SKIN FUNCTION AND WOUND HEALING PHYSIOLOGY

Regular evaluation and the setting of goals is essential to monitor the progress of the patient and their wound.To do this, is important to understand the physiology of the skin and the way normal wound healing progresses in order to plan and provide effective wound management. This article describes the structure and function of the skin and outlines the four normal phases of healing.

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Wound healing is an exciting and continually developing field, with new technologies and research playing a large part in improving the quality of patient care. The role of the nurse in wound care is all encompassing, stretching from the initial assessment of the wound and the patient, to making the correct decisions about treatment and beyond. Regular evaluation, and the setting of goals is essential to monitor the progress of the patient and the wound. To do this, a baseline knowledge of the functions and anatomy of the skin and wound healing physiology is required.

Functions of the skin

The skin, often referred to as the largest body organ, has six main functions:

»Protection: the skin serves as the main protective barrier, preventing damage to internal tissues from physical trauma, ultraviolet (UV) light, temperature changes, toxins and bacteria (Butcher and White, 2005).
As well as preventing harmful substances from entering the body, it also controls the loss of vital substances (Graham-Brown and Burns, 1998).

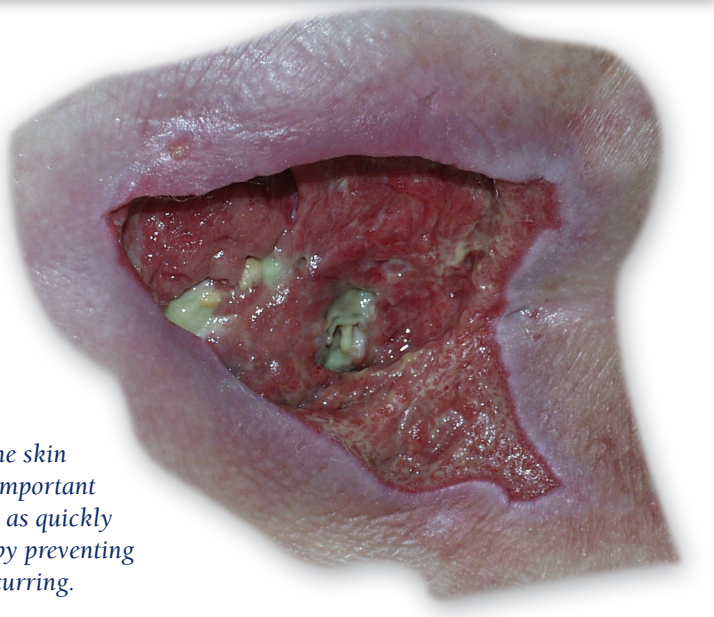

Figure 1. When the skin is breached, it is important to close the defect as quickly as possible, thereby preventing infection from occurring.

»Sensation: the nerve endings present in the skin allow the body to detect pain, and changes in temperature, touch and pressure.

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»Thermoregulation: the skin allows the body to respond to changes in temperature by constricting or dilating the blood vessels within it. The sweat glands produce sweat which stays on the skin allowing the body to cool down. When the body is cold, the hair erector pili contract, raising the hair and trapping warm air next to the skin.

»Excretory function: the skin excretes waste products in sweat which contains water, urea and albumin. Sebum is an oily substance which is excreted by the sebaceous glands, helping to lubricate and protect the skin.

»Metabolism: when UV light is present, the skin produces vitamin D which is required for calcium absorption.

»Non-verbal communication: the skin can convey changes in mood through colour changes such as blushing. The skin also gives clues as to our physical well-being (Flanagan and Fletcher, 2003).

