ВОЛГОГРАДСКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ

Skin grafting

Manual in clinical anatomy by O.D. Chulkov, A.S. Mazunov, E.E. Pisareva, E.A. Barinova

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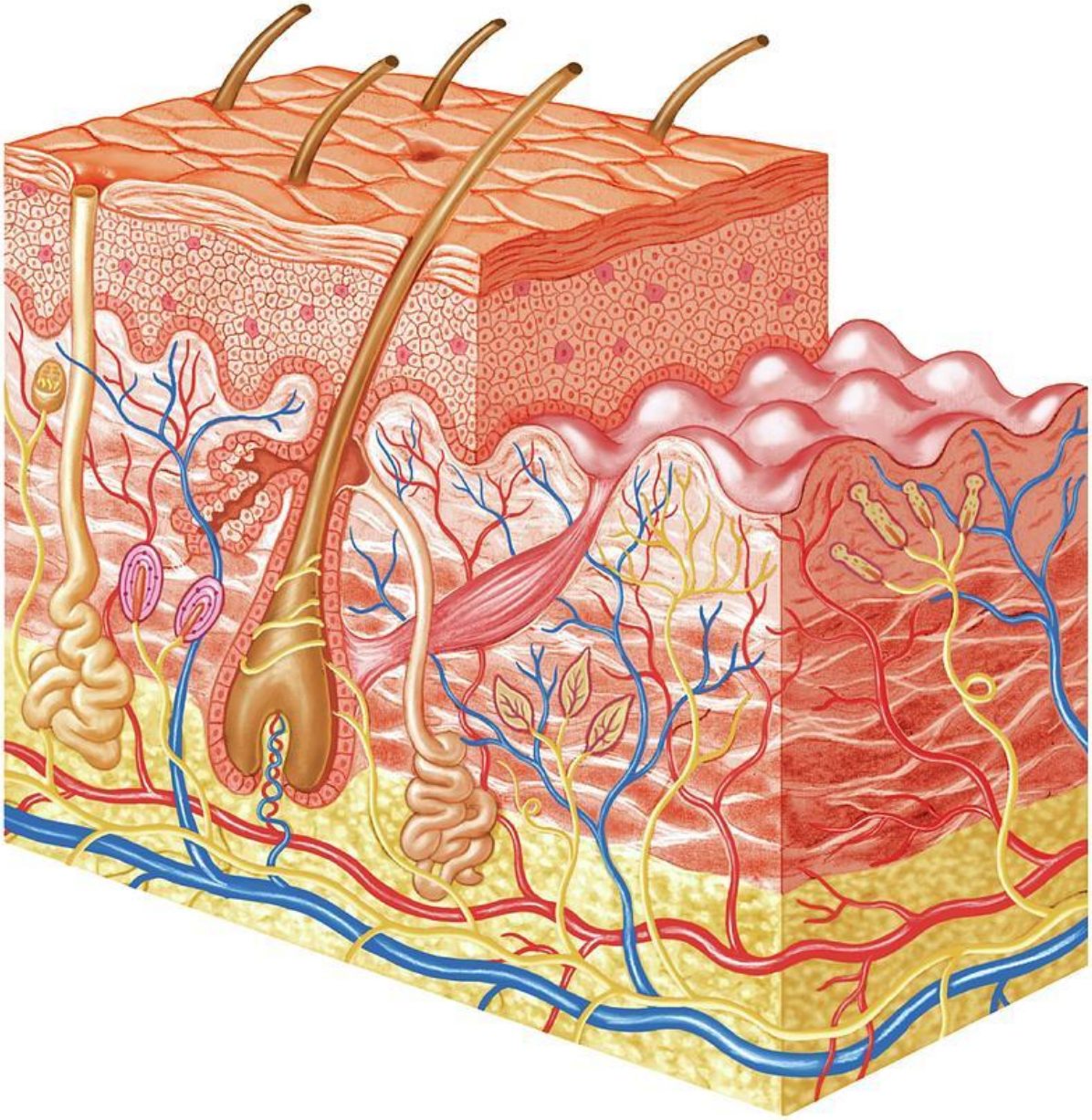
Skin anatomy and histology

The skin is the largest organ of the human body. It is also known as the integument or integumentary system because it covers the entire outside of the body. The organ constitutes almost 8-20% of body mass and has a surface area of approximately 1.6 to 1.8 m^2, in an adult.



Skin anatomy and histology

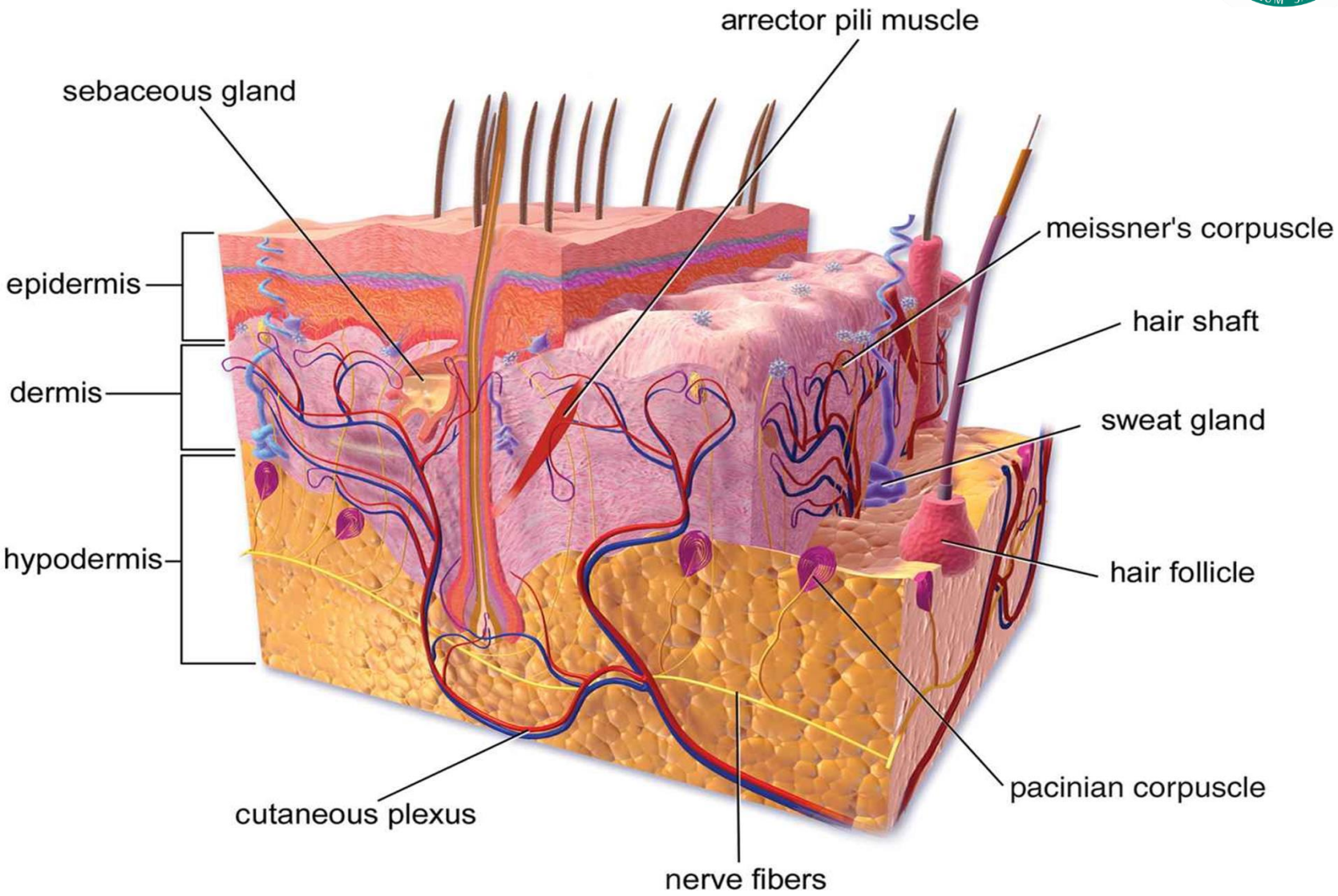
Skin anatomy and histology

The skin consists of two main layers: the outer layer, or epidermis, which lies on and is nourished by the thicker dermis. These two layers are approximately 0.04–0.08 in (1–2 mm) thick. But it is considered by some authors to be comprised of three major layers: epidermis, dermis and hypodermis, which contain certain sublayers.

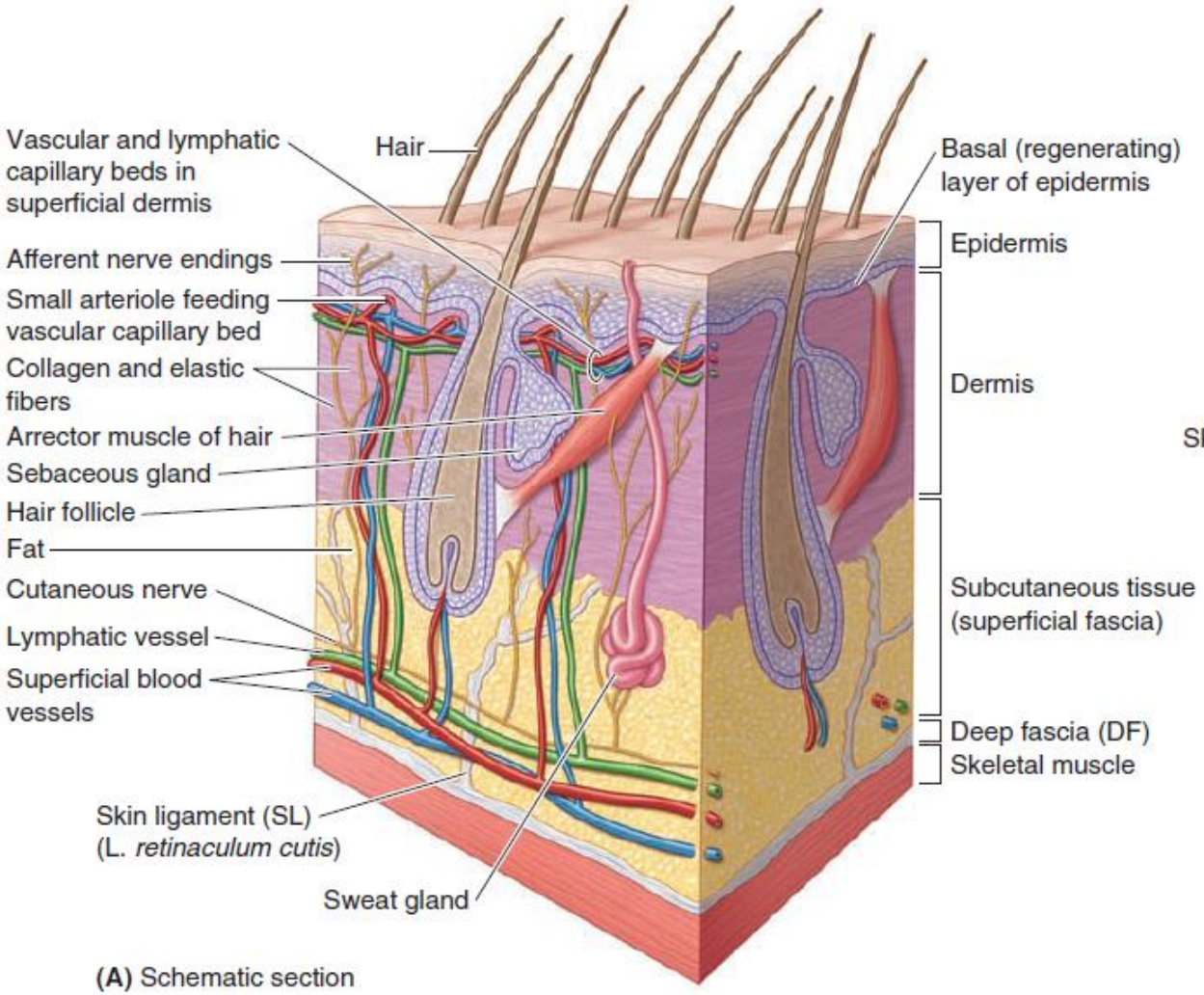
Skin anatomy and histology

The organ has a variety of embryological origins, which accounts for the different types of structures that are found within it. The developing embryo contains several layers; significant to this topic are the ectoderm and mesenchyme layers that give rise to the epidermis and dermis, respectively. Note that the structures originated from different embryo layers cannot be restored (regenerated) from each other!

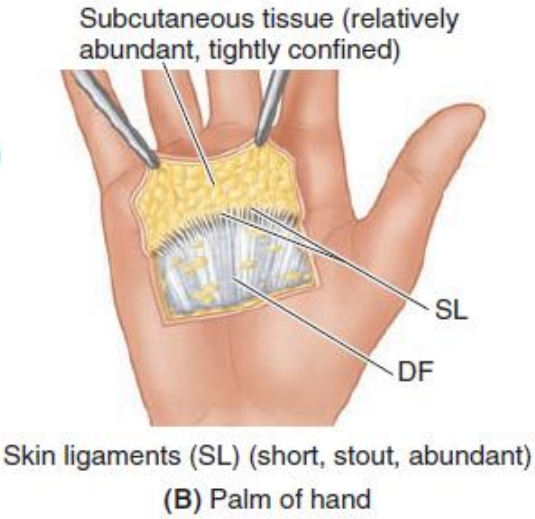
Skin anatomy and histology



Skin anatomy and histology

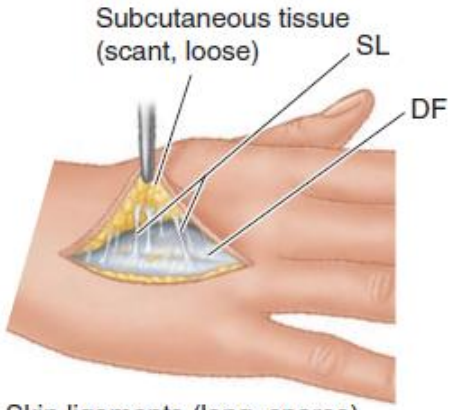


(A) Schematic section



Skin ligaments (SL) (short, stout, abundant)

(B) Palm of hand



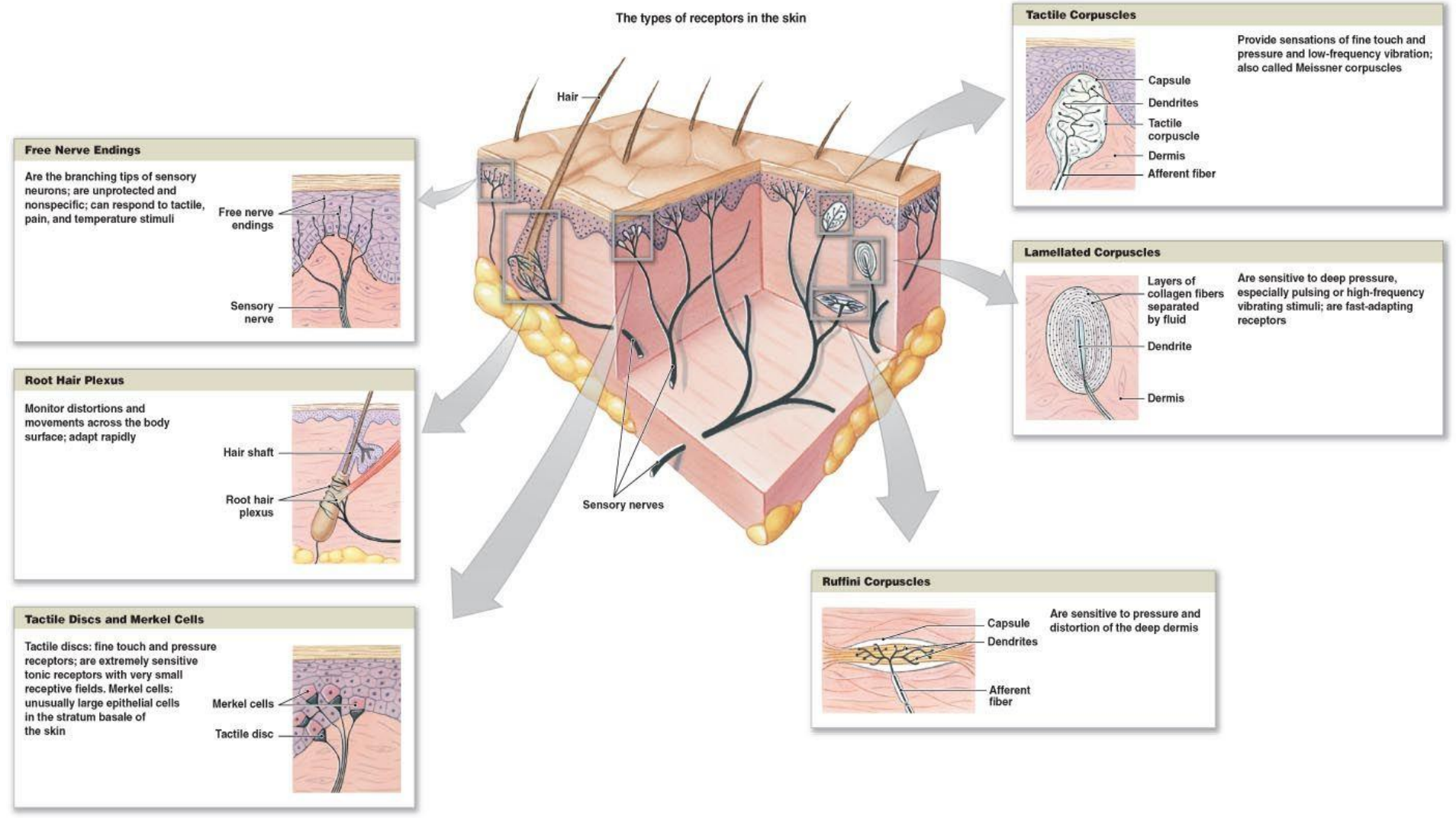
Skin ligaments (long, sparse)

(C) Dorsum of hand

The skin provides

- Protection for the body from environmental effects, such as abrasions and harmful substances, including patogens
- Containment of the tissues, organs, and vital substances of the body, preventing dehydration
- Heat regulation through sweat glands, blood vessels, and fat deposits
- Sensation (e.g., pain) by way of superficial nerves and their sensory endings
- Protection from harmful ultraviolet light
- Synthesis and storage of vitamin D

Skin anatomy and histology

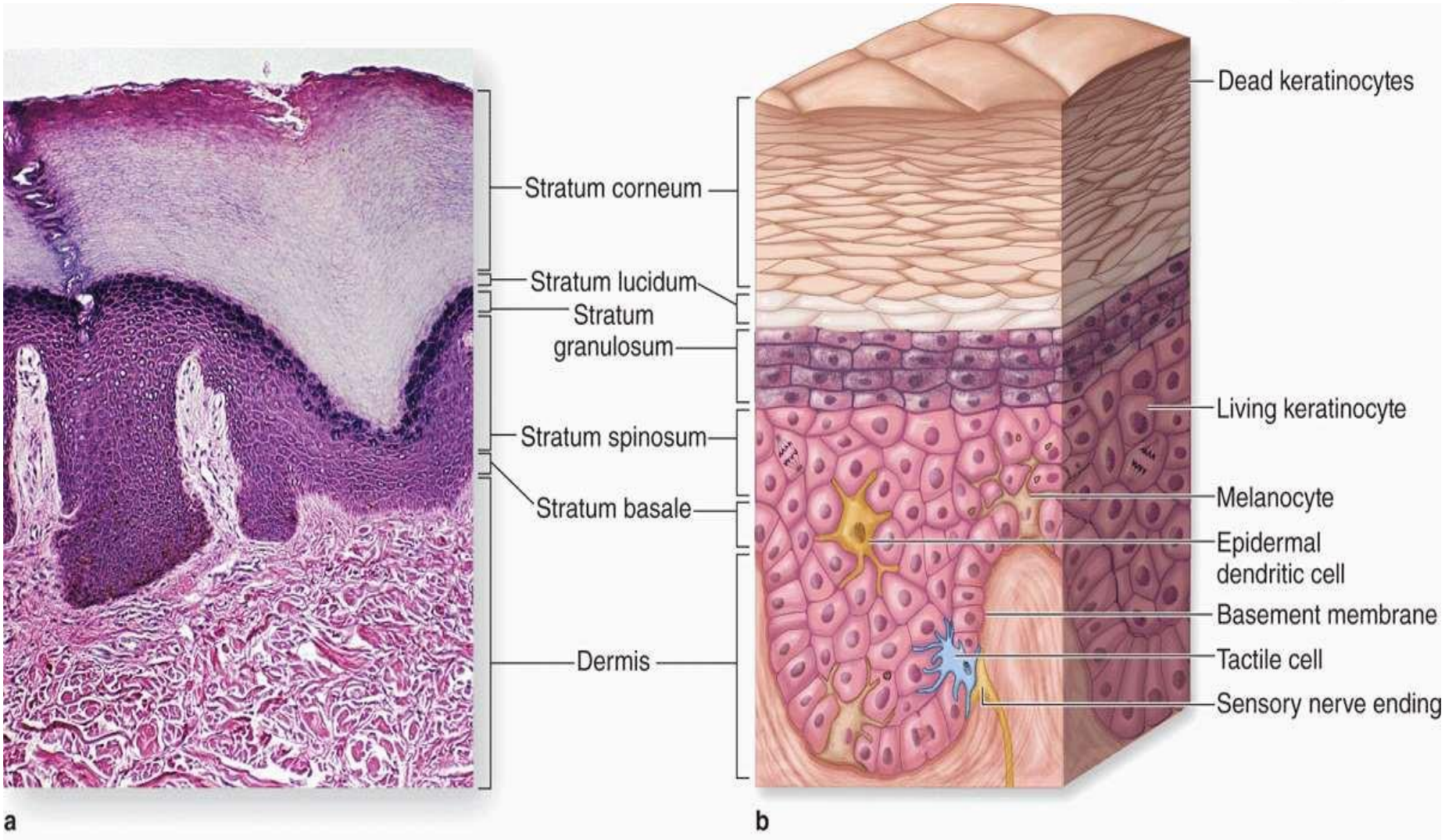


Skin anatomy and histology

The epidermis is the uppermost layer of the skin. Going from deep to superficial, it consists of five layers;

- basal layer (stratum basale/germinativum)
- prickle cell layer (stratum spinosum)
- granular layer (stratum granulosum)
- clear layer (stratum lucidum)
- cornified layer (stratum corneum)

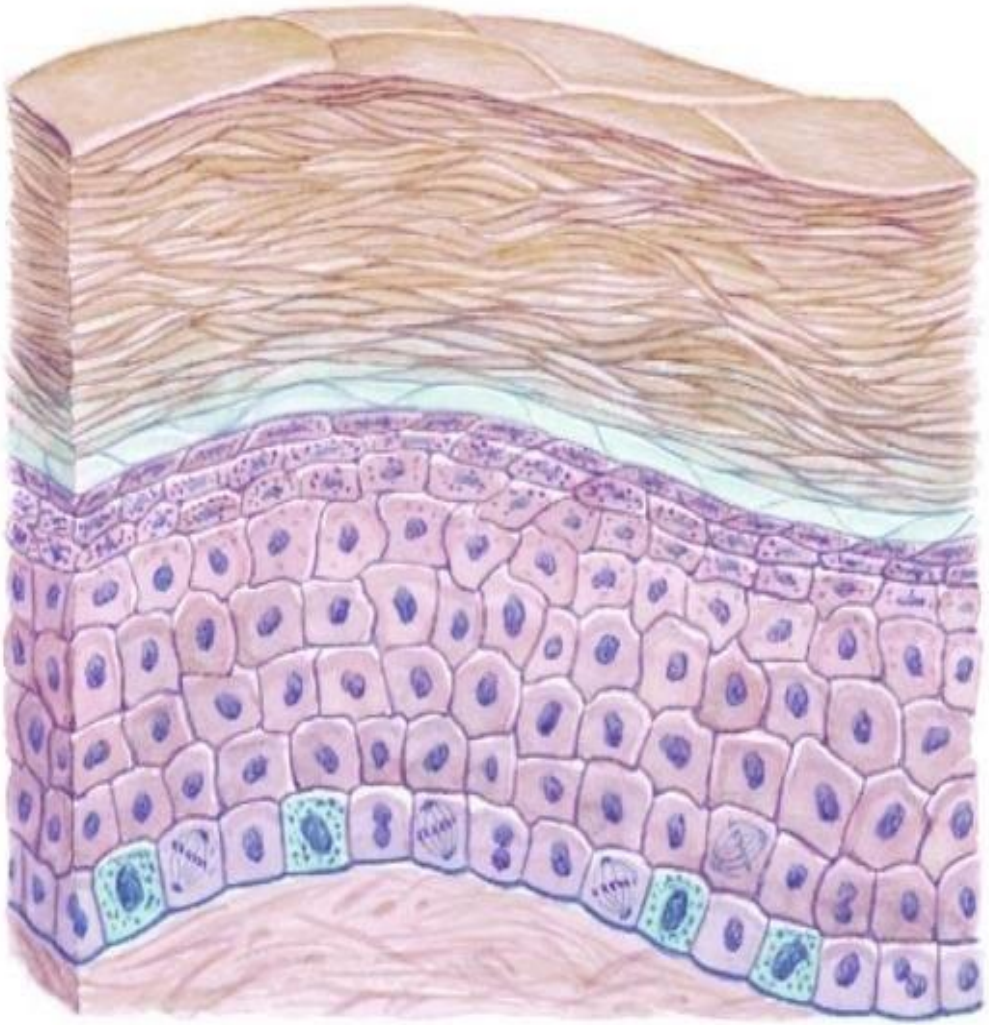
Skin anatomy and histology



Skin anatomy and histology

There are also mature non-keratinocytes that exist in the epidermis. These include the melanocytes (which are derived from embryonic neural crest), and lymphocytes and Langerhans cells that arise from bone marrow dendritic cells. The melanocytes synthesize and store melanin, which not only contributes to the color of the skin and hair, but also provides protection against ultraviolet radiation.

