BIO 4162 Human Anatomy & Physiology 2

Winter Quarter 2003, Thursday Evenings

Carl Moxey

Textbook
EN Marieb, 2001
Human Anatomy and Physiology, 5/e
Benjamin Cummings
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Lecture	Date	Lecture Topics
I	02 January	Nervous System Organization and Function [Marieb: 11]
II	09 January	Brain Development and Anatomy 1 [Marieb: 12]
III	16 January	Brain Anatomy 2 [Marieb: 12]
IV	23 January	Review Basic Chemistry [Marieb: 2] Principles of Physiology & Membrane Transport Systems [Marieb: 3]
V	30 January	Introduction to Membrane Potentials [Marieb: 11] Action Potentials & Impulse Conduction by Neurons [Marieb: 11]
VI	06 February	**Mid-Term Exam** « A Sampler of Questions »
VII	13 February	Muscle Microanatomy and Physiology [Marieb: 9]
VIII	20 February	Basics of Neurophysiology [Marieb: 13]
IX	27 February	Neurophysiologic Input: Sensory Systems [Marieb: 15]
X	06 March	Neurophysiologic Output: Motor Systems [Marieb: 14]
XI	13 March	**Final Exam** « A Sampler of Questions »
XII	--	Please review for A&P 3: Basics of Endocrinology [Marieb: 17]

If you need to contact me, my email address
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University College at Northeastern University: The Write Place.

Possessing the skills for effective communication will be invaluable in your future endeavors.
This course affirms its commitment to practice-oriented education.

Prerequisites	BIO 4161 or equivalent is recommended.
Description	Anatomy of the central nervous system: evolution and general design; anatomy of the brain stem, cerebellum, diencephalon, and cerebrum. Membrane dynamics: structure of the membrane; movements across membranes; fluid and solute distribution. Action potentials and impulse conduction. Skeletal muscle physiology: muscle microanatomy; contraction; excitation-contraction coupling. Cerebral functioning. Sensory physiology: afferent signaling; receptor functions; pain. Motor systems: efferent signaling; autonomic nervous system; Endocrinology: intercellular chemical messengers; receptors; endocrine organs and their hormones; hormone chemistry; hormone action: postreceptor events; negative feedback; receptor regulation.
Course objectives	To understand the anatomy and physiology of the human central nervous system and how it functions in homeostasis. To understand the structure of the cell membrane and how it operates to regulate cellular input, output, and communication. To understand the molecular basis of skeletal muscle contraction and the behavior of different fiber types. To learn the endocrine organs and the hormones they produce, and to understand how the endocrine system functions in homeostasis. To learn how to use the Internet as a tool for gathering information.
Methodology	Class lectures based upon the distributed outlines. This material may, from time to time, be augmented by assigned readings, Internet searches, or video presentations. Exams will be based on the lecture presentations and any other assigned material.
Requirements	Two examinations, as specified on the fine print page.
[http://webpages.charter.net/cfmoxey/ap2/bio4162_syllabus_2003w.html]	

Higher Learning. Richer Experience.

Determination of the final grade:

Mid-term exam	..... 45%
Final exam	..... 55%

This is the fine print

Course content.
What you need to know. Anatomy and physiology are demanding fields of study requiring the student to be disciplined and attentive to detail. There is much to learn and a very short period in which to learn it. Students who attend the lectures regularly, take adequate notes during lecture, and study regularly do well in these courses. While there are no formal prerequisites at this time, a baseline of knowledge is presumed: a working command of spoken and written English; the ability to perform basic arithmetic operations; an elementary knowledge of plane and solid geometry; basic biology, including structure of the cell, evolution, and development; basic chemistry, including atomic structure, elements, compounds, and energy; and some knowledge of physics, such as the laws of motion.
This may look like a formidable list, but do not be put off by it; there is nothing in the list that should not be expected of any student taking a college biology course. Except for the language issue, any deficit can be overcome by additional reading by the student at the appropriate time.
Studying. I am not an expert in designing effective study habits, but I will offer a few suggestions:
1. Be interested in the material. I believe that even if every other suggestion is ignored, when a student is truly interested in a subject, he or she takes the time to explore it in greater detail. The more one investigates something, the more expert one becomes.
2. Study often. Try not to wait until the night before the midterm or final to cram. If one studies a little bit after each class session, not only does the material seem more familiar, but there is the chance for additional consolidation of the material into memory.
3. Study what is important. Always study the material presented in lecture and any assigned reading. Additional reading of the textbook or linked webpages should not be ignored, but if pressed for study time, go with learning the material that the test is known to cover.
4. Generate questions and answers. And do not make them trivially simple. Test them out on other students in the class.
5. Study as a group. If the group members test one another, make sure that at least one person in the group knows the correct answer to the test question.

