

HBY350 PHYSIOLOGY: SPECIFIC TOPICS

Learning Objectives and Goals Described on a Lecture-by-Lecture Basis

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These lecture objectives are subject to change as the course progresses.

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Lectures 1-4. Basic Principles (Dr. Clausen)

Lecture 1 discusses basic physiological control systems. The student is expected to be able to

- 1.1 describe basic control theory (e.g., concepts related to feedback control systems including set points, integrators, effectors, feedback);
- 1.2 discuss positive and negative feedback, open- and closed-loop gain;
- 1.3 discuss homeostasis at a cellular and whole-body level.

Lecture 2 discusses membranes and the internal environment. The student is expected to be able to

- 2.1 describe the bilayer structure of membranes and micelles, including the chemical structure of phospholipids;
- 2.2 discuss the hydrophobic nature of the bilayer that renders it a good insulator;
- 2.3 describe the functions of membrane proteins (e.g., transporters, enzymes, receptors, identity markers, cell adhesion, cytoskeleton attachment, etc.);
- 2.4 describe the basic body compartments (e.g., intracellular, extracellular, plasma, transcellular), including their respective solute compositions;
- 2.5 solve numerical problems using the indicator-dilution method for measuring the different body-compartment volumes.

Lecture 3 discusses transport systems. The student is expected to be able to

- 3.1 discuss simple diffusion, including determinants of the diffusion constant in free solution, membrane permeability constants, partition coefficients and the Einstein relationship;
- 3.2 solve numerical problems related to uni- and bidirectional (net) fluxes and flows occurring by diffusion, as well as the distance-time relationship for diffusion;
- 3.3 discuss the characteristics of facilitated diffusion, active transport and other protein-mediated transport systems;
- 3.4 discuss bulk flow, and why macroscopic organisms require cardiovascular and respiratory systems;
- 3.5 describe osmosis, the concept of osmotic pressure, and the concept of a reflection coefficient;
- 3.6 solve numerical problems related to water flow across membranes (e.g., compute osmolarity and osmotic pressure, compute water fluxes and flows).

Lecture 4 discusses maintenance of cell volume. The student is expected to be able to

- 4.1 describe the terms isosmotic, hypoosmotic and hyperosmotic, and to contrast their definitions with the terms isotonic, hypotonic and hypertonic;
- 4.2 compare the differences between the concepts of equilibrium versus steady state, as related to solute gradients across a membrane;

- 4.3 discuss the role of the Na^+, K^+ -ATPase (sodium pump) in maintaining solute gradients across cells, as well as maintaining cell volume;
- 4.4 solve quantitative problems related to determination of cell-volume following changes in extracellular-solution composition;
- 4.5 discuss clinical aspects of dehydration and over hydration, and the significance of different infusion solutions (e.g., normal saline) in treating these disorders.

Lectures 5-9. Electrophysiology of excitable cells and synaptic transmission (Dr. Clausen).

Lecture 5 discusses the concept of a membrane potential. The students are expected to be able to

- 5.1 discuss the concept of a diffusion (or equilibrium) potential;
- 5.2 describe the forces leading to net inward or outward ionic flows across membranes;
- 5.3 calculate equilibrium potentials using the Nernst equation;
- 5.4 describe the concept of a membrane's ionic conductance, and contrast it with membrane ionic permeability;
- 5.5 compute the membrane potential of a cell given ionic gradients and membrane conductances of the different ionic species;
- 5.6 compute the membrane potential of a cell using the Goldman equation;
- 5.7 describe the net ionic currents in a resting cell, and how these currents are countered by the activity of the sodium pump.

Lecture 6 discusses the action potential in neurons and skeletal-muscle cells. The students are expected to be able to

- 6.2 describe the ionic basis for the resting potential, and define the terms hyperpolarization and depolarization;
- 6.3 describe the operation of a voltage clamp;
- 6.4 describe the ionic basis for the action-potential threshold, the rapid depolarization (spike), rapid repolarization, and hyperpolarized after potential phases of the action potential;
- 6.5 describe the voltage- and time-dependence of the gating phenomena (e.g., activation and inactivation of Na^+ channels, and activation of K^+ channels);
- 6.6 describe why action potentials are considered "all or none" phenomena, and predict how changes in the ionic gradients will change the appearance of action potentials;
- 6.7 describe the pharmacological actions of local anesthetics, as well as tetrodotoxin and tetra-ethyl ammonium;
- 6.8 describe the concepts of absolute and relative refractory periods.

Lecture 7 discusses propagation of action potentials in neurons and skeletal-muscle fibers. The students are expected to be able to

- 7.1 describe the electrotonic currents that flow near an excited region of a neuron, and how these currents depolarize neighboring resting membrane to threshold;

- 7.2 describe action-potential conduction in an unmyelinated axon, and why conduction is normally unidirectional;
- 7.3 describe the determinants of the length constant of an axon, and why larger unmyelinated axons exhibit faster conduction velocities than smaller axons;
- 7.4 describe the function of myelin, and why it increases the length constant;
- 7.5 describe saltatory conduction;
- 7.6 discuss the spacing of the nodes of Ranvier in regards to a neuron's safety factor;
- 7.7 answer the question: Why are small interneurons unmyelinated?
- 7.8 discuss the clinical implications of demyelinating diseases, in regards to nerve transmission.

Lecture 8 discusses generator and synaptic potentials. The students are expected to be able to

- 8.1 describe where generator, excitatory and inhibitory post-synaptic, and end-plate potentials occur;
- 8.2 describe the ionic basis for these potentials, as well as their duration, in comparison to that of neural action potentials;
- 8.3 discuss temporal and spatial summation, and how a neuron's cell body acts as an integrator;
- 8.4 discuss why inhibitory post-synaptic potentials can sometimes be "silent" (or even depolarizing) potentials, yet still be effective in preventing excitation;
- 8.4 discuss the differences in the membrane properties in the soma and dendrites of a neuron, in comparison with the initial segment (axon hillock) and axon;
- 8.5 discuss how differences in generator-potential amplitudes leads to frequency encoding of stimulus intensity;
- 8.6 discuss in detail the anatomy of a simple pressure receptor, the Pacinian corpuscle, and how the multilamellar structure mediates receptor adaptation.

Lecture 9 discusses the operation of a chemical synapse. The students are expected to be able to

- 9.1 discuss the properties of an electrical synapse, how they involve gap junctions, and why they are ineffective in conveying communication from small to large cells;
- 9.2 describe the anatomy of a chemical synapse (e.g., presynaptic nerve terminal and membrane, synaptic vesicles, synaptic cleft, sub- and postsynaptic membrane);
- 9.3 discuss where these synapses are found in the body;
- 9.4 describe the events starting with the arrival of the presynaptic action potential and the exocytosis of neurotransmitter, and why these processes are dependent on extracellular Ca^{++} ;
- 9.5 discuss diffusion of transmitter across the cleft, the subsequent binding to receptors on the subsynaptic membrane, and the opening of postsynaptic ionic channels;
- 9.6 compute the time required for transmitter diffusion in the cleft, and discuss why this time does not account for the observed synaptic delay;

- 9.7 discuss the fate of released neurotransmitter (e.g., reuptake, hydrolysis, or diffusion), and how these relate to closure of postsynaptic channels;
- 9.8 describe why a single neurotransmitter can be excitatory in some regions of the body, yet inhibitory in others;
- 9.9 describe the characteristics of a number of different transmitters (e.g., norepinephrine, acetylcholine, dopamine, etc.), and their effects at well-described locations (e.g., neuromuscular junction, spinal motor neurons, etc.).
- 9.10 list the characteristics of neuromodulators, and contrast these with neurotransmitters;
- 9.11 describe the pharmacological actions of curare, atropine, black-widow spider venom, phosphorus-containing insecticides and nerve gas;
- 9.12 discuss presynaptic inhibition and facilitation.

