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Systems Overview

The four tissue types join together to form organs and organ systems.

Each organ system has particular structures and functions, but all organ systems share 4 characteristics:

1. Specialization for performing specific functions.
2. Functional independence: the ability to respond to local stimuli.
3. Dependence on other organ systems for nutrients, oxygen, and waste disposal.
4. Integration of activity through neural and hormonal signals.

There are 11 organ systems, which may be grouped by function:

Support and Movement:
- Integumentary system
- Skeletal system
- Muscular system

Regulation and Control
- Nervous System
- Endocrine System

Fluids and Transport
- Cardiovascular system
- Lymphatic system

Environmental Exchange
- Respiratory system
- Digestive system
- Urinary system

Reproduction and Development
- Male and female reproductive systems and embryonic development

CHAPTER 5: The Integumentary System

The Integumentary System: An Overview, p. 154

Objectives:
1. Components of the integumentary system, their physical relationship to each other and to the subcutaneous layer.
2. The general functions of the integumentary system.

The integumentary system or integument is the largest system of the body.
- 16% of body weight
- 1.5 to 2 square meters in area
The integument is made up of 2 parts:
   1. the cutaneous membrane, or skin, and
   2. the accessory structures

**Figure 5.1**
The cutaneous membrane is made up of 2 parts:
   1. the outer epidermis or superficial epithelium (epithelial tissues) and
   2. the inner dermis, composed of connective tissues

The accessory structures include hair, nails, and multicellular exocrine glands. These structures generally originate in the dermis and extend through the epidermis to the skin’s surface.

The integument interacts with the circulatory system through blood vessels in the dermis, and with the nervous system through sensory receptors for pain, touch, temperature etc.

Below the dermis is a subcutaneous layer of loose connective tissue, also known as the superficial fascia or hypodermis (where hypodermic injections are administered).

The functions of skin and its subcutaneous layer include:
   1. *Protection* of underlying tissues and organs against shock, abrasion, fluid loss and chemical attack.
   2. *Excretion* of salts, water, and organic wastes by glands.
   3. *Maintenance of body temperature* by insulation (heating) and sweat evaporation (cooling).
   5. *Storage* of lipids.

*The Epidermis, p. 155*

Objectives:
1. The main structural features of the epidermis, the functional significance of each.
2. Account for individual differences in skin color.
3. The effects of UV radiation on the skin, the role of melanocytes in sunlight exposure.

**Figure 5-2**
The epidermis is an avascular stratified squamous epithelium that relies on diffusion of nutrients and oxygen from capillaries in the dermis.

The most abundant cells in the epidermis are the keratinocytes (so called because they contain large amounts of the protein keratin).

Most of the body is covered by thin skin, which has only 4 layers of keratinocytes in the epidermis.
The palms of the hands and soles of the feet are covered with thick skin, which has 5 layers of keratinocytes in its epidermis.

*Layers of the Epidermis, p. 155*

**Figure 5-3**

The 5 layers or strata of keratinocytes in the thick skin of the epidermis are (from the deep basal lamina to the free surface) the:

1. *stratum germinativum*
2. *stratum spinosum*
3. *stratum granulosum*
4. *stratum lucidum*, and the
5. *stratum corneum*

The *stratum germinativum* ("germinative layer") is attached to the basal lamina by hemidesmosomes, forming a strong bond between the epidermis and the dermis.

- Stratum germinativum forms epidermal ridges that determine our fingerprint pattern, and dermal papillae or tiny mounds. Ridges and papillae increase the area of the basal lamina, strengthening the attachment between the epidermis and dermis.
- Stratum germinativum has many germinative (stem) cells, called basal cells, which replace keratinocytes that are shed at the skin’s surface.
- Skin surfaces that have no hair have many Merkel cells in their stratum germinativum that respond to touch by releasing chemicals that trigger nervous system responses.
- Melanocytes (cells containing the pigment melanin) are also scattered throughout the stratum germinativum.

The *stratum spinosum* ("spiny layer") consists of cells produced by division of the stem cells of the stratum germinosum.

- Stratum spinosum is 8 to 10 layers of keratinocytes bound together by desmosomes. The cells are shrunken so that their cytoskeletons stick out, making them appear spiny.
- Stratum spinosum contains Langerhans cells, which are active in the immune response against microorganisms and skin cancer.
- Stratum spinosum continues to divide, increasing the thickness of the epithelium.

The *stratum granulosum* ("grainy layer") stops dividing and starts producing the proteins keratin (the tough, fibrous protein that makes up hair and nails) and keratohyalin (dense granules that cross-link keratin fibers).

- Once protein fibers are produced, stratum granulosum cells dehydrate and die, creating a tightly interlocked layer of keratin fibers surrounded by keratohyalin.

