Skin wound healing: The miracle of in vivo repair from “bleeding” to “scarless”

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2025.10.30

如果身体自带“撤销键”？

Contents

The structure and function of the skin

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脸皮厚

Is the face the thickest (skin)?

Interesting skin knowledge

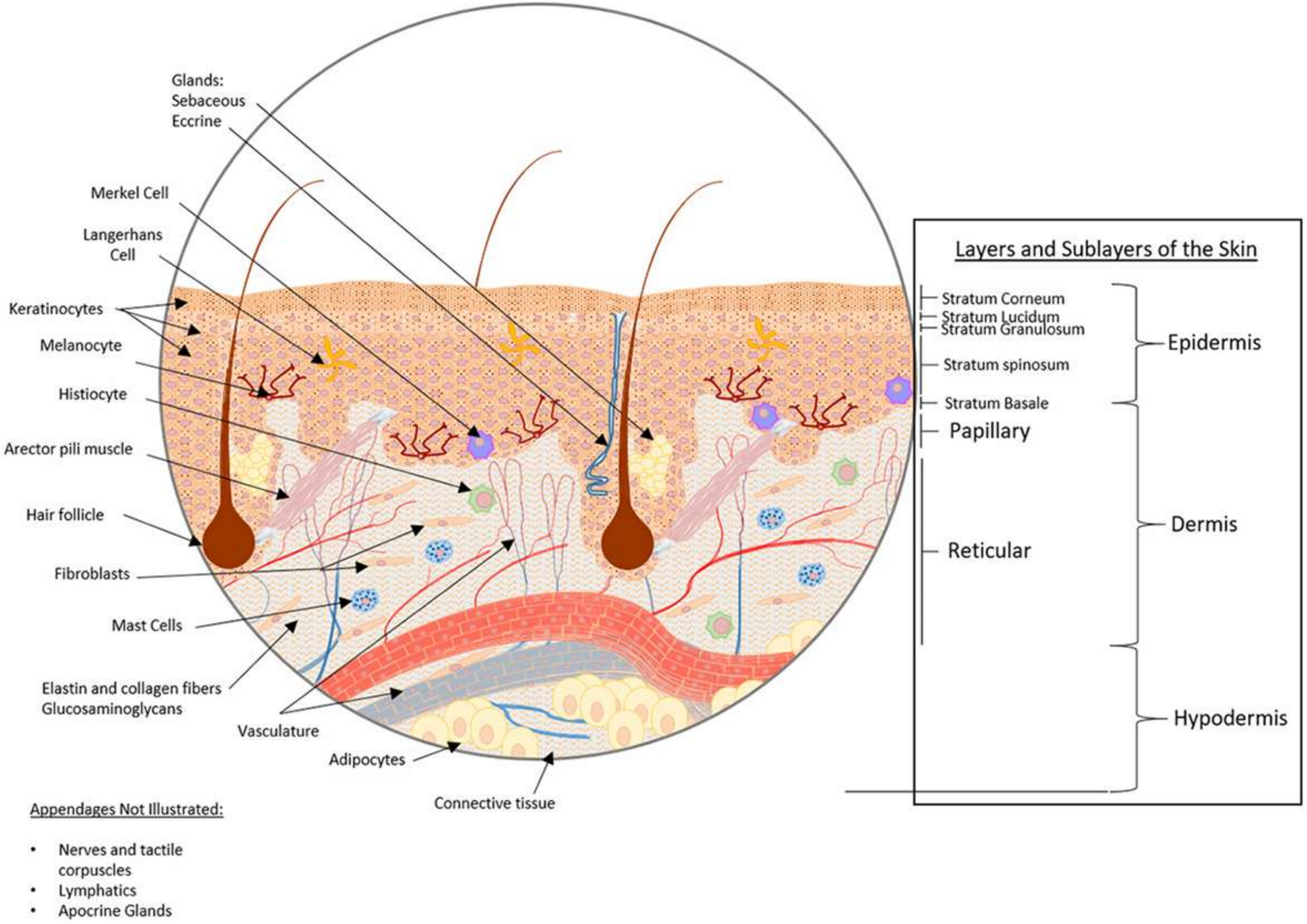
类别	部位	平均厚度	特点说明
🧱 **最厚的皮肤**	**足底（Sole）**、**手掌（Palm）**	**约 3–4 mm**（角质层可达 1.5 mm）	角质层极厚，适应高摩擦与压力；无毛发、皮脂腺丰富；防滑、防裂。
🪶 **最薄的皮肤**	**眼睑（Eyelid）**	**约 0.3–0.5 mm**（角质层仅约 0.05 mm）	血管丰富，皮下组织疏松，易肿胀、起皱；是全身最脆弱的皮肤区域。

- **皮肤厚不代表角质层厚**：例如背部皮肤真皮厚，但角质层不厚。
- **女性皮肤一般比男性薄约 10–20%**，但皮下脂肪多，触感柔软。
- **老化导致皮肤变薄**，主要是**真皮层胶原减少**，不是角质层变薄。
- **皮肤是人体最大的器官**，覆盖面积约为 2 平方米

Content

- What is the basic structure of the skin?
- What are the main functions of the skin in the human body?

