Anatomy and physiology of the skin

Jane Harry

ABSTRACT

Skin protects the body from physical damage and infiltration by bacteria. It helps the body regulate temperature and is an important part of human sensory perception and communication. This article describes the different layers of the skin and their functions. It also includes a guide to performing a thorough skin assessment, as well as information on common skin problems. Nurses should understand the anatomy and physiology of the skin and be aware of how different conditions affect it, and how these may appear in people with different skin tones. How the ageing process impacts the skin is also described.

Key words: Skin ■ Anatomy ■ Physiology ■ Dermis ■ Epidermis ■ Hypodermis ■ Skin conditions

Skin is the largest organ of the human body by surface area, weighing between 2 kg and 4.5 kg (16% of total body weight) and covering approximately 2 m^2. The skin is between 1 mm and 2 mm thick, depending on the area of the body it covers, and includes accessory structures such as hair, nails and glands (Tortora and Derrickson, 2023). Without skin we would not be protected from the environment, we would be more susceptible to infection and we would not be able to regulate our body temperature. The skin can heal itself if it gets damaged. It changes as we age. Like all other organs, the skin can fail and this can be potentially life changing or fatal for the patient.

The skin is like a window for health professionals as it can show symptoms and provide clues to underlying disease processes going on within the body, such as ulcerative colitis, pyoderma gangrenosum and diabetes, to mention a few. It is complex not only in structure, but also in the microbiome that lives on it. The skin connects us to the world outside and the world within our bodies.

Functions of the skin

Protection

Covering the body, the skin provides not only a physical barrier that protects the underlying structure from physical damage, bacterial infiltration, dehydration and against ultraviolet radiation, but also acts as a chemical barrier, protecting the body from external moisture. Hair and nails also offer additional protection to vulnerable areas.

Barrier to infection

Cells within the epidermis and dermis are important in providing an immune response if infiltrated by a pathogen.

Sensory perception and communication

The skin has an abundance of nerve endings (cutaneous sensory receptors), which help the brain to determine and process sensations experienced by the body such as touch, vibration, itch, temperature, pressure and pain.

Temperature regulation

Skin temperature is generally considered to be between 32°C and 35°C. This is an approximation, and can vary according to body region and environment (Lee et al, 2019). Heat is transferred from the air to the body when the ambient temperature is greater than skin temperature (Baker, 2019). The skin's response to a raised environmental temperature or exercise is to stimulate the sweat glands to produce sweat to reduce the temperature of the skin surface, which helps to lower the internal body temperature. This does not, however, happen in all cases, and some patients suffering with hyperhidrosis have abnormally high levels of sweating that is not always associated with high levels of physical activity. In cold weather the production of sweat reduces, which in turn helps to conserve heat. Hairs also play an important role in helping the body to maintain heat by standing on end via the contraction of the arrector pili muscle, trapping the heat next to the skin. Subcutaneous fat also acts as a heat source when it is cold (Peate and Evans, 2020).

The dermis houses approximately 8–10% of the blood volume for a resting adult. During exercise the blood volume increases, which helps to reduce the heat that is felt. During strenuous exercise the blood vessels vasodilate, which allows more blood to circulate through the muscles (Tortora and Derrickson, 2023). The skin acts as a thermostat for the body, constantly detecting changes in the environment and sending signals to the brain so it in turn can respond to keep the body alive (Lyman, 2020).

Production of vitamin D

The production of vitamin D starts in the skin where vitamin D_3 is produced from its precursor molecule in response to the presence of sunlight. Vitamin D is essential in the regulation

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Article submitted: December 2024

Accepted for publication: May 2025

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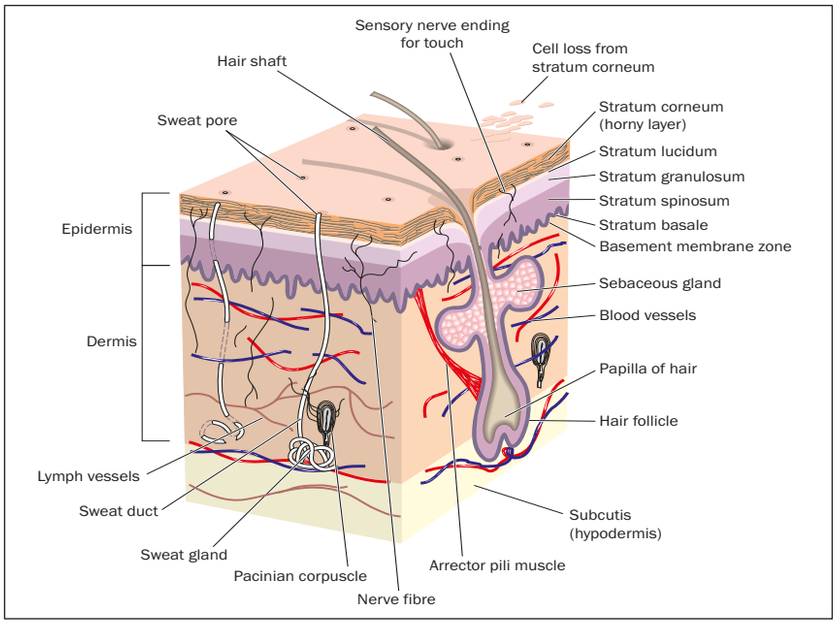