*Stratum lucidum* ("clear layer") is found only in thick skin, where it covers the stratum
granulosum.
- Cells of stratum lucida are flat, dense and filled with keratin.

The exposed surface of the skin is stratum corneum ("horn layer"), consisting of 15 to 30 layers of keratinized cells.
- Keratinization, the formation of a layer of dead, protective cells filled with keratin, occurs on all exposed skin surfaces except the eyes.
- It takes 15 to 30 days for a cell to move from the stratum germinosum to the stratum corneum.
- The stratum corneum is water resistant, and lasts about 2 weeks before it is shed and replaced.
- Interstitial fluid lost by evaporation through the stratum corneum is called insensible (imperceptible) perspiration. Sensible perspiration is the water produced by sweat glands.
- Water loss (dehydration) through the skin is increased by damage to the stratum corneum, such as burns and blisters (insensible perspiration), or by immersion in a hypertonic solution such as seawater (osmosis). Immersion in a hypotonic solution (freshwater) causes water gain and wrinkling by osmosis.

The Basis of Skin Color, p. 158

Skin color depends on:
1. pigment
2. circulation

The 2 pigments of the epidermis are carotene and melanin.

Carotene, an orange-yellow pigment found in carrots and other orange vegetables, accumulates in epidermal cells and in fatty tissues of the dermis. Carotene can be converted to vitamin A.

Figure 5-5

Melanin, a yellow-brown or black pigment, is produced by melanocytes in the stratum germinativum and stored in transport vesicles called melanosomes, which can be transferred to keratinocytes.
- Skin color depends on the rate of melanin production, not the number of melanocytes.
- Melanin protects the skin from the damaging effects of ultraviolet (UV) radiation (DNA mutations and burns, which lead to cancer and wrinkles).

Capillaries in the skin, carrying oxygenated red blood, contribute to skin color.
- When blood vessels dilate from heat, skin turns red.
- When blood flow decreases, skin pales.
- Severe reduction in blood flow or oxygenation can give skin a bluish tint called cyanosis.
Several diseases can produce changes in skin color:
- Jaundice, a yellow color resulting from buildup of bile from the liver.
- Diseases of the pituitary gland that cause skin darkening.
- Vitiglio, a loss of color (melanocytes).

*The Epidermis and Steroid Production, p. 159*

In the presence of UV radiation, epidermal cells convert a steroid into cholecalciferol (vitamin D3), which is then converted by the liver and kidneys into the hormone calcitriol, which is essential for absorption of calcium and phosphorus. Insufficient vitamin D production or nutritional supplementation can cause the bone disease *rickets.*

*The Roles of Epidermal Growth Factor, p. 161*

Epidermal growth factor (EGF), produced by salivary glands and glands of the duodenum, is a powerful peptide growth factor responsible for:
- promoting division of germinative cells
- accelerating the production of keratin
- stimulating epidermal growth and repair
- stimulation synthesis and secretion in epithelial glands
- EGF is used in laboratories to grow skin grafts.

*Key*
The epidermis is a multilayered, flexible, self-repairing barrier that prevents fluid loss, protects from UV radiation, produces vitamin D3, and resists abrasion, chemicals and pathogens.

**III. The Dermis, p. 161**

Objective:
1. Structure and functions of the dermis

*Dermal Organization, p. 161*

The dermis, located between the epidermis and the subcutaneous layer, has 2 components, the outer papillary layer and the deeper reticular layer.

The papillary layer:
- consists of areolar tissue
- contains smaller capillaries, lymphatics and sensory neurons
- has dermal papillae projecting between epidermal ridges

The reticular layer:
- consists of dense irregular connective tissue
- contains larger blood vessels, lymph vessels and nerve fibers
- contains collagen and elastic fibers
- contains connective tissue proper

Epidermal accessory structures (hair follicles, sweat glands) extend into the dermis.

Dermatitis is an inflammation, primarily of the papillary layer, caused by infection, radiation, mechanical irritation, or chemicals (such as poison ivy), characterized by itch or pain.

The dermis is both strong (due to collagen fibers) and elastic (due to elastic fibers). The amount of water in the skin cells, known as skin turgor, also helps skin maintain flexibility.

Dehydration, age, hormonal changes and UV exposure can reduce skin’s elasticity, resulting in sagging and wrinkles. Excessive stretching due to pregnancy or weight gain can cause stretch marks. Topical creams that promote blood circulation (Retin-A) can stimulate dermal repair.

**Figure 5-7**

Collagen and elastic fibers in the dermis are usually arranged in parallel bundles that resist forces in a specific direction. The pattern of these bundles in the skin establishes Lines of Cleavage that are clinically important:
- a cut parallel to a line of cleavage tends to remain shut and heal well.
- a cut across (right angle to) a line of cleavage tends to pull open and scar.