The skin needs to remain intact to allow the body to perform these

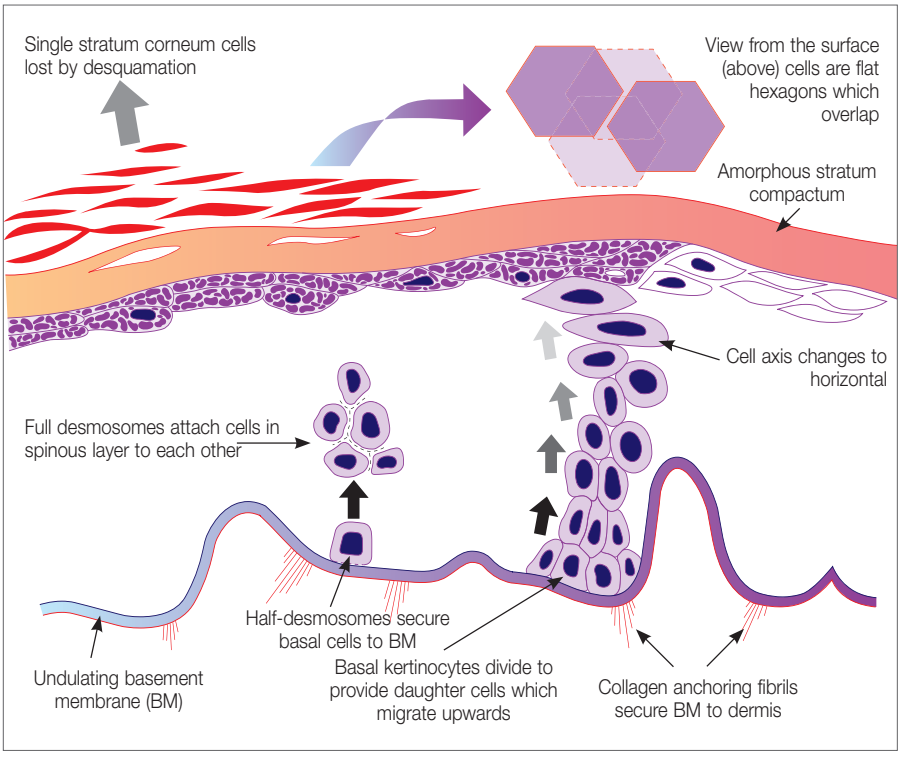

Figure 2. A diagrammatic view of a skin section, illustrating key features of epidermal biology.

vital functions. When the skin is breached, it is important to close the defect as quickly as possible, thereby preventing infection from occurring and allowing normal skin function to return.

Anatomy and physiology of the skin

The skin consists of two main layers: the outermost region is the epidermis and the underlying region, the dermis. Beneath the dermis is the hypodermis.

Epidermis

The epidermis (*Figure 2*) consists mostly of tissue called stratified epithelium. Stratified epithelium consists of one or more layers of cells. Epithelium always has one free surface, which means that no other cells adhere to it. The opposite surface of the epithelium is a basement membrane. This is a non-cellular layer, rich in proteins and polysaccharides, that lies between the epithelium and the underlying connective tissue. The cells arise in the epidermis, but are pushed towards its free surface as rapid and ongoing cell division produces new cells beneath them.

Most cells of the epidermis are called keratinocytes. Each is a tiny factory for manufacturing keratin, a tough, water-insoluble protein. These cells start to produce keratin when they reach the mid-epidermal regions. By the time they reach the skin's free surface, they are dead and flattened.

The epidermis is divided into five layers:

- The stratum corneum (horny layer)
- Stratum lucidum (clear layer)
- Stratum granulosum (granular layer)
- Stratum spinosum (prickle-cell layer)
- Stratum basale (basal layer).

Sometimes the stratum spinosum and stratum basale are collectively known as the stratum germinativum.

Stratum corneum

This is the tough, waterproof, uppermost layer of the epidermis. The stratum corneum consists of dead cells which are fibrous in nature and contain keratin. The dead cells assist in the protective role of the skin by resisting certain chemicals and changes in pH and temperature. Millions of the cells are worn off daily, but cell divisions push up replacements continually. This contributes to the skin's ability to repair itself following trauma. Keratin is also capable of absorbing water which may lead to skin maceration from prolonged exposure to an excessively moist environment, eg. wound exudate, urine.

Stratum lucidum

This is a transparent layer of cells that are not always present, especially in areas of the body where the skin is thinner. This layer is thought to provide extra protection as it is present in areas exposed to wear and tear, such as the palms of the hand and soles of the feet.

Stratum granulosum

The stratum granulosum is the layer in which the keratinocytes lose their nuclei and begin to flatten and die, and where keratinisation starts to take place.

Stratum spinosum

Above the basal layer is the

stratum spinosum. This layer of the epidermis contains living cells which contain spiny processes known as desmosomes. These assist in maintaining the integrity of the epidermis.

Stratum basale

This is the lowest layer of the epidermis, and is also known as the basement membrane. The stratum basale is one cell thick and forms a definite border between the dermis and the epidermis.

The basal cells which make up the stratum basale constantly divide, allowing the continuous regeneration of the skin. The daughter cells are slowly driven, by the active cell division, into the other layers of the epidermis where they undergo various development stages.

