BIOLOGY 2030 WA – INTRODUCTORY HUMAN PHYSIOLOGY
DR. R. OMELJANIUK

INSTRUCTOR: Dr. Robert J. Omeljaniuk, CB-4013.

LABORATORY COORDINATOR: Mr. Mike Moore, c/o Biology Department Office.

TEXTBOOK: Sherwood, L. Human Physiology - From Cells to Systems (6th ed). Thomson, Brooks-Cole. 2004. 802 pp. ISBN: 0-534-39501-5.

LABORATORY MANUAL: Lab manuals for physiology accompany the textbook in the bookstore. Purchase the correct lab manual.

PROPOSED CURRICULUM: To follow.

LABORATORY EXERCISES: Student attendance and active participation in laboratories is mandatory; students who miss their assigned lab period must reschedule their exercise with Mr. Moore. Every reasonable attempt will be made to accommodate student requests.

TENTATIVE LAB SCHEDULE:
1. Neurophysiology: Week A is Jan 19 to 23, Week B is Jan 26 to Jan 30.
2. Cardiorespiratory physiology: Week A is Feb 02 to Feb 06, Week B is Feb 09 to Feb 13.
3. Renal physiology: Week A is Feb 23 to Feb 27, Week B is Mar 02 to Mar 06.
4. Blood: Week A is Mar 09 to Mar 13, Week B is Mar 16 to Mar 20.

COURSE MARKING OUTLINE

1. Midterm Test. 11 Feb 09. 30% of Final Mark
   Students who miss the Midterm Exam for a valid, and documented reason may elect to have the final exam assume 60% of their final mark.
2. Lab Assignments Exercises. 40% of Final Mark
3. Final Exam. Registrar Scheduled 30% of Final Mark

BIOLOGY 2030: Principles of Physiology Proposed Curriculum:

1. Introductory Reading Assignment.
   Students should have a working knowledge of the following material. The purpose of this assignment is to ensure that all students have a common frame of reference in order to support their progression in the course.

.

Serial	Reference	Title	Page(s)
a	Chapter 02	Cell Physiology	20-51
b	Table 2-3	Summary of cell structures and functions	42
c	Figure 2-3	Overview of the secretion process for proteins synthesized by the endoplasmic reticulum	26
d	Figure 2-8	Forms of endocytosis	30

e	Table 2-2	Overview of cellular energy production from glucose	32
f	Figure 2-14	Comparison of energy yield and products under anaerobic and aerobic conditions	38
g	Figure 2-24	Interconnections between cytoskeletal structures and organelles	47

SECTION I-NEUROPHYSIOLOGY.

Serial		Reference	Title	Page(s)
1			Chapter 03. The plasma membrane and membrane potential; and Chapter 04. Principles of neural and hormonal communication	52-83 85-129
	a		Membrane structure and composition	53-58
	b	Figure 3-3	Fluid mosaic model of plasma membrane structure	55
	c		Communication between cells is largely orchestrated by extracellular chemical messengers	111-112
	d		Extracellular chemical messengers bring about cell responses primarily by signal transduction	112-113
	e		Some extracellular chemical messengers open chemically gated channels	113
	f		Unassisted membrane transport	72-78
	g	Figure 3-7	Diffusion	61
	h	Figure 3-8	Diffusion through a membrane	62
	i	Spare		
	j	Figure 3-9	Relationship between solute and water concentration in a solution	63
	k	Figure 3-10	Osmosis	64
	l	Figure 3-11	Movement of water and a penetrating solute unequally distributed across a membrane	64
	m	Figure 3-12	Osmosis in the presence of an unequally distributed non-penetrating solute	65
	o	Figure 3-13	Osmosis when pure water is separated from a solution containing a non-penetratinge solute	65
	p		Assisted membrane transport	66-73
	q	Figure 3-14	Schematic representation of carrier-mediated transport:facilitated diffusion	67
	r	Figure 3-16	Active transport	70
	s	Figure 3-17	Na^+-K^+-ATPase pump	70
	t		Membrane potential	73-79
	u	Figure 3-19	Determination of membrane potential by unequal distribution of positive and negative charges across the membrane	75
	v	Figure 3-20	Equilibrium potential for K^+	76
	w	Figure 3-21	Equilibrium potential for Na^+	78
	x	Figure 3-22	Effect of concurrent K^+ and Na^+ movement on establishing their resting potential	78

