Course Learning Goals

An overall goal of this course is to enable students to understand the role of molecules, cells, tissues, organs, and organ systems (endocrine, nervous, muscular and immune systems) in human health and disease. This class focuses on understanding physiology –the functioning of a living organism and its component parts. This requires going beyond memorization of facts to acquire an understanding of how and why the body functions the way it does, and what happens when it does not function properly.

More explicitly, students will able to:

1. Demonstrate an understanding of the physiology and basic regulatory concepts related to the functioning of life processes. The life processes to be studied in IPHY 3470 will include Cell Physiology, Neurophysiology, Endocrinology, Muscle Physiology, and Immunology.

2. Name the key physiology themes (homeostasis & regulation, structure/function relationships, compartmentation, biological energy transformation, and communication & information flow), and be able to provide or recognize examples of each from the different organ systems.

3. Discuss the significance of maintaining homeostasis to the survival of the whole organism.

4. Demonstrate the use of the scientific method and quantitative reasoning to field of physiology.

5. Demonstrate a mechanistic (how) and teleologic (why) understanding of the levels of organization comprising the human organism.

6. Demonstrate an understanding of the physiology and basic regulatory concepts of the organ systems associated with this course and the mechanisms that allow the body to carry out those functions, and predict how a perturbation (e.g., disease, experimental manipulation) will alter function.

7. Integrate knowledge of the major systems to outline how these systems interact to maintain homeostasis.

8. Develop critical thinking skills in order to be able to think like a physiologist, and solve physiologically-relevant problems.

Introduction to Physiology

Readings: Chapter 1, Human Physiology (6th edition), pg. 1-24

Prior to covering this section, students should be able to:

- Outline the levels of biological organization for living organisms from atom to system.
- Name the physiological systems of the human body, their major organs, and their major function(s).

Terminology

anatomy	physiology	teleological
mechanistic (mechanism)	homeostasis	pathophysiology
law of mass balance	hypothesis	regulated variable
set point	stimulus	sensor
input signal	integrator (integrating center)	output signal
target	physiological response	afferent pathway
efferent pathway	feedforward control	negative feedback
positive feedback	independent variable	dependent variable
control	bar graph	histogram
line graph	scatterplot	x-axis
y-axis	disequilibrium	equilibrium

When students complete this chapter, they should be able to:

1. Describe the discipline of physiology and identify whether a physiologist would study a given topic or research area.

2. Provide a mechanistic (how) or teleological (why) explanation for a physiological phenomenon.

3. Name the key themes in physiology and be able to provide or identify examples of each.

4. Differentiate between homeostasis and equilibrium.

5. Predict how the system will respond to a perturbation in homeostasis.

6. Diagram or identify the regulated homeostatic variable, sensor, integrator, and effector/target in a homeostatically regulated system.

7. Identify the type of control strategy (feedforward, positive and negative feedback) being employed in a given scenario.

8. Describe the key elements of a well-designed experiment and give scenarios for which each design is most appropriate.
9. Identify the key components of graphs, interpret basic meaning from graphical data, and determine when it is appropriate to use a particular graph type with a particular data set.

Cell Physiology

Readings: Chapters 2, 3, and 5, Human Physiology (6th edition), pg. 32-37, 49-56, 62-89 and 139-166

Prior to covering this section, students should be able to:

- Demonstrate an understanding of basic chemistry and biology as it relates to physiology.
- Draw the fluid mosaic model of a typical cell membrane and show how the membrane structure relates to its general functions.
- Describe the function of organelles found in our cells.

Terminology

carbohydrates	lipids	proteins
nucleotides	agonist	antagonist
competitive inhibitor	modulators	up-regulation
down-regulation	saturation	affinity
specificity	competition	cell
lumen	extracellular fluid	intracellular fluid
interstitial fluid	plasma	cell membrane
organelles	gap junctions	tight junctions
anchoring junctions	epithelial tissue	connective tissue
muscle tissue	neural tissue	permeable
impermeable	diffusion	electrical gradient
chemical gradient	Fick's law of diffusion	structural proteins
membrane enzymes	receptors	channel proteins
ion channels	gated channels	carrier proteins
facilitated diffusion	primary active transport	secondary active transport
ATPases	vesicular transport	phagocytosis
receptor-mediated endocytosis	pinocytosis	transcytosis
resting membrane potential	electrochemical gradient	Nerst equation

When students complete these chapters, they should be able to:

Chapter 2: Molecular Interactions

1. Differentiate the four types of biomolecules (carbohydrates, lipids, proteins, nucleotides) and describe the basic roles they play in the body.