Overview of Skin Structure

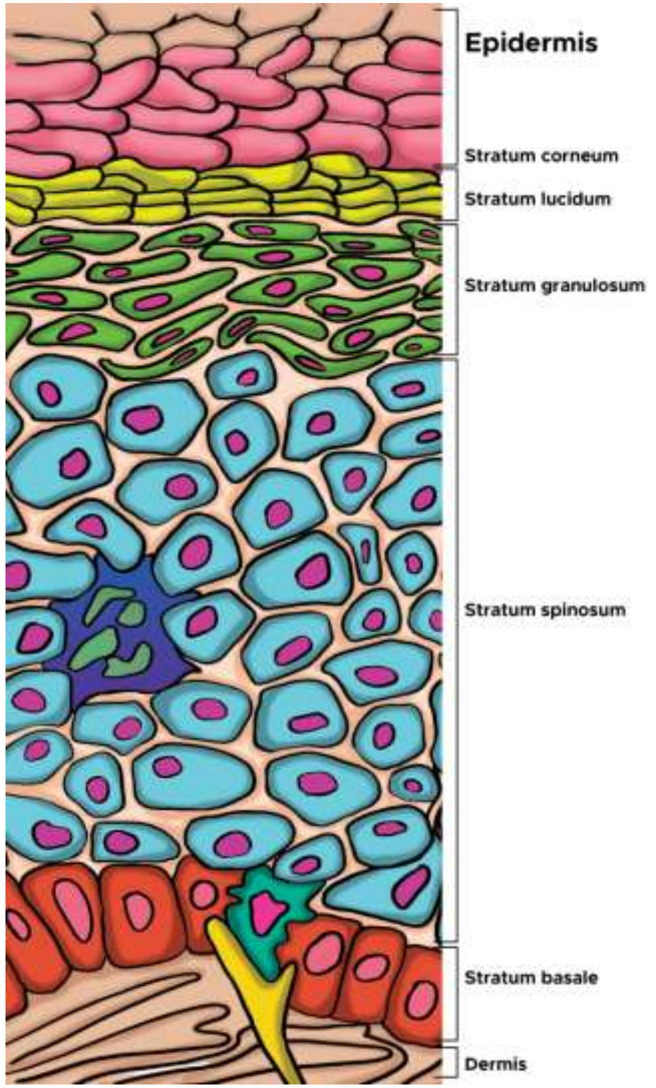


Randall et al., 2018, *Frontiers in Bioengineering and Biotechnology*

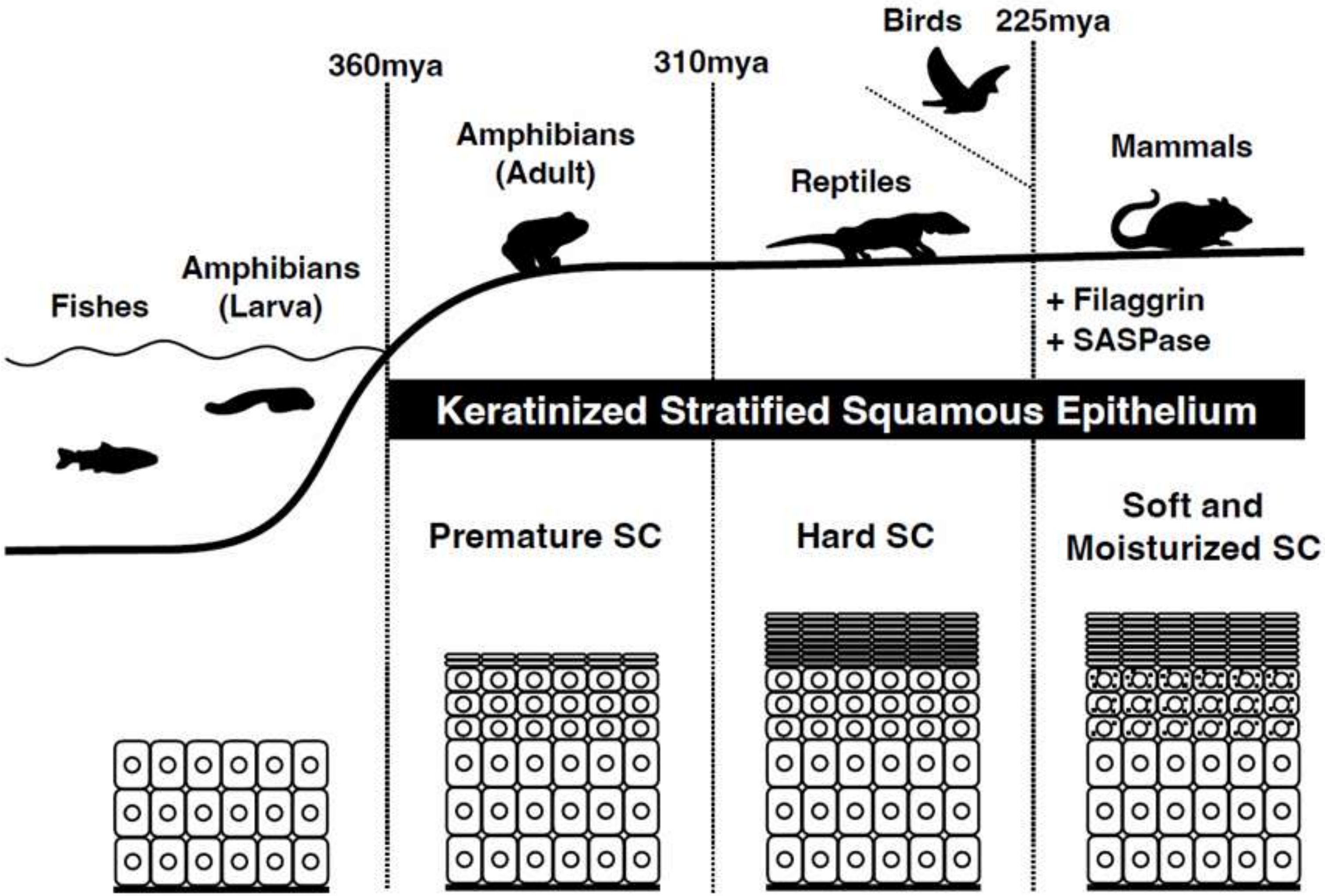
Structure and Function of Each Layer of the Epidermis