	y	Figure 3-23	Counterbalance between passive Na^+ and K^+ leaks and the active Na^+-K^+ pump	79
		Table 3-3	Concentration and permeability of ions responsible for membrane potential in a resting nerve cell	75
2			Chapter 04. Principles of neural and hormonal communication	85-129
	a		Introduction	85-87
		Figure 4-4	Current loss across the plasma membrane	89
		Figure 4-5	Decremental spread of graded potentials	89
	b		Graded potentials	87-89
	c	Figure 4-3	Current flow during a graded potential	88
	d		Action potentials	89-100
	e	Figure 4-6	Changes in membrane potential during an action potential	90
	f	Figure 4-7	Conformations of voltage-gated sodium and potassium channels	91
	g	Figure 4-9	Permeability changes and ion fluxes during an action potential	92
	h	Figure 4-11	Contiguous conduction	95
	i	Table 4-1	Comparison of graded potentials and action potentials	96
	j	Figure 4-13	Absolute and relative refractory periods	97
	k		Myelination increases the speed of conduction of action potentials	98-100
	l		Synapses and neuronal integration	101-111
	m	Figure 4-16	Synaptic structure and function	103
	n	Figure 4-17	Postsynaptic potentials	104
		Figure 4-18	Determination of the grand postsynaptic potential by the sum of the activity in the presynaptic inputs	106
		Figure 4-19	Presynaptic inhibition	109
3			Selected references from Chapter 5	
		Table 5-1	Functions of glial cells	135
	a	Figure 5-25	Spinal nerves	169
	b	Figure 5-26	Spinal cord in cross section	170
	c	Figure 5-31	The withdrawal reflex	174
4			Selected references from Chapter 6	
	a		Receptor Physiology	183-187
	b	Figure 6-3	Conversion of receptor and generator potentials into action potentials	184
	c	Figure 6-5	Tonic and phasic receptors	185
	d	Table 6-1	Coding of sensory information	186
5			Selected references from Chapter 7	
	a		Autonomic nervous system	234-240
	b	Figure 7-2	Autonomic nervous system	235
	c	Table 7-3	Effects of autonomic nervous system on various organs	238

	d	Table 7-4	Distinguishing features of the sympathetic and parasympathetic nervous system	241

1. Introduction.
   - eg. Stimulus transduction. baroreceptors and pressoreceptors.
   - a. Information analysis; ie. central nervous system.
   - b Efferent responses; eg. blow avoidance.
   - c. Order of topics:
     - (1) neuronal and glial structures;
     - (2) neuronal electrical properties;
     - (3) gross anatomy and subdivision of nervous system function; and
     - (4) specialized neuronal structures and function.

2. Neuronal and glial structures and functions.
   - a. Glial cells.
     - (1) electrical insulation;
     - (2) mechanical support;
     - (3) metabolic support; and
     - (4) modulation of neurotransmitter activity; eg. schwaan cells and myelination.
   - b. Neurons.
     - (1) soma (cell body);
     - (2) axon;
     - (3) axon hillock;
     - (4) axon terminal; and
     - (5) dendrites.

3. Neuronal electrical properties.
   - a. Passive electrical properties.
     - (1) resistance;
     - (2) capacitance;
     - (3) conductance; and
     - (4) membrane voltage.

4. Active electrical properties.
   - a. non-self propogating potentials; and
   - b. self-propogating action potentials.

5. Nernst equation, goldman equation.

6. Determinants of membrane voltage in neurons.
   - a. dielectric properties of the membrane;
   - b. K^+ leakage;
   - c. Na^+/K^+-ATPase; and
   - d. role of digitalis.

7. Action potentials.
   - a. Vmr;
   - b. depolarization;
   - c. threshold voltage;
   - d. repolarization;

e. hyperpolarization;
f. activation/inactivation of ion-channels (Na^+-, K^+-, Ca^{++}-channels, passive Cl^- conductance).

8. Neurotoxins.
   a. tetrodotoxin; and
   b. tetraethylammonium.

9. Properties of action potentials.
   a. all or nothing;
   b. stereotyped shape;
   c. threshold voltage (Vt);
   d. self-propogating;
   e. finite conduction velocity (effect of neuron diameter, nodes of ranvier); and
   f. relative vs absolute refractory periods.

10. Stimulation of action potentials.
   a. Pacemeaker neurons.
      Cyclic gNa^+, and gK^+;
   b. Sensory receptor potentials.
      eg. muscle spindles.
   c. Synaptic potentials.
      (1) ephapse (gap junctions) vs synapse;
      (2) inhibitory vs stimulatory; and
      (3) presynaptic vs post-synaptic.