2. Explain how protein function can be modulated by chemical (agonists, antagonists, competitive inhibitors, etc.) or physical (temperature, pH) factors.

3. Explain protein affinity, specificity, competition, and saturation and identify which process is occurring when presented with a graph.

Chapter 3: Compartmentation: Cells and Tissues

4. Predict the function of a cell based upon the number or concentration of specific organelles (e.g., nucleus, Golgi apparatus, endoplasmic reticulum, mitochondria), or *vice versa* (given function, predict relative number of organelles).

5. Describe the steps of protein synthesis and explain why the steps take place in different subcellular compartments.

6. Discuss the similarities and differences between the four different types of tissue (epithelial, connective, muscle, neural) found in our bodies.

7. Predict physiological functions of tissues based on their anatomical properties, including the types of cell junctions present.

Chapter 5: Membrane Dynamics

8. Predict whether a molecule will cross a cell membrane by simple diffusion, protein-mediated transport, or vesicular transport and explain what factors contribute to its movement.

9. Summarize the properties of diffusion and predict how the rate of diffusion would change when these parameters are altered.

10. Differentiate between the categories of membrane proteins according to structure and function.

11. Differentiate between the types of protein-mediated transport (facilitated diffusion, primary active transport, secondary active transport) and diagram the mechanisms of each, including the general energy requirements.

12. Differentiate between the processes of phagocytosis, endocytosis, and exocytosis and diagram the mechanisms of each.

13. Identify the factors that are responsible for establishing and maintaining the charge separation across the plasma membrane (resting membrane potential).

14. Predict how changes in chemical or electrical gradients, or membrane permeability, will influence:
    a. The movement of an ion
    b. The equilibrium potential for an ion (E_{ion})
    c. The membrane potential of a cell

Metabolism

Readings: Chapters 4 and 22, Human Physiology (6th edition), pg. 100-101, 105-124, 744, 753-760

Prior to covering this section, students should be able to:

- Explain the relationships between the following terms: potential/kinetic energy, endergonic/exergonic/coupled reactions, net free energy, reversible/irreversible reactions, and activation energy.
- Explain why it is necessary that living organisms require a catalyst (enzyme) present to carry out a reaction.
- Determine the probability a chemical reaction proceed when presented with various chemical reactions differing in activation energy levels.
- Describe the metabolic processes below and determine the key substrates, products, and net energy yields from each process (in the presence and absence of oxygen).
    a. Glycolysis
    b. Citric acid cycle
    c. Electron transport system

Terminology

energy	chemical work	transport work
mechanical work	enzymes	metabolism
catabolism	anabolism	high-energy phosphate bond
glycolysis	citric acid cycle	electron transport system
aerobic	anaerobic	oxidative phosphorylation
adenosine triphosphate (ATP)	gene	messenger RNA (mRNA)
protein	carbohydrate	lipid
insulin	glucagon	gluconeogenesis
lipogenesis	glycogenesis	lipolysis
glycogenolysis		

When students complete these chapters, they should be able to:

Chapter 4: Energy and Cellular Metabolism

1. Identify the type of work being done, or energy being used, in a given scenario.

2. Explain the roles of enzymes in biological reactions, and know the function of key enzyme types.

3. Predict how changes in any of the steps of cellular metabolism will influence these pathways and in what cellular location(s).

4. Describe how the information in a gene becomes a functional protein by means of transcription, mRNA processing, translation, and post-translational modification.

5. Predict how changes in any of the steps of protein synthesis will influence the levels of DNA, mRNA, protein, etc. and in which cellular location(s).

Chapter 22: Metabolism and Energy Balance

6. Describe under what general conditions anabolic (gluconeogenesis, lipogenesis, glycogenesis) versus catabolic (glycolysis, lipolysis, glycogenolysis) processes would occur, and why.

7. Describe the general mechanism for homeostatic regulation of blood glucose, and predict the effects of changes in insulin or glucagon levels.

Cellular Communication

Readings: Chapter 6, Human Physiology (6th edition), pg. 174-186, 189-200

Terminology

local communication	long-distance communication	paracrine signal
autocrine signal	hormones	neurocrine
neurotransmitter	neuromodulator	neurohormone
cytokine	receptor proteins	signal molecule (ligand)
endocrine	exocrine	ligand gated
enzyme receptors	G-protein coupled receptors	primary messenger
secondary messenger	protein kinase	protein phosphatases
signal amplification	amplifier enzyme	cAMP
agonist	antagonist	up-regulation
down-regulation	tonic control	antagonistic control

When students complete this chapter, they should be able to:

1. Differentiate between the various cell-to-cell communication methods (paracrine, autocrine, endocrine, exocrine) and identify when one communication method might be used instead of another.