Figure 1. Anatomy of the skin

Table 1. Anatomy of the epidermis: from base to top

Sub-layer	Description
Stratum basale	This layer, which is directly in contact with the dermis, is thin, often 1 cell thick, and consists of stem cells that are continuously dividing, renewing and pushing cells up through the epidermal layers. During embryonic development these stem cells give rise to other types of appendages such as sweat glands and hair follicles. Also present within this layer are Merkel cells, which are present in the epidermis of hairless skin and make contact with the nerve cells and give the sensory function of touch to the skin
Stratum spinosum	This layer contains 8–10 layers of cells including keratinocytes, which are many sided (polyhedral) with spiny projections that fit into desmosomes (intercellular junctions), linking them closely together. The keratinocytes also start to synthesise fat in their cells, which ultimately forms the mortar required between the cells once they reach the stratum corneum to provide a waterproof barrier. Long chains of melanocytes are also present in this layer, which produce melanin by melanogenesis. This protects the skin from harmful UV rays. Langerhans cells are also present. They attack bacteria and viruses, helping to prevent infection
Stratum granulosum	This layer is 3–5 cells thick. As the keratinocytes continue to move through the layers, they lose their nucleus (apoptosis) here, which renders the cells unable to perform metabolic reactions and they flatten and die. This layer helps to reduce water loss by lamellor granules, which are secretory organelles found in keratinocytes that form a water barrier
Stratum lucidum	This layer is not always present in some areas of the body. It provides extra protection to areas that are susceptible to wear and tear, such as over joints, to protect the skin from damage during movement, and on the hands and soles of the feet. This layer is composed of numerous dead keratinocytes containing a transparent protein called eleidin, which eventually transforms to keratin. This layer sits just under the stratum corneum and is 4–5 cells thick
Stratum corneum	This is the outer layer of the epidermis and is mostly made up of dead skin cells getting ready to be shed, comprising keratin and dead keratinocytes. As the dead keratinocytes move up through the layers they finally reach the stratum corneum. The keratinocytes have become hardened interlocking plaques that are cemented together by a fatty mortar they have produced to form a brick-like structure that provides the skin's waterproof barrier. This helps to maintain the pH of the skin and is 20–30 layers thick. Here the cells finally reaches the end of the process, having taken between 25 and 45 days to shed. The average human sheds 18 kg of skin over a lifetime

Source: Maranduca et al, 2019; Peate and Evans, 2020; Marieb 2021

of calcium in the body and affects the bone deposition and serum calcium levels (Chowdhury et al, 2019).

Excretion

The skin removes heat and water, plus some small by-products such as ions and several organic compounds within the sweat that is produced.

Layers of the skin

The skin is comprised of three layers: the epidermis, the dermis and the hypodermis or subcutis (*Figure 1*).

Epidermis

This is the top (outermost) layer of the skin and it is constantly shedding millions of dead skin cells. It is estimated that normal skin sheds approximately 18 kg over a lifetime and humans have a completely new epidermis every 25–45 days (Marieb, 2021).

The epidermis is further broken down into five sub-layers (*Table 1)*. It is important to understand how keratinocytes move up through the layers in order to understand different skin conditions and the effects of them on the skin and the repair process of the tissues. The continuous cycle of keratinocytes being produced in the stratum basale and the shedding of cells shows the skin's remarkable ability to repair and heal.

Dermis

The dermis makes up the majority of the skin's thickness and mostly consists of connective tissue. The main purpose of the dermis is to provide nutrients and blood supply to the epidermis to produce the keratinocyte cells. There are two sub-layers within the dermis, the papillary and the reticular layers (*Table 2*).