Examinations.
Format. Examinations will be multiple choice/true-false or brief answer/fill-in/short essay, depending on class size. Unless otherwise noted, questions will be based on the material presented in lecture; the

distributed lecture session outlines will serve as a guide for the material covered. This statement does not preclude the possibility of questions being asked which might serve to test the student's ability to visualize, analyze, or interpret other data germane to the field of inquiry. In addition, questions may not just test rote memorization of data, but may require the student to analyze data to arrive at the correct answer. From time to time, questions may be added as lateral-thinking challenges to the student. Answering these questions is voluntary on the part of the student, and any answer, or lack thereof, will in no way affect the grade earned by the student on the didactic portion of the examination.

Exam protocol. Students must put all study materials (textbooks, notes, review cards, whatever) away at the time the examinations are handed out; further review of material once the exam has been distributed will not be permitted. It is incumbent upon the student to read the examination instructions carefully, to heed any additions or corrections indicated by the instructor, and to ask the instructor if something is not clearly explained or questioned. Be aware, however, that such questions may not be answered because to do so would betray the answer.

All exams must be returned by the designated end time for that examination; failure to turn in the exam by that time will result in a zero for the examination. If a student is late for a scheduled exam, the student will be permitted to take that examination provided that no student has already completed the exam and left the room; in addition, the student must complete the exam and turn it in by the designated end time of the examination.

During an examination, the student may not listen to any playback device, digital or analog, including, but not limited to, tape recorders, CD players, camcorders, &c. The use of calculators requires permission of the instructor.

Challenges. Any challenge to a question on an exam or to a grade earned on an exam must be submitted in writing by the class following the posting or review of the answers or grades for that exam.

Missed exams. No makeup examinations will be given. In the case of genuine emergency, prior notice or subsequent documentation must be provided. Failure to do so will result in a grade of zero being posted for that exam. Please see the lecture syllabus for information on how to contact me.

Extra credit. No. Why not?

1. To be fair, extra credit, if offered to one student, must be offered to all.
2. The time spent on an extra credit project would better be used in studying the assigned material.

Classroom behavior.

Deportment. Proper class deportment is expected. Questions that seek to clarify or expand the lecture material are always welcome. Disruptive classroom behavior will not be tolerated, and frivolous questions that are totally off-topic, persistent argumentative questions, or questions that only serve as self-aggrandizement fall within the purview of such behavior. Students engaged in such unsociable activity

will be asked to leave. If the offender or offenders cannot be identified, then the lecture will be terminated, but the class will be responsible for whatever material would have been covered. Impolite behavior, such as wearing a baseball cap indoors, is merely gauche, not disruptive, and so, cannot be barred.

Portable communication devices. The use of beepers or cellular phones during class can be quite disruptive to the lecture environment. Therefore, all beepers and cellular phones must be turned off prior to entering the lecture room. Exceptions to this policy must be cleared with the instructor. Violation of this directive will be considered equivalent to disruptive classroom behavior.

Grading.

The assignment of letter grades to one's overall course average will be determined by the following rule: If the class mean is ≥ 78, then standard letter-equivalencies will pertain; i.e., 78=C+, 80=B-, 84=B, etc. If the class mean is < 78, then this mean score will be given the grade of C+. For example, if the mean=70, then 70=C+. If you obtain the mean score on all yours tests, you are guaranteed to receive a grade no lower than C+. Grades on a particular examination should always be viewed in a comparative light, and if a letter grade has been attached to the exam, that letter grade indicates the position of the earned score on that exam within the ABCDF-grading system.

Academic honesty.

The student is encouraged to study with other students, to share notes and ideas. All examinations, laboratory exercises, and other assignments, must be completed by the student alone. Examinations and quizzes administered in this class during previous quarters are not available for review by the student, and any student who reviews such will be considered to have cheated. Neither this nor any other form of academic dishonesty will be tolerated. The following is quoted from the *University College 1998-1999 Bulletin* [p. 24]:

> Students must accept the responsibility to be honest and to respect ethical standards in meeting their academic assignments and requirements. Integrity in academic life requires that students demonstrate intellectual and academic achievement independent of all assistance except that authorized by the instructor. Consequently, all work submitted to meet course requirements, whether it takes the form of papers, examinations, laboratory reports, computer projects, quizzes, or any other work assigned, is expected to be the student's own work produced specifically for each course. Students who fail to meet the responsibility of academic integrity as defined here are subject to disciplinary sanctions ranging from reduction in grade or failure in the assignment or course to dismissal from the University. Details on the Code of Student Conduct and complete disciplinary procedures are outlined in the *University College Student Handbook*.

Academic Assistance.

Unfortunately, due to the very nature of an evening educational division, conference scheduling is an impossibility. If you need academic assistance beyond a mere clarification of lecture or lab material, the good folks at 180 Ryder Hall will be more than happy to assist you (617-373-2400). Tutorial information can be obtained from the Office of Academic and Student Affairs (617-373-8300). For more details on the services University College offers you, please see the latest *Bulletin*.

