3 The Anatomy and Functions of Skin

3.1 Introduction

Skin is considered to be the largest organ of the human body with an average surface area of 1.6–2 m² and accounts for about 15% of the total body weight of an adult human. It is the outer covering of the body and has multiple layers (2-3 mm thick) which protect underlying muscles, bones, ligaments and internal organs. It is an interface with the environment and protects the body against pathogens, controls water loss, regulates the body temperature, enables sensation to be perceived and plays a key role in the synthesis of vitamin D. It also acts as a water-resistant barrier, to protect essential nutrients in the body, and absorbs oxygen required for the outer-most layer of cells. It is composed of mainly three layers. As shown in Figure 3.1, the outer-most layer is called the epidermis, which serves as a barrier and protects the body from any infection. The second layer is called the dermis and consists of connective tissues which cushion the body from stress and strain. The inner-most layer is the fatty subcutaneous tissue called the hypodermis and contains larger blood vessels and nerves; it insulates the body and absorbs shock.

3.2 The Epidermis

The epidermis is composed of the outer-most layers of skin cells. Epidermis means ‘upon’ or ‘over’ dermis and normally contains 4 layers. The structure of the epidermis is shown in Figure 3.2. It does not contain any blood vessels and therefore the cells obtain diffused oxygen from the surrounding air. The outer-most cell layer is known as the stratum corneum and is composed mostly of corneocytes, which are keratinocyte cells that are in their last stage of differentiation. Keratinocyte cells constantly migrate from the stratum basale layer of the epidermis, become differentiated into corneocytes and reach the skin surface. These cells are continuously sloughed off from the skin surface by the rubbing or washing process. Corneocyte cells are bridged together via junctions called corneodesmosomes, which are embedded within keratin proteins and stacked layers of hydrophobic lipids along with other fatty acids and ceramides [2] in the extracellular space. In thick skin, found on the palms of the hand and soles of the feet in the human body, an additional layer exists called the stratum lucidum, which is
clear or translucent (under the microscope). This is a thin layer of dead and flattened keratinocyte cells surrounded by oily substances of exocytosis and helps reduce friction and shear forces between the stratum corneum and stratum granulosum.

![Figure 3.1 Schematic figure of the structure of human skin layers. Adapted from Madhero88 and M. Komorniczak, Skin Layers, Wikimedia Commons.](http://en.wikipedia.org/wiki/File:Skin_layers.png)

The stratum granulosum is a thin layer above the stratum spinosum. It consists of keratinocytes which have migrated from the lower layers but do not contain nuclei and thus appear granular, hence they are sometimes called granular cells. These cells release polar lipids into the extracellular space which are then converted into nonpolar lipids and form a lipid barrier arranged parallel to the cell surface. This hydrophobic lipid envelope is responsible for the skin's barrier properties. Some of these hydrophobic lipids include glycosphingolipids and phospholipids, which are converted into ceramides and free fatty acids respectively. The granular cells consist of a protein structure termed keratohyalin, which is rich in histidine.
and cysteine, and is involved in the keratinisation process and binding the keratin filaments together. Keratin is a water-repellent protein that gives the epidermis its toughness and protective quality. The spinous layer, called the stratum spinosum, consists of polyhedral keratinocytes with large nuclei and is active in synthesising cytokeratin filaments, a fibrillar protein which forms tonofibrils that converge to create desmosomes; these structures allow strong cell-to-cell connections between adjacent keratinocytes. This layer is enriched with polar lipids, glycosphingolipids, free sterols, phospholipids and catabolic enzymes. Langerhans cells, which are mainly found in this layer, are immunologically active and protect the body from infection by capturing and processing antigens. The basal layer or stratum basale mainly consists of proliferating and nonproliferating keratinocytes attached to the basement membrane, which separates the dermis from the epidermis. Melanocytes, Langerhans cells and Merkel cells are other cells found in this layer. Melanin, the pigment primarily responsible for skin colour is produced by melanocytes; melanin also protects skin from the damaging effects of ultraviolet (UV) radiation. The number of melanocytes is greater in facial skin and outer arm skin; they also increase upon chronic exposure to light. However, the number of melanocytes is similar for white and black skin. Merkel cells are associated with the sense of touch and the discrimination of shapes and textures; they are found in large numbers in touch-sensitive sites such as the fingertips and lips. The epidermis is an avascular tissue containing approximately 95% keratinocytes, which are differentiated and delaminate from the basement membrane migrating upwards through the layers and, after losing the nucleus, fuse to squamous sheets. Normally keratinocytes are continuously produced based on the loss of cells via shedding from the skin surface. It is believed that the lifespan of an individual keratinocyte cell is around 6 weeks [4], i.e., the time taken for the entire epidermis to be renewed [5]. Calcium is considered to be the key regulator in the formation of epidermal layers. Keratinocyte differentiation is proportional to the calcium gradient in the epidermal layers, with the stratum basale and stratum corneum having a very low concentration of calcium whereas the stratum granulosum contains the highest. Low calcium concentrations stimulate the proliferation of keratinocytes, whereas high concentrations inhibit proliferation and enhance differentiation. The epidermal calcium gradient plays a key role in the dynamic equilibrium and is maintained using conduction, diffusion and the binding of calcium [6].
3.3 The Dermis

