Anat 125

Human Anatomy

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Human Anatomy
with Laboratory Exercises

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Section 1 – Cells, Epithelial and Connective Tissues, and Skin

Cellular Anatomy

Plasma membrane

- composed of a phospholipid bilayer and various proteins
- act to enclose cell and regulate passage of substances
- membrane permeability depends on integral and carrier proteins, lipid solubility, molecular size and ionic charge

Cilia

- extensions of cytoplasm containing microtubules
- secrete mucous and move

Microvilli

- plasma membrane specializations that increase surface area

Membranous Organelles

All of the material inside of the cell except for the **nucleus** is called the **cytoplasm**. The membranous organelles include the mitochondria, nucleus, endoplasmic reticulum, Golgi complex, lysosomes, and peroxisomes. The **cytosol** is the cytoplasm minus the **membranous organelles.**

Cytoplasm

- All of the material inside of the cell except for the nucleus; includes 80% to 90% water plus various electrolytes

Mitochondria

- composed of double phospholipid bilayers forming an outer membrane and an inner membrane
- Much of the inner membrane forms deep folds called **cristae**)
- site for cellular energy production

Nucleus

- bounded by a double walled membrane with pores
- contain Chromatin - protein and DNA
- contains the Nucleolus - protein and RNA

Endoplasmic reticulum (ER)

- consists of interconnected membranes, and tubules between the membranes, that connect to the nucleus
- act as transportation pathways and storage sites
- Rough ER - ribosomes on membranes, synthesize proteins
- Smooth ER - no ribosomes, synthesize lipids

Golgi apparatus

- consists of membranous sacs continuous with ER
- acts in cellular secretion thru production of Vesicles, synthesize carbohydrate compounds

Lysosomes

- vesicles containing digestive enzymes, common in phagocytic cells
- digest cellular debris and pathogens

Peroxisomes

- vesicles containing enzymes that produce and breakdown hydrogen peroxide
- oxidize cellular debris and pathogens

Non-Membranous Organelles

The non-membranous organelles are of course the molecular clusters in the cell that are not bounded by phospholipid bilayers. These include the ribosomes, the cytoskeleton, and other structures such as the centrioles.

Ribosomes

- free of or attached to ER; composed of protein and RNA
- Site for building proteins using messenger and transfer RNA

Fibrils and Microtubules

- act as a cytoskeleton
- Fibrils are specialized in muscle for contraction (Myofibrils)
- Microtubules transport macromolecules

Centrioles

- 9 evenly spaced bundles of 3 microtubules per bundle
- act in separation of chromatids during cell division

Cell Cycle and Mitosis

Interphase: G - between cell division

- centrioles replicate
- S1 - DNA replicates
- G2 - enzymes and other proteins synthesized

Mitosis - cell division

Prophase - chromatin material condenses as chromosomes

Metaphase - chromosomes line up

Anaphase - chromatids of each chromosome separate

Telophase - cytokinesis occurs (cells splits in two)

Cellular Anatomy - Laboratory

Model of Cell

Plasma membrane • Cytoplasm • Lipid Bilayer • Cilia • Microvilli	
Membranous Organelles • Cytoplasm • Mitochondria • Nucleus • Endoplasmic reticulum (ER) • Golgi apparatus • Vesicles • Lysosomes • Peroxisomes	
Non-membranous Organelles • Ribosomes • Fibrils and Microtubules • Centrioles	

Mitosis

<table>
<tr><td>Interphase</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Mitosis

• Prophase
• Metaphase
• Anaphase
• Telophase</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
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Tissues

Clusters of similar cells are referred to as tissues. Although there are probably as least two hundred different types of tissues, four major categories of tissues are commonly discussed. These categories include epithelial, connective, muscle and nervous tissues and are summarized in the accompanying table on the next page.

Epithelial Tissues

Epithelial tissues are composed of cells tightly bonded together by glycoprotein deposits, desmosomes, and tight junctions.

- Anatomically, epithelial tissues are avascular (do not contain blood vessels), are connected to underlying tissue by a basement membrane, and contain germinative cells (cells that undergo mitosis).
- Functionally, epithelial tissues act as a **barrier**, line body cavities or other openings, and produce secretions (function as glands).

Connective Tissues

Connective tissues are composed of widely separated secretory cells and of the substances secreted from these cells (the matrix).

- Anatomically, connective tissues are vascular and contain fibers composed mainly of protein and/or contain a gelatin like substance (ground substance).
- Functionally, connective tissues provide **structure**, support and protection.

Muscle Tissues

Muscle tissues are composed of cells with large quantities of actin and myosin.

- Anatomically, muscle tissues are vascular and cells vary from long and spaghetti shaped to short and spindle shaped.
- Functionally, muscle tissues are specialized to contract and provide **movement**.

Nervous Tissues

Nervous tissue is composed of intermingling neurons and glial cells.

- Anatomically, nervous tissue is vascularly isolated and cells vary from long, stringy and branched to short and compact.
- Functionally, nervous tissue is specialized to **process** and transmit signals.

Summary of the four major categories of tissues

Tissue	Cell Structure	Vasculature	Function
Epithelial	small cells tightly bonded together	no blood vessels	act as a **barrier** and produce **secretions**
Connective	small cells widely separated and surrounded by secreted substances	blood vessels intermingle with cells	provide **structure**, **support** and protection
Muscle	vary from long and spaghetti shaped to short and spindle shaped	blood vessels intermingle with cells	**contract** and provide **movement**
Nervous	vary from long, stringy and branched to short and compact	blood vessels are isolated from neurons	**process** and **transmit** signals

Epithelial Tissues

General Function and Anatomical Features

- act as a barrier
- produce secretions (function as glands)
- line body cavities, tubes; cover organs
- contain Germinative cells (cells that undergo mitosis)
- connected to underlying tissue by a Basement Membrane
- are Avascular (do not contain blood vessels)
- cells are tightly bonded together by Glycoprotein deposits, Desmosomes, Tight Junctions

Classification of Epithelial Tissues and Cells

- single layered (Simple and Pseudostratified)
- multilayered (Stratified, Transitional)
- flat (Squamous), cube-like (Cuboidal), tall (Columnar), oval (seen in Transitional Epithelium)

Simple Epithelia

Simple Squamous

- cover visceral organs, line body cavities
- permit diffusion and filtration (easiest to pass through)

Simple Cuboidal

- line exocrine glands, ducts, renal tubules, cover ovaries
- permit secretion*, excretion, or absorption

Simple Columnar

- line digestive tract
- provide protection, permit absorption and secretion*

Non-Simple Epithelia

Pseudostratified Ciliated Columnar

- line respiratory airways
- provide protection, permit secretion*, ciliary movement (sweep away debris)

Stratified Squamous

- epidermis of skin (keratinized), ends of GI tract (non-keratinized)
- provide protection

Transitional

- line ureter and bladder
- permit distension

Glandular Epithelia

Unicellular Glands - single columnar cells - Goblet cells

Multicellular Glands - comprised of simple cuboidal epithelia

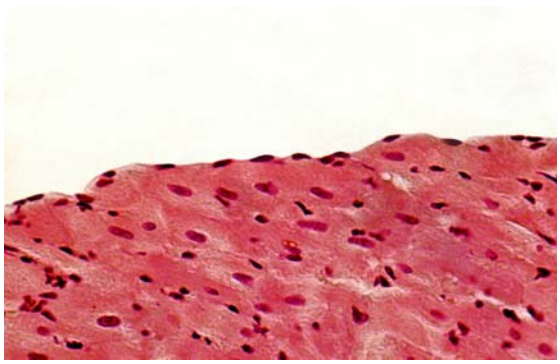
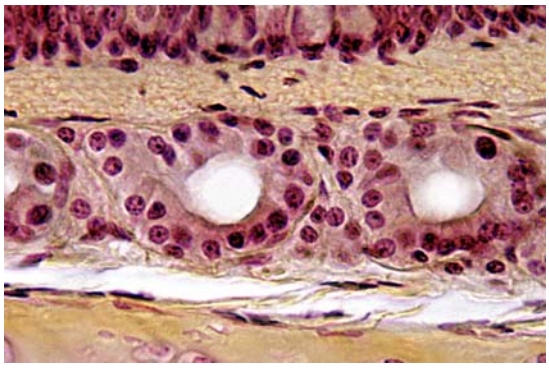
- Tubular glands - secretory portion tubular
- Acinar glands - secretory portion enlarged (bulb-like)
- Simple - ducts do not branch (intestine, stomach, skin)
- Compound - ducts branch (mammary, salivary, pancreas)

Glandular Secretion

- Holocrine – whole cell discharged (sebaceous glands of skin)
- Apocrine - membrane pinches off (mammary glands and apocrine sweat glands)
- Merocrine - transmembrane secretion (salivary glands, pancreatic glands, and merocrine sweat glands)

Epithelial Tissues - Laboratory

Histology of Simple Epithelial Tissues

Simple Squamous Epithelium	
Simple Cuboidal Epithelium	
Simple Columnar Epithelium	

Histology of Non-Simple Epithelial Tissues

Pseudostratified Ciliated Columnar Epithelium	
Stratified Squamous Epithelium	
Transitional Epithelium	

Histology of Glandular Epithelial Tissues

Unicellular glands • Goblet cells		
Multicellular Glands • Merocrine sweat gland • Sebaceous gland		

Connective Tissues

General Function and Anatomical Features

- provide structure, support and protection
- serve in transport
- consist of specialized secretory cells and of substances secreted from these cells (the Matrix)
- contain fibers composed mainly of Protein
- contain a gelatin like substance (Ground Substance)

Fibrous Connective Tissues

Matrix produced by Fibroblasts

Areolar Connective Tissue

- fine collagen fibers
- Mast cells
- around nerves and vessels
- between muscles, in skin, binds organs, holds tissues
- permit diffusion

Dense Regular Connective Tissues

- thick collagen fibers
- in tendons, ligaments
- provides strong support in longitudinal direction

Dense Irregular Connective Tissues

- thick collagen fibers
- in skin, fibrous capsules of organs and joints
- provides strong support in all directions

Cartilage Tissues

matrix produced by Chondrocytes

Hyaline Cartilage

- thick gelatin matrix
- in joint surfaces of bones, nose, respiratory airways
- provides flexible support
- is a precursor to bone

Osseous Tissues

Matrix produced by Osteoblasts - Osteocytes

Bone

- calcium phosphate deposits and collagen fibers
- in skeleton
- provides rigid support
- mineral metabolism

Adipose Tissue

Composed of Adipocytes that accumulate lipids

- store fat droplets
- under skin, around heart, kidneys, eyeballs, joints
- provides protection, stores fat, insulates

Connective Tissues - Laboratory

Histology of Connective tissues

Areolar Connective Tissue • Fibroblasts • fine Collagen fibers • Elastic fibers • Mast cells	
Dense Irregular Connective Tissue • Fibroblasts • thick Collagen fibers	
Dense Regular Connective Tissue • Fibroblasts • thick Collagen fibers	

Elastic Connective Tissue • Fibroblasts • Elastic Fibers	
Hyaline Cartilage • Chondrocytes • Chondroitin Sulfate	
Osseous Tissue • Osteocytes • Calcium Phosphate • Collagen fibers	
Adipose Tissue • Adipocytes • Lipids	

Muscle and Nervous Tissues

Muscle Tissues

General Function

- cells are specialized to contract
- (Anatomical Features and Organization of Muscle Tissues are considered with the Muscular System)

Nervous Tissues

General Function

- cells are specialized to transmit signals
- (Anatomical features and Organization of Nervous Tissues are considered with the Nervous System)

Integumentary System

Layers of the Integument

Epidermis

- composed of Stratified-Squamous-Epithelium connected by a Basement-Membrane
- functions to control skin-permeability, provide a barrier to pathogens, and to synthesize vitamin-D.

Stratum-Corneum - dead cell residue and Keratin – TOP stratum

Stratum-Lucidum - organelles completely disappear

Stratum-Granulosum - keratinization begins here and organelles begin to disappear

Stratum-Spinosum - cells attached by spine like projections

Stratum-Basale (Germinativum) – Cells are cuboidal and mitotically active - BOTTOM

Dermis

- functions to nourish epidermis, restrict and destroy pathogens, store lipids, attach skin to underlying tissue, provide for sensory-detection, assist in thermoregulation by way of blood vessels.

Papillary-Layer

- composed of Areolar-Connective-Tissue
- contain many Blood-Capillaries and Lymphatic-vessel
- contain Meissner's-Corpuscles for detecting light-touch

Reticular-Layer

- composed of Dense-Irregular-Connective-Tissue
- contain Blood-Vessels, Lymph-Nodes and Lymphatic-Vessel
- contain Pacinian-Corpuscles for detecting deep-pressure

Hypodermis (Subcutaneous-Layer)

- composed of Adipose-Tissue
- functions to provide cushioning and storage of fat.
- contains loose connective tissue and blood vessels.

Skin Thickness

Thick-skin

- stratum lucidum - *distinct*
- stratum corneum - *thick*
- papillay layer - *thin*

Thin-skin

- stratum lucidum - *absent*
- stratum corneum - *thin*
- papillay layer - *distinct*

Epidermal-Derivatives (Accessory Structures)

Hair-Follicles

- are formed by invagination from the epidermis
- function to protect skull and to assist in sensory detection.

Papilla - connective tissue

Matrix - epithelial cells that are mitotically active and similar to stratum germinativum

- functions to provide growth of Hair

Hair-Shaft and Root - exposed and deep portions of hair

Arrector-Pili-Muscles

- Smooth-Muscle connecting to hair follicle
- Function to straighten hair.

Sebaceous-Glands (Oil-Glands)

- associated with hair follicles
- secrete sebum (mainly a lipid) into hair follicles, function to lubricate and protect hair shaft and surrounding skin
- anatomically are simple-branched-acinar-glands
- functionally are Holocrine-Glands (secrete via whole cell secretion)

Sudoriferous-Glands (Sweat-Glands)

Merocrine-(Eccrine)-Sweat-Glands - associated with epidermis

- Secrete sweat onto surface of epidermis, widely distributed throughout the body, function to excrete salts, water, and organic-wastes.
- anatomically are simple-coiled-tubular-glands
- functionally are Merocrine-Glands (secrete via transmembrane transport)

Apocrine-Sweat-Glands - associated with hair follicles

- secrete into hair follicle, most common in axillary and pubic region, function to provide an odorous secretion.
- anatomically are simple-coiled-tubular-glands
- functionally are Apocrine-Glands (secrete via membrane pinching)
- (Mammary-Glands are specialized apocrine sweat glands)

Integumentary System - Laboratory

Model of Skin

Epidermis • Stratum Corneum • Stratum Lucidum • Stratum Granulosum • Stratum Spinosum • Stratum Germinativum	
Dermis • Papillary Layer • Reticular Layer • Tactile (Meissner's) Corpuscle • Sebaceous glands • Merocrine sweat glands	
Hypodermis • Lamellated (Pacinian) corpuscle	

Hair Follicles • Papilla • Matrix • Hair • Arrector Pili muscle	

Histology of Skin

Thick Skin

Epidermis • Stratum Corneum • Stratum Lucidum • Stratum Granulosum • Stratum Spinosum • Stratum Germinativum	
Dermis • Reticular Layer • Merocrine sweat glands	

Hypodermis	

Thin Skin / Scalp

Epidermis • Stratum Corneum • Stratum Granulosum • Stratum Germinativum	
Dermis • Papillary Layer • Reticular Layer • Sebaceous glands • Merocrine sweat glands	

Hypodermis	

Hair Follicles • Papilla • Matrix • Hair	

Cutaneous receptors

• Tactile (Meissner's) Corpuscle • Lamellated (Pacinian) corpuscle	

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Practice Questions – Cells, Tissues, and Skin

For matching questions, choices may be used more then once or not at all.

1-5. Matching

A)	Nucleus	transport synthesized substances throughout the cell	1) _____
B)	Ribosomes	package synthesized substances for secretion	2) _____
C)	Mitochondria	produce ATP from glucose and fatty acids	3) _____
D)	Golgi Apparatus	site for protein synthesis in the cytoplasm	4) _____
E)	Endoplasmic Reticulum	contains the genetic DNA code	5) _____

6-10. Matching

A)	surfaces of cell membrane	hydrophilic	6) _____
B)	inside of cell membrane	hydrophobic	7) _____
C)	none of the above	contains lipids	8) _____
D)		contains receptors	9) _____
E)		contains phosphate groups	10) _____

11-15. Matching

A)	connective tissue cells	have membranes	11) _____
B)	epithelial cells	cells secrete a matrix material	12) _____
C)	muscle cells	cells are specialized to shorten	13) _____
D)	neurons	cells are tightly connected together	14) _____
E)	all of the above	cells are specialized to conduct signals	15) _____

16-20. Matching

A)	Transitional Epithelium	line exocrine glands, ducts, renal tubules	16) _____
B)	Simple Cuboidal Epithelium	line body cavities and blood vessels	17) _____
C)	Simple Columnar Epithelium	line respiratory airways	18) _____
D)	Simple Squamous Epithelium	line ureter and bladder	19) _____
E)	Pseudostratified Ciliated Columnar Epithelium	line digestive tract	20) _____

21-25. Matching

A)	Pseudostratified Ciliated Columnar Epithelium	sweep away debris	21) _____
B)	Stratified Squamous Epithelium	provide(s) a barrier	22) _____
C)	Simple Squamous Epithelium	often found in glands	23) _____
D)	Simple Cuboidal Epithelium	easiest to diffuse through	24) _____
E)	All of the above	found in skin and esophagus	25) _____

26-30. Matching

A)	dense regular connective tissue	accumulates lipids	26) _____
B)	loose connective tissue	contains chondroitin	27) _____
C)	hyaline cartilage	contains calcium phosphate	28) _____
D)	adipose tissue	contains mainly collagen protein fibers	29) _____
E)	none of the above	contains elastin and collagen protein fibers	30) _____

31-35. Matching

A)	Fibroblasts	found in Fibrous Connective Tissue	31) _____
B)	Adipocytes	found in Hyaline cartilage	32) _____
C)	Osteocytes / osteoblasts	found in Adipose Tissue	33) _____
D)	Chondrocytes / chondroblasts	found in Osseous Tissue	34) _____
		found in hypodermis	35) _____

36-40. Matching

A)	Fibroblasts	found in papillary layer of the dermis	36) _____
B)	Adipocytes	produce mainly collagen fibers	37) _____
C)	Osteocytes / osteoblasts	produce chondroitin sulfate	38) _____
D)	Chondrocytes / chondroblasts	produce calcium phosphate	39) _____
E)		found in the hypodermis	40) _____

41-45. Matching

A)	dense irregular connective tissue	often called "fat"	41) _____
B)	loose connective tissue	contains elastic fibers	42) _____
C)	hyaline cartilage	often found under loose CT	43) _____
D)	adipose tissue	found under most epithelium	44) _____
		found at end of joints and in trachea	45) _____

46-50. Matching

A)	thin skin	epidermis is thin	46) _____
B)	thick skin	epidermis is thick	47) _____
C)	none of the above	often contains hair follicles	48) _____
		Loose connective tissue layer of dermis is thin	49) _____
		Loose connective tissue layer of dermis is thick	50) _____

51-55. Matching

A)	Stratum Lucidum	composed of dead cells filled with Keratin	51) _____
B)	Stratum Corneum	contains cells that are cuboidal in shape	52) _____
C)	Stratum Spinosum	contains cells that are ‘growing’	53) _____
D)	Stratum Granulosum	nuclei and organelles disappear	54) _____
E)	Stratum Germinativum	keratohyalin is formed here	55) _____

56-60. Matching

A)	Papillary layer of Dermis	origin of hair follicles	56) _____
B)	Reticular layer of Dermis	contains blood vessels	57) _____
C)	Hypodermis	composed of adipose tissue	58) _____
D)	Epidermis	composed of stratified squamous epithelium	59) _____
E)	A, B and C	composed of loose (areolar) connective tissue	60) _____

61-65. Matching

A)	merocrine sweat glands	secrete into hair follicles	61) _____
B)	sebaceous glands	anatomically are bulb-like glands	62) _____
C)	hair follicles	secrete sweat onto surface of epidermis	63) _____
D)	A and B	are a continuation of the 'epidermis' into the dermis	64) _____
E)	none of the above	anatomically are simple coiled tubular glands	65) _____

Section 2 –Osseous Tissue, Bone, and the Skeleton

Osseous Tissue and Bone

General organization of bone

Diaphysis

- the shaft of a bone
- composed mainly of dense bone

Epiphysis

- the heads of a bone
- composed mainly of spongy bone

Articular Cartilage

- covering at end of the epiphysis
- composed of: Hyaline cartilage

Marrow Cavity

- open interior of a bone
- lined by the endosteum

Endosteum

- lining of the marrow cavity
- composed of: an epithelial cellular layer with Osteoblasts and Osteoclasts

Bone Marrow

- adipose tissue and hemopoietic tissue (blood cells) in marrow cavity

Periosteum

- covering around the outside of a bone
- composed of: Dense Irregular (Fibrous) Connective Tissue

Joint Capsule

- continuation of the periosteum around a joint

Ligaments

- continuation of the periosteum that connects bone to bone
- composed of dense regular connective tissue

Tendons

- continuation of the periosteum that connects bone to muscle
- composed of dense regular connective tissue

Dense (Compact) Bone

located mainly in the diaphysis of a bone

Osteon (Haversian System)

- basic unit of organization with a CentralCanal (Haversian Canal) for passage of blood vessels

Lamellae - circularly arranged layers of bone matrix

Interstitial Lamellae - bone matrix between the lamellae

Lacunae - the spaces in the bone matrix for the osteocytes

Osteocytes - the bone cells in the lacunae

Canaliculi - the channels in the bone matrix

Periosteum

- covering around the outside of a bone
- composed of: Dense Irregular (Fibrous) Connective Tissue

Spongy (Cancellous) Bone

located mainly in the heads of bone and near the marrow cavity

Trabeculae

- basic unit of organization, somewhat like an osteon

Lacunae

Osteocytes

Endosteum

- lining inside a bone (marrow cavity)
- composed of: an epithelial cellular layer with:

Simple Squamous Epithelial cells - act as a barrier

Osteoblasts - cells responsible for producing new bone matrix

Osteoclasts - cells responsible for destroying old bone matrix

Cartilage (hyaline)

the major precursor for most bone (also covers epiphysis at joints)

a connective tissue composed of a matrix made of chondroitin sulfate

Lacunae - spaces within the cartilage matrix

Chondrocytes - the cartilage producing cells in the lacunae

Perichondrium

- covering around cartilage
- composed largely of: Dense Irregular (Fibrous) Connective Tissue

Osseous Tissue and Bone - Laboratory

Bone Sectioned

Long Bone • Diaphysis • Epiphysis • Epiphyseal line • Marrow cavity • Periosteum • Endosteum	

Model of Bone

Compact Bone • Volksmann's canals (perforating canals) • Osteons • Haversian canals (central canals) • Calcium phosphate matrix • Lacunae • Osteocytes • Lamellae • Canaliculi • Interstitial lamellae • Periosteal plates	

Spongy Bone • Trabeculae • Lacunae • Osteocytes • Marrow Cavity • Endosteum	

Histology of Bone and related structures

Compact Bone • Osteons • central canals • Calcium phosphate matrix • Osteocytes in Lacunae • Lamellae • Canaliculi	
Spongy Bone • Trabeculae • Osteocytes in Lacunae • Marrow Cavity • Endosteum • Simple Squamous Epithelial cells • Osteoblasts • Osteoclasts • Hyaline cartilage • Epiphyseal plate	

Cartilage • Perichondrium • Cartilage matrix • Chondrocytes in Lacunae	

Ligaments and Tendons
 	
• Dense regular connective tissue
  • Fibroblasts
  • Collagen fibers	

Skeletal Organization, Bone, and Skull Markings

Organization of skeleton

Axial Skeleton

- Skull
- Hyoid bone
- Vertebrae
- Ribs and Sternum

Appendicular Skeleton

Upper Appendicular

- Shoulder girdle - clavicle and scapula
- Arms - humerus, ulna, radius
- Hands and Fingers - carpals, metacarpals, phalanges

Lower Appendicular

- Pelvic girdle - coxa
- Thighs - femur
- Legs - tibia and fibula
- Feet and Toes - tarsals, metatarsals, phalanges

Shapes of bones

Flat bone - flat, such as bones of the roof of the skull

Sutural bones - grow between flat bones of skull

Irregular bone - complex, such as vertebrae

Long bone - long, such as bones of the limbs

Short bone - boxy, such as bones of the wrist and ankles

Sesamoid bone - develop inside tendons, such as knee cap

Bone Markings

- projections or elevations where tendons and ligaments attach
- perforations or depressions where blood vessels and nerves pass

general

Process - any projection or bump

Ramus - an extension making an angle

attachments for tendons or ligaments

Trochanter - large, rough projection

Tuberosity - smaller, rough projection

Tubercle - small, round projection

Crest - prominent ridge

Line - low ridge

for joints

Head - expanded articular end

Condyle - smooth, rounded articular process

Trochlea - smooth, grooved articular process

Facet - small, flat articular process

Spine - pointed process

depressions

Fossa - shallow depression

Sulcus - narrow grove

openings

Foramen - rounded passageway

Fissure - cleft

Meatus - canal

Sinus – chamber

Features and Foramen of the Skull

Occipital Bone

- Occipital Condyles – joint surfaces for articulating with the first cervical vertebra (C1)
- Foramen Magnum (for medulla/spinal column; vertebral artreries)
- Jugular Foramen (for vagus and glossopharyngeal nerves; internal jugular veins)
- Hypoglossal Canal (for hypoglossal nerve)