Nervous System Organization and Function

Functions

- orientation
- coordination
- conceptual thought

General plan

- central nervous system (CNS)
  - brain
  - spinal cord
- peripheral nervous system (PNS)
  - cranial nerves
  - spinal nerves
  - autonomic nervous system (ANS)
    - sympathetic
    - parasympathetic

Nervous tissue

- neurons
  - cell body (perikaryon)
  - dendrites
  - axons
  - synapses

- myelin sheath
    - Schwann cells
    - nodes of Ranvier
- classification of neurons
    - unipolar
    - bipolar
    - multipolar
- neuroglia
    - astrocytes
        - fibrous, white matter
        - protoplasmic, gray matter
    - oligodendrocytes
    - microglia
- nerves
    - investments
        - endoneurium
        - perineurium
        - epineurium
    - tracts
- ganglia
    - sensory
    - autonomic

nuclei and nerve centers

peripheral nerve endings

- receptors
- effector nerves
- motor end-plate
- synapse

Brain Development and Anatomy 1

Early development

- formation of the neural tube: neural groove and neural folds
- cranial expansions [vesicles]
    - prosencephalon [forebrain]
    - mesencephalon [midbrain]
    - rhombencephalon [hindbrain]
- flexures
    - cephalic
    - pontine
    - cervical
- ventricles
- development of the vesicles
    - forebrain
        - olfactory bulbs [rhinencephalon]
        - cerebral hemispheres [telencephalon]
            - optic vesicles
        - diencephalon
            - pineal body
        - infundibulum
    - mesencephalon
        - tectum [forms optic lobes in lower vertebrates]
            - corpora quadrigemina

- hindbrain
  - cerebellum
  - pons
  - medulla oblongata
  - [metencephalon + myelencephalon]

Brain stem [1]

- medulla oblongata
  - fourth ventricle
    - inferior velum forms its roof
  - ascending and descending tracts
    - decussation of the pyramids
  - respiratory, vasomotor, cardiac centers
  - nuclei for cranial nn IX–XII
  - olivary nuclei [relay centers between cerebral cortex/basal ganglia and cerebellum]
  - reticular formation
- pons
  - floor of the fourth ventricle
  - pontine nuclei
  - middle cerebellar peduncles
  - nuclei for cranial nn V–VIII
  - reticular formation
  - corticospinal, corticobulbar, and corticopontine tracts

Mesencephalon

- midbrain [mesencephalon]
  - cerebral aqueduct (aqueduct of Sylvius)
  - cerebral peduncles
  - nuclei for cranial nn III–IV and anterior part of V
  - red nucleus and rubrospinal tract
  - superior cerebellar peduncle
  - corpora quadrigemina
    - superior colliculi [visual, auditory, tactile reflex centers]
    - inferior colliculi [auditory reflex centers]

Cerebellum [2, 6]

- anatomy
  - peduncles
    - superior... midbrain
    - middle... pons
    - inferior (restiform body)... medulla oblongata
  - cerebellar hemispheres
  - vermis

- cerebellar cortex
  - folia cerebelli
  - fissures
  - arbor vitae
  - layers
    - outer molecular layer [input]
    - Purkinje cell layer [output]
      - to deep cerebellar and lateral vestibular nuclei
    - inner granular layer [input]

functional considerations

- functions quickly with no storage
  - coordination of somatic motor activity
  - regulation of muscle tone
  - maintenance of equilibrium
- lesions
  - do not result in paralysis
  - ataxia [3]
  - hypotonia [4] and asthenia
  - tremors and nystagmus [5]
  - ipsilateral representation

Forebrain

- diencephalon
  - rostral limit is the interventricular foramina (foramina of Monro)
  - third ventricle
    - lateral walls are the thalami
    - intermediate mass [variable, ~60%]
    - roof is the epithalamus
    - floor is the hypothalamus
  - thalamus
    - major sensory center
    - crude, uncritical consciousness [the reptilian brain]
  - epithalamus
    - choroid plexus and the production of cerebrospinal fluid (CFS)
    - pineal body
    - posterior commissure where it joins midbrain
  - hypothalamus
    - optic chiasm
    - infundibulum
      - from tuber cinereum
    - mammillary bodies
    - functions
      - regulation of body temperature, metabolism, sleep, emotions, sexual drive
      - integrated with endocrine system

Brain Anatomy 2

Cerebrum

topology

- longitudinal fissure
- corpus callosum
- surfaces: dorsolateral, inferior, medial
- poles: frontal, occipital, temporal
- cortex
  - lobes
    - frontal
    - parietal
  - gyri
  - sulci
    - lateral sulcus (Sylvian fissure)
      - insula
      - temporal lobe
        - primary auditory center: Brodmann [1] area 41 [2], [3]
          secondary centers: Brodmann areas 42, 22
      - parietal lobe
        - speech center: Brodmann area 44

central sulcus (fissure of Rolando)

frontal lobe

precentral gyrus

primary motor cortex: Brodmann area 4

parietal lobe

postcentral gyrus

somatesthetic cortex: Brodmann areas 1–3

calcarine sulcus

visual area: Brodmann area 17

parietooccipital sulcus

parietal lobe

occipital lobe

sulcus cinguli parallels corpus callosum

gyrus cinguli: smell association

collateral sulcus inferiorly

hippocampal gyrus lies medial

uncus: smell & taste appreciation

association areas

white matter

association tracts

short association fibers

long association fibers

- commissural tracts
    - corpus callosum
    - anterior and posterior commissural tracts
- projection tracts
    - ascending [afferent] mostly from thalamus
    - descending [efferent]
    - corona radiata

