Anatomy Lecture Outline Section 1: The Integumentary System

Introduction to the Integumentary System

The integumentary system is considered an organ because it is made up of different tissues. Actually, it contains *all four of the primary tissues*; epithelium, connective, muscle and nervous. The integument is comprised of: 1) the cutaneous membrane (**skin**); and 2) associated structures (**hair**, **glands** and **nails**). The most superficial portion of the integumentary system is comprised of stratified squamous (keratinized) epithelial tissue which makes the **epidermis** (epi - above or upon). Deep to this is a combination pf areolar and dense irregular connective tissue that makes up most of the **dermis**. The associated structures include **exocrine glands** (sebaceous and sweat), **hair** and **hair follicles**, and finger and toe **nails**.

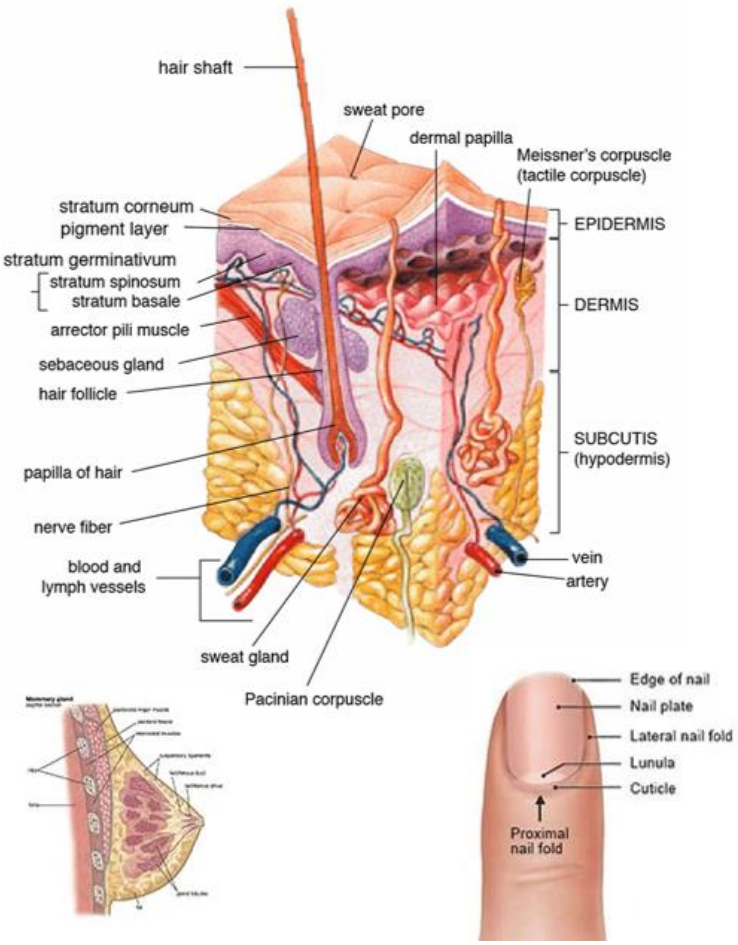
Gross Anatomy of the skin, hair, glands and nails

The Integumentary system includes the skin and the associated accessory structures hair, glands and nails. Note that the skin is a type of membrane, which can be referred to as the *cutaneous membrane*. Ask yourself, what is a membrane? It is like a formula:

Membranes in Anatomy = $\frac{\text{Epithelial Tissue}}{\text{Connective Tissue}}$

When examining models, drawings or slides of the skin, keep in mind that it will always be superficial epithelium and deep connective tissue. Review the characteristics of epithelial and connective tissue and see these qualities apply when examining the skin and its function. Examine the accessory structures of the skin (hair, glands and nails) remembering that they are all derived from epithelial tissue but originate in the dermis portion of the skin.