Skin anatomy and histology



Layer of Epidermis

Stratum corneum
Consists of many layers of keratinized dead cells that are flattened and nonnucleated; cornified

Stratum lucidum
A thin, clear layer found only in the epidermis of the lips, palms, and soles

Stratum granulosum
Composed of one or more layers of granular cells that contain fibers of keratin and shriveled nuclei

Stratum spinosum
Composed of several layers of cells with centrally located, large, oval nuclei and spinelike processes; limited mitosis

Stratum basale
Consists of a single layer of cuboidal cells in contact with the basement membrane that undergo mitosis; contains pigment-producing melanocytes

Skin anatomy and histology

The prickle cell and basal layers are collectively referred to as the Malpighian layer. The basal, prickle cell and granular layers are metabolically active regions of the epidermis. The basal layer undergoes continuous mitosis throughout life. The daughter cells ascend the epidermal layers, while undergoing morphological changes throughout its journey. It also develops clefts and ridges that are perceived on the thickened areas of skin as imprints (i.e. fingerprints and footprints).

Skin anatomy and histology

The epidermis is significantly thicker in the regions of the palms and soles, when compared to other areas of the body. Furthermore, there are no sebaceous glands or hair follicles located in the skin in the palms and soles, while those structures are found in other areas of the body. The thick, hairless skin in the palms and soles is therefore called glabrous skin, while skin elsewhere is referred to as hirsute (hairy) skin. Of note, the stratum lucidum is absent from hirsute skin but present in glabrous skin.

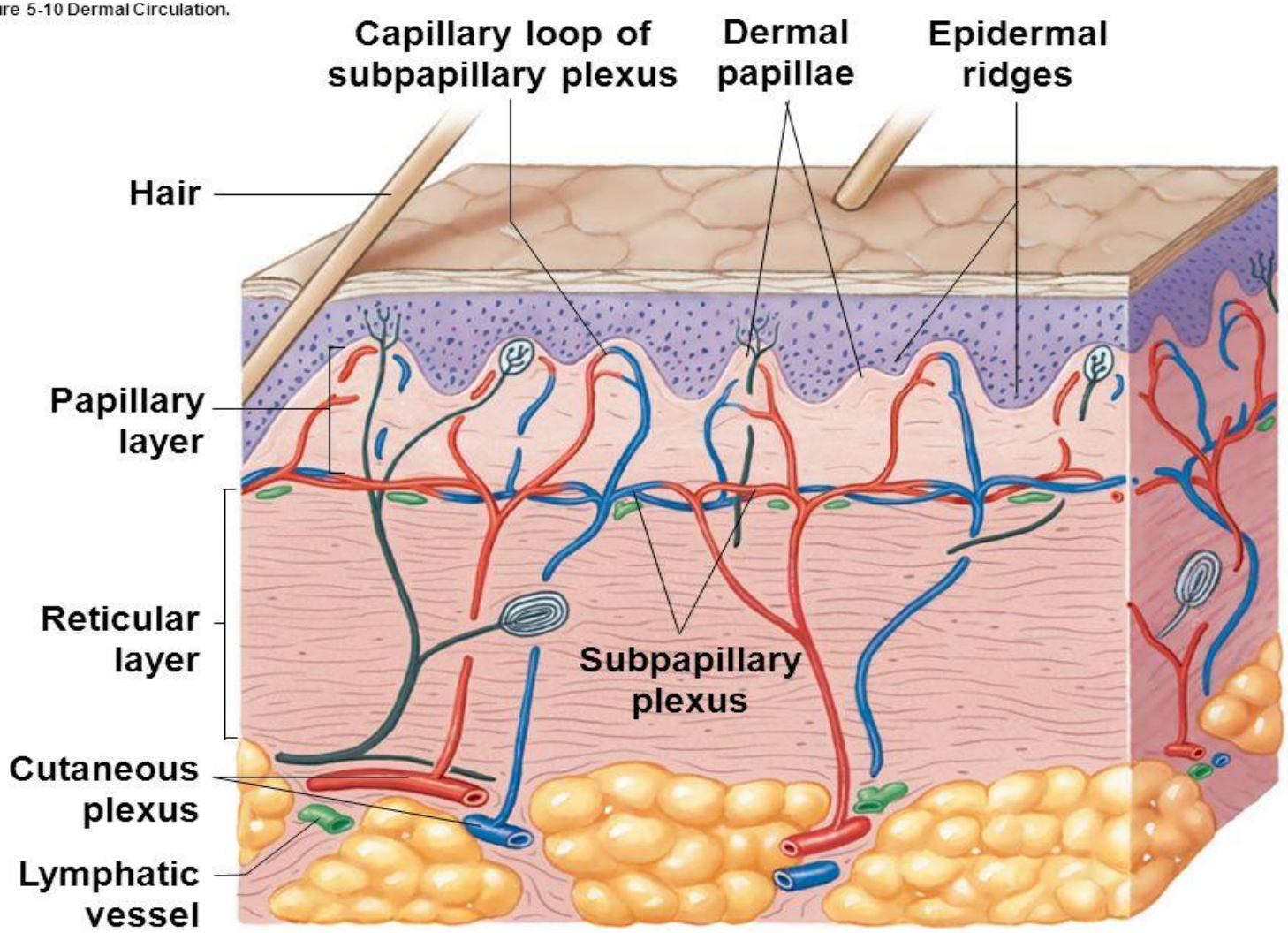
Key facts about the epidermis	
Cell types	Keratinocytes - squamous epithelial cells that originate from basal stem cells; continuously mature from basal to corneum layer and desquamate Melanocytes - synthesise melanin that gives color to the skin and protects it from ultraviolet radiation Langerhans cells - antigen presenting cells Merkel cells - mechanoreceptors
Layers	Stratum basale (germinativum) - stem cells constantly undergoing mitosis, regenerate other layers Stratum spinosum - contains post-mitotic cells from stratum basale that contain keratine fibrils; melanosomes, Langerhans cells Stratum granulosum - flattened, polygonal pycnotic cells that contain keratohyaline granules, Odland bodies Stratum lucidum - present only in palms and soles; translucent cells filled with keratine filaments Stratum corneum - dead, non-nucleated cells filled with keratine filaments

Skin anatomy and histology

Deep to the epidermis is the dermis. It lies deep to the basement membrane of the stratum basale. The dermis contains the blood vessels, nerves, sweat glands, hair follicles, and oil (sebaceous) glands. The dermis consists mainly of connective tissue, which is largely made up of a protein called collagen. Collagen gives the skin its flexibility and provides structural support. The fibroblasts that make collagen are the main type of cell in the dermis. The integrity of the fibrous network varies with age and even within particular regions of the body.

Skin anatomy and histology

Figure 5-10 Dermal Circulation.



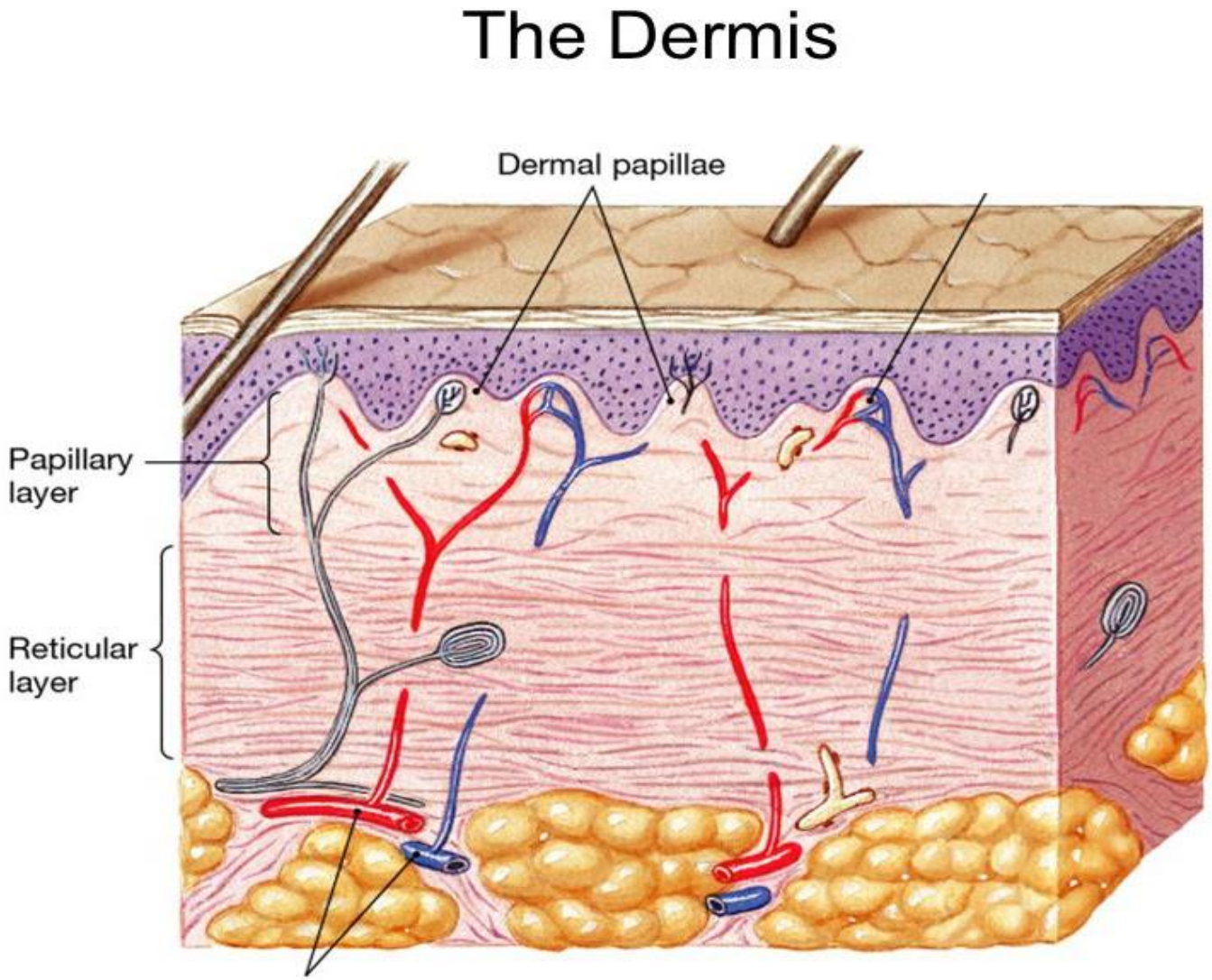
Skin anatomy and histology

While the connective tissue network is strong enough to hold the skin together, it still allows epidermal appendages, neurovasculature, and lymphatics to pass through its substance. Skin varies in thickness in different parts of the body; it is thickest on the palms and soles of the feet, and thinnest on the eyelids. In general, men have thicker skin than women, and adults have thicker skin than children. After age 50, however, the skin begins to grow thinner again as it loses its elastic fibers and some of its fluid content.

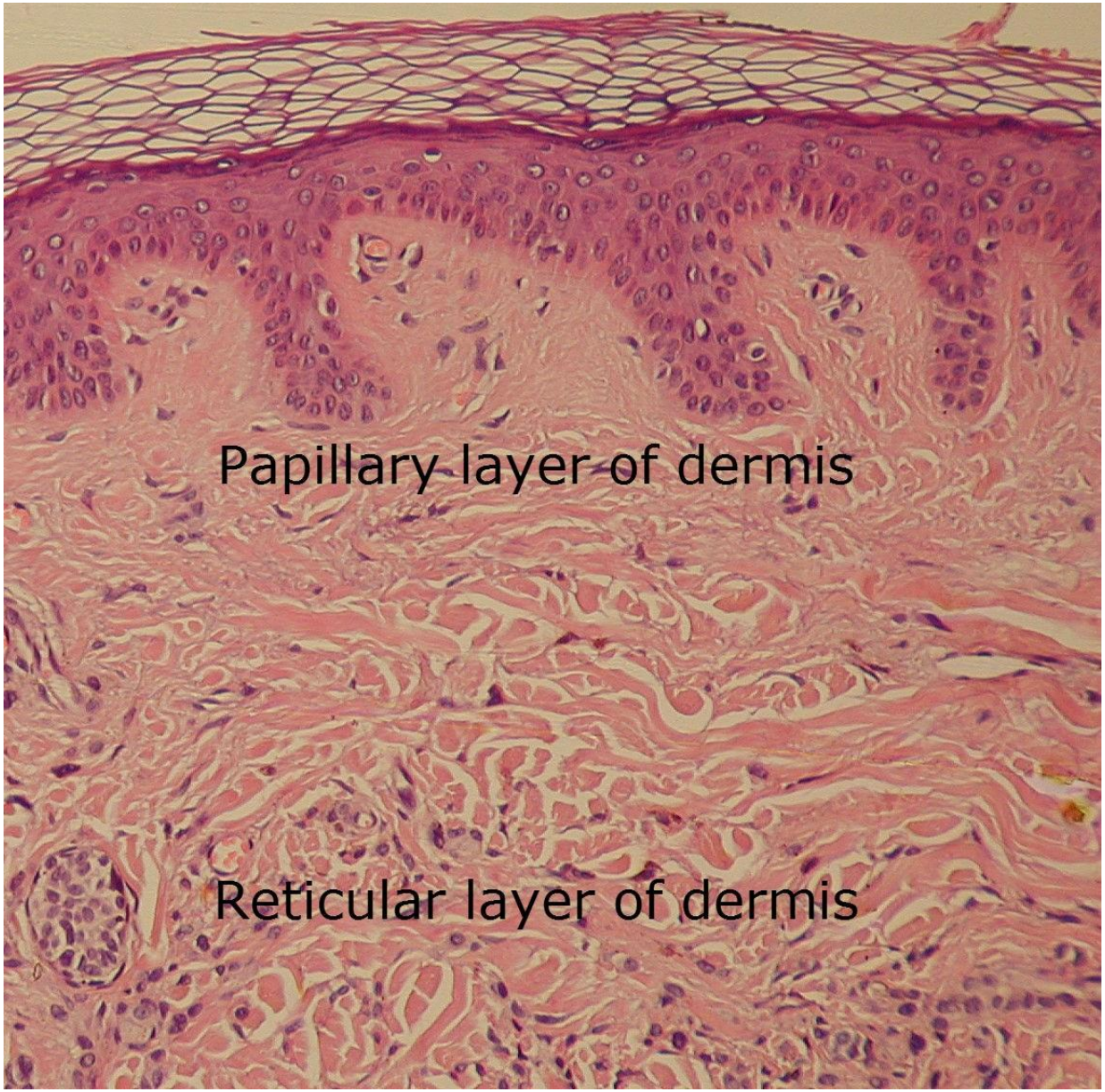
Skin anatomy and histology

There are two definitive layers of the dermis. The more superficial of the two is the papillary layer. It is characterized by dermal papillae, which are raised irregular projections that interlace with the epidermal ridges of the epidermis. They are less abundant and smaller in thin skin that has minimal mechanical stress, when compared to in areas of thicker skin (i.e. palms and soles), where they tend to form curved parallel lines.

Skin anatomy and histology



Skin anatomy and histology

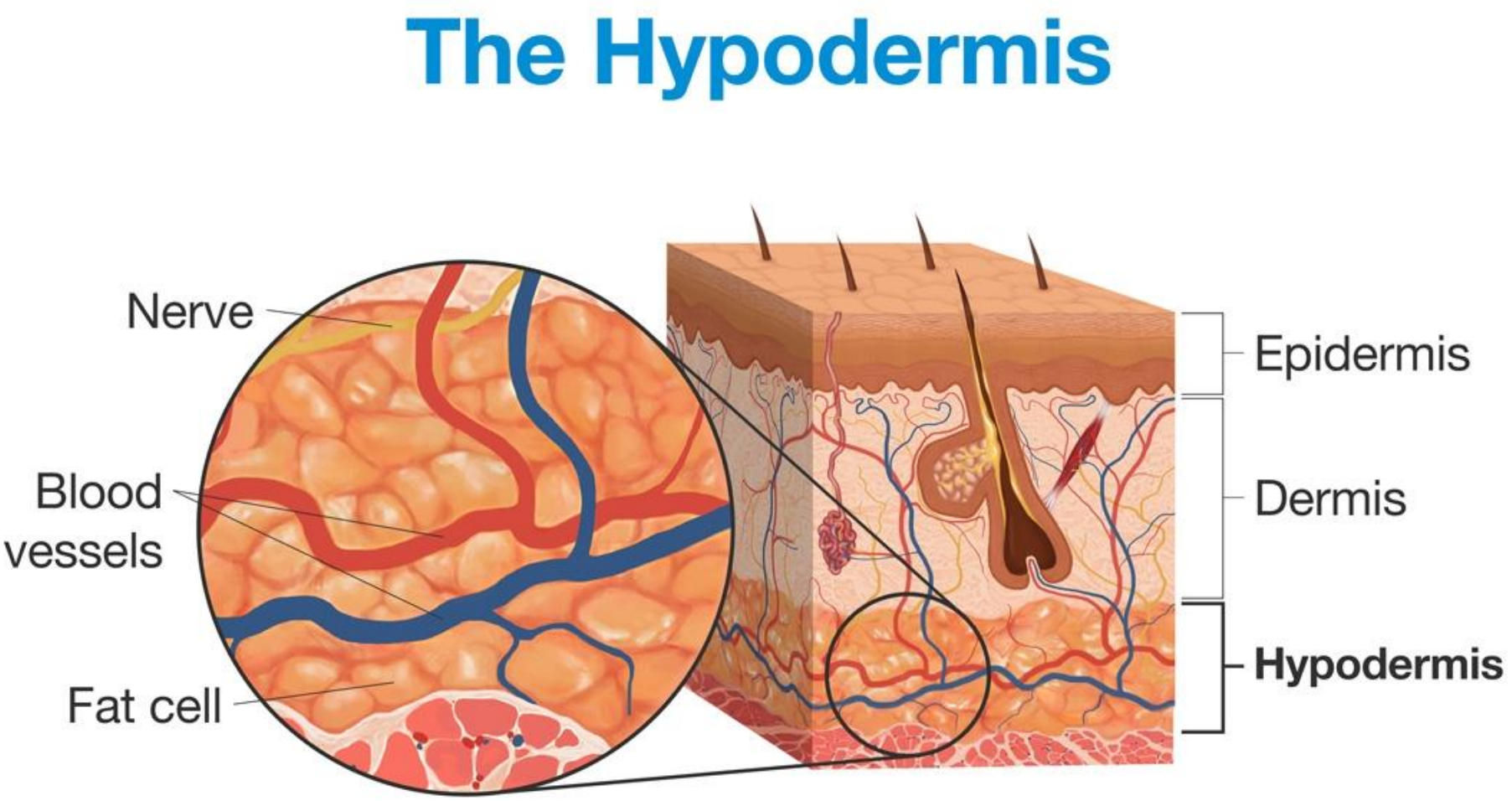


Deep to the papillary layer is the reticular layer of the dermis. There is no clear demarcation between the two structures.