Parietal bones

- Lambdoidal Suture – joint between the parietal bones and the occipital bone
- Sagittal Suture – joint between the parietal bones
- Coronal Suture – joint between the parietal bones and the frontal bone

Frontal Bone

- Orbit – the eye socket
- Frontal Sinus – marrow cavities in the frontal bone
- Supraorbital Foramen (for supraorbital nerve, sensory branch of ophthalmic nerve)

Maxillary Bone

- Maxillary Sinus – marrow cavities of the maxillary bones
- Infraorbital Foramen (for infraorbital nerve, maxillary branch of trigeminal nerve)

Ethmoid Bone

- Crista Galli – anterior attachment site for the dura mater of the brain
- Cribriform Plate (for olfactory nerves)
- Superior and Middle Nasal Conchae – extensions of bone into the nasal cavity
- Perpendicular Plate – a sheet of bone that forms the superior part of the nasal septum

Vomer Bone – a sheet of bone that forms the inferior part of the nasal septum

Sphenoid Bone

- Sella Turcica – forms a protective barrier for the pituitary gland
- Optic Foramen (canal) (for optic nerve)
- Superior Orbital Fissure (for 3 cranial nerves to eye muscles)
- Foramen Rotundum (for maxillary branch of trigeminal nerve)
- Foramen Ovale (for mandibular branch of trigeminal nerve)
- Foramen Spinosum (for vessels to membranes around CNS)
- Sphenoid Sinus - marrow cavitiy of the sphenoid bone

Temporal Bone

- Squamous Suture – joint between the temporal bone and the parietal bone
- External Acoustic Meatus – external entry for the ear
- Internal Acoustic Meatus (for Vestibulocochlear nerve)
- Carotid Foramen (Canal) (for internal carotid artery)
- Foramen Lacerum (for internal carotid artery)
- Mandibular Fossa – joint surface for mandible
- Styloid Process – muscle attachment site
- Mastoid Process – muscle attachment site
- Stylomastoid Foramen (for facial nerve)

Mandible

- Coronoid Process – muscle attachment site
- Mandibular Condyles – joint surface for articulating with the temporal bone
- Mental Foramen (for mental nerve)
- Mandibular Foramen (for inferior alveolar nerve, sensory branch of mandibular nerve)

Skull – Laboratory

Occipital bone • Occipital Condyles • Foramen Magnum • Jugular Foramen • Hypoglossal Canal	
Parietal bones • Lambdoidal Suture • Sagittal Suture • Coronal Suture	
Frontal bone • Orbit • Frontal Sinuses • Supraorbital Foramen	
Nasal bones	

Maxillary bones (Maxilla) • Alveolar Processes • Maxillary Sinuses • Inferior Orbital Foramen	
Lacrimal bones	
Ethmoid bone • Crista Galli • Cribriform Plate • Superior and Middle Nasal Conchae • Perpendicular Plate	
Inferior nasal conchae	

Vomer bone • Nasal Septum (the vomer bone, the perpendicular plate of the ethmoid bone, and cartilage)	
Palatine bones	
Sphenoid bone • Lesser and Greater Wings • Sella Turcica • Optic Foramen (Canal) • Superior Orbital Fissure • Foramen Rotundum • Foramen Ovale • Foramen Spinosum • Sphenoid Sinus	

Zygomatic bones • Temporal Process (of Zygomatic Bone) • Zygomatic Process of Temporal Bone • Zygomatic Arch	
Temporal bones • Squamous Suture • External Acoustic Meatus (External Auditory Canal) • Internal Acoustic Meatus (Internal Auditory Canal) • Mastoid Process • Styloid Process • Stylomastoid Foramen • Mandibular Fossa • Carotid Foramen (Canal) • Foramen Lacerum	
Mandible • Ramus • Coronoid Process • Body • Angle • Condylar Processes (Mandibular Condyles) • Mandibular Foramen	

Features and Foramen of the Vertebrae

General Features

- Body – anterior weight bearing portion
- Vertebral foramen – central opening for spinal cord
- Spinal Processes – posterior muscle attachment sites
- Transverse Processes – lateral muscle attachment sites
- Pedicle – connects transverse processes to body
- Lamina – cconnects spinal processes to transverse processes
- Superior and Inferior Articular Processes – articulations between adjacent vertebrae posterior to bodies
- Intervertebral Discs – joint cushions between adjacent bodies
- Intervertebral foramen (for spinal nerves)

Cervical vertebrae (C1-C7)

- Transverse foramen (for vertebral arteries)
- C1 (Atlas)
- C2 (Axis)
- Odontoid process (Dens) – pivot on C2 for rotation of C1
- C7 (Vertebra Prominens) – pronounced spinal process

Thoracic vertebrae (T1-T12)

- Facets on transverse processes, T1-T10 – for joints with tubercle of ribs
- Facets / Demifacets on body, T1-T12 – for joints with head of ribs

Ribs

- Fixed ribs (1-10) – contain tubercle and head and articulate with thoracic T1-T10
- Floating ribs (11-12) – contain head only and articulate with thoracic T11-T12

Sternum

- Manubrium – articulates with the clavicle bones and with ribs 1 and 2
- Body – articulates with ribs 3-10
- Xiphoid process

Lumbar vertebrae (L1-L5)

Sacrum (S1-S4)

- Sacral canal – contains anterior and posterior roots from the spinal cord
- Sacral foramen (for spinal nerves)

Vertebrae - Laboratory

Specimens

General Features • Body • Pedicle • Lamina • Vertebral foramen • Spinal process • Transverse processes • Superior and Inferior Articular processes • Intervertebral foramen • Intervertebral discs	
Cervical vertebrae (C1-C7) • Transverse foramen • C1 (Atlas) • C2 (Axis) o Odontoid process (Dens) • C7 (Vertebra prominens)	
Thoracic vertebrae (T1-T12) • Facets (on transverse processes, T1-T10) [for tubercle of rib] • Facets / Demifacets (on body, T1-T12) [for head of rib]	

Ribs • Fixed ribs (1-10) • Floating ribs (11-12) • Tuberculum (Tubercle) (ribs 1-10) • Capitulum (Head) (ribs 1-12)	
Sternum • Manubrium • Body • Xiphoid process	
Lumbar vertebrae (L1-L5)	
Sacrum and Coccyx • Base and Apex • Sacral canal • Sacral foramen	

Articulations of the Upper Appendicular Skeleton

Clavicle

- Sternal end - articulates with manubrium of sternum
- Acromial end - articulates with acromion process of scapula

Scapula

- Acromion process - articulates with acromial end of clavicle
- Glenoid fossa (cavity) - articulates with head of humerus

Humerus

- Head - articulates with glenoid fossa of scapula
- Trochlea - articulates with trochlear notch of ulna
- Coronoid fossa - depression for coronoid process of ulna
- Olecranon fossa - depression for olecranon process of ulna
- Capitulum - articulates with head of radius

Ulna

- Trochlear notch - articulates with trochlea of humerus
- Coronoid process - articulates with coronoid fossa of humerus
- Olecranon process - articulates with olecranon fossa of humerus
- Head - articulates with Lunate bone of wrist

Radius

- Head of radius - articulates with capitulum of humerus
- Styloid process of radius - articulates with Scaphoid bone of wrist

Carpus

- Lunate - articulates with head of Ulna
- Scaphoid - articulates with styloid process of radius
- Trapezium - articulates with metacarpal I
- Trapezoid - articulates with metacarpal II
- Capitate - articulates with metacarpals III and IV
- Hamate - articulates with metacarpals IV and V

Metacarpals

- Metacarpals - articulate with Proximal Phalanges

Phalanges

- Digits (fingers)
- Proximal Phalanges - articulate with Middle Phalanges
- Middle Phalanges - articulate with Distal Phalanges
- Pollex (thumb)
- Proximal Phalanx - articulates with Distal Phalanx

Upper Appendicular Skeleton - Laboratory

Pectoral girdle

Clavicle • Sternal end • Acromial end	
Scapula • Superior border • Medial (vertebral) border • Lateral (axillary) border • Glenoid fossa (cavity) • Subscapular fossa • Coracoid process • Acromial process • Scapular spine • Supraspinous fossa • Infraspinous fossa	

Arm

Humerus • Head • Greater tubercle • Lesser tubercle • Shaft • Deltoid tuberosity • Trochlea • Capitulum • Coronoid fossa • Olecranon fossa	
Ulna • Trochlear notch • Olecranon • Coronoid process • Radial notch • Head of ulna • Styloid process of ulna	
Radius • Head of radius • Neck of radius • Radial tuberosity • Styloid process of radius	

Wrist and Hand

Carpus • Lunate • Scaphoid • Trapezium • Trapezoid • Capitate • Hamate • Triquetrum • Pisiform	
Hand • Metacarpals - 1 thru 5 • Phalanges - 1 thru 5 • fingers - Digits o Proximal, Middle, and Distal Phalanges • thumb - Pollex o Proximal and Distal Phalanges	

Articulations of the Lower Appendicular Skeleton

Ilium

- Sacroiliac Joint - articulates with sacrum

Pubis

- Pubic tubercle - articulates with Inguinal Ligament
- Pubic Symphysis – medial surface articulates with pubis on opposite side

Coxa

- Acetabulum - articulates with head of femur

Femur

- Head - articulates with acetabulum of coxa
- Lateral and Medial Condyles - articulate with lateral and medial condyles of tibia
- Intercondylar Fossa - depression for Intercondylar eminence of tibia

Tibia

- Lateral and Medial Condyles - articulate with lateral and medial condyles of femur
- Intercondylar Eminence - articulates with the Intercondylar fossa of the femur
- Margin of Lateral Condyle - articulates with head of the fibula
- Medial Malleolus - articulates with Talus bone of ankle

Fibula

- Head of Fibula - articulates with Margin of Lateral Condyle of tibia
- Lateral Malleolus - articulates with talus bone of ankle

Tarsus

Talus - articulates with medial malleolus of tibia and lateral, malleolus of fibula - articulates with Calcaneus

Calcaneus - articulates with Navicular and Cuboid

Navicular - articulates with Cuneiforms

Cuneiforms I-III - articulate with Metatarsals I-III

Cuboid - articulates with Metatarsals IV-V

Metatarsals

Metatarsals - articulate with Proximal Phalanges

Phalanges

Digits (little toes)

Proximal Phalanges - articulate with Middle Phalanges

Middle Phalanges - articulate with Distal Phalanges

Hallux (big toe)

Proximal Phalanx - articulates with Distal Phalanx

Lower Appendicular Skeleton - Laboratory

Coxa

Ilium • Anterior inferior iliac spine • Anterior superior iliac spine • Iliac crest • Posterior superior iliac spine • Posterior inferior iliac spine • Greater sciatic notch	
Ischium • Ischial spine • Lesser sciatic notch • Ischial tuberosity • Ischial ramus	
Pubis • Inferior ramus • Pubic body • Pubic Symphysis • Superior ramus	

Coxa • Acetabulum • Obturator foramen • Sacroiliac joint	

Leg

Femur • Head • Neck • Greater trochanter • Lesser trochanter • Gluteal tuberosity (tubercle) • Linea aspera • Lateral condyle • Medial condyle • Intercondylar fossa • Lateral epicondyle • Medial epicondyle	
Patella	
Tibia • Lateral condyle • Medial condyle • Intercondylar eminence • Tibial tuberosity • Anterior crest • Medial malleolus	

Fibula • Head of fibula • Lateral malleolus	

Ankle and Foot

Tarsus • Talus • Calcaneus • Navicular • 1st Cuneiform • 2nd Cuneiform • 3rd Cuneiform • Cuboid	
Foot • Metatarsals - 1 thru 5 • Phalanges - 1 thru 5 • Little toes - Digits o Proximal, Middle, and Distal Phalanges • big toe - Hallux o Proximal and Distal Phalanges	

Joints and Movement

Classification of Joints

Synarthroses - no movement

- Suture - example: skull

Amphiarthroses - little movement

- Symphysis - example: between vertebrae, os coxae

Diarthroses - free movement

- Synovial joint

Structure of a synovial joint

Articular cartilage - hyaline cartilage without perichondrium

Synovial membrane - lines joint cavity

Joint (articular) capsule - continuation of the periosteum that surrounds a joint

Synovial fluid - lubricates joint

Menisci - fibrocartilage pads between articular surfaces

Fat pads - around edges of joint

Accessory ligaments - localized thickenings of joint capsule

- Extracapsular ligaments - continuations of the periosteum exterior to a joint
- Intracapsular ligaments - continuations of the periosteum in the interior of a joint

Bursae - pockets of synovial fluid around tendons and ligaments

Shoulder joint

Glenohumeral ligament - glenoid fossa to head of humerus

Coracohumeral ligament - coracoid process of scapula to humerus

Coracoacromial ligament - coracoid process to acromial process

Coracoclavicular ligament - coracoid process to clavicle

Glenoid labrum - articular cartilage covering glenoid fossa)

Subacromial, Subcoracoid, and Subdeltoid bursae

Hip joint

Ileofemoral, Pubofemoral, and Ischiofemoral ligaments

Ligamentum teres (an intracapsular ligament)

Knee joint

Patellar and Popliteal ligaments

Tibial and Fibular Collateral ligaments

Anterior and Posterior Cruciate ligaments (intracapsular ligaments)

Medial and Lateral menisci

Practice Questions – Osseous Tissue, Bone, and the Skeleton

Note: choices may be used more then once or not at all.

1-5. Matching

A)	spongy (cancellous) bone	bone that is relatively solid	1) _____
B)	compact (dense) bone	layer that lines the marrow cavities	2) _____
C)	periosteum	composed of fibrous connective tissue	3) _____
D)	endosteum	bone that is a network with many spaces	4) _____
E)	none of the above	major component of the epiphyses of bones	5) _____

6-10. Matching

A)	Osteocytes	these cells are found throughout compact and spongy bone	6) _____
B)	Osteoclasts	are the cells responsible for producing new bone	7) _____
C)	Osteoblasts	are the cells found in fibrous connective tissue	8) _____
D)	Chondrocytes	are the cells responsible for destroying bone	9) _____
E)	none of the above	are the cells found in cartilage	10) _____

11-15. Matching

A)	Diaphysis	composed of adipose tissue and blood tissue	11) _____
B)	Epiphysis	near the joint end of a long bone	12) _____
C)	Bone Marrow	found in spaces of spongy bone	13) _____
D)	none of the above	found in the medullary cavity	14) _____
		often referred to as the shaft	15) _____

16-20. Matching

A)	Diaphysis	composed of hemopoetic tissue	16) _____
B)	Epiphysis	composed mainly of spongy bone	17) _____
C)	Bone Marrow	composed mainly of dense bone	18) _____
D)	none of the above	means "from end to end"	19) _____
		means "around the end"	20) _____

21-25. Matching

A)	Periosteum	connects bone to bone	21) _____
B)	Endosteum	contains osteoblasts and osteoclasts	22) _____
C)	Ligaments	covering around the outside of a bone	23) _____
D)	none of the above	composed of dense regular fibrous connective tissue	24) _____
		composed of dense irregular fibrous connective tissue	25) _____

26-30. Matching

A)	sagittal suture	connects parietal to temporal	26) _____
B)	coronal suture	connects parietal to sphenoid	27) _____
C)	squamous suture	connects parietal to occipital	28) _____
D)	lambdoidal suture	connects parietal to parietal	29) _____
E)	none of the above	connects parietal to frontal	30) _____

31-35. Matching

A)	occipital bone	contains the optic foramen	31) _____
B)	temporal bones	contains the foramen magnum	32) _____
C)	sphenoid bone	contains the external auditory canal	33) _____
D)	ethmoid bone	forms a major part of the floor of the nose	34) _____
E)	maxilla	contains the Crista Galli and Perpendicular Plate	35) _____

36-40. Matching

A)	forms part of nasal septum	vomer bone	36) _____
B)	forms part of nasal cavity	frontal bone	37) _____
C)	contains sella turcica	sphenoid bone	38) _____
D)	forms part of orbit	conchae of Ethmoid bone	39) _____
E)	C and D	perpendicular plate of Ethmoid bone	40) _____

41-45. Matching

A)	forms posterior part of orbit (eye socket)	vomer bone	41) _____
B)	forms inferior part of orbit (eye socket)	sphenoid bone	42) _____
C)	forms part of nasal septum	maxillary bone	43) _____
D)	contains sella turcica	zygomatic bone	44) _____
E)	B and D	perpendicular plate of Ethmoid bone	45) _____

46-50. Matching

A)	foramen ovale	for nerves for eye movement	46) _____
B)	optic foramen	for trigeminal nerve	47) _____
C)	jugular foramen	for jugular veins	48) _____
D)	foramen magnum	for optic nerve	49) _____
E)	superior orbital fissure	for spinal cord	50) _____

51-55. Matching

A)	carotid foramen	for nerves for eye movement	51) _____
B)	jugular foramen	for the carotid artery	52) _____
C)	foramen magnum	for auditory nerve	53) _____
D)	internal auditory canal	for jugular vein	54) _____
E)	superior orbital fissure	for spinal cord	55) _____

56-60. Matching

A)	1st cervical vertebra	connects to sacrum	56) _____
B)	5th lumbar vertebra	connects to maxilla	57) _____
C)	Ethmoid bone	connects to frontal bone	58) _____
D)	Vomer bone	connects to occipital bone	59) _____
E)	Mandible	connects to temporal bone	60) _____

61-65. Matching

A)	ribs 1-10	connect to vertebrae at the bodies and transverse processes	61) _____
B)	ribs 11 and 12	connect to the vertebrae only at the bodies	62) _____
C)	none of the above	contain capitulum and no tubercle	63) _____
		contain capitulum and tubercle	64) _____
		are called the floating ribs	65) _____

66-70. Matching

A)	mandibular condyles	connect to talus bones	66) _____
B)	occipital condyles	connect to temporal bones	67) _____
C)	ribs 1 through 1	connect to transverse processes	68) _____
D)	ribs 11 and 12	connect to body of vertebrae only	69) _____
E)	lateral malleoli	are often referred to as 'floating ribs'	70) _____

71-75. Matching

A)	joint capsule	composed of fibrous connective tissue	71) _____
B)	articular cartilage	found at the joint ends of bone	72) _____
C)	synovial membrane	composed of hyaline cartilage	73) _____
D)	none of the above	found around a joint	74) _____
		lines joint cavity	75) _____

76-80. Matching

A)	ulna	is located laterally in the standard anatomical position	76) _____
B)	radius	connects to the Scaphoid bone	77) _____
C)	none of the above	connects to the Lunate bone	78) _____
		connects to the capitulum	79) _____
		connects to the trochlea	80) _____

81-85. Matching

A)	connects to manubrium	Head of humerus	81) _____
B)	connects to scapula	Trochlea of humerus	82) _____
C)	connects to radius	Sternal end of clavicle	83) _____
D)	connects to ulna	Capitulum of humerus	84) _____
E)	none of the above	Acromial end of clavicle	85) _____

86-90. Matching

A)	Capitate	connects to the 1st metacarpal	86) _____
B)	Trapezium	connects to the 2nd metacarpal	87) _____
C)	Trapezoid	connects to the 3rd metacarpal	88) _____
D)	Triquetrum	connects to the 4th metacarpal	89) _____
E)	none of the above	connects to the 5th metacarpal	90) _____

91-95. Matching

A)	Lunate bone	connects to the triquetrum	91) _____
B)	Scaphoid bone	connects to the trapezium	92) _____
C)	A and B	connects to the capitate	93) _____
D)	none of the above	connects to radius	94) _____
		connects to ulna	95) _____

96-1000. Matching

A)	ilium of coxa	connects with the head of the femur	96) _____
B)	condyles of femur	connect with condyles of tibia	97) _____
C)	acetabulum of coxa	connects with head of fibula	98) _____
D)	none of the above	connects with the sacrum	99) _____
		connect with patella	100) _____

101-105. Matching

A)	ulna	contains the greater trochanter	101) _____
B)	tibia	contains the deltoid tuberosity	102) _____
C)	femur	contains the gluteal tuberosity	103) _____
D)	fibula	contains the linea aspera	104) _____
E)	humerus	contains the trochlea	105) _____

106-110. Matching

A)	underside of lateral condyle of tibia	connects with lateral malleolus	106) _____
B)	Metatarsals	connects with medial malleolus	107) _____
C)	Talus bone	connects with the head of the fibula	108) _____
D)	none of the above	connects with the calcaneus bone	109) _____
		connects with the navicular bone	110) _____

111-115. Matching

A)	underside of lateral condyle of tibia	connects to tibia	111) _____
B)	lateral and medial malleolus	connects to fibula	112) _____
C)	condyles of femur	connects to talus bone	113) _____
D)	acetabulum	connects to the calcaneus bone	114) _____
E)	talus bone	connects to the head of the femur	115) _____

116-120. Matching

A)	Cuboid	connects to the 1st metatarsal	116) _____
B)	1st Cuneiform	connects to the 2nd metatarsal	117) _____
C)	2nd Cuneiform	connects to the 3rd metatarsal	118) _____
D)	3rd Cuneiform	connects to the 4th metatarsal	119) _____
E)	none of the above	connects to the 5th metatarsal	120) _____

Section 3 – Muscle Tissue and Skeletal Muscles

Muscle Tissues

General Function and Anatomical Features

- cells are specialized to contract
- cells vary from ribbon to spindle shaped
- tissue is vascular
- connected between bones, in heart, in vessels, airways, intestines

Classification of muscle tissues

Skeletal Muscle (extrafusal muscle)

- cells are long, ribbon shaped with multiple nuclei, and are arranged in parallel
- cells are connected side by side with fibrous connective tissue
- skeletal muscle cells are responsible for the contraction of skeletal muscles

Intrafusal Muscle

- Short cells with single nuclei that are surrounded by sensory nerve receptors
- the cells are attached in parallel to the Skeletal muscle cells
- the intrafusal muscle cells and their associated receptors are responsible for detecting the degree of skeletal muscle stretch

Cardiac Muscle

- cells are short, rectangular shaped with single nuclei
- cells are connected together end to end by interdigitations of the
- cell membranes, visible as the Intercalated Discs
- cells are connected side by side with fibrous connective tissue
- cardiac muscle cells are responsible for contraction of the heart

Smooth Muscle

- cells are small, spindle shaped cells with single nuclei
- the cells are connected end to end and side by side with fibrous connective tissue
- smooth muscle cells are responsible for contraction of blood vessels, the respiratory airways, the gastrointestinal tract, and other internal organs

Organization of skeletal muscles

Epimysium

- dense irregular (fibrous) connective tissue arising from Tendons that surrounds skeletal muscles

Fascicles

- within the skeletal muscle the skeletal muscle cells are organized as bundles

Perimysium

- the fascicles are surrounded by a dense irregular (fibrous) connective tissue

Endomysium

- the individual skeletal muscle cells are surrounded by a dense irregular (fibrous) connective tissue
- Intrafusal Muscle Cells are attached in parallel to groups of one or more skeletal muscle cells by the endomysium

Organization of individual muscle cells (muscle fibers)

Sarcolemma - a cell membrane surrounds the muscle cell

Motor End Plate

- the sarcolemma contains specialized regions for receiving signals from neurons

Sarcoplasm - the cell contains cytoplasm

Myofibrils

- much of the interior of a muscle cell is composed of bundles of protein fibers arranged in parallel
- each Myofibril is composed of bundles of many and alternating myofilaments
    - thin filaments (the protein Actin)
    - thick filaments (the protein Myosin)

Sarcoplasmic reticulum

- a structure similar to the endoplasmic reticulum surrounds the myofibrils

Transverse tubules

- invaginations of the sarcolemma that carry signals to the sarcoplasmic reticulum

Sarcomeres

- groups of myofibrils that include
- Actin-Myosin-Myosin-Actin form functional units for muscle shortening

Organization of Sarcomeres (In a longitudinal view:)

A-band - the thick filaments (Myosin) are visible
I-band - the thin filaments (Actin) are visible
M-line - the junction between adjacent thick filaments (myosin)
Z-line - the junction between adjacent thin filaments (actin)
Zone of overlap - the region where thick filaments (myosin) and thin filaments (actin) overlap is visible

Skeletal Muscle Tissue - Laboratory

Model of Skeletal Muscle

Cable • Epimysium • Fascicles • Perimysium • Endomysium	

Models of Skeletal Muscle Cell

Muscle Cell in cross section • Sarcolemma • Motor End Plate • Sarcoplasm	
Myofibrils in longitudinal section • thin filaments (the protein Actin) • thick filaments (the protein Myosin) • Sarcoplasmic reticulum • Transverse Tubules • Sarcomeres • A-band • I-band • M-line • Z-line • Zone of overlap	

Histology of Skeletal Muscle

Skeletal Muscle in cross section • Epimysium • Fascicles • Perimysium • Endomysium	
Skeletal Muscle in longitudinal section • thin filaments (the protein Actin) • thick filaments (the protein Myosin)	
Neuromuscular Junction • Motor End Plate • Axon Terminals	

Muscle Contraction

Anatomy of Sliding Filament mechanism

Actin Chain

- Composed of round strands of chains of actin molecules
- Active Sites - binding sites on the actin molecules
- Tropomyosin - protein chain that parallels the actin chain and covers the active sites
- Troponin - protein that binds to both actin and tropomyosin, holding the tropmyosin in place

Myosin Chain

- Composed of helical array of myosin molecules
- Globular Heads (cross bridges) - enlarged end of myosin molecule that projects away from the center of the thick filament
- ADP and phosphate - bound to the cross bridges (the cross bridge acts as an ATPase, breaks down ATP, and stores the energy)

Sarcomere

- repeating unit of the myofibrils consisting of actin, myosin, myosin, actin

Transverse Tubules

- begin at the sarcolemma, travels perpendicular to the sarcolemma and encircles the sarcomeres and comes in close contact with the sarcoplasmic reticulum
- conducts action potential from the sarcolemma toward the sarcoplasmic reticulum

Sarcoplasmic reticulum

- surrounds each sarcomere and is similar in structure to the endoplasmic reticulum
- stores calcium by way of a calcium ion pump

Contraction cycle

Generation of an action potential

- the sarcolemma has the ability to conduct an electrical impulse (excitable membrane).
- A massive change in membrane permeability leads to a depolarization that sweeps across the cell (the action potential.)
- a neurotransmitter binds to receptors on the motor end-plate and leads to the opening of chemically gated sodium channels

Conduction of an action potential

- the action potential is immediately conducted across the cell and travels down each of the transverse tubules to act on the sarcoplasmic reticulum
- the influx of sodium leads to the opening of voltage gated sodium channels
- the sequential opening and closing of sodium channels along the membrane is the action potential

Action on sarcoplasmic reticulum to release calcium

- arrival of the action potential activates and opens calcium channels in the membrane of the sarcoplasmic reticulum, permitting release of the stored calcium

Action of calcium

- calcium binds to the troponin molecule, moving the troponin-tropomyosin complex and exposing the active sites
- myosin cross bridges bind to the active sites using the energy stored in the myosin molecule
- the globular head pivots toward the center of the sarcomere (ADP and phosphate is released)
- cross bridges detach when the myosin head binds another ATP molecule
- free myosin head breaks down the ATP, retaining the ADP and phosphate, and storing the energy
- myosin cross bridges bind to the active sites and the cycle repeats until calcium concentration returns to normal (by way of active transport into the sarcoplasmic reticulum)

Muscular Organization

Overview

An observable movement of the body generally involves muscles pulling on bones, skin or muscle.