The stratum basale also controls the transfer of key proteins and oxygen between the dermis and epidermis, as the epidermis does not have a blood supply of its own. The stratum basale also supports the epidermis with fibrils which reach into the dermis. Also scattered within this layer are specialised cells called melanocytes which make melanin, the brown substance that accumulates when skin is suntanned. We all have similar numbers of melanocytes, but those of dark-skinned people are genetically programmed to make far more melanin than those with fair skin.

Dermis

The primary function of the dermis is to provide support and nutrients to the epidermis. The two layers identified within the dermis are the papillary layer and the reticular layer.

The papillary layer, or stratum papillare, is the upper layer of the dermis, which is clearly demarcated from the epidermis by an undulated border. This wave-like structure increases the contact area with the epidermis, and ensures that the blood vessels of the dermis provide the stratum basale of the epidermis with optimal nourishment. The papillary layer consists of loose connective tissue, capillaries, elastic fibres, reticular fibres and collagen.

The thicker, reticular layer, or stratum reticulare, contains denser connective tissue, larger blood vessels, elastic fibres, and bundles of collagen arranged in layers.

The main constituent of the dermis is the proteinous connective tissue made up of arc-shaped, elastic fibres and undulated, nearly inelastic, collagen fibres. These are responsible for the high elasticity and tensile strength of the dermis, and fend off damage from everyday stretching and other mechanical insults.

Glycosaminoglycans (also known as mucopolysaccharides) bind with the proteinous connective tissue to form proteoglycans. These form a gel-like mass that can absorb and expel water like a sponge.

Other constituents of the dermis are various types of cells such as fibroblasts, mast cells and other tissue cells, as well as a multitude of blood and lymph vessels, nerve endings, hot and cold receptors, and tactile sensory organs.

Hypodermis

The hypodermis (also known as the superficial fascia), is a tissue that anchors the skin while allowing some freedom of movement. It provides support for the dermis and is made up of largely adipose tissue, connective tissue, and blood vessels. Fat stored in the hypodermis helps to protect internal structures and also provides insulation against cold.

Wound healing physiology

Wound healing physiology can be complex. The wound healing process can be affected by a number of external and internal influences. Therefore, when treating a patient with a wound, it is essential that a thorough patient history is taken and underlying conditions that could influence healing are diagnosed. The main aim of the wound healing process is to restore the damaged area to normal strength and function (or as normal as possible). However, for some patients with wounds, particularly in palliative care settings, wound healing will not be the ultimate aim but, rather, improving their quality of life (Leaper and Harding, 1998).

Wounds are often divided into acute or chronic, and heal by primary or secondary intention.

Acute wounds are those which result from surgery or trauma, and usually have a relatively short, uneventful healing time. Burns, due to the area of tissue damage, will often behave more like chronic wounds.

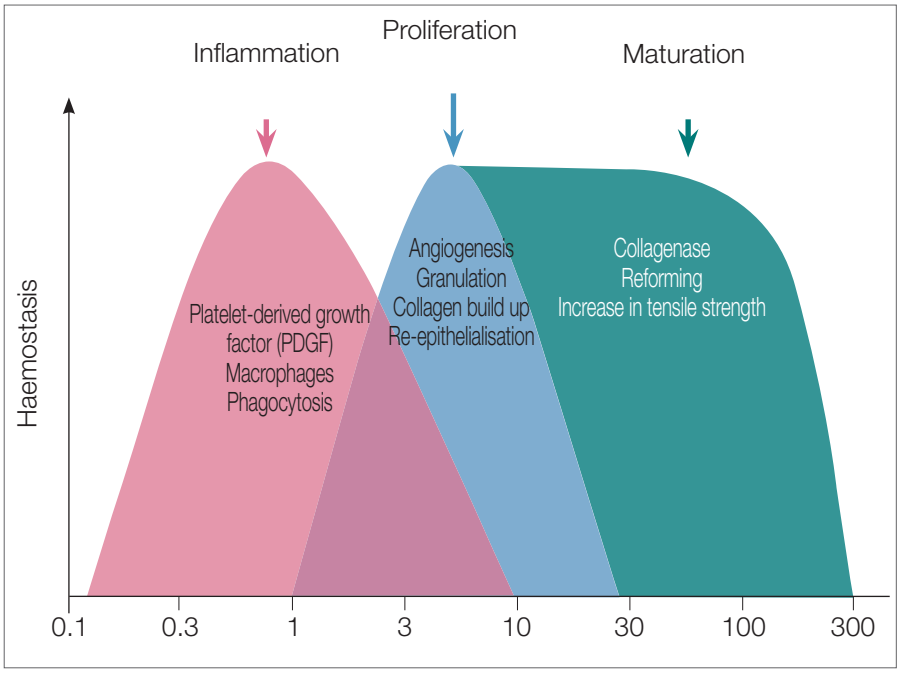

Figure 3. The wound healing process. This graph represents approximate timescales and illustrates the overlap that occurs during the healing process.