Lectures 10-12. Skeletal, cardiac and smooth muscle (Dr. Clausen).

Lecture 10 discusses the cellular basis for skeletal-muscle contraction. The student is expected to be able to

- 10.1 describe the structure of muscle fibers by defining the terms myofibril, sarcomere, sarcolemma, transverse tubules and sarcoplasmic reticulum;
- 10.2 discuss the basis for the banded microscopic appearance of muscle fibers;
- 10.3 describe the fine structure of the sarcomere by defining the terms A-band, I-band, H-zone, M-line, Z-line;
- 10.4 describe the structure of the thin (actin) and thick (myosin) filaments, noting the orientation of the cross bridges in relation to the thin filaments;
- 10.5 describe the crossbridge cycle in mechanical as well as biochemical terms;
- 10.6 describe the physiological basis of rigor mortis;
- 10.7 discuss the structure of the regulatory proteins troponin and tropomyosin, noting their conformational changes resulting from increases in intracellular Ca^{++} levels;
- 10.8 discuss excitation-contraction coupling from the initiation of the action potential at the endplate, to propagation over the sarcolemma and transverse tubules, to release of Ca^{++} from the sarcoplasmic reticulum;
- 10.9 discuss the roles of dihydropyridine and ryanodine receptors in excitation-contraction coupling, as well as the function of the Ca^{++} pumps and calsequestrin in terminating contraction;
- 10.10 discuss the multiple roles that ATP plays in muscle contraction;
- 10.11 discuss the physiological basis for the clinical disorder myotonia congenita.

Lecture 11 discusses skeletal-muscle mechanics. The student is expected to be able to

- 11.1 describe the differences between isometric and isotonic contractions;
- 11.2 discuss isometric and isotonic twitch recordings, noting latency, contraction and relaxation times, duration, and intracellular Ca^{++} levels;

- 11.3 analyze twitch recordings quantitatively (e.g., predict isotonic latency given an isometric response, compute shortening velocity, etc.);
- 11.4 describe the basis for the shortening velocity versus load relationship in a muscle;
- 11.5 describe the basis for a sustained (tetanic) contraction, in regards to twitch summation and fusion frequency;
- 11.6 discuss why tetanic contractions produce higher contraction force than twitches;
- 11.7 discuss thermodynamic efficiency of muscles, heat production and shivering;
- 11.8 discuss the active length-tension relationship in muscle, the arrangement of thick and thin filaments at each point of the curve, and how this led to the sliding-filament theory;
- 11.9 discuss the need for the anatomical hinge arrangement of muscles and joints due;
- 11.10 calculate the forces a muscle exerts in suspending an external load (e.g., barbell);
- 11.11 describe the different types of skeletal muscle (e.g., fast versus slow), their different function, and their metabolism (i.e., glycolytic versus oxidative);
- 11.12 describe the role of creatine phosphate in buffering ATP levels.

Lecture 12 discusses smooth and cardiac muscle. The student is expected to be able to

- 12.1 contrast the cellular structure of cardiac muscle with that of skeletal muscle, noting differences in filament arrangement, intercalated disks, amounts of sarcoplasmic reticulum, transverse tubules, etc.
- 12.2 describe why cardiac muscle cannot operate anaerobically;
- 12.3 describe excitation-contraction coupling in cardiac muscle;
- 12.4 describe the physiological basis for the action of cardiac glycosides;
- 12.5 describe the length-tension relationship in cardiac muscle, in comparison with skeletal muscle;
- 12.6 describe the ionic basis for the cardiac action potential in different regions of the heart, noting especially how pacemaker currents mediate spontaneous myogenic activity;
- 12.7 discuss why cardiac muscle cannot produce tetanic contractions;
- 12.8 discuss the dual innervation of cardiac muscle, types of cholinergic and adrenergic receptors, and hormonal sensitivity of cardiac muscle;
- 12.9 discuss the anatomy and functions of smooth muscle in different parts of the body;
- 12.10 describe the differences between single- and multiunit smooth muscle;
- 12.11 describe the cellular organization of smooth muscle, including filament ratio, lack of sarcomeres, rarefied sarcoplasmic reticulum, dense bodies, etc.
- 12.12 describe excitation-contraction coupling in smooth muscle, including the roles of calmodulin and myosin light-chain kinase;
- 12.13 describe types of electrical activity in smooth muscle, including action potentials, pacemaker and slow-wave potentials;
- 12.14 discuss myogenic activity in smooth muscle, as well as how activity is modulated by hormones and the autonomic nervous system.

Lectures 13-14. Neural wiring and reflexes (Dr. Clausen).

Lecture 13 discusses general properties of neurons and neural wiring circuits. The students are expected to be able to

- 13.1 describe the principle of adaptation, and its role in modulating afferent (sensory) information arising from sensory receptors;
- 13.2 describe the principles of convergence and divergence;
- 13.3 describe how incoming sensory information can be prolonged or shortened via neural connections that act as feedback circuits;
- 13.4 discuss frequency encoding of different amplitudes of sensory information;
- 13.5 define the term recruitment, in regards to perception of different stimulus intensities;
- 13.6 discuss lateral inhibition, its purpose and how it is wired;
- 13.7 discuss how neural connections can be formed to implement arithmetic and logic circuits;
- 13.8 define the term reciprocal innervation;
- 13.9 discuss the different classes of sensory receptors, their specificity, and why one perceives a poke in the eye as a flash of light;
- 13.10 define the term receptive field.

Lecture 14 discusses spinal reflexes. The students are expected to be able to

- 14.1 describe the anatomy and function of the different classes of muscle-spindle fibers;
- 14.2 describe the anatomy at a given level of the spinal cord, showing how afferent neurons enter the spinal cord, and efferent neurons exit the cord;
- 14.3 discuss the differences between the extra- and intrafusal muscle fibers, as well as their innervation;
- 14.4 describe the myotatic (stretch) reflex;
- 14.5 describe the spinal interconnections that mediate reciprocal innervation of a muscle and its antagonist, coactivation of a muscle and a synergist muscle, as well as the crossed-extensor reflex;
- 14.6 describe the differences observed when muscles are stimulated to contract via α -activation, γ -activation, and α - γ -coactivation;
- 14.7 discuss the anatomy, function and spinal interconnections involving the Golgi tendon organs;
- 14.8 discuss in detail the withdrawal reflex starting from initiation of a painful stimulus in the foot leading to foot withdrawal while supporting the body with the opposite leg;
- 14.9 discuss the clinical use of paralytic (curare-like) drugs during surgery, and the pathology resulting from tetanus-toxin poisoning.