The dermis is a hive of activity and is a complex network of nerves, blood vessels and lymphatic vessels. It is estimated that the network of blood vessels in the skin is 11 miles in length (Lyman, 2020). The fibroblasts within the dermis provide the matrix to secure collagen and to provide strength and stability to the skin, which is important during wound healing. The collagen also binds water, thus helping the skin to stay hydrated. This forms a gel-like substance that constitutes the bulk of the dermis and acts as a cushion and lubricant. The elastin allows the skin to stretch and rebound while keeping its shape (Marieb, 2021). Hyaluronic acid is also present here and binds cells together, it also lubricates joints and shapes the eyeball. The hyaluronic acid within this layer helps the skin to repair following sun damage.

The dermis is also host to an impressive array of immune cells that are ready at a moment's notice to protect the body from infiltrating organisms. A few of these cells are also present in the epidermis. These are called Langerhans cells, and they act as lookouts for intruder organisms and spread the message to the cells in the dermis to prepare them for action. They also engulf the invading molecules and break them down into smaller pieces called epitopes. The Langerhans cells then produce a 'bar code', which is unique to each intruder and transport this information to the lymph nodes for cataloguing, so the T cells (lymphocytes) and B cells can recognise the invader again

(Lyman, 2020). Similarly, in the dermis, the T cells send a message to the other cells to organise a response to the invader. The antibody-producing B cells develop a memory for the invading pathogen when it breaches the barrier of the skin. This in turn helps with quicker production of antibodies in the future should the same pathogen breach the skin again.

Dermal macrophages and histocytes are also present; they are phagocytic and will engulf matter and offer a secondary protection to the skin. Mast cells, which are present around the blood vessels, nerves, sweat glands and hair follicles of the dermis, are packed with powerful molecules and granules, which are released when exposed to a stimulant. Mast cells contain histamine, which cause the symptoms of inflammation and allergy. When histamine is released it causes the small blood vessels of the dermis to increase blood flow to the area.

Hypodermis

The hypodermis, also known as the subcutaneous layer, lies beneath the dermis and anchors the dermis to the underlying fascia surrounding the muscle or bone. The hypodermis is mainly composed of adipose tissue with the role of fat storage and provides cushioning and insulation.

Table 2. Sub-layers within the dermis

Sub-layer	Description
Papillary	The papillary layer is in contact with the epidermis and is approximately one-fifth of the thickness of the total of the dermis and is less dense than the reticular layer. It contains the elastin fibres, blood vessels and nerve endings that supply the epidermis. There are dermal papillae present that interlock with the rete pegs (epithelial extensions) of the dermis, locking the two structures together. Some of the dermal papillae contain capillary loops that provide oxygen and nutrients to the epidermis. Also contained within this layer are nerve endings and touch receptors (Meissner's corpuscles). The epidermal ridges or fingerprints are unique to each person and are created in the dermal papillae lying on the dermal ridges. The two layers of the epidermis and dermis are interlocked in an undulating interface, with the dermis extending into the epidermis in a series of ridges – which are most pronounced on the fingers and toes, forming the spirals that are unique to each individual
Reticular	This denser layer of the dermis makes up approximately 80% of the dermis and is mostly made up of collagen and elastin fibres that support and give strength to the dermis. Nerve endings, which are sensitive to cold and pressure, are found deep in the reticular layer of the dermis. This layer is attached to underlying structures such as muscle and bone by a subcutaneous layer called the hypodermis or superficial fascia

Source: Peate and Evans, 2020; Lyman, 2020; Marieb, 2021

Skin appendages

Hair

More than 90% of the body is covered in hairs. They are involved in the recognition of sensation, including social exchanges, and they also have the ability to detect objects (Gould, 2018). Hair follicles are complex structures formed by the epidermis and the dermis. The base of the hair follicle (bulb) is deep within the dermis; on the face it can originate in the subcutaneous fat. A smooth band of muscle called the arrector pili attaches to the bulb. This muscle is controlled by the parasympathetic nervous system and can cause the hair to stand on end (Lavers, 2017). The development of hair is a cycle that starts with the anagen stage (active growth). The hair then transitions through the catagen phase when growth slows. The telogen stage is the final and resting phase of the hair follicle prior to the shedding phase and the length of this is proportional to the length of the hair.

The colour of hair is genetically determined and depends on the amount of melanin present. White hair is caused by the absence of melanin and the replacement of melanin with tiny air bubbles, which makes the hair appear white.