Table 1.

Stages of wound healing

Stage of healing	Time scale
Haemostasis	Within approximately ten minutes
Inflammation	Approximately three days
Proliferation	Approximately 28 days
Maturation	Up to a year or more

Chronic wounds are wounds such as leg ulcers, pressure ulcers, diabetic foot ulcers, and malignant wounds. Chronic wounds tend to have prolonged healing times, are prone to episodes of infection, and may have increased levels of exudate due to prolonged inflammation.

Primary intention healing refers to a wound where the wound edges have been brought together by sutures, clips, staples or glue. There is often minimal tissue loss and the healing process is relatively short.

In secondary intention healing, there is an open wound, occasionally a cavity, which heals from the base of the wound and, in the latter stages, by contraction of the wound edges.

When studying wound healing, it is important to remember that most descriptive models refer to the healing of acute wounds and the data is often extrapolated to include chronic wounds. Chronic wounds do not follow the normal sequence of events, hence their chronicity, so delays and interruptions to the healing process will be encountered. Healing is a dynamic process where the descriptive stages overlap and do not occur in isolation of each other.

The wound healing process can be divided into four main phases which do not occur in isolation: haemostasis, inflammation, proliferation and maturation (*Figure 3*). This means that it is difficult to place a definite time scale on the sequence of events (*Table 1*). It is also important to remember that in chronic wounds there will be large variations in the wound-healing process, depending on the patient and the presentation of the wound.

Haemostasis

Haemostasis, or the arrest of bleeding, describes the normal physiological response of the body following wounding. The volume of blood lost depends on the severity of the injury and the blood vessels involved. The cut surfaces of the blood vessels expose connective tissue which attracts platelets to the site of the injury. Platelets enter the area and, on coming into contact with collagen in the walls of the damaged blood vessels, stick together. This aggregation activates the platelets to release a number of agents (including platelet-derived growth factor [PDGF]) that trigger the clotting cascade (Silver, 1994). This results in initial vasoconstriction that reduces blood flow through the damaged vessels. As a result, the area surrounding the wound may appear pale.

Platelet aggregation and the release of bradykinin and histamine result in a build up of pressure within the capillary, causing the vessel to dilate. This can be viewed as erythema on the surface of the skin (Shields and O'Kane, 1994). The increase in blood flow helps to flush debris and bacteria from the wound, and the vessel dilation promotes the movement of fluid into the tissues. This response is observed at the wound site