Lectures 15-18. The central and peripheral nervous systems (Dr. Walcott).

Lecture 15 discusses the blood-brain barrier, cerebral spinal fluid, the anatomy of the brain, and the major functions of the different structures. The student is expected to be able to

- 15.1 describe the meninges and blood-brain barrier, and the composition and genesis of cerebral spinal fluid;
- 15.2 describe the concepts of a control system and positive and negative feedback in regards to neural interconnections in the brain;
- 15.3 describe the general characteristics of the somatosensory (somesthetic) system, including sensory fields and dermatomes;
- 15.4 describe the anatomy and function of the dorsal column-medial lemniscal pathway;
- 15.5 discuss the cerebral cortex and Brodman's areas, and particularly, the organization of the somesthetic cortex (precentral gyrus).

Lecture 16 continues the discussion of the brain, as well as the major ascending neural pathways. The student is expected to be able to

- 16.1 describe the anatomy and function of the ventral spinothalamic pathway;
- 16.2 describe the anatomy and function of the lateral spinothalamic pathway;
- 16.3 discuss how hemisection lesions at various levels of the cord affects somesthetic sensation.
- 16.4 describe the anatomy and function of the spinocerebellar pathways;
- 16.5 describe the anatomy of the cerebellum, and the effects of lesions on motor behavior;
- 16.6 discuss the general organization of the diencephalon, midbrain, pons and medulla.

Lecture 17 continues the discussion of the brain, as well as the major descending neural pathways. The student is expected to be able to

- 17.1 discuss the pyramidal and extrapyramidal systems;
- 17.2 describe the anatomy and functions of the corticobulbar and corticospinal pathways;
- 17.3 discuss the structure and function of the extrapyramidal pathways, and the function of the basal ganglia;
- 17.4 discuss the relative roles of all the descending pathways on the control of motor neurons;
- 17.5 describe the differences between lower motoneuron (flaccid) and upper motoneuron (voluntary) lesions.

Lecture 18 discusses the autonomic nervous system. The student is expected to be able to

- 18.1 describe the general characteristics of the autonomic nervous system;
- 18.2 discuss the origin and pathway of the sympathetic division of the system;
- 18.3 describe the neurotransmitters released at the preganglionic synapse, and the nerve endings;
- 18.4 discuss the chain ganglia and convergence;
- 18.5 describe the effects of sympathetic activation, notably the alarm (fight or flight) response;
- 18.6 describe the origin and pathway of the parasympathetic system;
- 18.7 discuss examples of the varied effects of parasympathetic activation;

- 18.8 discuss the two major ways that sympathetic and parasympathetic system control tissues, notably, where they control effectors with opposite action (e.g., the pupil) and where they have the opposite effect on the same target cells (e.g., the AV node).

Lectures 19. Neuroendocrinology (Dr. Johnson).

Lecture 19 introduces neuroendocrine functions. The student is expected to be able to

- 19.1 describe the different types of hormones and autoids;
19.2 describe the different classes of hormone receptors;
19.3 characterize the three principal mechanisms for transmembrane signal transduction via cell surface receptors (ion channel, second messenger mediated signalling, and receptor-enzymes);
19.4 describe the regulation of hormone release and feedback in the hypothalamic-pituitary system, and the influence this has on systemic functioning.

Lectures 20-26. Cardiovascular system (Dr. Johnson).

Lecture 20 discusses cardiovascular organization, blood flow, and distribution. The student is expected to be able to

- 20.1 describe the different types of blood vessels;
20.2 define the physical properties of diameter, innervation, musculature, and elasticity that contribute to vessel function;
20.3 relate the influence of a vessel's physical characteristics and of blood viscosity to their influence on blood flow through the vessel, as described by Poiseuille's law.

Lecture 21 discusses cardiac contractility. The student is expected to be able to

- 21.1 define the anatomical structures of the heart;
21.2 identify the differences in the mechanisms by which calcium is mobilized in cardiac and skeletal muscles to initiate muscle contraction;
21.3 describe the ionic basis of the cardiac resting and action potentials, and describe the differences in the appearance of the action potential in different regions of the heart;
21.4 describe the temporal relationship between the cardiac action potential and the cardiac muscle contraction and the effects that sodium and calcium channel blockers have on both;
21.5 relate the changes in ion conductances to cardiac automaticity and action-potential propagation, and discuss hormone-induced effects on these processes ;
21.6 relate the changes in diastolic depolarization rates in pacemaker cells to the propagation of the cardiac action potential, and discuss the influence this has on the refractory period of cardiac tissues.

Lecture 22 discusses the EKG. The student is expected to be able to

- 22.1 describe the basis of lead placement and the nature and magnitude of the voltages measured in a simple three-lead (leads I, II and III) EKG;
- 22.2 relate the changes in ionic conductances that occur during the cardiac action potential with the voltages measured during the EKG;
- 22.3 understand the temporal relationship between action potential propagation, the cardiac mean electrical axis, and the resulting EKG;
- 22.4 define the segments and intervals of the normal EKG;
- 22.5 compute the mean electrical axis for simple models of the EKG;
- 22.6 identify gross differences in cardiac rhythms by comparison of EKG recordings in normal versus obviously abnormal patients.

Lecture 23 discusses the cardiac cycle. The student is expected to be able to

- 23.1 define the phases of the cardiac cycle;
- 23.2 understand the passive nature of cardiac valve functioning;
- 23.3 relate onset of ventricular contraction with isovolumetric contraction, and discuss the dependence of blood flow on transvalvular pressures;
- 23.4 relate ejection velocities with developed pressures and valve openings and closings;
- 23.5 correlate changes in arterial pressure, aortic blood flow and ventricular volume with heart sounds and the EKG.

Lecture 24 discusses intrinsic and extrinsic regulation of the heart. The student is expected to be able to

- 24.1 define preload, afterload, and positive and negative inotropic and chronotropic regulation;
- 24.2 relate preload- and afterload-induced changes in ventricular volume and changes in aortic pressure with the Frank-Starling law;
- 24.3 describe the relationship between changes in heart rate and cardiac force development;
- 24.4 describe the effect of sympathetic amines on the work-pressure relationship, and describe the implications this has for functioning in the normal and failed heart.
- 24.1 describe the location and function of carotid and aortic baroreceptors and chemoreceptors, and the pathways involved in the regulation of cardiac function;
- 24.2 describe the dependence of heart rate on changes in carotid chemoreceptor stimulation and in blood volume (Bainbridge reflex);
- 24.3 relate the three hormone systems that regulate blood volume in response to changes in atrial pressure (ADH, atriopeptins) or renal perfusion (renin-angiotensin-aldosterone), and discuss the changes in these that occur upon significant reductions in blood volume;
- 24.4 define stroke volume, systolic and diastolic cardiac reserve, and the relative influences of these and of heart rate on cardiac output in hearts of normal and exercising individuals.