2. Contrast the role of a signal molecule (ligand) versus a receptor in directing a change in cell response.

3. Differentiate between the categories of cell surface receptors that activate a cascade in the cell (ligand gated, enzyme receptors, G-protein coupled receptors).

4. Describe the role of a primary messenger, secondary messenger, and protein kinase in a signal transduction cascade initiated by a plasma membrane receptor.

5. Outline the cAMP pathway and be able to predict how changes at any level will affect the pathway.

6. Identify the physiological outcome to a stimulus based upon receptor specificity, up- or down-regulation).

7. When presented with a graph of receptor affinity, differentiate between a low and high affinity receptor.

8. Identify how the actions of a ligand are typically terminated.

9. Differentiate tonic vs. antagonistic control and be able to identify examples of each.

Endocrine System

Readings: Chapter 7, Human Physiology (6th edition), pg. 206-230

Terminology

endocrinology	peptide hormone	steroid hormone
amine hormone	anterior pituitary	posterior pituitary
vasopressin	oxytocin	trophic hormone
portal system	prolactin	growth hormone
follicle stimulating hormone	luteinizing hormone	gonadotrophins
thyroid-stimulating hormone	adrenocorticotrophic hormone	synergism
permissiveness	antagonism	hypersecretion
atrophy	hyposecretion	primary pathology
secondary pathology		

When students complete this chapter, they should be able to:

1. Create a chart that distinguishes the three classes of hormones (peptides, steroids, amino-acid derivatives) according to how they are:
    a. Synthesized
    b. Stored
    c. Released
    d. Transported in the blood
    e. Cellular mechanism of action

2. Predict the classification of an unknown hormone from knowledge of its synthesis, storage and release, transport in the blood, and cellular mechanism of action.

3. Explain why it is important that hormones are broken down (metabolized) and predict the consequences on a target cell if high concentrations of hormones are maintained over time (chronically).

4. Explain the interaction between organs and glands of the endocrine system, including those of the hypothalamic-pituitary axis, and those involved in blood glucose homeostasis.

5. For a given endocrine control system, determine the stimulus, afferent pathway, integrator, efferent pathway, and effector. Explain how feedforward and feedback mechanisms regulate the pathways and where regulation occurs.

6. Apply knowledge of different hormone interactions (synergism, permissiveness, antagonism) to predict the expected response from a target cell in the presence of multiple hormones.

7. Diagnose primary and secondary endocrine pathologies by applying knowledge of feedback loops and hormone hypersecretion, hyposecretion, and abnormal tissue responsiveness.

Nervous System

Readings: Chapters 8, 10, and 11, Human Physiology (6th edition) pg. 239-243, 250-264, 266-273, 328, 332-333, 377-394

Prior to covering this section, students should be able to:

- When presented with a representation of a neuron, explain the main function of dendrites, soma, trigger zone, axon, axon terminal, and synapse.

Terminology

central nervous system	peripheral nervous system	somatic motor division
autonomic division	sympathetic branch	parasympathetic branch
presynaptic cell	postsynaptic cell	synaptic cleft
mechanically gated channel	chemically gated channel	voltage-gated channel
graded potential	action potential	Ohm's law
resistance	current (I_{ion})	all-or-none
depolarization	repolarization	hyperpolarization
refractory period	myelin	synaptic vesicles
acetylcholinesterase (AChE)	chemoreceptors	mechanoreceptors
thermoreceptors	photoreceptors	transduction
receptor potential	fight-or-flight	rest and digest
autonomic ganglion	preganglionic neuron	postganglionic neuron
vagus nerve	alpha receptors	beta receptors
muscarinic receptors	nicotinic receptors	neuromuscular junction
acetylcholine	norepinephrine	

When students complete these chapters, they should be able to:

Chapter 8: Neurons: Cellular and Network Properties

1. Describe the system level organization of the nervous system in terms of both anatomy and function.

2. Describe the direction and function of information flow through the regions of a neuron in response to input from another neuron.

3. Compare and contrast the function and location (CNS, PNS) of the three major classes of neurons (afferent, interneuron, efferent).

4. Contrast the structure and function of the three types of ion channels (mechanical, chemical, voltage-gated) found in the plasma membrane.

5. Diagram graded potentials and explain how they can either inhibit or initiate an action potential.

6. Diagram an action potential and describe the roles of ions and ion channels (and their gating mechanisms) during the rising phase, falling phase, and refractory periods.

7. Explain why a typical neuron needs both graded and action potentials in order to integrate information and allow for appropriate cellular communication.

8. When presented with a graph of an action potential, indicate when the membrane is being depolarized, repolarized, and hyperpolarized.