**Figure 5-8**

Arteries supplying the skin form a network along the reticular layer of the dermis called the cutaneous plexus. Smaller arteries reaching the papillary layer form a capillary network called the papillary plexus.

The capillaries return to a venous plexus deep to the papillary plexus, then to a venous plexus in the subcutaneous layer. Damage to these blood vessels results in “black and blue” bruising or contusion.

Nerve fibers in the skin control blood flow, gland secretions and sensory receptors.
- Merkel cells are monitored by tactile disks.

**Key**
The dermis provides mechanical strength, flexibility and protection for underlying tissues. It is highly vascularized and contains many types of sensory receptors.
IV. The Subcutaneous Layer, p. 163

Objective:
1. The structure and functions of the subcutaneous layer

Below the integument, the subcutaneous layer or hypodermis stabilizes the position of the skin but allows separate movement.

The subcutaneous layer is made of elastic areolar and adipose tissues, connected to the reticular layer of the integument by interwoven connective tissue fibers.

Because the subcutaneous layer has few capillaries and no vital organs, it is the site of subcutaneous injections using hypodermic needles.

Deposits of subcutaneous fat, which accumulate in different areas in men and women due to hormonal effects, are the subject of cosmetic liposuction procedures.

V. Accessory Structures, p. 164

Objectives:
1. Mechanisms of hair production, structural basis for hair texture and color.
2. Kinds of glands in the skin, the secretions of each.
3. The role of sweat glands in the skin, the secretions of each.
4. Anatomical structure of nails, how they are formed.

The integumentary accessory structures (hair, hair follicles, sebaceous and sweat glands, and nails) are derived from the epidermis during embryonic development.

They are located in the dermis, but project through the epidermis to the skin surface.

Hair and Hair Follicles, p. 164

The human body is covered with hair, except for the palms, soles, lips, and portions of external sex organs.

Hairs have many functions, they:
- protect and insulate
- guard openings such as the nose against particles and insects
- are sensitive to very light touch

Figure 5-9a
Nonliving hairs are produced by hair follicles deep in the dermis.
- The follicle is wrapped in a dense connective tissue sheath.
- The base of each follicle is surrounded by sensory nerves called the root hair plexus

- Involuntary smooth muscles called arrector pili cause hairs to stand on end and
produce “goose bumps.”
- The lower part of the hair, attached to the integument, is the hair root.
- The upper part of the hair, not attached to the integument, is the hair shaft.
- Each hair follicle has a sebaceous gland which lubricates the hair.

**Figure 5-9b**
Each hair begins deep in the dermis, in the hair bulb, which contains a mound of connective tissue, capillaries and nerves called the hair papilla.
- Basal cells within the hair matrix divide to produce the actual hair.
- As cells of the hair matrix divide, the hair grows, pushing up and out of the skin.

A hair has 3 layers:
- the central core or medulla
- the middle layer or cortex, and
- the surface or cuticle
(Note that the core is not the cortex.)

As hair is produced, it is keratinized.
- The medulla contains flexible soft keratin
- The cortex and cuticle contain stiff hard keratin

The follicle walls are also organized in several layers:
- The inner layer, in contact with the cuticle in the lower portion of the hair root, is the internal root sheath.
- The external root sheath extends from the skin surface to the hair matrix.
- The glassy membrane is a dense connective tissue sheath in contact with the surrounding connective tissues of the dermis.

As hair grows, it is firmly attached to the matrix of the follicle. Scalp hair grows from 2 to 5 years, then the follicle becomes inactive. A hair attached to an inactive follicle is a club hair. When the follicle again becomes active and produces a new hair, the club hair is shed. This is the hair growth cycle.

Adult humans have 2 types of hairs:
- soft, fine vellus hairs cover most of the body surface.
- heavier, pigmented terminal hairs grow on the head and eyebrows, and on other parts of the body after puberty.

Hair color, produced by melanocytes at the hair papilla, is determined genetically.

*Glands in the Skin, p. 167*

The skin has 2 types of exocrine glands: sebaceous (oil) glands and sweat glands.

**Figure 5-10**
Sebaceous glands (oil glands) are holocrine glands that secrete sebum.
Sebum contains lipids and other ingredients that lubricate and protect the epidermis, and inhibit bacteria.

Sebaceous glands can be associated with hair follicles (simple branched alveolar glands) or can discharge directly onto the skin surface (sebaceous follicles).

*Figure 5-11*

There are 2 types of sweat glands (sudoriferous glands): apocrine and merocrine.