Skin anatomy and histology

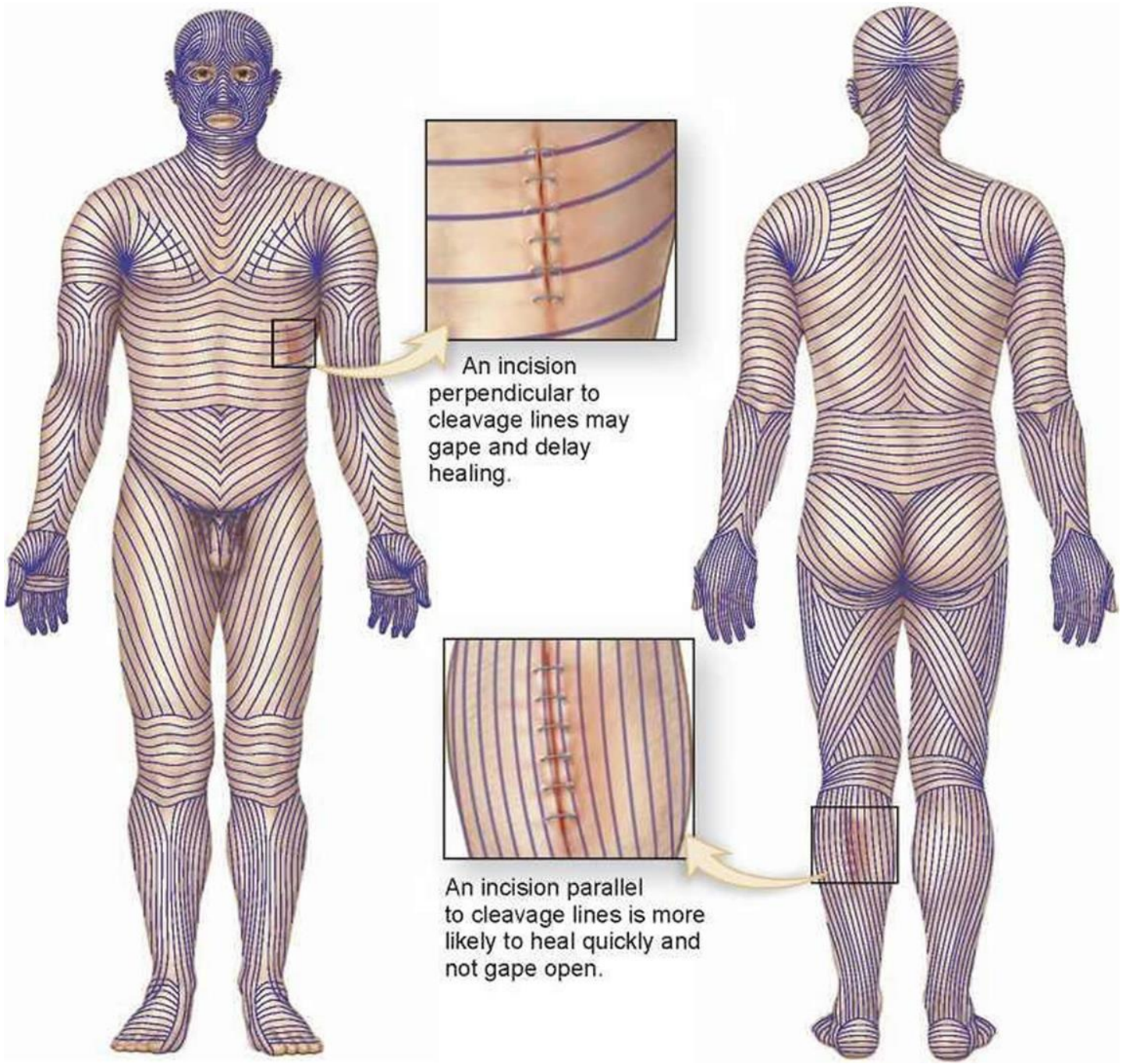
Finally, the dermis rests on a layer of loose connective tissue known as the hypodermis. It is a superficial fascial sheath with interspersed adipose tissue (panniculus adiposus). The fascia reduces the friction between the dermis and deeper musculature, while the adipose tissue participates in thermoregulatory mechanisms as well as disperses forces generated from direct impact.

Skin anatomy and histology



Skin anatomy and histology

In 1861, Karl Langer (an Austrian anatomist) discovered the now widely accepted Langer's lines. These topographical landmarks are used in surgical procedures as guidelines for points of incisions. Otherwise known as cleavage lines, these markings correspond with the orientation of dermal collagen fibers. Incision along these lines result in healing with minimal scarring and subsequently, a less apparent postoperative scar.



Langer's lines, Langer lines of skin tension, or sometimes called cleavage lines

Skin anatomy and histology

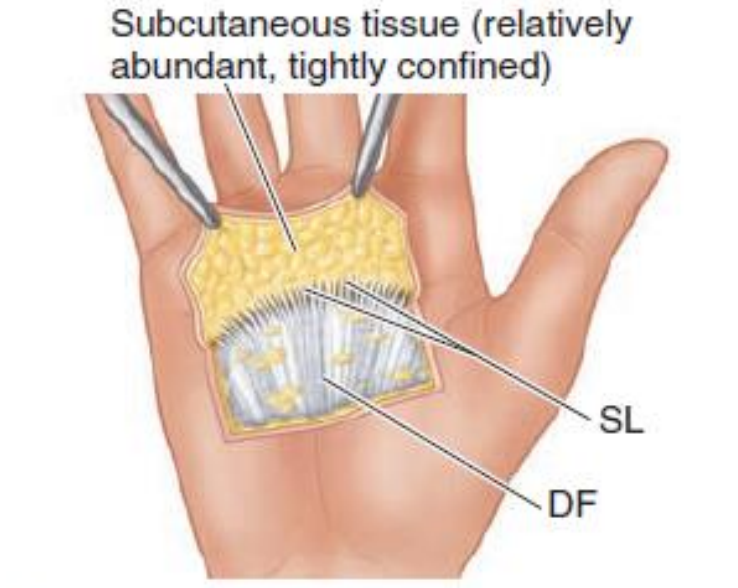
An incision or laceration across tension lines disrupts a greater number of collagen

fibers, causing the wound to gape and possibly heal with

excessive (keloid) scarring. Surgeons make their incisions

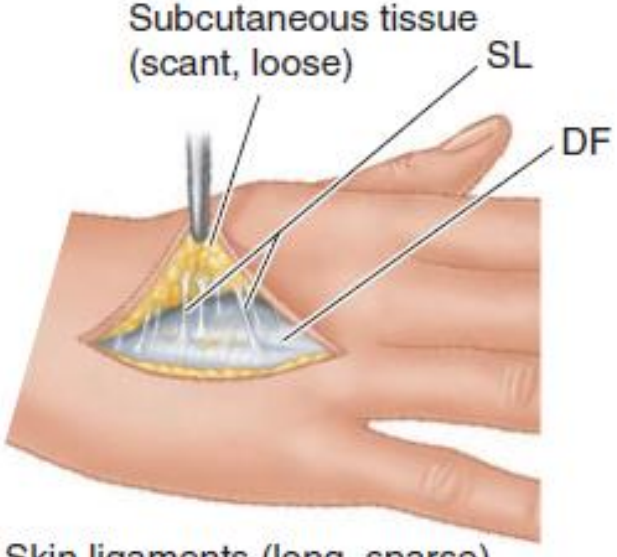
parallel with the tension lines when other considerations

(e.g., adequate exposure, avoiding nerves) are not of greater importance.



Skin ligaments (SL) (short, stout, abundant)

Palm of hand



Skin ligaments (long, sparse)

Dorsum of hand

Skin ligaments (L. retinacula cutis), consisting of numerous small fibrous bands, extend through the subcutaneous tissue and attach the deep surface of the dermis to the underlying deep fascia. The length and density of these ligaments determine the mobility of the skin over deep structures.

Skin grafting

Grafting refers to a surgical procedure to move tissue from one site to another on the body, or from another creature, without bringing its own blood supply with it. Instead, a new blood supply grows in after it is placed. A similar technique where tissue is transferred with the blood supply intact is called a flap.

Skin grafting

Skin grafting is a surgical procedure in which skin or a skin substitute is placed over a burn or non-healing wound.

Purpose

A skin graft is used to permanently replace damaged or missing skin or to provide a temporary wound covering. This covering is necessary because the skin protects the body from fluid loss, aids in temperature regulation, and helps prevent disease-causing bacteria or viruses from entering the body.

Skin grafting

Skin grafting is sometimes done as part of elective plastic surgery procedures, but its most extensive use is in the treatment of burns. For first or second-degree burns, skin grafting is generally not required, as these burns usually heal with little or no scarring. With third-degree burns, however, the skin is destroyed to its full depth, in addition to damage done to underlying tissues. People who suffer third-degree burns often require skin grafting.

Skin grafting

Wounds such as third-degree burns must be covered as quickly as possible to prevent infection or loss of fluid. Wounds that are left to heal on their own can contract, often resulting in serious scarring; if the wound is large enough, the scar can actually prevent movement of limbs. Non-healing wounds, such as diabetic ulcers, venous ulcers, or pressure sores, can be treated with skin grafts to prevent infection and further progression of the wounded area.

Skin grafting: Classification

Grafts can be classified by their thickness, the source, and the purpose.

By source:

- Autologous: The donor skin is taken from a different site on the same individual's body (also known as an autograft).
- Isogeneic: The donor and recipient individuals are genetically identical (e.g., monozygotic twins, animals of a single inbred strain; isograft or syngraft).

Skin grafting: Classification

By source (continued):

- Allogeneic: The donor and recipient are of the same species (human → human, dog → dog; allograft).
- Xenogeneic: The donor and recipient are of different species (e.g., bovine cartilage; pig skin; xenograft or heterograft).
- Prosthetic: Lost tissue is replaced with synthetic materials such as metal, plastic, or ceramic (prosthetic implants).

Skin grafting: Classification

Allografts, xenografts, and prosthetic grafts are usually used as temporary skin substitutes, that is a wound dressing for preventing infection and fluid loss. They will eventually need to be removed as the body starts to reject it. Autologous grafts and some forms of treated allografts can be left on permanently without rejection. Genetically modified pigs can produce allograft-equivalent skin material, and tilapia skin is used as an experimental cheap xenograft in places where porcine skin is unavailable and in veterinary medicine.

Skin grafting: Classification

By thickness: There are two basic types of skin grafts: split-thickness (STSG) and full-thickness (FTSG) grafts.

Split-thickness

A split-thickness skin graft (STSG) is a skin graft including the epidermis and part of the dermis. Its thickness depends on the donor site and the needs of the person receiving the graft. It can be processed through a skin mesher which makes apertures onto the graft, allowing it to expand up to nine times its size.

Skin grafting: Classification

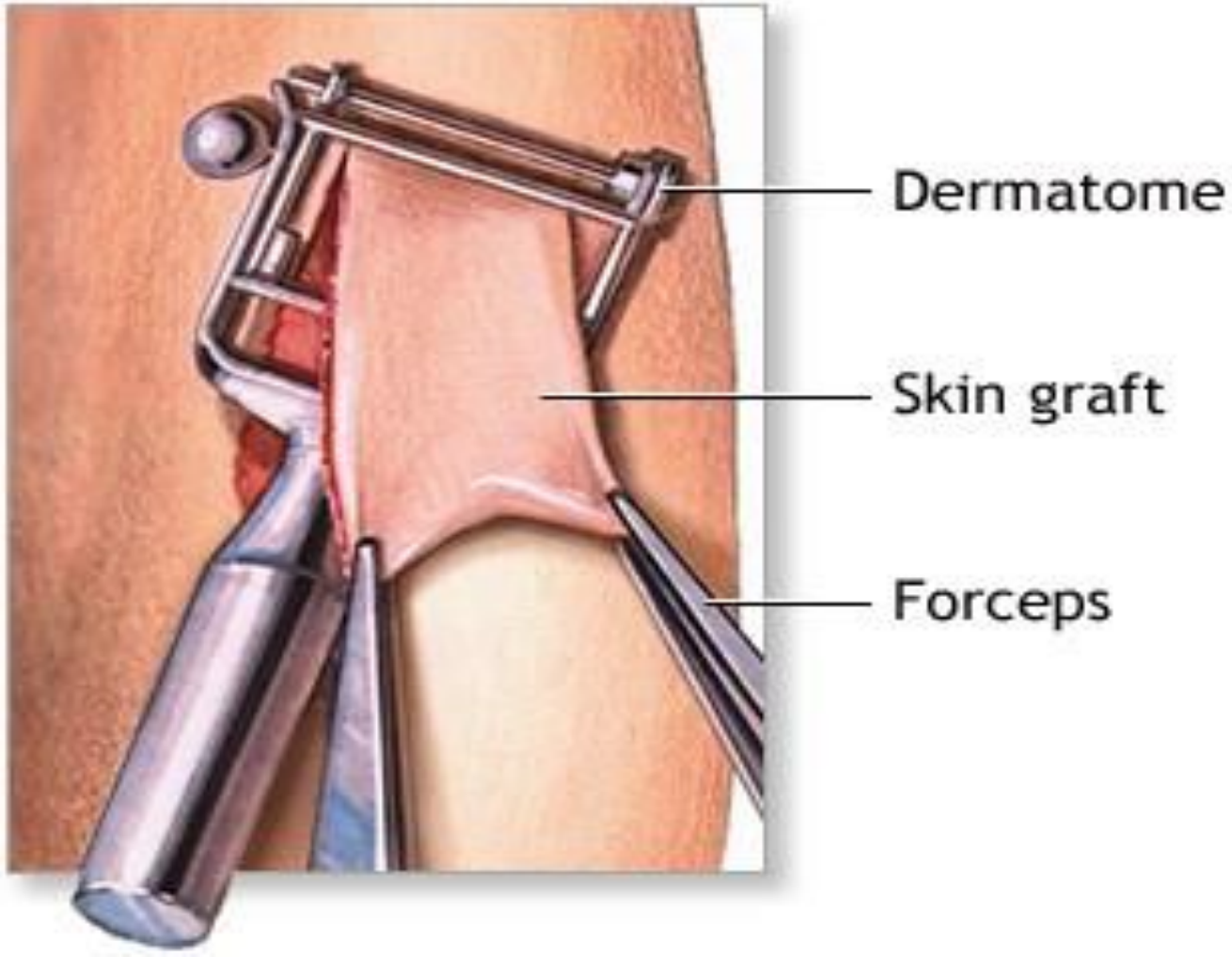
By thickness: Split-thickness (continued)

Split-thickness grafts are frequently used as they can cover large areas and the rate of autorejection is low. The same site can be harvested again after six weeks. The donor site heals by re-epithelialisation from the appendages of epidermis deepened in dermis and hypodermis (hair follicles and sweat glands) and from the epidermis of surrounding skin and requires dressings.

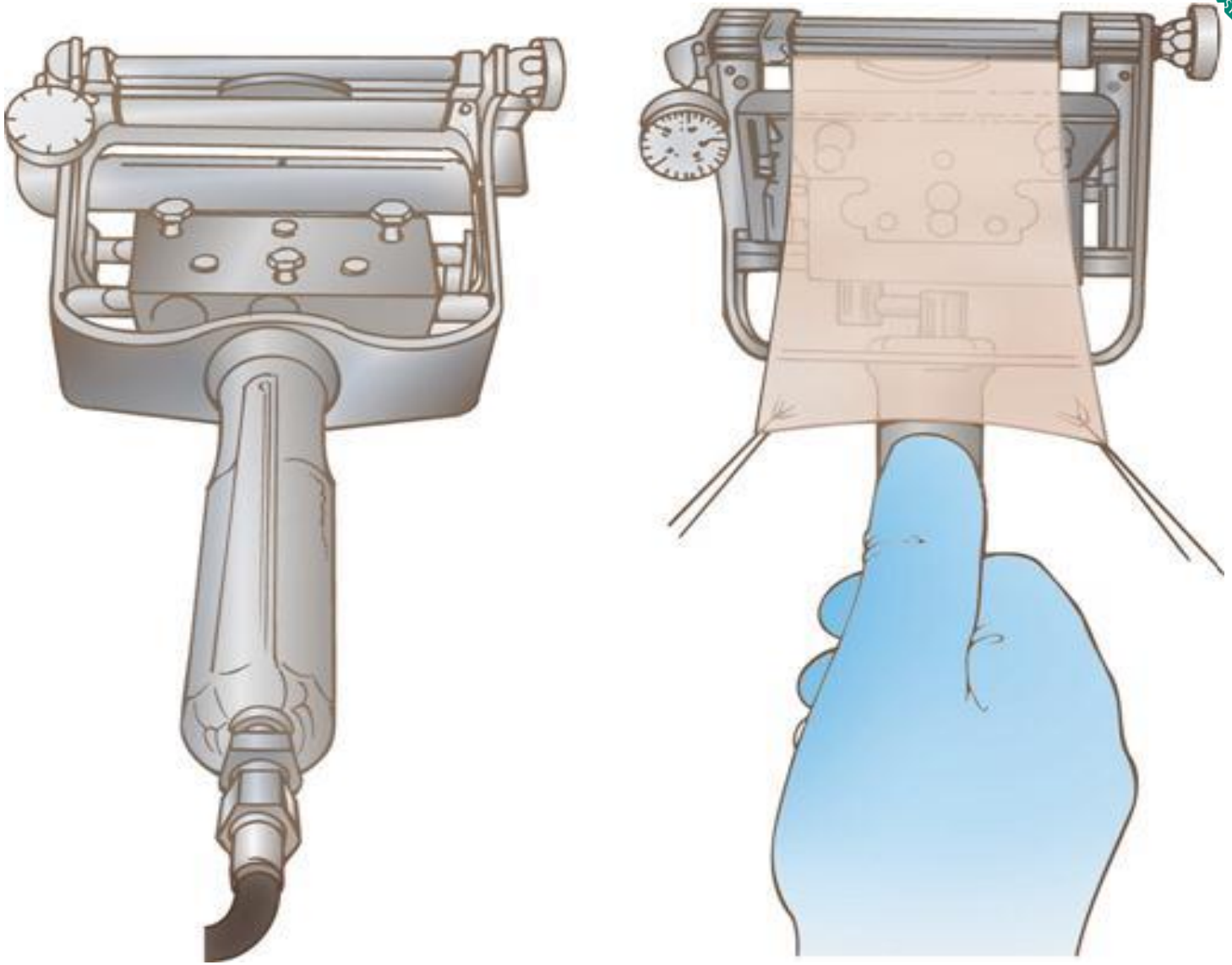
Dermatomes

A dermatome is a surgical instrument used to produce thin slices of skin from a donor site and is the main tool for skin graft harvesting. Dermatomes can be operated either manually or electrically. The use of different types of safety razors as a dermatome has been described by some authors. Manual dermatomes are also known as hand-held dermatomes.

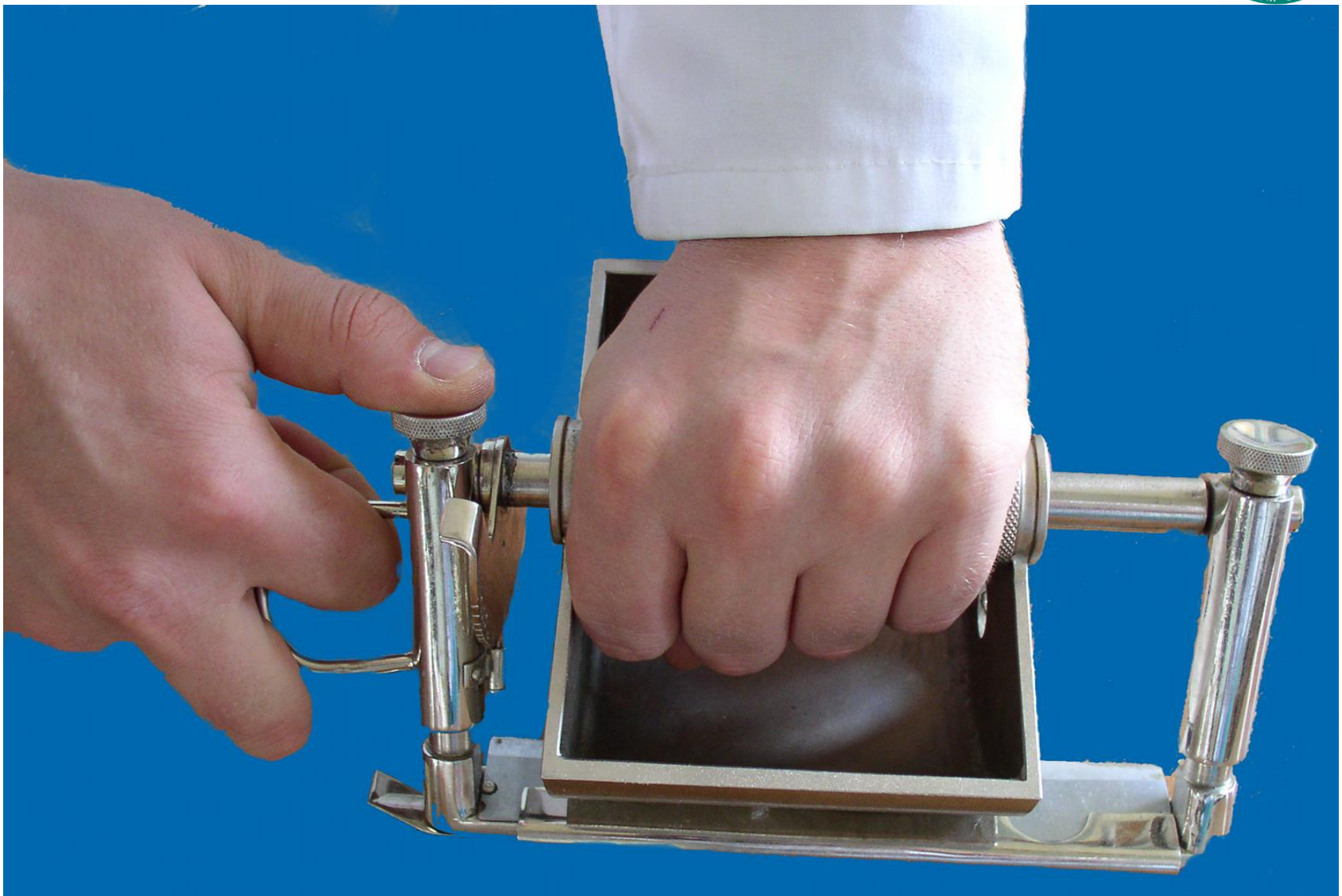
Dermatomes



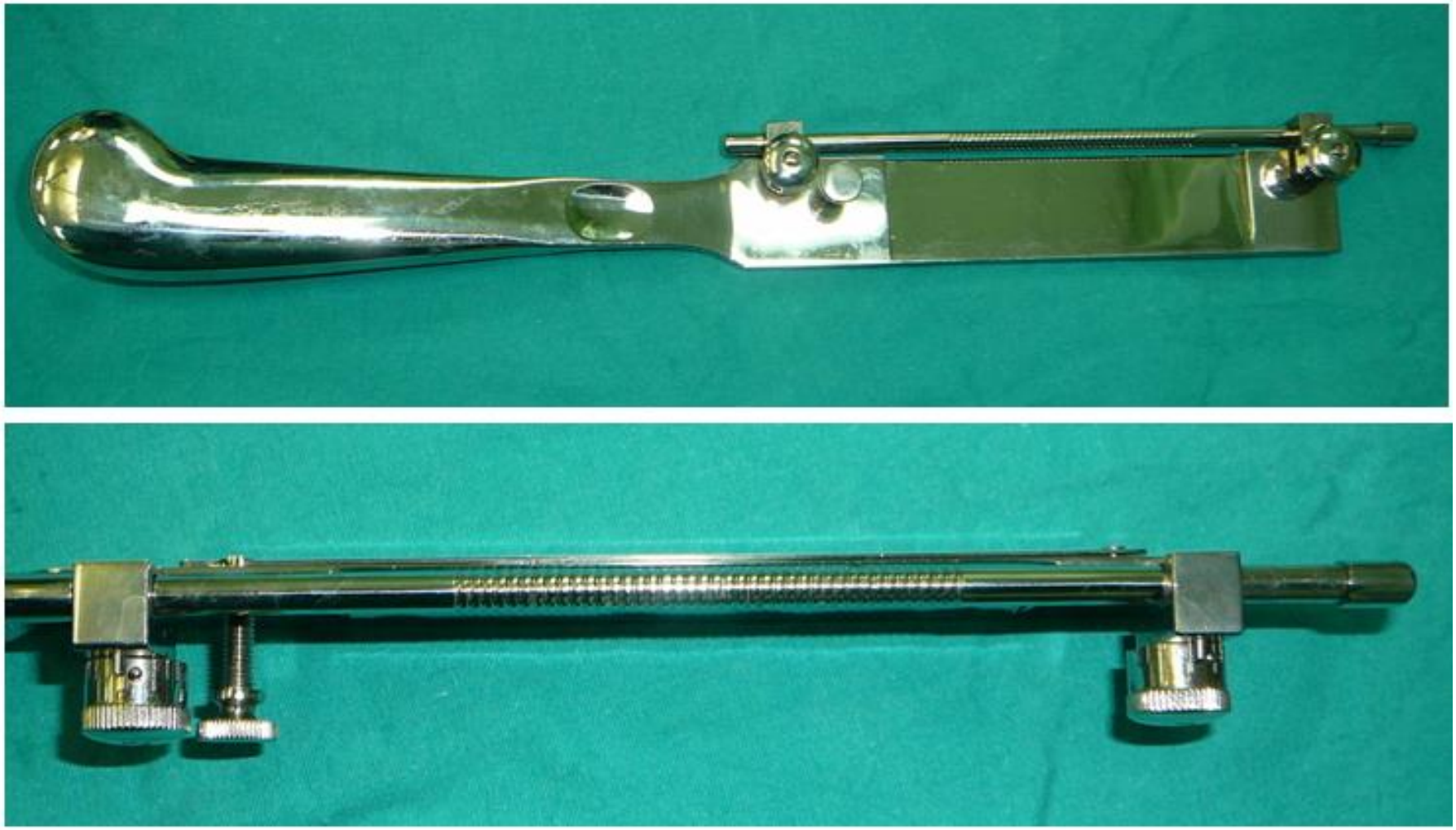
Dermatomes



Hand-held Padgett dermatome



An example of hand dermatome (schink type): frontal view (top) and lateral view showing Skin Graft thickness adjustment mechanism (bottom)



Dermatomes

Disadvantages of hand-held knives are harvesting of grafts with irregular edges and grafts of variable thickness. Additionally, its lenght makes many areas inaccessible to harvest skin grafts which poses another disadvantage. Electrical dermatomes are better for cutting out thinner and larger strips of skin with a more homogenous thickness. Humeca developed a new dermatome for free handed harvesting skin graft with a predetermined thickness of about 0,25 mm.