层次	主要组成
基底层（Stratum Basale）	默克尔细胞、角质形成细胞、黑素细胞
棘层（Stratum Spinosum）	多层角质形成细胞，朗格汉斯细胞
颗粒层（Stratum Granulosum）	含脂质颗粒的角质形成细胞
透明层（Stratum Lucidum）	薄层致密的死亡细胞（仅厚皮肤存在）
角质层（Stratum Corneum）	角化死亡细胞（角质细胞）

特性	主要功能
与真皮相邻，具**有丝分裂活性**	产生新的角质形成细胞，决定皮肤颜色，机械感知
细胞呈“棘状”外观	提供**结构强度**与免疫功能
细胞核逐渐消失，是“活细胞”与“角化层”的**过渡区**	形成**屏障脂质**，维持防水性
透明、无核、致密	增强手掌与足底等厚皮肤的**防护作用**
最外层，无核、富含角蛋白	形成**防水屏障**，抵御外界刺激与机械损伤

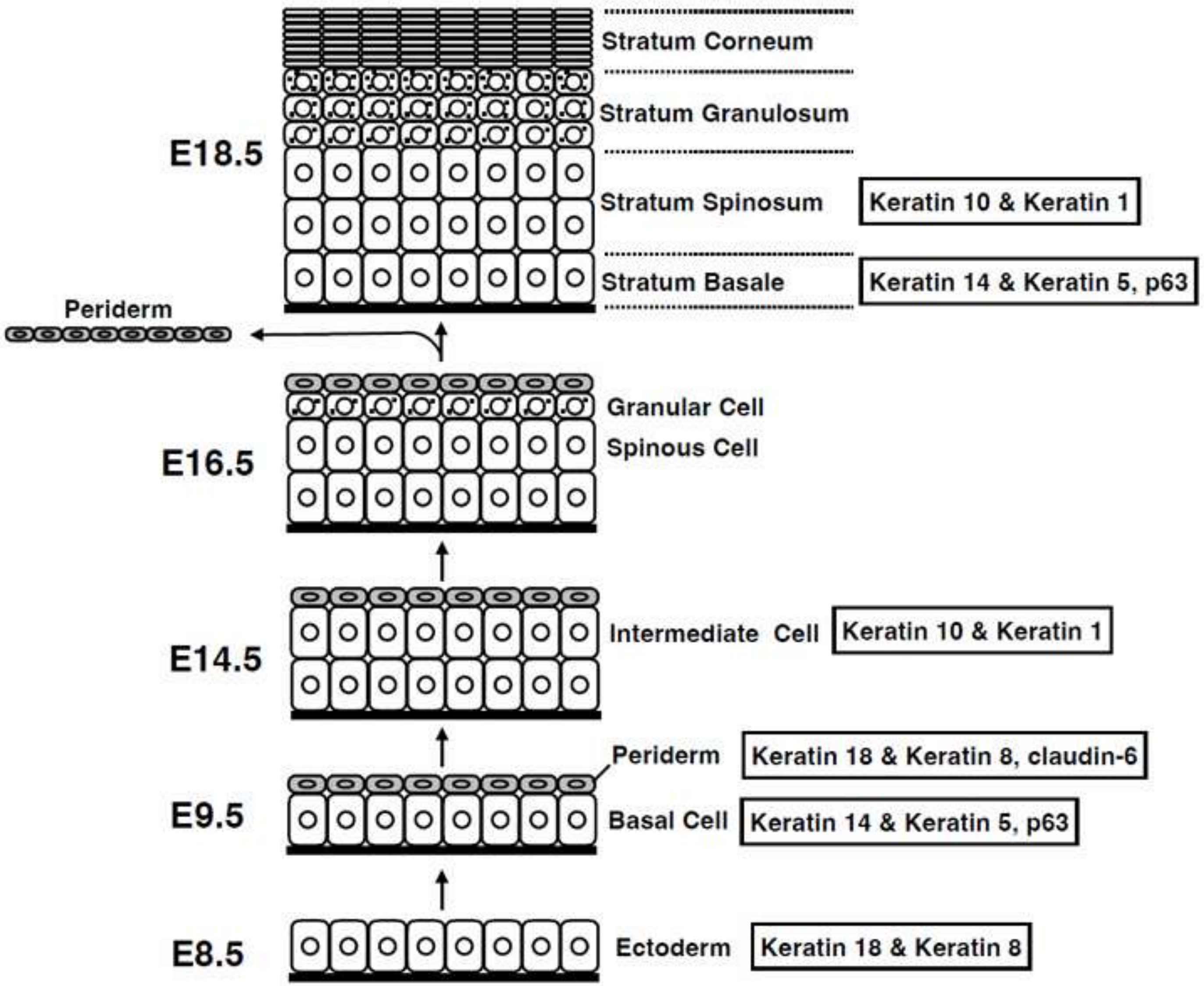


Evolution from amniotes to mammals



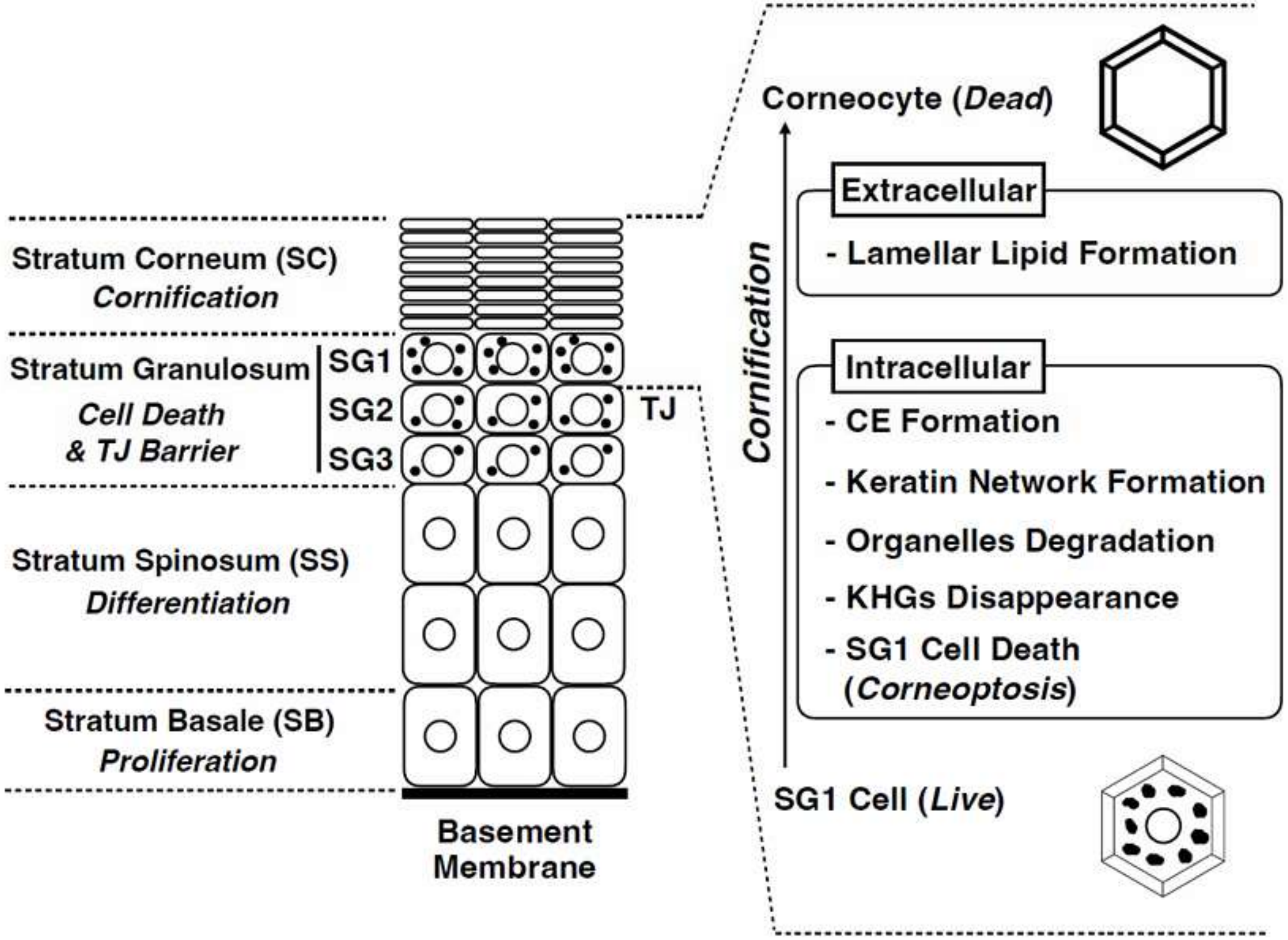
Matsui, T et al., 2023, *J Dev Biol*

Development of the epidermis



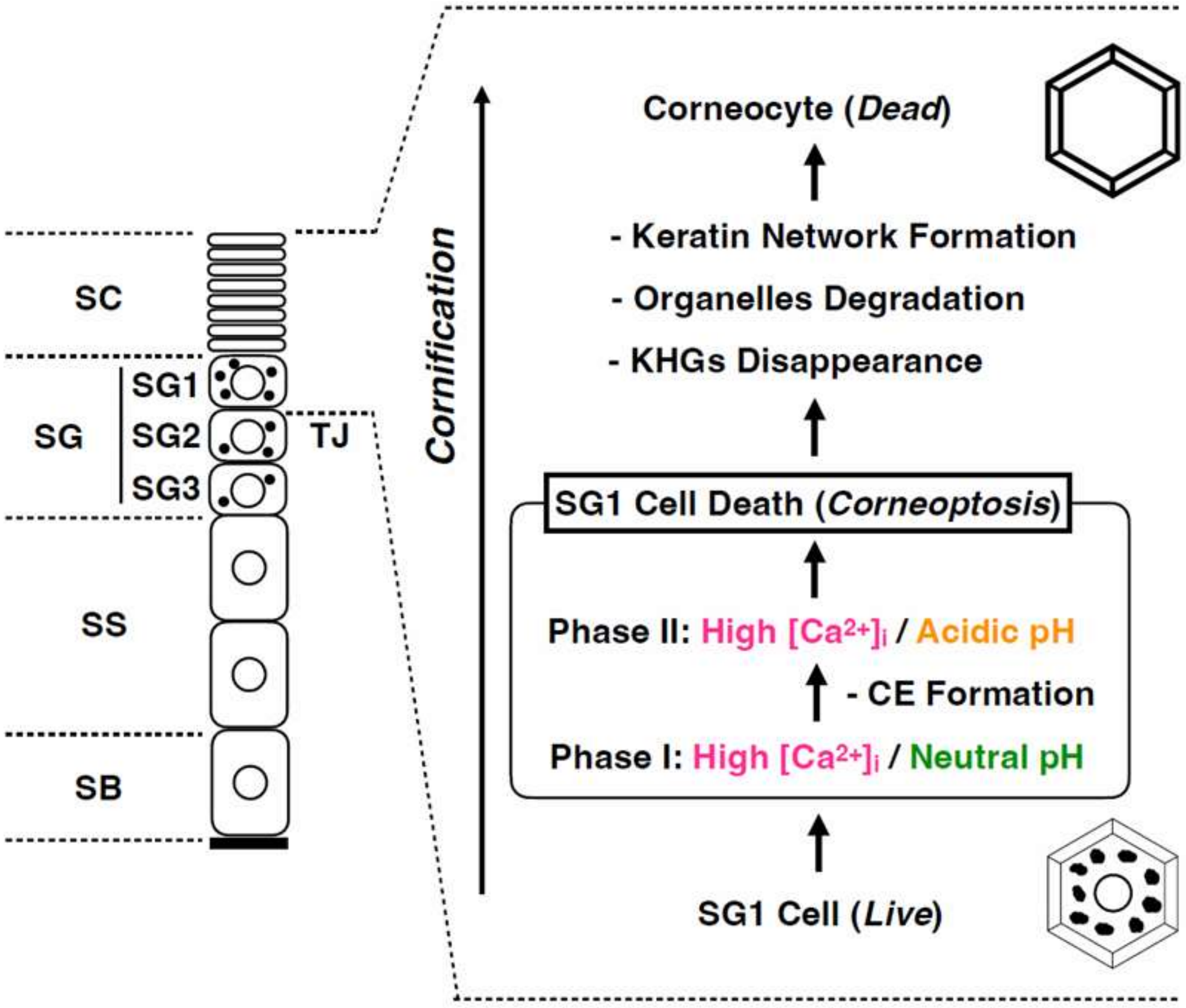
Matsui, T et al., 2023, *J Dev Biol*