**Apocrine sweat glands** are found in the armpits, around the nipples and groin. (They are not actually apocrine secretions, but merocrine.) Associated with hair follicles, apocrine sweat glands produce sticky, cloudy secretions that can break down and cause odors. Apocrine glands are controlled by myoepithelial cells that squeeze secretions onto the skin surface in response to hormonal or nervous signals.

**Merocrine (eccrine) sweat glands** are widely distributed over the body surface, especially on the palms and soles. These are coiled, tubular glands that discharge directly onto the skin surface. Merocrine sweat is sensible perspiration, mostly water with some salts and other organic compounds.

Merocrine sweat has several functions:
- cooling the surface of the skin
- excreting water and electrolytes
- flushing microorganisms or harmful chemicals from the skin surface

**Other integumentary glands** include:
- mammary glands, which produce milk, and
- ceruminous glands, which protect the eardrum by producing cerumen or earwax.

The autonomic nervous system (ANS) controls sebaceous glands and apocrine sweat glands uniformly over the entire body.

Merocrine sweat glands are controlled independently, so sweating can occur in one area and not another.

**Thermoregulation**, the main function of sensible perspiration, works with the cardiovascular system as a vital part of homeostasis.

**Key**
The skin plays a major role in controlling body temperature by acting as a radiator. Heat from dermal circulation is removed by evaporation of sensible perspiration.

*Nails, p. 169*
**Figure 5-12**
Fingernails and toenails protect the delicate tips of our digits.
- Nails are dead cells packed with keratin.
- Nail production occurs in a deep epidermal fold near the bone called the **nail root**.
- Various metabolic disorders can cause changes in nail structure.

The visible portion of the nail, the **nail body**, covers a portion of the epidermis called the **nail bed**. The sides of the nails lie in **lateral nail grooves** surrounded by **lateral nail folds**. The thick skin beneath the **free edge** of the nail is the **hyponychium**. At the proximal edge of the visible nail, where it emerges from the epidermis, is the **eponychium** or **cuticle**, at the tip of the **proximal nail fold**. The pale crescent moon-shape at the base of the nail is the **lunula**.

**VI. The Response of the Integument to Injury, p. 170**
**Objective:**
1. How the skin responds to injury and repairs itself

*Repair of Localized Injuries to the Skin, p. 170*

Because skin has so many active germinative cells, it responds rapidly to changes in health, activity or injuries.

There are 4 steps in the regeneration of localized skin injuries.

**Figure 5-13a**
Step 1: Bleeding occurs. Mast cells trigger an inflammatory response.

**Figure 5-13b**
Step 2: Blood clots form a **scab** that stabilizes and protects the area. Germinative cells migrate around the wound. Macrophages clean the area. Fibroblasts move in and divide, along with endothelial cells of damaged blood vessels, producing **granulation tissue**.

**Figure 5-13c**
Step 3: Over time, fibroblasts replace damaged tissues with a fibrous repair called **scar tissue**. Inflammation decreases and the clot begins to disintegrate.

**Figure 5-13d**
Step 4: Fibroblasts continue to strengthen the area until a raised section of scar tissue called a **keloid** forms.

**Figure 5-14**
A method of estimating the percentage of integument damaged by burns is the “rule of nines,” which divides the surface area of the adult body into multiples of nine.
VII. Aging and the Integumentary System, p. 173

Objective:
1. The effects of aging on the skin

The effects of aging on the integumentary system include:
- Epidermal thinning
- Decreased numbers of Langerhans cells
- Decreased vitamin D3 production
- Decreased melanocyte activity
- Decreased glandular activity (sweat and oil glands)
- Reduced blood supply
- Decreased function of hair follicles
- Reduction of elastic fibers
- Decreased hormone levels
- Slower repair rate

VIII. Integration with Other Systems, p. 175

Figure 5-15

The integumentary system protects and interacts with all internal organ systems. Because the integument is so visible, changes in skin appearance can be used to diagnose disorders in other systems.

SUMMARY

In Chapter 5 we learned about:

The division of the integument into epidermis and dermis.

The division of epidermis into thin skin and thick skin.

The layers of the epidermis:
  stratum germinosum
  stratum spinosum
  stratum lucidum
  stratum corneum

The roles of epidermal ridges and dermal papillae.

The functions of specialized cells:
  Langerhans cells
  Merkel cells

The skin pigments
  carotene
  melanin
The metabolic functions of epidermis:
  vitamin D3  
  epidermal growth factor

The divisions of the dermis
  papillary layer  
  reticular layer

Mobility of the dermis
  stretch marks  
  lines of cleavage

Blood supply of the dermis
  cutaneous plexus  
  papillary plexus

The role of the subcutaneous layer

The structure of hair and hair follicles

The glands of the skin
  sebaceous  
  sweat  
  ceruminous

The structure of nails

The processes of inflammation and regeneration

The effects of aging on the integument