Anatomy and Physiology: The Integumentary System and Membranes

AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

I. Overview of the Integumentary System

- **Definition:** The integumentary system is the body's protective outer covering. The word "integument" means "covering."
- **Components:** Primarily includes the skin, hair, and nails.
- **Skin (Cutaneous Membrane):**The largest and heaviest organ of the body, both in area and weight.
- A multicellular membrane.
- Composed of two main layers:
- **Epidermis:** The most superficial layer, composed of epithelial tissue.
- **Dermis:** The layer deep to the epidermis, primarily composed of connective tissue.
- **Hypodermis:** A layer deep to the dermis, not technically part of the skin, composed mostly of adipose tissue.
- **Hair:** Filaments made of hard keratin, growing from follicles in the dermis.
- **Nails:** Hardened plates of hard keratin, growing from a matrix under a skin fold.

II. Types of Multicellular Membranes

- **Cutaneous Membrane (Skin):**A dry membrane.
- The outer epidermis consists of dead, cornified cells.
- Primary function: barrier between the body and the external environment.
- **Mucous Membranes (Mucosa):Location:** Line internal hollow structures that are continuous with the external environment (e.g., alimentary canal from mouth to anus, vagina, trachea).
- **Function:** Produce mucus (a thick, slippery, viscous fluid) for lubrication and protection.
- **Mucus (noun, m-u-c-u-s) vs. Mucous (adjective, m-u-c-o-u-s):** Homophones with different spellings and meanings.
- **Properties:** Remain moist due to continuous mucus production.

- **Serous Membranes (Serosa):Location:** Line closed body cavities and cover organs within those cavities (e.g., around the heart, lungs). These cavities are *not* continuous with the external environment.
- **Structure:** Each serous membrane is a single membrane folded back on itself, creating two layers:
- **Parietal Layer:** More superficial, forms a "wall" with the surroundings.
- **Visceral Layer:** Deeper, in direct contact with the organ it covers.
- **Serous Fluid:** A thin, watery fluid filling the small space between the parietal and visceral layers, produced by the membranes themselves.
- **Function:** Allows organs to move freely against surrounding structures without friction or damage (e.g., heart beating, lungs expanding and contracting).
- **Examples:Pericardium:** Around the heart.
- **Pleura:** Around each lung.
- **Analogy:** Fist in a water-filled balloon, where the balloon wall is the serous membrane and the water is the serous fluid.
- **Synovial Membranes:Location:** Line the synovial cavity (fluid-filled space) in highly movable joints (e.g., knee, ankle).
- **Synovial Fluid:** Has the consistency of raw egg white, much thicker than serous fluid, provides lubrication.
- **Components:** Part of the membrane is formed by hyaline cartilage on the ends of bones, which also provides slipperiness and cushioning.
- **Function:** Facilitate smooth movement between bones in joints, preventing bone-on-bone friction.

III. Functions of the Integumentary System

- **Protection (Main Function):Mechanical Damage:Keratin:** Fibrous protein in skin cells making them tough (cornified/horny). Soft keratin in skin, hard keratin in hair and nails.
- **Adipose Tissue (in Hypodermis):** Provides cushioning against physical trauma.
- **Sensory Receptors:** Detect pressure, touch, and pain, allowing for awareness and avoidance of danger.
- **Chemical Damage:** Offers resistance to moderate acids and bases.
- **Microbial Damage:Physical Barrier:** Prevents entry of harmful microorganisms.
- **Acid Mantle:** A thin, acidic, salty solution on the skin surface that inhibits bacterial growth.
- **Phagocytes (e.g., Dendritic Cells):** Specialized immune cells in the skin that engulf invaders.
- **UV Radiation Damage:Melanin:** Pigment produced by melanocytes that absorbs UV light, protecting DNA in skin cells (forms a "parasol" over the nucleus).
- DNA repair mechanisms also exist.
- **Thermal Damage:** Sensory receptors detect extreme temperatures, prompting withdrawal.