Structure of the mammalian epidermis and major cornification processes



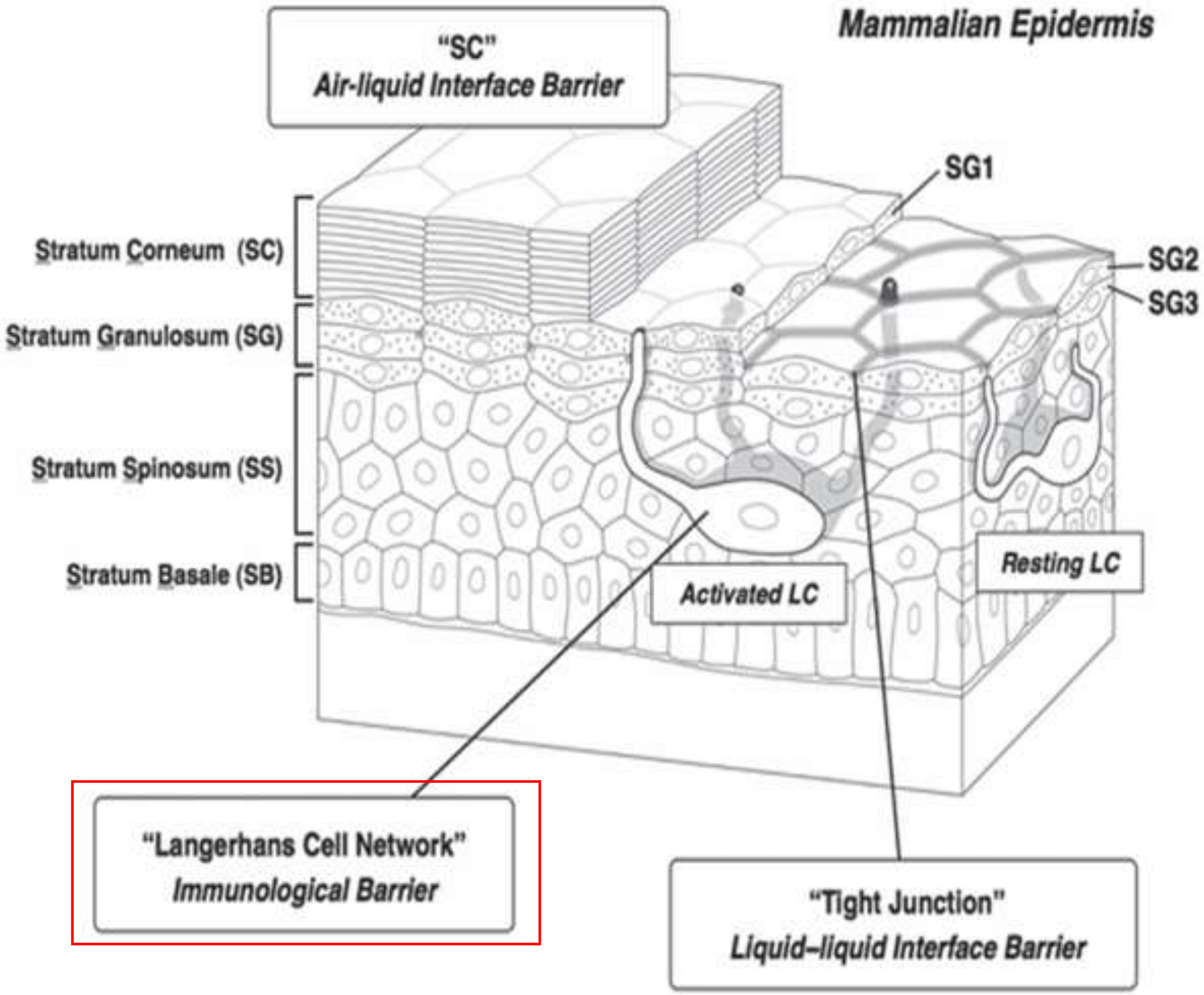
Matsui, T et al., 2023, *J Dev Biol*

Functional cell death: Corneoptosis



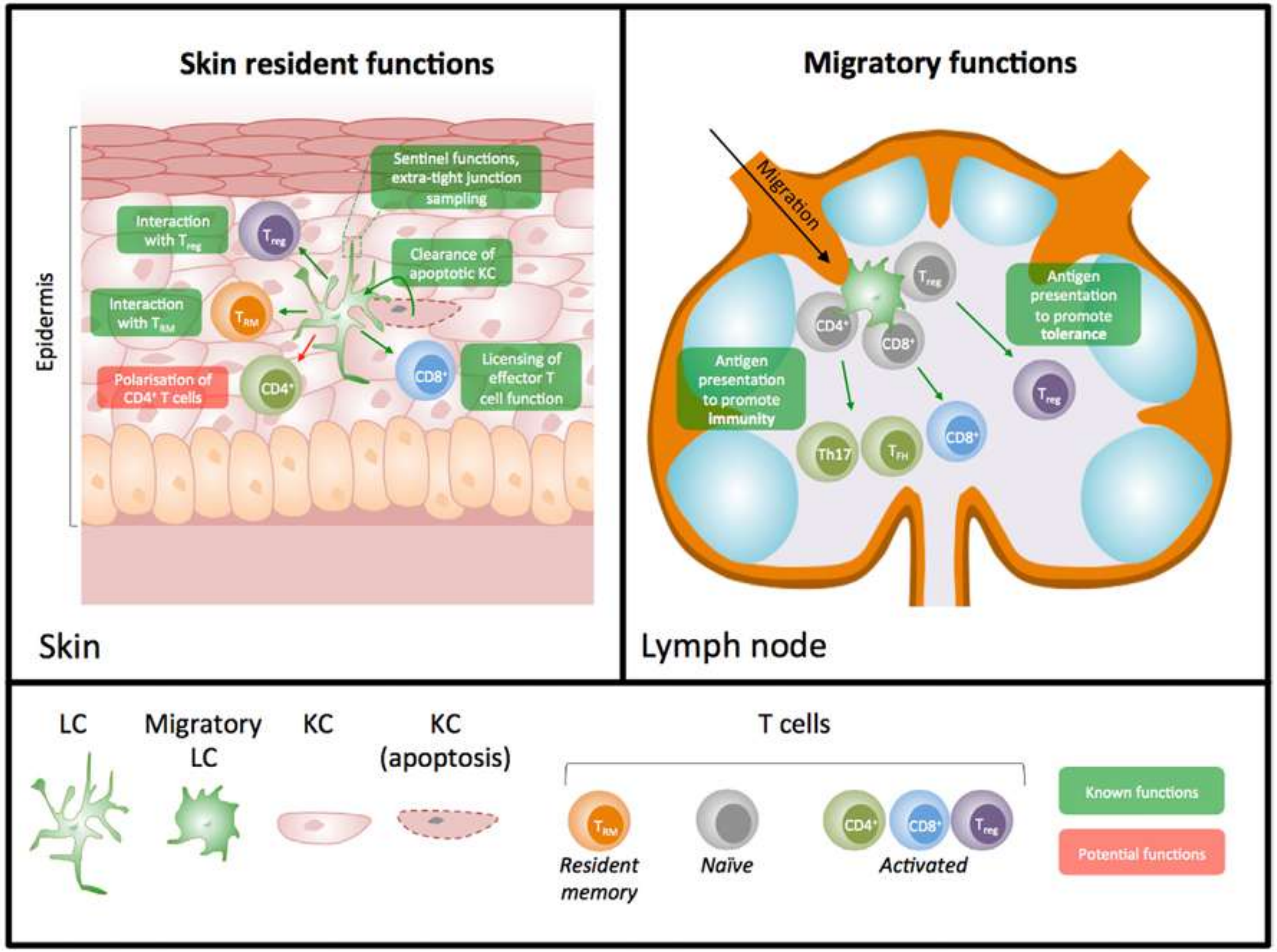
Matsui, T et al., 2023, *J Dev Biol*

Structure of mammalian epidermis and its three barrier elements



Matsui, T et al., 2015, *Int. Immunol*

Diagram illustrating known and predicted skin resident versus migratory roles for Langerhans cells (LC)



West, H. C. et al., 2018, *Front. Immunol.*

Cell Types in the Epidermis

1. 角质形成细胞（Keratinocyte）
2. 朗格汉斯细胞（Langerhans Cell）
3. 默克尔细胞（Merkel cells）
4. 黑素细胞（Melanocytes）

