COURSE LEARNING GOALS

Students will be 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 Human Physiology II will include the metabolic, digestive, respiratory, circulatory, urinary, and reproductive systems.

2. Describe the functioning of life processes for the human physiological systems using basic chemical/biochemical, physical, and mathematical concepts.

3. Explain the significance of integrative physiology in research, clinical, and applied settings.

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

5. Demonstrate a teleologic (why) and mechanistic (how) understanding of the life processes examined in this course.

6. Demonstrate how the physiological systems discussed in Human Physiology I and II contribute to the maintenance of homeostasis across the cellular to organism levels.

CHAPTER 21 – THE DIGESTIVE SYSTEM

Main goal for Chapter 21:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the digestive system response to that disturbance.

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

- Diagram the structures a piece of food passes through as it travels from the mouth to the anus.
- Describe the location and function of the four layers of the gastrointestinal (GI) tract wall: the mucosa, submucosa, muscularis externa, and serosa. Include the predominant tissue type in each layer.

Interactive Physiology CD: Digestive System

- Orientation
- Anatomy Review
- Control of Digestive System
- Motility, Secretion, Digestion and Absorption

Terminology:

bile	bile salts	metabolism
bolus	segmental contractions	G cells
chyme	mucosa	pancreas
ECL (paracrine) cells	mucous cell	pancreatic proteases
gastric phase	pepsin	intestinal phase
gastrointestinal tract	digestion	absorption
goblet cell	enterendocrine cell	acinar cell
long reflex	short reflex	migrating motility complexes
motility	secretion	muscularis externa
parietal cell	chief cell	enterokinase
plicae	submucosa	gallbladder
salivary amylase	pancreatic amylase	cholecystokinin
secretin	gastric inhibitory peptide	cephalic phase
serosa	enteric nervous system	peristalsis
trypsinogen	trypsin	lipase
vomiting	diarrhea	columnar epithelial cell

Students should be able to:

1. Differentiate between digestion and metabolism.

2. Provide a summary of motility, secretion, digestion, and absorption in the different regions of the digestive system.

3. Describe the purpose of the three patterns of contractions in the gastrointestinal system: migrating motor complexes, peristalsis, and segmental contractions.

4. Match the appropriate cell type (parietal, goblet, columnar epithelial, chief, mucous, G, acinar cells) to its function, secretion, and location within the gastrointestinal tract.

5. Differentiate between the functions of the cephalic, gastric, and intestinal phases of digestion.

6. Diagram and explain the interaction of the long and short reflexes that control digestive system function.

7. Explain the role of gut hormones (gastrin, secretin, motilin, ghrelin, leptin) in local and systemic control of digestion and other physiological processes.

8. Describe how the gastrointestinal system serves as part of the body's immune system.

9. Explain the protective reflexes the digestive system uses (vomiting, diarrhea) to protect the body against foreign invaders.

CHAPTER 22 – METABOLISM AND ENERGY BALANCE

Main goals for Chapters 22:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the metabolic response to that disturbance.

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

- Diagram and differentiate the general anabolic pathways for the synthesis of carbohydrate, fat, and protein.

Interactive Physiology CD: Muscular System

- Muscle Metabolism

Terminology:

physiology	metabolism	homeostasis
feeding center	glucostatic theory	thermodynamics
lipostatic theory	leptin	neuropeptide Y
ghrelin	satiety center	direct calorimetry
kilocalorie (Kcal)	indirect calorimetry	respiratory quotient (RQ)
respiratory exchange ratio (RER)	basal metabolic rate (BMR)	resting metabolic rate (RMR)
diet-induced thermogenesis	anabolic pathways	catabolic pathways
fed (absorptive) state	fasted (postabsorptive) state	adenosine triphosphate (ATP)
nutrient pools	lipoprotein lipase	apoproteins
ketone bodies	insulin	glucagon
oxygen consumption	glycolysis	gluconeogenesis
beta-oxidation	lipogenesis	glycogenesis
lipolysis	cholesterol	glycogenolysis
carbohydrate	triglyceride	amino acids
fat	free fatty acid	protein
glucose	glycogen	energy output
energy balance	energy intake	internal heat production
external heat input	core temperature	convection
temperature balance	conduction	thermoregulatory center
body temperature	nonshivering thermogenesis	hypothalamic thermostat
radiation	shivering thermogenesis	mitochondrial uncoupling
evaporation		

Students should be able to:

1. Discuss the interaction of the three nutrient pools of the body (free fatty acid, glucose, and amino acid pool) under varying conditions (e.g., fed, fasted, or exercise states).
    a. Include the following terms in your discussion: lipogenesis, lipolysis, glycogenesis, gluconeogenesis, glycogenolysis, protein anabolism, and protein catabolism.