11. Neurochemical synapse
   a. Structure;
   b. electrical events;
   c. vesicular release;

   d. receptors;
   e. post-synaptic electrical events;
   f. quantal neurotransmitter release and conception of FM-signaling;
   g. overview of intracellular, interstitial, and vascular ion concentrations.

12. Interneuronal communication.
   a. presynaptic;
   b. post-synaptic; and
   c. inhibition vs facilitation

13. Neuropharmacology.
   a. Neurotransmitters.
      (1) direct vs indirect actions;
      (2) actions at ion-channels;
      (3) intracellular events
         (a) adenyl cyclase;
         (b) G-proteins;
         (c) protein phosphorylation;
         (d) Ca^{++}-mobilization; and
         (e) membrane lipid metabolism.

b. Classes of neurotransmitters.

(1) acetylcholine;
(2) biogenic amines;
(3) peptide and proteins; and
(4) amino acids.

c. Detailed examination of acetylcholine and catecholamines.
(1) actions;
(2) metabolism;
(3) receptors; and
(4) pharmacology.

14. Factors modulating chemical neurotransmission.
a. Synapse fatigue.
(1) depletion; and
(2) pharmacological modulation.
b. Metabolic alterations.
(1) pH; and
(2) ventilation.
c. Oxygen sensitivity.
d. Drug effects.
(1) methyl xanthines;
(2) strychnine;
(3) amphetabmines;
(4) local vs general anaesthetics; and
(5) "designer drugs".

15. Sensory receptors.
a. Environmental and internal stimuli and their transduction.
(1) mechanoreceptors;
(2) thermoreceptors;
(3) nocioreceptors;
(4) photoreceptors; and
(5) chemoreceptors.

b. Primary receptors vs secondary receptors.
(1) golgi tendon organs; and
(2) hair cells.

c. Detailed examination of structure, function and regulation of muscle spindles.
(1) posture;
(2) patellar reflex; and
(3) voluntary movement.

d. Detailed examination of structure, function, and regulation of hair cells.

16. Sensory information processing.
a. Spinal cord anatomy;
b. Dorsal lemniscal system.
(1) anatomy;

(2) function; and
(3) information processing.

c. Anterolateral system.
(1) anatomy;
(2) function; and
(3) information processing.

d. Somatosensory cortex-brodman areas.

17. Autonomic nervous system.

a. Anatomy.
(1) comparison of somatic vs autonomic systems; and
(2) comparison of sympathetic vs parasympathetic systems.

b. Pharmacology.
(1) Adrenergic receptors.
□-receptors vs □-receptors.
(2) Cholinergic receptors.
Nicotinic-receptors vs muscarinic-receptors.

c. Examples of affected target organs.
Heart, lungs, gut, bladder, vasculature, adrenal medulla, and fat cells.

SECTION II-MUSCLE PHYSIOLOGY

1. Comparative organization.
a. Striated (skeletal) muscle;
b. Cardiac muscle; and
c. Smooth muscle.

2. Skeletal muscle.

Detailed microanatomy (actin myofilaments, myosin myofilaments).

Serial		Reference	Title	Page(s)
1		Chapter 08	Muscle Physiology	253-297
	a		Structure of skeletal muscle	254-257
	b	Figure 8-2	Levels of organization in a skeletal muscle	255
	c		Molecular basis of skeletal muscle contraction	257-265
	d	Figure 8-5	Structure of myosin molecules and their organization within a thick filament	257
	e	Figure 8-6	Composition of a thin filament	257
	f	Figure 8-7	Role of calcium in turning on cross-bridges	258
	g	Figure 8-9	Cross-bridge activity	260
	h	Figure 8-10	The T-tubules and sarcoplasmic reticulum in relationship to the myofibrils	261
	i	Figure 8-12	Calcium release in excitation-contraction coupling	262
	j	Figure 8-13	Cross-bridge cycle	263
	k	Spare		
	l	Figure 8-16	Summation and tetanus	267
	m	Figure 8-17	Length-tension relationship	268

	n		Skeletal muscle metabolism and fiber types	272-279
	o	Figure 8-22	Metabolic pathways producing ATP used during muscle contraction and relaxation	273
	p		Muscle receptors provide afferent information needed to control skeltal muscle activity	282-285
	q	Figure 8-25	Muscle spindle function	284
	r	Figure 8-26	Patellar tendon reflex	285
	s		Neuromuscular junction	242-247
	t	Figure 7-6	Events at a neuromuscular junction	245

3. Sliding filament theory of skeletal muscle contraction.
   a. Sequence of events;
   b. Graded muscle contraction;
   c. Summation.
      (1) clonus; and
      (2) tetany.
   d. Facilitation.
      (1) rigor mortis; and
      (2) tetanus toxin; and
   e. Isometric versus isotonic muscle contraction.