Muscles produce movements by pulling (shortening or contracting) *not* by pushing.

Muscle Connections

Muscles pull on bones, skin or other muscles by way of cord like extensions commonly called tendons.

Tendons –The connective tissue that intermingles with muscle cells and surrounds a muscle, and that in turn extends away from the muscle.

Origin – The connection at the end of the tendon that anchors the muscle to a bone.

Insertion – The connection at the end of the tendon that attaches to the bone (or skin) that moves.

Reciprocal Control

Movements in opposing directions are caused by different muscles connecting to complementary portions of a bone.

Agonist – The muscle that, by way of contraction, can cause the movement of interest.

Antagonist – The muscle that, by way of contraction, can cause an opposing movement.

Head and Trunk Muscles

Muscles of Facial Expresssion			
Action	*Muscle*	*Origin*	*Insertion*
Scalp			
Raise eyebrow	Frontalis	aponeurosis	eyebrow
tense scalp	Occipitalis	occipital	aponeurosis
Eye			
Close eyes	Orbicularis oculi	medial orbit	eyelids
Mouth			
Elevate lips	Levator Labii	maxillae	orbicularis oris
Depress lips	Depressor Labii	mandible	lower lip
Protude lips	Mentalis	mandible	skin of chin
Depress angle	Depressor Anguli	mandible	angle of lower lip
Compress lips	Orbicularis Oris	maxillae mandible	lips
Compress cheeks	Buccinator	maxillae mandible	orbicularis oris
Mouth to side	Risorius	fascia parotid	angle of mouth
Mouth back, up	Zygomaticus	zygomatic	angle of mouth

Muscles of Chewing and Swallowing			
Action	*Muscle*	*Origin*	*Insertion*
Muscles of Mastication			
Elevate jaw	Temporalis	temporal	coronoid mandible
	Masseter	zygomatic arch	lateral mandible
Move jaw to side	Pterygoideus	pterygoid plate	medial mandible
Compress cheeks	Buccinator	maxillae mandible	orbicularis oris
Muscles of the Tongue			
Depress tongue	Genioglossus	mandible, medial	body of tongue
Elevate tongue	*Styloglossus	styloid process	sides of tongue
Extrinsic Muscles of the Larynx			
Elevate larynx	Digastricus	mastoid, mandible	hyoid bone
	Stylohyoid	styloid process	hyoid
	Mylohyhoid	mandible	hyoid
	Geniohyoid	mandible	hyoid
	Thyrohyoid	thyroid cartilage	hyoid
Depress larynx	Omohyoid	clavicle	hyoid, scapula
	Sternohyoid	manubrium clavicle	hyoid
	Sternothyroid	manubrium	thyroid cartilage

* not visible in models

Extrinsic Eye Muscles			
Action	*Muscle*	*Origin*	*Insertion*
Extrinsic Muscles of the Eye			
Eye down	Inferior rectus	sphenoid	inf., medial eye
Eye lateral	Lateral rectus	sphenoid	lateral eye
Eye medial	Medial rectus	sphenoid	medial eye
Eye up	Superior rectus	sphenoid	sup., medial eye
Eye up, side	Inferior oblique	maxilla, anterior	inf., lateral eye
Eye down, side	Superior oblique	sphenoid	sup., medial eye

Muscles of the Spine and Trunk			
Action	*Muscle*	*Origin*	*Insertion*
Muscles of the Spine			
Extend head	Semispinalis capitis	c t vertebrae	occipital bone
	Splenius capitis	c vertebrae	mastoid occipital
Flex head	Sternocleidomastoid	manubrium, clavicle	mastoid
Extend spine	Spinalis	t l vertebrae	t vertebrae
	Longissimus	t l vertebrae	t l vertebrae
	Iliocostalis Lumborum	ileum, t l vertebrae	ribs
Flex spine	Quadratus Lumborum	ileum	rib, l vertebrae
Oblique and Rectus Muscles			
Elevate ribs, Expand ribcage	Scalene	c vertebrae	1-2 ribs
	Ext. Intercostals	inferior ribs	superior ribs
Contract ribcage	Int. Intercostals	superior ribs	inferior ribs
Depress ribs, Flex waist	Rectus Abdominus	5-7 ribs xiphoid	pubis
Compress abdomen	External Oblique	5th to 12th ribs	ilium linea alba
	Internal Oblique	ilium	lower ribs
	Transverse Abdominus	lower ribs	pubis linea alba
Expand chest	Diaphragm	xiphoid 4-10 ribs	tendon sheet

Head and Trunk Muscles - Laboratory

Muscles of Facial Expresssion

Scalp and Eye

• Frontalis • Occipitalis • Orbicularis oculi	

Mouth

• Levator Labii • Depressor Labii • Mentalis • Depressor Anguli • Orbicularis Oris • Buccinator • Risorius • Zygomaticus	

Muscles of Chewing and Swallowing

Muscles of Mastication

• Temporalis • Masseter • Pterygoideus • Buccinator	

Muscles of the Tongue

• Genioglossus • Styloglossus	

Extrinsic Muscles of the Larynx

• Digastricus • Stylohyoid • Mylohyhoid • Geniohyoid • Thyrohyoid • Omohyoid • Sternohyoid • Sternothyroid	

Extrinsic Eye Muscles

Extrinsic Muscles of the Eye

• Inferior rectus • Lateral rectus • Medial rectus • Superior rectus • Inferior oblique • Superior oblique	

Muscles of the Spine and Trunk

Muscles of the Spine

• Semispinalis capitis • Splenius capitis • Sternocleidomastoid • Spinalis • Longissimus • Iliocostalis Lumborum • Quadratus Lumborum	

Oblique and Rectus Muscles

• Scalene • Ext. Intercostals • Int. Intercostals • Rectus Abdominus • External Oblique • Internal Oblique • Transverse Abdominus • Diaphragm	

Movements

Flexion - reduction in the angle between joint elements

Extension - increase in the angle between joint elements

Rotation - movement around an axis

Medial Rotation - movement around an axis toward the center of the body

Lateral Rotation - movement around an axis outward from the center

Abduction - movement away from the midline of the body

Adduction - movement toward the midline of the body

Inversion - turning sole of foot inward

Eversion - turning sole of foot outward

Supination - palm facing front

Pronation - palm facing back

Dorsiflexion - heel down, toes up

Plantar flexion - toes down, heel up

Protraction - movement forward in the horizontal plane

Retraction - movement backward in the horizontal plane

Elevation - movement upwards

Depression - movement downwards

Movement of the Shoulder and Arms

Movements of the Shoulder Girdle (Muscles insert on the Scapula)

Elevation - the muscles will have an origin superior to the scapula

(Levator Scapulae, Trapezius)

Depression - the muscles will have an origin inferior to the scapula

(Pectoralis Minor)

Abduction - the muscles will have an origin lateral to the scapula

(Serratus Anterior)

Adduction - the muscles will have an origin medial to the scapula

(Rhomboideus Minor, Rhomboideus Major)

Movements of the Upper Arm (Muscles insert in most cases on the Humerus)

Abduction - the muscles will have an origin superior to the humerus

(Deltoid, Supraspinatus)

Adduction - the muscles will have an origin inferior to the humerus

(Pectoralis Major, Latissimus Dorsi)

Flexion - the muscles will have an origin anterior to the humerus

(Pectoralis Major)

Extension - the muscles will have an origin posterior to the humerus

(Triceps Brachii Long Head, Latissimus Dorsi)

Medial Rotation - the muscles will have an origin medial to the humerus and an insertion on the anterior humerus

(Teres Major)

Lateral Rotation - the muscles will have an origin medial to the humerus and an insertion on the posterior humerus

(Teres Minor, Infraspinatus)

Movement of the Lower Arm (Muscles insert on the Radius or Ulna)

Flexion - the muscles will have an origin proximal and anterior to the radius or ulna

(Biceps Brachii, Brachioradialis, Brachialis)

Extension - the muscles will have an origin proximal and posterior to the ulna

(Triceps Brachii Lateral, Medial and Long Head)

Movement of the Wrist (Muscles insert on the Metacarpals or palm)

Flexion - the muscles will have an origin proximal and anterior to the wrist

(Palmaris Longus, Flexor Carpi Radialis, Flexor Carpi Ulnaris)

Extension - the muscles will have an origin proximal and posterior to the wrist

(Extensor Carpi Radialis, Extensor Carpi Ulnaris)

Pronators - the muscles will have an origin medial to the radius

(Pronator Teres, Pronator Quadratus)

Movement of the Fingers (Muscles insert in most cases on the Phalanges)

Flexion - the muscles will have an origin proximal and anterior to the hand

(Flexor Digitorum Profundus and Superficialis, Flexor Pollicus Longus)

Extension - the muscles will have an origin proximal and posterior to the hand

(Extensor Digitorum, Extensor Pollicus Longus)

Abduction - the muscles will have an origin posterior to the thumb

(Abductor pollicis Longus)

Upper Body Muscles

Muscles of the Shoulder and Upper Arm			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that move the Shoulder Girdle			
Elevator	Levator Scapulae	cervical 1-4	scapula, medial
	Trapezius	occipital thoracic	scapula, clavicle
Depressor	Pectoralis Minor	3-5 ribs	scapula, coracoid
Abductor	Serratus Anterior	1-9 ribs	scapula, medial
Adductor	Rhomboideus Major	thoracic	scapula, medial
	Rhomboideus Minor	C7-T1	Scapula, coracoid
Muscles that move the Upper Arm			
Abductors	Deltoid	scapula, acromion	humerus deltoid
	Supraspinatus	scapula, supraspinus	humerus greater
Adductors	Pectoralis Major	ribs stern clav	humerus greater
	Latissimus Dorsi	thoracic lumbar	humerus lesser
Flexors	Pectoralis Major	ribs stern clavicle	humerus greater
	Coracobrachialis	scapula, coracoid	humerus shaft
Extensors	Latissimus Dorsi	thoracic lumbar	humerus lesser
	Triceps (long)	scapula	ulna, olecranon
Lateral Rotators	Infraspinatus	scapula	humerus
	Teres Minor	scapula	humerus
Medial Rotators	Teres Major	scapula	humerus

Muscles of the Lower Arm and Wrist			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that move the Lower Arm			
Flexors	Biceps Brachii	scapula	radius, radial
	Brachioradialis	humerus	radius, styloid
	Brachialis	humerus	ulna
Extensors	Triceps (lat/med)	humerus	ulna, olecranon
	Anconeus	humerus	ulna, olecranon
Muscles that move the Wrist			
Flexors	Palmaris Longus	humerus, medial	palm
	Flexor Carpi Radialis	humerus, medial	metacarpal 2
	Flexor Carpi Ulnaris	humerus ulna	metacarpal 3-5
Extensors	Extensor Carpi Radialis Longus	humerus, lateral	metacarpal 2
	Extensor Carpi Radialis Brevis	humerus	metacarpal 3
	Extensor Carpi Ulnaris	humerus ulna	metacarpal 5
Pronators	Pronator Teres	humerus ulna	radius
	Pronator Quadratus	ulna	radius

Muscles of theFingers and Thumb			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that move the Fingers			
Flexors	Flexor Digitorum Profundus	ulna	phalanges 2-5
	Flexor Digitorum Superficialis	humerus radius	phalanges 2
Extensors	Extensor Digitorum	humerus	phalanges 2-5
	Extensor Digitorum Minimi	humerus	phalanges 5
Muscles that move the Thumb			
Flexors	Flexor Pollicus Longus	radius	phalanges 1
Extensors	Extensor Pollicus Longus	ulna	phalanges 1
	Extensor Pollicus Brevis	radius	phalanges 1
Abductor	Abductor Pollicus Longus	ulna radius	metacarpal 1
Adductor	Adductor Pollicus	metacarpals	phalanges 1

Upper Body Muscles - Laboratory

Muscles of the Shoulder and Upper Arm

Muscles that move the Shoulder Girdle (Scapula)

• Levator Scapulae • Trapezius • Pectoralis Minor • Serratus Anterior • Rhomboideus Major • Rhomboideus Minor	

Muscles that move the Upper Arm (Humerus)

• Deltoid • Supraspinatus • Pectoralis Major • Latissimus Dorsi • Pectoralis Major • Coracobrachialis • Latissimus Dorsi • Triceps (long) • Infraspinatus • Teres Minor • Teres Major	

Muscles of the Lower Arm and Wrist

Muscles that move the Lower Arm (Radius / Ulna)

• Biceps Brachii • Brachioradialis • Brachialis • Triceps (lat/med) • Anconeus	

Muscles that move the wrist (Carpus)

• Palmaris Longus • Flexor Carpi Radialis • Flexor Carpi Ulnaris • Extensor Carpi Radialis Longus • Extensor Carpi Radialis Brevis • Extensor Carpi Ulnaris • Pronator Teres • Pronator Quadratus	

Muscles of the Fingers and Thumb

Muscles that move the Fingers (Digits)

• Flexor Digitorum Profundus • Flexor Digitorum Superficialis • Extensor Digitorum • Extensor Digitorum Minimi	

Muscles that move the Thumb (Pollex)

• Flexor Pollicus Longus • Extensor Pollicus Longus • Extensor Pollicus Brevis • Abductor Pollicus Longus • Adductor Pollicus	

Movements of the Thigh and Leg

Movements of the Thigh (Muscles insert in most cases on the Femur)

Flexion - the muscles will have an origin proximal and anterior to the femur

(Iliopsoas, [Tensor Fasciae Latae, Pectineus, Gracilis, Sartorius, Rectus Femoris])

Extension - the muscles will have an origin proximal and posterior to the femur

(Gluteus Maximus, [Biceps Femoris, Semitendinosus, Semimembranosus])

Abduction - the muscles will have an origin proximal and lateral to the femur

(Gluteus Medius, Gluteus Minimus, Tensor Fasciae Latae)

Adduction - the muscles will have an origin proximal and medial to the femur

(Adductor Magnus, Adductor Longus, Gracilis, Pectineus)

Medial Rotation - the muscles will have an origin medial or lateral to the femur and an insertion on the anterior and lateral femur

(Gluteus Medius, Gluteus Minimus, Tensor Fasciae Latae, Adductor Magnus, Adductor Longus)

Lateral Rotation - the muscles will have an origin medial to the femur and an insertion on the posterior and lateral femur

(Piriformis, [Pectineus])

Movements of the Lower Leg (Muscles insert in most cases on the tibia)

Flexion - the muscles will have an origin proximal and posterior to the tibia

(Biceps Femoris, Semitendinosus, Semimembranosus, Gracilis, Sartorius)

Extension - the muscles will have an origin proximal and anterior to the tibia

(Rectus Femoris, Vastus Intermedius, Vastus Lateralis, Vastus Medialis)

Movements of the Ankle (Muscles insert on the Metatarsal or Calcaneus)

Dorsiflexion - the muscles will have an origin proximal and anterior to the metatarsals

(Tibialis anterior)

Plantar flexion - the muscles will have an origin proximal and posterior or lateral to the calcaneus or metatarsals

(Gastrocnemius, Soleus, Fibularis Longus, Fibularis Brevis, Tibialis Posterior)

Movement of the Toes (Muscles insert on the Phalanges)

Extension - the muscles will have an origin proximal and anterior to the phalanges

(Extensor Digitorum Longus, Extensor Hallucis Longus)

Flexion - the muscles will have an origin proximal and posterior to the phalanges

(Flexor Digitorum Longus, Flexor Hallucis Longus)

Lower Body Muscles

Muscles of the Hip and Thigh			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that Move the Thigh			
Flexors	Iliacus	ilium	femur
	Psoas Major	l vertebrae	femur
	Psoas Minor	l vertebrae	femur
	(Tensor Fasciae Latae, Pectineus, Gracilis, Sartorius, Rectus Femoris)		
Extensors	Gluteus Maximus	ilium, crest	femur, gluteal
	(Biceps Femoris, Semitendinosus, Semimembranosus)		
Abductors	Gluteus Medius	ilium, crest	femur, greater
	Gluteus Minimus	ilium, lateral	femur, greater
	Tensor Fasciae Latae	ilium, crest	iliotibial
Adductors	Adductor Magnus	pubis, inferior	femur, linea
	Adductor Longus	pubis, inferior	femur, linea
	Gracilis	pubis, ischium	tibia
	Pectineus	pubis, superior	femur
Lateral Rotators	Piriformis	sacrum	femur, greater
	(Pectineus)		

Muscles of the Leg and Ankle			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that Move the Leg			
Flexors (Hamstrings)	Biceps Femoris	ischium femur	fibula tibia
	Semitendinosus	ischium, tuber.	tibia, post.
	Semimembranosus	ischium, tuber.	tibia, post
	Gracilis	pubis ischium	tibia, med
	Sartorius	ilium, ant. inf.	tibia, med
Extensors (Quadriceps)	Rectus Femoris	ilium, ant. inf.	tibia, tuber.
	Vastus Intermedius	femur, linea dist.	tibia, tuber.
	Vastus Lateralis	femur, linea prox.	tibia, tuber.
	Vastus Medialis	femur, linea	tibia, tuber.
Muscles that Move the Ankle			
Dorsiflexors	Tibialis anterior	tibia, lateral	1st metatarsal
Plantar flexors	Gastrocnemius	femur	calcaneus
	Soleus	fibula tibia	calcaneus
	Plantaris	femur	calcaneus
	Tibialis Posterior	tibia, fibula	2-4 metatarsal
Evertors	Fibularis Longus	tibia, fibula, lateral	1st metatarsal
	Fibularis Brevis	fibula	5th metatarsal

Muscles of the Toes			
Action	*Muscle*	*Origin*	*Insertion*
Muscles that Move the Little Toes			
Extensors	Extensor Digitorum Longus	tibia fibula, ant.	2-5 phalanges
Flexors	Flexor Digitorum Longus	tibia, post. med.	2-5 phalanges
Muscles that Move the Big Toes			
Extensors	Extensor Hallucis Longus	fibula, anterior	1st phalanges
Flexors	Flexor Hallucis Longus	fibula, posterior	1st phalanges

Lower Body Muscles - Laboratory

Muscles of the Hip and Thigh

Muscle that move the Thigh

• Iliacus • Psoas Major • Psoas Minor • Gluteus Maximus • Gluteus Medius • Gluteus Minimus • Tensor Fasciae Latae • Adductor Magnus • Adductor Longus • Gracilis • Pectineus • Piriformis	

Muscle that move the Leg

• Biceps Femoris • Semitendinosus • Semimembranosus • Gracilis • Sartorius • Rectus Femoris • Vastus Intermedius • Vastus Lateralis • Vastus Medialis	

Muscles that move the Ankle

• Tibialis anterior • Gastrocnemius • Soleus • Plantaris • Tibialis Posterior • Fibularis Longus • Fibularis Brevis	

Muscles of the Toes

Muscles that move the Little Toes

• Extensor Digitorum Longus • Flexor Digitorum Longus	

Muscles that Move the Big Toes

• Extensor Hallucis Longus • Flexor Hallucis Longus	

Practice Questions – Muscle Tissue and Skeletal Muscles

Note: choices may be used more then once or not at all.

1-5. Matching

A)	Epimysium	surrounds whole skeletal muscles	1) _____
B)	Perimysium	come(s) together to form tendons	2) _____
C)	Endomysium	surrounds muscle fascicles	3) _____
D)	Muscle Fascicles	bundles of muscle cells	4) _____
E)	A, B and C	connects individual skeletal muscle cells	5) _____

6-10. Matching

A)	Muscle Fascicles	bundles of muscle cells	6) _____
B)	Endomysium	fibrous connective tissue around muscle fascicles	7) _____
C)	Perimysium	fibrous connective tissue around a skeletal muscle	8) _____
D)	Epimysium	fibrous connective tissue around individual muscle cells	9) _____
E)	Fascia	fibrous connective tissue around groups of skeletal muscles	10)_____

11-15. Matching

A)	Muscles	are grouped together as bundles in a muscle cell	11) _____
B)	Myofibrils	are grouped together to form a muscle fascicle	12) _____
C)	Muscle Fascicles	are grouped together to form a myofibril	13) _____
D)	Actin and Myosin	are grouped together to form a muscle	14) _____
E)	Muscle Cells (Muscle Fibers)	are grouped together to form a limb	15) _____

16-20. Matching

A)	Sarcomere	neurotransmitter sensitive portion of cell membrane	16) _____
B)	Sarcolemma	unit of Actin-Myosin-Myosin-Actin	17) _____
C)	Sarcoplasm	cytoplasm of muscle cell	18) _____
D)	Motor End Plate	muscle cell membrane	19) _____
E)	Sarcoplasmic Reticulum	stores calcium	20) _____

21-25. Matching

A)	Z-line	site for joining of myosin	21) _____
B)	I-band	site for joining of actin	22) _____
C)	M-line	contains myosin and actin	23) _____
D)	A-band	composed mainly of actin	24) _____
E)	C and D	contains myosin	25) _____

26-30. Matching

A)	actin	contains binding sites that act break apart ATP	26) _____
B)	myosin	heads are straight in relaxed muscle	27) _____
C)	troponin-tropomyosin	heads are bent in contracted muscle	28) _____
D)	none of the above	contains binding sites for myosin	29) _____
		covers binding sites on actin	30) _____

31-35. Place the following in the order that leads to muscle contraction.

