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# Physiology of the skin

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## Aim and intended learning outcomes

The aim of this article is to review the structure and physiology of the skin. This information should enable nurses to provide effective skin care for patients. After reading this article you should be able to:

- Describe the structure of the layers of the skin.
- Outline the major functions of those layers.
- Relate structure and function to the major physiological roles of the skin.
- Identify common risks to the structural integrity of the skin.

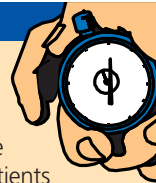
## Introduction

The skin is the largest vital organ in the human body and the most visible. The main function of the skin is to act as a barrier, protecting the warm moist internal environment from the essentially hostile, dry and cool external environment in which we live. It is a common belief that the skin acts as a total barrier to the penetration of external substances. In fact, it is permeable to many substances, including perfumes and dyes with which we may be in frequent contact.

Apart from protection, the skin plays critical roles in the control of body temperature and blood pressure. It also has endocrine functions and contains numerous sensory receptors (Box 1). The condition of the skin often reflects underlying disease processes. It is important that nurses observe and attend to patients' skin. An understanding of the structure and physiology of the skin enables nurses to assess what might be causing changes in its texture, appearance or integrity (Fig. 1). It is claimed that

## TIME OUT 1

Consider your practice and how you assess the skin of patients in your care. Is this a formal process or part of routine care? Are you confident that patients are receiving adequate skin assessment? Is this being documented? Are there particular factors to be considered in your clinical area?



healthcare professionals are poorly educated in the management of skin problems and diseases (APGS 2000, APPGS 1998). Assessment of skin by nurses frequently occurs as part of everyday care-giving. When a patient is being washed and dressed, nurses often take the opportunity to examine the skin informally, particularly in relation to skin integrity and pressure areas. However, with fewer registered staff performing hands-on care, it is possible that this significant aspect of skin care is being overlooked. When this is the case, it becomes important that formal skin care assessments are performed and documented. An understanding of the structure and function of the skin can assist in this process. In addition, an awareness of how the skin can be affected by underlying disease can help nurses to evaluate deterioration or change in a patient's condition.

The skin is divided into two main layers: the epidermis and dermis. A third layer, the hypodermis, will be briefly described.

## The epidermis

The epidermis is composed of a stratified squamous epithelium. Epithelial cells are one of the four main

## In brief

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### Summary

Knowledge of the anatomy and physiology of the skin, and its major roles in thermo-regulation, protection, vitamin D metabolism and control of blood pressure can assist nurses in assessment of skin conditions and general physiological disturbances. The protective roles of the skin are emphasised in discussion about skin cancers and the use of transdermal drug delivery mechanisms.

### Key words

- Anatomy and physiology
- Skin and skin disorders

These key words are based on subject headings from the British Nursing Index. This article has been subject to double-blind review.

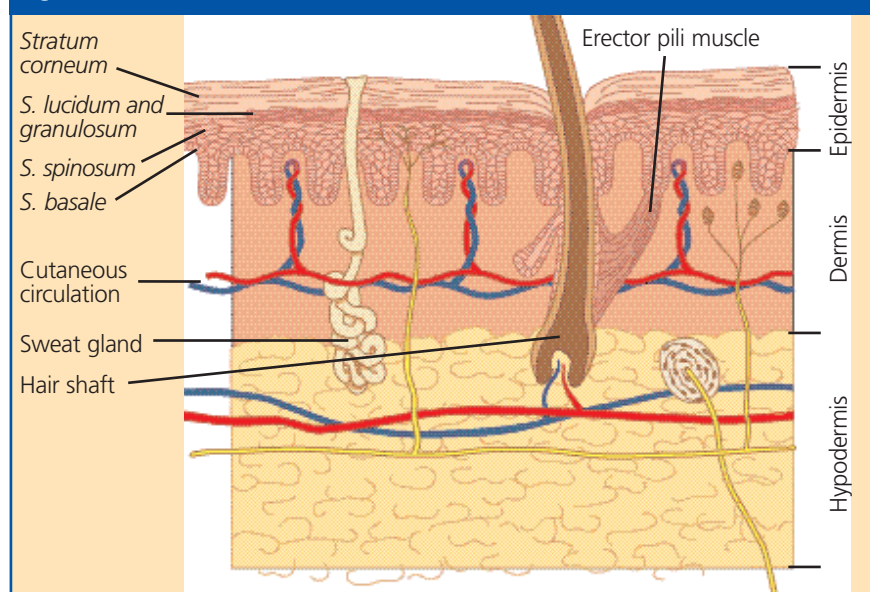
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# Tissue viability