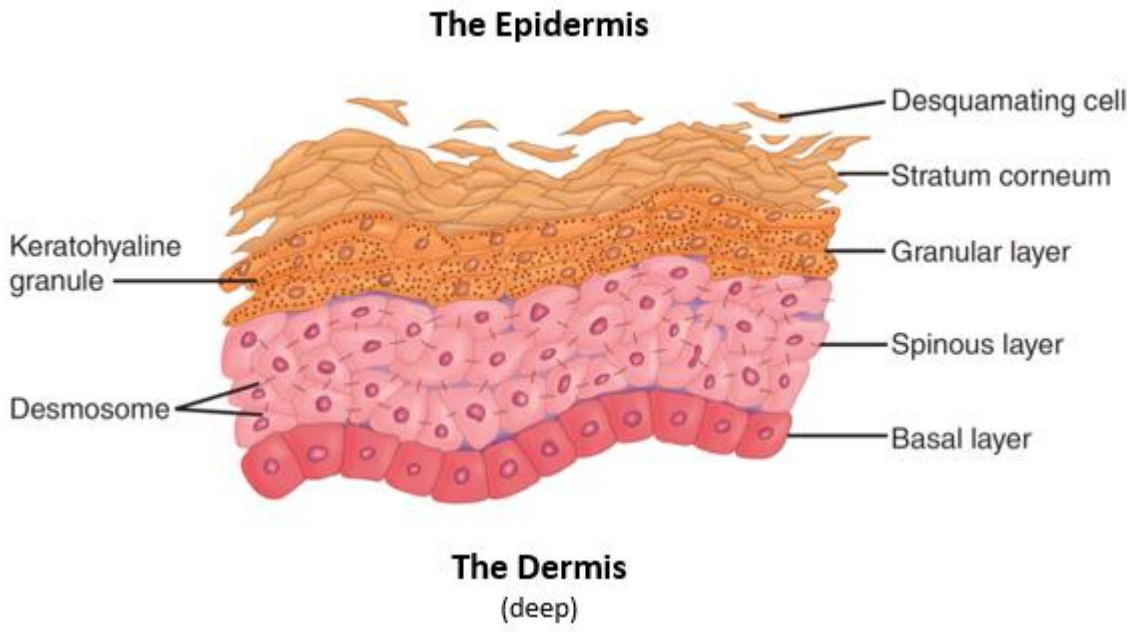
As usual, epi- means above, upon or on top. Sometimes a source of confusion is the naming of the apocrine sweat gland; the 'apo' part means apical or top portion, such that it infers the secretion is made by cleaving off the top of the cell. However, it is believed that this type of gland actually secretes by means of merocrine mode. It is interesting to note that the integumentary system contains all four tissue types.



General Functions of Integumentary System

- **A.** Gives Physical Protection
- **B.** Prevents Pathogen Invasion
- **C.** Restricts Desiccation (Dehydration)
- **D.** Provides Sensory Perception
- **E.** Vitamin D Production

A. The Epidermis – The most superficial layer of the skin is made of epithelial tissue. It is classified as stratified squamous keratinized (dry) epithelium. The epidermis has either 4 (thin skin) or 5 (thick skin) distinct layers or 'strata' that can be identified. Below is a description of each of the possible layers, from the deepest layer to the most superficial.



1. Stratum Basale (Germinativa) – composed essentially of a single row of cells that make the deepest layer of the epidermis. Roughly the cells in this layer are about 80-90% keratinocytes and 10-20% melanocytes. The keratinocytes have mitotic potential which means they can divide and rapidly reproduce in order to continue replacing themselves. These are the 'stem cell' of the bulk of the epidermis – the name germinativa means 'to germinate', like a seed beginning to grow. These cells are sitting directly on the basement membrane, which is attached to connective tissue directly deep to it. The melanocytes located in this layer are the cells that produce the dark pigmented molecule melanin. When melanin granules are released into the tissue in response to UVA light stimulation, the skin becomes darker. The melanin provides protection to the nucleus (where the DNA resides) of keratinocytes against UVA irradiation, to prevent UVA related cellular damage.

2. Stratum Spinosum – can be several cell layers thick. Mostly spindly keratinocytes with some scattered Langerhans cells that provide immunological protection. The term spinosum means 'spiny'; the spiny appearance of the cells in this area is somewhat due to the histological preparation. Some cells are beginning to die here, due to distance away from nutrients and oxygen in the blood supply of the dermis.

3. Stratum Granulosum - from 3 to 5 layers of flattened keratinocytes containing darkly staining keratohyaline and lamellated granules, these are very effective waterproofing hydrophobic substances that provide the protection against dehydration of the body at the surface of the skin.

4. Stratum Lucidum - a thin translucent band of a few cells, this layer is only found in thick skin, that is, the skin found on the **palms** of the hands and **soles** of the feet. Lots of keratin here in this layer. Cells in this layer are dead, as they are too far away from the capillaries in the underlying connective tissue.