- basal ganglia
    - caudate nucleus, putamen, claustrum, amygdaloid nucleus, globus pallidus [putamen + globus pallidus = lentiform nucleus]
    - internal capsule [between caudate and lentiform nuclei]
    - external capsule [outside of lentiform nucleus]
    - claustrum [lies lateral to external capsule]

- conditioned reflexes
    - Pavlovian conditioning
    - milk let-down

Ventricles of the brain

- fourth ventricle
    - choroid plexus
        - capillaries are part of pia, but covered with ependymal cells
        - production of CSF
    - median aperture (foramen of Magendie)
    - lateral aperture (foramina of Luschka)
    - hydrocephalus

- cerebral aqueduct (aqueduct of Sylvius)
    - lies within mesencephalon
- third ventricle
    - choroid plexus
    - interventricular foramina (foramina of Monro)
- lateral ventricles
    - septum pellucidum
    - central portion
        - choroid plexus
    - anterior, posterior, and inferior horns
- arachnoid villi of the superior sagittal sinus

Meninges of the brain

- dura mater
    - periosteal dura
    - meningeal dura
        - falx cerebri
            - superior and inferior sagittal sinuses
        - tentorium cerebelli
            - transverse and superior petrosal sinuses
            - straight sinus
        - falx cerebelli
            - occipital sinus
        - diaphragma sellae

- arachnoid
    - subdural space
    - subarachnoid space
        - arachnoid trabeculae
    - over the gyri, pia + arachnoid = leptomeninx
    - cisterns
    - arachnoid villi
- pia mater

Blood supply to the brain

- common carotid a
    - external carotid a
    - internal carotid a
        - enters carotid canal
        - posterior communicating a
        - ophthalmic a
        - anterior cerebral a
        - middle cerebral a
- subclavian a
    - internal thoracic a
    - thyrocervical trunk
    - costocervical trunk