Fig. 1. Structure of the skin



cell types in the body. Epithelial tissue separates the internal and external environments of the body. Therefore, it is found not only in the skin but also lines the digestive, respiratory and urogenital tracts. Any part of these systems that is exposed to mechanical irritation, for example, the skin, mucosa of the mouth, nose and vagina, is covered in multiple (stratified) layers of epithelial cells, the uppermost of which are flattened (squamous).

Epithelial cells are always found in sheets, bound together by tight junctions that form between the cells and allow the passage of variable amounts of paracellular traffic (Bray *et al* 1999). Some cells are so tightly bound together that for any substance to travel from one side of the epithelial sheet to the other, it must go through, rather than between, the cells. Other epithelia, for example, those lining the small intestine, are more loosely bound and allow greater movement of substances via the paracellular route. The epidermis of the skin is an example of a tight epithelial tissue. However, this does not prevent the passage of substances across the skin. More material penetrates the skin than is commonly assumed, as will be described below.

Cells in the basal layer of the epidermis undergo mitosis and, of the two daughter cells produced, one remains within the basal layer and the second migrates upward through the layers to the surface. This upward progression takes about 28 days and is accompanied by major changes in cellular content that lead to distinct layering in the appearance of the epidermis under the microscope (Fig. 1) (Tortora and Grabowski 2000). Keratin production begins in the *stratum spinosum*. This continues through the *stratum granulosum*, where the cells lose their

nuclei and die. The *stratum lucidum* and *stratum corneum* are composed of dead cells, packed with keratin and surrounded by lipids.

This flattened outer layer of cells is given structural strength by the presence of keratin. Keratin is an insoluble protein, which is also the major component of hair and nails in humans, as well as horns and hooves in animals (Burton 1990). The lipids surrounding the cells provide protection against water loss and penetration. The ability of the superficial layers of the epidermis to desquamate provides protection against mechanical abrasion (Tortora and Grabowski 2000).

Little is known about the control of cell turnover in the epidermis. It is difficult to study, as the epidermis is only about 120 micrometres thick and contains many cells in different stages of differentiation (Forslind *et al* 1997). The normal cell cycle for a keratinocyte (from mitosis to mitosis) is about six days, but since it takes 28 days for daughter cells to reach the skin surface and be shed, not all the basal keratinocytes are active at the same time. If the signals that control this process were known, this would have a significant impact on the treatment of skin diseases such as psoriasis, where there is increased basal cell activity and increased transit time to the skin surface (Burton 1990, Forslind *et al* 1997).

In addition to the epidermal cells, or keratinocytes, the basal layer of the epidermis contains melanocytes. These cells produce melanin, which is inserted into neighbouring keratinocytes and provides protection against ultraviolet radiation. In Caucasian skin, the melanin tends to disintegrate as the epidermal cells move up through the layers of the epidermis (Burton 1990). Melanin production is stimulated by ultraviolet radiation and various systemic hormones, most notably adrenocorticotrophic hormone (ACTH) which is why people with primary adrenal insufficiency or Addison's disease often present with a tanned appearance (Porth 1998). The role of melanin in protection against ultraviolet radiation will be discussed below.

**Accessory structures of the epidermis** The epidermis also contains a number of accessory structures. Hair shafts are composed of a layer of epidermal cells that project down below the dermis. At the root of the growing hair is a knot of blood vessels. Hair shafts become particularly important as a source of epidermal cells for re-epithelialisation in burns and wounds, where the epithelial layer itself is lost. If a wound or burn is sufficiently deep that the hair roots are also lost, the replacement scar tissue will be hairless.

Hair shafts are associated with specialised nerve endings that help to detect fine touch on, or movement across, the surface of the skin. Also associated with the hair shaft are sebaceous glands that produce sebum, a lipid secretion. These glands are

## Box 1. Functions of the skin

- Protection
- Thermoregulation
- Sensation
- Synthesis of vitamin D
- Assistance in control of blood pressure



most active in the hair follicles of the head, neck, back and chest. Sebum production is stimulated by hormones, in particular the androgen hormones (but also thyroid and growth hormones), and this can lead to the formation of acne (Burton 1990).