9. Explain how neurotransmitters communicate information across chemical synapses from the axon terminal to a post-synaptic neuron, and be able to predict how changes in these steps will influence the cellular response.

10. Describe the three mechanisms (uptake, enzyme clearance, diffusion) used to terminate the actions of neurotransmitters, and be able to predict how changes in these would influence synaptic transmission.

Chapter 10: Sensory Physiology

11. Differentiate between chemoreceptors, mechanoreceptors, thermoreceptors, and photoreceptors and identify the adequate stimulus for each.

12. Explain how sensory receptors transduce stimulus energy into electrical signals that can be used by the nervous system.

13. Explain how the CNS distinguishes stimulus intensity and duration.

Chapter 11: Efferent Division: Autonomic and Somatic Motor Control

14. Determine when the parasympathetic (rest and digest) and sympathetic nervous (fight or flight) systems will dominate over the other.

15. Compare chemical signaling in the two autonomic branches including:
    a. Ganglionic and postganglionic synapses
    b. Neurotransmitters
    c. Receptors
    d. Target tissues and their responses
    e. Second messenger mechanisms associated with each receptor type

16. Diagram the anatomy of a somatic motor pathway and describe the events at the neuromuscular junction.

17. Highlight differences between the somatic motor division and the autonomic division.

Muscular System

Readings: Chapters 12 and 13, Human Physiology (6th edition) pg. 401-422, 441-449

Prior to covering this section, students should be able to:

- Define the following terms as they relate to skeletal muscle: origin, insertion, joint, flexor, extensor, antagonistic muscle groups.
- Draw a series of diagrams to show the different levels of organization of skeletal muscle.
- Compare and contrast the morphological and contractile properties of smooth and cardiac muscle with those of skeletal muscle.
- Compare and contrast the three different muscle fiber types (slow-twitch, fast-twitch oxidative, fast-twitch glycolytic).

Terminology

actin	myosin	thick filament
thin filament	crossbridge	sarcomere
sliding filament theory	power stroke	myosin ATPase
troponin	tropomyosin	rigor state
excitation-contraction coupling	twitch	fatigue
summation	tetanus	motor unit
isotonic contraction	isometric contraction	eccentric
concentric	proprioceptors	muscle spindles
stretch reflex	Golgi tendon organ	Golgi tendon reflex
monosynaptic reflex	polysynaptic reflex	

When students complete these chapters, they should be able to:

Chapter 12: Muscles

1. Diagram the sequence of events involved in muscle contraction, from neuronal action potential through cell signaling to force output, and predict how a change in any of these steps will affect contraction.

2. Compare and contrast isometric and isotonic (concentric, eccentric) contractions.

3. Explain how summation increases force of contraction.

4. Graph and explain the force-length relation with corresponding sarcomere alignment, and be able to predict a change in force according to this relation.

5. Graph and explain the force-length relation with corresponding sarcomere alignment, and be able to predict a change in force according to this relation.

6. Discuss the different causes of fatigue.

7. Predict muscle characteristics (force production, fatigability, primary role, etc.) given fiber type distributions, or *vice versa*.

8. Describe what a motor unit is and how skeletal muscles can create graded contractions of varying force and duration.

Chapter 13: Control of Body Movement

9. Diagram and describe the structures and mechanisms involved in producing spinal and autonomic reflexes.

10. Match the specific components of a skeletal muscle reflex to the general steps of a reflex.

11. Draw a muscle spindle, diagram the stretch reflex, and explain the purpose of this reflex.

12. Draw a Golgi tendon organ, diagram the Golgi tendon reflex, and explain the purpose of this reflex.

Immune System

Readings: Chapter 24, Human Physiology (6th edition), pg. 801-820, 825-830

Terminology

immune response	antigen	immunodeficiency diseases
autoimmune diseases	innate immunity	acquired immunity
primary lymphoid tissue	secondary lymphoid tissue	basophils
mast cells	neutrophils	eosinophils
macrophage	monocytes	lymphocytes
plasma cells	dendritic cells	natural killer cell
inflammation	antibodies	

When students complete this chapter, they should be able to:

1. Compare and contrast the six major cell types of the immune system.

2. Describe the major functions of the immune system.

3. Compare and contrast innate and acquired immunity in terms of:
    a. Specificity of response
    b. Timing of response
    c. Effector cells used to eliminate a potential pathogen

4. Differentiate between primary and secondary lymphoid tissues.

5. Describe the general processes involved in inflammation.

6. Describe how the body differentiates between self and non-self and explain how the breakdown of this safeguard can lead to autoimmune diseases.

7. Given a scenario, predict a person's blood type.

8. Explain how stress can affect immunity.