Nails

Nails provide protection to the end of digits and make the fine motor movements of the digits more effective. The nail is made up of a transparent plate of keratin derived from an invagination of epidermis. The nail plate is a product of cell division in the nail matrix, and this is partially visible as the pale (half-moon) area on the nail. The cuticle of the nail is an extension of the stratum corneum of the nail fold to the nail plate and seals this join to prevent infection or a foreign body entering. Nails grow throughout a person's life but the rate at which they grow slows as we age. The average growth rate for nails is 1 mm per week and the time taken for a fingernail to completely grow back from the matrix is approximately 6 months. Toenail growth is at one third the rate of fingernails and a new toenail will take approximately 18 months to regrow (Graham-Brown et al, 2017).

Sebaceous glands/sweat glands

These help with the thermoregulation of the skin and can produce up to 500 ml of sweat per day (Nigam and Knight, 2017). Sweat glands begin in the subcutaneous fat and are tightly coiled organs capable of producing large quantities of sweat. This is mostly made up of water, with some salt particles that help the body to stay cool when the outside temperature is hot; they also activate as a response to fear. On a hot day or in times of fear the brain sends a signal to the hypothalamus, which in turn signals the endocrine glands to send a signal to the sweat glands to produce sweat, helping the body to cool. The skin has millions of these glands, but they are most dense in number on the palms of the hands, soles of the feet, in the groin and the axillae. Glands that open onto hair follicles do not become active until puberty.

Ageing skin

The skin starts to change as humans age. The epidermal turnover slows as we age, leading to thinner skin, which could potentially increase the risk of trauma and infections. The barrier function of the skin changes as sebum production reduces, the acid mantle that supports the cells in the stratum corneum and provides the waterproof barrier to the skin reduces, and the skin therefore becomes drier and more prone to itching, dryness and infection. It becomes less flexible, and the collagen becomes tougher,

Table 3. Components of a comprehensive skin assessment

Component	Considerations
Patient's medical history	■ Intrinsic (advancing age, diabetes, atrophy or thin skin) and extrinsic risk factors ■ Wound-related risk factors, eg infection, odour, previous infections and any previous problems with wound healing ■ Previous treatments used for any skin condition ■ Skin condition history: conditions in childhood. Are there any seasonal variations? ■ Medication history ■ Any known allergies
Skin assessment	■ When examining the skin, ensure adequate light and examine all of the skin, not just the area with which the patient has reported an issue, to ensure that all conditions are considered. This should be a top to toe assessment, involving: – Skin texture and firmness – Any colour changes: determine whether this is erythema that is blanchable or non-blanchable – Any temperature differences – If there is a skin condition present: how does it feel to the patient? Is it itchy or sore? Is a rash or dryness present? – Inspection of the nails and hair. These can give an indication of generalised disease such as psoriasis or localised pathology – Identification of any skin abnormalities or wounds and their sites and distribution pattern. Document and photograph in line with local policies – Identification of any bruises/burns and scalds. These could indicate that the patient may be vulnerable, and safeguarding should be considered – Indication of self-harm wounds. These wounds often do not present in a pattern typical of a skin condition but rather in the form of cut marks, blisters, purpura, oedema, erythema or nodules, which can be misleading when diagnosing. It is important that if the health professional thinks the wounds could be self-inflicted that they spend time with the patient, using good communication skills. They should offer support and treatment in a non-judgemental, holistic approach and involve mental health services ■ Photographs of any skin abnormality should be taken by a medical photography department if available. If not, local policies should be followed
Does the patient have any risk factors for vulnerable skin?	■ Previous skin disease ■ Any previous medication reactions or allergies ■ Social history: such as occupation (exposure to chemicals, long periods of standing, repeated handwashing). Hobbies. Alcohol (alcoholism is a risk for psoriasis worsening). Smoking is strongly linked to palmo-plantar pustulosis and hidradenitis suppurativa. Is there a history of sun exposure? ■ Check on toiletry, bathing and cosmetic products used. What does the patient wash with? Is the patient able to wash and cleanse their skin regularly in line with treatment plans? This is a particular concern in homeless patients and patients relying on others for personal care ■ Family history of skin conditions such as eczema, asthma, hay fever, psoriasis, genetic diseases or skin cancer
Assessment of the patient's knowledge about his/her skin condition	■ Be careful with the language used when talking with the patient; patients may have a different name for a condition or symptom, so ask them to describe it to you, for example bed sore versus pressure ulcer ■ Find out what the patient knows about their skin condition and treatments ■ Find out how the skin condition affects the patient's life: does it restrict the patient's lifestyle? Use a quality-of-life tool to assess this

Source: adapted from: Williams et al, 2018; Mitchell, 2021

which leads to wrinkles and shearing. Melanin is less evenly produced, which makes the skin more prone to sun damage. Fewer sweat glands lead to less effective temperature control and a greater risk of hypothermia (Saxon et al, 2014).