vertebral a

through transverse processes of superior six cervical vertebrae

spinal branches

anterior spinal a

cerebellar branches

posterior inferior cerebellar a

anterior inferior cerebellar a

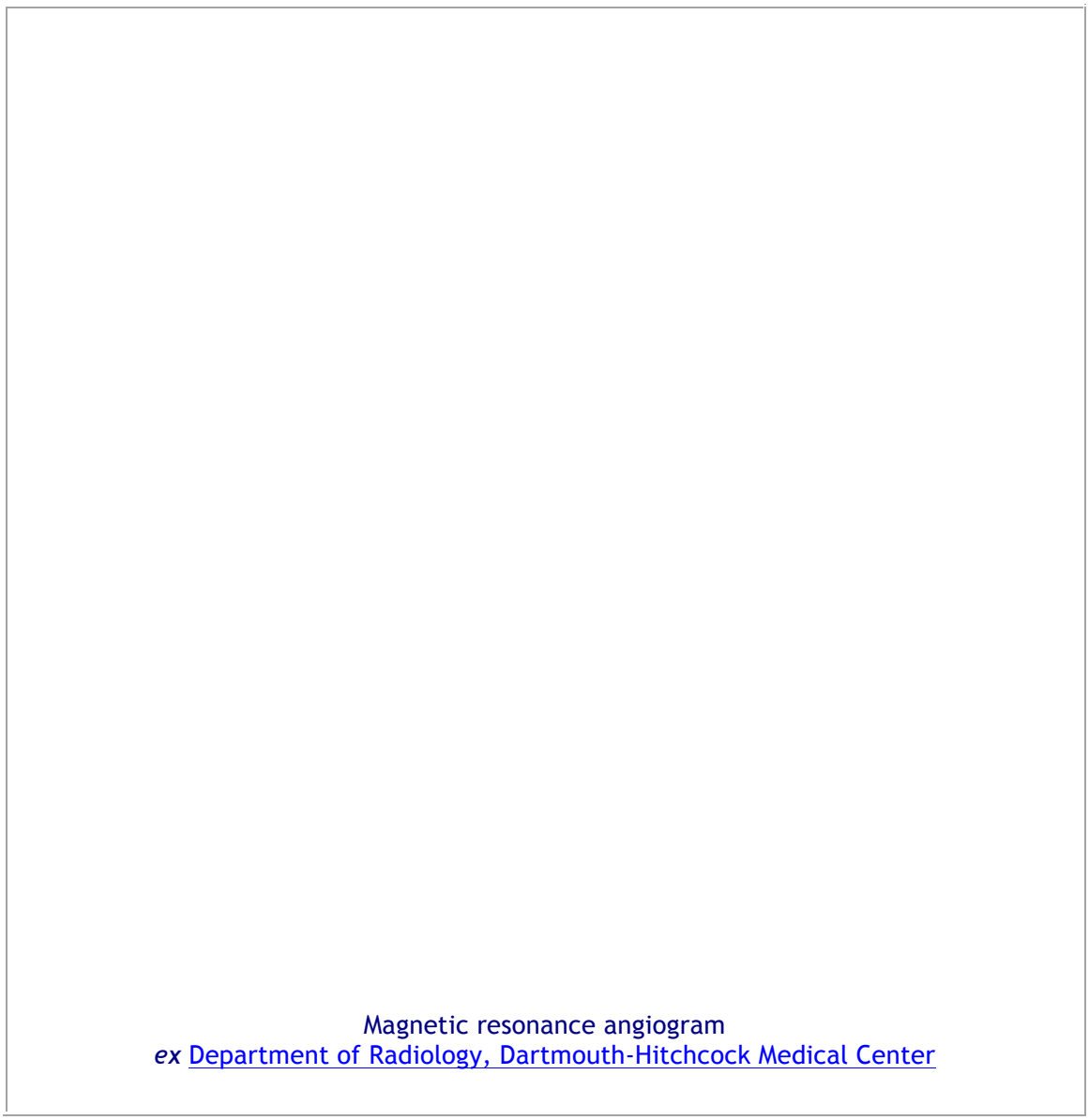
forms basilar a

posterior cerebral aa

circle of Willis (circulus arteriosus cerebri)

R posterior cerebral a -> R posterior communicating a ->
R internal carotid a -> R anterior cerebral a ->
anterior communicating a -> L anterior cerebral a ->
L internal carotid a -> L posterior communicating a ->
L posterior cerebral a -> basilar a bifurcation ->
R posterior cerebral a ->...

ex DAVID, an Online Atlas of Human Anatomy for Clinical Imaging Diagnosis



Magnetic resonance angiogram
ex Department of Radiology, Dartmouth-Hitchcock Medical Center

Membrane Physiology 1

Plasma membrane

- intracellular vs extracellular fluid
- trilaminar structure [1]
  - phospholipids
    - hydrophilic [polar] vs hydrophobic [nonpolar]
  - cholesterol
  - membrane proteins
    - channels
      - selectivity
      - defective chloride channels and cystic fibrosis (CF) [2]
    - carrier molecules
    - receptor sites
    - membrane-bound enzymes
    - filamentous elements and the cytoskeleton
    - recognition markers
  - fluid mosaic model
  - membrane carbohydrates
    - orienting and anchoring proteins
    - recognition markers

Cell-to-cell adhesions

- extracellular matrix as the biological “glue”
    - glycosaminoglycan gel
    - proteins
        - collagen
        - elastin
        - fibronectin
- cell junctions
    - desmosomes (macula adherens)
    - tight junctions
    - gap junctions
        - connexons

Membrane transport

- permeability
    - impermeable
    - semipermeable
- solubility
- forces
    - passive forces
    - active forces and ATP (adenosine triphosphate)

diffusion down a concentration gradient (chemical gradient) [3]

- net diffusion
- equilibrium state
- Fick's law of diffusion [4]

movement along an electrical gradient

- cations
- anions

osmosis

- solute
- solvent
- concentration
- hydrostatic pressure
- osmotic pressure
- isotonic, hypotonic, and hypertonic solutions

carrier-mediated transport

- characteristics
  - specificity
  - saturation and the transport maximum (T_m)
  - competition
- facilitated diffusion

- active transport uses “pumps”
  - phosphorylation at low-concentration side
  - ATPase activity
  - dephosphorylation at high-concentration side
  - conformational shifts
  - Na^+-K^+ ATPase (sodium-potassium pump)
    - phosphorylation of carrier on intracellular side

vesicular transport

- endocytosis
  - pinocytosis
  - phagocytosis
- exocytosis

Membrane Physiology 2

Membrane potentials [1]

measured in millivolts (mV)

Ion	Extracellular Concentration	Intracellular Concentration	Relative Permeability
Na^+	140	12	1
K^+	4	135	50 - 75
Cl^-	150	5	10
A^-	0	65	0

effect of sodium-potassium pump

3 Na^+ out for 2 K^+ in

effect of K^+ movement alone

Nernst equation for K^+ equilibrium potential [2]

$E_{K^+} = -60 \log_{10}[C_i]/[C_o]$ mV

-92 mV

effect Na^+ movement alone

Nernst equation for Na^+ equilibrium potential

$E_{Na^+} = -60 \log_{10}[C_i]/[C_o]$ mV

+64 mV

effect Cl^- movement alone

Nernst equation for Cl^- equilibrium potential

$E_{Cl^-} = +60 \log_{10}[C_i]/[C_o]$ mV

-89 mV

effect of Na^+ and K^+ concurrent movements

potassium flows out along chemical gradient

sodium flows in along electrochemical gradients

sodium-potassium pump

Action Potentials and Impulse Conduction

Excitable tissues

- muscle
- nerve

Graded potentials

- properties
  - proportional to magnitude of triggering event
  - show decremental decay and propagation
  - can be depolarizing or hyperpolarizing
  - can be summed
- important examples
  - postsynaptic potentials
  - receptor potentials
  - end-plate potentials
  - pacemaker (ramp) potentials