Lecture 25 discusses systemic regulation of cardiac output and blood flow. The student is expected to be able to

- 25.1 define active hyperemia and the relationship between tissue metabolic activity and blood flow through it;
- 25.2 describe the differences in systemic responses to α - versus α -adrenergic agents, and characteristic sympathetic amines eliciting these effects;
- 25.3 identify agents and mechanisms by which vascular resistance is modulated via changes in arteriolar diameter (e.g., α - versus β -adrenergic sympathetic amines and blockers, calcium channel blockers, carbon dioxide, adenosine, and other metabolites);
- 25.4 trace the reflexes, pathways, and hormonal regulatory systems that are invoked by a normal individual to counteract the effects of blood loss through hemorrhage;
- 25.5 note the temporal differences in the responsiveness and effectiveness of the systems involved in responses to blood loss through hemorrhage (e.g., baroreceptors, renin-angiotensin, ADH, aldosterone, etc.).

Lecture 26 discusses the microcirculation. The student is expected to be able to

- 26.1 understand the structure and function of tissue capillary beds;
- 26.2 understand the characteristics, limits, and relative importance in diffusion (Fick's law), filtration, and the movement of large molecules in transcapillary exchange;
- 26.3 define arterial and interstitial hydrostatic and oncotic pressures and determine net capillary filtration rates;
- 26.4 identify those components in blood composition, and capillary filtration properties, that are important for lymph formation under normal conditions, and edema formation under abnormal conditions;
- 26.5 integrate the role of microcirculation with general systemic cardiovascular regulation and function.

Lecture 27-28. Hematology, iron metabolism and hemostasis (Dr. Clausen).

Lecture 27 discusses hematology and iron metabolism. The student is expected to be able to

- 27.1 describe the composition of blood, including the numbers of the different cell types, the composition of plasma and serum, etc.
- 27.2 discuss the functional roles of erythrocytes, leukocytes and thrombocytes;
- 27.3 describe the functional significance of the shape of erythrocytes;
- 27.4 describe the functions of hemoglobin and carbonic anhydrase;
- 27.5 discuss erythropoiesis, where it occurs in infants versus adults, the normal rate of production of RBCs, and the cellular stages of RBC production;
- 27.6 describe the mechanism of diapedesis, and why mature RBCs cannot cross capillaries;
- 27.7 discuss the role of erythropoietin in the control of erythropoiesis;

- 27.8 discuss the dietary requirements for RBC production, and why surgical removal of the stomach causes pernicious anemia;
- 27.9 discuss polycythemia, and why physical training for short times at high altitude fails to increase the hematocrit;
- 27.10 describe the structure of hemoglobin, noting the different protein subunits, and the structure of the iron-containing porphyrin ring;
- 27.11 discuss the hemoglobin abnormality that causes sickle-cell anemia, why the disorder is widespread, the symptoms of the disorder and how it is treated;
- 27.12 discuss RBC breakdown by the spleen and reticuloendothelial system, the formation and excretion of bilirubin, and causes of jaundice;
- 27.13 describe the mechanism of intestinal iron absorption, the daily rate of absorption, and why absorptive capacity is insufficient to supply the iron needed for erythropoiesis;
- 27.14 discuss the roles of ferritin and transferrin in iron buffering and transport.

Lecture 28 discusses iron metabolism and hemostasis. The students are expected to be able to

- 28.1 discuss the different mechanisms of hemostasis, including vasoconstriction, vessel cohesion, plug and thrombus formation, and clot retraction;
- 28.2 discuss the structure of thrombocytes, and their role in forming platelet plugs and initiating the clotting cascade;
- 28.3 describe the functional significance of the cascade of activation in the formation of fibrin;
- 28.4 describe the extrinsic clotting pathway and the role of tissue factor, the intrinsic pathway and contact activation, and the common pathway;
- 28.5 discuss the genesis of the clotting factors, and why severe gallbladder disease can lead to clotting disorders;
- 28.6 discuss the characteristics of the vitamin-K-dependent factors and how they are activated on the platelet surface;
- 28.7 describe the lytic pathway and its means of activation;
- 28.8 discuss the two most common types of hemophilia, the causes, symptoms and treatment, and why individuals suffering from hemophilia can still form fibrin clots;
- 28.9 contrast the different actions of the in vitro anticoagulants (e.g., heparin) and the oral anticoagulants (e.g., warfarin).

Lectures 29-30. Special senses (Dr. Walcott).

Lecture 29 discusses vision. The students are expected to be able to

- 29.1 describe the structure of the eye, noting the major structures and the efferent innervation;
- 29.2 discuss how images are focused on the retina, showing where the major light bending occurs and how changes in the lens permit focusing of near and distant objects;
- 29.3 describe clinical disorders of image formation (e.g., presbyopia, myopia and hyperopia), and how corrective lenses are designed to overcome these disorders;
- 29.4 describe the functions of the different cell types of the retina;

- 29.5 describe how humans perceive color;
- 29.6 describe the cellular anatomy of the photoreceptors;
- 29.7 discuss how a photon of light interacts with rhodopsin, and the cycle of bleaching and subsequent restoration of rhodopsin;
- 29.8 discuss the intracellular events that follow detection of a photon, ultimately leading to a decrease in the dark current;
- 29.9 discuss the different behavior of ganglion cells, notably ON center and OFF center cells;
- 29.10 discuss the anatomy of the central visual pathways, and the functional differences in simple, complex and hypercomplex cells.

Lecture 30 discusses hearing, the vestibular system, taste and smell. The students are expected to be able to

- 30.1 describe the anatomy of the external, middle and internal ear;
- 30.2 describe how sound intensity is measured, and the amplitudes of common sounds;
- 30.3 describe in detail the inner ear, discussing the scala vestibuli, scala media, scala tympani, the vestibular membrane, organ of corti and the basilar membrane;
- 30.4 describe how sounds are transmitted in the inner ear, how frequency coding is accomplished by the basilar membrane, and how the hair cells function to change the activity of the auditory afferent neurons;
- 30.5 describe the role of efferent innervation to the hair cells of the inner ear;
- 30.6 discuss the function of the vestibular system in detecting head position, and changes in linear and rotational acceleration;
- 30.7 discuss the anatomy of the semicircular canals, including their composition, and the structure of the hair cells;
- 30.8 discuss how displacement of the utricle is mediated by changes in head position and linear acceleration, while displacement of the cupola in the semicircular canals is mediated by changes in rotational acceleration;
- 30.9 show how these changes affect the hair cells, and how this results in changes in the activity of afferent neurons of the vestibular nerve;
- 30.10 define the term rotational nystagmus, and discuss how it causes rotation of the eye;
- 30.11 describe the structural differences between taste receptors and olfactory receptors;
- 30.12 describe what is meant by the term primary flavors, but discuss why tastes cannot be broken down to simple combinations of these primary flavors;
- 30.13 discuss why molecules must first be solubilized before being sensed either by taste or olfactory receptors;
- 30.13 discuss some of the current evidence as to how taste receptors sense sour and bitter stimuli (e.g., the role of K^+ channels);
- 30.14 discuss the role of olfactory binding protein in sensing the presence of lipophilic molecules.

Lectures 31-37. Pulmonary physiology (Dr. Cameron).