The dermis is the skin’s second layer which is thick, fibrous and elastic (made mostly of collagen, elastin and fibrillin), and gives the skin its flexibility and strength. It protects the epidermis and contains the nerve endings, sweat glands, oil (sebaceous) glands, hair follicles and blood vessels as shown in Figures 3.1 and 3.3. The thickness of the dermis varies significantly depending upon the anatomic location, with the fine structure varying depending on its depth. The dermis is mainly divided into two layers; the papillary dermis or stratum papillare and reticular dermis or stratum reticulare. The superficial layer forms conic projections alternating with epidermal rete ridges, which increases the contact surface area between the dermis and epidermis enabling better adhesion between these two layers. This layer consists of loose bundles of collagen and thin elastic fibres which stretch perpendicular to the dermo-epidermal junction. Nerve bundles are found in great quantities in the neurovascular bundles of the dermis. Meissner’s corpuscles are touch receptors located at the tip of dermal papillae. Each corpuscle consists of a number of flattened layers of cells, each with an elongated nucleus; the neuron within is coiled among these cells. When the corpuscle is deformed by pressure the nerve endings are stimulated. Vater–Pacini corpuscles are
encapsulated receptors found in deep layers of the skin which sense vibratory pressure and touch; these nerve endings sense pain, touch, pressure and temperature. Some areas of the skin contain more nerve endings than others, for example, the fingertips and toes contain many nerves and are extremely sensitive to touch.

In humans there are two types of sweat glands; the eccrine sweat glands are primarily involved in the regulation of heat and are found mostly on the soles of the feet. These sweat glands are a band of epithelial cells which grow downwards from the epidermal ridge. The proximal coiled secretory duct and the straight tubular structure in the lower dermis, and the intraepidermal spiral duct that opens onto the skin are the three main components of the eccrine sweat gland. These glands produce sweat in response to heat and stress, which is composed of water, salt and other chemicals; as sweat evaporates from the skin, it helps cool the body. The sweat gland is composed of glycogen-rich clear secretory cells, dark mucoidal cells and myoepithelial cells specialised in contractile properties. Specialised sweat glands in the armpits and the genital region, called apocrine sweat glands, secrete a thick, oily sweat that produces a characteristic body odour. The basal secretory coils of apocrine glands are normally located entirely in the subcutaneous fat and do not open directly onto the skin surface, as a result the exact chemical composition of this secretion is unknown.

The sebaceous glands secrete an oily or waxy matter called ‘sebum’ into hair follicles. Sebum keeps the skin moist and soft, and lubricates and waterproofs the skin in addition to acting as a barrier against foreign substances. Sebaceous glands are found on all parts of the skin, with the exception of the palms of the hand and soles of the feet, with significant amounts on the face and scalp. Hair follicles produce the various types of hair found throughout the body; the number and distribution of hair follicles over the body is established during foetal development and no extra follicles are added after birth. Hair not only contributes to a person’s appearance but has a number of important physical roles, including regulating body temperature, providing protection from injury and enhancing sensation. A portion of the follicle also contains stem cells which are capable of regenerating any damaged epidermis. Nutrients to the skin are provided by the blood vessels of the dermis. The blood vessels also regulate the body temperature via dilation in hot conditions, facilitating a large amount of blood to circulate near the skin surface, where the heat can be dissipated; during cold conditions, the blood vessels constrict, retaining the body’s heat.