Cell Types in the Epidermis

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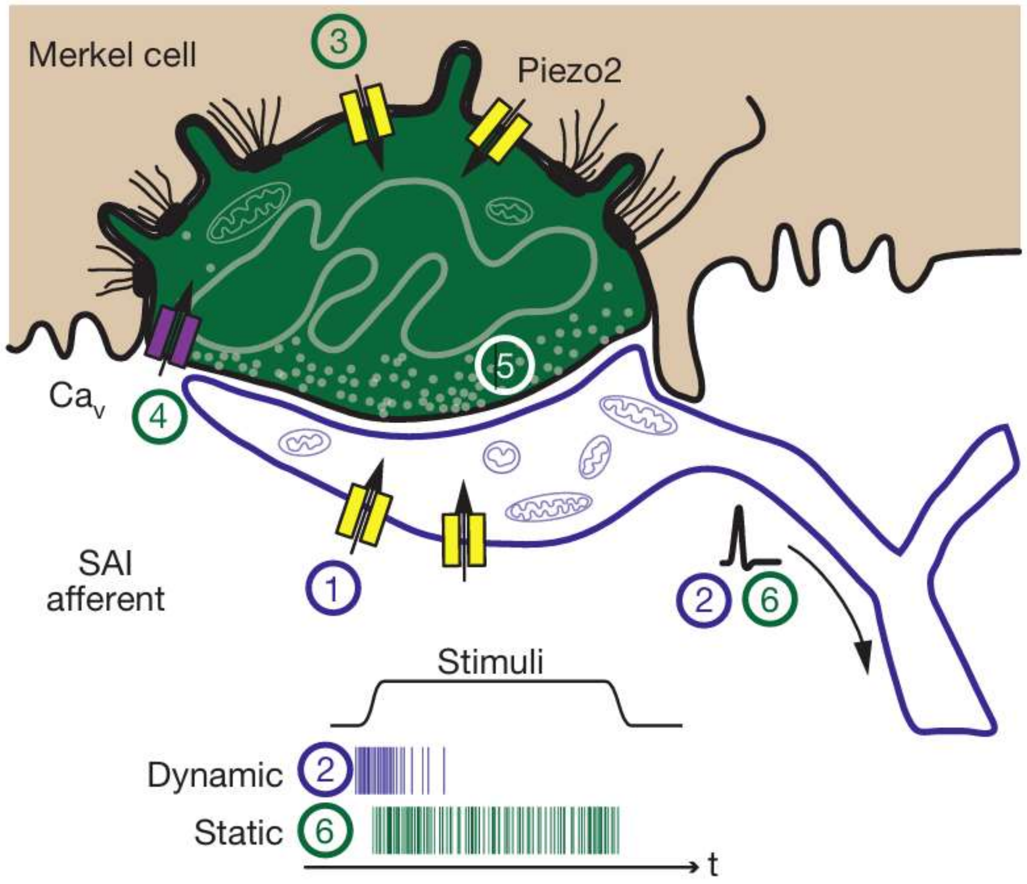
