Structure and function of skin, hair and nails

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Abstract

The skin is the largest organ of the human body. It is a complex epithelial and mesenchymal tissue comprising a multilayered stratified epidermis, adnexal structures such as hair follicles, sweat glands and sebaceous glands, a dermis containing collagen and elastic fibres, and underlying subcutaneous fat. More than 1000 disease entities involving the skin have been described, and up to 20% of all patient referrals to general practitioners involve skin pathology. Infections, drug reactions and diseases such as psoriasis, eczema, urticaria and skin cancer impose a considerable burden on healthcare resources and significantly affect patients' quality of life. Knowledge of the structure and function of the skin and its appendages is paramount to understanding the biology of healthy skin and the pathophysiology of skin diseases.

Keywords Dermis; epidermis; hair follicles; keratinocytes; melanocytes; nail apparatus; subcutaneous fat

Key points

- Skin is derived from ectoderm (epidermis) and mesoderm (dermis, subcutis)
- Skin provides a mechanical barrier against the external environment, and has further roles in thermoregulation, metabolism and the regulation of fluid balance
- Skin pigment (melanin) is synthesized by melanocytes within the basal layer of the epidermis and then distributed to surrounding keratinocytes. Variation in skin colour results from differences in the type of melanin generated and the way it is packaged and transported (melanosomes)
- Dermis is mainly composed of collagen and elastic fibres, synthesized by fibroblasts, embedded in a proteoglycan-rich matrix. Water makes up 60% of the weight of the dermis
- Skin diseases that disrupt the normal function of the epidermis and the dermis are common, especially eczema, acne vulgaris, psoriasis and cancer (basal cell carcinoma, squamous cell carcinoma, melanoma)

Structure of the skin

The skin accounts for about 15% of the total body weight of an adult and has a surface area of 1.5–2 m^2, making it the largest organ in the human body. Skin consists of three main zones (Figure 1a):

- epidermis
- dermis
- subcutis.

Skin diseases can affect each region of the skin.

Epidermis

The epidermis is the outermost layer of the skin.[1] The principal cell is the keratinocyte (95% of cells). Melanocytes, Langerhans cells and Merkel cells account for the remaining 5%. The epidermis is divided into four main layers depending on the state of keratinocyte differentiation (Figure 1b).

The basal layer consists of a single layer of keratinocytes. These cells proliferate and commit daughter cells to terminal differentiation, which ends in formation of the stratum corneum.[1] This process usually takes about 40 days, but is shorter in diseases such as psoriasis.

Melanocytes, which are dendritic cells derived from the neural crest, also sit in the basal layer. Melanocytes synthesize melanin, which is packaged in subcellular organelles (melanosomes) and then transported to the neighbouring basal keratinocytes. Each melanocyte supplies melanin to approximately 30–40 surrounding keratinocytes. The melanosomes form a 'melanin cap' that protects basal keratinocyte nuclei from harmful ultraviolet radiation. There is little racial variation in the number of melanocytes. Skin colour is determined by the number and size of the melanosomes and the nature of the melanin (eumelanin versus phaeomelanin).[2] The surface pH of human skin ranges from 4.3 to 5.3; it is lower in people with darker skin because melanin by-products are acidic.

The brick-like shape of keratinocytes is provided by a cytoskeleton made of keratin intermediate filaments. As the epidermis differentiates, the keratinocytes become flattened as a result of the action of filaggrin, a protein component of keratohyalin granules, on the keratin filaments.[3] Keratin and filaggrin comprise 80–90% of the mass of the epidermis. Loss-of-function mutations in filaggrin are very common, affecting up to 10% of the population. They are the major genetic risk factor for atopic eczema and several other allergic disorders. Abnormalities in keratinocyte differentiation may contribute to common skin conditions, such as psoriasis (Figure 2).

The outermost layer of the epidermis is the stratum corneum. The cells here, known as corneocytes, have lost their nuclei and cytoplasmic organelles. The plasma membranes of corneocytes contain highly insoluble cornified envelopes, formed by the cross-linking of soluble protein precursors including involucrin and loricrin. The latter contributes 70–85% of the mass of the cornified cell envelope. It also contains several lipids (fatty acids,