4. Energy transformations in skeletal muscle.
   a. Direct ATP utilization.
      (1) ATP; and
      (2) creatine phosphate;
   b. Glycogen and lactic acid as energy sources;

   c. Aerobic metabolism;
   d. Comparison of energy sources; and
   e. Replacement of oxygen.
      (1) alactic oxygen debt; and
      (2) lactic oxygen debt.
   f. Metabolism Review.
      (1) glycolysis;
      (2) TCA-cycle; and
      (3) electron transport chain.

5. Smooth muscle.
   a. Comparison of skeletal and smooth muscle;
   b. Sliding filament theory in smooth muscle cells; and
   c. Visceral smooth muscle versus multiunit smooth muscle.

Serial		Reference	Title	Page(s)
1			Smooth muscle and cardiac muscle cell.	
	a		Smooth and cardiac muscle	285-293
	b	Figure 8-28	Schematic representation of the arrangement of thick and thin filaments in a smooth muscle cell in contracted and relaxed states	288
	c	Figure 8-29	Calcium activation of myosin in smooth muscle	289

	d	Figure 8-32	Schematic representation of innervation of smooth muscle by autonomic postganglionic nerve terminals	292
		Table 8-3	Comparison of muscle types	286-287
		Table 8-4	Various means of initiating action potentials in excitable tissues	291

6. Cardiac muscles.

Serial		Reference	Title	Page(s)
1		Chapter 09	Cardiac physiology	298-335
	a		Anatomy of the heart	300-305
	b	Figure 9-2	Blood flow through and pump action of the heart	301
	c	Figure 9-6	Organization of cardiac muscle fibres	304
	d		Electrical activity of the heart	305-315
	e	Figure 9-8	Specialized conduction system of the heart	306
	f	Figure 9-10	Spread of cardiac excitation	309
	g	Figure 9-7	Pacemaker activity of cardiac autorhythmic cells	305
	h	Figure 9-11	Action potential in contractile cardiac muscle cells	310
	i	Figure 9-15	Electrocardiogram waveforms in lead 2	313
	j		Cardiac output and its control	320-326
	k	Table 9-3	Effects of the autonomic nervous system on the heart and structures that influence the heart	321
	l	Figure 9-22	Intrinsic control of stroke volume (Frank-Starling curve)	323
	m	Figure 9-25	Control of cardiac output	325

a. General and comparative morphology of cardiac myocytes.
   (1) atial;
   (2) ventricular; and
   (3) conductive.

b. Electrical activity of the heart.
   (1) organ level;
   (2) Ionic basis of electrical activity-sequence of events.
      (a) Ca^{++}-channels;
      (b) K^{+}-channels; and
      (c) Na^{+}/Ca^{++}-exchange and Ca^{++}-ATPase.
   (3) refractory period;
   (4) pacemaker potential;
   (5) autonomic control-sympatheic vs parasympathetic; and
   (6) pharmacology-Na^{+}-channel blockers, Ca^{++}-channel blockers.

c. The cardiac cycle.
   (1) diastole;
   (2) systole; and
   (3) heart sounds.

d. Measurement of cardiac function.
   (1) heart sounds;
   (2) blood pressure; and
   (3) Electrical activity - Electrocardiogram (EKG).
      (a) P-wave;

(b) QRS-complex; and
(c) T-wave.

e. Kinetic relationship between heartbeat rate and blood flow.

f. Frank-Starling law.

SECTION III-VASCULAR SYSTEM.