5. Stratum Corneum - the most superficial (external) layer of the epidermis, it is many cell layers thick and is cornified (horn-like) because it is a thoroughly keratinized layer, filled with dead cells that provide a substantially protective and waterproof barrier. This stratum is thickest in thick skin (palms and soles) and the cellular attachments of epithelium can keep 20 to 30 cell layers remaining in the stratum corneum.

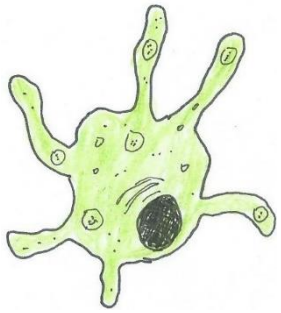
B. Cells of the Epidermis

The strata of the epidermis contain four (4) different types of cells.

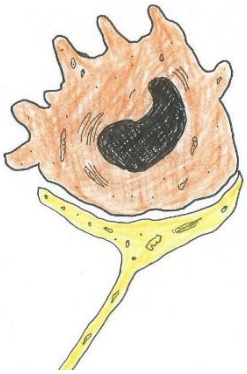
1) Keratinocytes represent about 80 to 90% of all cells found in the epidermis. They start as the stem cell in the stratum basale of the epidermis and can be referred to as "basal cells". These cells make **keratin**, a tough lipoprotein that acts as a sealing and waterproof agent for skin. The main function of keratinocytes is creating a protective barrier against environmental elements, such as pathogens (bacteria, fungi and viruses), heat, UVA radiation and water loss. If pathogens begin to invade the superficial epidermis, keratinocytes react by producing pro-inflammatory mediators, particularly chemokines which attract leukocytes to the site of invasion. Go leukocytes.

Structural proteins like keratin, and antimicrobial agents contribute to the important barrier function of this cell in the skin. Keratinized epithelial tissue means it is waterproofed (dry) and this cornification provides a significant physical barrier, especially in thick skin (palms and soles). The fully cornified keratinocytes that form the outermost layer are constantly shed and replaced by new cells.

2) Melanocytes make up about 10% of the cells in the epidermis. These cells make **melanin**, a dark brown pigment which is primarily responsible for skin color. *There are actually two main types of melanin. Melanocytes (from Greek melas meaning 'dark or black') are located mostly in the stratum basale of the epidermis. After synthesizing melanin, it is packed into a little container called a melanosome (an organelle) and transported along its arm-like structures (dendrites) so that they can reach and release its melanin to the keratinocytes, which take up the melanin for protection against ultraviolet A (UVA) radiation.



3) Merkel cells (Merkel-Ranvier) are tactile discs that act as receptors for light touch found in the epidermis. They are usually associated with a sensory nerve ending for tactile information, but also may play a role resolving fine spatial detail of touch.



4) Langerhans cells are the defense cells of the epidermis. They are a type of immune cell that can phagocytose an invader. They are most prominent in the stratum spinosum, but can be found in all layers of the epidermis and can also wiggle into the papillary layer of the dermis. Langerhans are dendritic cells that can take up and process microbial antigens to become antigen-presenting cells – quite an accomplishment in the world of defense cells.

C. The Dermis

The dermis of the skin is the connective tissue portion of the cutaneous membrane. The dermis is divided into two regions or layers, the superficial papillary layer and the deep reticular layer. A different type of connective tissue is predominate in each of these layers.

The Papillary Layer: This region is immediately deep to the stratified squamous keratinized epithelium of the epidermis and is composed of **areolar connective tissue**. The underside of the **epidermal ridges** of the epidermis (also known as fingerprints) interlocks with the **dermal papillae** of the papillary region, assisting in the holding together of these two tissues. It is about 1/5 of the total thickness of the dermis. The other basic elements of the papillary layer are:

a. A network of blood vessels and capillaries here called the **papillary plexus**. The rich blood supply in this areolar connective tissue enables the epidermis above it to be well supplied with nutrients and oxygen, at least the basal end of that epithelial tissue.
b. Free nerve endings are located here. These detect basic sensations of hot and cold and general pain.
c. Meissner's (tactile) corpuscles are sensory nerve receptors for the detection of light touch. They are nestled in the dermal papillae in the papillary layer of dermis. The close proximity to the epidermis allows for detection of distention of the surface of the skin.