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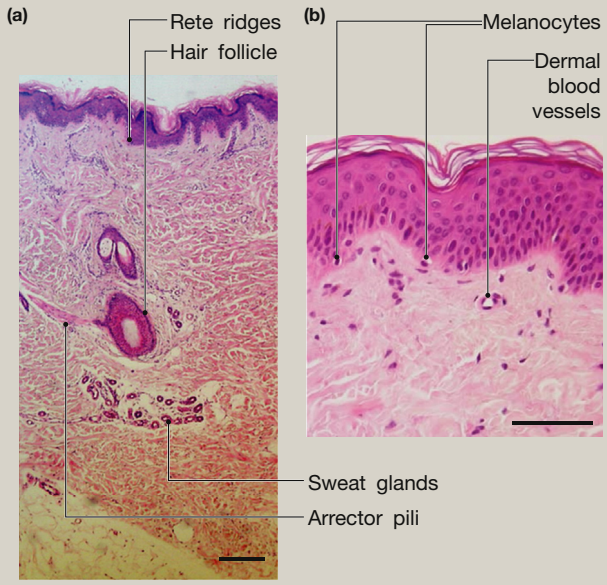

(a) Haematoxylin and eosin staining of normal skin (chest) shows the three layers of the skin, namely the epidermis, dermis and the subcutis. Adnexal structures such as hair follicles, arrector pili muscle and sweat glands are clearly seen. **(b)** Higher magnification of normal skin shows the four principal layers of the epidermis. Melanocytes are scattered within the basal layer of the epidermis (bar = 50 μm).

Figure 1

sterols, ceramides) released from lamellar bodies within the upper, living epidermis.

Langerhans cells are bone marrow-derived, antigen-presenting dendritic cells found throughout the epidermis. Merkel cells within the epidermis transmit sensory information from the skin to the sensory nerves.

Dermal–epidermal junction

The epidermis is separated from the dermis by the cutaneous basement membrane zone (BMZ; Figure 3). Although less than 200 nm across, this region of skin is composed of an intricate network of macromolecules that link the keratin intermediate filaments of basal keratinocytes with collagen fibres in the superficial dermis. The main function of the proteins and glycoproteins within the BMZ is to provide adhesion between the epidermis and the dermis. Defects in these molecules result in skin blistering.[4]

Figure 2 Psoriasis affecting the scalp and occipital hairline.

Dermis

The dermis is 0.5–5 mm thick, depending on body site: a thin dermis is found on the eyelid, and a thick dermis is present on the skin of the back. It is subdivided into two main layers:

- papillary dermis, which is in contact with the BMZ and is richly supplied with blood vessels and sensory nerve endings
- reticular dermis, which is the principal part of the dermis that is in contact with the subcutis.

The dermis is composed of interstitial (collagen fibres, elastic tissue, ground substance) and cellular (fibroblast, mast cell, plasma cell, lymphocytes, dermal dendritic cell, histiocyte) components.[1] It also contains blood vessels (superficial and deep plexi), lymphatic channels and sensory nerves (free nerve endings, end-corpuscles, which include Pacinian corpuscles that sense vibration, and Meissner corpuscles, responsible for tactile and pressure sensations).

About 70% of the dry weight of the dermis is made up of collagens, of which the predominant types are types I and III. Elastic fibres are less tough than collagen fibres but impart extensible properties to the skin. They account for about 5% of the dry weight of the dermis and consist of elastin and elastic microfibrils (e.g. fibrillin).

Collagen and elastic fibres are deposited by fibroblasts. These are mesenchymal cells that show considerable embryonic heterogeneity and body site diversity. Different subpopulations of fibroblasts differentially contribute to skin homeostasis, wound healing, scarring and the formation of hair follicles.

The dermis also contains histiocytes – antigen-presenting cells that phagocytose and degrade foreign substances and present antigens to T cells. Mast cells are distributed near dermal blood vessels; they are responsible for secreting chemotransmitters such as histamines during an allergic reaction. Within the dermis lie 1.5–4 $\times$ 10^6 sweat glands, which are subdivided into eccrine and apocrine glands. Most thermoregulatory sweating and sweat fluid comes from eccrine glands.

Subcutis

The subcutis is the innermost layer of the skin and is composed of lipocytes.[5] These are arranged into fat lobules, which are separated from one another by fibrous septae. Bundles of fibres originating from the dermis and extending into the subcutis strengthen the connection between these two compartments. In non-obese individuals, about 80% of all body fat is located within the subcutis. Fat also has an endocrine function, generating hormones such as leptin that contribute to regulation of appetite and metabolic energy control.

Structure of hair

Humans have up to 5 million hairs.[1] There are three types of hair:

- lanugo hair, which is shed soon after birth
- vellus hair, which is fine hair distributed mostly over the body
- terminal hair, which is longer and coarser.

Fewer than 2% of men and 45% of women go through life with a full head of hair.