Serial		Reference	Title	Page(s)
1		Chapter 10	The blood vessels and blood pressure	336-383
		Table 10-1	Features of blood vessels	342
	a	Figure 10-1	Distribution of cardiac output at rest	338
	b	Figure 10-4	Basic organization of the cardiovascular system	340
	c	Figure 10-10	Arteriolar vasoconstriction and vasodilation	346
		Table 10-4	Arteriolar smooth muscle adrenergic receptors	353
	d	Figure 10-18	Exchanges across the capillary wall	356
	e	Figure 10-19	Capillary beds	357
	f	Figure 10-22	Bulk flow across the capillary wall	359
	g	Figure 10-24	Initial lymphatics	362
	h	Figure 10-25	Lymphatic system	363
	i	Figure 10-31	Effect of contraction of the skeletal muscles of the legs in counteracting the effects of gravity	367
	j	Figure 10-32	Function of venous valves	368
	k	Figure 10-28	Factors that facilitate venous return	365

1. Organization and anatomy.
   Circuit of blood flow.

2. Generalized structure of blood vessels.

3. Capillaries and lymphatic system.
   a. Microscopic and functional anatomy;
   b. Exchange mechanisms.
      (1) diffusion;
      (2) bi-directional pinocytosis;
      (3) diapedesis; and
      (4) Ultrafiltration.
      Balance of osmotic and hydrostatic pressures.

4. Lymphatic system.
   a. gross and cellular organization;
   b. function; and
   c. regulation.

5. Venous system.
   a. Dynamic reservoir for blood;
   b. Return of blood to heart-valves; and
   c. Consequences of venous system failure.

6. Arterial system.
   a. Elastic arteries.
   b. Muscular arteries and arterioles.
   c. Regulation of blood flow.
      (1) Flow=pressure/resistance. (Resistance is a function of vasoconstriction and vasodilation).
      (2) Direct regulation.
         (a) Myogenic response;
         (b) Autoregulation; and
         (c) Local regulators of blood flow.
            (i) histamine;
            (ii) serotonin; and
            (iii) kinins.
      (3) Indirect regulation.
         (a) Neural control of vasomotor state.
            (i) Afferent paths.
               - emotion;
               - thermoreceptors;
               - baroreceptors;
               - mechanoreceptors; and
               - blood chemistry.
            (ii) Efferent paths.
               - sympathetic adrenergic;
               - sympathetic cholinergic;
               - parasympathetic; and
               - adrenal.
         (b) Endocrine control of vasomotor state.
            (i) Efferent paths.
               - epinephrine;
               - vasopressin; and
               - angiotensin (comparison of flow vs pressure control).

7. Regulation of heart productivity.
   a. Stroke rate.
      (1) vagus nerve (acetylcholine, increased gK^+, decreased Vm); and
      (2) sympathetic neurons (noradrenalin, increased Vm).
   b. Stroke volume.
      (1) Frank-Starling law;
      (2) Myocardial contractility.
         (a) Pharmacology. (eg. barbituates); and
         (b) Training.

SECTION IV-EXCRETION AND OSMOREGULATION.

Serial		Reference	Title	Page(s)
1		Chapter 14	The urinary system	500-545
	a		Introduction	501-507
	b	Figure 14-1	The urinary system	503
	c	Figure 14-6	Basic renal processes	507

	d	Spare		
	e		Glomerular filtration	507-514
	f	Figure 14-7	Layers of the glomerular membrane	508
	g	Table 14-1	Forces involved in glomerular filtration	509
	h	Figure 14-11	The juxtaglomerular apparatus	512
	i	Spare		
	j	Figure 14-12	Baroreceptor reflux influence on the GFR in long-term regulation of blood pressure	513
	k		Tubular reabsorption	514-523
	l	Figure 14-14	Steps of transepithelial transport	515
	m	Figure 14-15	Sodium reabsorption	516
	n	Figure 14-16	Renin-angiotensin-aldosterone system	518
	o	Figure 14-19	Water reabsorption in the proximal tubule	522
	p	Figure 14-20	Passive reabsorption of urea at the end of the proximal tubule	523
	q		Tubular secretion	523-526
	r		Potassium ion secretion is controlled by aldosterone	523-525
	s	Figure 14-22	Dual control by aldosterone of K^+-secretion and Na^+-reabsorption	525
	t	Table 14-3	Summary of transport across proximal and distal portions of the nephron	526
	u		Vasopressin-controlled, variable H_2O reabsorption occurs in the final tubular segments	532-535
	v	Figure 14-26	Mechanisms of action of vasopressin	533
	w	Figure 14-27	Excretion of urine of varying concentration depending on the body's needs	534
	x	Figure 14-28	Countercurrent exchange in the renal medulla	536
		Table 14-4	Handling of sodium and water by various tubular segments of the nephron	537

1. Introduction.
   a. regulation of $C0_2$;
   b. regulation of salts; and
   c. regulation of nitrogenous wastes.

2. Urea and nitrogen sources.
   a. Urea biosynthesis; and
   b. Utility of urea.

3. The human kidney.
   a. Gross and microanatomy.
   b. Definition of operations.
      (1) filtration;
      (2) ultrafiltration;
      (3) osmosis;
      (4) passive diffusion; and
      (5) active transport.