Action potentials

- terminology
  - polarization
  - depolarization
  - hyperpolarization
  - repolarization
- threshold potential

channel gating

- types
  - voltage-gated channels
  - chemical-messenger gated channels [ligand-gated channels]
- gates are all-or-nothing
- depolarization results from opening voltage-gated Na^+ channels
  - Na^+ permeability increases to 600 × K^+ permeability
  - duration 0.5 msec
  - closing of inactivation gates
- repolarization results from opening voltage-gated K^+ channels
  - K^+ permeability increases to 300 × Na^+ permeability
  - Na^+ channels return to original configuration
  - K^+ channels close

Na^+- K^+ pump restores ion concentration gradients

propagation

- role of the axon hillock
- conduction by local current flow
  - nondecremental
- saltatory conduction
  - myelination
  - multiple sclerosis
- refractory period
  - role of the Na^+ activation gates

- all-or-nothing law

Synapses

- morphology
  - presynaptic neuron
    - synaptic knob
    - synaptic vesicles
    - neurotransmitter substance
  - postsynaptic neuron
    - subsynaptic membrane
  - synaptic cleft
- unidirectional transmission
- excitatory synapses
  - excitatory postsynaptic potential (EPSP)
  - Parkinsonism
    - dopamine deficiency
    - treatment with L-dopa

- inhibitory synapses
    - inhibitory postsynaptic potential (IPSP)
    - strychnine
        - competes with glycine at postsynaptic receptor
        - no IPSPs generated
        - results in unchecked excitatory input
    - tetanus toxin
        - prevents release of gamma-aminobutyric acid (GABA)
        - results in unchecked excitatory input
- synaptic delay
- neurotransmitter removal from the synaptic cleft
    - cholinesterase
    - monoamine oxidase
    - catechol-O-methyltransferase (COMT)
- the grand postsynaptic potential (GPSP)
    - temporal summation
    - spatial summation

Skeletal Muscle Physiology

Structure of skeletal muscle

- muscle fiber
  - myofibrils
    - thick filaments
      - myosin
    - thin filaments
      - actin
  - banding
    - A band
      - H zone
      - M line
    - I band
      - Z line
  - sarcomere
  - transverse tubules at A-I junction
  - sarcoplasmic reticulum
    - lateral cisternae
- thick filament
  - actin binding site
  - myosin ATPase site

thin filament

actin

G actin

F actin

tropomyosin

troponin

binding sites

actin

tropomyosin

Ca^{2+}

Molecular basis of skeletal muscle contraction

sliding filament mechanism

power stroke

excitation-contraction coupling

1. ATP hydrolyzed by ATPase
   ADP & P_i attached to myosin
   energy stored in cross-bridge
2. Ca^{2+} released at excitation
   actin disinhibited
   actin-myosin binding
3. Power stroke of cross-bridge
   ADP & P_i released
4. Fresh ATP binds to myosin head
   myosin detaches from actin
   GoTo 1

rigor mortis

relaxation

sarcoplasmic reticulum Ca^{2+}-pump

contractile activity

latent period: <10 msec

contraction time: ~50 msec

relaxation time ~50 msec

Mechanics of contraction

determinants of whole-muscle tension

twitch

number of fibers contracting

size of muscle

number of motor units recruited

number of muscle fibers per motor unit

tension developed by each contracting fiber

frequency of stimulation

twitch summation

tetanic contraction

length-tension relationship

extent of fatigue

duration of activity

asynchronous recruitment of motor units

- type of fiber
  - oxidative, fatigue-resistant
  - glycolytic, fatigue-prone
- thickness of fiber
  - hypertrophy
  - atropy

types of contraction

- isotonic
- isometric

Muscle metabolism

Energy sources for ATP

- existing ATP
- creatine phosphate
- oxidative phosphorylation: aerobic
- glycolysis: anaerobic

muscle fiber types

Characteristic	Slow Oxidative (Type I)	Fast Oxidative (Type IIa)	Fast Glycolytic (Type IIb)
myosin ATPase activity	low	high	high
speed of contraction	slow	fast	fast
resistance to fatigue	high	intermediate	low
oxidative phosphorylation capacity	high	high	low
enzymes for anaerobic glycolysis	low	intermediate	high
fiber color	red	red	white

Neurophysiology 1

The cerebral cortex and intellectual functions of the brain

Physiologic anatomy of the cerebral cortex

cell types

granular

fusiform

pyramidal

cortical layers

I	molecular layer
II	external granular layer
III	pyramidal cell layer
IV	internal granular layer
V	large pyramidal cell layer
VI	fusiform cell layer

agranular cortex... motor

granular cortex... sensory

thalamocortical system

Cortical functional areas

primary sensory areas

somatic, visual, auditory

examples of loss: anencephalic infant

sensory association areas

examples of loss: dyslexia

Wernicke's area

role in cerebration

storage of complicated memory patterns?