Humeca electrical dermatome, whole body of cordless electrical dermatome (top right), justification site (top left), easily harvesting STSG (bottom left), and rechargeable batteries with its charging unit (bottom right).

Electrical dermatome

Hypertrophic scarring due to flame burn injury of mandibular region (Left), well-developed granulation after the application of hyalomatrix skin substitute (esterified hyaluronic acid) for three weeks following to excision of scarred tissues (right), final result with thin STSG for epidermal replacement (center)

Skin grafting: Classification

By thickness: Full-thickness grafts

A full-thickness graft involves removing all of the epidermis and dermis from the donor site. These are usually taken from the abdomen, groin, forearm, or area above the clavicle (collarbone). They tend to be smaller pieces of skin, as the donor site from where it's harvested is usually pulled together and closed in a straight-line incision with stitches or staples.

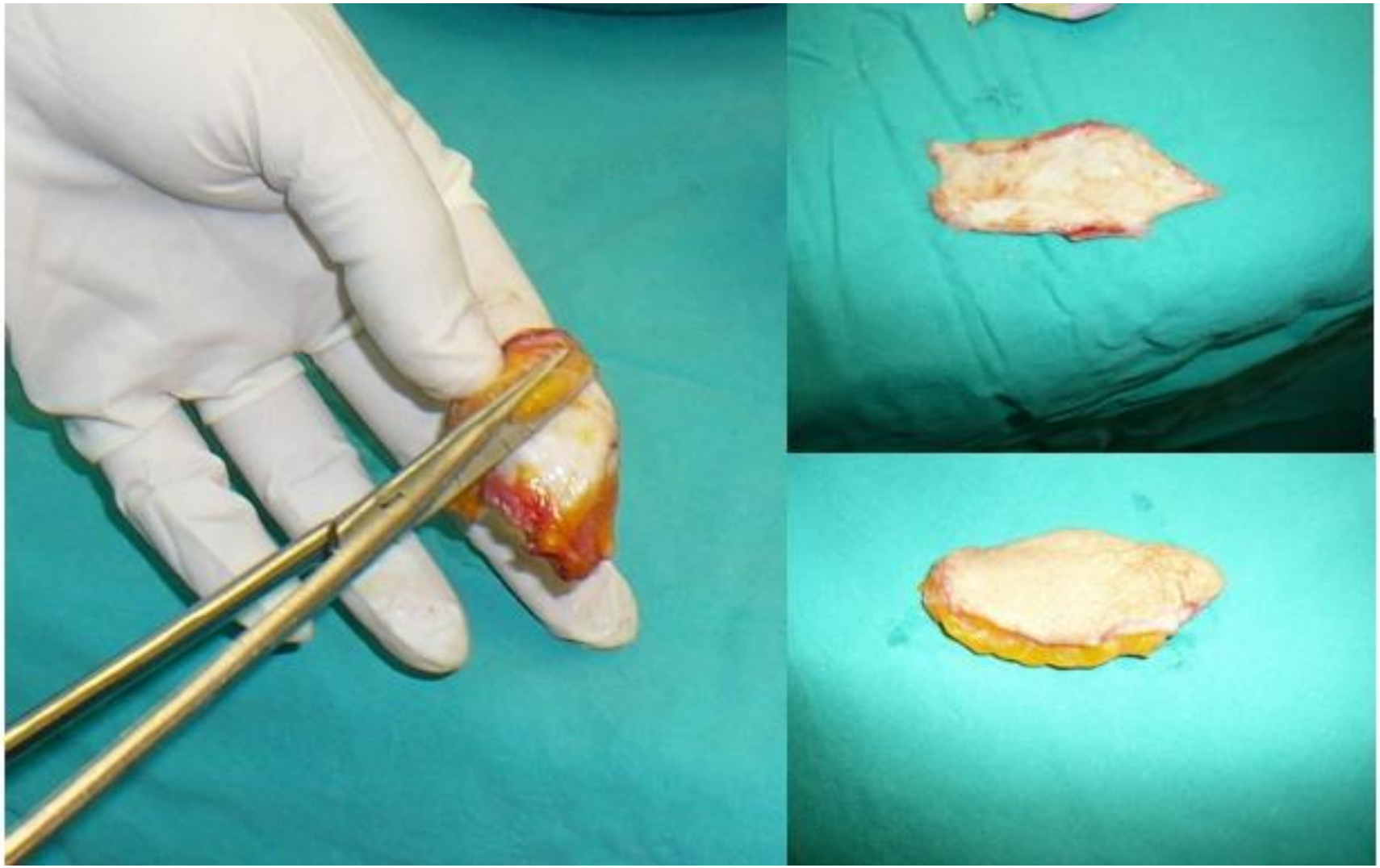
Skin grafting: Classification

A full-thickness graft is removed from the donor site with a scalpel rather than a dermatome. After the surgeon has cut around the edges of the pattern used to determine the size of the graft, he or she lifts the skin with a special hook and trims off any fatty tissue. The graft is then placed on the wound and secured in place with absorbable sutures.

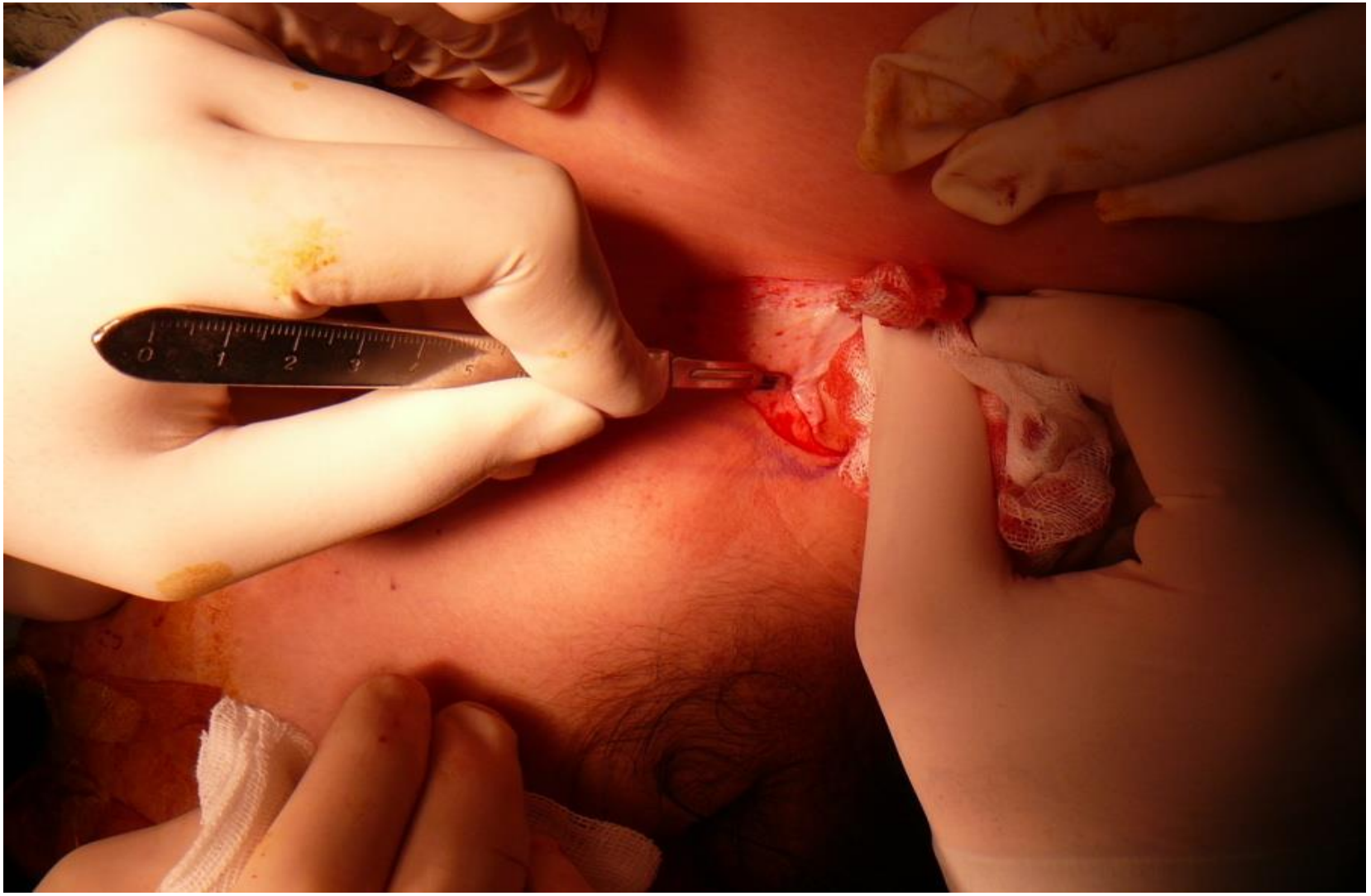
Skin grafting: Classification

There are two techniques for harvesting FTSGs. In the meticulous technique where a sharp dissection is done, only the skin may be obtained. Second one can be described as rough technique. After the incision the predetermined graft donor site, graft can be harvested easily and rapidly by inclusion of subcutaneous fat tissue.

Rough technique harvesting FTSG: defatting of graft (left), after the procedure (top right) and prior to the procedure the graft including subcutaneous fat (bottom, right).



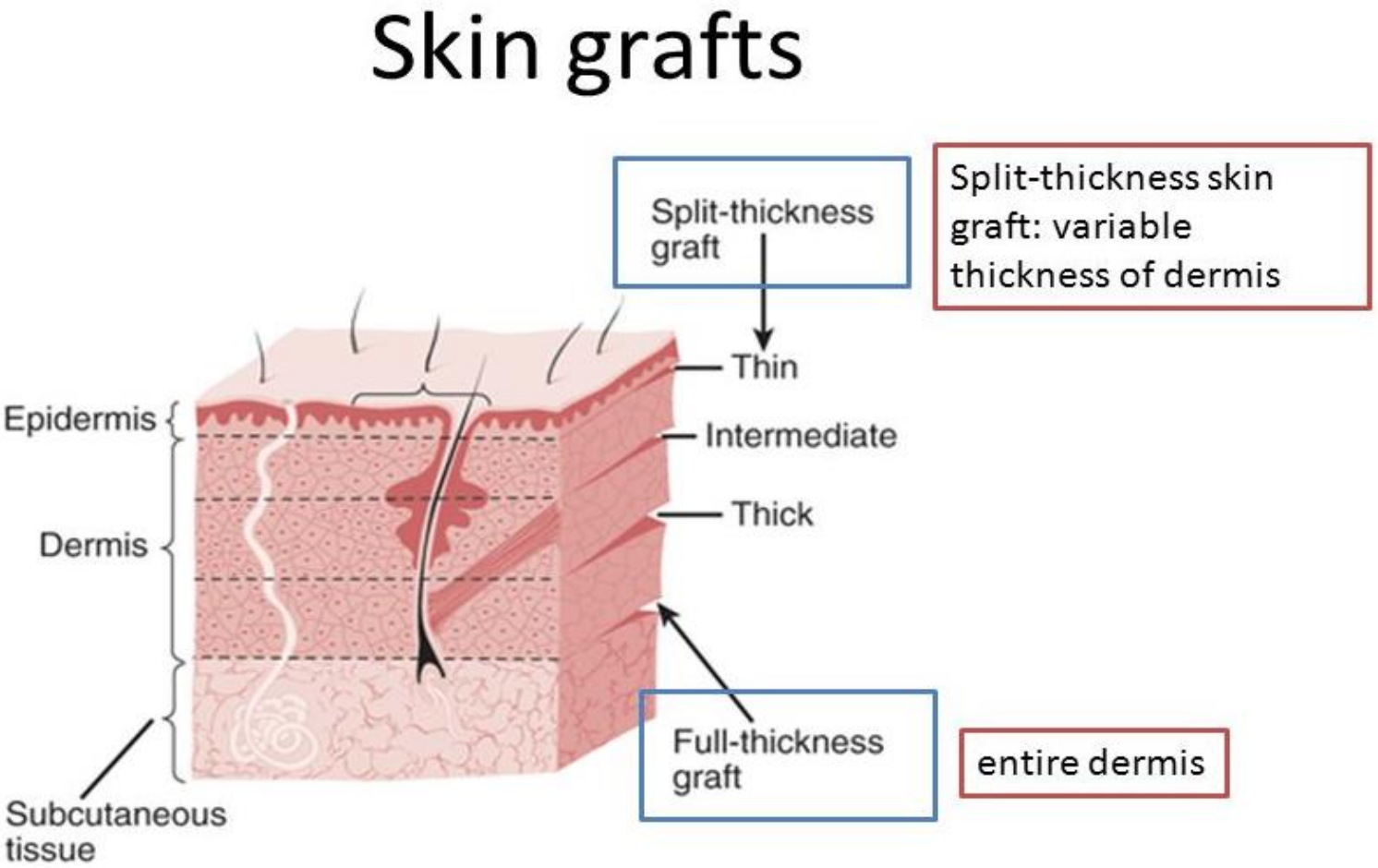
Meticulouse technique for harvesting FTSG



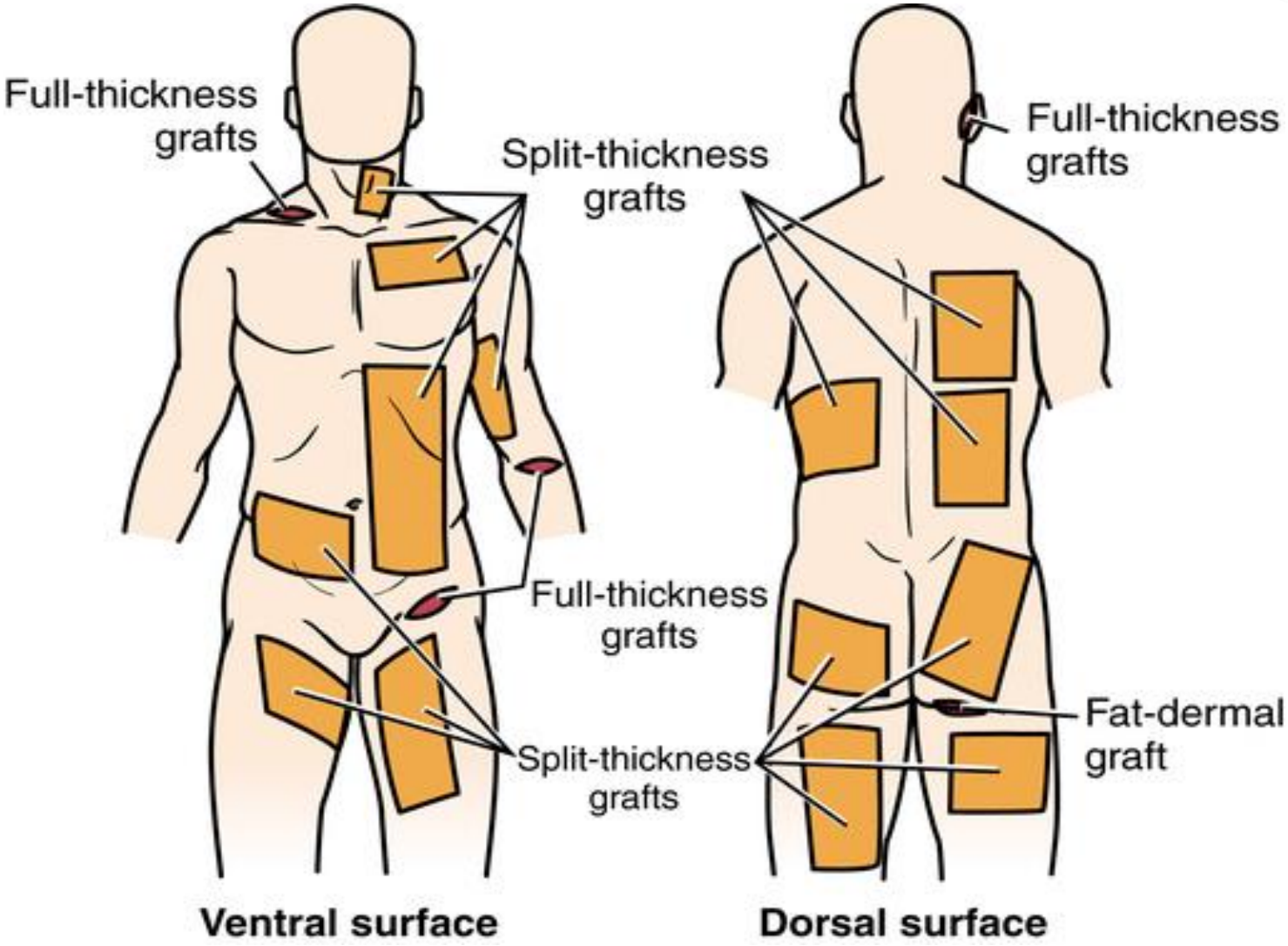
Skin grafting: Classification

In the rapid technique where the skin is harvested with its subcutaneous attachments, there will be need of a following defatting process, since those structure may prevent graft vascularisation. Easily harvested with a scalpel, defatting or thinning the dermis increases the chance of “graft take.” FTSGs are commonly harvested from the inguinal region, flank or from the postauricular area. These donor sites can be closed primarily, care should be taken to select a harvest site that does not contain hair.

Skin grafting: Classification



Donor sites


Full-thickness grafts
Split-thickness grafts
Full-thickness grafts
Full-thickness grafts
Split-thickness grafts
Fat-dermal graft
Ventral surface
Dorsal surface

Skin grafting: Classification

Donor site selection of composite graft which is composed of multiple structures like skin and cartilage requires a more complicated approach, as defects of aesthetic subunits have their own characteristics and need a more close attention in the repair process. Good examples of using composite graft are eyelash reconstruction with strip composite eyebrow grafts and alar rim defect repair with composite auricular graft.

Composite grafts

Posterior occipital donor site : after the harvest (top) and closing the donor site primarily (bottom)

Skin grafting: Classification

Types of skin grafting can also be divided into free (proper grafts) and non – free (flaps). **Flaps and grafts** are the two main surgical procedures utilized to repair soft tissue loss.

A free skin graft is a piece of skin that has been completely separated from its local blood supply and transferred to a wound at another site, where it must establish new vascular connections through the recipient bed to survive.

Types of composite skin grafts	Used for	Additional content tissue
Strip eyebrow graft	Eyelash reconstruction	Subcutaneous fat
Conchal / helical composite grafts	Alar rim / columella restoration	Auricular cartilage
Scalp punch, pinch (follicular) grafts	Hair restoration	Subcutaneous fat
Strip scalp grafts	Eyebrow reconstruction	Subcutaneous fat

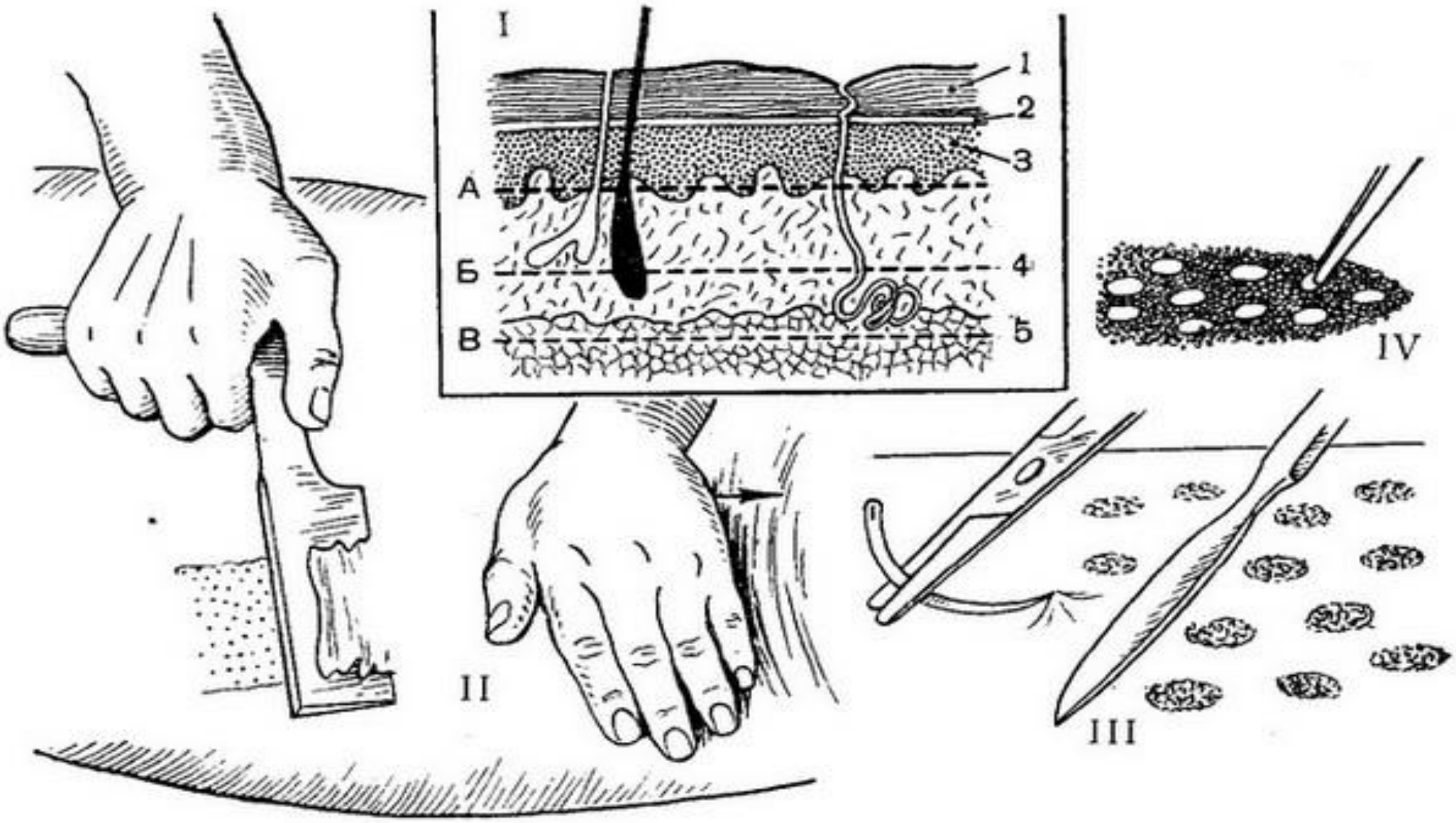
Skin grafting

Sir Astley Cooper removed skin from an amputed thumb and used it for stump defect covarage in 1817(Tiersch C : Über Hautverplanzung. Verh Dtsch Ges Chir 15-17, 1886). Nevertheless skin grafting was not fully accepted for clinical use untill the last quarter of the 19th century. Reverdin was first to draw attention to the technique by successfully performing small pinch grafts in 1872 (Reverdin JL: De la greffe epidermique. Arch Gen Med 19: 276; 555, 703, 1972.)