2. Explain the components of energy balance (energy intake and energy output) and predict how behavioral modifications can alter energy balance.

3. Explain how metabolic rate can be quantified.

4. Describe the source of heat that contributes to body temperature and determine why this is energetically costly in terms of ATP utilization.

5. Given a diagram/scenario, identify and explain the key components of temperature balance: heat loss (conductive, radiant, convective, and evaporative) and heat gain (internal (metabolism and muscle contraction) and external heat (radiation and conduction) in the human body, and predict how environmental factors (i.e., temperature, humidity) can alter temperature balance.

6. Compare and contrast the central (hypothalamic) and peripheral mechanisms for maintaining body temperature.

7. Using examples in which body temperatures stray outside normal conditions (i.e., hyperthermia, hypothermia, fever, heat exhaustion, heat stroke, exercise), explain the feedforward/feedback mechanisms involved in how the body attempts to re-establish body temperature homeostasis.

CHAPTER 17 – MECHANICS OF BREATHING
CHAPTER 18 – GAS EXCHANGE AND TRANSPORT

Main goals for Chapters 17 & 18:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the respiratory system response to that disturbance.

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

- Identify and explain how muscles of the respiratory system accomplish quiet inspiration, quiet expiration, and forced expiration.
- Diagram the airflow from the mouth to the alveoli.
- Compare and contrast the functions of the three major epithelial cells of the alveoli: alveolar macrophage, type I alveolar cells, and type II alveolar cells.

Interactive Physiology CD: Respiratory System

- Anatomy Review
- Gas Exchange
- Gas Transport

Terminology:

cellular respiration	gas exchange	ventilation
type II alveolar cell	alveolar macrophage	type I alveolar cell
Dalton's Law	surfactant	atmospheric pressure
tidal volume	Boyle's Law	partial pressure
residual volume	inspiratory reserve volume	expiratory reserve volume
inspiratory capacity	vital capacity	total lung capacity
intrapleural pressure	functional residual capacity	goblet cells
barometric pressure	mucus	alveolar pressure
LaPlace's Law	inspiration	expiration
bronchodilation	compliance	elastance
alveolar ventilation	Poiseuille's Law	bronchoconstriction
diffusion	total pulmonary ventilation	anatomic dead space
hypoxia	dead space ventilation	solubility
hyperoxia	partial pressure	Henry's Law
deoxyhemoglobin	hemoglobin	oxyhemoglobin
Bohr effect	oxy-hemoglobin dissociation curve	hemoglobin saturation
chloride shift	2,3-diphosphoglycerate (2,3-DPG)	carbonic anhydrase
peripheral chemoreceptors	carbaminohemoglobin	central pattern generator
aortic bodies	central chemoreceptors	carotid bodies
pulmonary capillary transient time	Hering-Breuer inflation reflex	bicarbonate
arterial/venous oxygen content	pulmonary circulation	systemic circulation
P_AO_2, P_ACO_2, P_aO_2, P_aCO_2,P_vCO_2, P_vO_2	arterial/venous carbon dioxide content	Fick's Law

Students should be able to:

1. Compare and contrast cellular respiration (ATP production) and gas exchange on the structure and functions involved in each.

2. Explain how the changes in pleural pressures drive inhalation.

3. Apply the three gas laws (the rules that govern the behavior of gases in air) to explain how each are involved in breathing.

4. Discuss how various environmental conditions (altitude, percent humidity, temperature) influence barometric pressure.

5. Explain why the partial pressure of oxygen (P_{O2}) and carbon dioxide (P_{CO2}) differs in various compartments (lungs, blood, tissues) and under varying conditions (sea level, altitude, dry air, 100% humidity) and explain how these differences contribute to the movement of gases throughout the body.

6. Describe and illustrate how lung volumes (tidal volume, inspiratory reserve volume, expiratory reserve volume, and residual volume) are related to lung capacities (vital capacity, total lung capacity, inspiratory capacity, and functional residual capacity).

7. Diagram the alveolar pressure (mmHg), intrapleural pressure (mmHg), and volume of air (ml) moved during several cycles of inspiration and expiration at rest. Using the diagrams, predict and explain how these would change during varying conditions (hyperventilation and hypoventilation).

8. Differentiate between the concepts of compliance and elasticity (elastance) and how these might change in various disease states to affect breathing.

9. Explain how surfactant reduces surface tension at the alveoli, decreasing the work of breathing.

10. Describe how and why airway diameter is the primary determinant of airway resistance. Based on this principle discuss the mechanism of how chemicals (paracrines and neurotransmitters) can alleviate the symptoms of respiratory distressed states such as asthma and allergic responses.