angular gyrus for visual signals

dominant hemisphere

role of language in function of Wernicke's area

Wernicke's area in the nondominant hemisphere

visual patterning, spatial relationships, somatic experiencing

face recognition area

inferior occipital and temporal lobes

prosophenosia

prefrontal areas

choice of behavioral options for social/physical situations

prevention of distractibility [loss of thought sequencing]

elaboration of thought and prognostication

Thoughts, consciousness, and memory

holistic theory of thoughts

cortical, thalamic, limbic, and upper reticular involvement in analysis of general qualities

cerebral cortex in formation of discrete qualities

consciousness... continuing stream of awareness of surroundings/thoughts

memory

sensory memory

very short, hundreds of msec

- primary memory
  - a few seconds to a few minutes
  - replaced by new data
- secondary memory
  - long-term storage
  - requires search

physiological basis of memory [1]

- reverberating circuit theory of primary memory
- alteration of synapses for secondary memory
  - anatomic changes in synapses
  - physicochemical changes in pre- or postsynaptic elements
    - habituation and facilitator terminals
      - serotonin
      - adenylate cyclase
      - cyclic AMP [cAMP]
      - protein kinase
    - reduction of potassium conductance
      - prolongation of action potential
      - prolongation of calcium channel activation
      - increased release of neurotransmitter
    - formation of the memory engram

- consolidation of memory
  - 5–10 min for minimal, one hour for maximal
  - role of rehearsal in memory transference
  - codification of memories during consolidation
- role of the hippocampi (most medial portions of temporal lobe cortex)
  - anterograde amnesia
- role of thalamus?
  - retrograde amnesia

Analytical operations of the brain

- analysis of information by splitting its qualities
- analysis of new information by comparison with memories
- analysis of patterns

Function of the brain in communication

- sensory aspects
  - auditory receptive aphasia [word deafness]
  - visual receptive aphasia [word blindness]
  - Wernicke's aphasia [sensory aphasia]
    - inability to interpret thought

motor aspects

- formation of thoughts to be expressed
  - Wernicke's area
- motor control of vocalization
  - Broca's area
  - motor aphasia
- articulation
  - facial and laryngeal regions of motor cortex
  - cerebellum, basal ganglia, sensory cortex

Neurophysiology 2

Sensory systems

Afferent input

somatic sensation

- somatesthetic
- proprioceptive

special senses

- vision
- hearing
- taste
- smell

uses of sensory input

- control of efferent output
- reticular formation and cortical arousal and consciousness
- stored for future reference
- perception: the conscious interpretion of the external world
  - limited receptor modalities
  - differential processing of input
  - manipulation of input to produce altered “reality”

Receptor physiology

- receptors have differential sensitivities to various stimuli
  - stimulus modality
  - transduction
  - adequate stimulus and the law of specific nerve energies
  - receptor types
    - photoreceptors
    - mechanoreceptors
    - thermoreceptors
    - chemoreceptors
    - nociceptors
  - compound sensations: wetness
- altered membrane permeability of receptors results in graded receptor potential
  - causes
    - mechanical stimulation
    - chemical signals
    - temperature
    - electromagnetic radiation
  - increased intensity of stimulus results in increased receptor potential
  - increased receptor potential results in increased frequency of action potentials [Why?]
    - frequency code [number of action potentials]
    - population code [number of activated receptors]

- adaptation
  - tonic receptors
    - proprioceptors
    - nociceptors
  - phasic receptors
    - off response
- somatosensory pathways
  - destinies of afferent information
    - reflex arc
    - ascending pathway
  - labeled lines
  - decoding the stimulus
    - stimulus modality
      - receptor type
      - ascending pathway
    - stimulus location
      - location of activated receptor field
      - pathway to somatesthetic cortex
    - stimulus intensity
      - frequency of action potentials
      - number of activated receptors
  - activation of sensory pathway
    - phantom pain

- acuity is influenced by receptor field size
    - somatesthetic cortical homunculus

Pain [1]

- protective mechanism
    - motivated behavioral responses
    - emotional responses
    - subjective interpretation
- categories of pain receptors
    - mechanical nociceptors
    - thermal nociceptors
    - polymodal nociceptors
- free nerve endings
- sensitization by prostaglandins
- pathways
    - fast pain pathway
        - myelinated A-delta fibers
    - slow pain pathway
        - unmyelinated C fibers
        - role of bradykinin
        - capsaicin

- synapse with second-order neuron
  - substance P
    - activates ascending pathways
      - somatosensory cortex
      - thalamus
      - reticular formation
    - roles of hypothalamus and limbic system
  - glutamate
    - AMPA[a] receptors
      - generate action potentials in dorsal horn cells
      - transmission of pain message to higher centers
    - NMDA[b] receptors
      - Ca^{2+} entry into dorsal horn cells
      - induces hyperexcitability

analgesia

- periaqueductal gray matter and reticular formation
  - descending analgesic system
  - blocking substance P release from afferent synaptic terminal
  - opiate receptors for endorphins, enkephalins, and dynorphin