A)	myosin shortens and pulls actin toward center of the sarcomere	31) _____
B)	calcium binds to troponin and exposes active sites on actin	32) _____
C)	calcium is released from sarcoplasmic reticulum	33) _____
D)	nerve sends a signal to the muscle cell	34) _____
E)	myosin binds to actin	35) _____

36-40. Matching

A)	tense scalp	Orbicularis Oris	36) _____
B)	elevate lips	Levator Labii	37) _____
C)	compress lips	Zygomaticus	38) _____
D)	raise eyebrows	Occipitalis	39) _____
E)	smile (elevate angle of mouth)	Frontalis	40) _____

41-45. Matching

A)	retract and elevate mouth	Mentalis	41) _____
B)	compress cheeks	Platysma	42) _____
C)	move ears	Temporalis	43) _____
D)	flex neck	Buccinator	44) _____
E)	none of these	Zygomaticus	45) _____

46-50. Matching

A)	move mandible to side	Styloglossus	46) _____
B)	elevate mandible	Genioglossus	47) _____
C)	elevate tongue	Pterygoideus	48) _____
D)	depress tongue	Temporalis	49) _____
E)	none of these	Masseter	50) _____

51-55. Matching

A)	elevate mandible	Masseter	51) _____
B)	compress cheeks	Buccinator	52) _____
C)	depress tongue	Temporalis	53) _____
D)	depress lips	Genioglossus	54) _____
E)	none of these	Depressor Labii	55) _____

56-60. Matching

A)	move eye down	Inferior oblique	56) _____
B)	move eye laterally	Superior oblique	57) _____
C)	move eye medially	Superior rectus	58) _____
D)	move eye up and laterally	Lateral rectus	59) _____
E)	none of the above	Medial rectus	60) _____

61-65. Matching

A)	elevate larynx	external intercostals	61) _____
B)	depress larynx	internal intercostals	62) _____
C)	elevate ribs / expand ribcage	stylohyoid	63) _____
D)	depress ribs /contract ribcage	omohyoid	64) _____
		Scalenes	65) _____

66-70. Matching

A)	extend head and neck	stylohoid	66) _____
B)	flex head and neck	digasticus	67) _____
C)	depress larynx	sternohyoid	68) _____
D)	elevate larynx	splenius (capitis)	69) _____
E)	none of these	sternocleidomastoid	70) _____

71-75. Matching

A)	depress ribs / contract rib cage	Scalenes	71) _____
B)	elevate ribs / expand rib cage	Internal Oblique	72) _____
C)	compress abdomen	External Oblique	73) _____
D)	A and B	Internal Intercostals	74) _____
E)	none of these	External Intercostals	75) _____

76-80. Matching

A)	origin	a muscle that opposes the action of another muscle	76) _____
B)	agonist	a muscle primarily responsible for a movement	77) _____
C)	insertion	the end of a muscle that acts as the anchor	78) _____
D)	antagonist	the end of the muscle that usually moves	79) _____
E)	none of the above	the humerus is the _____ for the deltoid	80) _____

81-85. Matching

A)	fle x head	semispinalis capitis	81) _____
B)	flex waist	sternocleidomastoid	82) _____
C)	extend head	splenius (capitis)	83) _____
D)	extend thigh	rectus abdominus	84) _____
E)	none of these	sartorius	85) _____

86-90. Matching

A)	elevate scapula (shoulder)	Rhomboideus	86) _____
B)	depress scapula (shoulder)	Pectoralis Minor	87) _____
C)	abduct scapula (shoulder)	Levator Scapulae	88) _____
D)	adduct scapula (shoulder)	Serratus Anterior	89) _____
E)	none of these	Semispinalis Capitis	90) _____

91-95. Matching

A)	extend / adduct Humerus (upper arm)	Deltoid	91) _____
B)	flex / adduct Humerus (upper arm)	Biceps Brachii	92) _____
C)	abduct Humerus (upper arm)	Pectoralis major	93) _____
D)	extend Ulna (lower arm)	Latissimus Dorsi	94) _____
E)	flex Radius (lower arm)	Triceps Brachii Lateral Head	95) _____

96-100. Matching

A)	inserts on first metatarsal	teres minor	96) _____
B)	inserts on first metacarpal	rhomboideus minor	97) _____
C)	inserts on scapula	tibialis anterior	98) _____
D)	inserts on humerus	extensor carpi radialis	99) _____
E)	none of these	abductor pollicis longus	100) _____

101-105. Matching

A) extend Metacarpals (wrist)
B) extend Ulna (lower arm)
C) flex Metacarpals (wrist)
D) flex Radius (lower arm)
E) none of these

Extensor Carpi Radialis 101) _____
Flexor Carpi Ulnaris 102) _____
Extensor Digitorum 103) _____
Palmaris Longus 104) _____
Brachioradialis 105) _____

106-110. Matching

A) laterally rotate humerus (upper arm)
B) medially rotate humerus (upper arm)
C) laterally rotate femur (thigh)
D) pronate wrist
E) evert ankle

Piriformis 106) _____
Teres Minor 107) _____
Teres Major 108) _____
Infraspinatus 109) _____
Pronator Teres 110) _____

111-115. Matching

A) laterally rotates humerus
B) medially rotates humerus
C) adducts femur
D) abducts femur
E) flex femur

Iliopsoas 111) _____
Teres major 112) _____
Infraspinatus 113) _____
Gluteus medius 114) _____
Adductor Magnus 115) _____

116-120. Matching

A) originates on humerus
B) originates on scapula
C) originates on femur
D) none of these

biceps brachii long head 116) _____
biceps brachii short head 117) _____
triceps brachii long head 118) _____
biceps femoris short head 119) _____
triceps brachii lateral head 120) _____

121-125. Matching

A) flex Femur (thigh)
B) extend Femur (thigh)
C) abduct Femur (thigh)
D) adduct Femur (thigh)
E) none of Femur (thigh)

Iliopsoas 121) _____
Gluteus Medius 122) _____
Gluteus Maximus 123) _____
Adductor Magnus 124) _____
Tensor Fascia Latae 125) _____

126-130. Matching

A) flex Tibia (lower leg)
B) extend Tibia (lower leg)
C) none of these

Rectus Femoris 126) _____
Vastus Muscles 127) _____
Biceps Femoris 128) _____
Semitendinosus 129) _____
Semimembranosus 130) _____

131-135. Matching

A) flex lower leg
B) extend lower leg
C) extend lower arm
D) adduct/flex upper arm
E) adduct/extend upper arm

Latissimus Dorsi 131) _____
Pectoralis Major 132) _____
Rectus Femoris 133) _____
Biceps Femoris 134) _____
Triceps brachii 135) _____

136-140. Matching

A)	evert foot	Flexor Hallucis Longus	136) _____
B)	extend digits	Peroneus Longus	137) _____
C)	dorsiflex foot	Tibialis anterior	138) _____
D)	plantar flex foot	Gastrocnemius	139) _____
E)	none of these	Plantaris	140) _____

141-145. Matching

A)	plantar flex foot	Soleus	141) _____
B)	dorsiflex foot	Gastrocnemius	142) _____
C)	none of these	Tibialis Anterior	143) _____
		Quadriceps muscles	144) _____
		Extensor Digitorum Longus	145) _____

146-150. Matching

A)	inserts on first metatarsal	Deltoid	146) _____
B)	inserts on first metacarpal	Tibialis anterior	147) _____
C)	inserts on humerus	Rhomboideus minor	148) _____
D)	inserts on scapula	Extensor carpi radialis	149) _____
E)	none of these	Abductor pollicis longus	150) _____

151-155. Matching

A)	Triceps Brachii Lateral Head	inserts on the Tibia	151) _____
B)	Triceps Brachii Long Head	inserts on the Radius	152) _____
C)	Biceps Femoris	originates on the Femur	153) _____
D)	Biceps Brachii	originates on the Scapula	154) _____
E)	A and D	originates on the Humerus	145) _____

146-150. Matching

A)	inserts on the medial border of the scapula	Gastrocnemius	146) _____
B)	inserts on the tibial tuberosity	Serratus Anterior	147) _____
C)	inserts on the calcaneus bone	Peroneus Longus	148) _____
D)	inserts in the fifth metacarpal	Quadriceps Muscles	149) _____
E)	none of the above	Flexor Carpi Ulnaris	150) _____

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Section 4 – Nervous Tissue and Nervous System

Nervous System, Neurons, Nerves, and Glial Cells

Overview

Sensory (Afferent) - carry signals toward nervous system

Motor (Efferent) - carry signals out of nervous system

Central Nervous System [CNS]- inside dorsal body cavity

Peripheral Nervous System [PNS]- outside of dorsal body cavity

Somatic Nervous System - control skeletal muscle

Autonomic Nervous System - control smooth muscle or glands

Types of neurons

Unipolar neurons

- *commonly are sensory neurons*
- cell bodies are in the PNS within Ganglia

Bipolar neurons - occur in retina of eye

Multipolar neurons

- *commonly are motor neurons*
- cell bodies are in the CNS

Unipolar (Sensory) Neuron structure

Dendrite / Sensory Receptors

- Detects sensory signals
- generates nervous signals
- transfer nervous signals to axon

axon (Peripheral Process)

- conducts signals from the dendrites to the vicinity of the cell body

Cell Body

- usually located in the peripheral nervous system along the route of the axon
- contain Nissl granules (RNA that shows with Nissl stain)

Axon (Central Process)

- conducts signals from the vicinity of the cell body toward the synaptic bulbs
- contain neurotubules that facilitate transport within axons

Axon Collaterals - major branches of the axon

Synaptic Bulbs - release neurotransmitters

Multipolar (Motor or Interneuron) Neuron structure

Cell Body

- usually located in the central nervous system
- contain Nissl granules (RNA that shows with Nissl stain)

Axon Hillock

- narrowing of the cell body that connects to the axon
- site for formation of action potentials
- do not contain Nissl granules

Axon

- continuation of the axon hillock
- conduct signals away from the cell body / axon hillock
- contain neurotubules that facilitate transport within axons

Axon Collaterals - major branches of the axon

Synaptic Bulbs (knobs, boutons) - release neurotransmitters

Dendrites

- receive signals from other neurons and transfer signals to the cell body
- RNA and ribosomes (Nissl granules) extend into dendrites

Peripheral nerves

Peripheral Nerves are bundles of axons outside of that CNS surrounded by fibrous connective tissue.

Epineurium – Fibrous connective tissue that surrounds the nerve

Perineurium – Fibrous connective tissue that separates the nerve into smaller bundles and surrounds these bundles

Nerve Fascicles – Smaller bundles of axons within the nerve

Endoneurium – Fibrous connective tissue that surrounds individual Schwann Cells wrapped around the axons within a fascicle

Neuroglial Cells

Schwann cells

- Flat cells that roduce myelin and wrap around axons in PNS to provide an insulating myelin sheath

Nodes of Ranvier - gaps between adjacent Schwann cells

Oligodendrocytes

- Octopus-like cells with tentacles that produce myelin and wrap around axons in CNS to provide an insulating myelin sheath

Myelin Sheath - insulating lipid material in in the plasma membrane of Schwann cells and Oligodendrocytes

Astrocytes

- Star-like cells positioned between neurons and blood capillaries
- Provide a structural framework
- Provide a filtration barrier between the blood and neurons (blood-brain barrier)
- Contribute to growth and integrity of synapses and may function somewhat like neurons

Microglia

- Phagocytic cells that migrate through CNS
- Provide an intrinsic immune system for the brain

Ependymal cells

- Line cavities in the CNS (such as central canal of spinal cord and the ventricles of the brain)
- Provide a barrier and a means for chemical communication between the cerebral spinal fluid and neurons in the central nervous system

Neurons, Glial Cells, and Nerves - Laboratory

Models

Unipolar Neuron
 	
• Cell Body
  o Nucleus
  o Nucleolus
• Peripheral Axons
• Central Axons	

Multipolar Neuron
 	
• Cell Body
  o Nucleus
  o Nucleolus
• Dendrites
• Axons Hillock
• Axons
• Schwann Cells
• Myelin Sheath
• Nodes of Ranvier	

Peripheral Nerve • Perineurium • Nerve Fascicle • Epineurium • Endoneurium • Schwann Cell • Axon	

Histology

Multipolar Neuron
 	
• Cell Body
  o Nucleus
  o Nucleolus
• Dendrites
• Axons Hillock
• Axons
• Schwann Cells
• Myelin Sheath
• Nodes of Ranvier	

Peripheral Nerve (c.s) • Perineurium • Nerve Fascicle • Epineurium • Endoneurium • Schwann Cell • Axon	
Peripheral Nerve (teased) • Schwann Cell • Axon • Nodes of Ranvier	

Spinal Cord and Spinal Nerves

Spinal Meninges

Dura Mater - fibrous connective tissue sac around spinal cord

Epidural Space - outside of dura mater

Subdural Space - under dura mater, contains cerebrospinal fluid

Arachnoid - vascular regions between pia mater and dura mater

Pia Mater- epithelium adhering to spinal cord

Denticulate Ligaments - connections between the pia and dura mater

Central Canal - located in the commissure and contains cerebrospinal fluid

Spinal Cord

Cervical Region – gives rise to the Cervical Plexus

Cervical Enlargement - expanded region giving rise to Brachial Plexus

Thoracic Region - gives rise to Thoracic Spinal Nerves

Lumbar Enlargement - expanded region giving rise to Lumbar Plexus

- located inside of lower thoracic vertebrae

Sacral Region - expanded region giving rise to Sacral Plexus

- located inside of lower thoracic vertebrae

Conus Medullaris - end of spinal cord

Filum Terminale - continuation of the pia mater of the spinal cord from the conus medullaris to the coccyx

Cauda Equina - dorsal and ventral roots within spinal column

Spinal Nerve Plexi and Nerves

Cervical Plexus

- group of nerves passing through upper cervical vertebrae, distribute to neck and diaphragm

Phrenic Nerve - nerve to diaphragm

Brachial Plexus

- group of nerves passing through lower cervical vertebrae, distribute to arms

Thoracic Spinal Nerves

- individual nerves passing through thoracic vertebrae, distribute to the trunk

Lumbar Plexus

- group of nerves passing through lumbar vertebrae, distribute to thigh

Femoral Nerve - nerve to thigh

Sacral Plexus

- group of nerves passing through sacrum, distribute to leg

Sciatic Nerve - nerve to leg

Spinal Sensory and Motor Organization and Spinal Reflexes

Sensory and Motor Organization

Afferent (sensory)

Posterior (Dorsal) Horns - entry point for sensory neurons

Posterior (Dorsal) Root - contain axons of sensory neurons

Posterior (Dorsal) Root Ganglia - contain cell bodies of sensory neurons

Commissure - connects the right and left sides of the Horns

Efferent (motor)

Somatic

Anterior (Ventral) Horns - contain cell bodies of somatic motor neurons

Anterior (Ventral) Root - axons of somatic motor neurons

Autonomic

Lateral horns - contain cell bodies of autonomic motor neurons

Anterior (Ventral) Root - axons of autonomic preganglionic motor neurons

Ganglia and Nuclei

Ganglia – groups of neuron cell bodies in the Peripheral Nervous System

Nuclei – groups of neuron cell bodies in the Central Nervous System

Spinal Reflexes

Tendon reflex

- Prevent unusually high tension in a muscle, triggered by high tension in a tendon

Golgi tendon organs : sensory neurons

- inhibitory interneurons are stimulated by the sensory neurons
- motor neurons responsible for tension are inhibited by the inhibitory interneurons, leading to relaxation of the skeletal muscles responsible for the high tension

Stretch reflexes

- Provide for automatic adjustment of muscle tone, triggered by changes in muscle tone

Muscle Spindles: sensory neurons

- Extrafusal Muscle - the skeletal muscle that makes up the bulk of the entire muscle
- Intrafusal Muscle - specialized skeletal muscle fibers that make the muscle spindle
- Nuclear bag region - a region central to the intrafusal fibers that is monitored by receptors of sensory neurons
- Alpha Motor Neurons - neurons responsible for contraction of the extrafusal muscle
- Gamma Motor Neurons - neurons responsible for contraction of the intrafusal muscle
- alpha motor neurons are stimulated directly by activation of the sensory neurons of the muscle spindle, leading to contraction of the affected extrafusal skeletal muscle

Relaxation of the muscle spindle decreases the stimulation of alpha motor neurons, leading to relaxation of the affected extrafusal skeletal muscle.)

- gamma motor neurons are stimulated by neurons in the brainstem and cerebral and cerebellar cortex
- stimulation of gamma motor neurons causes contraction of intrafusal muscle fibers, causing stretch of the muscle spindles, leading to a reflex contraction of skeletal muscle

Regulation of posture

- Stretch reflexes play a major role in maintaining posture by reflex countering inappropriate muscle contraction or relaxation

Spinal Cord, Spinal Neurons – Laboratory

Models and Specimens

Spinal Cord (longitudinal) • Cervical Enlargement • Thoracic Region • Lumbar Enlargement • Sacral Region • Conus Medullaris • Filum Terminale • Cauda Equina • Anterior Median Fissure	

Spinal Nerve Plexi and Nerves
 	
• Cervical Plexus (C1-C5)
  o Phrenic Nerve
• Brachial Plexus (C5-T1)
• Thoracic Spinal Nerves (T1-T12)
• Lumbar Plexus (T12-L4)
  o Femoral Nerve
• Sacral Plexus (L4-S4)
  o Sciatic Nerve	

Spinal Cord and Meninges (cross) • Dura Mater • Epidural Space • Subdural Space • Arachnoid • Pia Mater • Denticulate Ligaments • Central Canal	

Spinal Cord • Spinal Commissure • Central Canal • Anterior Horns • Anterior Root • Posterior Horns • Posterior l Root • Posterior Root Ganglia • Anterior Columns • Lateral Columns • Posterior Columns (Axons)	

Histology of the Spinal Cord

Spinal Meninges • Anterior Median Fissure • Dura Mater • Subdural Space • Arachnoid • Subarachnoid Space (Interstitial Space) • Pia Mater	
Spinal Cord • Spinal Commissure • Central Canal • Anterior Horns • Anterior Root • Posterior Horns • Posterior l Root • Posterior Root Ganglia • Anterior Columns • Lateral Columns • Posterior Columns (Axons)	

Cranial Nerves, Brainstem and Subcortical Structures

Cranial Nerves

Olfactory nerve (I) - special sensory, smell

Optic nerve (II) - special sensory, vision

Oculomotor nerve (III) - motor, eye movement (remaining four muscles of the eye)

Trochlear nerve (IV) - motor, eye movement (superior oblique muscle)

Trigeminal nerve (V) - mixed sensory and motor; face, mouth, mastication

Abducens nerve (VI) - motor, eye movement (lateral rectus muscle)

Facial nerve (VII) - mixed sensory and motor; anterior 2/3 tongue, facial expression

Vestibulocochlear nerve (VIII) - special sensory, balance and hearing

Glossopharyngeal nerve (IX) - mixed sensory and motor; posterior 1/3 tongue, carotid arteries, swallowing

Vagus nerve (X) - mixed sensory and motor; visceral organs

Spinal Accessory nerve (XI) - motor, neck

Hypoglossal nerve (XII) - motor, tongue movements

Brain Stem

Medulla Oblongata – involved, in part, in respiration, blood pressure and heart rate

Medullary Pyramid - ventrally located, contains pyramidal tracts from motor cortex

Medullary Olive - laterally located, contains olivary nuclei

Nucleus Gracilis and cuneatus (Posterior Column Nuclei) - termination sites of fasciculus gracilis and fasciculus cuneatus (general somatic senses)

Pons – involved in interconnection and integration of cerebral cortex, cerebellar cortex and brainstem

Superior, Middle and Inferior Cerebellar Peduncles - carry signals to and from the cerebral cortex, brainstem and cerebellum

Midbrain (Mesencephalon) – involved in interconnection and integration of cerebral cortex, and brainstem

Mammillary Bodies – involved in interconnection of Limbic System, Pre-Frontal Cortex and brainstem

Cerebral Peduncles (Crus Cerebri) - connect midbrain to cerebral cortex

Superior Colliculi - involved in reflex eye movements

Inferior Colliculi - involved in reflex head movements toward sounds

Hypothalamus - site for major neural autonomic and endocrine integration and control

Optic Chiasm - site of crossing of optic nerves

Optic Tracts - connections to cerebral cortex

Pituitary Gland – anterior and posterior pituitary hormones

Thalamus - filter and select sensory information; the “Gateway” to the cerebral cortex

Lateral Geniculate nuclei - for vision, cn II

Medial Geniculate nuclei - for hearing, cn VIII

Intermediate Mass - connection between right and left thalamus

Pineal Gland - involved in circadian rhythms using melatonin

Subcortical Structures

Corpus Callosum - connects right with left cerebral hemispheres

Anterior Commissure - accessory to corpus callosum

Fornix - connects brainstem and hypothalamus to hippocampus

Hippocampus - involved in formation of long term memory

Amygdala - involved with feeling of emotion

Basal Nuclei (ganglia) – Modifies cerebral cortical commands after evaluating signals from cerebral cortex, cerebellum, and brainstem; disturbed in Parkinsonism

Cranial Nerves, Brainstem and Subcortical Structures - Laboratory

Models and Specimens of Cranial Nerves

Cranial Nerves I through VI • Olfactory nerve (I) • Optic nerve (II) • Oculomotor nerve (III) • Trochlear nerve (IV) • Trigeminal nerve (V) • Abducens nerve (VI)	
Cranial Nerves VII through XII • Facial nerve (VII) • Vestibulocochlear nerve (VIII) • Glossopharyngeal nerve (IX) • Vagus nerve (X) • Spinal Accessory nerve (XI) • Hypoglossal nerve (XII)	

Models and Specimens of Brainstem

Medulla Oblongata • Medullary Pyramid • Medullary Olive • Nucleus Gracilis • Nucleus Cuneatus	

Pons • Superior Cerebellar Peduncle • Middle Cerebellar Peduncle • Inferior Cerebellar Peduncle	
Midbrain (Mesencephalon) • Mammillary Bodies • Cerebral Peduncles • Superior Colliculi • Inferior Colliculi	
Hypothalamus • Optic Chiasm • Optic Tracts • Pituitary Gland	

Thalamus
 	
• Pineal Gland
• Thalamus
  o Lateral Geniculate nuclei
  o Medial Geniculate nuclei
  o Intermediate Mass	

Models and Specimens of Subcortical and Limbic Structures

Subcortical
 	
• Corpus Callosum
• Anterior Commissure
• Basal Nuclei (ganglia)
  o Caudate Nucleus
  o Globus Pallidus*
  o Putamen*
  o Substantia Nigra*	

Limbic • Fornix • Hippocampus • Amygdala	

* pending availability of specimens

Brain and Cortex

Cranial meninges

Dura Mater, arachnoid and pia mater

Dural Sinuses - act as veins

- Superior Sagittal Sinus
- Transverse Sinus

Falx Cerebri - dura mater between cerebral hemispheres

Tentorium Cerebelli - dura mater between cerebellum and cerebrum

Ventricles

Septum Pellucidum - separates lateral ventricles

Lateral Ventricles - wing like spaces under cerebral hemispheres

Interventricular Foramen - connects lateral ventricles with third ventricle

Third Ventricle - slit like space in center of diencephalon

Midbrain Aqueduct (Cerebral Aqueduct) - connects third ventricle with fourth ventricle

Fourth Ventricle - space under cerebellum

Choroid Plexus - produces cerebrospinal fluid

Cerebrum - Cerebral Cortex

Longitudinal Fissure

Central Sulcus

- Frontal Lobe – generally motor in function
  - Precentral Gyrus (Primary Motor Cortex) – control of fine movement
  - Motor Association Cortex – Integration of information for complex movements
  - Speech-Motor Cortex – involved in production of speech; (Broca's area)
  - Pre-Frontal Cortex – involved in decision making; direction of attention
- Parietal Lobe – generally sensory in function
  - Postcentral Gyrus (Primary Somatosensory Cortex) – perception of sensation from skin (Cutaneous) and muscle (proprioceptive)
  - Sensory Association Cortex – integration of sensory signals; direction of sensory attention
    - Left Association Cortex – involved in production of meaning to language; (Wernicke's area)
    - Right Association Cortex – involved in production of meaning to spatial relationships

Parieto-occipital Sulcus

- Occipital Lobe – generally sensory in function
  - Visual Cortex – perception of visual sensation
- Visual Association Cortex – perception of visual content and meaning

Lateral Sulcus

Temporal Lobe – generally sensory in function

Primary Auditory Cortex – perception of auditory sensation

Auditory Association Cortex – perception of auditory content and meaning; extend into parietal cortex

Gustatory and Olfactory Cortex – perception of gustatory and olfactory sensation

Insular Cortex [at deep extent of lateral sulcus] – involved in providing knowledge about outcome of events

Parahippocampal Gyrus [overlies the hippocampus]

Hippocampus - involved in formation of long term memory

Amygdala - involved with feeling of emotion

Cerebellum - Cerebellar Cortex

Anterior and Posterior Lobes – involved in monitoring and timing of motor events

Vermis

Brain and Cortex - Laboratory

Models and Specimens of Cranial meninges and Ventricles

Cranial meninges
 	
• Dura Mater
• Dural Sinuses
  o Superior Sagittal Sinus
  o Transverse Sinus
• Falx Cerebri
• Tentorium Cerebelli	

Ventricles • Septum Pellucidum • Lateral Ventricles • Interventricular Foramen • Third Ventricle • Midbrain Aqueduct (Cerebral Aqueduct) • Fourth Ventricle o Choroid Plexus	

Models and Specimens of Cerebral Cortex

Fissures and Sulci • Longitudinal Fissure • Central Sulcus • Parieto-occipital Sulcus • Lateral Sulcus	