The Reticular Layer: This region is made of tough dense irregular connective tissue. Contains more of the same as in papillary layer. It accounts for approximately 4/5 of the total thickness of the dermis and deep to this tissue is the hypodermis. The abundance of collagen fibers 'irregularly' arranged allow for distention of this tissue in multiple directions. It turns out that the fibers are methodically arranged - as evident by lines of tension/cleavage that are seen in the dermatomes of the body, yielding directionality and creases in the skin.

The other basic elements of the reticular layer are:

a. A larger network of blood vessels located here called the **cutaneous plexus**. This blood supply often sits deep in the reticular layer and even in the hypodermis region too. This vascular bed is to supply all of the associated structures found in the reticular layer of the dermis.
b. Bundles of collagen fibers (crisscrossing)
c. More free nerve endings are located here, including those responsible for deeper pain sensation.
d. Pacinian (lamellated) corpuscles are located deep in the reticular layer of dermis and are mechanoreceptors for the detection of deep pressure. This is in contrast to the Meissner's corpuscles which are for light touch.
e. Numerous cell types may be found in this region, including: Fibroblasts; Adipocytes; Macrophages Mast cells (histiocytes), and Leukocytes.

D. Hypodermis

The hypodermis can also be referred to as the subcutaneous layer and also superficial fascia. These are three different names for the same region. This layer is deep to the reticular layer of the dermis and consists mostly of adipose tissue with a very good blood supply. One of its main functions is to stabilize the skin and for protection and insulation.

E. Accessory Structures of the Integumentary System are Epidermal Appendages

All of the *accessory structure*s in the integument, that is, hair, glands and nails, are actually all derived from the epidermis, that is, they are made of ***epithelial tissue***. It may appear as if these structures are derived from the connective tissue of the dermis because of their location, but they are made of epithelia tissue derived from the epidermis.

1. Hair – This fluffy stuff on the surface of your skin grows from a hair matrix in the hair papilla that has a good blood supply enclosed in the region of the hair bulb and sheath. Hair has an inner layer, an outer layer a protective cuticle. The hair is housed in a hair follicle, which is like another protective shell for the hair. There are several additional structures that are associated with the hair and the hair follicle. Here are the main structures associated with hair:

a. Arrector pili is smooth muscle associated with a hair follicle. It is attached to the hair follicle and when it contracts, it stands the hair erect, when you are cold, afraid or angry, often resulting in 'goose bumps'.
b. Nerve plexus around base of hair, detects movement of the hair, also painful when hair is pulled out.
c. Sebaceous glands - make the oily substance sebum, to keep hair supple and conditioned.

<u>The actual **hair** has 3 layers</u>: The medulla, cortex and cuticle.

The **medulla** (from 'marrow' in Latin) is the innermost layer of the hair and is composed of large cells. Represented as green in the drawing to the right. These cells form a shaft through the middle of the hair. Different amounts of medulla may be present in a hair. The **cortex** (from Latin 'bark of a tree' or outer husk) is the layer between the cuticle and medulla and contains keratin and pigment (melanin or trichosiderin). Represented as blue the drawing to the right. It represents the bulk and strength of hair. This intervening layer of the hair is made of spindle shaped cells and the pigment granules that give color to the hair. Ovoid bodies of large pigment granules may be found here, and cortical fusi (small bubble-like structures) are also in the cortex. The **cuticle** (Latin diminutive for skin), is the outermost layer of the hair. Represented as red in the drawing to the right. It is transparent and protects the inner layers. A healthy cuticle gives a shiny appearance for hair and unhealthy cuticle gives lifeless look. It is basically made of keratin. The cuticle is really a series of overlapping scales and is very resistant to chemical decomposition.

Hair thickness is anywhere between 1/1500 to 1/450 inches (17 to 181 microns) thick. Hair color is the biggest factor in thickness. Flaxen hair is the finest (1/1500 to 1/500 inches, 17 to 51 microns) and black hair the coarsest (1/450 to 1/140 inches, 56 to 181 microns)

Note: There are several significant problems with using hair characteristics in criminal cases – most notably that hair is not uniform! Hair from the **same person** may not be exactly the same! This is why a minimum of 12 hair samples are taken at different places on a person's head. Even This Is Not Enough! This is because different parts on the same hair can look very different!