Notes

[a] (S)-2-Amino-3-(3-hydroxy-5-methylisoxazol-4yl)propionic acid

[b] N-methyl-D-aspartate

Neurophysiology 3

Motor systems

Efferent output

homeostatic and nonhomeostatic output

neurotransmitters: only two

acetylcholine

norepinephrine

Autonomic nervous system

two-neuron motor chain

preganglionic vs. postganglionic fibers

sympathetic

sympathetic chain ganglia

collateral ganglia

adrenergic

alpha (α)

excitatory response in effector organ

beta

β_1

excitatory

β_2

inhibitory

parasympathetic

- terminal ganglia
- cholinergic
  - nicotinic receptors
    - autonomic ganglia
  - muscarinic receptors
    - effector cells
    - atropine is selective muscarinic blocker

release of neurotransmitter by varicosities

dual innervation of most visceral organs

- sympathetic and parasympathetic tone
- sympathetic and parasympathetic dominance

control of autonomic activities

- spinal reflexes
  - urination, defecation, erection
- medulla
  - cardiovascular, respiratory, digestive centers
- hypothalamus
  - integration of autonomic, somatic, endocrine responses
- frontal cortex
  - emotional autonomic responses

Somatic nervous system

motor neurons act as final common pathway

end plate potential (EPP) is larger than EPSP, thus resulting in action potential

acetylcholinesterase

- short duration of ACh binding: ~10^{-9} sec

vulnerabilities of the NMJ

- black widow spider venom
  - causes explosive release of ACh
- botulinum toxin
  - blocks release of ACh (~10^{-4} mg is lethal)
- curare
  - competitively binds with ACh receptor
- organophosphates
  - irreversibly inhibit AChE

The Endocrine System

Intercellular chemical messengers

target cells

paracrines

- histamine

neurotransmitters

- acetylcholine

hormones

- T_3 and T_4

neurohormones

- GnRH

General principles

specificity of communication depends on specialization of target-cell receptors

complementarity of endocrine and nervous systems

- type of chemical messenger
- distance of action of chemical messenger
- means of specificity
- anatomic arrangement
  - “wired” vs. “wireless”

major functions

regulation of organic metabolism, water and electrolyte balance

inducing adaptive changes to stress

promoting smooth, sequential growth and development

controlling reproduction

regulating red blood cell production

along with ANS, controlling and integrating circulation, digestion

speed of response

fast vs. slow

duration of action

Hormones

Not a Complete Listing of Hormones		
Organ		**Hormone(s)**
hypothalamus		releasing hormones: TRH, CRH, GnRH, GHRH, PRH, PIH
posterior pituitary		antidiuretic hormone (vasopressin)
		oxytocin
anterior pituitary		thyroid-stimulating hormone (TSH)
		adrenocorticotropic hormone (ACTH)
		growth hormone (GH)
		follicle-stimulating hormone (FSH)
		luteinizing hormone (LH)
		prolactin
thyroid gland	follicular cells	tetraiodothyronine (T_4)
		triiodothyronine (T_3)
	C cells	calcitonin

adrenal cortex	aldosterone
	cortisol
	androgens (esp. DHEA)
adrenal medulla	epinephrine
	norepinephrine
endocrine pancreas (islets of Langerhans)	insulin β cells
	glucagon α cells
parathyroid	parathormone
testis	testosterone
	inhibin
ovary	estrogen
	progesterone
	inhibin
pineal gland	melatonin
placenta	estrogen
	progesterone
	chorionic gonadotropin (hCG)
	chorionic somatomammotropin (hCS)
kidney	renin
	erythropoietin
stomach	gastrin
duodenum	secretin
	cholecystokinin
	gastric inhibitory polypeptide (GIP)
liver	somatomedins
skin	vitamin D
thymus	thymosin
heart	atrial natriuretic hormone

Hormonal types

- peptides
- amines
    - derived from the amino acid tyrosine
    - catecholamines
- thyroid hormones
- steroids
- behavior
    - hydrophilic vs. hydrophobic
    - lipophobic vs. lipophilic
- mechanisms of synthesis
    - peptide hormones
    - steroid hormones
        - cholesterol
    - amines
- transport

Modes of action

postreceptor events

- hydrophilic hormones
    - intracellular second messenger
        - cAMP
        - adenylate cyclase

lipophilic hormones

gene activation

hormone levels are regulated by changes in secretion rate

negative feedback

output of a system opposes a change in input

neuroendocrine reflexes

diurnal or circadian rhythms

response of target cell can be regulated by altering number of receptors

abnormal

testicular feminization syndrome

normal

down regulation

permissiveness

one hormone enhances responsiveness to another

synergism

FSH + testosterone

antagonism

progesterone and estrogen during pregnancy