Skin grafting

Blair and Brown (1929) first used the term “intermediate split-thicknes graft” (Blair VP, Brown JB: Use and uses of large split skin grafts of intermediate thickness. Surg Gynecol Obstet 49: 82-97, 1929.) Afterwards, Padgett described a technique for thick skin grafting (Padgett EC. Skin grafting of the burned patient. Plast Reconstr Surg. 2(4): 368-74, 1946). Skin grafting has been the most commonly used technique for reconstruction of cutaneous defects over the last decades.

Skin grafting



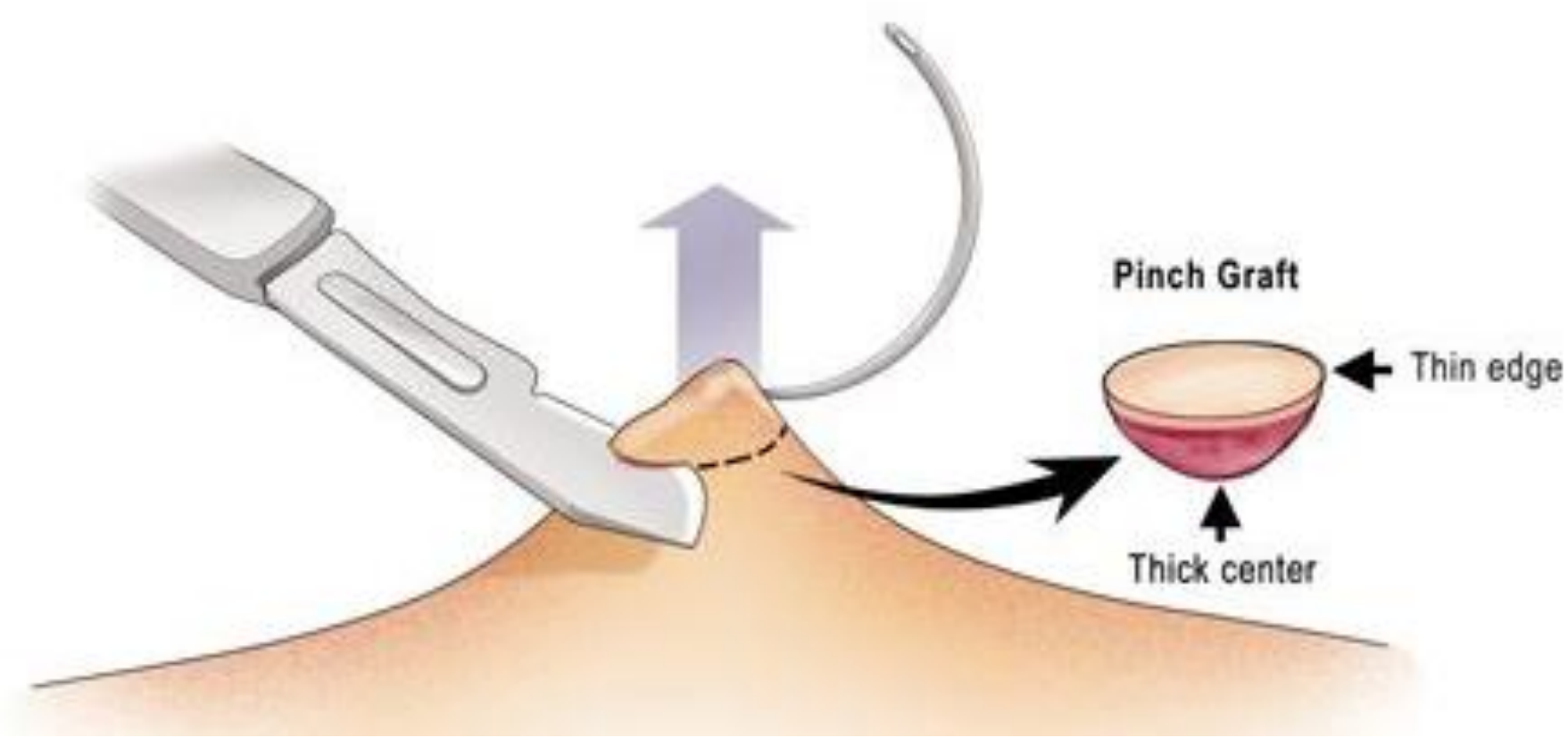
Skin grafting

The idea of a free skin grafting belongs to Brugere (1818), but for the first time started to perform Reverdin (1869) and Russian doctor S. P. Yanovich-Chainsky.

Labels to the previous slide: Methods of free skin grafting.

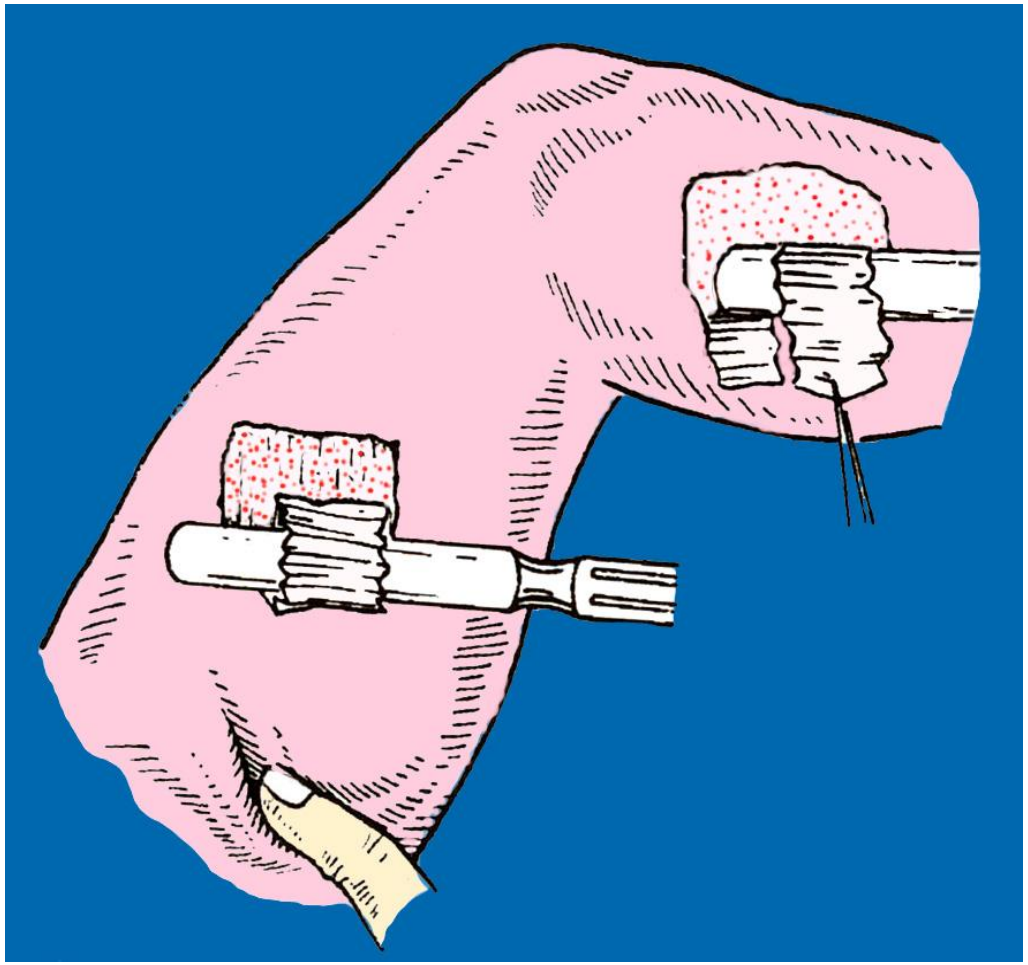
I - diagram shows the thickness of the skin section; II - the capture of the flap by Thiersch ; III and IV – by Yanovich-Chainsky.

Skin grafting



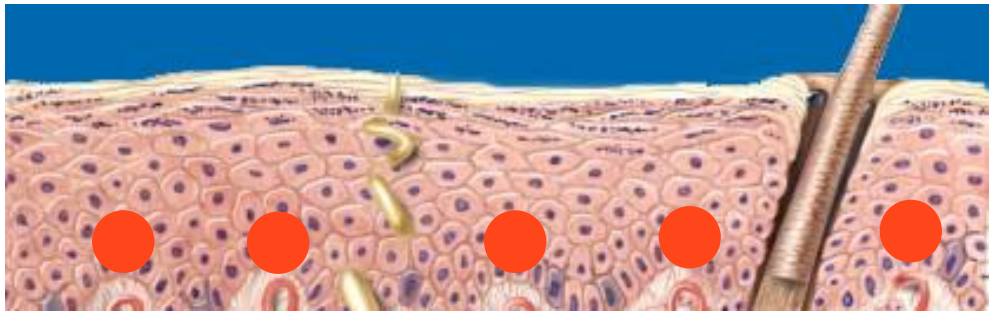
The Reverdin graft, also known as a pinch graft, is a method to promote epithelialization for superficial wounds. The intervention is minimally invasive.

Skin grafting



In 1874, Thiersch extended the use of the pinch graft using large sheets of thin skin grafts to cover the wounds (Tiersch C: Über Hautverplanzung. Verh Dtsch Ges Chir 15-17, 1886.)

Skin grafting



In 1874, Thiersch extended the use of the pinch graft using large sheets of thin skin grafts to cover the wounds (the symptom of “blood dew”)

Skin grafting

Mini skin graft harvesting with simple forceps and curved tip scissors (top) and the donor site after MSG harvesting (right). MSG that applied to a skin defect are shown (bottom).

Skin grafting

The instruments required are 1.5 or 1.2mm punches, small jeweler's or graft holding forceps, and a small curved tip scissors for mini skin grafting. For micro skin grafting additional tools are spraying device, silver’s skin grafting knife and spoon for spreading MSG. Although the micrograft technique is labour-intensive, if the expansion needed is at least 1:6, the aesthetic and functional results obtained are comparable to, or better than, those with meshed grafts.

Skin grafting

Pinch grafts should be full thickness 2-5 mm in diameter with free spaces of 5-10 mm between each of the grafts. Punch grafts are obtained by using a punch biopsy instrument, 3-5 mm in diameter. Pinch and punch grafts can also be called as patch or stamp grafts. Mini punch graft (MPG) may be used in transplantation for repigmentation surgery of vitiligo, or some minor skin defects (Lahiri K. Evolution and evaluation of autologous mini punch grafting in vitiligo).

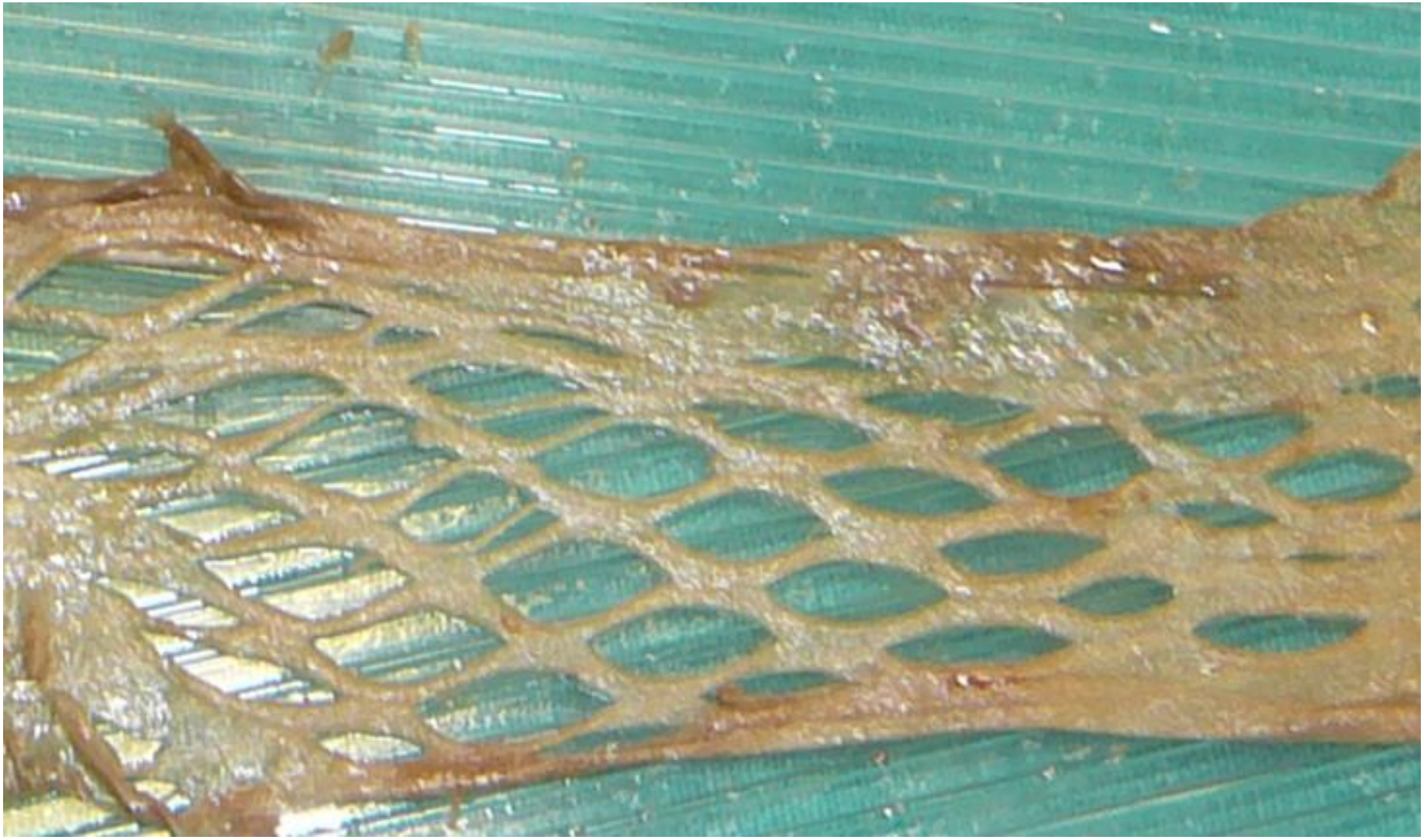
Skin grafting

The graft is carefully spread on the bare area to be covered. It is held in place by a few small stitches or surgical staples. The graft is initially nourished by a process called plasmatic imbibition in which the graft "drinks plasma". New blood vessels begin growing from the recipient area into the transplanted skin within 36 hours in a process called capillary inosculation.

Skin grafting

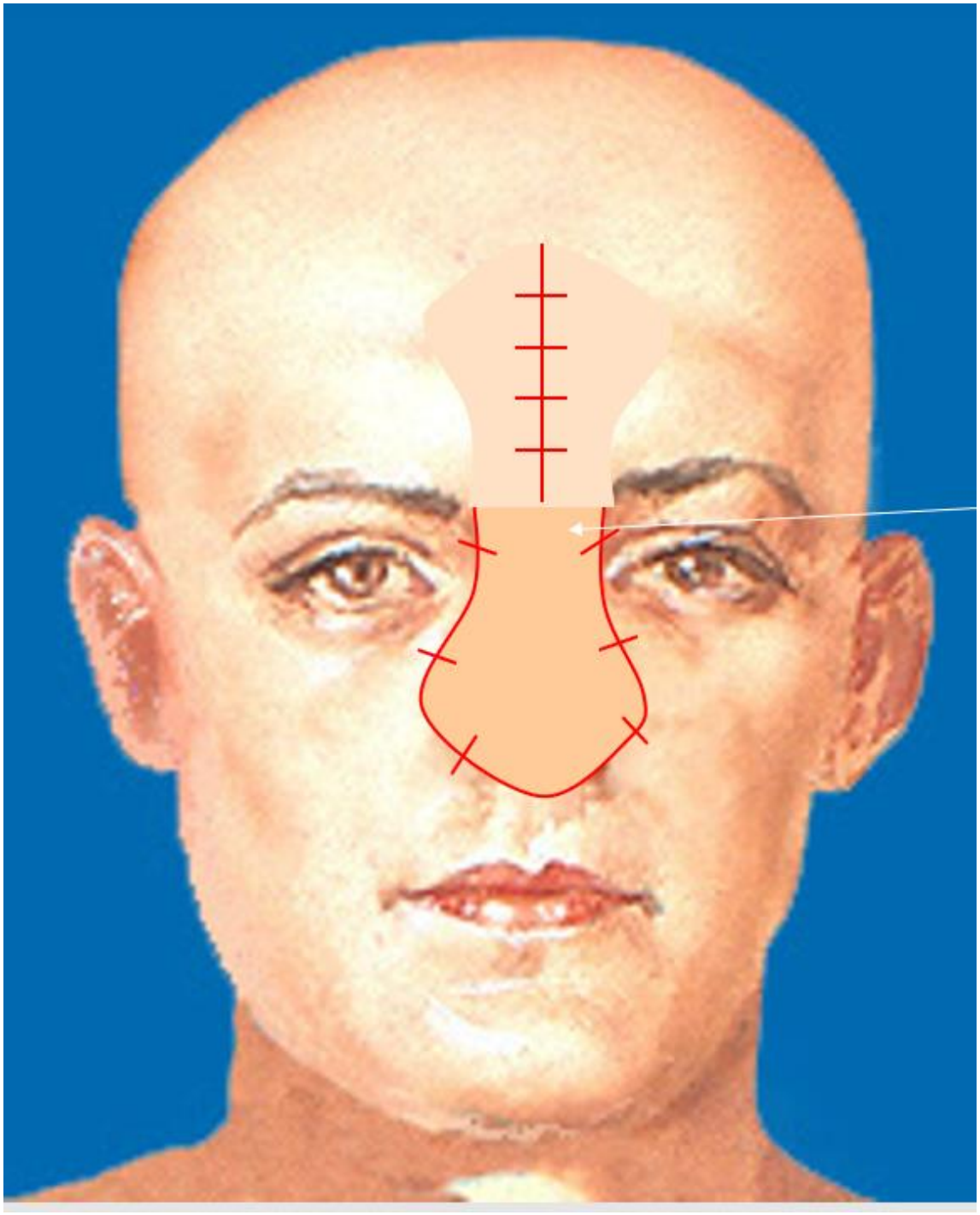
To prevent the accumulation of fluid under the graft which can prevent its attachment and revascularization, the graft is frequently meshed by making lengthwise rows of short, interrupted cuts, each a few millimeters long, with each row offset by half a cut length like bricks in a wall. In addition to allowing for drainage, this allows the graft to both stretch and cover a larger area as well as to more closely approximate the contours of the recipient area. However, it results in a rather pebbled appearance upon healing that may ultimately look less aesthetically pleasing.

Meshed skin graft



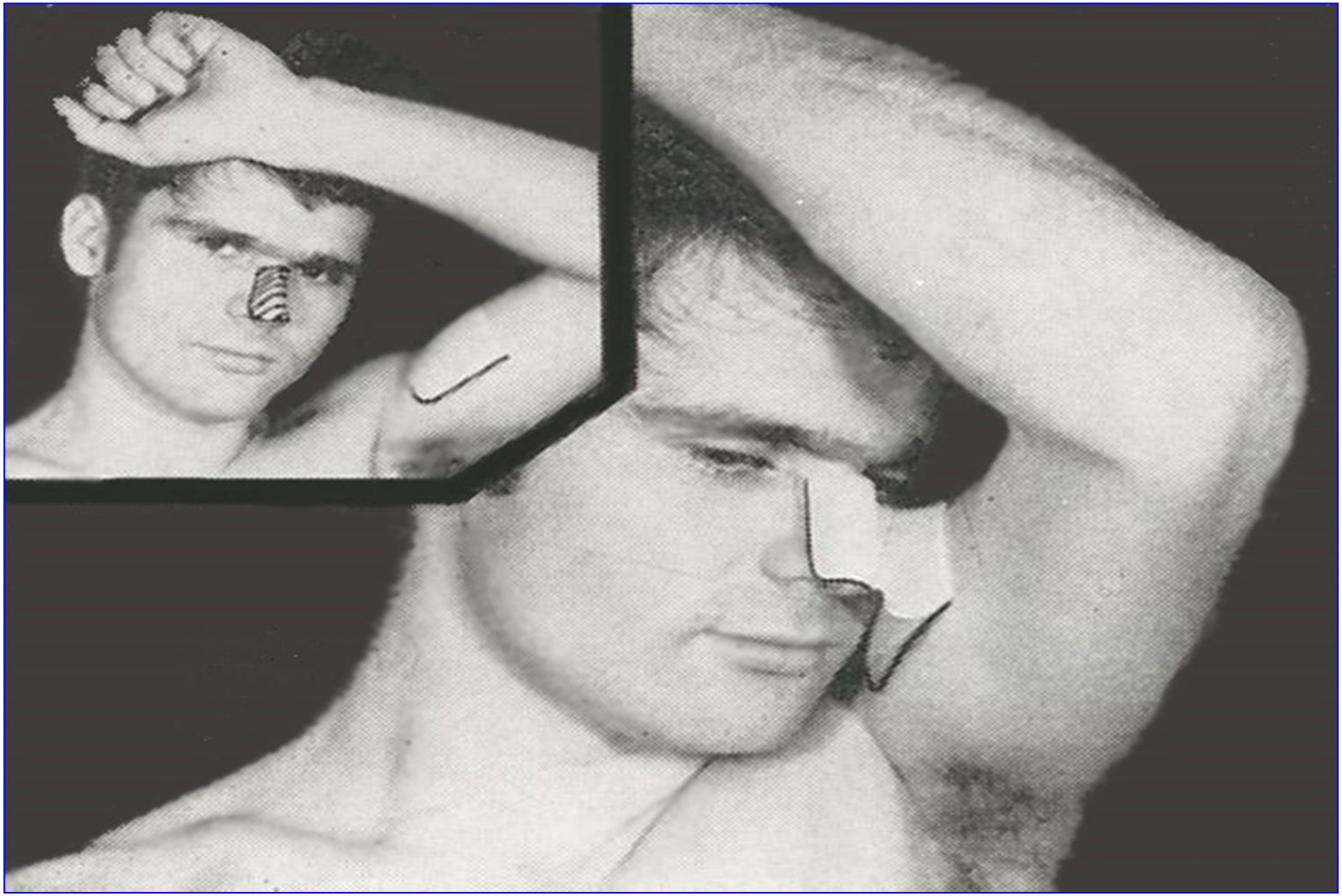
Non-free full-thickness skin grafting (with flaps)

The technique of skin harvesting and transplantation was initially described approximately 2500-3000 years ago with the Hindu Tilemaker Caste, in which skin grafting was used to reconstruct noses that were amputated as a means of judicial punishment.