Frontal Lobe • Precentral Gyrus (Primary Motor Cortex) • Motor Association Cortex • Speech-Motor area • Pre-Frontal Cortex	
Parietal Lobe • Postcentral Gyrus (Primary Somatosensory Cortex) • Sensory Association Cortex • Language area • Spatial area	
Occipital Lobe • Visual Cortex • Visual Association Cortex	
Temporal Lobe • Primary Auditory Cortex • Auditory Association Cortex • Gustatory and Olfactory Cortex • Insular Cortex • Parahippocampal Gyrus	

Cerebellar Cortex • Anterior Lobe • Posterior Lobe • Vermis	

Sensory Receptors

Anatomical classes of receptors

- Free nerve endings - ends of dendrites
- Encapsulated nerve endings - ends of dendrites enclosed in fibrous connective tissue
- Accessory sensory receptor cells - separate cells that connect to the dendrites of sensory neurons

General senses

Usually refer to sensations related to the skin or internal organs: pain, touch, pressure, temperature, movement, body chemistry

Nociceptors

- respond to damage / pain
- usually consist of free nerve endings

Thermoreceptors

- respond to temperature
- usually consist of free nerve endings

Mechanoreceptors

- respond to movement
- Tactile receptors (found mostly in skin)
- usually consist of encapsulated nerve endings

Chemoreceptors

- respond to chemical changes
- usually consist of free nerve endings signals

Special senses

Usually refer to sensations related to the ears, nose, tongue, eyes: hearing, balance, smell, taste, vision

Mechanoreceptors

Auditory receptors (Hair cells)

- respond to movement
- are accessory sensory receptor cells

Vestibular receptors (Hair cells)

- respond to movement
- are accessory sensory receptor cells

Chemoreceptors

Olfactory receptors

- respond to chemical changes
- are accessory sensory receptor cells

Gustatory receptors

- respond to chemical changes
- are accessory sensory receptor cells

Photoreceptors

- respond to light
- are accessory sensory receptors

Hearing and Balance

Ear

External Ear

- Pinna - cartilage of ear
- External Auditory Canal
- Tympanic Membrane - ear drum

Middle Ear

- Eustachian Tube (Pharyngotympanic tube)
- Auditory Ossicles
  - Malleus - connected to tympanic membrane
  - Incus - amplifies movement of Malleus
  - Stapes - connected to Oval Window

Inner Ear

- Cochlea - for hearing
  - Oval Window - membrane that connects to auditory ossicles
  - Round Window - membrane that permits pressure changes
- Vestibule - for equilibrium
  - Saccule and Utricle- for sensation of gravity, acceleration
  - Semicircular Canals (SC) - for sensation of head rotation
    - Anterior Semicircular Canals - respond to nodding of head
    - Posterior Semicircular Canals - respond to sideways tilting of head
    - Lateral Semicircular Canals - respond to horizontal rotation of head
  - Ampulla - contains the sensory receptors

Bony Labyrinth - bone surrounding Cochlea and Vestibule

Cochlea

Vestibular Duct - contains Perilymph moved by the oval window

Tympanic Duct - contains Perilymph that moves the round window

Cochlear Duct - contains Endolymph and Organ of Corti

Vestibular Membrane - separates Scala Vestibuli and Scala Media

Basilar Membrane - separates Scala Tympani and Scala Media

Tectorial Membrane - overlies the organ of Corti

Organ of Corti - contains Hair Cells (accessory sensory receptors)

Spiral Ganglion - location of Cell Bodies of the Cochlear Nerve

Cochlear Nerve - auditory branch of the Vestibulocochlear Nerve

Hearing, Balance and Vision - Laboratory

Models of the Ear

External Ear • Pinna • External Acoustic Canal • Tympanic Membrane	
Middle Ear • Eustachian Tube (Auditory Tube) • Auditory Ossicles • Malleus • Incus • Stapes	
Inner Ear • Cochlea • Oval Window • Round Window	

Inner Ear
 	
• Vestibule
• Saccule and Utricle
• Semicircular Canals
  o Anterior Semicircular Canal
  o Posterior Semicircular Canal
  o Lateral Semicircular Canal
• Ampulla
• Vestibular nerve	

Model and **Histology of the Cochlea**

Cochlea • Vestibular Duct • Tympanic Duct • Cochlear Duct • Vestibular Membrane • Basilar Membrane • Tectorial Membrane • Organ of Corti • Spiral Ganglion • Cochlear Nerve	

Models of the Eye

Fibrous Tunic • Sclera • Cornea	

Vascular Tunic (Uvea)
 	
• Iris
  o Pupil
  o Pupillary Constrictor Muscles
  o Pupillary Dilator Muscles
• Lens
• Ciliary Body
  o Ciliary Muscles
  o Suspensory ligaments
• Choroid	

Neural Tunic • Pigment Layer • Retina • Fovea • Optic Disc • Optic Nerve	
Chambers • Anterior Chamber • Posterior Chamber • Aqueous Humor • Vitreous Chamber • Vitreous Humor	

Histology of the Retina

Retina
 	
• Pigment cells
• Rods and Cones (Photoreceptors)
  o Outer segment
  o Inner segment
• Bipolar cells
• Ganglion cells	

Practice Questions – Nervous Tissue and Nervous System

Note: choices may be used more then once or not at all.

1-5. Matching

A)	motor neurons	commonly are multipolar neurons	1) _____
B)	sensory neurons	commonly are unipolar neurons	2) _____
C)	none of the above	found in posterior root ganglia	3) _____
D)		found in anterior root ganglia	4) _____
E)		found in anterior horn	5) _____

6-10. Matching

A)	axons	conduct signals long distances in sensory neurons	6) _____
B)	dendrites	carry signals toward motor neuron cell bodies	7) _____
C)	none of the above	carry signals from motor neuron cell bodies	8) _____
D)		connect (at synaptic junctions) to muscle	9) _____
E)		are found in spinal nerves	10) _____

11-15. Matching

A)	microglia	myelinate (insulate) neuron processes in the CNS	11) _____
B)	astrocytes	myelinate (insulate) neuron processes in the PNS	12) _____
C)	Schwann cells	produce a barrier between neurons and blood	13) _____
D)	oligodendrocytes	are phagocytic cells in the CNS	14) _____
E)	C and D	wrap around neurons in layers	15) _____

16-20. Matching

A)	central nervous system	sensory receptors	16) _____
B)	peripheral nervous system	peripheral nerves	17) _____
		spinal cord	18) _____
		eyeballs	19) _____
		brain	20) _____

21-25. Matching

A)	somatic	refers to integumentary and muscular systems	21) _____
B)	afferent	refers to visceral (internal) organ systems	22) _____
C)	efferent	refers to outside of the dorsal body cavity	23) _____
D)	autonomic	refers to incoming or sensory signals	24) _____
E)	peripheral	refers to outgoing or motor signals	25) _____

26-30. Matching

A)	anterior horn	contains cell bodies of sensory neurons	26) _____
B)	anterior root	contains cell bodies of motor neurons	27) _____
C)	posterior horn	contains axons of sensory neurons	28) _____
D)	posterior root	dorsal gray matter of spinal cord	29) _____
E)	posterior root ganglion	contains axons of motor neurons	30) _____

31-35. Matching

A)	Endoneurium	bundles of axons	31) _____
B)	Perineurium	insulation around axons	32) _____
C)	Epineurium	fibrous connective tissue around a nerve	33) _____
D)	Myelin	fibrous connective tissue around fascicles	34) _____
E)	none of the above	fibrous connective tissue around Schwann cells	35) _____

36-40. Matching

A)	originates from the cervical plexus	sciatic nerve	36) _____
B)	originates from the brachial plexus	phrenic nerve	37) _____
C)	originates from the lumbar plexus	femoral nerve	38) _____
D)	originates from the sacral plexus	thoracic nerve	39) _____
E)	none of the above	radial and ulnar nerves	40) _____

41-45. Matching

A)	gamma motor neurons	connect to extrafusal muscle	41) _____
B)	alpha motor neurons	connect to intrafusal muscle	42) _____
C)	none of the above	connect to inhibitory interneurons	43) _____
		connect to muscle spindle sensory neurons	44) _____
		adjust the length and sensitivity of muscle spindles	45) _____

46-50. Place in order the structures that **muscle stretch signals** travel through the PNS and CNS.

A)	anterior root / spinal nerve	46) _____
B)	muscle spindle receptors	47) _____
C)	posterior root ganglion	48) _____
D)	posterior horn	49) _____
E)	anterior horn	50) _____

51-55. Matching

A)	interventricular foramen	produces cerebrospinal fluid	51) _____
B)	spinal commissure	connects right and left cerebrum	52) _____
C)	cerebral aqueduct	connects third and fourth ventricle	53) _____
D)	corpus callosum	connects third and lateral ventricle	54) _____
E)	choroid plexus	connects left and right spinal horns	55) _____

56-60. Matching

A)	glossopharyngeal nerve	motor, tongue movements	56) _____
B)	hypoglossal nerve	sensory and motor; visceral organs	57) _____
C)	trigeminal nerve	sensory and motor; face, mouth, mastication	58) _____
D)	vagus nerve	sensory anterior 2/3 tongue; motor facial expression	59) _____
E)	facial nerve	sensory posterior 1/3 tongue, carotid arteries; motor swallowing	60) _____

61-65. Matching

A)	optic nerve	motor, eye movement (superior oblique muscle)	61) _____
B)	trochlear nerve	special sensory, balance and hearing	62) _____
C)	olfactory nerve	special sensory, vision	63) _____
D)	oculomotor nerve	special sensory, smell	64) _____
E)	vestibulocochlear nerve	motor, eye movement	65) _____

66-70. Matching

A)	medulla oblongata	connects to the pituitary	66) _____
B)	hypothalamus	is located below the 4th ventricle	67) _____
C)	midbrain	is a continuation of the spinal cord	68) _____
D)	pons	located between the midbrain and medulla	69) _____
		is located just posterior to the hypothalamus	70) _____

71-75. Matching

A)	medulla oblongata	part of the diencephalon	71) _____
B)	hypothalamus	controls visceral organs	72) _____
C)	thalamus	controls endocrine responses	73) _____
D)	A and B	is a continuation of the spinal cord	74) _____
E)	B and C	acts as a gate keeper to the cerebral cortex	75) _____

76-80. Matching

A)	thalamus	integrate sensory and motor cortical signals	76) _____
B)	cerebellum	connection between right and left cerebrum	77) _____
C)	basal nuclei	monitors and times contraction of muscles	78) _____
D)	choroid plexus	produces cerebrospinal fluid	79) _____
E)	corpus callosum	selects sensory information	80) _____

81-85. Matching

A)	hippocampus	essential for emotions	81) _____
B)	basal nuclei	includes the caudate nucleus	82) _____
C)	amygdala	located superior and lateral to the thalamus	83) _____
D)		includes regions implicated in Parkinsonism	84) _____
E)		necessary for establishing (or recall of)long term memory	85) _____

86-90. Matching

A)	frontal cortex	location of the visual cortex	86) _____
B)	postcentral gyrus	involved in decision making	87) _____
C)	precentral gyrus	location of the primary motor cortex	88) _____
D)	occipital cortex	location of the language processing region	89) _____
E)	none of the above	location of the primary Somatosensory cortex	90) _____

91-95. Matching

A)	projects to posterior column nuclei	thalamus	91) _____
B)	projects to primary sensory cortex	pyramidal tracts	92) _____
C)	projects to ventral horns	spinothalamic tract	93) _____
D)	projects to thalamus	nucleus cunneatus and gracilis	94) _____
E)		fasciculus cunneatus and gracilis	95) _____

96-100. Place in order the structures that **touch signals** travel through the CNS.

A)	posterior horn	96) _____
B)	post-central gyrus	97) _____
C)	posterior thalamus	98) _____
D)	posterior column pathways (gracilis and cuneatus)	99) _____
E)	posterior column nuclei (gracilis and cuneatus) of medulla oblongata	100) _____

101-105. Matching

A)	receives auditory signals	occipital lobe	101) _____
B)	receives visual signals	inferior colliculus	102) _____
C)	none of the above	superior colliculus	103) _____
		lateral geniculate nucleus	104) _____
		medial geniculate nucleus	105) _____

106-110. Place in order the structures that light passes through the eye.

A)	outer segment of photoreceptors (portion with visual pigments)	106) _____
B)	inner segment of photoreceptors (portion with cell nuclei)	107) _____
C)	retinal ganglion cells	108) _____
D)	bipolar cells	109) _____
E)	pigment layer	110) _____

111-115. Place in order the structures that **visual neural signals** travel through the eye and CNS.

A)	lateral geniculate nuclei	111) _____
B)	retinal ganglion cells	112) _____
C)	photoreceptors	113) _____
D)	bipolar cells	114) _____
E)	optic nerve	115) _____

116-120. Place in order the structures that **sound waves** pass through the ear.

A)	scala vestibule (vestibular duct)	116) _____
B)	tectorial membrane	117) _____
C)	auditory ossicles	118) _____
D)	cochlear duct	119) _____
E)	oval window	120) _____

121-125. Matching

A)	respond to rotation of head	posterior semicircular canal	121) _____
B)	respond to nodding of head	superior semicircular canal	122) _____
C)	respond to sideways tilting of head	lateral semicircular canal	123) _____
D)	respond to gravity and acceleration	utricle and saccule	124) _____
E)	none of the above	cochlea	125) _____

Section 5 –Autonomic, Endocrine, and Reproductive Systems

Autonomic Nervous System

General Neural Organization

Two motor neurons are involved in the connection between the central nervous system and peripheral target organs.

Preganglionic neurons

- The first motor neuron in line
- Cell bodies are located within the central nervous system
- Axons leave the CNS to reach ganglionic neurons in the peripheral nervous system

Ganglionic neurons

- The second motor neuron in line
- Cell bodies are located in autonomic ganglia in the peripheral nervous system
- Axons leave the autonomic ganglia to reach target cells in the peripheral organs.

Parasympathetic Division

Brainstem and Sacral Spinal organization

Brainstem nuclei (or Sacral Lateral Horns) - contain cell bodies of parasympathetic preganglionic neurons (the first motor neurons in line)

Cranial Nerves (or Sacral Anterior Roots) - carry axons of parasympathetic preganglionic neurons out of brainstem or sacral spinal cord

Parasympathetic ganglia – contain cell bodies of parasympathetic ganglionic neurons (the second motor neurons in line) with which axons of preganglionic neurons synapse, mostly in the target organs.

Parasympathetic Ganglia

Ciliary, Sphenopalatine, Submandibular and Otic Ganglia:

- Axons of preganglionic neurons travel through the III, VII, and IX cranial nerves and synapse on ganglion neurons.
- Axons of the postganglionic neurons control target organs in the
    - Head – pupil constriction, salivary secretion

Thoracic Intramural Ganglia:

- Axons of preganglionic neurons travel through the X cranial nerve and synapse on ganglion neurons.
- Axons of the postganglionic neurons control organs in the
    - Thoracic cavity – bronchoconstriction, bradycardia
    - Abdominal cavity – gastrointestinal secretion, peristalsis

Pelvic Intramural Ganglia:

- Axons of preganglionic neurons travel from the sacral spinal cord through the pelvic nerve and synapse on ganglion neurons.
- Axons of the postganglionic neurons control organs in the
    - Pelvic cavity – defecation, urination, erection

Neurotransmitters

- preganglionic neurons release acetylcholine which act on receptors on the ganglionic neurons
- postganglionic neurons release acetylcholine which act on receptors of the target organs

Sympathetic Division

Spinal organization

Lateral Horns - contain cell bodies of sympathetic preganglionic neurons (the first motor neurons in line)

Anterior Roots - carry axons of sympathetic preganglionic neurons out of spinal cord

Sympathetic Ganglia – contain cell bodies of sympathetic ganglionic neurons (the second motor neurons in line) with which axons of preganglionic neurons synapse, in one of three major groups of ganglia.

Sympathetic Ganglia

Sympathetic Chain Ganglia and Cervical Sympathetic Ganglia:

- Axons of preganglionic neurons travel through the White Rami and synapse on ganglionic neurons in the sympathetic chain ganglia.
- Axons of the ganglionic neurons travel through the Gray Rami and into spinal nerves to control target organs in the
    - Head – pupil dilation
    - Thoracic cavity – bronchodilation, cardioacceleration, ionotropy
    - Skin and blood vessels in muscle – piloerection, sweating, vasodilation

Celiac and Mesenteric Ganglia:

- Axons of preganglionic neurons travel through the White Rami and pass through the sympathetic chain ganglia without synapsing,
- Travel through splanchnic nerves, and synapse in the Celiac and Mesenteric Ganglia.
- Axons of the ganglionic neurons travel through the splanchnic nerves to control target organs in the
    - Abdominopelvic cavity – vasoconstriction, intestinal relaxation

Adrenal Medulla:

- Axons of preganglionic neurons travel through the White Rami and pass through the sympathetic chain ganglia and the Celiac Ganglia without synapsing,
- The axons of preganglionic neurons synapse in the adrenal medulla on ganglionic neurons that in turn release catecholamines into the blood circulation.

Neurotransmitters

- preganglionic neurons release acetylcholine which act on receptors on the ganglionic neurons
- postganglionic fibers release norepinephrine which act on receptors of the target organs

Autonomic Nervous System - Laboratory

Parasympathetic

Brainstem • Medulla Oblongata • Preganglionic Neurons • Parasympathetic Ganglia • Ganglioic Neurons • Acetylcholine	
Sacral Spinal Cord • Sacral Spinal Cord • Preganglionic Neurons • Parasympathetic Ganglia • Ganglioic Neurons • Acetylcholine	

Sympathetic

Chain Ganglia • Thoracic Spinal Cord • Preganglionic Neurons • White Rami • Sympathetic Chain Ganglia • Ganglioic Neurons • Gray Rami • Target Organ • Acetylcholine • Norepinephrine	
Celiac and Mesenteric Ganglia • Thoracic Spinal Cord • Preganglionic Neurons • White Rami • Splanchnic Nerves • Sympathetic Celiac and Mesenteric Ganglia • Ganglioic Neurons • Acetylcholine • Norepinephrine	
Adrenal Medulla • Thoracic Spinal Cord • Preganglionic Neurons • White Rami • Splanchnic Nerves • Adrenal Medulla • Ganglioic Neurons • Acetylcholine • Norepinephrine	

Neural Endocrine Organization

General Neural Organization

Chemical signals originate from neurons and are sent directly to other neurons or muscle cells

- Neural signals are transmitted along an axon to the synaptic bulb of the neuron.
- From the synaptic bulb chemical messengers are released into the synaptic cleft.
- The chemical messenger travels across the synaptic cleft to act on another neuron or muscle cell.
- By definition the chemical messenger is called a neurotransmitter.
- The neurotransmitter exerts its influence by attaching to receptors in the postsynaptic membrane of the target cells.

General Endocrine Organization

Chemical signals originate from neurons *or* from glandular epithelial cells and are sent through the blood to reach other cells.

Neurons

- Neural signals are transmitted along an axon to the synaptic bulb of the neuron.
- From the synaptic bulb chemical messengers are released into surrounding interstitial space.
- The chemical messenger is transported into the blood to act on other cells.
- By definition the chemical messenger is called a hormone.
- The hormone exerts its influence by attaching to receptors in the membrane of the target cells.

Glandular Epithelial Cells

- Chemical signals traveling through the blood attach to receptors in the membrane of glandular epithelial cells.
- The glandular epithelial cells in turn release a chemical messenger into the surrounding interstitial space.
- The chemical messenger is transported into the blood to act on other cells.
- By definition the chemical messenger is called a hormone.
- The hormone exerts its influence by attaching to receptors in the membrane of the target cells.

Overview of Endocrine glands

- Hypothalamus - vasopressin, oxytocin, hypothalamic regulatory hormones
- Pituitary gland
    - Anterior - TSH, ACTH, FSH, LH, PRL, GH
    - Posterior - vasopressin, oxytocin
- Thyroid gland - thyroxine, triiodothyronin, calcitonin
- Parathyroid gland - parathormone
- Heart - atrial natriuretic peptide
- Pancreas - insulin, glucagon
- Adrenal gland
    - Medulla - epinephrine, norepinephrimne
    - Cortex - aldosterone, cortisol, testosterone
- Kidney - renin, erythropoetin
- Digestive tract - gastrin, secretin, cholecystokinin, others
- Gonads
    - Ovaries - estrogen, progesterone, relaxin, inhibin
    - Testes - testosterone, inhibin

Endocrine Glands - Laboratory

Models and Specimens

Head and Neck • Hypothalamus • Pituitary • Thyroid • Parathyroid	
Thoracic region • Heart	
Abdominal region • Pancreas • Adrenal • Kidney • GI Tract	
Pelvic region • Ovaries • Testes	

Histology of Pancreas, Thyroid, Adrenal and Pituitary

Pancreas
• Pancreatic islets
  o Alpha cells
  o Beta cells	

Parathyroid gland • Chief cells	
Thyroid gland • Interfollicular cells (C cells) • Thyroid follicles • Follicular cells • Colloid	

Adrenal gland
 	
• Adrenal medulla
  o Chromaffin cells
 	
• Adrenal cortex
  o Zona Glomerulosa
  o Zona Fascicularis
  o Zona Reticularis	

Pituitary gland, *l.s.*
 	
• Infundibulum
• Median eminence
• Posterior Pituitary
  o axons
• Anterior Pituitary
  o glandular epithelial cells	

Pancreas, Thyroid, Adrenal, and Kidney

Pancreatic Hormones

Source	*Hormone*	*Action*
pancreatic Alpha cells	glucagon	increase breakdown of glycogen to glucose
pancreatic Beta cells	insulin	increase transport of glucose into cells

Thyroid and Parathyroid Hormones

Source	*Hormone*	*Action*
Thyroid follicles	Thyroxin (T4) Triiodothyronin (T3)	stimulate cellular metabolism; increase heat production and energy consumption
Thyroid "C" cells	calcitonin	stimulates osteoblasts
Parathyroid Chief cells	parathormone	stimulates osteoclasts

Adrenal medullary hormones

Source / anatomical region	*Hormone*	*Action*
Chromaffin Cells (ganglionic neurons)	Epinephrine Norepinephrine	Varies depending on receptors

Adrenal cortical hormones

Source / anatomical layer	*Hormone*	*Action*
Zona glomerulosa	Aldosterone	increases renal reabsorption of sodium ions and water
Zona fascicularis	Cortisol	stress response promotes utilization of lipids and proteins (glucose sparing)
Zona reticularis	Testosterone	stimulates muscle growth

Renal Hormones

Cells / Source	*Hormone*	*Action*
JG cells	Renin	converts angiotensinogen to angiotensin
kidney	Erythropoietin	stimulates erythrocyte production
	Calcitriol	increases intestinal calcium absorption

Hypothalamus and Pituitary Gland

Hypothalamus

- contains cell bodies of hypothalamic neurons that send axons to the posterior pituitary and/or to the median eminence

Posterior Pituitary

- contains axons of hypothalamic neurons that produce vasopressin and oxytocin

Median eminence

- region of hypothalamus that contains axons of hypothalamic neurons that produce hypothalamic regulatory hormones

Anterior Pituitary and Intermediate Lobe

- contain glandular epithelial cells that produce pituitary hormones in response to hypothalamic regulatory hormones

Hypophyseal Portal System (Pituitary Portal Vessels)

- connects the capillaries of the median eminence to the capillaries of the anterior pituitary

Posterior Pituitary (Neurohypophysis)

Contains axons of hypothalamic neurons

Source	*Hormone*	*Action*
Hypothalamic axons in Posterior Pituitary	Vasopressin	increases reabsorption of water
Hypothalamic axons in Posterior Pituitary	Oxytocin	facilitates milk ejection

Anterior Pituitary (Adenohypophysis)

Contains glandular epithelial cells that produce pituitary hormones in response to hypothalamic regulatory hormones

Hypothalamic Regulatory Hormone	*Anterior Pituitary Hormone*	*Action*
Thyrotropin Releasing Hormone (TRH)	Thyroid Stimulating Hormone (TSH);	stimulates T3 and T4 production by thyroid follicles
Corticotropin Releasing Hormone (CRH)	Adrenocorticotropic Hormone (ACTH)	stimulates cortisol production by adrenal cortex
Somatotropin Releasing Hormone (GHRH) and Inhibiting Hormone (GHIH)	Growth Hormone (GH)	stimulates somatomedin production by liver
Gonadotropin Releasing Hormone (GnRH)	Follicle Stimulating Hormone (FSH)	stimulates follicle development and estrogen production in female; spermatogenesis in male
Gonadotropin Releasing Hormone (GnRH)	Luteinizing Hormone (LH)	stimulates ovulation and progesterone production in female; testosterone production in male
Prolactin Releasing Hormone (PRH) and Inhibiting Hormone (PIH)	Prolactin (PRL)	stimulates milk production; reabsorption of electrolytes

Male Reproductive System and Spermatogenesis

Scrotum, Testes, and Penis

Scrotum

Dartos – layer of smooth muscle within dermis of scrotum which wrinkles the scrotum to decrease heat loss