11. Calculate total pulmonary ventilation (L/min), dead space ventilation (ml), and alveolar ventilation (ml/min). Predict what happens to these variables if you manipulate tidal volume and/or breathing rate.

12. Describe the local control of arterioles and bronchioles due to changes in concentration of oxygen and carbon dioxide.

13. Using Fick's law of diffusion, predict how alterations in the four factors (surface area, concentration gradient, membrane thickness, and diffusion distance) can influence the rate of diffusion of oxygen and carbon dioxide across cell layers.

14. Diagram and explain the two ways in which oxygen is transported in the blood: dissolved in plasma and bound to hemoglobin (Hb).

15. Discuss how plasma P_{O2}, changes to plasma P_{O2} and the number of binding sites available determine the amount of oxygen that binds to hemoglobin.

16. Using the oxygen-Hb dissociation curve, predict the percent O_2 saturation of hemoglobin at various P_{O2} values (20, 40, 100 mmHg) or perturbations to the system (temperature, pH, metabolites, 2,3-DPG), and determine if this value favors O_2 loading or unloading between blood and tissues.

17. Diagram and explain the three ways carbon dioxide is transported in the blood: dissolved in plasma, converted to bicarbonate ion, and bound to hemoglobin (Hb).

18. Predict how hypoventilation or hyperventilation influence the transport of oxygen and carbon dioxide.

19. Describe how the central nervous system regulates quiet and forced breathing.

20. Compare and contrast how central vs. peripheral chemoreceptors regulate ventilation.

21. Explain how protective reflexes (coughing, sneezing, and the Hering-Breuer inflation reflex) guard the lung from physical injury or irritation.

CHAPTER 14 – CARDIOVASCULAR PHYSIOLOGY
CHAPTER 15 – BLOOD FLOW AND THE CONTROL OF BLOOD PRESSURE
CHAPTER 16 - BLOOD

Main goals for Chapters 14, 15, & 16:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the circulatory system response to that disturbance.

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

- Compare and contrast the structure/function of cardiac muscle cells vs. skeletal muscle and smooth muscle cells. Describe what unique properties of cardiac muscles are essential to its function.
- Compare and contrast the structure (diameter, wall thickness, tissue type) and function of arteries, arterioles, capillaries, venules, and veins.
- Describe the composition of the blood and the general function of its cellular elements.

Interactive Physiology CD: Cardiovascular System Topics

Terminology:

arterio-venous $(a\text{-}v)_{02}$ difference	total blood volume	atherosclerosis
afterload	blood pressure	diastolic pressure
arrhythmia	ejection fraction	stroke volume
arterioles	systole	capillaries
autorhythmic cells	venules	resting membrane potential
baroreceptors	contractile cells	white blood cell (leukocyte)
bundle branches	red blood cell (erythrocyte)	T wave
cardiac cycle	purkinje fibers	bradycardia
depolarization	P wave	atrioventricular (AV) bundle
desmosome	repolarization	pacemaker potential
end diastolic volume	gap junction	preload
filtration	end systolic volume	platelet (thrombocyte)
heart	colloid osmotic pressure	veins
heart rate	arteries	venous return
hyperpolarization	cardiac output	refractory period
myocardium	viscosity	intercalated disk
myogenic autoregulation	vasodilation	hydrostatic pressure
pressure gradient	mean pressure	pulmonary circulation
pulse pressure	systemic circulation	peripheral resistance
QRS complex	systolic pressure	diastole
respiratory pump	tachycardia	serum
sinoatrial (SA) node	Frank-Starling curve	electrocardiogram (ECG/EKG)
summation period	atrioventricular (AV) node	skeletal muscle pump
vasoconstriction	action potential	Poiseulle's Law
Fick equation	hydrostatic pressure	

Students should be able to:

1. Describe the functions of the cardiovascular system.

2. Compare and contrast the structure/function of (a) the pulmonary and systemic circulations, (b) an artery and a vein, and (c) atria and ventricles.

3. Explain the importance of the systemic circuit of the cardiovascular system being arranged in parallel verses series.

4. Describe how pressure gradients allow blood to move through the heart chambers and around the body.

5. Using Poiseuille's law ($R = 8L\eta/\pi r^4$), predict what happens to resistance of blood flow when the length of the "tube" increases, the viscosity of the blood increases, and the "tube's" radius increases, and vice versa.