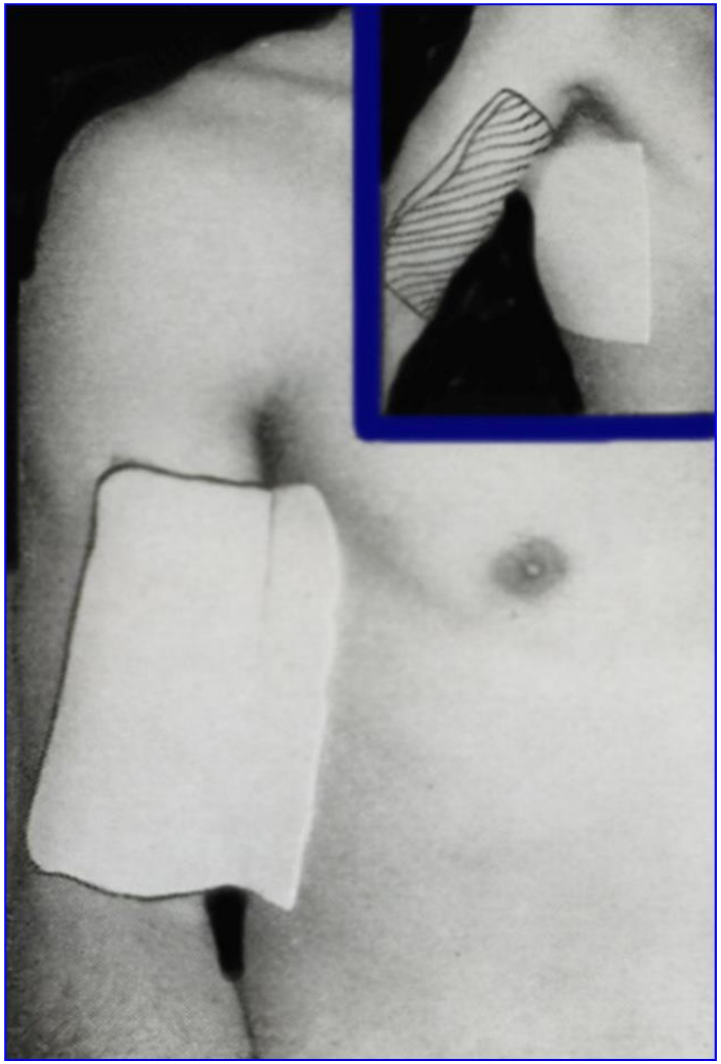


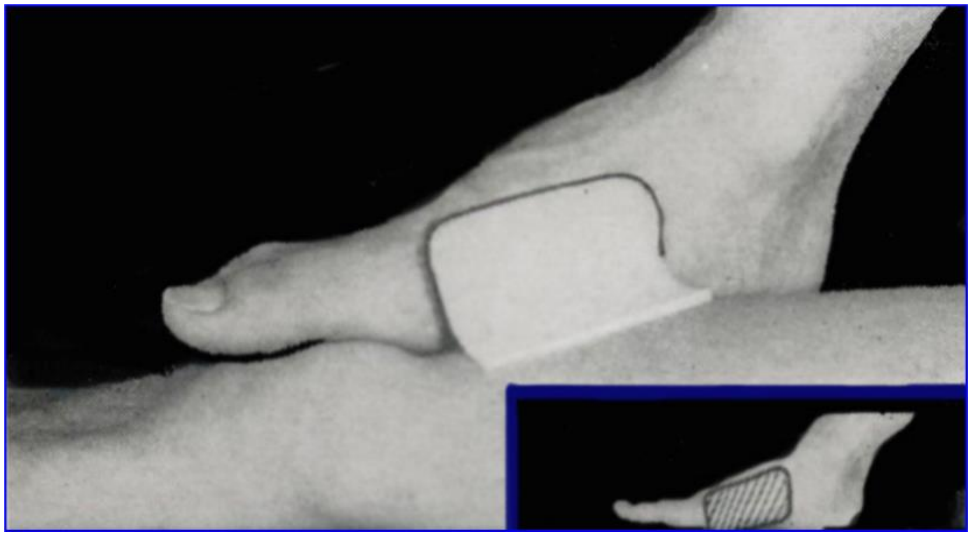
The Hindu technique of skin harvesting and transplantation used to reconstruct noses that were amputated as a means of judicial punishment.

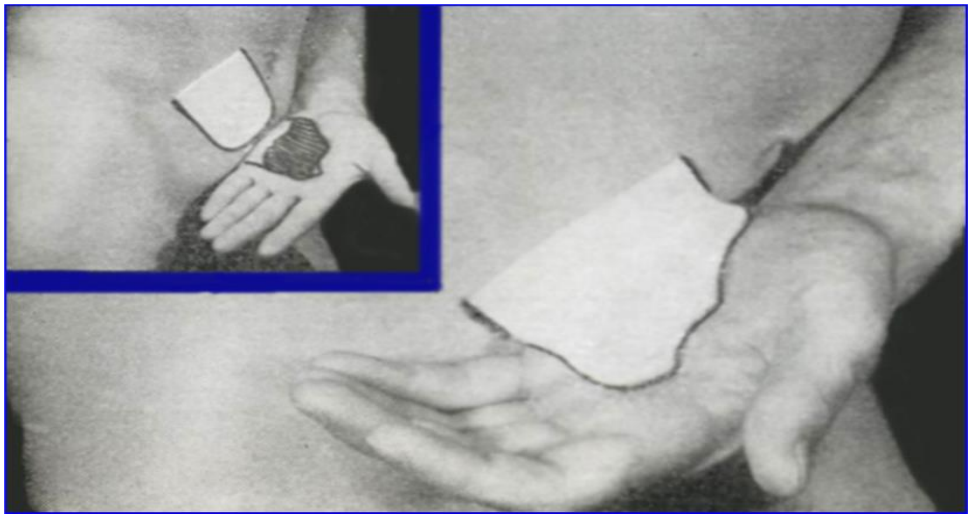
Italian method with the feeding pedicle of the skin flap



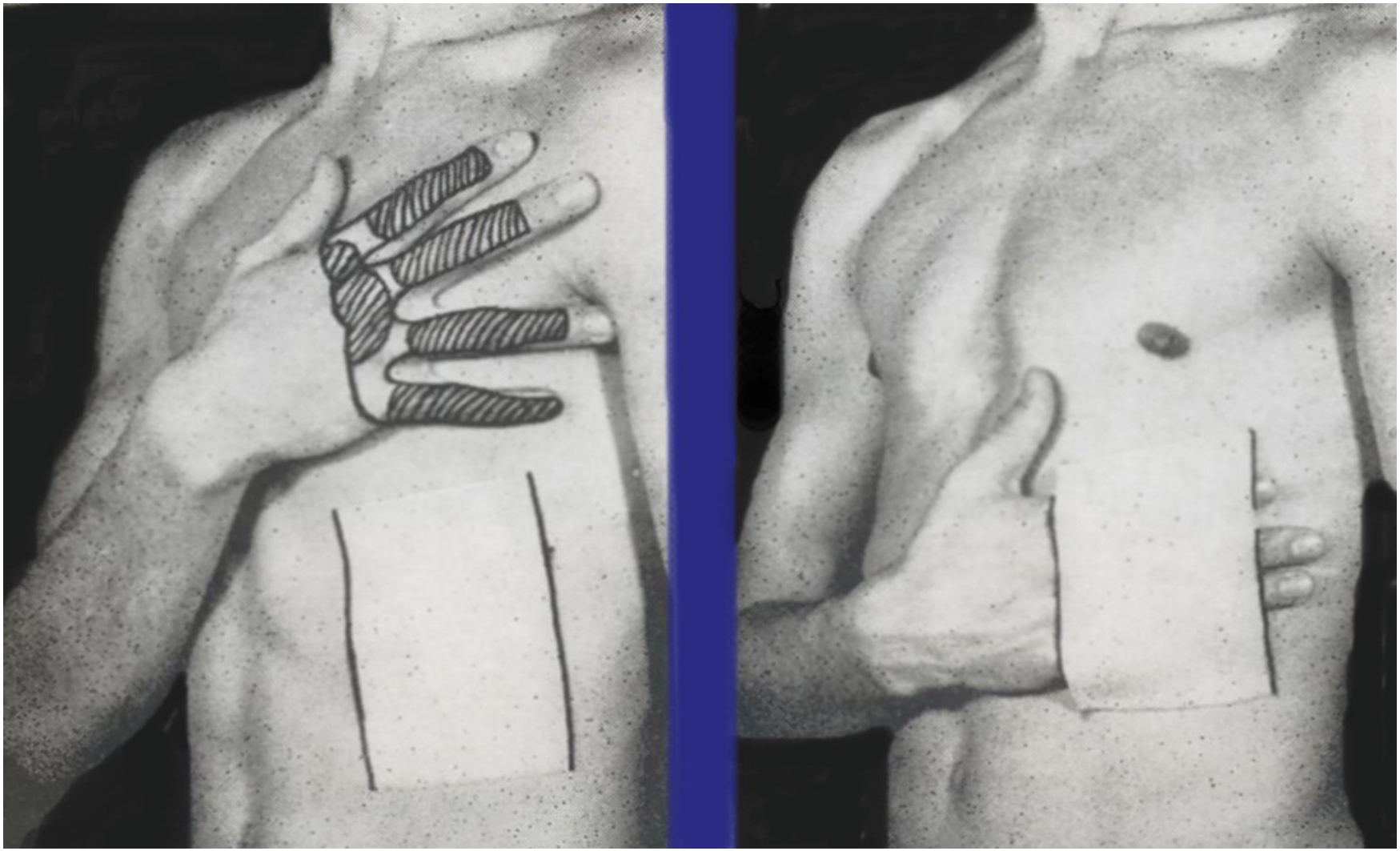
Italian method with the feeding pedicle of the skin flap: modifications





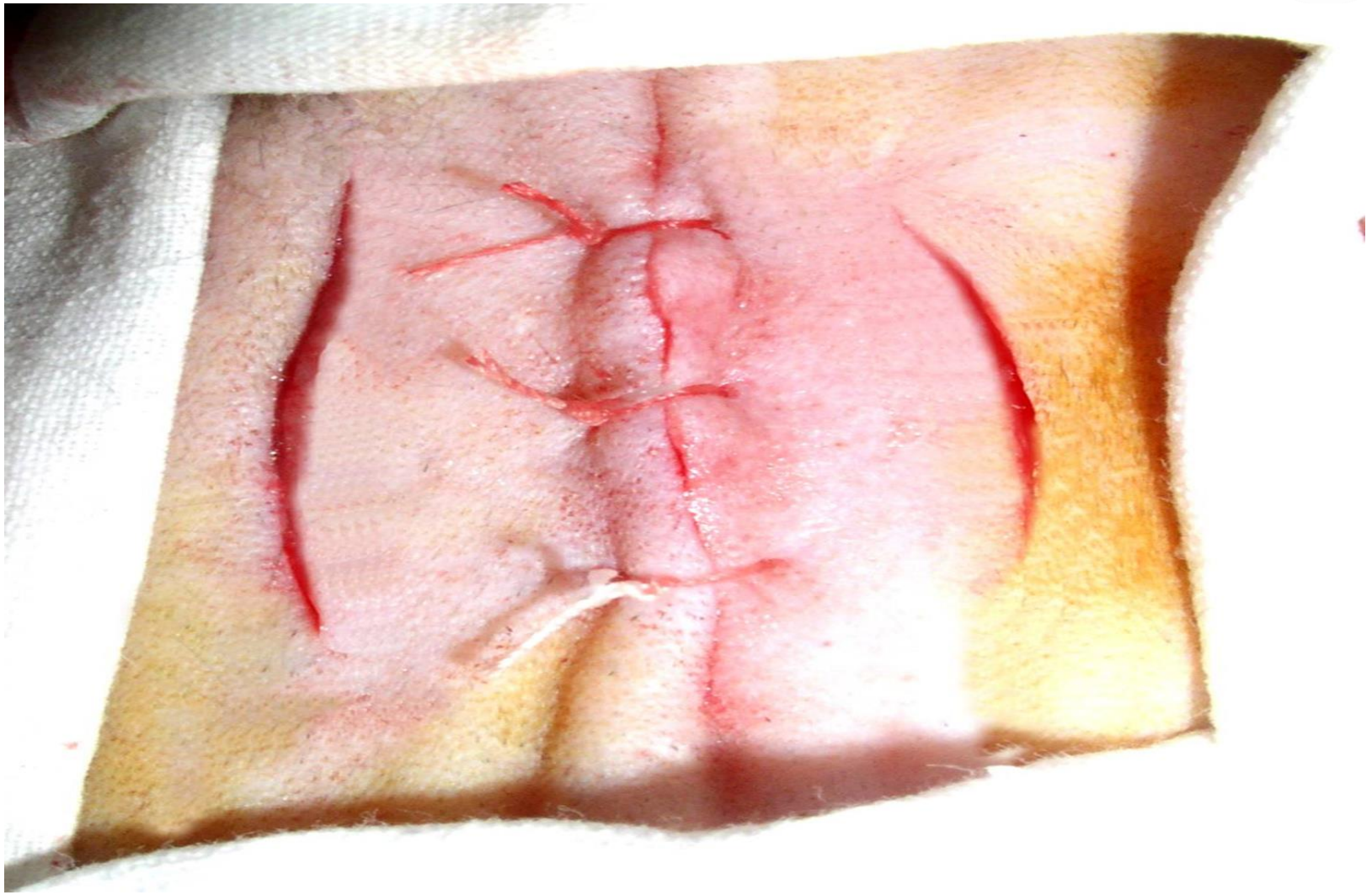


Plastic with flap on two feeding pedicles



Full-thickness skin grafting with adjacent tissues: applying relaxing cuts

Full-thickness skin grafting with adjacent tissues: applying relaxing cuts



Full-thickness skin grafting with adjacent tissues: applying relaxing cuts (notching method)

Full-thickness skin grafting with adjacent tissues: applying relaxing cuts (notching method)

Full-thickness skin grafting with adjacent tissues: formation and movement of a sliding u - shaped flap

Full-thickness skin grafting with adjacent tissues: formation and movement of a sliding u - shaped flap

Full-thickness skin grafting with adjacent tissues: modification by Limberg

Alexander Karlovich Limberg

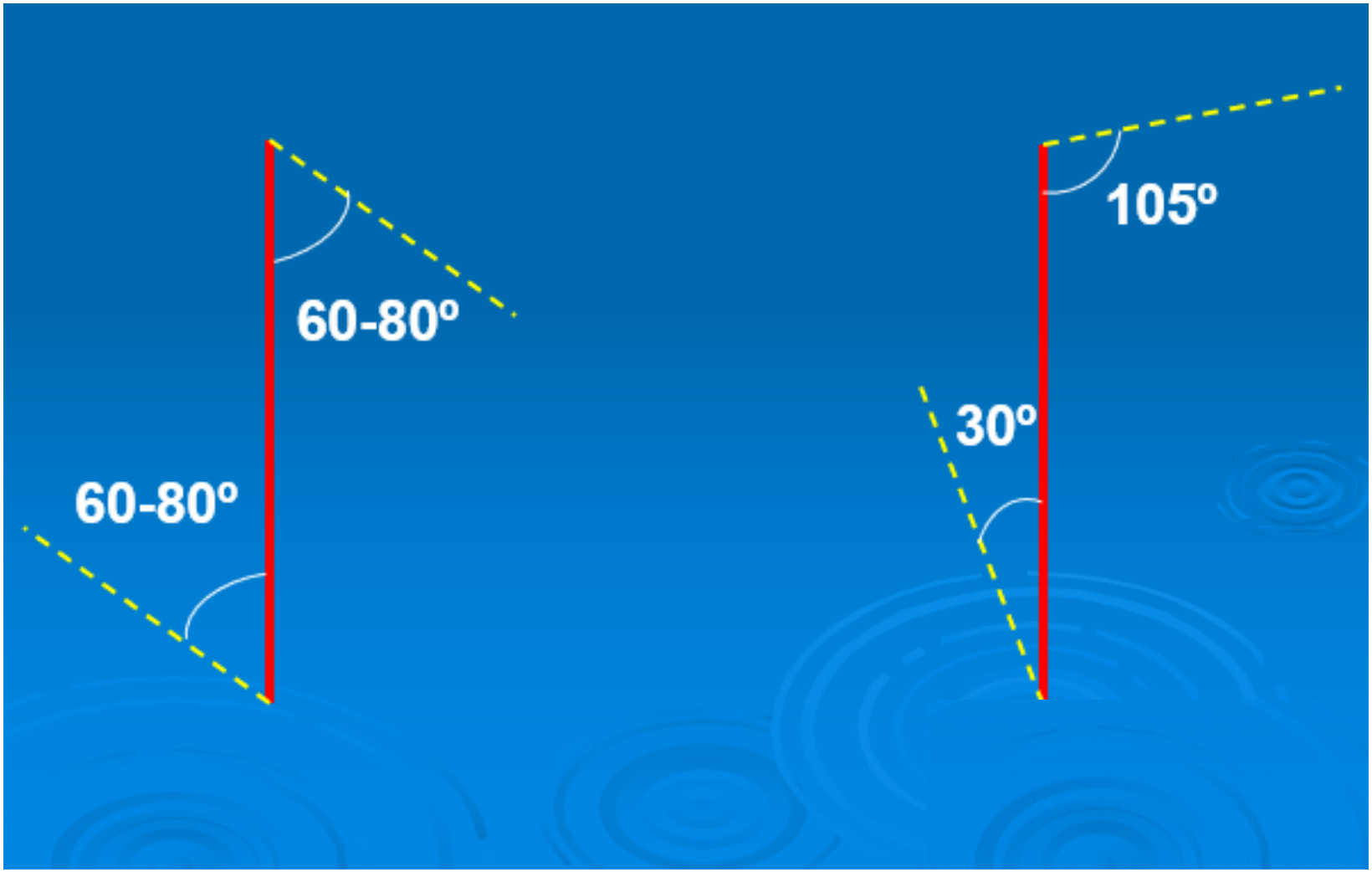
(November 14 (26), 1856,

Teve, Estonia — February 16

(March 1) 1906, Saint

Petersburg)

Full-thickness skin grafting with adjacent tissues: modification by Limberg (plastic with counter flaps – symmetrical or asymmetrical)