Cremaster muscle – layer of skeletal muscle underneath dermis which raises the scrotum to decrease heat loss

Testes

Lobules – regions containing seminiferous tubules

Seminiferous tubules – coils of tubing in the lobules that produce sperm

Straight tubule – transports sperm from seminiferous tubules

Rete testis – mixes sperm

Efferent ducts – transports sperm to epididymis

Epididymis – site for maturation of sperm

Spermatic Cord – includes Vas deferens, testicular vessels and nerves

Ductus Deferens (Vas deferens) – transports sperm

Ampulla – enlarged region of Ductus Deferens; site for storage of sperm

Seminal Vesicle – produces seminal fluid that dilutes the sperm and provides nutrients

Ejaculatory Duct – connection between ampulla and prostatic urethra

Prostate Gland – produces prostatic fluid (fluid and enzymes)

Urethra and associated structures

Prostatic Urethra – passes thru prostate

Bulbourethral Glands – produces a lubricating fluid

Penile Urethra – passes thru penis

External Urethral Meatus – opening of urethra

Penis

Corpus Spongiosum - surrounds the penile urethra and becomes engorged with blood

Corpora Cavernosa - dorsal to the corpus spongiosum and becomes engorged with blood

Glans Penis

End of penis surrounding Corpus Spongiosum

Seminiferous Tubules

Interstitial Cells - between tubules; produce testosterone

Sertoli Cells

- attached to inner surface of tubules; maintain a blood-testis barrier, permit development of spermatids, secrete inhibin

Spermatogonia - stem cells for production of sperm

Primary Spermatocytes – from mitosis of spermatogonia

Secondary Spermatocytes – from meiosis I of spermatocytes

Spermatids – from meiosis II of spermatocytes

Spermatozoan – from maturing of spermatids

Penis

Penile Urethra - passes thru penis

Corpus Spongiosum - surrounds the penile urethra and becomes engorged with blood

Corpora Cavernosa - dorsal to the corpus spongiosum and becomes engorged with blood

Dorsal Arteries and Veins

Central Arteries

Hormones and Male Reproduction

FSH stimulates Spermatogenesis

LH stimulates interstitial cells

Interstitial cells produce Testosterone

Spermatogenesis and chromosome distribution

Spermatogonium

- contains 23 pairs of chromosomes
- undergoes mitosis through out adult life
- produces a primary spermatocyte and a daughter spermatogonium

Primary Spermatocyte

- contains 23 pairs of chromosomes with 2 chromatids each
- undergoes meiosis I(1) in the seminiferous tubules
- produces two secondary spermatocytes

Secondary Spermatocyte

- contains 23 single chromosomes with 2 chromatids each
- undergoes meiosis II(2) in the seminiferous tubules
- produces two spermatids

Spermatid

- contains 23 chromosomes with one chromatid each

Male Reproductive System – Laboratory

Models of Scrotum, Testes, and Penis

Scrotum • Dartos • Cremaster muscle	
Testes • Lobules • Seminiferous tubules • Straight tubule • Rete testis • Efferent ducts Epididymis	
Spermatic Cord • Ductus Deferens • Testicular Artery • Pampiniform Plexus of the Testicular Vein • Ilioinguinal and Genitofemoral nerves	

Ductus Deferens (Vas deferens) • Ampulla • Seminal Vesicle • Ejaculatory Duct • Prostate Gland	
Urethra • Prostatic Urethra • Bulbourethral Glands • Penile Urethra • External Urethral Meatus	
Penis • Corpus Spongiosum • Corpora Cavernosa • Glans	

Histology of Seminiferous Tubules and Penis

Seminiferous Tubules • Interstitial Cells • Sertoli Cells • Spermatogonia • Primary Spermatocytes • Secondary Spermatocytes • Spermatids • Spermatozoan	
Penis • Penile Urethra • Corpus Spongiosum • Corpora Cavernosa • Dorsal Arteries and Veins • Central Arteries	

Female Reproductive System

Ovaries, Uterus, and Vagina

Ovaries

Uterine Tubes (Fallopian tubes)

- Fimbrae – catches ovulated 'egg'
- Infundibulum – attaches fimbrae to the uterine tubes
- Ampulla – expansion of tubes
- Isthmus – narrowing of tubes

Broad Ligament and associated ligaments

- Mesovarium –extension of broad ligament between ovary and uterine tube
- Ovarian Ligament – supports ovary; extends toward uterus
- Suspensory Ligament – supports ovary; extends laterally toward pelvic wall
- Uterosacral Ligaments – supports uterus; extend posteriorly
- Round Ligaments - supports uterus; extend anteriorly

Uterus

- Uterosacral Ligaments (extend posteriorly)
- Round Ligaments (extend anteriorly)
- Fundus, Body, Isthmus, and Cervix
- External Orifice (Cervial Os)

Uterine wall

- Endometrium – cuboidal epithelium intermingled with blood vessels; for implantation of the embryo
- Myometrium – muscular layer
- Perimetrium – fibrous connective tissue

Vagina and external genitalia

- Vaginal Entrance and Canal
- Urethral Opening
- Labia Minora
- Labia Majora
- Clitoris – erectile tissue

Pubic Symphysis

Mons Pubis –adipose tissue

Ovary (Microscopic)

Oocytes (are primary oocytes)

Primary follicle

- follicular (granulosa) cells enlarge and undergo cell division

Secondary follicle

- follicular cells separate and Follicular fluid collects in pockets

Mature follicle (Graafian follicle)

- the oocyte projects into an expanded central chamber the primary oocyte completes miosis I and becomes a secondary oocyte

Zona pellucida – glycoprotein that attaches the oocyte to follicular (granulosa) cells

Corona radiata – first layer of follicular cells surrounding the oocyte

Cumulus Oophorus – the follicular cells that surround the oocyte

Corpus luteum

- the follicular cells of the empty follicle differentiate into luteal cells

Corpus albicans

- the corpus luteum is replaced by fibrous connective tissue

Uterus (Microscopic)

Endometrium

Functional zone – sloughs off during menstruation

Basilar zone – source for re-growth of Functional zone

Myometrium – muscular layer

Perimetrium – connective tissue surrounding Uterus

Hormones and Female Reproduction

FSH stimulates Ovarian Follicle development

Ovarian Follicles (Granulosa cells) produce Estrogen

LH stimulates Ovulation and formation of the Corpus Luteum

Corpus Luteum (Luteal cells) produces Progesterone

Oogenesis and chromosome distribution

Oogonium

- contains 23 pairs of chromosomes
- undergoes mitosis only before birth
- produces primary oocytes

Primary Oocyte

- contains 23 pairs of chromosomes with 2 chromatids each
- undergoes meiosis I(1) in the ovary (in mature ovarian follicle)
- produces one secondary oocyte and one polar body

Secondary Oocyte

- contains 23 single chromosomes with 2 chromatids each
- undergoes meiosis II(2) after penetration by the sperm
- produces one ovum and one polar body

Ovum

- contains 23 chromosomes with one chromatid each

Female Reproductive System - Laboratory

Models of Ovaries, Uterus, and Vagina

Ovaries (sectioned) • Primary Oocytes • Developing Follicle • Mature Follicle • Developing Corpus Luteum • Corpus Luteum • Corpus Albicans	
Ovary and Uterine (Fallopian) Tubes • Fimbrae • Infundibulum • Ampulla • Isthmus	
Broad Ligament and ligaments • Broad Ligament • Mesovarium • Ovarian Ligament • Suspensory Ligament • Uterosacral Ligaments • Round Ligaments	
Uterus • Fundus • Body • Isthmus • Cervix • External Orifice (Cervical Os)	

Uterine wall • Endometrium • Myometrium • Perimetrium	
Vagina and external genitalia • Vaginal Entrance • Vaginal Canal • Urethral Opening • Labia Minora and Majora • Clitoris	
Pubic Symphysis • Pubic Symphysis • Mons Pubis	

Histology of Ovary and Uterus

Ovary
 	
• Oocytes
• Primary follicle
• Secondary follicle
• Mature follicle
  o Antrum
  o Zona pellucida
  o Corona radiata
• Corpus luteum
• Corpus albicans	

Uterus
• Endometrium
  o Functional zone
  o Basilar zone
• Myometrium
• Perimetrium	

Practice Questions – Autonomic, Endocrine, and Reproductive Systems

Note: choices may be used more then once or not at all.

1-5. Matching

A)	sympathetic	ganglionic/postganglionic neurons in adrenal medulla	1) _____
B)	parasympathetic	preganglionic cell bodies mainly in thoracic cord	2) _____
C)	none of the above	preganglionic cell bodies mainly in brain stem	3) _____
		preganglionic axons in vagus nerve	4) _____
		preganglionic axons in white rami	5) _____

6-10. Matching

A)	norepinephrine	released by sympathetic pre-ganglionic neurons	6) _____
B)	acetylcholine	released by sympathetic post-ganglionic neurons	7) _____
C)	A and B	released by parasympathetic pre-ganglionic neurons	8) _____
D)	none of the above	released by parasympathetic post-ganglionic neurons	9) _____
		released by adrenal ganglionic neurons (chromaffin cells)	10) _____

11-15. Matching

A)	celiac and mesenteric ganglia	controls pupils of eyes	11) _____
B)	chain ganglia	control heart and lungs	12) _____
		control abdominal organs	13) _____
		control blood vessels in GI tract	14) _____
		control blood vessels in skeletal muscle	15) _____

16-20. Matching

A)	autonomic nervous system	mainly controls smooth muscle	16) _____
B)	somatic nervous system	mainly controls skeletal muscle	17) _____
		utilizes 1 efferent motor neuron	18) _____
		utilizes 2 efferent motor neurons	19) _____
		controls visceral organs and vessels	20) _____

21-25. Matching

A)	celiac and mesenteric ganglia	found in target organs	21) _____
B)	sympathetic chain ganglia	found adjacent to the aorta	22) _____
C)	intramural ganglia	also known as chain ganglia	23) _____
D)	adrenal medulla	most peripheral sympathetic ganglion	24) _____
		found mainly in <u>para</u>sympathetic nervous system	25) _____

26-30. Matching

A)	parathormone	produced by pancreatic Beta cells	26) _____
B)	epinephrine	produced by pancreatic Alpha cells	27) _____
C)	calcitonin	produced by parathyroid chief cells	28) _____
D)	glucagon	produced by adrenal chromaffin cells	29) _____
E)	insulin	produced by thyroid interfollicular ("C") cells	30) _____

31-35. Matching

A) produced by thyroid interfollicular (‘C’)cells
B) produced by thyroid follicular cells
C) produced by the pancreatic islets

insulin 31) _____
glucagon 32) _____
calcitonin 33) _____
thyroxine 34) _____
triiodothyronin 35) _____

36-40. Matching

A) testosterone
B) epinephrine
C) aldosterone
D) cortisol
E) renin

produced by adrenal zona reticularis 36) _____
produced by adrenal chromaffin cells 37) _____
produced by adrenal zona fascicularis 38) _____
produced by adrenal zona glomerulosa 39) _____
produced by juxtaglomerular apparatus 40) _____

41-45. Matching

A) adrenal medulla
B) anterior pituitary
C) posterior pituitary
D) none of the above

releases thyroid stimulating hormone into blood 41) _____
releases acetylcholine into blood 42) _____
releases epinephrine into blood 43) _____
releases ACTH into blood 44) _____
releases TSH into blood 45) _____

46-50. Matching

A) posterior pituitary
B) anterior pituitary
C) none of the above

produces luteinizing Hormone 46) _____
produces Vasopressin 47) _____
produces oxytocin 48) _____
produces thyroxin 49) _____
produces ACTH 50) _____

51-55. Matching

A) posterior pituitary
B) median eminence
C) anterior pituitary
D) all of the above
E) A and C

contains blood capillaries 51) _____
contains glandular epithelial cells 52) _____
often referred to as the pituitary gland 53) _____
composed of axons from hypothalamic neurons 54) _____
site of secretion of hypothalamic regulatory hormones 55) _____

56-60. Matching

A) adrenocorticotropic Hormone
B) thyroid stimulating Hormone
C) follicle stimulating Hormone
D) growth hormone
E) prolactin

stimulates milk production 56) _____
stimulates thyroxine secretion 57) _____
stimulates cellular metabolism 58) _____
stimulates estrogen production 59) _____
stimulates cortisol secretion from the adrenal cortex 60) _____

61-65. Matching

A) Follicle stimulating hormone
B) Luteinizing hormone

stimulates ovulation 61) _____
stimulates spermatogenesis 62) _____
stimulates follicle development 63) _____
stimulates production of testosterone 64) _____
stimulates production of progesterone 65) _____

66-70. Matching

A)	mitosis (duplication)	primary spermatocytes → secondary spermatocytes	66) _____
B)	meiosis I (halving)	spermatogonia → primary spermatocytes	67) _____
C)	meiosis II (duplication of halves)	secondary spermatocytes → spermatids	68) _____
D)	none of the above	sertoli cells → interstitial cells	69) _____
		spermatids → spermatozoan	70) _____

71-75. Matching

A)	epididymis	site for storage of sperm near the ejaculatory duct	71) _____
B)	prostate gland	site for maturation of sperm near the testis	72) _____
C)	seminal vesicle	produces a lubricating fluid	73) _____
D)	bulbourethral gland	produces prostatic fluid	74) _____
E)	ampulla of vas deferens	produces seminal fluid	75) _____

76-80. Place the following in the order that sperm pass.

A)	seminiferous tubules	76) _____
B)	Rete testes	77) _____
C)	epididymis	78) _____
D)	vas deferens	79) _____
E)	ejaculatory duct	80) _____

81-85. Matching

A)	ampulla of uterine tube	site for production of follicles	81) _____
B)	endometrium	site for production of secondary oocyte	82) _____
C)	ovary	preferred site for implantation of embryo	83) _____
D)	none of the above	common site for penetration of oocyte by sperm	84) _____
		the functional zone sloughs off during the menstrual cycle	85) _____

86-90. Place the following in the order that the oocyte / egg passes.

A)	fimbrae	86) _____
B)	mature follicle	87) _____
C)	body of uterus	88) _____
D)	isthmus of uterine tube	89) _____
E)	ampulla of Fallopian tube	90) _____

91-95. Matching

A)	follicular phase of endometrial growth	requires estrogen	91) _____
B)	luteal phase of endometrial growth	starts after ovulation	92) _____
C)	menses	requires progesterone	93) _____
		occurs in absence of ovarian steroids	94) _____
		associated with final growth of endometrium	95) _____

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Section 6 – Cardiovascular System

Cardiovascular Organization

Circulatory Circuits

Pulmonary circuit

- Pulmonary circuit - carries blood to and from the lungs
- Pulmonary Arteries - carry blood away from the heart to the lungs
- Pulmonary Veins - carry blood from the lungs to the heart

Systemic circuit

- Systemic circuit - carries blood to and from the rest of the body
- Systemic Arteries - carry blood from heart to other organs
- Systemic veins - carry blood from other organs to the heart

Lymphatic vessels

- carry lymph from tissues to systemic veins

Relationship between the Heart and Blood Vessels

Right side of the heart

Right atrium

- receives blood from the systemic circuit via the Inferior and Superior Vena Cava

Right ventricle

- discharges blood into pulmonary circuit via the Pulmonary Trunk and Arteries

Right atrioventricular valve (tricuspid valve)

- controls movement of blood between the right atrium and right ventricle

Pulmonary semilunar valve

- controls movement of blood between the right ventricle and the pulmonary circuit

Left side of the heart

Left atrium

- receives blood from the pulmonary circuit via the Pulmonary Veins

Left ventricle

- discharges blood into systemic circuit via the Aorta

Left atrioventricular valve (bicuspid valve, mitral valve)

- controls movement of blood between the left atrium and the left ventricle

Aortic semilunar valve

- controls movement of blood between the left ventricle and the systemic circuit

The Heart

Superficial Anatomy

Pericardial cavity - located between the heart and the pericardial sac

Parietal pericardium – lines the pericardial sac

Visceral pericardium (epicardium) – covers the heart

Base – region where the major arteries and veins connect

Apex – tip of the heart

Coronary sulcus – groove between the atria and the ventricles

Interventricular sulcus – depression between the ventricles

Right atrium – receives blood from the systemic circuit

Right ventricle – discharges blood into pulmonary circuit

Left atrium – receives blood from the pulmonary circuit

Left ventricle – discharges blood into systemic circuit

Superior Vena Cava – returns blood from upper systemic organs to the right atrium

Inferior Vena Cava – returns blood from lower systemic organs to the right atrium

Pulmonary Trunk – carries blood to the lungs from the left ventricle

Pulmonary Veins – returns blood from the lungs to the left atrium

Ascending Aorta – carries blood to systemic organs from the left ventricle

Aortic Arch – a bend in the aorta that allows vessel to branch to the upper body before descending to the lower body

Ligamentum Arteriosus - remnant of the fetal vascular connection between the pulmonary trunk and the aortic arch

Sectional Anatomy

Interventricular Septum – Heart wall between left and right ventricles

Right atrioventricular valve (tricuspid valve) controls movement of blood between the right atrium and right ventricle

Pulmonary semilunar valve – controls movement of blood between the right ventricle and the pulmonary circuit

Left atrioventricular valve (bicuspid valve, mitral valve) – controls movement of blood between the left atrium and the left ventricle

Aortic semilunar valve – controls movement of blood between the left ventricle and the systemic circuit

Chordae tendinae – tendonous fibers that brace the Cusps

Papillary muscles – cardiac muscle connect to the chordae tendinae

Trabeculae carnae – deep groves and folds in the ventricles

Fossa ovale - remnant of the fetal opening between right and left atria

Fetal Heart

Foramen ovale - opening between right and left atria

Fossa ovale - remnant of the fetal opening between right and left atria

Ductus arteriosus - vascular connection between pulmonary trunk and aortic arch

Ligamentum Arteriosus - remnant of the fetal vascular connection between pulmonary trunk and aortic arch

Coronary Circulation

Coronary Arteries - originate at the base of the ascending aorta

- Right Coronary artery - follows coronary sulcus
- Marginal branch - extends along right border
- Posterior Interventricular branch (Posterior Descending) - within the posterior interventricular sulcus
- Left Coronary artery - follows coronary sulcus
- Anterior Interventricular branch (Anterior Descending) - within the anterior interventricular sulcus
- Circumflex branch - follows coronary sulcus; part fuses with right coronary artery; part extends along left border

Coronary (Cardiac) Veins - empty into the Coronary Sinus and then right atrium

- Anterior cardiac veins - adjacent to marginal branch arteries
- Small cardiac Vein - lateral to Anterior cardiac veins; empties into the coronary sinus
- Middle cardiac vein - adjacent to posterior descending arteries
- Great cardiac vein - adjacent to anterior descending arteries; empties into the coronary sinus
- Posterior cardiac vein - adjacent to circumflex branch arteries
- Coronary Sinus - in posterior coronary sulcus; empties into the right atrium

Heart Wall

Epicardium (visceral pericardium)

- covers exterior of heart
- consists of a mesothelial (simple squamous) layer and a connective tissue layer

Myocardium

- muscular wall of the heart
- contains cardiac muscle, connective tissue, blood vessels, nerves

Endocardium

- covers interior of heart
- consists of an endothelial (simple squamous) layer

Cardiac Muscle

Cardiac muscle cells - short cells with single nuclei

Intercalated discs - sites of membrane bonding at ends of adjacent cardiac muscle cells

Endomysium - fibrous connective tissue connecting cardiac muscle cells together side by side

Cardiac Pumping and Muscle Contraction

The Heart as a Pump

Cardiac cycle

- period between one heart beat and the next
- Blood moves from one chamber to the next when the pressure in the first chamber exceeds that in the second.

Atrial Relaxation

- leads to a decrease in atrial pressures.
- As the atrial pressures become less than the venous pressures, blood moves from the veins to the atria.

Ventricular Relaxation (Diastole)

- leads to a rapid decrease in ventricular pressure.
- As the ventricular pressures become less than the arterial pressures, the semilunar valves close.
- As the ventricular pressures become less than the atrial pressures, the atrioventricular valves open and blood moves from the atria to the ventricles.
- The diastolic pressure differences between the atria and the ventricles leads to about 70% of ventricular filling.

Atrial Contraction

- leads to a rapid increase in atrial pressures.
- As the atrial pressures increase, more blood moves from the atria to the ventricles

Ventricular Contraction (Systole)

- leads to a rapid increase in ventricular pressure
- As the ventricular pressures exceed the atrial pressures, the atrioventricular valves close.
- As the ventricular pressures exceed the arterial pressures, the semilunar valves open and blood moves to the arteries.

Coordination of Cardiac Muscle Contraction

- The atria must contract from the appendages toward the AV valves.
- The ventricles must contract from the apex toward the semilunar valves.
- The contraction is coordinated by specialized cells

Nodal cells

- membranes depolarize spontaneously and cyclically
- Pacemaker cells - those that cycle fastest
    - Sinoatrial node – in posterior wall of right atrium – produces intrinsically about 70-80 action potentials per minute
    - Atrioventricular node – in floor of right atrium near ventricle – produces intrinsically about 40-60 action potentials per minute

Conduction Fibers

- Conducting fibers in the atrial wall
- atrioventricular node
- AV bundle (bundle of His) - travels along interventricular septum
- Bundle Branches - divide along interventricular septum and radiateacross the inner surface of the right and left ventricles
- Purkinje fibers - branches to contractile cells

Conduction pathway

SA node → atrial conduction fibers → AV node → AV bundle → bundle branches → Purkinje fibers

Electrocardiogram (EKG)

- P wave - depolarization of the atria
- QRS complex - depolarization of the ventricles
- T wave - repolarization of the ventricles
- PR interval - prolonged by damage to conduction system or AV node
- QT interval - prolonged by damage to conduction system, ischemia or myocardial damage

Heart – Laboratory

Models and Specimens of Heart

Superficial Anatomy

Heart • Pericardial Cavity • Parietal pericardium • Visceral pericardium (Epicardium • Base • Apex	
Major Veins • Superior vena cava • Inferior vena cava • Pulmonary veins(right and left)	
Major arteries • Ascending aorta • Pulmonary trunk • Pulmonary arteries (right and left)	
Chambers • Right Atria and Auricle (Atrial Appendage) • Left Atria and Auricle (Atrial Appendage) • Right Ventricle • Left Ventricle	

Sectional Anatomy

Right side • Right Atrioventricular (AV) valve (tricuspid valve) • Fossa ovale • Chordae tendinae • Papillary muscles • Trabeculae carnae • Pulmonary semilunar valve	
Left side • Left Atrioventricular (AV) valve (bicuspid valve, Mitral valve) • Fossa ovale • Chordae tendinae • Papillary muscles • Trabeculae carnae • Aortic Semilunar valve	

Coronary Circulation

Coronary Arteries • Right Coronary artery • Marginal branch • Posterior Interventricular branch (Posterior Descending) • Left Coronary artery • Anterior Interventricular branch (Anterior Descending) • Circumflex branch	
Coronary Veins • Anterior cardiac veins • Small cardiac Vein • Middle cardiac vein • Great cardiac vein • Posterior cardiac vein • Coronary Sinus	

Fetal Heart

• Foramen ovale (becomes the fossa ovale after birth) • Ductus arteriosus (becomes the ligamentum arteriosus after birth)	

Histology of the Heart

Heart Wall • Epicardium (visceral pericardium) • Myocardium • Endocardium	
Cardiac Muscle • Cardiac muscle cells • Intercalated discs • Endomysium	

Blood Vessels, Microcirculation and Lymphatic Vessels

Blood Vessels

Arteries

- carry blood from the heart and toward the capillaries
- Contain a prominent layer of smooth muscle that is under the control of the autonomic nervous system and various hormones
- Arterioles - small arteries that connect to the capillaries

Capillaries

- serve as the site for transfer between blood and interstitial space
- consist of a layer of simple squamous epithelium (endothelium)

Veins

- carry blood away from capillaries and to the heart
- contain extensions of the endothelium that serve as valves
- Venuoles - small veins that connect to the capillaries

Arteries and Veins

Tunica Interna

- endothelial lining (endothelium) - simple squamous epithelium
- elastic connective tissue (internal elastic lamina)

Tunica Media

- concentric sheets of smooth muscle

Tunica Externa

- connective tissue sheath
- lastic connective tissue (external elastic lamina)

Smooth Muscle -

Smooth muscle cells

- short, spindle shaped cells with single nuclei

Endomysium

- fibrous connective tissue connecting smooth muscle cells together side by side and end to end

Microcirculation

Fluid moves between blood (vascular space) and the interstitial space, and between the interstitial space and cells (intracellular space)

Vascular space

- space in the lumen of blood vessels that contains the blood

Interstitial space

- space between cells and between cells and the capillaries that contains the Interstitial fluid

Intracellular space

- space inside of cells that contains the cytoplasm

Blood Capillaries

- thin walled vessels between the smallest arteries and veins where exchange of oxygen, nutrients, wastes and other
- substances occurs between the blood and the interstitial fluid.