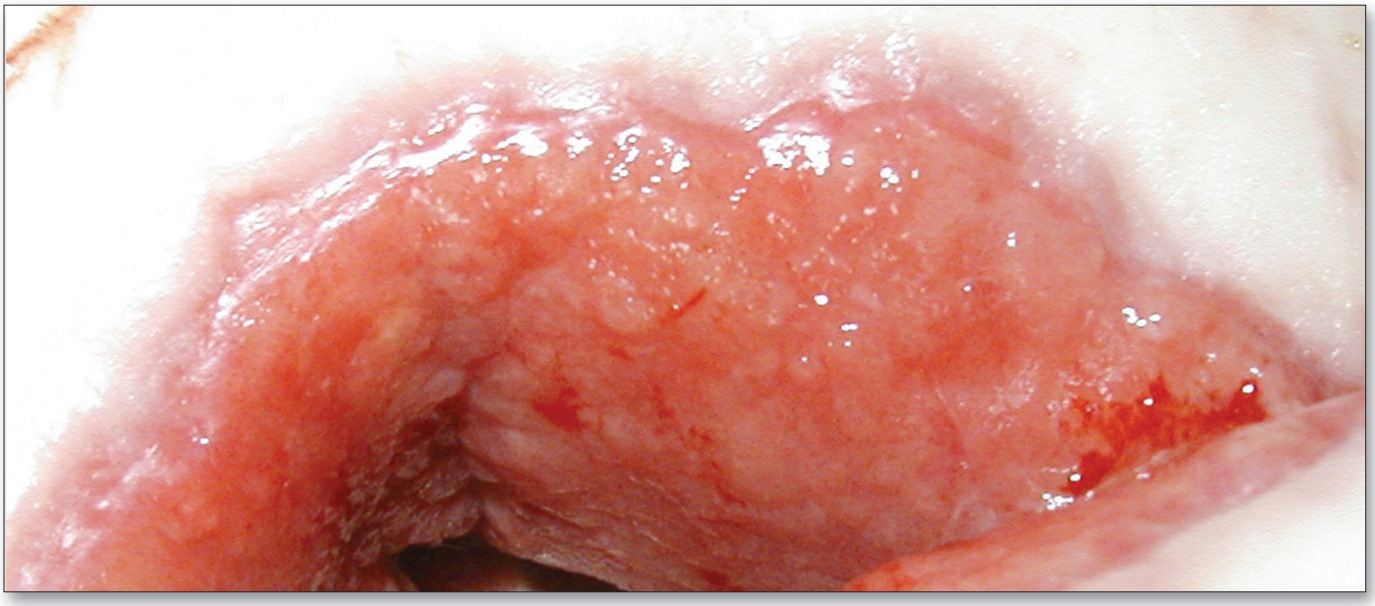

Figure 4. Granulation tissue. Note the slightly bumpy appearance and bright red coloration consistent with the laying down of new collagen and an increase in the vascularity of the tissue.

as redness, heat, and swelling. In most cases, approximately five to 10 minutes after injury, the vessels are sealed and haemostasis is achieved.

Inflammation

It is important to realise that inflammation is a 'normal' vascular and cellular response to any kind of injury, not only a wound. Healing will not progress if the inflammatory response does not occur. The inflammatory phase of wound healing lasts approximately three to five days in acute wounds, but in chronic wounds can be protracted. The inflammatory phase begins as soon as the injury is sustained.

The release of PDGF and proteases assists in attracting chemical agents and cells to the area. This phase of wound healing is recognised by visible erythema, oedema, and increased heat which is a result of the increased blood flow to the area and the vessel wall permeability (Hart, 2002).

Inflammation is characterised by:

- Redness (rubor)
- Swelling (tumor)
- Heat (calor)
- Pain (dolor).

The rise in extracellular fluid as it passes through the vessel walls (extravasation) gives rise to oedema (swelling). The increase in blood flow brings with it a rise in local temperature (heat), and the increase in pressure from the volume of extracellular fluid leads to pain.

The extra blood flow resulting from vasodilation leads to extra white cells (neutrophils) at the site, which cleanse the wound area of bacteria and devitalised tissue. Monocytes are also attracted to the area by PDGF. Monocytes transform into macrophages which continue with the cleansing activity and are essential if healing is to progress (Leibovich and Ross, 1975). Macrophages secrete the proteases collagenase and elastase. These enzymes break down damaged tissue that is not required. Inflammatory exudate in a healthy wound contains many vital ingredients to assist the healing process. Two agents that are important for wound bed preparation (Falanga, 2002) include the proteases and neutrophils identified above. Although the presence of exudate is vital for cell activity, it can also damage intact skin, so exudate needs to be managed to prevent further breakdown in the wounded area.

Proteins of the complement system (so called because it complements the action of antibodies in the blood) are activated and stimulate the release of histamine, and also assist in the attack and destruction of microbes (Silver, 1994).

The proliferative phase

Vascular endothelial growth factor (VEGF) released by the macrophages stimulates the formation of new blood vessels