- **Desiccation (Drying Out):**Skin is waterproof due to **glycolipids** (water-resistant lipids) secreted between epidermal cells, forming a "mortar" that seals the "brick-like" cells.
- Prevents continuous evaporation of water from deeper, moist tissues.
- **Thermoregulation (Maintenance of Body Temperature):Too Hot:Sweat Production:** Eccrine (merocrine) sweat glands produce watery sweat that evaporates from the skin surface, removing heat (evaporative cooling).
- **Increased Blood Flow (Flushing):** More blood is sent to the skin surface, allowing heat to dissipate conductively from the warmed blood to the environment.
- **Too Cold:Decreased Blood Flow (Paling):** Blood flow to the skin is reduced, conserving heat within the body.
- **Horripilation (Goosebumps):** Erector pili muscles contract, causing hair to stand on end, trapping a layer of insulating still air close to the skin (more effective in furrier mammals).
- **Excretion (Minor Function):Urea and Uric Acid:** Small amounts of nitrogenous waste products (similar to those found in urine) are excreted in sweat.
- **Synthesis of Vitamin D:Process:** UV radiation triggers a series of chemical conversions starting with cholesterol in skin cells, moving through the liver and kidneys, to produce active vitamin D (calcitriol).
- **Function:** Vitamin D is vital for the absorption of calcium from food in the small intestine, essential for bone health and other bodily functions.

IV. Anatomy of the Skin Layers

- **Epidermis:Tissue Type:** Stratified squamous epithelium (many layers of flattened cells).
- **Cell Life:** Deeper cells (closer to dermal capillaries) are alive and undergo mitosis; superficial cells are dead.
- **Layers (Strata), from deep to superficial:Stratum Basale (Basily):**Deepest layer, rests on the basement membrane.
- Cells are cuboidal and actively dividing (mitosis) to produce new cells.
- Contains:
- **Keratinocytes:** Main type of epidermal cell, produce keratin.
- **Melanocytes:** Produce melanin and transfer it to keratinocytes via phagocytosis of their extensions.
- **Merkel Cells:** (not heavily discussed in source, but mentioned as superficial sensory receptors)
- **Stratum Spinosum:**Several layers of keratinocytes that produce keratin fibers.
- Appear "spiny" in prepared slides due to desmosome connections and cell shrinkage.
- Contains **Dendritic Cells** (Langerhans cells): Immune cells that engulf foreign material and present it to white blood cells.
- **Stratum Granulosum:**Cells produce and export granules containing proteins that link keratin fibers, making the cells tougher.
- Cells also produce **lamellar bodies** (lipid-rich products) that are exuded to waterproof the skin.

- **Stratum Corneum:**Outermost layer, composed of many layers of dead, flattened, hardened (cornified/horny) cells called **corneocytes**.
- Cells are waterproof due to glycolipids between them.
- Continuously shed from the surface.
- **Thin vs. Thick Skin:Thin Skin:** Has the four strata listed above (most body areas).
- **Thick Skin:** Found on soles of feet and palms of hands.
- Has an additional fifth stratum: **Stratum Lucidum** (clear/transparent layer) between stratum granulosum and stratum corneum.
- All strata are thicker than in thin skin.
- **Dermis:Tissue Type:** Mostly connective tissue.
- **Thickness:** Much thicker than the epidermis.
- **Layers:Papillary Layer:**More superficial part of the dermis, forms wavy projections called **dermal papillae**.
- Each papilla contains blood capillaries that supply nutrients to the living epidermal cells.
- Also contains superficial sensory receptors (mechanoreceptors).
- **Reticular Layer:**Deeper and thicker part of the dermis.
- Named for the **reticular** (network-like) arrangement of collagen and elastic fibers, providing strength in all directions.
- Houses hair follicles, glands (sweat and sebaceous), and deeper sensory receptors.
- **Blood Vessels:** Major vessels are deep in the dermis, superficial to the hypodermis, allowing for heat exchange.
- **Hypodermis:Tissue Type:** Primarily adipose tissue (fat cells/adipocytes), a type of connective tissue.
- **Functions:** Energy storage, cushioning, thermal insulation.
- **Not Skin:** Technically distinct from the skin layers.