Lymphatic Capillaries

- recovers plasma lost from the blood capillaries for return to the systemic venous circulation

Lymphatic vessels

Collect fluid that leaks out of the blood capillaries and return it to the systemic venous circulation

Lymphatic capillaries

- recover interstitial fluid
- composed of endothelial cells with no basement membrane
- overlapping endothelial cells act as one way valves

Lymphatic nodules

- filter and destroy pathogens in the lymphatic fluid
- composed of reticular tissue and lymphocytes
- interspersed along the lymphatic vessels

Thoracic duct

- collects lymph from the body below the diaphragm and from the left half of the body above the diaphragm
- empties into the venous system at the junction of theleft internal jugular vein and the left subclavian vein

Right lymphatic duct

- collects lymph from the right side of the body above the diaphragm
- empties into the venous system at the junction of theright internal jugular vein and the right subclavian vein

Blood Vessels - Laboratory

Systemic Arteries

Aortic arch
 	
• Brachiocephalic artery
  o Right common carotid artery
  o Right subclavian artery
• Left common carotid artery
• Left subclavian artery	

Subclavian arteries (Right and Left)
 	
• Vertebral artery (Right and Left)
• Axillary artery (Right and Left)
• Brachial artery (Right and Left)
  o Radial artery (Right and Left)
  o Interosseous artery (Right and Left)
  o Ulnar artery (Right and Left)
  ▪ Palmar arteries (Right and Left)
  ▪ Digital arteries (Right and Left	

Carotid arteries • External carotid artery (Right and Left) • Internal carotid artery (Right and Left)	

Circle of Willis
 	
• Vertebral artery (Right and Left)
• Basilar artery
  o Posterior cerebral artery (Right and Left)
  ▪ Posterior communicating artery (Right and Left)
 	
• Internal carotid artery (Right and Left)
  o Middle cerebral artery (Right and Left)
  o Anterior cerebral artery (Right and Left)
  ▪ Anterior communicating artery	

Descending Aorta
 	
• Inferior phrenic artery (Right and Left)
• Celiac trunk
  o Gastric artery
  o Hepatic artery
  o Splenic artery
• Superior mesenteric artery
• Renal artery (Right and Left)
• Adrenal artery (Right and Left)
• Gonadal artery (Right and Left)
• Inferior mesenteric artery
• Common iliac artery (Right and Left	

Common iliac artery (Right and Left)
 	
• Internal iliac artery (Right and Left)
• External iliac artery (Right and Left)
  o Deep femoral artery (Right and Left)
  o Femoral artery (Right and Left)
  ▪ Popliteal artery (Right and Left)
  ▪ Anterior tibal artery (Right and Left)
  ▪ Dorsalis pedis artery (Right and Left)
  ▪ Posterior tibial artery (Right and Left)
  ▪ Fibularis artery (Right and Left)	

Deep Systemic Veins

Superior vena cava
 	
• Brachiocephalic vein (Right and Left)
  o Internal jugular vein (Right and Left)
  o Vertebral vein (Right and Left)
  o External jugular vein (Right and Left)
  o Subclavian vein (Right and Left)	

Subclavian vein (Right and Left)
 	
• Axillary vein (Right and Left)
  o Brachial vein (Right and Left)
  ▪ Radial vein (Right and Left)
  ▪ Ulnar vein (Right and Left)	

Inferior vena cava • Phrenic vein (Right and Left) • Hepatic vein (Right and Left) • Renal vein (Right and Left) • Adrenal vein (Right and Left) • Gonadal vein (Right and Left) • Common iliac vein (Right and Left)	

Common iliac vein (Right and Left)
 	
• Internal iliac vein (Right and Left)
• External iliac vein (Right and Left)
  o Femoral vein (Right and Left)
  o Popliteal vein (Right and Left)
  ▪ Anterior tibial vein (Right and Left)
  ▪ Posterior tibial vein (Right and Left)
  ▪ Fibularis vein (Right and Left)	

Hepatic Portal System Inferior vena cava • Hepatic veins • liver • Hepatic portal vein • Gastric vein • Splenic vein o Inferior Mesenteric vein • Superior Mesenteric vein	

Superficial Veins

Superficial Branches of Subclavian vein
 	
• Cephalic vein (Right and Left)
• Basilic vein (Right and Left)
  o Median Cubital vein (Right and Left)
  o Median Antebrachial vein (right and left)	

Superficial Branches of Femoral vein • Great saphenous vein (Right and Left) • Small saphenous vein (Right and Left)	

Lymphatic vessels

• Thoracic duct • Right lymphatic duct	

Histology of Arteries and Veins

Tunica Interna • endothelium • internal elastic lamina Tunica Media Tunica Externa • external elastic lamina	
Smooth Muscle • Smooth muscle cells • Endomysium	

Blood

Functions of blood

- transports gases, nutrients and metabolic wastes
- delivers enzymes and hormones
- regulates pH and electrolyte composition of interstitial fluids
- restricts fluid losses by way of the clotting reaction
- defends the body against toxins and pathogens
- helps regulate body temperature

Composition of blood

Plasma - 55%

- water - 92% of plasma
- electrolytes, nutrients, organic wastes
- proteins
    - albumins - major contributor of osmolarity, transport lipids
    - globulins - transport ions, hormones, lipids
    - fibrinogen - converted to fibrin in clotting reaction

Formed elements (blood cells) - 45%

- Red blood cells, White blood cells, Platelets
- hematocrit - percentage of whole that is composed of red blood cells

Blood cells

Erythrocytes (Red blood cells)

- cytoplasm contains hemoglobin
- flattened, no nucleus, mitochondria or ribosomes
- transport oxygen and carbon dioxide

Leukocytes (White blood cells)

Neutrophils (57%)

- engulf pathogens and debris
- release cytotoxins

Eosinophils (2.4%)

- engulf antibody bound pathogens
- attack parasites with cytotoxins

Basophils (0.6%)

- release histamine
- complement histamine release by Mast cells

Monocytes (6.5%)

- engulf or capture pathogens and debris
- enter tissues to become Macrophages

Lymphocytes - small (28%)

- B-lymphocytes form antibodies
- T-lymphocytes attack viruses and invaded cells

Lymphocytes - large (3%)

- NK-lymphocytes attack damaged or foreign cells

Platelets

- clump together, activate coagulation

Immunity

Nonspecific defenses

Microphages

- located in tissue and derived from neutrophils and eosinophils
- neutrophils - phagocytize cellular debris, pathogens and antibody bound pathogens
- eosinophils - phagocytize parasites and antibody coated pathogens

Macrophages

- tissue phagocytes derived from monocytes
- engulf cellualr debris and pathogens , or bind to pathogens, or release cytotoxic chemicals

Specific defenses (Immunity)

Lymphocytes

- Cytoxic T-cells - attack foreign cells or body cells infected by viruses
- B-cells - differentiate into plasma cells which produce antibodies
- Natural Killer (NK) cells - attack foreign cells, normal cells infected with viruses, or cancer cells appearing in normal tissue

Cellular immunity

- direct attack by cytotoxic T-cells

Humoral immunity

- attack by circulating antibodies

Functions of the lymphatic system

- There is a continual movement of fluid from the capillaries, into the interstitial spaces between tissue cells, and back to the circulation via the lymphatic vessels.
- Return of lost plasma from the capillaries
- Collect, capture and destroy pathogens in the body

Lymphatic tissues and organs

- connective tissues dominated by lymphocytes

Lymph nodes - contain macrophages and lymphocytes acting on lymph

Thymus - site for maturation of T-cells

Major Ducts

Right Lymphatic Duct – collects lymphatic fluid from right side of head and neck, right shoulder and arm, and right side of thorax

Thoracic Duct – collects lymphatic fluid from left side of head and neck, left shoulder and arm, left side of thorax, and all of the body below the thorax

Blood – Laboratory

Histology of Blood

Erythrocytes flattened, no nucleus	
Neutrophils pale granules in cytoplasm, multi-lobed beaded nucleus	
Lymphocytes, small very little cytoplasm, round nucleus	
Lymphocytes, large relatively little cytoplasm, rounded bean nucleus	

Monocytes large cell, pale cytoplasm, lima bean shaped nucleus	
Eosinophils reddish granules in cytoplasm, bi-lobed nucleus	
Basophils dark bluish granules in cytoplasm, bi-lobed nucleus	
Platelets cytoplasmic fragments, no nucleus	

Formed elements - slide of blood smear

Identify erythrocytes, each of the white cells, and platelets. Perform a differential white count by examining 100 white cells and tallying the number that are:

Table 1. Differental white count.

White Blood Cells	Tally
neutrophils	
lymphocytes	
monocytes	
eosinophils	
basophils	

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Practice Questions – Cardiovascular System

Note: choices may be used more then once or not at all.

1-5. Matching

A)	Left atrium	receives blood from the pulmonary veins	1) _____
B)	Right atrium	discharges blood into pulmonary arteries	2) _____
C)	Left ventricle	receives blood from the coronary sinus	3) _____
D)	Right ventricle	discharges blood into systemic arteries	4) _____
E)	none of the above	receives blood from the system veins	5) _____

6-10. Matching

A)	Mitral valve	located between right ventricle and pulmonary trunk	6) _____
B)	Right AV valve	located between right atrium and ventricle	7) _____
C)	Aortic Semilunar valve	located between left atrium and ventricle	8) _____
D)	Pulmonary semilunar valve	located between left ventricle and aorta	9) _____
E)	none of the above	also known as the bicuspid valve	10) _____

11-15. Place the following in the order that blood moves through the heart, starting at the lungs.

A)	Left atrium	11) _____
B)	Mitral valve	12) _____
C)	Tricuspid valve	13) _____
D)	Aortic semilunar valve	14) _____
E)	Pulmonary trunk	15) _____

16-20. Matching

A)	contraction of the ventricles	sucks blood into ventricles	16) _____
B)	relaxation of the ventricles	closes the semilunar valves	17) _____
C)	none of the above	opens the atrioventricular valves	18) _____
		closes the atrioventricular valves	19) _____
		discharges blood out of the ventricles	20) _____

21-25. Matching

A)	epicardium	composed of simple squamous epithelium	21) _____
B)	myocardium	very thick in the interventricular septum	22) _____
C)	endocardium	also called the visceral pericardium	23) _____
D)	A and B	composed of cardiac muscle	24) _____
E)	none of these	lines the inside of the heart	25) _____

26-30. Matching

A)	epicardium	analogous to the tunica externa of blood vessels	26) _____
B)	myocardium	analogous to the tunica interna of blood vessels	27) _____
C)	endocardium	analogous to the tunica media of blood vessels	28) _____
D)	none of these	also called the visceral pericardium	29) _____
		composed of cardiac muscle	30) _____

31-35. Matching

A)	right coronary artery	is connected to right atrium	31) _____
B)	left coronary artery	is connected to ascending aorta	32) _____
C)	coronary sinus	branches to form the marginal arteries	33) _____
D)	A and B	branches to form the circumflex artery	34) _____
		branches to form the anterior descending artery	35) _____

36-40. Matching

A)	SA node	located near the vena cava	36) _____
B)	AV node	located near the tricuspid valve	37) _____
C)	none of these	connects to the AV bundle (of His)	38) _____
		directly paces the contraction of the atria	39) _____
		directly paces the contraction of the ventricles	40) _____

41-45. Place the following in the order that signals pass through the cardiac conduction system.

A)	atrial conduction fibers	41) _____
B)	bundle branches	42) _____
C)	bundle of His	43) _____
D)	SA node	44) _____
E)	AV node	45) _____

46-50. Matching

A)	tunica externa	is very thick in arteries	46) _____
B)	tunica interna	contains elastic connective tissue	47) _____
C)	tunica media	composed mostly of smooth muscle	48) _____
D)	A and B	contains simple squamous epithelium	49) _____
E)	none of these	composed mostly of fibrous connective tissue	50) _____

51-55. Matching

A)	intracellular space	contains blood	51) _____
B)	interstitial space	contains cytoplasm	52) _____
C)	vascular space	also called extracellular space	53) _____
D)	A and B	surrounds lymphatic capillaries	54) _____
E)	B and C	found between connective tissue fibers	55) _____

56-60. Matching

A)	right lymphatic duct	collects lymph from the left leg	56) _____
B)	thoracic duct	collects lymph from the left arm	57) _____
C)	A and B	collects lymph from the right leg	58) _____
D)	none of these	collects lymph from the intestines	59) _____
		empty(ies) into the subclavian veins	60) _____

61-65. Matching

A)	carries oxygen poor blood	aorta	61) _____
B)	carries oxygen rich blood	coronary sinus	62) _____
C)	none of these	hepatic portal vein	63) _____
		right pulmonary vein	64) _____
		left pulmonary artery	65) _____

66-70. Matching

A)	internal jugular vein	drains blood from the legs	66) _____
B)	saphenous veins	drains blood from the brain	67) _____
C)	cephalic vein	drains blood from outside of the head	68) _____
D)	basilic vein	drains blood from the lower surface of the arm	69) _____
E)	none of these	drains blood from the upper surface of the arm	70) _____

71-75. Matching

A)	blood drains into hepatic portal vein	splenic vein	71) _____
B)	blood drains directly into vena cava	gastric veins	72) _____
		adrenal veins	73) _____
		gonadal veins	74) _____
		superior mesenteric vein	75) _____

76-80. Place the following in the order that blood travels to reach the <u>right hand</u>, starting at the aortic arch.

A)	radial artery	76) _____
B)	axillary artery	77) _____
C)	brachial artery	78) _____
D)	subclavian artery	79) _____
E)	brachiocephalic artery	80) _____

81-85. Place the following in the order that blood travels to reach the anterior brain, starting at the vertebral arteries. Assume damage to the internal carotid arteries in the neck.

A)	basilar artery	81) _____
B)	anterior cerebral arteries	82) _____
C)	posterior cerebral arteries	83) _____
D)	posterior communicating arteries	84) _____
E)	internal carotid arteries in the skull	85) _____

86-90. Matching

A)	superior mesenteric vein	drains blood from the arms	86) _____
B)	external jugular vein	drains blood from the brain	87) _____
C)	cephalic veins	drains blood from the ovaries	88) _____
D)	gonadal veins	drains blood from outside of the head	89) _____
E)	none of these	drains blood from the small intestines	90) _____

91-95. Matching

A)	water	another name for white blood cells	91) _____
B)	fibrin	major component of blood clots	92) _____
C)	leukocytes	makes up about 95% of plasma	93) _____
D)	erythrocytes	another name for platelets	94) _____
E)	thrombocytes	carry oxygen	95) _____

96-100. Matching

A)	basophils	release histamine that in turn dilates blood vessel	96) _____
B)	monocytes	are subdivided into B, T, and NK cells	97) _____
C)	eosinophils	restrain potential pathogens	98) _____
D)	neutrophils	engulf and digest parasites	99) _____
E)	lymphocytes	engulf debris	100) _____

101-105. Matching

A)	Blood type A+	has antibodies to neither the A or B protein	101) _____
B)	Blood type B+	has antibodies to both the A and B protein	102) _____
C)	Blood type AB+	has antibodies to the A protein only	103) _____
D)	Blood type O+	has antibodies to the B protein only	104) _____
E)	none of the above	has antibodies to the Rh protein	105) _____

Section 7 –Respiratory, Digestive and Urinary Systems

Comparative Histological Organization of Visceral Organs

The cardiovascular system, respiratory system, digestive system, and urinary system share many common features. They are composed of tubing with an overlapping histological organization.

Heart

- Endocardium – an epithelial lining of simple squamous epithelium
- Myocardium – a region composed of concentric sheets of cardiac muscle
- Epicardium – a sheath of fibrous connective tissue and squamous epithelium

Blood Vessels

- Endothelium – an epithelial lining of simple squamous epithelium
- Tunica Interna – the Endothelium and underlying elastic connective tissue
- Tunica Media – a region composed of concentric sheets of smooth muscle
- Tunica Externa – a sheath of fibrous connective tissue with elastic connective tissue

Bronchial Tree

- Mucosa – an epithelial lining, most commonly, of pseudostratified ciliated columnar epithelium
- Submucosa – a region composed variously of fibrous connective tissue, hyaline cartilage, and smooth muscle

Gastrointestinal Tract

- Mucosa – an epithelial lining, most commonly, of simple columnar epithelium (stratified squamous epithelium in esophagus and anus)
- Submucosa – a region composed, most commonly, of fibrous connective tissue
- Muscularis Externa – a region composed of two (or three) sheaths of smooth muscle; one concentric and the other longitudinal

Kidney

- Renal Tubules– small tubing composed, most commonly, of simple cuboidal epithelium

Ureter and Bladder

- Mucosa – an epithelial lining composed of a transitional epithelium
- Submucosa – a region composed largely of sheets of smooth muscle

Uterine Tube and Ductus Deferens

- Mucosa – an epithelial lining, most commonly, of ciliated and non-ciliated columnar epithelium
- Submucosa – a region composed largely of concentric sheets of smooth muscle

Uterus

- Endometrium – a thick epithelial lining, composed largely of-cuboidal epithelium intermingling with blood vessels
- Myometrium – a region composed largely of concentric sheets of smooth muscle
- Perimetrium – a region composed largely of fibrous connective tissue

Glands

- Glandular Epithelium – typically composed of a cuboidal-like epithelium

Respiratory Airways

Upper respiratory tract

Nose

External nares – nostrils

Nasal cavity (ies)

Nasal septum – partition in the nasal cavity composed of the perpendicular plate of the ethmoid bone, the vomer bone, and nasal cartilage; produces a right and a left nasal cavity

Hard palate – floor of the nose composed of maxillary and palatine bone

Soft palate – soft tissue posterior to the hard palate

Internal nares – connection between nasal cavity and nasopharynx

Nasal conchae – projections from lateral walls of nasal cavity

superior, middle and inferior

Nasal meatus(i) (superior, middle and inferior) - spaces between adjacent conchae for air passage

superior, middle and inferior

Pharynx

Auditory tube (Eustachian tube) – connects nasopharynx to middle ear

Nasopharynx - behind internal nares

Oropharynx - behind tongue

Laryngopharynx - behind larynx

Larynx

Glottis - opening of larynx

Epiglottis – surrounds the glottis

Thyroid cartilage – major anterior structure of the larynx

Cricoid cartilage – major posterior structure of the larynx

Ventricular folds – narrowing of the glottis superior to the vocal cords

Vocal folds – narrowing of the glottis inferior to the vocal cords

Vocal cords – fibrous connective tissue “strings” between the ventricular and vocal folds

Trachea

Tracheal cartilage – structural corrugations of the trachea

Primary bronchi

Right primary bronchus – right branch of trachea
Left primary bronchus – left branch of trachea

Secondary bronchi

Right secondary bronchi – 3 or 4 branches of right primary bronchus
Left primary bronchi – 2 branches of left primary bronchus

Lower respiratory tract

Lungs

Cardiac notch – depression in left lung for pericardium

Lobes

Right lung – superior, middle and inferior lobes
Left lung – superior and inferior lobes

Intrapulmonary (Segmental) bronchi – tertiary and smaller bronchi

Terminal bronchioles – branches of the smallest segmental bronchi

Respiratory bronchioles – branches of the terminal bronchiole

Alveolar ducts – branches of the respiratory bronchiole

Alveolar Sacs – clusters of alveoli that form around the alveolar ducts

Alveoli – the site of gas exchange with the blood

Pulmonary circulation

right and left pulmonary arteries
right and left pulmonary veins

Pleural cavities

Mediastinum – extends above and below pericardial sac to separate the left and right pleural cavities

Pleural cavity – space on either side of the pericardial cavity for the lungs

Parietal pleura – simple squamous epithelium that lines pleural cavities and covers the mediastinum

Visceral pleura – simple squamous epithelium that covers thelungs

Pleural space – space between parietal and visceral pleura

Histology of Trachea and Lungs

Trachea

Mucosa – epithelium and connective tissue

- PCCE – Pseudostratified ciliated columnar epithelium
- Lamina propria – fibrous connective tissue of the mucosa

Submucosa – connective tissue with mucous glands and blood vessels

- Tracheal cartilage – hyaline cartilage
- Trachealis muscle – between open ends of tracheal cartilage

Intrapulmonary (Segmental) Bronchi

Mucosa

- PCCE
- Lamina propria

Submucosa

- smooth muscle layer
- cartilage plates
- mucus glands (periodically)

Terminal bronchioles

Mucosa

- Simple Cuboidal-like Epithelium with less cilia
- PCCE begins to disappear

Submucosa

- smooth muscle layer begins to disappear
- No cartilage plates

Respiratory bronchioles

Mucosa

- Simple Squamous Epithelium
- No PCCE

Submucosa

- No smooth muscle
- No cartilage plates

Alveolar ducts and Alveoli

Mucosa

- Simple Squamous Epithelium
- Surfactant cells are interspersed
- Elastic fibers are prominent
- Capillaries are prominent

Pulmonary Ventilation

Pleura and pleural fluid

- Pleural cavities – contain the lungs
- Parietal pleura – lines pleural cavities and covers the mediastinum
- Visceral pleura – covers the lungs
- Pleural fluid – secreted by pleura and fills the pleural space

- the pleural fluid creates a fluid bond (and an associated negative intrapleural pressure) that pulls the visceral pleura and the parietal pleura together

Inhalation (Inspiration)

During quiet inhalation, the diaphragm muscles contract, and:

1. The diaphragm descends and the ribcage expands
2. The parietal pleura of the diaphragm and chest pull on the visceral pleura of the lungs, and at about the same time:
3. The lungs expand
4. The elastic connective tissue of the lungs stretches
5. Pressure decreases in the lungs and air is drawn in.

During forced inhalation contraction of the external intercostal muscles, the serratus anterior and posterior muscles, and the sternocleidomastoid and scalene muscles, increase the size of the thoracic cavity by expanding the ribcage.

Exhalation (Expiration)

During quiet exhalation, the diaphragm muscles relax and:

1. The elastic connective tissue of the lungs recoils
2. The lungs shrink, and at about the same time :
3. The visceral pleura of the lungs pull on the parietal pleura of the diaphragm and chest
4. The diaphragm ascends, and the ribcage contracts
5. Pressure increases in the lungs and air is expelled.

During forced exhalation contraction of the internal intercostal muscles, the rectus abdominus and the oblique muscles assist in decreasing the size of the thoracic cavity by compressing the ribcage and compressing the abdominal contents.

Gas Exchange and Transport

Partial Pressures

atmospheric pressure – 760 mmHg (15 psi)
partial pressure (p) – pressure contribution by a single gas

- 20.8 percent of atmospheric pressure due to oxygen
- 0.04 percent of atmospheric pressure due to carbon dioxide

region	*pO_2 mmHg*	*pCO_2 mmHg*
Alveoli	~100	~40
systemic venous blood and pulmonary arterial blood	~40	~45
systemic arterial blood and pulmonary venous blood	~100	~40
Tissues	~20	~50

Gas Exchange

Diffusion between alveoli and pulmonary capillaries

- alveolar O2 diffuses to pulmonary blood
- pulmonary blood CO2 diffuses to alveoli

Diffusion between systemic capillaries and tissues

- systemic blood O2 diffuses to tissues
- tissue CO2 diffuses to systemic blood

Oxygen Transport and Exchange

- In the lungs, where the oxygen concentration within the alveoli is greater than the oxygen concentration of the blood, oxygen moves into the blood and combines with hemoglobin.
- In the systemic tissues, where the oxygen concentration of the tissues is less than the oxygen concentration of the blood, oxygen dissociates from hemoglobin and moves out of the blood.

Carbon Dioxide Transport and Exchange

- In the lungs, where the carbon dioxide concentration within the alveoli is less than the carbon dioxide concentration of the blood, hydrogen ions combine with bicarbonate ions to form carbonic acid. The carbonic acid dissociates into carbon dioxide and water, and the carbon dioxide moves out of the blood.
- In the systemic tissues, where the carbon dioxide concentration of the tissues is greater than the carbon dioxide concentration of the blood, carbon dioxide moves into the blood and combines with water to form carbonic acid. The carbonic acid dissociates into hydrogen ions and bicarbonate ions.