Lecture 31 is an overview of pulmonary physiology. The student is expected to be able to

- 31.1 distinguish between cellular (internal) and external respiration, and be able to define the respiratory quotient;
- 31.2 understand the need for and the mechanism by which oxygen and carbon dioxide are exchanged with the atmosphere;
- 31.3 list the other functions of the respiratory system besides gas exchange;
- 31.4 list the component organs and structures that comprise the respiratory system;
- 31.5 describe the structural characteristics of the airways, the alveolar-capillary unit, the chest wall and muscles of respiration, and the neural components of the respiratory system.

Lecture 32 discusses the mechanics of breathing. The student is expected to be able to

- 32.1 describe the actions of the respiratory muscles and the resultant motions of the rib cage and abdomen as well as the effects this muscular activity has on intrathoracic and intra-abdominal volumes;
- 32.2 summarize the changes that take place in intrapleural and alveolar pressures, airflow, and lung volume during the course of a normal breath;
- 32.3 understand the basic pressure-volume relationship and the meaning of compliance both for normal as well as diseased (restrictive and obstructive) lung;
- 32.4 describe the role of alveolar surface forces in generating lung recoil, and the function of surfactant;
- 32.5 understand the elastic recoil properties of the chest wall and how the lung and chest wall interact;
- 32.6 describe the various types of airflow as well as the determinants of airway resistance;
- 32.7 describe the distribution of airway resistance and the factors that contribute to it, including dynamic compression of the airways.

Lecture 33 discusses lung volumes and capacities as well as alveolar ventilation. The student is expected to be able to

- 33.1 define the different subdivisions of lung volume and know which measurements can be made with a spirometer and which require indirect methods;
- 33.2 describe how changes in lung and chest wall mechanics affect lung volumes in healthy and diseased states;
- 33.3 understand and interpret information obtained from tests of forced expiration;
- 33.4 define alveolar ventilation and describe the relationship between tidal volume, anatomic dead space, and alveolar ventilation;
- 33.5 calculate minute and alveolar ventilation;
- 33.6 know the normal values of O₂ and CO₂ in the lungs and blood and how changes in ventilation affect these values;
- 33.7 understand the regional distribution of ventilation.

Lecture 34 discusses pulmonary circulation. The student is expected to be able to

- 34.1 appreciate the differences between the pulmonary and systemic circulations, with particular reference to the bronchial circulation.
- 34.2 describe the determinants and factors that affect pulmonary vascular resistance.
- 34.3 describe the regional distribution of blood flow in the lung and explain how the interrelationships of alveolar pressure, pulmonary arterial pressure and pulmonary venous pressure affect this distribution.

Lecture 35 discusses pulmonary diffusion and blood gas transport. The student is expected to be able to

- 35.1 appreciate the differences between the diffusion and bulk flow of a gas into and out of the lungs;
- 35.2 describe the diffusion paths of O₂ and CO₂ at the alveolar-capillary and the capillary-tissue interface;
- 35.3 understand the fundamental law of diffusion and the factors in the lungs that influence diffusion;
- 35.4 appreciate the dynamics of O₂ and CO₂ movement across the alveolar-capillary interface;
- 35.5 understand the relationship between the partial pressure of O₂ and CO₂ in the blood and the amount of each that is physically dissolved;
- 35.6 describe the chemical combination of O₂ with hemoglobin and the O₂ dissociation curve;
- 35.7 describe the physiological consequences of the shape of the O₂ dissociation curve and list factors that can affect this curve;
- 35.8 appreciate the relative importance of the various forms in which CO₂ is transported in the blood and be able to describe the CO₂ dissociation curve;
- 35.9 explain in molecular terms the Bohr and Haldane effects.

Lecture 36 discusses arterial blood gases and pulmonary pathophysiology. The student is expected to be able to

- 36.1 understand how arterial blood gases and pH are measured and what normal values are for PO₂, PCO₂, and pH;
- 36.2 appreciate how the bicarbonate-CO₂ system functions in acid-base balance, and be able to use the Henderson-Hasselbalch equation to relate plasma pH, PCO₂ and HCO₃⁻ concentrations;
- 36.3 understand the causes of respiratory acidosis and alkalosis;
- 36.4 know the potential causes of hypoxic hypoxia and other forms of hypoxia;
- 36.5 describe the mechanisms by which hypoventilation, diffusion impairment, and shunting produce arterial hypoxia;
- 36.6 describe the regional differences in ventilation and perfusion and understand the consequences of ventilation-perfusion mismatch.

Lecture 37 discusses the control of breathing. The student is expected to be able to

- 37.1 describe the general organization of the respiratory control system;
- 37.2 describe the structures that constitute the central controller, being able to specify which components are responsible for the generation of spontaneous rhythmicity;
- 37.3 list several cardiopulmonary and other reflexes that influence the breathing pattern;
- 37.4 understand the mechanisms by which the respiratory control system maintains the arterial CO_2 , O_2 and pH;
- 37.5 describe the responses of the respiratory system to exercise.

Lectures 38-43. Renal physiology (Dr. Moore).

Lecture 38 is an overview of basic renal function and anatomy, followed by a discussion of renal hemodynamics and glomerular filtration. The student should

- 38.1 know the four basic elements of renal function, including: glomerular filtration, tubular reabsorption and secretion, endocrine function;
- 38.2 know the basic features of the vascular and tubular systems, and the juxtaglomerular apparatus;
- 38.3 understand the distribution of hydrostatic and oncotic pressures in the renal vasculature;
- 38.4 know the permselective characteristics of the glomerular capillary wall;
- 38.5 be able to describe the determinants of glomerular filtration rate (GFR), including glomerular capillary hydrostatic and oncotic pressures, intratubular pressure, and the ultrafiltration coefficient;
- 38.6 understand the concept of filtration fraction.

Lecture 39 deals with renal hemodynamics and basic nephron transport. The student should

- 39.1 know the effects of changes in pre- and postglomerular resistances on renal blood flow (RBF) and GFR;
- 39.2 understand RBF autoregulation and tubuloglomerular feedback mechanisms.
- 39.3 know the effects of sympathetic nervous system and vasoactive humoral factors on GFR and RBF;
- 39.4 appreciate the fundamental aspects of epithelial cell structure and function;
- 39.5 be able to describe the different membranes in epithelial cells, including basolateral and apical membranes, and tight junctions;
- 39.6 be able to define the following: osmosis, primary and secondary active transport, passive transport, secretory mechanisms;
- 39.7 understand proximal tubular reabsorption and secretion: Na^+ , Cl^- , water, other ions and organic solutes;
- 39.8 be able to describe how proximal reabsorption is regulated by angiotensin II and “physical forces”;

- 39.9 understand osmotic equilibration of the descending limb tubular fluid with the medullary interstitium;
- 39.10 understand the cellular mechanism of tubular fluid dilution in the ascending limb;
- 39.11 know that sodium reabsorption is regulated by aldosterone and atrial natriuretic factor;
- 39.12 understand that potassium secretion in the distal tubule and collecting duct is regulated by aldosterone;
- 39.13 know that water reabsorption in the distal tubule and collecting duct is regulated by ADH;

Lecture 40 concerns the use of clearance techniques to measure renal function. The student should

- 40.1 be able to define filtered load, excretion rate, renal clearance;
- 40.2 be able to calculate GFR values using inulin clearance (*Calculations/problems given*);
- 40.3 be able to calculate renal plasma flow and RBF using PAH clearance and hematocrit (*Calculations/problems given*);
- 40.4 be able to use solute clearance to characterize tubular transport (*Calculations/problems given*);
- 40.5 understand the basis for the clinical use of plasma creatinine and urea levels to assess renal function;
- 40.6 be able to construct and analyze renal solute excretion curves, and know how they can be used to study carrier-mediated tubular transport (*Calculations/problems given*).