Eccrine sweat glands are found within the dermis, but their ducts travel through the epidermis to release sweat onto the skin surface. Sweat is formed by the active secretion of sodium in the base of the sweat gland, under the stimulus of the sympathetic nervous system. Sodium attracts water into the gland duct, and potassium, chloride and urea are also secreted (Bray *et al* 1999, Burton 1990). The main function of sweat is to assist in the maintenance of body temperature. Evaporation of water from the skin surface can account for about 15 per cent of heat loss at room temperature (Bray *et al* 1999). Sweating becomes increasingly important for heat loss as external temperatures increase, but is less effective in a humid environment. In extreme conditions, up to one litre an hour of fluid can be lost through sweating. This could rapidly give rise to a potentially dangerous fluid and electrolyte imbalance (Bray *et al* 1999).

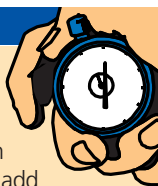
### The dermis

While the cells of the epidermis are numerous and closely linked, those in the dermis are separated by a complex mesh of extracellular material. The main cells of the dermis are fibroblasts, but there are also immune and inflammatory cells, nervous tissue and blood vessels (Tortora and Grabowski 2000). Collagen, elastin and other extracellular fibres are the major constituents of the dermis. These give the skin strength and flexibility. Collagen is the most common and important structural protein in the body. In the dermis, it is arranged in an intricate, orderly network that provides strength and resists stretching. During wound healing this orderly array is disturbed and the resultant scar tissue will always be weaker than intact skin (Clark 1996).

Elastin is another structural protein that provides flexibility. Reduced production of collagen and elastin with age, combined with damage from ultraviolet radiation, lead to the development of wrinkles and sagging of the skin.

### TIME OUT 2

Cosmetic companies sometimes suggest the use of products containing collagen or elastin. Adverts occasionally claim that some haircare products will 'add new life to your hair'. Chemical peels are often advertised as a way of removing wrinkles. Why are these claims to be regarded with scepticism?



Collagen and elastin are relatively large proteins and, contrary to what the cosmetics industry would have us believe, topical application is ineffective as a replacement because they are too large to be absorbed through the epidermis. Adding 'new life' to your hair is impossible, since the hair shaft is composed of keratin, a non-living protein. Chemical peels can only remove the superficial layers of the epidermis and wrinkling is produced by changes in the dermis. If the peel were to penetrate as far down as the dermis, it would lead to severe scarring.

**Functions of the dermis** The dermis provides structural strength and flexibility to the skin. It also contains the blood supply for the epidermis, which has no blood vessels of its own. The system of capillaries and venules in the dermis plays an essential role in the control of body temperature and blood pressure.

The dermis has an extensive network of blood vessels. At the surface closest to the epidermis there is the normal circulatory series of arterioles, capillaries and venules. Lower down there is a complex of deep veins that acts as a reservoir for approximately 1.5 litres of blood (Bray *et al* 1999). Under sympathetic nervous stimulation, for example, during hypotension or haemorrhage, these veins are constricted and the blood they contain is pushed into the general circulation. At the same time, blood flow to the skin is restricted causing a pale, cool and mottled appearance (Porth 1998). Skin is able to survive with relatively little oxygen supply and, therefore, can tolerate reduced blood flow much better than other body tissues (Bray *et al* 1999).

### TIME OUT 3

Why should a patient who presents with cool, pale, clammy skin be kept comfortably warm but not hot while the underlying cause of his or her problem is investigated and treated?



The vasoconstriction that occurs in response to hypotension or shock results in pale, cool skin. Because sympathetic stimulation also triggers the production of sweat, the patient's skin is often clammy. It is important that this is recognised as a symptom of an underlying, serious condition. Nurses should not attempt to warm the 'cold' patient until fluid volume has been replaced, as this causes vasodilation and it is vitally important that blood volume is reserved for central circulation. Once the cause of the shock is remedied, blood circulation will be restored to the skin.

In prolonged shock states, the core body temperature increases, even though the patient's skin feels cool and clammy. This is related to the other main function of the skin circulation – control of body temperature.