4. Juxtaglomerular nephron.
   (a) Nephron structure and function;
   (b) Ultrastructure of Bowman's capsule;
   (c) Glomerulus.
      (1) structure;
      (2) filtration; and
      (3) Regulation of filtration.
         Balance sheet of osmotic and hydrostatic pressures in glomerulus and capsule.
   (d) Reabsorbtion and secretion.
      (1) glucose;
      (2) proteins;
      (3) urea; and
      (4) salt and water.

5. Pathway and fate of glomerular filtrate.
      (1) proximal tubule;
      (2) descending limb of Henle's loop;
      (3) ascending limb of Henle's loop;
      (4) distal tubule;
      (5) collecting tubule;
      (6) collecting duct; and
      (7) role of urea.

6. Review and integration of differential permeability, active and passive functions.

8. Secretory properties of the nephron.

9. Role of kidney in regulation of blood pH.

10. Endocrine regulation of kidney function.
   a. vasopressin;
   b. aldosterone;
   c. neural:endocrine path (angiotensin II).

SECTION V-RESPIRATION.

Serial		Reference	Title	Page(s)
1		Chapter 13	The respiratory system	450-499
	a		The respiratory system does not participate in all steps in respiration	451-452
	b	Figure 13-2	Anatomy of the respiratory system	453
	c	Figure 13-4	Alveolus and associated pulmonary capillaries	454
	d	Figure 13-25	Oxygen and CO_2 exchange across pulmonary and systemic capillaries caused by partial pressure gradiants	477

	e		Factors other than the partial pressure gradiant influence the rate of gas transfer	476-479
	f	Table 13-5	Factors that influence the rate of gas transfer across the alveolar membrane	478
	g		Gas transport	479-487
	h	Table 13-6	Methods of gas transport in the blood	480
	i	Figure 13-29	Effect of increased P_{CO2}, H^+, temperature, and 2,3-bisphosphoglycerate on the O_2-Hb curve	483
	j	Figure 13-30	Carbon dioxide transport in the blood	485
	k		Control of respiration	487-496
	l	Figure 13-32	Respiratory control centres in the brain stem	490
	m	Table 13-8	Influence of chemical factors on respiration	490
	n	Figure 15-33	Location of peripheral chemoreceptors	491

1. Gross and microstructure.
   Structural versus respiratory regions.

2. Functions of respiratory system.

3. Gas transport.
   a. Physical solution in plasma;
   b. Hemoglobin.
      (1) structure;
      (2) capacity;
   c. Oxygen:hemoglobin binding.
      (1) advantage of allosteric relationship of 02 and hemoglobin; and
      (2) Modulation of oxygen transport.
         (a) $C0_2$-direct effects;
         (b) Bohr-effect;
         (c) temperature effects;
         (d) 2,3-diphosphoglycerate; and
         (e) CO effects.
   d. $C0_2$ transport.
      (1) physical solution;
      (2) carbamino compounds;
      (3) bicarbonate; and
      (4) hemoglobin.

4. Control of respiration.
   a. Review of controllers.
      (1) sensors; and
      (2) effectors.
   b. Neural control of respiration.
      (1) control pattern generator;
      (2) Supraspinal organization.
         (a) Medulla oblongata.
            (i) dorsal respiratory group;
            (ii) ventral respiratory groups;
            (iii) PONS; and
            (iv) suprapontine structures.

(3) Spinal organization.
(4) Sensors.
(a) Airway and lung receptors.
(i) Myelinated afferents.
Slow-adapting receptors.

Brueur-Hering Inflation Reflex;
Brueur-Hering Deflation Reflex;
Bronchodilation; and
Tachycardia.

Fast adapting receptors.
-lung receptors and responses
- tracheal/bronchial receptors and responses

(ii) Non-myelinated afferents.
Locations;
Chemical vs physical activation; and
Biologic actions and reflexes.

(b) Chest wall receptors.

c. Chemical control of respiration.
(1) Sensory systems.
(a) aortic body; and
(b) carotid body.
(2) Acute ventilatory responses.
(a) Altered $C0_2$-apneic threshold;
(b) Altered 02-haldane effect; and
(c) altered pH.