Lecture 41 is about the renal medullary urine concentrating mechanism and the control of body fluid osmolarity by ADH and thirst. The student should

- 41.1 understand obligatory water excretion vs ADH-dependent water excretion;
- 41.2 appreciate that the generation of concentrated urine occurs via active countercurrent multiplication;
- 41.3 understand the mechanism of passive equilibration of the tubular fluid in the descending limb;
- 41.4 be able to describe the process of active dilution of tubular fluid in the ascending limb and the concurrent deposition of NaCl into the medullary interstitium;
- 41.5 understand ADH-dependent dissipation of distal tubular fluid hypotonicity in the cortex.
- 41.6 understand ADH-dependent osmotic withdrawal of water in the CD;
- 41.7 be able to describe urea recycling in the medulla;
- 41.8 know how hypotonic urine is generated and excreted;
- 41.9 be able to describe passive countercurrent exchange in the vasa recta;
- 41.10 be able to describe body water and solute balance;
- 41.11 know the cellular actions of ADH in the renal tubule;
- 41.12 appreciate how water balance is regulated by ADH secretion and thirst.

Lecture 42 concerns regulation of renal sodium excretion and extracellular fluid volume by the renin-angiotensin-aldosterone system (RAS) and atrial natriuretic peptide (ANP); also regulation of renal potassium excretion is discussed. The student should

- 42.1 know the effect of dietary sodium intake on renal sodium excretion;
- 42.2 be able to describe the components of the RAS and factors that control renin secretion, including: renal baroreceptor, sympathetic nervous system, macula densa;
- 42.3 know the actions of angiotensin II (and III), including: inhibition of renin secretion, stimulation of aldosterone and ADH secretion, peripheral and renal vasoconstriction;
- 42.4 be able to describe the actions of aldosterone in the distal tubule and collecting ducts to increase luminal membrane Na⁺ and K⁺ permeabilities and sodium-pump activity;
- 42.5 know the effects of aldosterone on renal sodium and potassium excretion;
- 42.6 know that atrial distension stimulates ANP secretion;
- 42.7 be able to describe the actions of ANP, including: peripheral and renal vasodilation, plasma extravasation, inhibition of collecting duct Na⁺ transport and enhancement of renal sodium excretion;
- 42.8 appreciate the integrated actions of the ADH, ANP and RAS in response to expansion/contraction of extracellular fluid volume.
- 42.9 be able to describe the distribution of potassium in the body;
- 42.10 understand the factors that influence plasma potassium, including: dietary intake, cell lysis, plasma pH;
- 42.11 appreciate how excess plasma potassium is buffered by cellular potassium uptake;
- 42.12 know that plasma potassium concentration is regulated by the kidney;
- 42.13 know that most of the filtered potassium is reabsorbed in the proximal tubule and Henle's loop;
- 42.14 know that active reabsorption in distal tubule and CD can reduce potassium excretion to low levels;
- 42.15 understand the mechanism of secretion of potassium in distal tubule and CD;
- 42.16 know that passive potassium secretion occurs across the luminal membrane;
- 42.17 understand how potassium secretion and excretion are regulated by aldosterone;
- 42.18 appreciate the interactions between renal sodium and potassium excretion.

Lecture 43 concerns regulation of renal acid excretion. The student should

- 43.1 understand the production of fixed and volatile acids in the body;
- 43.2 know the major body buffer systems;
- 43.3 be able to describe the bicarbonate-CO₂ buffer system;
- 43.4 appreciate the importance of respiratory regulation of CO₂ and responses to changes in blood pH;
- 43.5 be able to describe and use the Henderson-Hasselbalch equation to analyze buffering of fixed acids and bases and the impact of changes in blood CO₂ (*Calculations/problems given*);
- 43.6 be able to describe buffering by phosphate, protein, bone, and other buffer systems;

- 43.7 know how the kidney responds to basic acid-base disorders;
- 43.8 understand the renal response to metabolic acidosis and alkalosis;
- 43.9 know the role of respiratory compensation for metabolic acidosis/alkalosis;
- 43.10 understand that the kidneys excrete excess acid/base and produce bicarbonate;
- 43.11 appreciate that the kidneys provide compensation for respiratory acidosis and alkalosis;
- 43.12 know basic cellular mechanism of tubular proton secretion and the generation of new bicarbonate;
- 43.13 be able to describe the major tubular fluid buffers: filtered bicarbonate, titratable buffers, ammonia;
- 43.14 be able to calculate net renal acid excretion (*Calculations/problems given*).

Lecture 44. The regulation of plasma calcium and phosphate concentrations, and bone formation (Dr. Cameron). The student is expected to:

- 44.1 know that the GI tract, bone, and kidney are important for calcium and phosphate homeostasis;
- 44.2 understand how calcium and phosphate metabolism is regulated by parathyroid hormone (PTH), vitamin D, calcitonin;
- 44.3 know the effects of PTH and vitamin D on GI absorption, bone uptake/release and renal excretion;
- 44.4 be able to describe the integrated responses to hypocalcemia and hypophosphatemia;
- 44.5 understand the function of osteoclast and osteoblast cells in bone;
- 44.6 understand the hormonal regulation of osteoclast and osteoblast activity.

Lectures 45-48. Gastrointestinal physiology (Dr. Scarlata).

Lecture 45 begins with an overview of gastrointestinal physiology, and then starts a discussion of motility and secretions of the individual organs. The student is expected to be able to

- 45.1 describe the major functions of the GI tract (bulk transport, secretion, digestion and absorption);
- 45.2 list the major anatomical structures of the GI tract, and describe the general characteristics shared by these structures (e.g., connective tissue, smooth muscle, intrinsic nerves, epithelia, etc);
- 45.3 describe the microanatomy of different regions of the GI tract (e.g., villi, crypts, microvilli, lacteals, etc., in small intestine);
- 45.4 discuss epithelial function (absorption, secretion, paracrine and endocrine function), as well as the life time for transitional epithelia;
- 45.5 describe electrical activity in GI smooth muscle (e.g., basic electrical rhythm), and the characteristic types of motility (peristalsis, segmentation, etc.) in different muscle layers, and in different regions of the tract;
- 45.6 discuss the role of intrinsic and extrinsic nerves in regulating motility and secretions.

- 45.7 discuss the production of saliva, its composition and how it varies with secretion rate, as well as the functions of saliva, mastication, and salivary amylase;
- 45.8 discuss the phases of swallowing, how it is mediated by voluntary as well as smooth muscle, the roles of the upper- and lower esophageal sphincters, pathological conditions (esophageal reflux and achalasia), and how the swallowing reflex is altered when drinking.