Full-thickness skin grafting with adjacent tissues: modification by Limberg

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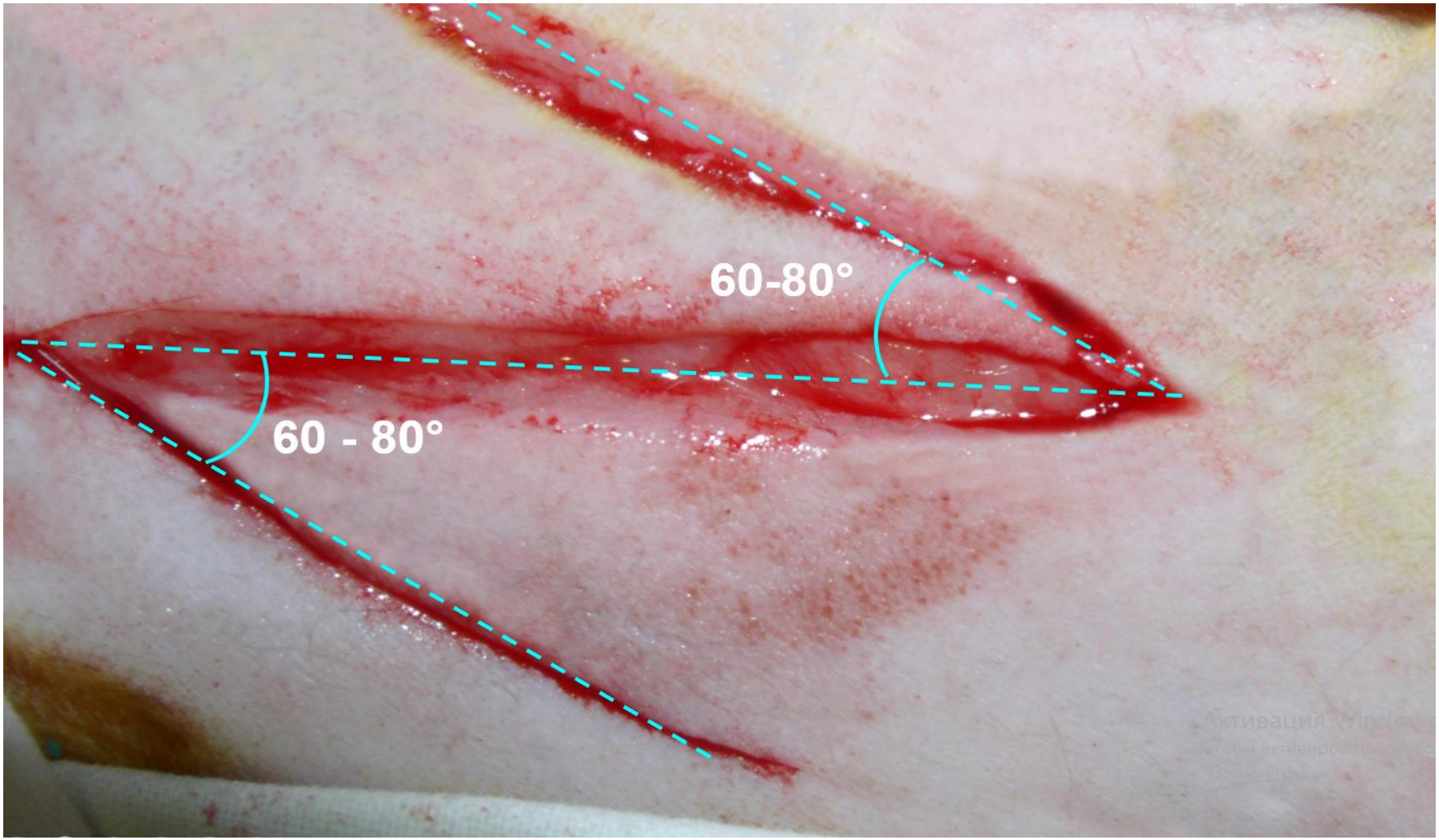
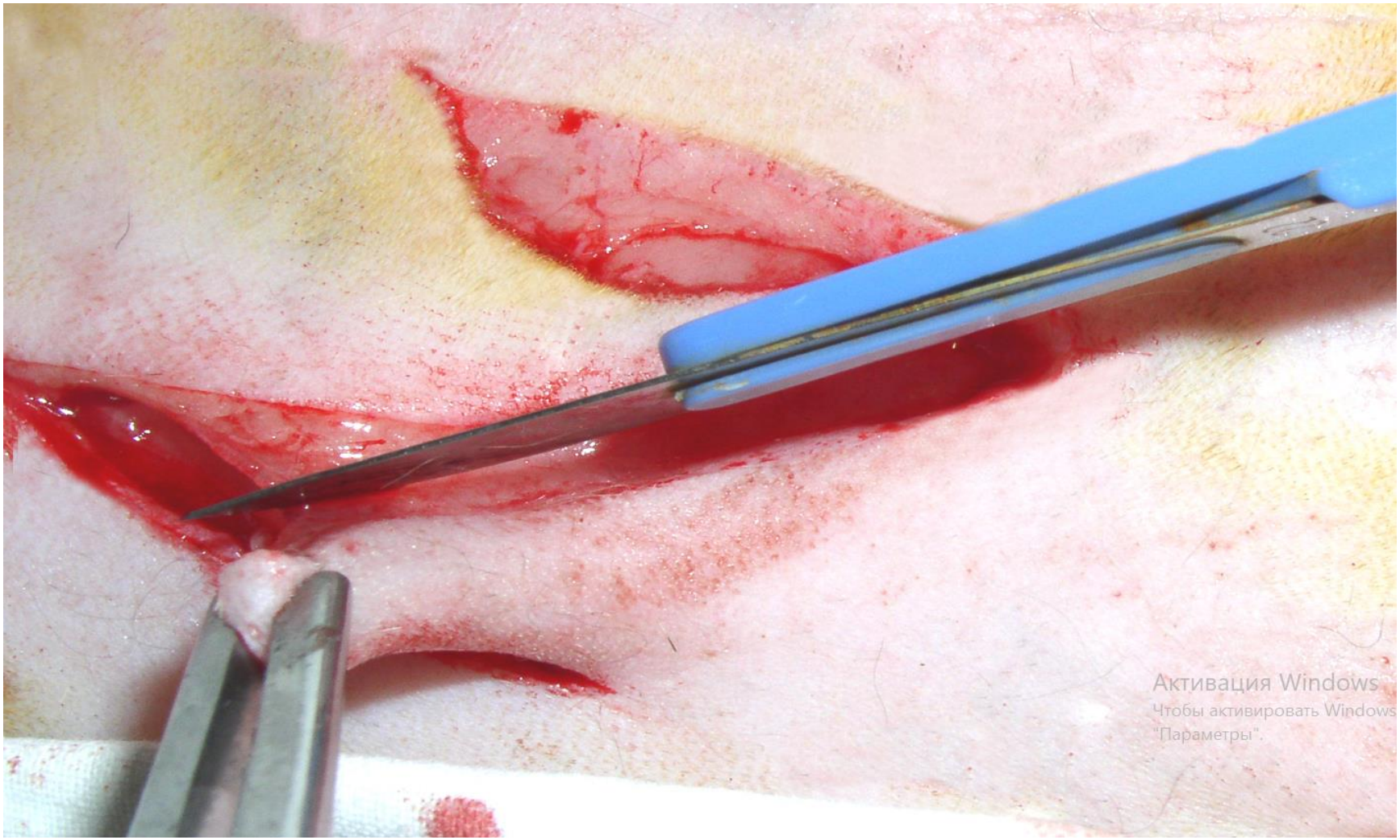
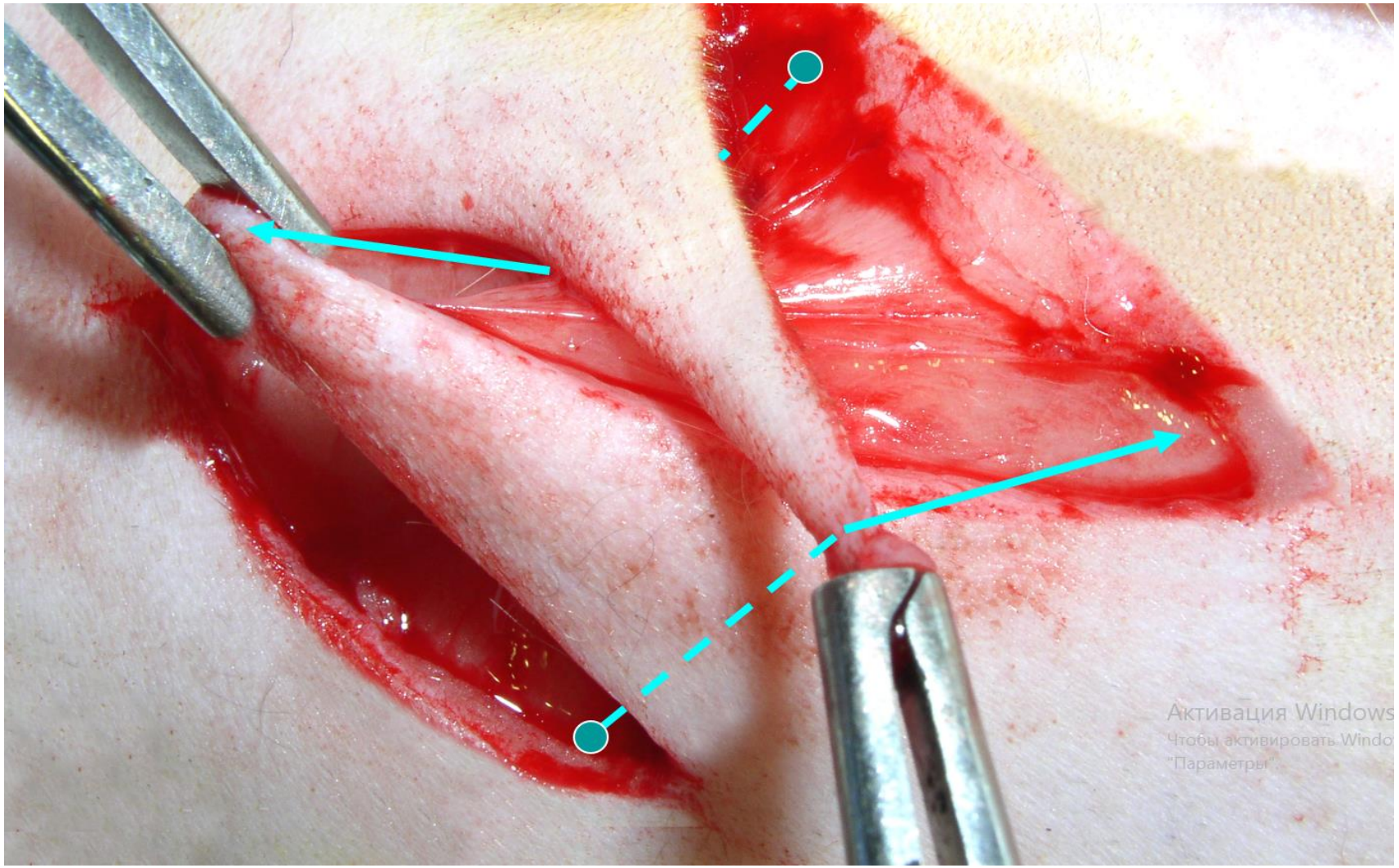


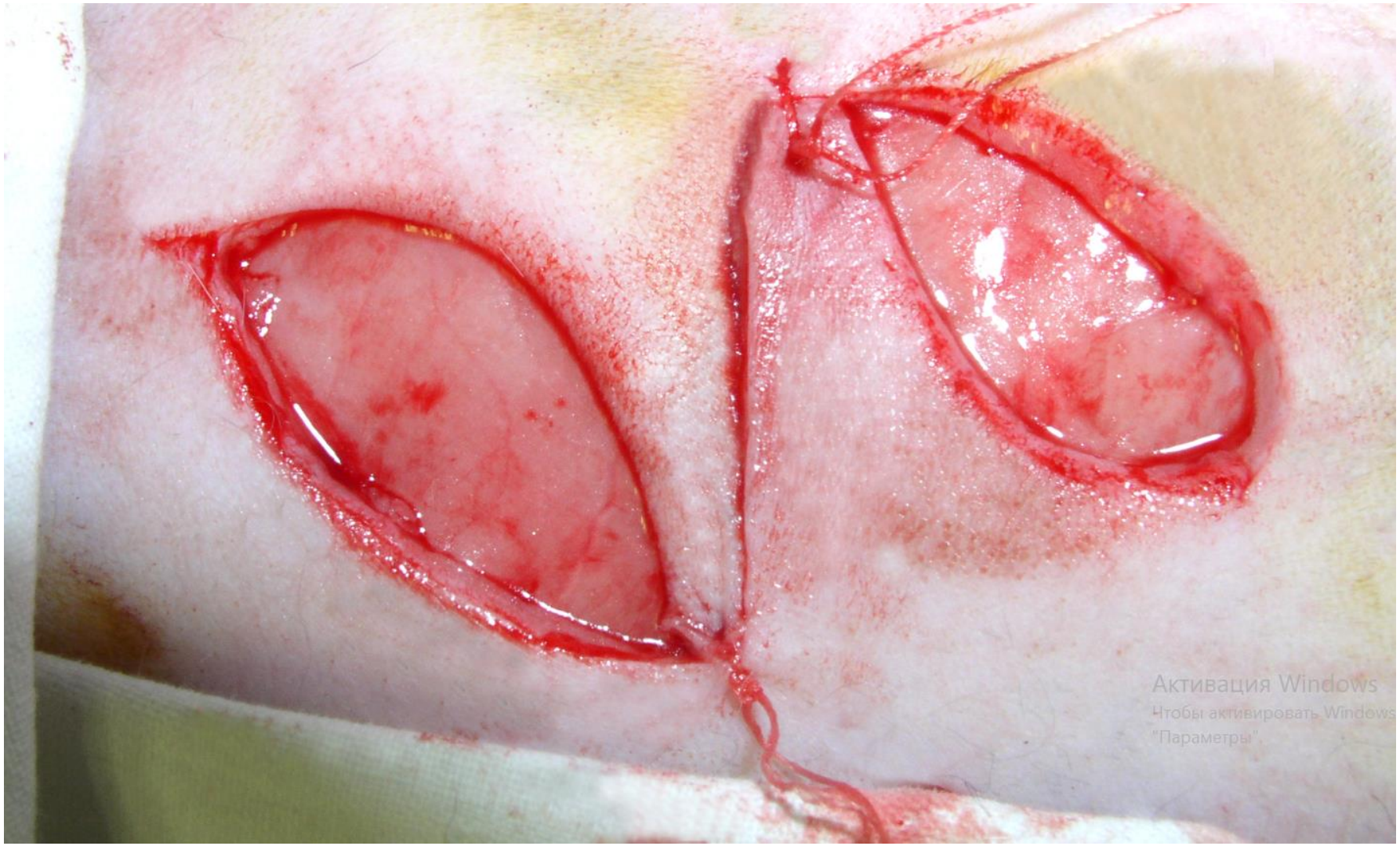
Full-thickness skin grafting with adjacent tissues: modification by Limberg



Full-thickness skin grafting with adjacent tissues: modification by Limberg



Full-thickness skin grafting with adjacent tissues: modification by Limberg



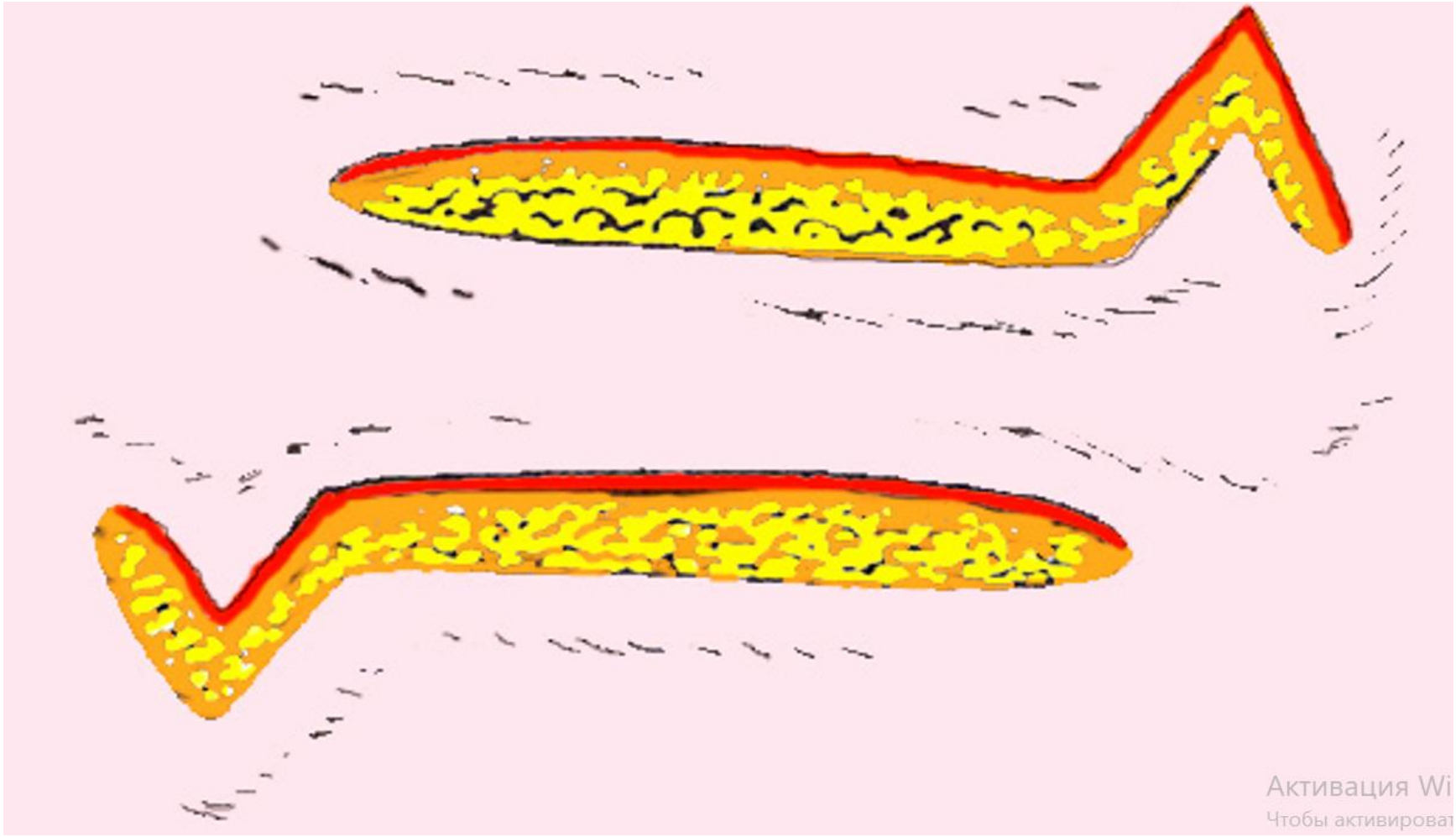
Full-thickness skin grafting with adjacent tissues: modification by Limberg

Non-free full-thickness skin grafting (with flaps)

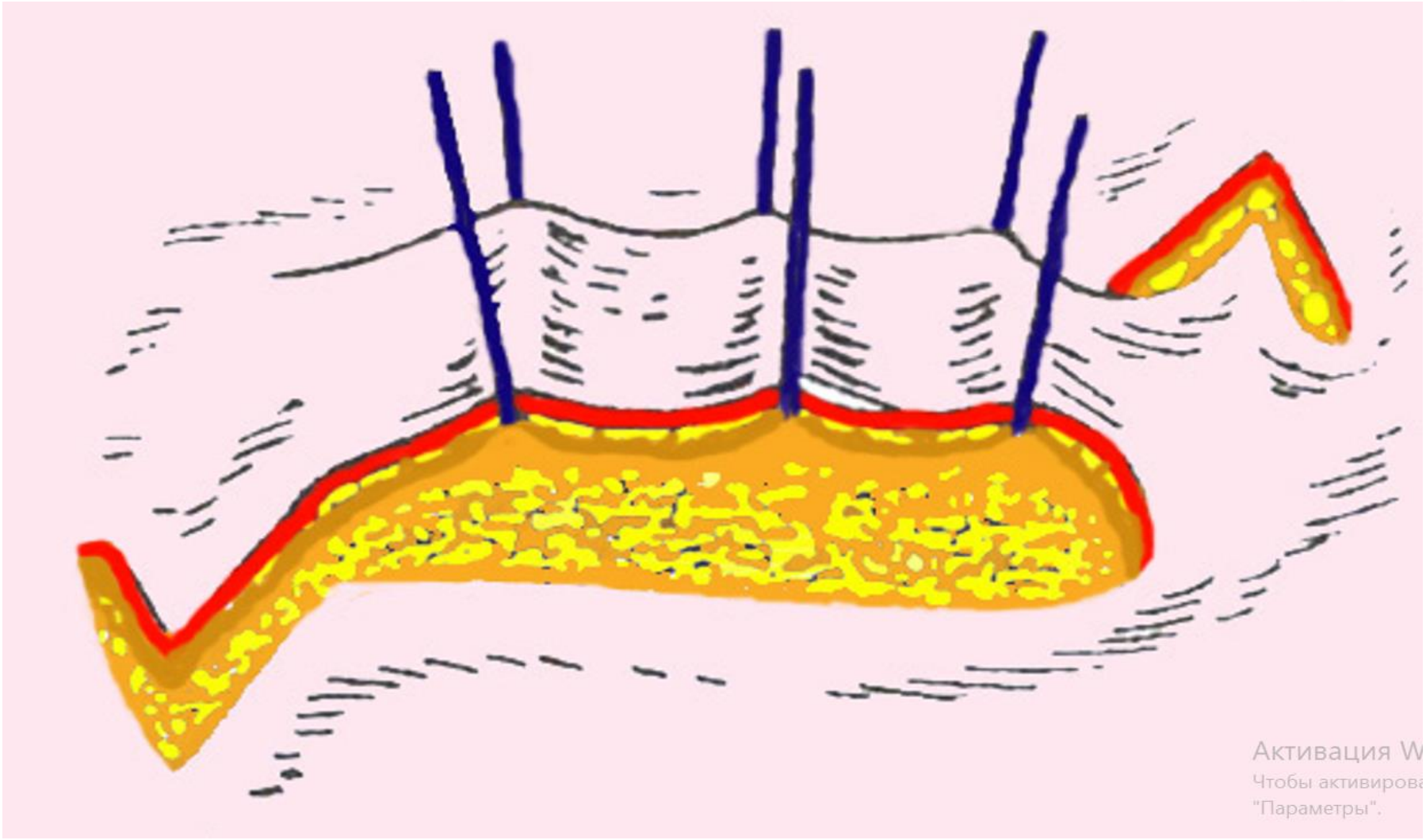
Vladimir Petrovich Filatov (Russian: Владимир Филатов, 15 [O.S. 27] February 1875 in Mikhaylovka, Penza Governorate, Russian Empire – 30 October 1956 in Odessa, Ukrainian SSR) was a Russian Empire and Soviet ophthalmologist and surgeon best known for his development of tissue therapy. The tubed pedicle flap ("walking skin flap") was first described by Filatov in 1917.