Hair Follicles – act as a protective covering for the living growing hair bulb and root. It is basically composed of an inner medulla and outer cortex and an external & internal root sheath.

2. Sudoriferous Glands – these are sweat glands, numerous on face, scalp, chest, and feet. There are two types of sweat glands: Merocrine and Apocrine.

a. *Merocrine* (or eccrine) – these produce watery sweat, primarily functions in thermoregulation, specifically for cooling the body down. They also contain lysozyme, an antimicrobial agent. The highest density of these glands is found on palms, soles and forehead. On the palms and soles the sweart works in concert with thick epidermal ridges, better known as finger prints and foot prints, where they increase the friction for better grip. These glands are by far the most numerous type of sweat gland in the body.

b. *Apocrine* – these glands are located in specific regions of the body, such as axillary areas, in the genital and anal regions and breasts. They produce more vicious type of sweat that is lipid rich and also contains chemical signal molecules called **pheromones**. These are odorless chemical signals that travel from one individual to another and can have an effect on behavior. A good example are 'musk-like' pheromones that are related to sexual attraction between individuals. Oxytocin is thought to be another pheromone released into the external environment by one individual and can have an effect on another individual especially common in bonding situations. For example, in the mother-child bonding of early infancy, close friendships, team sports and combat. In this capacity, apocrine sweat glands can be considered 'scent' glands for humans, though people are not consciously aware of the fragrance of the pheromones.

The structure of sudoriferous glands, whether merocrine or apocrine, is simple coiled tubular. The mode of secretion is merocrine for all sudoriferous glands too. This mode involves packing the material to be secreted into vesicles in the cytoplasm of the cells. These vesicles then fuse with the plasma membrane of the cell and release the contents of the vesicles to the outside by way of exocytosis (exo meaning out and cytosis meaning of the cell).

3. Sebaceous Glands. These glands make an oily, waxy material called sebum (meaning fat or tallow in Latin). They are exocrine glands located in the dermis of the skin to lubricate and waterproof the surface of the skin and hair. They occur in the greatest number on the face and scalp and are associated with hair follicles. They are essentially found on all parts of the skin, **except** the **palms** of the hands and **soles** of the feet. In addition, sebaceous glands are also found in hairless areas (or glabrous regions, meaning smooth), such as the skin of the eyelids, nose, penis, labia minora and nipples. Sebaceous glands within the eyelids are known as meibomian or tarsal glands; these are associated with eyelashes and contribute to maintaining the lubrication of the eyes with the oily secretion added to the lacrimal solution.
The structure of a sebaceous gland is compound acinar, with ducts leading directly to the hairs, also depositing sebum to the surface of the skin. The mode of secretion is holocrine, this process involves the cells of the secretory portion of the glans filling with so many vesicles that it causes the cells to rupture or burst, and as they disintegrate they release the sebum and the remnants cellular debris with the secreted sebum.

There is a difference between **sebaceous glands**, which have ducts that are connected to hair follicles, and **sebaceous follicles**, which are typically larger glands that are independent of hair follicles. One or more sebaceous gland may surround each hair follicle.

4. Ceruminous Glands. These glands are found in the external auditory (ear) canal and they produce earwax or **cerumen**. They are actually a type of modified sudoriferous (sweat) gland. Often located deep in the subcutaneous tissue of the external auditory canal, the structure of ceruminous glands are simple coiled tubular. Earwax or cerumen is made by the mixing sticky lipid rich secretion with sebum and dead epidermal cells to produce cerumen. The main role of cerumen is to keep the eardrum (tympanic membrane) pliable and to maintain the lubrication and waterproofing of the external auditory canal. It

also contains antimicrobial agents that kill bacteria, preventing colonization by microbes, otherwise they might set up a campsite in your cozy ear canal. Cerumen also serves as a sticky barrier trapping foreign particles like dust, fungal spores, etc., by coating the guard hairs of the ear.

5. Fingernails and Toenails. Finger nails in the body are made of heavily keratinized material that grows from the **nail root** and creates a visible **nail bed**. Finger and toenails are basically made up of dead epidermal skin cells, and can be thought of as a specialized modification of the *stratum corneum* of the epidermis. They are predominantly made of keratinocytes, which also make keratin, the lipoprotein found in nails that makes them tough.