V. Hair and Nails

- **Hair:Structure (from deep to superficial):Medulla:** Innermost layer (deeper).
- **Cortex:** Middle layer (more superficial than medulla).
- **Cuticle:** Outermost layer, composed of overlapping, shingle-like cells that help anchor the hair in the follicle.
- **Hair Follicle:** Located in the dermis, where hair growth begins.
- Contains a **hair papilla** with a rich blood supply for nutrient delivery to living cells.
- Cells divide in the hair matrix, pushing older cells upward.
- **Keratin Type:** Contains **hard keratin**, making it much tougher than skin.
- **Erector Pili Muscles:** Tiny muscles attached to hair follicles; contraction causes hair to stand on end (**horripilation/goosebumps**), trapping an insulating air layer.
- **Sebaceous Glands:** Most are associated with hair follicles, producing sebum (body oil) that lubricates hair and skin.
- **Apocrine Sweat Glands:** Located in specific areas (axillae, perineum), produce an odorless solution that bacteria metabolize into body odor. Not involved in thermoregulation.

- **Ceruminous Glands:** Produce cerumen (ear wax) in the ear canal.
- **Nails:Structure:Free Edge:** Part of the nail that extends beyond the finger/toe.
- **Nail Plate/Body:** Main visible part of the nail, dead hardened cells.
- **Nail Bed:** Skin deep to the nail plate.
- **Nail Matrix:** Living part under the skin fold where new nail cells are produced by cell division.
- **Cuticle (Eponychium):** Hardened fold of skin at the proximal end of the nail, covering the nail matrix.
- **Lunula:** Whitish, crescent-shaped area at the base of the nail, representing the visible part of the nail matrix.
- **Keratin Type:** Contains the most **hard keratin**, making nails the toughest part of the integumentary system.
- **Growth:** Cells produced in the nail matrix harden, die, and are pushed distally.

VI. Key Concepts

- **Hierarchy of Biological Organization:** Cells -> Tissues -> Organs -> Organ Systems (skin is an organ composed of different tissues).
- **Homeostasis:** Thermoregulation is a key example of negative feedback maintaining body temperature.
- **Sensory Input vs. Sensation:** Sensory input is information received by the nervous system; sensation is the higher-level processing of that input in the brain, leading to conscious awareness.
- **Extensive vs. Intensive Properties:** Heat is extensive (depends on amount of substance); temperature is intensive (average speed of particles, independent of amount).
- **Cell Division (Mitosis):** Crucial for continuous replacement of skin and hair cells.
- **Phagocytosis:** "Cell eating," a process used by keratinocytes to acquire melanin and by immune cells (dendritic cells) to engulf foreign invaders.

Quiz: Integumentary System and Membranes

Instructions: Answer each question in 2-3 sentences.

1. What are the three main components of the integumentary system, and what word defines the overall meaning of "integument"?
2. Explain why the skin is considered an organ, given the hierarchy of biological organization.

3. Describe the primary function of mucous membranes and provide two examples of where they are found in the body.
4. How do serous membranes facilitate the movement of internal organs, and what fluid is involved in this process?
5. What are the two primary reasons why the skin provides protection against desiccation (drying out)?
6. Explain the difference between eccrine (merocrine) and apocrine sweat glands in terms of their location and the purpose of their secretions.
7. Identify the two main layers of the skin, and state which is thicker and what type of tissue primarily comprises each.
8. Describe the function of melanocytes and explain how melanin protects the DNA in skin cells from UV radiation.
9. What are the two major categories of keratin found in the body, and where would you find the "hard" type?
10. Briefly explain why the cells in the stratum basale of the epidermis are constantly undergoing mitosis.