Respiratory Airways and Lungs - Laboratory

Models of Upper respiratory tract

Nose • External Nares • Nasal Cavity • Nasal Septum • Hard Palate • Soft Palate • Uvula • Internal Nares • Nasal Conchae • Nasal Meatus(i) (superior, middle and inferior)	
Pharynx • Nasopharynx • Oropharynx • Laryngopharynx	
Larynx • Glottis • Epiglottis • Thyroid cartilage • Cricoid cartilage • Vestibular folds (false vocal cords) • Vocal folds (true vocal cords)	

Trachea • Tracheal Cartilage	
Primary bronchi • Right Primary Bronchus • Left Primary Bronchus Secondary Bronchi	

Histology of Trachea

Mucosa • PCCE • Lamina propria Submucosa • Fibrous Connective Tissue • Tracheal cartilage • Trachealis muscle	

Models of Lower respiratory tract

Right lung • Superior, Middle and Inferior Lobes Left lung • Superior and Inferior Lobes • Cardiac notch	
Intrapulmonary Bronchi (Segmental Bronchi) Pulmonary Circulation • Right and Left Pulmonary Arteries • Right and Left Pulmonary Veins	
Pleural Cavities • Mediastinum • Parietal Pleura • Visceral Pleura • Pleural Space	

Histology of Lung

Lung Lobule • Visceral Pleura • Elastic Connective Tissue • Fibrous Connective Tissue	
Intrapulmonary Bronchi Mucous • PCCE • Lamina propria Submucosa • smooth muscle layer • cartilage plates	
Terminal Bronchioles Mucosa • Cuboidal Epithelium • Lamina propria Submucosa • no cartilage plates	

Respiratory Bronchioles Mucosa • Squamous Epithelium Submucosa • no cartilage plates	
Alveolar ducts and Alveoli • Simple Squamous Epithelium • Elastic Connective Tissue • Pulmonary Capillaries	

Gastrointestinal Tract and Digestion

Digestive Tract

Oral cavity

Parotid gland – largest of the salivary glands

Tongue

Hard ands soft palate

Uvula – between oral cavity and oropharynx; contains sensory receptors for swallowing

Teeth

Incisors – for clipping or cutting; single root

Cuspids – for tearing or slashing; single root

Bicuspids (Premolars) – for crushing, mashing and grinding; one or two roots

Molars – for crushing and grinding; three or more roots

Superior Alveolar nerves – innervate the upper teeth; branches of Maxillary nerve

Inferior Alveolar nerves– innervate the lower teeth; branches of Mandibular nerve

Pharynx

Oropharynx – posterior to tongue; contains sensory receptors initiating swallowing

Laryngopharynx – posterior to larynx, connects to esophagus

Esophagus

Upper esophageal sphincter – prevents regurgitation into pharynx

Lower esophageal sphincter (cardiac sphincter)

- controls movement of food into stomach; prevents regurgitation into esophagus

Stomach

Fundus, body, pyloris

Rugae - infoldings of the stomach

Pyloric sphincter – controls movement of chyme into duodenum

Small intestine

Duodenum

- first part of small intestine
- site for mixing chyme with secretions from the pancreas and liver/gallbladder

Plicae circularis – circular infoldings of small intestine

Common Bile duct – connects to duodenum from liver/gallbladder

Pancreatic duct – connects to duodenum from pancreas

Jejunum and ileum

- second and third parts of small intestine
- sites for most nutrient absorption

Mesentery – holds small intestines in place

Colon (Large Intestine)

Cecum – first part of colon

Ileocecal valve – controls movement of chyme into colon

Appendix – functions as a lymphatic organ

Ascending, transverse, descending colon – region for fluid reabsorption and vitamin B synthesis

Sigmoid colon – "S" shaped portion between the descending colon and the rectum

Taenia Coli – separated enlargements of longitudinal muscle

Haustrae – pouches formed by longitudinal muscle contraction

Mesentery (Mesocolon) – holds large intestines in place

Rectum – final storage site for feces

Internal and external anal sphincters

Liver and Pancreas

Liver

Gallbladder – stores bile

Cystic Duct – connects gallbladder to common bile duct

Hepatic Ducts – collects bile from liver and connects to common bile duct

Common Bile Duct – connects to duodenum after joining cystic and hepatic ducts

Pancreas

Pancreatic Ducts

Histology of GI tract, Liver and Pancreas

Teeth

Dentin – forms the bulk of the tooth and is similar to bone, no Osteocytes

Pulp Cavity – in the center of the tooth and similar to the marrow cavity

Root Canal – channel through which nerves and blood vessels reach the pulp

Periodontal Ligament – fibrous connective tissue that anchors the Dentin to the Alveolar bone; similar to periosteum / ligaments

Cementum – covers the Dentin of the Root and anchors the Periodontal Ligament; similar to but harder than Dentin

Root – the base(s) of the teeth

Crown – the visible portion of the tooth that projects above the Gingiva

Neck – the boundary between the Root and the Crown

Gingiva – attaches to the tooth above the Neck; an epithelial barrier

Enamel – covers the Dentin of the Crown; densely packed calcium phosphate

Esophagus

Mucosa

- Stratified Squamous Epithelium
- Lamina propria – fibrous connective tissue of the mucosa
- Muscularis mucosae – smooth muscle

Submucosa

- Fibrous Connective Tissue

Muscularis externa

- Inner circular layer – circular layer of smooth muscle; for peristalsis
- Myenteric plexus – autonomic ganglia and neurons
- Outer longitudinal layer – longitudinal layer of smooth muscle; for peristalsis

Adventitia - loose connective tissue

Stomach

Mucosa

- Simple Columnar Epithelium
- Gastric Pits – openings of the gastric glands into the interior of stomach
- Gastric Glands – deep in lamina propria - produce mucus
- Mucus Neck Cells – clear – produce mucus
- Parietal Cells – pinkish - produce hydrochloric acid
- Chief Cells - bluish – produce pepsinogen
- Lamina Propria – fibrous connective tissue of the mucosa
- Muscularis Mucosae – smooth muscle layer

Submucosa – loose connective tissue, no glands

Muscularis externa

- Inner circular layer
- Outer longitudinal layer
- Oblique layer (scattered in submucosa)

Serosa – simple squamous epithelium

Duodenum

Mucosa

- Intestinal Villi
- Simple Columnar Epithelium
- Goblet Cells – interspersed among columnar epithelia
- Intestinal Glands
- Lacteals – terminal lymphatics inside of the villi
- Lamina Propria – fibrous connective tissue of the mucosa
- Muscularis Mucosae

Submucosa

- Duodenal Glands
- Lymphatic Nodules

Muscularis Externa

- Inner Circular Layer
- Myenteric Plexus – autonomic ganglia and neurons
- Outer Longitudinal Layer

Serosa

Liver

Liver Lobules – sections of liver

Hepatocytes - detoxify blood, some produce bile

Central Vein - drains blood from sinusoids

Portal Areas

- Hepatic Portal Vein and Hepatic Artery
- Bile Ductule - carries bile away from lobules

Liver Sinusoids - channels formed between hepatocytes for passage of blood

Bile Canaliculi – channels between hepatocytes for passage of bile

Pancreas

Pancreatic lobules

Pancreatic Acini (acinar glands) - produce pancreatic juices

Panceatic Ductules - carry pancreatic juices from lobules

Digestion

Mouth

Carbohydrate digestion

- salivary amylase - breaks down carbohydrates to simpler sugars (disaccharides and trisaccharides)

Stomach

Protein digestion

- pepsin - breaks down proteins to polypeptides
- (pepsinogen is secreted and converted to pepsin by HCl)
- HCl - disrupts cell membranes in food, activates pepsin

Small intestine

Carbohydrate digestion

- pancreatic amylase (from pancreas) - breaks down carbohydrates to simpler sugars (disaccharides and trisaccharides)
- disaccharides are broken down into monosaccharides by intestinal enzymes

Protein digestion

- pancreatic proteinases (from pancreas: chymotrypsin, trypsin, carboxypeptidase, elastase) - break down proteins and polypeptides to short chain peptides
- dipeptides and tripeptides are broken down into amino acids by peptidase (from pancreas and small intestine)

Fat digestion

- bile (from liver) - emulsifies fats
- pancreatic lipase (from pancreas) - breaks down triglycerides to fatty acids and monoglycerides

Absorption

- simple sugars are absorbed through intestinal epithelium into blood capillaries
- amino acids are absorbed through the intestinal epithelium into blood capillaries
- large fatty acids (greater than 10 carbons) and monoglycerides enter the intestinal lacteals and lymphatics

Gastrointestinal Tract, Pancreas and Liver - Laboratory

Models of the Digestive Tract

Oral cavity • Parotid Gland • Hard Palate • Soft Palate Uvula	
Teeth / Jaw • Central Incisor • Lateral Incisor • Cuspid (Canine) • 1st Premolar • 2nd Premolar • 1st Molar • 2nd Molar • 3rd Molar	
Tooth • Dentin • Pulp Cavity • Root Canal • Periodontal Ligament • Cementum • Root • Crown • Neck • Gingiva • Enamel	

Esophagus • Upper Esophageal Sphincter • Lower Esophageal Sphincter (Cardiac Sphincter)	
Pharynx • Oropharynx • Laryngopharynx	
Stomach • Fundus • Body • Pyloris • Rugae • Pyloric Sphincter	

Small intestine
 	
• Duodenum
  • Plicae Circularis
  • Common Bile Duct
  • Pancreatic Duct
• Jejunum
• Ileum	

Small Intestine Wall • Intestinal Villi • Simple Columnar Epithelium • Goblet Cells • Intestinal Glands • Lacteals • Muscularis Mucosae • Duodenal Glands • Lymphatic Nodules • Inner Circular Layer • Myenteric Plexus • Outer Longitudinal Layer	
Colon • Ileocecal Valve • Cecum • Appendix • Ascending Colon • Transverse Colon • Descending Colon • Sigmoid Colon • Taenia Coli • Haustrae	
Rectum • Internal Anal Sphincters • External Anal Sphincters	

Models of the Liver and Pancreas

Liver • Falciform Ligament • Round Ligament • Left and Right Lobes • Gallbladder • Cystic Duct • Hepatic Duct • Common Bile Duct • Hepatic Veins • Hepatic Arteries • Hepatic Portal Vein	
Pancreas • Pancreatic Duct	

Histology of GI Tract, Liver and Pancreas

Esophagus
 	
• Mucosa
  o Stratified Squamous Epithelium
  o Lamina Propria
  o Muscularis Mucosae
• Submucosa
  o Mucous and Serous Glands
• Muscularis externa
  o Inner Circular Layer
  o Myentreric Plexus
  o Outer Longitudinal Layer
• Adventitia	

Stomach
 	
• Mucosa
  o Simple Columnar Epithelium
  o Gastric Pits
  o Gastric Glands
  ▪ Mucus Neck Cells
  ▪ Parietal Cells
  ▪ Chief Cells
  o Lamina Propria
  o Muscularis Mucosae
• Submucosa
• Muscularis Externa
  o Inner Circular Layer
  o Outer Longitudinal Layer
• Serosa	

Duodenum
 	
• Mucosa
  o Intestinal Villi
  o Simple Columnar Epithelium
  o Goblet Cells
  o Intestinal Glands
  o Lacteals
  o Lamina Propria
  o Muscularis Mucosae
• Submucosa
  o Duodenal Glands
  o Lymphatic Nodules
• Muscularis Externa
  o Inner Circular Layer
  o Myenteric Plexus
  o Outer Longitudinal Layer
• Serosa	

Liver
 	
• Liver Lobules
• Hepatocytes
• Central Vein
• Portal Areas
  o Hepatic Portal Vein and Hepatic Artery
  o Bile Ductule
• Liver sinusoids	

Pancreas • Pancreatic Lobules • Pancreatic Acini (Acinar Glands) • Panceatic Ductules	

Urinary System

Kidney

Renal capsule - layer of collagen fibers covering the kidney

Adipose capsule - layer of adipose tissue covering the renal capsule

Hilus - indentation

Renal artery - carries blood to kidney

Renal vein - drains blood from kidney

Ureter - drains urine from kidney

Cortex - outer region

Medulla - intermediate region

Sinus - inner 'hollow' region containing the calyces and pelvis

Pyramids - distinct units within the medulla

Lobe – pyramid, each adjacent ½ Renal Column, and corresponding cortex

Renal columns - extensions of the cortex between pyramids

Papillae - extensions of the pyramids that empty into the minor calyces

Renal pelvis - expansion of ureter at renal sinus

Major calyces - branchings of renal pelvis

Minor calyces - branchings of major calyces that surround the papilla

Blood supply to the Nephron

Renal artery

Interlobar arteries - radiate between lobes (pyramids)

Arcuate arteries - arch along boundary of medulla and cortex

Interlobular arteries - branchings within the cortex of a lobe

Afferent arteriole - carries blood to glomerulus

Glomerulus - enclosed capillary network

Efferent arteriole - carries blood away from glomerulus to peritubular capillaries

Peritubular capillaries - surround proximal and distal convoluted tubules

Vasa recta - vascular network extending into the renal medulla, parallels the loop of Henle

Interlobular veins

Arcuate veins

Interlobar veins

Renal vein

Nephron

Nephron - the functional unit of the kidney that consists of

Renal corpuscle (Bowman's capsule) - slide

Renal tubules

Collecting system

Renal corpuscle (Bowman's capsule)

Parietal Epithelium (Capsular Epithelium) – simple squamous epithelium forming outer wall

Visceral Epithelium (Glomerular Epithelium) – simple squamous epithelium that covers the enclosed capillary network (Glomerulus)

- Podocytes - cells of the glomerular epithelium that filter the blood plasma

Capsular space – space between capsular and glomerular epithelium

Glomerulus - enclosed capillary network

- Capillaries - fenestrated; incomplete simple squamous epithelium

Juxtaglomerular cells – specialized smooth muscle cells in the adjacent afferent arteriole (produce Renin)

Proximal Convoluted tubule (PCT)

- tubing whose lumen is continuous with the capsular space
- lined with simple cuboidal epithelium (with microvilli)

Nephron Loop (of Henle)

- tubing whose lumen is continuous with proximal convoluted tubule
  Thick Descending limb - lined with simple cuboidal cells (some microvilli)
  Thin Descending limb - lined with simple squamous cells
  Thin Ascending limb - lined with simple squamous cells
  Thick Ascending limb - lined with simple cuboidal cells

Distal Convoluted tubule (DCT)

- tubing whose lumen is continuous with loop of Henle
- lined with simple cuboidal epithelium

Macula Densa – taller cells of DCT near glomerulus (sense Sodium)

Collecting system

Collecting tubules - lined with simple cuboidal epithelium

Collecting ducts - lined with simple cuboidal epithelium (proximally)

Papillary ducts - lined with simple columnar epithelium

Filtrate and Urine Formation

The kidney acts on the blood to filter plasma, to reabsorb needed fluids and electrolytes, and to excrete unneeded substances. Plasma is filtered out of the blood by Glomerular Filtration. Substances are reabsorbed from the Renal Tubules into the peritubular capillaries.

Filtrate formation

Glomerular filtration

- afferent arteriole to glomerulus
- water and solute molecules through wall of glomerular capillaries, through glomerular epithelium and into capsular space
- glomerular filtration rate - ~125 ml/min

Urine formation

Tubular reabsorption and the proximal tubule

About 60% of filtered water and 65% of filtered solutes are reabsorbed in this region.

- reabsorption of glucose, amino acids, and other nutrients via facilitated transport and cotransport
- reabsorption of sodium, potassium, calcium, magnesium, phosphate and sulfate ions via active transport
- reabsorption of bicarbonate ions (and secretion of hydrogen ions) via active transport
- reabsorption of water via diffusion
- reabsorption of urea via diffusion

Osmotic gradient and the nephron loop

About 20% of filtered water and 25% of filtered solutes are reabsorbed in this region.

- reabsorption of water from Descending Limb via diffusion (The membrane of the thin descending limb contains open water channels.)

- reabsorption of sodium and chloride from Ascending Limb via active transport (The membrane of the thick ascending limb contains transport pumps and few water channels)

- increases osmotic pressure in peritubular fluid (countercurrent multiplication) responsible for water reabsorption from descending limb

Tubular secretion (and reabsorption) and the distal tubule (early segment)

About 5% of filtered sodium is reabsorbed in this region.

- secretion of potassium (and reabsorption of sodium) via active transport under control of aldosterone (The tubular membrane contains sodium / potassium pumps controlled by aldosterone.)

Tubular reabsorption and the distal tubule (late segment), collecting tubules and ducts

About 5% of filtered sodium and about 10% to 20% of filtered water is reabsorbed in this region.

- secretion of potassium (and reabsorption of sodium) via active transport under control of aldosterone (The tubular membrane contains sodium / potassium pumps controlled by aldosterone.)
- reabsorption of water via diffusion under control of vasopressin (The tubular membrane contains water channels controlled by vasopressin)
- secretion of hydrogen ions (and reabsorption of bicarbonate ions) via active transport

Urinary System - Laboratory

Models of Kidney

Kidney • Renal capsule • Hilus • Renal artery • Renal vein • Ureter • Cortex • Medulla • Sinus • Pyramids • Lobe • Renal columns • Papillae • Renal pelvis • Major calyces • Minor calyces	
Nephron • Renal corpuscle (Bowman's capsule) • Renal tubules • Collecting system	

Renal corpuscle
 	
• Parietal Epithelium (Capsular Epithelium)
• Visceral Epithelium (Glomerular Epithelium)
  • Podocytes
• Capsular space
• Glomerulus
  • Capillaries
• Afferent arteriole
• Efferent arteriole	

Renal Tubules Proximal Convoluted tubule (PCT) Nephron Loop (of Henle) • Thick Descending limb • Thin Descending limb • Thin Ascending limb • Thick Ascending limb Distal Convoluted tubule (DCT) • Macula Densa • Juxtaglomerular cells	

Collecting system • Collecting tubules • Collecting ducts • Papillary ducts • Calyces • Renal pelvis • Ureter • Bladder • Urethra	
Renal Vessels • Renal artery • Interlobar arteries • Arcuate arteries • Interlobular arteries • Afferent arteriole • Glomerulus • Efferent arteriole • Peritubular capillaries • Vasa recta • Interlobular veins • Arcuate veins • Interlobar veins • Renal vein	

Histology of Kidney

Kidney • Renal corpuscle • Glomerulus • Juxtaglomerular cells • Proximal convoluted tubules • Distal convoluted tubules • Macula densa	

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Practice Questions – Respiratory, Digestive, Urinary Systems

Note: choices may be used more then once or not at all.

1-5. Matching

A) high oxygen
B) low oxygen

systemic veins 1) _____
pulmonary veins 2) _____
pulmonary arteries 3) _____
air in trachea during inhalation 4) _____
air in trachea during exhalation 5) _____

6-10. Matching

A) normal inspiration
B) normal expiration
C) forced inspiration
D) forced expiration
E) none of these

involves abdominal oblique muscles 6) _____
involves internal intercostals muscles 7) _____
involves a small negative pulmonary pressure 8) _____
depends mainly on contraction of diaphragm muscles 9) _____
depends mainly on recoil of elastic tissue in the lungs 10) _____

11-15. Matching

A) visceral pleura
B) parietal pleura
C) A and B
D) none of these

covers the lungs 11) _____
covers the mediastinum 12) _____
lines the pleural cavities 13) _____
surrounds the pleural fluid 14) _____
composed of simple squamous epithelium 15) _____

16-20. Matching

A) inhalation
B) exhalation

involves a negative pulmonary pressure 16) _____
involves recoil of elastic tissue in the lungs 17) _____
involves contraction of diaphragm muscles 18) _____
visceral pleura of the lungs pulls on the parietal pleura 19) _____
parietal pleura pulls on the visceral pleura of the lungs 20) _____

21-25. Matching

A) contains "C" rings of cartilage
B) contains plates of cartilage
C) contains no cartilage

trachea 21) _____
alveolar duct 22) _____
terminal bronchioles 23) _____
respiratory bronchioles 24) _____
intrapulmonary (segmental) bronchi 25) _____

26-30.

A) contains pseudostratified ciliated columnar epithelium (PCCE)
B) contains stratified squamous epithelium
C) contains simple columnar epithelium

alveoli 26) _____
trachea 27) _____
stomach 28) _____
intestines 29) _____
esophagus 30) _____

31-35. Place the following in the order that air moves through the airways; starting in the mouth.

A) alveoli 31) _____
B) trachea 32) _____
C) bronchioles 33) _____
D) glottis of larynx 34) _____
E) intrapulmonary (segmental) bronchi 35) _____

36-40. Matching

A)	pulmonary capillaries	fluid leaks out of the blood	36) _____
B)	systemic capillaries	oxygen moves from the blood into cells	37) _____
C)	A and B	oxygen moves from alveoli into the blood	38) _____
D)	none of these	carbon dioxide moves from cells into the blood	39) _____
		carbon dioxide moves from the blood into the alveoli	40) _____

41-45. Place in order the structures through which food pass.

A) jejunum 41) _____
B) ileocecal valve 42) _____
C) cardiac sphincter 43) _____
D) pyloric sphincter 44) _____
E) internal anal sphincter 45) _____

46-50. Place in order the structures through which food pass.

A) ileum 46) _____
B) cecum 47) _____
C) pyloris 48) _____
D) jejunum 49) _____
E) duodenum 50) _____

51-55. Matching

A)	small intestine	produces bile	51) _____
B)	parotid gland	contains the haustrae	52) _____
C)	pancreas	contains the taenia coli	53) _____
D)	colon	contains the plicae circularis	54) _____
E)	liver	major source of digestive enzymes	55) _____

56-60. Matching

A)	produce pepsinogen	pancreas	56) _____
B)	produce enzymes	chief cells of stomach	57) _____
C)	produce mucous	parietal cells of stomach	58) _____
D)	produce HCl	duodenal glands (Brunner's glands)	59) _____
E)	none of the above	intestinal glands (crypts of Lieberkuhn)	60) _____

61-65. Matching

A)	peptidase	emulsifies fats	61) _____
B)	amylase	breaks down fats in intestine	62) _____
C)	pepsin	breaks down protein in stomach	63) _____
D)	lipase	breaks down carbohydrates in mouth and intestine	64) _____
E)	bile	breaks down small proteins to amino acids in intestine	65) _____

66-70. Matching

A)	chief cells	produce mucous in the small intestine	66) _____
B)	parietal cells	produce mucous in the stomach	67) _____
C)	duodenal glands	produce hydrochloric acid	68) _____
D)	mucous neck cells	are in the submucosa	69) _____
E)	A, B, and D	produce pepsinogen	70) _____

71-75. Matching

A)	outer longitudinal smooth muscle	responsible for producing mucous	71) _____
B)	inner circular smooth muscle	responsible for absorbing nutrients	72) _____
C)	digestive epithelium	responsible for shortening of GI tract	73) _____
D)	lamina propria	responsible for connecting epithelium	74) _____
E)	goblet cells	responsible for constriction of GI tract	75) _____

76-80. Matching

A)	elastic connective tissue	found in intestinal villi	76) _____
B)	smooth muscle	found around the alveoli	77) _____
C)	none of the above	found under the visceral pleura of the lungs	78) _____
		found in the submucosa of the digestive tract	79) _____
		found in the submucosa of the respiratory airways	80) _____

81-85. Matching

A)	epithelium is pseudostratified ciliated columnar (PCCE)	stomach	81) _____
B)	epithelium is stratified squamous	duodenum	82) _____
C)	epithelium is simple squamous	esophagus	83) _____
D)	epithelium is simple columnar	Thin loop of Henle	84) _____
E)	epithelium is simple cuboidal	Thick loop of Henle	85) _____

86-90. Matching

A)	found in renal medulla	renal columns	86) _____
B)	found in renal cortex	renal corpuscles	87) _____
C)	found in renal hilus	renal pelvis / ureter	88) _____
D)	none of the above	interlobular arteries	89) _____
		papillae of pyramids	90) _____

91-95. Place in order the vessels through which renal blood passes.

A)	efferent arteriole	91) _____
B)	afferent arteriole	92) _____
C)	interlobular arteries	93) _____
D)	peritubular capillaries	94) _____
E)	glomerular capillaries	95) _____

96-100. Place in order the structures through which urinary filtrate passes.

A)	descending limb of the loop of Henle	96) _____
B)	ascending limb of the loop of Henle	97) _____
C)	proximal convoluted tubule	98) _____
D)	distal convoluted tubule	99) _____
E)	collecting tubule	100) _____

101-105. Matching

A)	simple cuboidal epithelium with microvilli	ureter	101) _____
B)	simple squamous epithelium	capsular epithelium	102) _____
C)	simple cuboidal epithelium	glomerular epithelium	103) _____
D)	transitional epithelium	proximal convoluted tubules	104) _____
		thick ascending limb of the loop of Henle	105) _____

106-110. Matching

A)	water	absorbed into capillaries around Proximal Convoluted Tubules	106) _____
B)	sodium	absorbed into capillaries around loop of Henle	107) _____
C)	blood cells	filtered out of capillaries of renal corpuscles	108) _____
D)	A and B	absorbed into capillaries of intestinal villi	109) _____
E)	none of the above	usually kept in glomerular capillaries	110) _____

111-115. Matching

A)	collecting tubules and ducts	produce a renal hormone	111) _____
B)	distal convoluted tubule	detect sodium in the distal convoluted tubules	112) _____
C)	juxtaglomerular cells	located in the tunica media of the afferent arteriole	113) _____
D)	macula densa	water is reabsorbed into capillaries in response to vasopressin	114) _____
E)	none of these	sodium is reabsorbed into capillaries in response to aldosterone	115) _____

116-120. Matching

A)	filtrate is reabsorbed into capillaries from the _____	glomerulus	116) _____
B)	filters blood in kidney	loop of Henle	117) _____
C)	none of the above	distal convoluted tubule	118) _____
		proximal convoluted tubule	119) _____
		collecting tubules and ducts	120) _____