Assessment of the skin in practice

First, it is important to ensure that you have a warm, private room to carry out the skin inspection/assessment. Gain the patient's consent, check if a chaperone is required and ensure the necessary infection and protection measures have been taken in line with local policies. *Table 3* describes the important components of a comprehensive skin assessment.

Skin conditions that affect skin integrity

Several conditions can impact the integrity of the skin (*Table 4*).

Skin pigmentation and skin tone

Three pigments contribute to skin tone: melanin, carotene and haemoglobin. Only melanin is mostly located in the epidermis. The amount of melanin varies the skin colour from pale yellow to black. The number of melanocytes is about the same in all people. Differences in skin colour are mainly due to the amount of pigment the melanocytes produce and secrete to the keratinocytes (Peate and Evans, 2020). Freckles occur where the melanocytes have formed patches. Carotene is a yellowish orange pigment that is a precursor of vitamin A. It is found in the stratum corneum and fatty areas of the dermis and subcutaneous layer. The red colour is from haemoglobin as it is carried through the capillaries of the dermis.

There has long been systemic bias in the NHS, with information about non-white skin tones previously omitted from textbooks and guidance. Black and minority ethnic people have experienced bias in a variety of settings across health care: in maternity care with higher mortality rates, increased severity of COVID-19 cases, and with regard to assessment of skin tone – which can all lead to unequal outcomes for patients (Marshall et al, 2021).

There is a lack of research around skin tone in wound care. It has been shown that patients with a darker skin tones are more likely to be diagnosed with a higher category of pressure ulcers due to a lack of accurate assessment and early identification of tissue damage (Oozageer et al, 2018). Black and brown skin tones can present as violet, grey, brown or black tones when damage to the tissue is seen (Finlay et al, 2021). To optimise assessment and treatment outcomes for patients a thorough assessment of skin tone is essential: first, to establish a baseline, and then ongoing assessment to recognise changes in the skin. An evidence-based validated tool should be used such as the Skin Tone Tool (Marshall et al, 2021). This enables clinicians to choose the tone that most closely matches the inner upper arm as a baseline. Clinicians also need to understand how changes look in different skin tones and how to monitor for them.

Conclusion

The skin is a remarkable organ and a hive of activity, with a complex structure and function, protecting us from the external environment. It is a window for clinicians to help diagnosis of

Table 4. Conditions that impact the integrity of the skin

Condition	Impact
Rash	A rash may be a simple reaction to an irritant or the symptom of a medical condition
Dermatitis/eczema	An inflammation of the skin that can cause an itchy rash. Atopic dermatitis, a type of eczema, is the most common, causing patches of skin that are itchy, cracked and sore
Psoriasis	A genetic condition that causes silver scaly plaques on the skin
Pruritus	Often associated with dry skin, incidences of this increase with age. It can cause discomfort and increased episodes of itching, which may lead to scratching and damage to the skin barrier, disrupt the patient's sleep and affect quality of life
Cellulitis	An infection of the subcutaneous and dermis tissues that can progress to sepsis, requiring hospitalisation
Malignant melanoma/ basal cell carcinoma/ squamous cell carcinoma	Malignant melanoma, basal cell carcinoma and squamous cell carcinoma all result from sun damage; malignant melanoma is the most dangerous because it has propensity to spread and metastasise rapidly
Lipodermatosclerosis	Painful, tight, hardened subcutaneous tissue just above the ankle, due to infiltration and inflammation, which can lead to a distorted leg shape

Source: adapted from Williams et al, 2018

KEY POINTS

- The skin is a vital organ for the human body; it protects it from harmful influences such as UV rays, and offers protection from bacteria, viruses and fungi. It also provides a waterproof barrier, thermoregulation, excretion, produces vitamin D, and is vital in sensory perception and communication
- The skin is divided into 3 layers: the epidermis, dermis and hypodermis
- Skin assessment should form part of a basic holistic patient assessment. It is important to establish a baseline for the patient, especially around skin tone, so that changes can be detected early and treatment can be started
- As the skin ages it becomes thinner, has less elasticity, is more susceptible to damage and its barrier function diminishes. It is important to recognise this and introduce measures to protect it

systemic illness and needs to be understood to provide effective clinical assessments for patients. **BJN**

Declaration of interest: none

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CPD reflective questions

- What affects accurate and comprehensive skin assessment in your clinical practice? What impact do any issues/barriers have on patient outcomes?
- What barriers are there to effective documentation of skin assessment in your clinical practice?
- Are there any points in this article that require further reflection for yourself as a health professional or for your wider team?