The **nail matrix** is where the nails grows and is deep to the surface and so it receives oxygen and nutrients to remain healthy. The matrix becomes the nail plate and **nail bed** and as cells are continuously made they push older cells forward, compressing and flattening them until they become translucent (allow light to pass through). This is why you can see vascular tissue deep to the nail as a pink-ish color below the surface of the nail. EMTs or paramedics may use the *blanch test* on a fingernail bed to test peripheral perfusion. The nail is briefly squeezed to turn the nail bed white, then the pressure released and the normal pink should be restored within a few seconds. A delay in the return of a pink color may indicate shock or dehydration.

The little moons of finger and toe nails are called the **lunula** (meaning small moon) and represents the crescent-shaped visible part of nail matrix at the base of the visible nail. The **eponychium** and the cuticle are actually separate structures, and both help to create a protective seal at the proximal end of the nail. The eponychium is the fold of skin cells that makes the cuticle – which is an almost invisible layer of non-living skin cells that cover the proximal nail.

The **hyponychium** is also known as the "quick" of the nail. When you cut or bend your finger nail back too close to the quick, it can be painful! The hyponychium is located on the underside of the free edge and is essentially the junction of where the epidermis beneath the nail plate meets the skin of the fingertip. Here a seal forms to protect the nail bed and keep the nail body attached to the nail bed.

The **free edge** or free margin (margo liber) or distal edge is the anterior margin of the nail plate corresponding to the abrasive or cutting edge of the nail. The lateral margin (margo lateralis) lies beneath the nail wall on the sides of the nail and the **lateral nail fold** or groove (sulcus matricis unguis) are the cutaneous slits into which the lateral margins are embedded.

The rate of nail growth is related to the length of the distal phalanx (bone of the digits). For example, the nail of the index finger grows faster than the little finger; and fingernails grow up to four times faster than toenails. On average, nails grow at a rate of 3 mm (0.12 in) a month.

Nail are not an impermeable barrier, but are actually more permeable than skin. Nails are often composed of up to 10% water. What this means is that harmful and medicinal substances applied to the nails can penetrate into the body. Water and other substances including pesticides and other toxins can enter via nails, so it is worth being aware of what your nails are exposed to.

Skin Color

The color of the skin is related to three different pigmented molecules: **1) Melanin**; **2) Hemoglobin**; and **3) Carotene**. As we have already seen, melanocytes are one of four basic cell types found in the epidermis. **Melanocytes** make **melanin**, a dark brown molecule that is deposited in the epidermis of the skin. The melanocytes in the epidermis respond to ultraviolet radiation **A** (UVA) from the sun by making more melanin, which acts to protect the nucleus of living cells against damage from UVA rays.

Please Note: The sun's rays also contain ultraviolet radiation **B** (UVB), and it is UVB that is responsible for making **vitamin D** in the epidermis from a precursor molecule derived from cholesterol. Without exposure of the skin to UVB rays your body cannot make its own vitamin D. If you do not know how vitally important vitamin D is to your health, I strongly suggest you find out. It is also worth noting that it is the UV**A** that can create what is called "photo-damage" to your skin. You can think of the A for Aging and the B for Beneficial. According to what you may have learned, what time of the day should you be sure to avoid sun exposure, to be safe from danger? From 10am to 2pm, right? It turns out the only time to maximize UVB exposure is between the hours of, yes, 10am and 2pm. Hmph! So that advice seems contrary to good health. Furthermore, the use of toxic carcinogenic chemicals in sun block, such as the ingredient oxybenzone, act to block UVB, not A! In addition to blocking the good ray, it also introduces a steady stream of estrogen mimickers into the body.

Hemoglobin (Hb) is a pigmented molecule found in erythrocytes (red blood cells) of the blood. When oxygen gas (O_2) is bound to Hb, its color is bright red. When Hb has low O_2 levels a purple color will result and it virtually no O_2 is bound to Hb, then a blue color of the blood prevails. Therefore, the level of oxygenation of the blood will contribute the overall color of an individual's skin. An easy example to think of it is if you are asked to dig in the garden on a hot day, your completion will become more red, indication 2 things: an increased supply of blood to the skin (to cool down) and a more richly oxygenated blood supply, because you are outside using your body!

Finally, **carotene** is an orange-yellow pigments found in certain foods (like carrots, pumpkin and sweet potato) and the consumption of food containing carotene will contribute to an orangey-yellow of the skin. It tends to collect more in the stratum corneum.