The skin of the hands, feet and face contains a





large number of arteriovenous anastomoses. These blood vessels bypass the capillary bed. When the core body temperature increases, sympathetic nervous input to the skin is decreased, allowing these vessels and those of the deep vein complex to dilate (Bray *et al* 1999). This leads to an increase in blood flow near to the body surface, allowing heat to be lost across the skin. If sympathetic stimulation is increased, more body heat will be retained, causing a rise in core body temperature.

### The hypodermis

The hypodermis is composed of a layer of subcutaneous fat cells and forms the link between the skin and the rest of the body. Through it pass all the blood vessels and nerves supplying the skin. It also provides a cushioning layer and some thermal insulation when the external environment is cold (Tortora and Grabowski 2000).

### Endocrine functions of the skin

In the presence of sunlight, vitamin D is formed in the skin. This vitamin is a prohormone, or precursor, that is converted into the hormone calcitriol via pathways in the liver and kidneys. Calcitriol is required for the absorption of calcium from the small intestine.

A deficiency of vitamin D, and thus calcitriol, can lead to rickets in children and osteomalacia in adults (Bray *et al* 1999, Porth 1998). These are disorders that occur when there is deficient mineralisation of the bones. In children, this leads to stunted growth and bowing of the legs. In adults, bone pain, weakness and fragile bones can occur (Porth 1998).

The main dietary source of vitamin D is fish liver oils, so sun exposure is a major requirement for sufficient production. The ability of the skin to manufacture vitamin D is reduced with age. It is also reduced with the decrease in ultraviolet radiation reaching and penetrating the skin. This occurs in the presence of large amounts of melanin in dark skins, and also with the use of sunscreens. The amount of ultraviolet radiation penetrating the ozone layer decreases with increasing latitude, especially in the winter months. In some latitudes, there is insufficient ultraviolet radiation for the skin to produce any vitamin D between October and March (Holick *et al* 1991).

### TIME OUT 4

Do you consider any of the patients in your care to be at risk of vitamin D deficiency? What environmental factors might contribute to this problem?



Patients in long-term care and those who are

immobilised in the home might have little exposure to the sun and, therefore, be at risk. Other conditions, such as high levels of pollution, particularly for children with black skin, might also increase risk. Pollution decreases the amount of UV radiation reaching the skin (Holick *et al* 1991).

### Ultraviolet radiation and the skin

While the presence of ultraviolet radiation is essential for the production of vitamin D, it is now generally accepted that exposure to sun is not beneficial for the skin. Sunlight that reaches the earth's surface is mainly composed of ultraviolet radiation, with a wavelength of between about 290 nanometres (nm) up to 400nm, and visible light (Bickers 1991). Ultraviolet radiation is divided into three types depending on the wavelength. The shortest wavelength, and thus the most energetic or damaging, is UV-C which has a wavelength of between 10 and 290nm. This does not tend to reach the surface, as it is absorbed in the upper atmosphere by ozone. However, at high altitudes and in the presence of the ozone hole in the southern hemisphere, there is increased UV-C penetration.

UV-B radiation has a wavelength of between 290 and 320nm and is the primary cause of sun damage to the skin. UV-A has a longer wavelength (320 to 400nm) and, while it is less active in sunburn formation, it penetrates deeper into the dermis and can be responsible for changes to the matrix proteins of the skin. UV-B radiation does not penetrate so deeply, but is more readily absorbed by cellular deoxyribonucleic acid (DNA) and thus more damaging to the keratinocytes as it passes through the epidermis.

The effects of sun exposure on the skin can be divided into acute and chronic processes (Burton 1990, Fischetti 2001). Initially, there is little to indicate to a person that he or she is overexposed, but after between six to ten hours, a painful erythema develops, possibly due to the release of prostaglandins from damaged keratinocytes. Within a day or so, tanning occurs. This is due to stimulation of the melanocytes to produce more melanin that then forms a cap over the nuclei of surrounding keratinocytes to protect the cell DNA from further damage.

Chronic changes include premature ageing of the skin related to ultraviolet penetration of and damage to the collagen and elastin fibres of the dermis. Most important is the development of premalignant solar keratoses and malignant skin tumours. These arise from UV-A and UV-B damage to the DNA in the cell nuclei that leads to the development of cancerous cells (Bickers 1991, Burton 1990, Porth 1998).