Quiz Answer Key

1. The three main components of the integumentary system are the skin, hair, and nails. The word "integument" literally means "covering," reflecting its role as the body's outer protective layer.
2. The skin is considered an organ because it is composed of multiple different tissue types (epithelial in the epidermis, connective in the dermis) that work together to perform specific functions. This fits the definition of an organ within the hierarchy of biological organization, where different tissues combine to form a more complex structure with a specific job.
3. The primary function of mucous membranes is to line internal hollow structures continuous with the external environment and produce mucus. This mucus lubricates these passageways and provides protection. Examples include the entire alimentary canal (from mouth to anus) and the trachea.
4. Serous membranes facilitate the movement of internal organs by surrounding them with two layers (parietal and visceral) separated by a small space filled with serous fluid. This watery fluid acts as a lubricant, allowing organs like the heart and lungs to move freely against surrounding structures without damaging friction.
5. The skin provides protection against desiccation primarily due to its waterproof nature. This waterproof quality comes from the epidermis, where cells are tightly packed, and more specifically from the glycolipids secreted between the cells in the stratum granulosum, forming a water-resistant "mortar."
6. Eccrine (merocrine) sweat glands are distributed all over the skin and produce watery sweat primarily for thermoregulation through evaporative cooling. Apocrine sweat glands are concentrated in areas like the axillae and perineum; they produce an odorless

solution that bacteria metabolize into body odor, serving a different, often signaling, purpose rather than cooling.

7. The two main layers of the skin are the epidermis and the dermis. The dermis is much thicker than the epidermis. The epidermis is primarily composed of epithelial tissue, while the dermis is mostly made of connective tissue.
8. Melanocytes are specialized epidermal cells that produce melanin, a pigment molecule. Melanin protects the DNA in skin cells from UV radiation by absorbing the UV light. It clusters specifically on the superficial side of the cell's nucleus, acting like a parasol to shield the vulnerable DNA from damage.
9. The two major categories of keratin are soft keratin and hard keratin. Hard keratin is found in structures that require significant toughness, such as hair and nails, which are considerably stronger and more durable than the soft keratin found in the outer layers of the skin.
10. The cells in the stratum basale are constantly undergoing mitosis (cell division) to replace the billions of skin cells that are continuously lost from the outermost apical layer (stratum corneum) every day. This continuous production of new cells ensures that the skin barrier is maintained and replenished from the base upwards.

Essay Format Questions

1. Compare and contrast the structure, location, and primary functions of cutaneous, mucous, and serous membranes. Discuss how their anatomical adaptations suit their specific roles in the body.
2. Elaborate on the various protective functions of the integumentary system. Provide specific examples of cellular structures, secretions, or physiological responses that contribute to defense against mechanical, microbial, chemical, and UV radiation damage.
3. Describe the process of thermoregulation mediated by the integumentary system when the body temperature is too high. Include a detailed explanation of evaporative cooling and the role of blood flow, differentiating between heat and temperature.
4. Trace the journey of a keratinocyte from its origin in the stratum basale to its eventual shedding from the stratum corneum, describing the key changes it undergoes in each epidermal layer and the functional significance of these changes.
5. Discuss the relationship between the skin and the synthesis of Vitamin D. Explain the series of conversions involved, the role of UV radiation, and why Vitamin D is considered vital for overall body function, particularly calcium absorption.

Glossary of Key Terms

- **Acid Mantle:** A thin, acidic, and salty layer on the skin's surface that inhibits the growth of certain bacteria.
- **Adipose Tissue:** A type of connective tissue primarily composed of fat cells (adipocytes), found in the hypodermis, providing insulation and cushioning.
- **Alimentary Canal:** The continuous tube running from the mouth to the anus, lined by mucous membranes.
- **Apical Layer:** The most superficial (unattached) layer of cells in an epithelium.
- **Apocrine Sweat Glands:** Sweat glands concentrated in the axillae and perineum that produce an odorless solution metabolized by bacteria into body odor.
- **Basal Layer (Stratum Basale):** The deepest layer of the epidermis, resting on the basement membrane, where new cells are produced through mitosis.
- **Basement Membrane:** A thin, non-cellular layer that anchors epithelial tissues to underlying connective tissue.
- **Calcitriol:** The active form of Vitamin D, produced in the kidneys.
- **Calcium:** An essential element for bones, heart function, and other bodily processes, absorbed with the help of Vitamin D.
- **Capillaries:** The smallest blood vessels, responsible for nutrient and waste exchange with living cells.
- **Cortex (Hair/Organ):** Generally refers to the more superficial or outer part of an organ or structure, such as the hair cortex or cerebral cortex.
- **Corneocytes:** Hardened, dead, flattened cells found in the stratum corneum of the epidermis.
- **Cornified (Horny):** Describing cells that have become hardened and tough due to keratinization, like those in the stratum corneum.
- **Cutaneous Membrane:** Another name for the skin, referring to its function as a covering.
- **Cuticle (Hair/Nail):** The outermost layer of a hair shaft, composed of overlapping shingles, or the hardened skin fold at the base of a nail.
- **Dendritic Cells:** Immune cells found in the epidermis (also called Langerhans cells) that engulf foreign invaders and present their molecular structure to white blood cells.
- **Depilatory:** Referring to substances or methods that remove hair (from *pilus*, meaning hair).
- **Dermal Papillae:** Finger-like projections of the dermis that interdigitate with the epidermis, containing capillaries to supply nutrients.
- **Dermis:** The thick layer of skin deep to the epidermis, primarily composed of connective tissue, containing various structures like glands, hair follicles, and sensory receptors.
- **Desiccation:** The process of drying out or losing moisture.
- **Desmosomes:** Cell junctions that act like "spot welds," strongly anchoring adjacent cells together, particularly abundant in the stratum spinosum.
- **Eccrine Sweat Glands (Merocrine Sweat Glands):** The most common type of sweat gland, distributed widely over the skin, producing watery sweat for thermoregulation.
- **Electron Microscope:** A microscope that uses a beam of electrons to create magnified images, providing much higher resolution than light microscopes.