6. Compare and contrast the action potentials of **a myocardial contractile cell** vs. **a cardiac autorhythmic cell**. Be sure to include:
    a. Structure
    b. Resting membrane potential
    c. Ions and ion channels involved in depolarization, repolarization, and hyperpolarization
    d. Durations of the action potential
    e. Refractory and summation period of each (if any)

7. Predict how the autonomic nervous system alters pacemaker and action potentials.

8. Diagram and explain the electrical conduction pattern of the heart beginning with the wave of depolarization from an autorhythmic cell in the SA node down to the contractile cells at the apex of the heart.

9. Correlate the electrical waves of an ECG to the mechanical events in the atria and ventricles. Be sure to explain why there are only three electrical events but four mechanical events.

10. Summarize the factors that determine cardiac output.
    a. Cardiac output (Q) = heart rate (HR) x stroke volume (SV)
    b. Fick equation for oxygen uptake (V_{O2}) = cardiac output (Q) x arterio-venous (a-v) oxygen difference
    c. Predict what would happen to cardiac output if you varied heart rate by increasing autonomic nervous system activity.
    d. Graph and interpret a Starling curve for the intact heart. Using the Starling curve, predict what would happen to cardiac output if you varied stroke volume.
    e. Describe the relationship between stroke volume and venous return, including how the skeletal muscle pump, the respiratory pump, and sympathetic innervation of veins affect venous return.

11. Predict how alterations in blood pressure, cross sectional area of the blood vessels, total blood volume, and peripheral resistance affect **velocity of blood flow**.

12. Predict how alterations in blood flow, cross sectional area of the blood vessels, total blood volume, and peripheral resistance affect **mean arterial pressure**.

13. Explain the mechanisms (hydrostatic and colloid osmotic pressures) that allow for exchange between the plasma and interstitial fluid.

14. Use a graph of pressure verses the blood vessels; explain why the amplitude of pressure waves in the systemic circulation decrease over distance and does not reach zero.

15. Differentiate between the diastolic, systolic, and mean arterial pressure.

16. Explain the interaction between the nervous and cardiovascular system in the various mechanisms that regulate blood pressure, include a discussion of the role of the baroreceptors, the medulla, and the autonomic nervous system

17. Describe how the nervous (medulla, sympathetic and parasympathetic nervous systems) and cardiovascular systems (baroreceptors) regulate blood pressure.

18. Explain the general mechanism and risk factors behind the development of atherosclerosis.

19. Describe the various risk factors for cardiovascular disease, including whether these risk factors are controllable or uncontrollable.

20. Provide a general overview of the three steps of hemostasis (vasoconstriction, temporary blockage, blood coagulation) in tissue repair.

CHAPTER 19 – THE KIDNEYS
CHAPTER 20 – FLUID AND ELECTROLYTE BALANCE

Main goals for Chapters 19 & 20:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the kidney response to that disturbance.

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

- Order the major structures of the urinary system in their anatomical sequence from initial filtration at the kidneys to the urine leaving the body. Describe the major function of each structure.
- On a diagram of the nephron label the major regions (Bowman's capsule, efferent and afferent arterioles, vasa recta, glomerulus, proximal and distal tubule, and descending and ascending Loop of Henle), illustrating where each region lies in the medulla or cortex of the kidney.

Interactive Physiology CD: Kidney

- Anatomy Review

Terminology:

angiotensin I	transepithelial transport	ACE
basal lamina	podocytes	filtration slits
cortex	glomerulus	distal tubule
descending loop of Henle	ascending loop of Henle	collecting duct
filtration	reabsorption	secretion
filtration fraction	macula densa	granular cells
foot processes	filtration slits	basal lamina
glomerular filtration rate	angiotensin II	renin
hydrostatic pressure	colloid osmotic pressure	fluid pressure
juxtaglomerular apparatus	fenestrated capillaries	podocytes
nephron	afferent arteriole	efferent arteriole
peritubular capillaries	vasa recta	Bowman's capsule
proximal tubule	convoluted tubule	solute
renal corpuscle	proximal tubule	loop of Henle
saturation	creatinine	micturition
urine	renal physiology	medulla
osmolarity	extracellular fluid	intracellular fluid
water balance	plasma	interstitial fluid
vasopressin	antidiuretic hormone (ADH)	acidosis
kidney	ureter	renal artery
renal vein	myogenic feedback	tubularglomerular feedback
paracellular pathway	transport maximum	renal threshold
clearance	excretion	

Students should be able to:

1. Compare and contrast the four processes that occur in the urinary system (filtration, reabsorption, secretion, and excretion) in terms of structure, function, and composition of filtrate.

2. Predict the direction of movement of solutes, solvents, and water through the regions of the kidney according to osmotic and concentration gradients.