Vladimir Petrovich Filatov

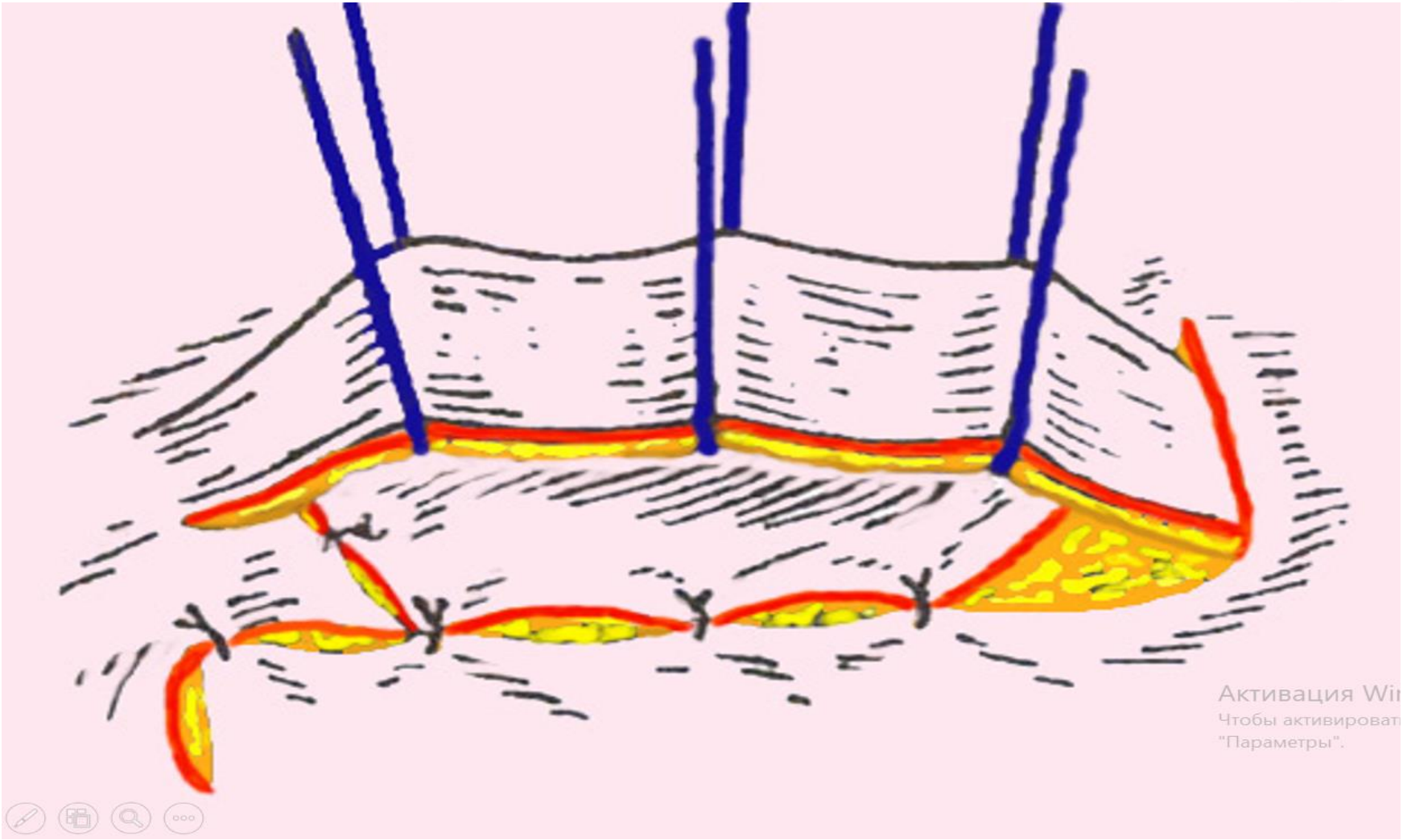
The stage of stem formation



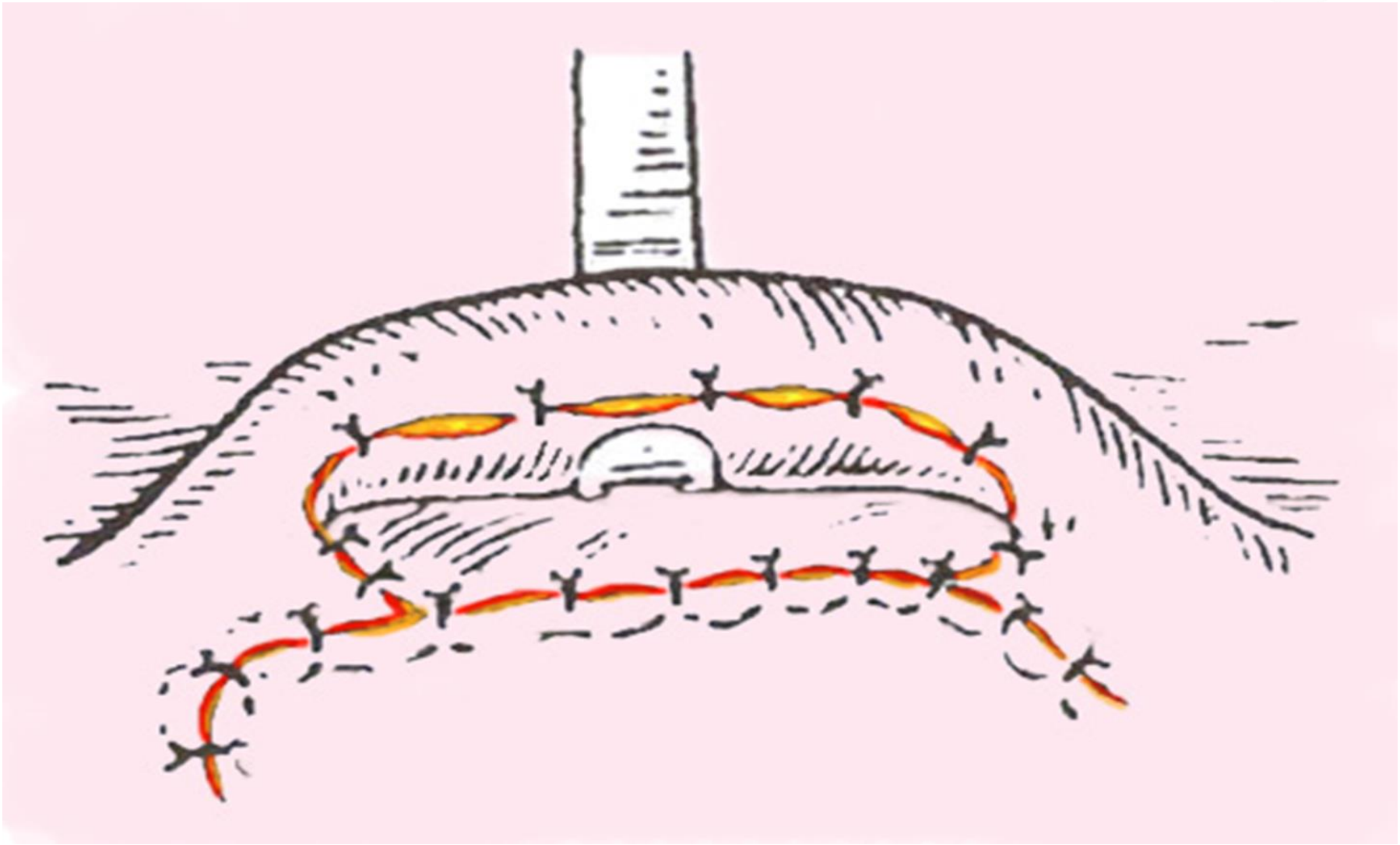
The stage of stem formation



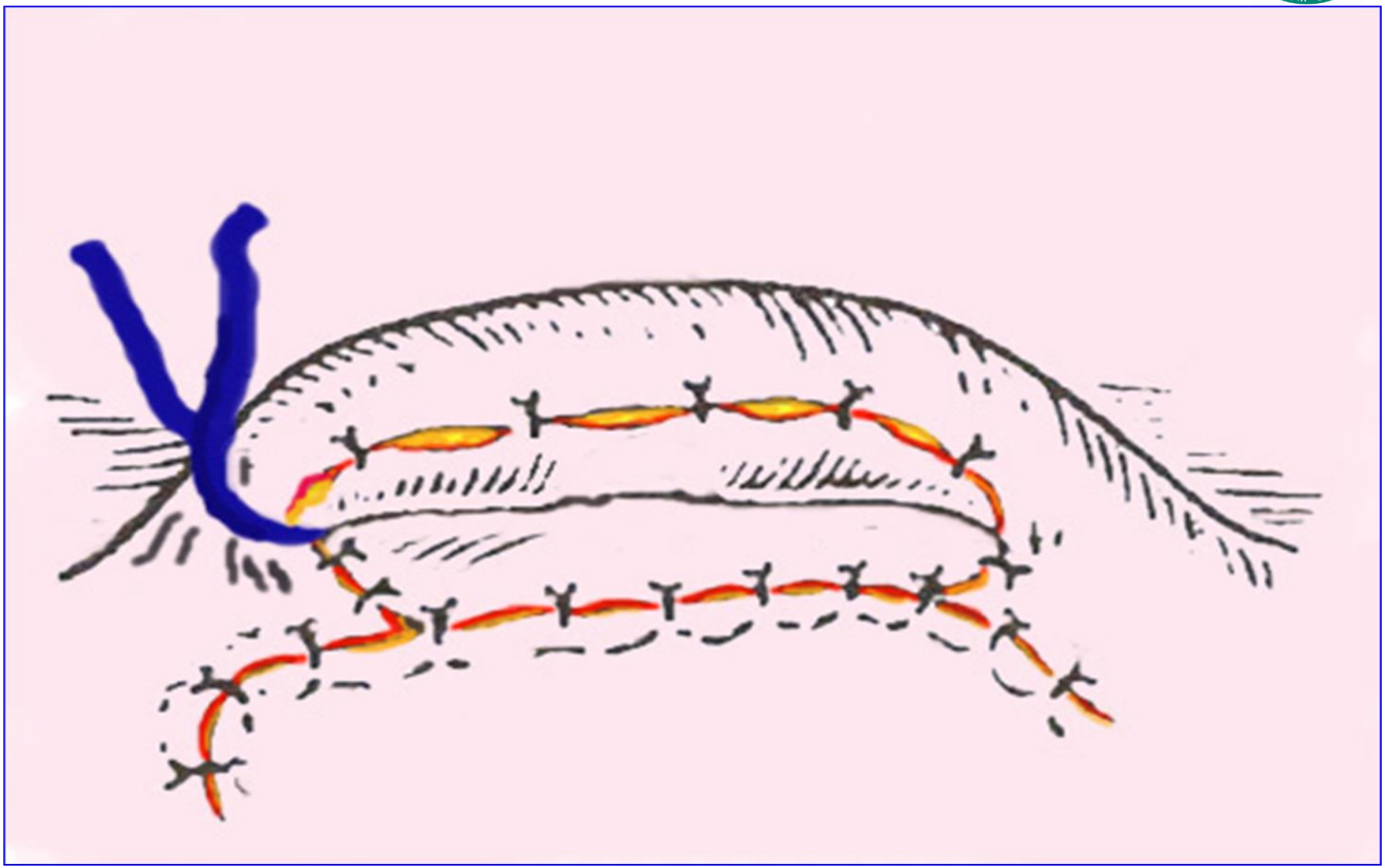
The stage of stem formation



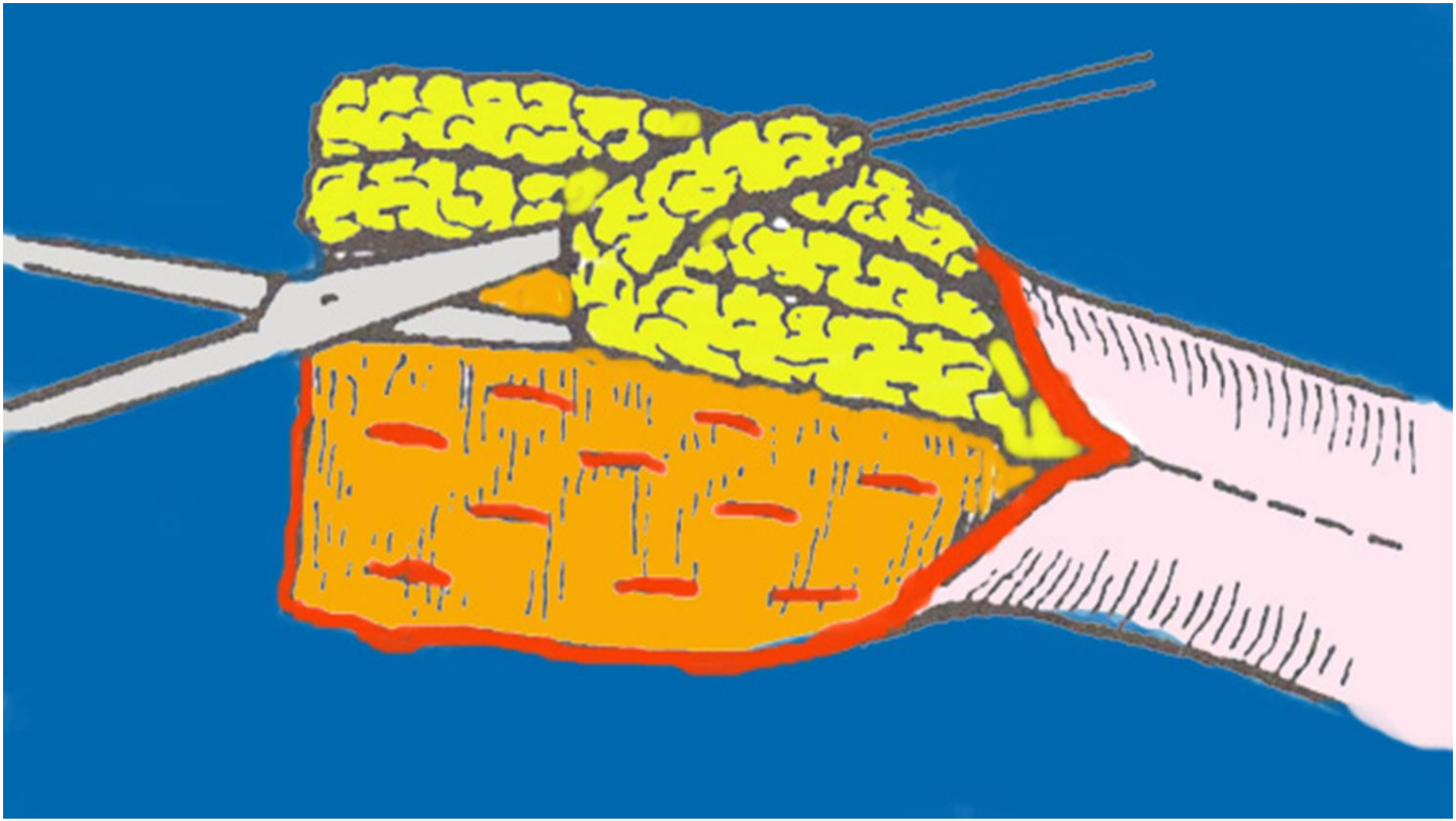
The stage of stem formation



Stem training stage

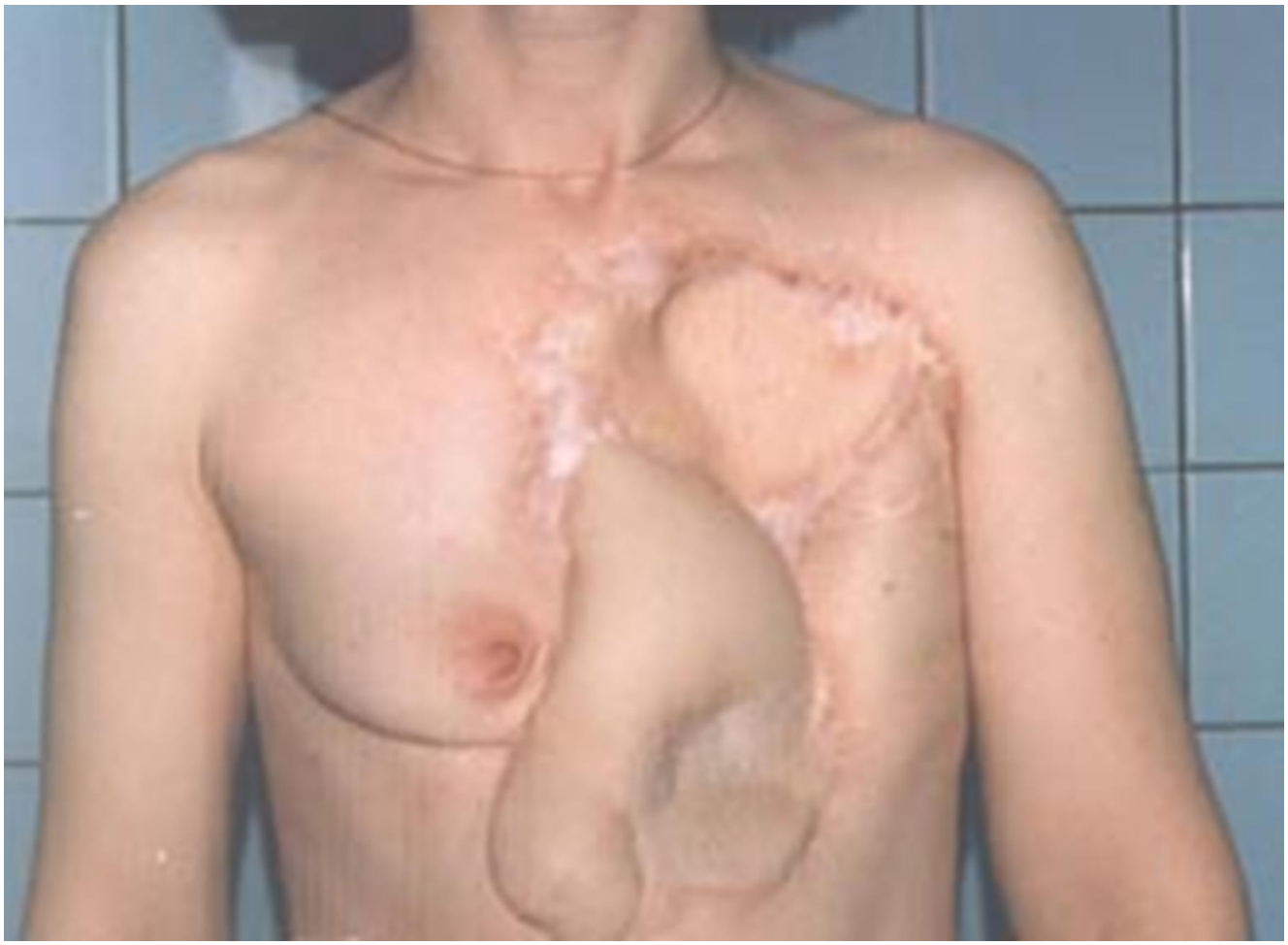


The stage of spreading the stem



The use of the Filatov stem in clinical practice

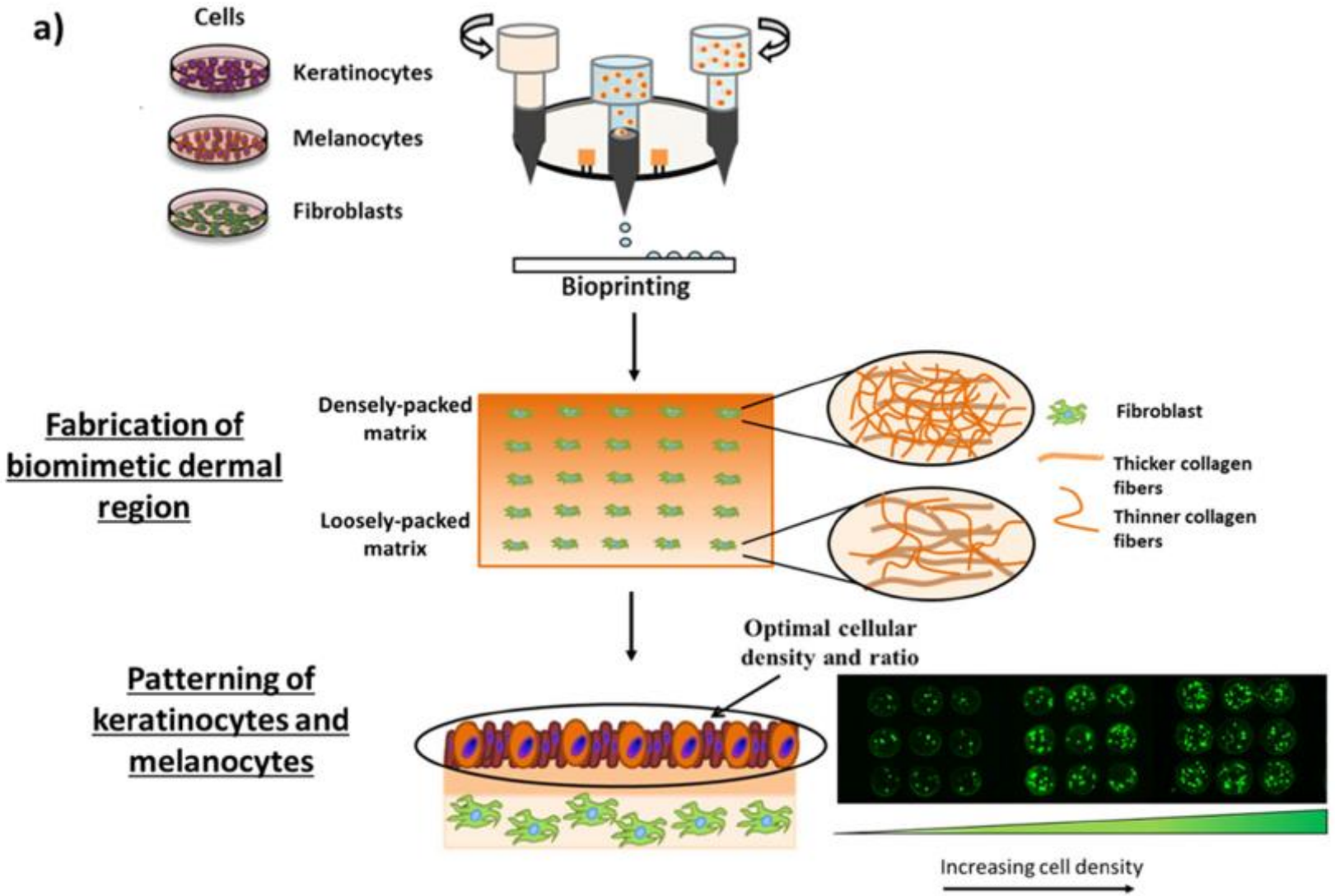
The use of the Filatov stem in clinical practice



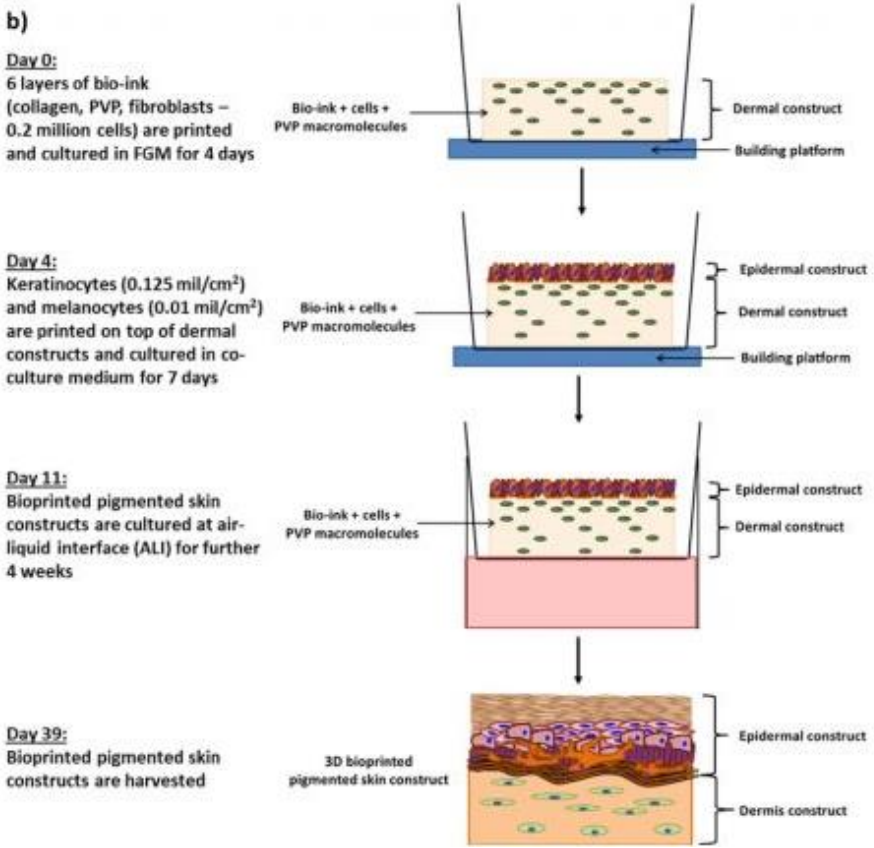
Alternatives and future expectations

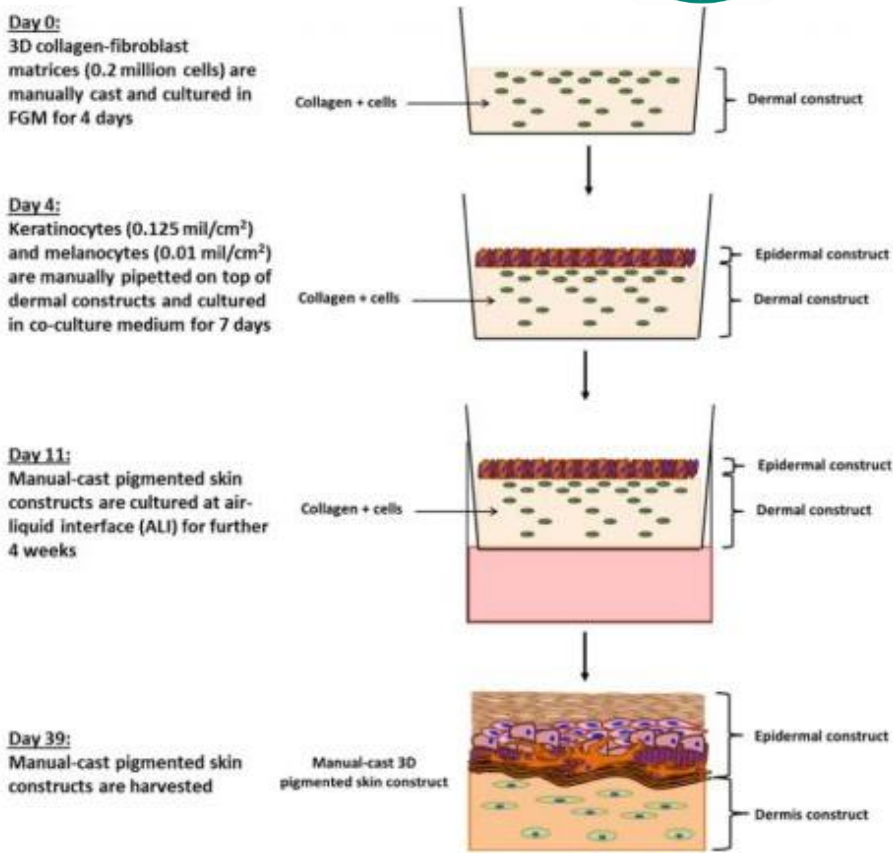
Cell cultured epithelial autograft (CEA) procedures take skin cells from the person needing the graft to grow new skin cells in sheets in a laboratory; because the cells are taken from the person, that person's immune system will not reject them. However because these sheets are very thin (only a few cell layers thick) they do not stand up to trauma, and the "take" is often less than 100%. Newer grafting procedures combine CEA with a dermal matrix for more support.

3D printing with multiple types of cells



3D printing with multiple types of cells





Left: 3D bioprinted sample vs Right: a manually cast sample

Alternatives and future expectations

There has been great progress in the development of artificial skin replacement products in recent years. Although nothing works as well as the patient's own skin, artificial skin products are important due to the limitation of available skin for allografting in severely burned patients. Unlike allografts and xenografts, artificial skin replacements are not rejected by the patient's body and actually encourage the generation of new tissue.

Alternatives and future expectations

Artificial skin usually consists of a synthetic epidermis and a collagen-based dermis. The artificial dermis consists of fibers arranged in a lattice that act as a template for the formation of new tissue. Fibroblasts, blood vessels, nerve fibers, and lymph vessels from surrounding healthy tissue grow into the collagen lattice, which eventually dissolves as these cells and structures build a new dermis.

Alternatives and future expectations

The synthetic epidermis, which acts as a temporary barrier during this process, is eventually replaced with a split-thickness autograft or with an epidermis cultured in the laboratory from the patient's own epithelial cells.

Sources

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- https://www.intechopen.com/chapters/18925#B23