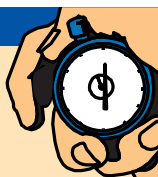
Chemical sunscreens act to reduce the effects of ultraviolet radiation by absorbing the energy con-



tained in the light waves before it penetrates and damages the epidermis. Physical sunscreens usually contain zinc oxide or titanium oxide and act by reflecting the light waves back off the surface of the skin (Bickers 1991). Guidelines on the prevention of skin cancer produced by national cancer organizations recommend the use of high (30+) SPF broad spectrum sunscreens. A broad spectrum sunscreen blocks both UV-A and UV-B radiation. Physical sunscreens are often referred to as sun-blocks. They are thick and opaque on application and do not disappear as readily into the skin as chemical screens.

#### TIME OUT 5

If you use a sunscreen, do you know whether it provides physical or chemical protection? Find out if it offers protection against UV-A and UV-B radiation.



#### The skin as a barrier

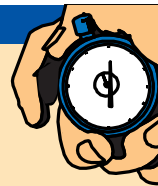
The skin forms a barrier between the moist internal body environment and the external world, but it does not form an impermeable barrier (Hotchkiss 1994). Substances can penetrate the skin through a variety of routes: through, or between, the cells of the epidermis or through sweat ducts or hair shafts. Any substance that causes dermatitis has penetrated at least the superficial layers of the epidermis, since it must do this to trigger an inflammatory response.

While the penetration of some substances through the epidermis and dermis is desirable, for example, medication, in other cases it is not and indeed might cause toxicity in the body. Of particular concern is the growing number of so-called therapeutic cosmetics (Draelos 1997). These involve cosmetic substances that are sheathed in a lipid soluble casing that is able to penetrate into the deeper layers of the skin. Because they are marketed as cosmetics, rather than drugs, these products are not subject to the same stringent testing requirements, but if they do have a physiological effect they might act on other structures beyond their intended target, possibly entering the blood stream and migrating to organs away from the skin (Draelos 1997).

Studies have shown that some of the commonly encountered chemicals in perfumes, soaps and cleaning fluids might be at least partially absorbed by the skin (Hotchkiss 1994). This effect is enhanced by the ethanol added to many aftershaves and perfumes because it alters the lipid barrier of the epidermis and allows deeper penetration. This has also been demonstrated with aromatherapy oils (Hotchkiss 1994).

#### TIME OUT 6

Transdermal drug administration has become increasingly popular. Why are only certain drugs able to be administered via this route? What are the risks associated with this type of drug administration?



The transdermal administration of drugs is a useful, non-invasive method for administering mainly low-molecular weight, lipid soluble medications (Kanikkannan *et al* 2000). Drugs such as nicotine, nitroglycerine, scopolamine and fentanyl are readily administered via skin patches. Research is ongoing into methods that will enhance skin penetration so that other drugs can be administered using the transdermal route. Phoresis is a process that uses ultrasound or low-level electrical currents to stimulate absorption, but it requires equipment which is not available to patients in the community (Roberts 1999). A further option is the use of chemical penetration enhancers that alter the structure of the stratum corneum to allow drug penetration (Kanikkannan *et al* 2000).

One risk associated with this route of administration is that the skin tends to absorb the drug rapidly from an applied patch. This then acts as a reservoir and the drug is slowly released from the skin over a period of hours (Alsaahaf and Stockwell 2000, Hotchkiss 1994). Removal of the patch will not stop delivery of the drug and there is a risk of overdose if a similar type of drug is administered via another route.

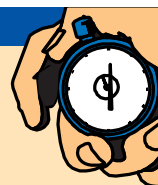
#### Conclusion

The skin fulfils a number of important roles in the protection and maintenance of a stable internal environment. As an organ, the skin has a complex structure and the way in which it functions is not yet fully understood. The information in this article will assist nurses in performing assessments of patients' skin.

Assessment should relate not only to the superficial appearance of the skin (although assessment of pressure areas, wounds and possible lesions is important), but also to the underlying activities of the skin. An understanding of the essential roles the skin plays in regulation of body temperature, blood pressure and vitamin D metabolism will help the nurse to provide holistic care and enhance monitoring of overall physical condition, particularly in seriously ill patients ■

#### TIME OUT 7

Now that you have completed the article, you might like to write a practice profile. Guidelines to help you are on page 55.



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