   Filtration:
   A. Describe the three structural filtration barriers (cells) that solutes must cross as they move from plasma to the lumen of Bowman's capsule. Be sure to include what components of blood these layers usually exclude.
   B. Compare and contrast the roles of hydrostatic, colloid osmotic pressures, and capsule fluid pressure in allowing movement of fluid across the filtration barriers (between the capillaries and the Bowman's capsule).
   C. Predict how factors such as dehydration or high blood pressure can affect the amount of filtrate created in the Bowman's capsule. Be sure to include the mechanisms that take place during filtration to respond to these states.
   D. Compare the four mechanisms that regulate filtration: myogenic response, local feedback, and neural and hormonal regulation.

   Reabsorption & Secretion:
   A. Explain the mechanisms, regulation, and ability of the nephron to modify the filtered fluid (filtrate) to prepare it for excretion. (How is it possible to filter 180 L of fluid and only excrete 1.5 L in a normal situation?)
   B. Differentiate and explain how low hydrostatic pressure, passive and active transport accomplish reabsorption of ions (Na^+, K^+, Ca^{2+}), urea, anions, glucose, and water to be reabsorbed back into the extracellular fluid to modify the initial filtrate in the nephron.
   C. Explain how the loop of Henle and the extracellular fluid concentrations in the medulla interact to conserve water from the filtrate.

   Excretion
   A. Summarize the purpose of the measurement of clearance as an estimate of excretion, renal handling, glomerular filtration, and why it is used clinically.

3. Diagram the micturition (urination) reflex.

4. Predict how changes to osmolarity, particularly the osmolarity of the extracellular fluid (ECF), are important to cell function and homeostasis in the body.

5. Describe how the renal and cardiovascular systems integrate to keep blood pressure/volume within a normal range.

6. Compare the routes of water gain and loss in the body.

7. Explain how the loop of Henle and vasa recta work together to create dilute renal filtrate.

8. Discuss the various homeostatic pathways (including the renin-angiotensin-aldosterone system) used to regulate blood pressure and the significance of having multiple pathways.

9. Describe how appetite for water and salt is important in regulating fluid volume and osmolarity.

10. Predict how changes in hydrogen ion concentration [H^+] influence extracellular pH.

11. Discuss the three mechanisms involved in regulating the body's plasma pH (buffers, ventilation, renal regulation of H^+ and HCO^{3-}), and explain the importance of these mechanisms in maintaining proper enzymatic and nervous system function.

Optional:

- Predict how the functions of the excretory system would alter during renal failure.
- Design a device that can filter the blood external to the body.
- Explain why the kidneys as an organ that, per gram of weight, uses more ATP than most other organs.
- Explain the purpose of modifying the initial filtrate throughout the nephron.

CHAPTER 26 – REPRODUCTION AND DEVELOPMENT

Main goal for Chapter 26:

- Given a homeostatic disturbance, formulate a teleologic (why) and/or mechanistic (how) discussion of the reproductive system response to that disturbance.

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

1. Identify the male and female gonads and gametes.

Terminology:

puberty	gonads	sex chromosomes
androgens	oogenesis	gametogenesis
oocytes	estrogens	progesterone
spermatogenesis	estradiol	inhibins
ovulation	menstruation	follicular phase
aromatase	menses	proliferative phase
luteal phase	placenta	lactation
labor	prolactin	menopause
andropause	gonadotropins	gametes
zygote	ovarian cycle	uterine cycle
pregnancy	birth (parturition)	

Students should be able to:

1. Predict what sex a zygote will become given the set of chromosomes (X, Y) it inherits.

2. Describe, compare, and contrast gametogenesis in males and in females.

3. Diagram the hypothalamic-pituitary-gonadal circuit and explain how negative feedback is involved the regulation of the secretion of gonadotropins.

4. Explain how the reproductive glands contribute to successful reproduction.

5. Diagram the hormonal control of spermatogenesis in males and describe how these hormones change with age.

6. Diagram the menstrual cycle, distinguishing between the ovarian cycle and the uterine cycle. Include all relevant hormones.

7. Compare and contrast the events of the four phases of sexual intercourse in males and in females.

8. Describe the mechanism of action of sexually transmitted diseases (STD) and their impact on reproductive function.

9. Discuss the awareness and significance of STDs as a global health issue.

10. Summarize the processes of fertilization, pregnancy, and birth (parturition).

11. Diagram the hormonal changes that occur upon implantation of an embryo in the uterus and how those changes continue during pregnancy.

12. Diagram the different roles of the nervous, endocrine, muscle, and reproductive systems necessary for a successful birth.

13. Describe and contrast menopause and andropause.