant for hypoactive bowel sounds and moderate diffuse tenderness, without rebound or guarding.

You also hear egophony - "E to A" changes on auscultation - in the abdomen.

Labs are completely normal.

You're stumped until a colleague suggests you get an abdominal x-ray, which shows the following:

Abdominal X-Ray
Large Vowel Obstruction

This patient, a 39 year old woman who works for a sign and placard company, has a large vowel obstruction.

The presence of a large vowel in the colon on plain film of the abdomen is pathognomic for this disorder, and clinches the diagnosis.

Large vowel obstruction is difficult to diagnose on physical exam alone, but the presence of "E to A" changes during auscultation of the abdomen is highly suggestive, and should prompt experienced clinicians to order abdominal films at their earliest convenience.

On further questioning, it was discovered that the patient had recently been involved in an untoward incident at work involving a "FOR SAL" sign.

A colonoscopy was performed, and the offending vowel was removed without complications. Vowel rest was advised, and the patient recovered fully.