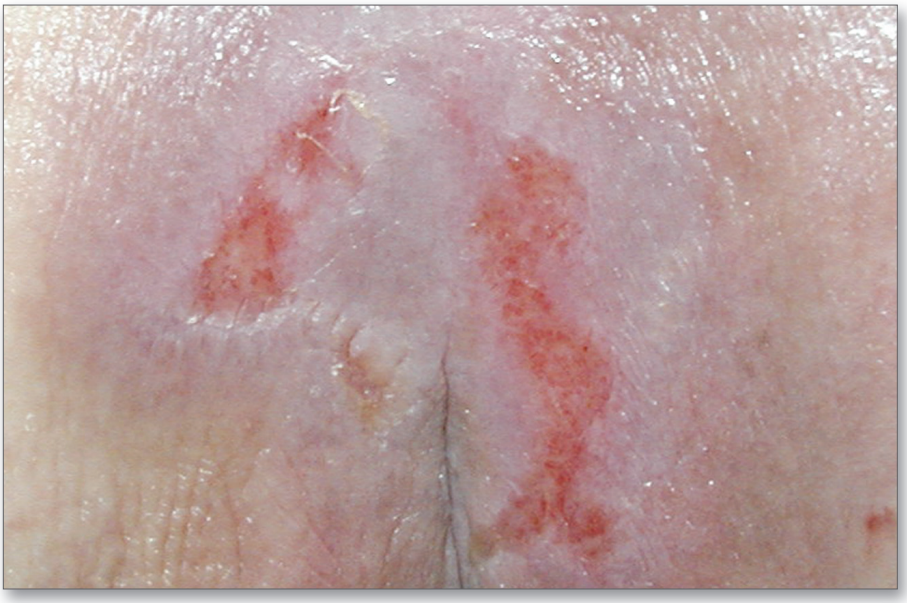

Figure 5: Epithelial tissue. During epithelialisation we can witness keratinocytes covering the wound from the edges and in islands from which they grow, due to their production in hair follicles, sweat glands and sebaceous glands.

(angiogenesis). The newly-formed blood vessels deliver oxygen and nutrients to the healing tissues.

Fibroblasts will start to divide and produce collagen which builds elasticity and strength in the wound. Together with glycosaminoglycans and proteoglycans, they form a ground substance or extracellular matrix (ECM). The ECM supports the new and developing blood vessels and fills the intracellular spaces with collagen fibres. The deposition of the extracellular matrix, together with angiogenesis, comprises the granulation tissue.

In acute wounds, granulation tissue forms within three to five days of injury. This stage overlaps with the inflammatory phase of healing, which can be noted in wounds containing both sloughy and granulating tissue.

Healthy granulation tissue is moist and appears bright red in colour (*Figure 4*). Unhealthy granulation tissue may be dark in colour and may bleed easily, indicating possible infection and poor vascular supply to the tissue.

Some fibroblasts change into specialist cells known as myofibroblasts, which begin to contract around the wound edges pulling them closer together. This process, known as contraction, is minimal in wounds which heal by primary intention but, due to the volume of tissue loss, is significant in wounds which heal by secondary intention. Once this has begun, re-epithelialisation will start to take place. New epithelial cells will begin to migrate from the edges of the wound and also from within hair follicles, sebaceous glands and sweat glands. The cells are white/pink in appearance and the layer is one cell thick once complete. The cells stop migrating once they have met other epithelial cells on the wound, by a process known as 'contact inhibition' (Garrett, 1998).

The new cells require the surface of the wound to be moist to allow this to occur. If the wound surface is allowed to dry out, the new cells must burrow underneath the dry tissue, which takes longer and there is a greater risk of infection.

Epithelialisation is influenced by the production of a number of growth factors (*Figure 5*). Macrophages produce keratinocyte growth factor (KGF) and this stimulates keratinocyte proliferation and migration through the extracellular matrix. The rate of epithelialisation is under the influence of epidermal growth factor (EGF) and transforming growth factor-ß (TGF-ß) (Tredget et al, 2005).

Maturation

The maturation phase of wound healing may take up to 18 months to complete (Silver, 1994). This phase is sometimes known as the remodelling phase of healing and, during this time, the wound is strengthened and the scar will change colour significantly.

Key Points

- A basic knowledge of the functions and anatomy of the skin and the wound healing process is important for wound care practitioners.
- The skin serves as a protective barrier which provides sensation, allows thermoregulation and excretes waste products in sweat.
- The skin consists of the epidermis and the dermis.
- Wound healing has four main phases: haemostasis, inflammation, proliferation and maturation.

Collagen bundles within the wound, which were once laid down in an irregular fashion, mature to form a stronger, more organised layer. In addition, the vascular network will decrease, which may leave the scar looking less red and, in many cases, the scar appears 'silver' or white in colour. The scar itself is relatively avascular and will not support hair follicles, sweat glands or sebaceous glands.

Conclusion

For many, the process of healing is straightforward, however, for a number of patients with chronic wounds, healing can be prolonged by factors which may relate to the type of wound, or, to the patient's general well-being. By understanding the physiology of normal wound healing and its relevant stages, we are better placed to intervene and provide management and treatment solutions when problems occur. **WE**

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