Lecture 46 continues discussion of motility and secretions in the individual organs. The student is expected to be able to

- 46.1 discuss the functions of the stomach, mechanism of secretion and function of gastric acid and pepsinogen, control and phases of acid secretion, gastric ulceration (causes and treatment), and mechanism and control of gastric motility;
- 46.2 describe the process of vomiting, what stimulates it, and how it is controlled;
- 46.3 discuss gallbladder secretion of bicarbonate, its function in neutralizing gastric acid, how it is produced, and how the secretion rate is regulated;
- 46.4 discuss pancreatic exocrine function, the phases of pancreatic secretion, the production of zymogens, the different pancreatic enzymes and their activation from inactive precursors;
- 46.5 describe liver and gallbladder production and concentration of bile salts, and what stimulates secretion of bile into the intestines;
- 46.6 discuss intestinal functions, intestinal surface anatomy and area, intestinal secretions, and secretion disorders leading to diarrhea (e.g., cholera);
- 46.7 describe intestinal motility, contrast it with gastric motility, discuss how it is mediated by myogenic activity, but regulated by neurogenic means (e.g., local reflexes and autonomic nervous system);
- 46.8 describe the major functions of the colon, its mucosal anatomy, and the types of motility;
- 46.9 discuss the process of defecation.

Lecture 47 discusses digestion in general, and digestion and absorption of carbohydrates and proteins. The student is expected to be able to

- 47.1 describe the hydrolysis of proteins, DNA and RNA, polysaccharides and triglycerides, leading to the production of amino acids, nucleic acids, monosaccharides and fatty acids;
- 47.2 discuss how digestion leads to an increase in intestinal osmolarity, thereby causing water secretion into the gut;
- 47.2 describe the different classes of hydrolytic enzymes, list the specific digestive enzymes, describe where they operate, and their pH dependence;
- 47.3 describe epithelial absorption in general terms, noting that amino acids and sugars enter the portal circulation, whereas lipids enter the lacteals;
- 47.4 describe the blood flow to the GI tract, discussing its relationship with the liver's portal circulation;
- 47.5 discuss carbohydrate digestion by salivary, pancreatic and brush-border amylases, noting why these enzymes are unable to digest cellulose;

- 47.6 describe absorption of monosaccharides via epithelial transport processes, how this is linked to salt and water absorption, and how knowledge of this processes led to an effective oral treatment of cholera;
- 47.7 describe the sources of protein (e.g., dietary, enzymes, cell turnover, etc.), and digestion by the different gastric and intestinal endo- and exopeptidases;
- 47.8 discuss absorption of amino acids by Na⁺-dependent epithelial transport processes, as well as endocytosis in the absorption of intact proteins (e.g., in conferring immunity to infants, and as a cause of food allergies).

Lecture 48 discusses the digestion and absorption of fats, and the absorption of vitamins, salts and water. The student is expected to be able to

- 48.1 discuss the different classes of lipophilic compounds, the problem of insolubility and the process of emulsification via bile salts;
- 48.2 discuss the structure of bile salts (primary versus secondary, conjugated versus unconjugated), their production by the liver, and concentration by the gallbladder;
- 48.3 discuss the enterohepatic circulation, and the different mechanisms of intestinal bile-salt reabsorption;
- 48.4 describe the process of emulsification of fats, digestion by lipases and the role of colipase, formation of micelles, and shuttling of micelles to the mucosal surface;
- 48.5 describe fat absorption, resynthesis triglycerides and phospholipids, the formation of chylomicrons, and the absorption into the lacteals;
- 48.6 list the absorption mechanisms for the different water- and fat-soluble vitamins, noting the special role of intrinsic factor in the absorption of vitamin B₁₂;
- 48.7 discuss the sources of gastrointestinal water and electrolytes, noting the relative volumes of the secretions by the different organs (e.g., salivary glands, stomach, etc.);
- 48.8 describe the epithelial processes involved in the active absorption of water and electrolytes;
- 48.9 discuss the definition of diarrhea and constipation, and causes and treatments of these disorders;
- 48.10 discuss hormonal control of the phases of digestion.

Lectures 49-53. Metabolism and growth (Dr. El-Maghrabi).

Lecture 49 discusses metabolism. The student is expected to be able to

- 49.1 describe the concepts of anabolism, catabolism and steady state;
- 49.2 describe how enzymes catalyze chemical reactions, and how they are regulated;
- 49.3 describe the common enzyme cofactors including ATP and NAD
- 49.3 outline how carbohydrates are metabolized under anaerobic conditions (glycolysis);
- 49.4 outline how ATP is synthesized in glycolysis

Lecture 50 continues the discussion of metabolism and the derivation of energy. The student is expected to be able to

- 50.1 outline how carbohydrates are metabolized under aerobic conditions (Krebs cycle and oxidative phosphorylation) and how ATP is synthesized.
- 50.1 describe the oxidation of fatty acids, and how fats can be used as energy sources;
- 50.2 describe how proteins can be used as energy sources, and how nitrogen is excreted;
- 50.3 calculate the net yields of ATP obtained from different energy sources.

Lecture 51 discusses the integration and regulation of metabolism. The student is expected to be able to

- 51.1 describe the major metabolic processes that occur during the absorptive and postabsorptive states;
- 51.2 describe how insulin is secreted from the pancreas and how it regulates blood glucose;
- 51.3 describe how glucagon is secreted and how it regulates blood glucose;
- 51.4 discuss signaling by second-messenger systems, and provide specific examples;
- 51.5 describe the effects of pancreatic somatostatin, epinephrine, cortisol, and other hormones, on the regulation of metabolism.

Lecture 52 continues the discussion of regulation of metabolism in health and disease. The student is expected to be able to

- 52.1 distinguish between type I and type II diabetes;
- 52.2 discuss different clinical measurements of diabetics
- 52.3 discuss the control of human growth by human growth hormone, thyroid hormone, and other hormones;
- 52.4 describe the role of releasing and inhibitory hormones in the control of anterior-pituitary hormone secretion.

Lecture 53 discusses the regulation of energy balance and body temperature. The student is expected to be able to

- 53.1 define the basal metabolic rate, and discuss how it is measured;
- 53.2 define the factors that control food intake, and the signals that produce satiety;
- 53.3 describe the processes by which thyroid hormones set the body's metabolic rate, and how the body responds to the cold;
- 53.4 discuss the mechanisms involved in the onset of fever, and the role of the hypothalamus.

Lectures 54-56. Immunology (Dr. Dixon).

Lecture 54 discusses the general functions of the immune system and introduces the cell types and organs that constitute the immune system. Innate (nonspecific) immunity will be discussed in detail. The student is expected to be able to

- 54.1 discuss the three major functions of the immune system (defense, distinguishing self from non-self and remembering past attacks), and the two types of responses (innate and adaptive);
- 54.2 describe the different cell types of the immune system (stem cells, myeloid cells and lymphoid cells);
- 54.3 discuss the functions of granulocytic cells (neutrophils, eosinophiles, basophiles and mast cells) and mononuclear cells (monocytes, macrophages and dendritic cells);
- 54.4 understand phagocytosis;
- 54.5 discuss the differences between B and T lymphocytes, their functions and antigen receptors;
- 54.6 describe the primary and secondary lymphoid organs;
- 54.7 describe innate immunity in terms of barriers (anatomic, physiologic, phagocytic and inflammatory) and understand the defense mechanisms that constitute these barriers.