- **Epidermis:** The outermost, superficial layer of the skin, composed of stratified squamous epithelium.
- **Erector Pili Muscles:** Tiny muscles attached to hair follicles; their contraction causes hair to stand on end, leading to horripilation (goosebumps).
- **Extensive Property:** A property that depends on the amount of substance present, such as heat.
- **Fagocytes:** Cells that perform phagocytosis, engulfing and digesting particles or cells.
- **Fagocytosis:** A type of endocytosis where a cell engulfs large particles or other cells, often referred to as "cell eating."
- **Free Edge (Nail):** The part of the nail plate that extends beyond the end of the digit and is not attached to the nail bed.
- **Glands:** Specialized structures in the skin that produce and secrete substances (e.g., sweat glands, sebaceous glands).
- **Glycolipid:** A lipid molecule with a carbohydrate attached, found in the "mortar" between epidermal cells, contributing to the skin's waterproofing.
- **Granules:** Small particles or secretions, particularly those produced by cells in the stratum granulosum.
- **Hard Keratin:** A very tough, fibrous protein found in hair and nails, providing significant structural strength.
- **Heat:** The energy of motion of particles, an extensive property.
- **Horripilation (Goosebumps):** The phenomenon of hair standing on end, typically due to cold or fright, caused by the contraction of erector pili muscles.
- **Hyaline Cartilage:** A type of cartilage with a glassy appearance, found at the ends of bones in highly movable joints, providing cushioning and slipperiness.
- **Hypodermis:** The layer of tissue deep to the dermis, primarily composed of adipose tissue, and not technically part of the skin.
- **Integumentary System:** The organ system comprising the skin, hair, and nails, providing external protection and other vital functions.
- **Intensive Property:** A property that does not depend on the amount of substance present, such as temperature.
- **Keratin:** A tough, fibrous protein found in skin, hair, and nails, providing structural integrity.
- **Keratinocytes:** The main cell type in the epidermis, responsible for producing keratin.
- **Kime:** The semi-fluid mass of partly digested food that passes from the stomach to the small intestine.
- **Lamellar Bodies:** Lipid-rich products produced by cells in the stratum granulosum that contribute to the skin's waterproofing.
- **Lunula:** The whitish, crescent-shaped area at the base of the nail, visible as it covers the nail matrix.
- **Mastication:** The process of chewing food.
- **Mechanoceptors:** Sensory receptors that respond to mechanical deformation, such as touch, pressure, or stretch.
- **Medulla (Hair/Organ):** Generally refers to the deeper or inner part of an organ or structure, such as the hair medulla or adrenal medulla.