### 3.4 Subcutaneous Fat

The lowermost layer of skin is the subcutaneous fat layer and is also called the ‘hypodermis’ meaning ‘beneath the skin’. It consists of loose connective tissue, elastin and cells such as fibroblasts, macrophages and adipocytes. This layer mainly consists
of fat cells (50% adipocytes, Figure 3.4) and plays an important role in our body by attaching the dermis to the muscles and bones via a special connecting tissue called septa, which consists of blood vessels, nerve cells and collagen.

The subcutaneous fat layer controls the body temperature (thermoregulation) via homeostasis. Excess body heat is controlled by vasodilation and sweating, which assists cooling via evaporation. An excessively cold body temperature is controlled via vasoconstriction and converting fat directly into heat energy by thermogenesis. Brown adipose tissue has a unique protein (uncoupling protein-1, also known as thermogenin) which allows the uncoupling of protons moving down their mitochondrial gradient from the synthesis of adenosine triphosphate, thus allowing the energy to be dissipated as heat [8]. Rev-Erb-α, a cell nucleus protein in brown fat, acts as a focal point for controlling the body temperature and is required for establishing and maintaining a fundamental body temperature rhythm, while affording adaptability to respond to environmental demands of unpredictable changes in ambient temperatures; this has

Figure 3.3 A normal dermis. Adapted from Kilbad, *Normal Epidermis and Dermis with Intradermal Nevus 10x*, Wikimedia Commons [7]
been recently reported in the journal Nature [9]. The subcutaneous fat layer is also a depot which acts as a protective pad protecting the muscles and bones from bumps and falls; it is a storehouse of energy and is considered to be an endocrine organ. The fat cells or lipocytes also produce a hormone called leptin which regulates the body weight by way of the hypothalamus [10].

![Figure 3.4 The hypodermis, the subcutaneous fat layer of the skin](image)

### 3.5 The Dermo-Epidermal Junction

The area of tissue that joins the epidermal and dermal layers of the skin is called the dermo-epidermal junction. This porous basement membrane zone allows the exchange of cells and fluid through it and provides mechanical support to the epidermis; it consists of dermal fibroblasts and basal keratinocytes. This structure can be divided into four components; 1) the basal cells in the *stratum basale* of the epidermis are connected to the basal lamina by rivet-like anchoring filaments of hemidesmosomes, this structure distributes the tensile and shearing forces through the epithelium, 2) the *lamina lucida*, 3) the basal lamina or basement membrane and 4) the subbasal lamina fibrous elements. The cells of the dermal papillae layer of the dermis are attached to the basal lamina by anchoring fibrils (collagen VII) and dermal microfibrils (Figure 3.5). The basal lamina includes an electron-lucent zone known as the *lamina*
“lucida” and a dense zone known as the lamina densa, both are synthesised by the basal cells of the epidermis and consist mainly of type IV collagen as well as anchoring fibrils and dermal microfibrils.

![Diagram of the dermo-epidermal junction](image)

**Figure 3.5** Schematic representation of the dermo-epidermal junction

### 3.6 Skin Functions

In general, skin functions can be classified as follows: the primary function of skin is to act as a protective barrier of the body against mechanical, thermal and physical injury, and noxious agents; it prevents loss of moisture (dehydration) and protects against the harmful effects of UV radiation from sun; it acts as a sensory organ, regulates temperature control and plays a significant role in immunological surveillance, and the skin synthesises vitamin D3 and also has cosmetic, social and sexual associations. Vitamin D3 is made when 7-dehydrocholesterol, present in skin, reacts with ultraviolet light (*via* natural daylight) that falls onto the skin; it is produced at the stratum basale and stratum spinosum. The destruction of microorganisms and interaction with the body’s immune system is performed by Langerhans cells, phagocytic cells and epidermal dentritic cells. Langerhans cells are dentritic cells found in all layers of the
epidermis, but mostly in the *stratum spinosum*; they are also found in the papillary dermis around the blood vessels. During skin infections, the Langerhans cells take up and process microbial antigens to become fully functional antigen-presenting cells. These cells secrete a variety of cytokines which are important in the pathogenesis of contact dermatitis, atopic dermatitis, histiocytosis X, human immunodeficiency virus-type 1 and skin graft rejection.

**References**