Lecture 55 describes adaptive immunity—the humoral and cell-mediated immune responses that are mediated by B cells and T cells, respectively. The student is expected to be able to

- 55.1 describe the four characteristics of adaptive immunity (antigenic specificity, diversity, immunologic memory, self/nonself recognition);
- 55.2 discuss the concept of humoral immunity, and how it is mediated by antibodies (immunoglobulins);
- 55.3 describe antibody structure, noting the linkage of the heavy and light chains and the different regions of the molecule (variable and F_c regions);
- 55.4 discuss the term epitope and describe how large antigens can have several epitopes;
- 55.5 discuss the different antibody functions (neutralization, agglutination, activation of the complement system, opsinisation, stimulation of NK cells);
- 55.6 describe the different antibody classes (IgG, IgM, IgA, IgE and IgD), their different structures and functions;
- 55.7 discuss antibody diversity and how it is produced;
- 55.8 discuss the concept of self antigens where the major histocompatibility complex (MHC) represents “self” and antigen bound to MHC is considered to “alter self”;
- 55.9 describe the two classes of major histocompatibility complex (MHC), and understand the MHC-restriction of T cells;
- 55.10 discuss the differences between cytotoxic T cells (T_C) and helper T cells (T_H) in the way they are activated and in their functions.

Lecture 56 discusses the central principle of adaptive immunity (the clonal selection theory) and finishes with some clinically relevant examples of immune system function. The student is expected to be able to

- 57.1 discuss the clonal selection theory and the importance of antigen diversity, antigen specificity, self-tolerance, clonal expansion and generation of memory cells;
- 57.2 discuss the rationale behind immunization;
- 57.3 describe the differences between passive and active immunization;
- 57.4 describe the different types of vaccinations (attenuated, inactivated and purified) and the immune responses they generate;
- 57.5 describe the failure of the self/nonself discrimination in autoimmune diseases
- 57.6 describe other problems that occur with the immune system, including superantigens, toxic shock syndrome and transplantation rejection;
- 57.7 discuss the consequences of HIV infection of T_H cells, how the HIV virus mutates to avoid the immune system and the development of AIDS.

Lectures 57-59. Reproductive physiology (Dr. Abumrad).

Lecture 57 discusses sexual reproduction and male reproductive physiology. The student is expected to be able to:

- 57.1 discuss meiosis, contrast the processes of mitosis and meiosis.
- 57.2 discuss the general features of male and female gonads, and the process of sexual differentiation during fetal development;
- 57.3 compare and contrast the functional cell types and the various hormones produced in the testis and ovary;
- 57.4 describe genotypic control of sexual development and its relationship to the phenotypic pathways taken by male and female embryos;
- 57.5 discuss the role of male-specific hormones in formation of the testis and accessory organs, and contrast this with the default female body pattern.
- 57.6 discuss the overall scheme of steroid-hormone (to testosterone and estrogens) and the points of regulation by pituitary hormones;
- 57.8 describe the role of pituitary control of male gonadal function, with emphasis on the negative-feedback loop between the anterior pituitary and testis;
- 57.9 discuss the hormonal factors that trigger meiosis and maturation of male gametic cells (including the microanatomy of the seminiferous tubules) with emphasis on the progression of events in spermiogenesis and spermatogenesis from spermatogonium to mature spermatozoa;
- 57.10 discuss the roles of Leydig and Sertoli cells and local hormonal production (particularly testosterone);
- 57.11 describe briefly the anatomy and function of male accessory sexual structures;
- 57.12 describe the nature of the bulbourethral and prostate gland secretions and their function, and the role of neural reflexes in controlling penile erection and ejaculation.
- 57.13 describe the progression of normal male puberty, including the roles of testosterone and dihydrotestosterone in controlling stature, muscle mass, fat deposition and secondary sexual characteristics;

Lecture 58 discusses female reproductive physiology. The students are expected to be able to:

- 58.1 describe the anatomy and function of the adult female gonads and accessory sexual structures (e.g., fallopian tubes, uterus, cervix and vaginal canal);
- 58.2 describe the microanatomy of the ovaries and show the various stages of oocyte maturation in the fertile adult female, and discuss maturation of the Graafian follicle, stressing the role of thecal and granulosa cells in local hormone production;
- 58.3 describe the role of various hormonal factors in oocyte maturation and control of the ovarian cycle;
- 58.4 describe the pathways of steroid hormone synthesis from the level of androgens to estradiol;
- 58.5 discuss interplay between ovarian hormone production and the hypothalamic/anterior pituitary axis, and the current understanding of the mid-cycle LH surge;
- 58.6 discuss the menstrual cycle and its relationship to the ovarian cycle, and the hormonal levels that signal changes in the microanatomy of the uterine wall;
- 58.7 describe the process of normal female puberty and menopause, including the roles of estrogens and androgens in the development of secondary sexual characteristics;
- 58.8 predict the consequences of estrogen withdrawal in the adult female, including the disruption of the feedback loop between the anterior pituitary and ovary, as well as the profound changes in bone physiology;
- 58.9 discuss the male and female human sexual responses (reading assignment);
- 58.10 discuss methods of contraception, and their relative effectiveness (reading assignment).

Lecture 59 discusses pregnancy, labor and delivery, and lactation. The student is expected to be able to:

- 59.1 describe the process and timing of fertilization, where it takes place, and preparation of the uterine lining required for implantation;
- 59.2 discuss the functions of the placenta (e.g., hormone production, oxygen and nutrient exchange, and barrier to maternal cells);
- 59.3 discuss the importance of capacitation of spermatozoa in the female reproductive tract, and their migration through the cervix;
- 59.4 describe the process of hormonal conditioning of the uterine wall, and its importance in implantation and survival of the embryo;
- 59.5 describe the early embryonic structures, particularly those giving rise to the placenta;
- 59.6 describe the functions of the mature placenta;
- 59.7 describe the sequence of hormonal factors derived from the developing embryo, corpus luteum and placenta, which maintain the pregnancy;
- 59.8 discuss the metabolic changes that occur in the pregnant female (e.g., the early anabolic state, handling of carbohydrates, and the later catabolic state);
- 59.9 discuss the relationship of hormonal changes (e.g., placental lactogen and insulin) in regards to the metabolic changes occurring in a pregnant female;

- 59.10 describe the hormonal requirements for preparation of the milk producing structures in mammary tissue during pregnancy;
- 59.11 know the factors that initiate and maintain contractions of the uterus, with emphasis on the neuroendocrine reflex arc between the uterine stretch receptors and the posterior pituitary;
- 59.12 describe briefly the processes of postpartum milk production and letdown, and describe how the breast is relieved of the hormonal conditioning that occurred during pregnancy rendering it capable of milk production;
- 59.13 discuss the role of prolactin in milk production, and how suckling triggers the neuroendocrine reflex that results in milk letdown.