- **Melanin:** A pigment molecule produced by melanocytes, responsible for skin color and protection against UV radiation.
- **Melanocytes:** Cells in the stratum basale of the epidermis that produce melanin.
- **Membrane:** A thin layer of tissue that covers a surface, lines a cavity, or divides a space.
- **Merkel Cells:** (briefly mentioned in source) Sensory receptors in the stratum basale associated with light touch.
- **Mitosis:** The process of nuclear division, part of cell division, leading to the creation of two daughter cells from a single parent cell.
- **Mucosa:** Another term for a mucous membrane.
- **Mucus (noun):** The sticky, viscous fluid produced by mucous membranes.
- **Mucous (adjective):** Pertaining to or producing mucus.
- **Nail Bed:** The skin located underneath the nail plate.
- **Nail Matrix:** The area at the proximal end of the nail, deep under the skin fold, where new nail cells are produced.
- **Organ:** A structure composed of two or more different tissue types working together to perform a specific function.
- **Papilla (general):** A small, nipple-like or finger-like projection.
- **Papillary Layer:** The superficial layer of the dermis, characterized by dermal papillae.
- **Parietal Layer:** The more superficial layer of a serous membrane, lining the cavity wall.
- **Pericardium:** The serous membrane surrounding the heart.
- **Perineum:** The region of the body between the anus and the external genitalia.
- **Pilus (plural Pili):** Latin for hair.
- **Plasma:** The extracellular matrix of whole blood, before clotting factors are removed.
- **Pleura (plural Pleurae):** The serous membrane surrounding each lung.
- **Reticular Layer:** The deeper, thicker layer of the dermis, named for its network-like arrangement of connective tissue fibers.
- **Sebaceous Glands:** Glands in the skin, often associated with hair follicles, that produce sebum (body oil).
- **Sebum:** An oily substance produced by sebaceous glands that lubricates the skin and hair.
- **Sensation:** The high-level processing of sensory input in the brain, leading to conscious awareness (e.g., touch, smell).
- **Sensory Input:** Information received by the central nervous system from sensory receptors.
- **Sensory Receptors:** Specialized cells or structures that detect stimuli from the environment or within the body.
- **Serum:** The watery fluid remaining after blood cells and clotting proteins have been removed from plasma.
- **Serous Fluid:** A thin, watery lubricating fluid found between the layers of serous membranes.
- **Serous Membranes (Serosa):** Membranes that line closed body cavities and cover organs, producing serous fluid to reduce friction.
- **Serumin:** The anatomical name for ear wax.
- **Seruminous Glands:** Glands in the ear canal that produce cerumin (ear wax).

- **Soft Keratin:** A type of keratin found in epidermal skin cells, tougher than normal cells but less tough than hard keratin.
- **Stratified:** Describing an epithelium with multiple layers of cells.
- **Stratum Corneum:** The outermost layer of the epidermis, composed of many layers of dead, flattened, hardened cells.
- **Stratum Granulosum:** The epidermal layer where cells begin to produce granules and lamellar bodies, initiating toughening and waterproofing.
- **Stratum Lucidum:** A clear, transparent layer of the epidermis found only in thick skin (palms and soles), located between the stratum granulosum and stratum corneum.
- **Stratum Spinosum:** The epidermal layer characterized by "spiny" appearing cells (due to desmosomes) actively producing keratin fibers.
- **Sweat Glands:** Glands in the skin that produce sweat for thermoregulation (eccrine) or other purposes (apocrine).
- **Synovial Cavity:** The fluid-filled space within highly movable joints.
- **Synovial Fluid:** A viscous, lubricating fluid found in synovial cavities, with a consistency similar to raw egg white.
- **Synovial Membrane:** The membrane lining the synovial cavity in movable joints.
- **Temperature:** A measure of the average kinetic energy (speed) of particles, an intensive property.
- **Thermoregulation:** The process of maintaining stable body temperature, a key aspect of homeostasis.
- **Urea:** A nitrogen-containing waste product, primarily processed by the kidneys, but small amounts are excreted in sweat.
- **Ultraviolet (UV) Radiation:** A type of light energy from sunlight that can damage DNA and cause mutations.
- **Viscera:** The internal organs, especially those in the abdomen.
- **Visceral Layer:** The deeper layer of a serous membrane, directly covering an organ.
- **Vitamin D:** A vital molecule, partially synthesized in the skin upon UV exposure, crucial for calcium absorption in the small intestine.