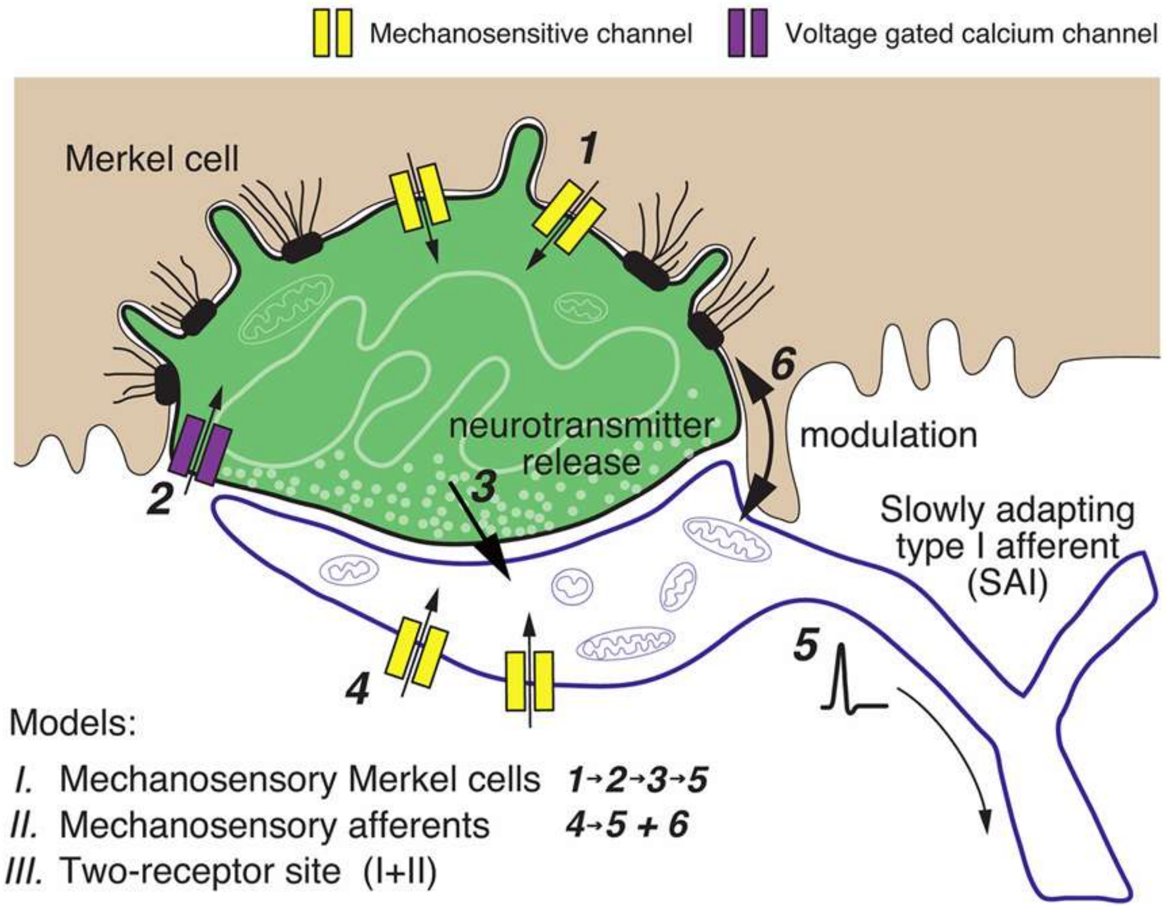
4. 黑素细胞（Melanocytes）

Model of active Merkel cell inputs in touch reception



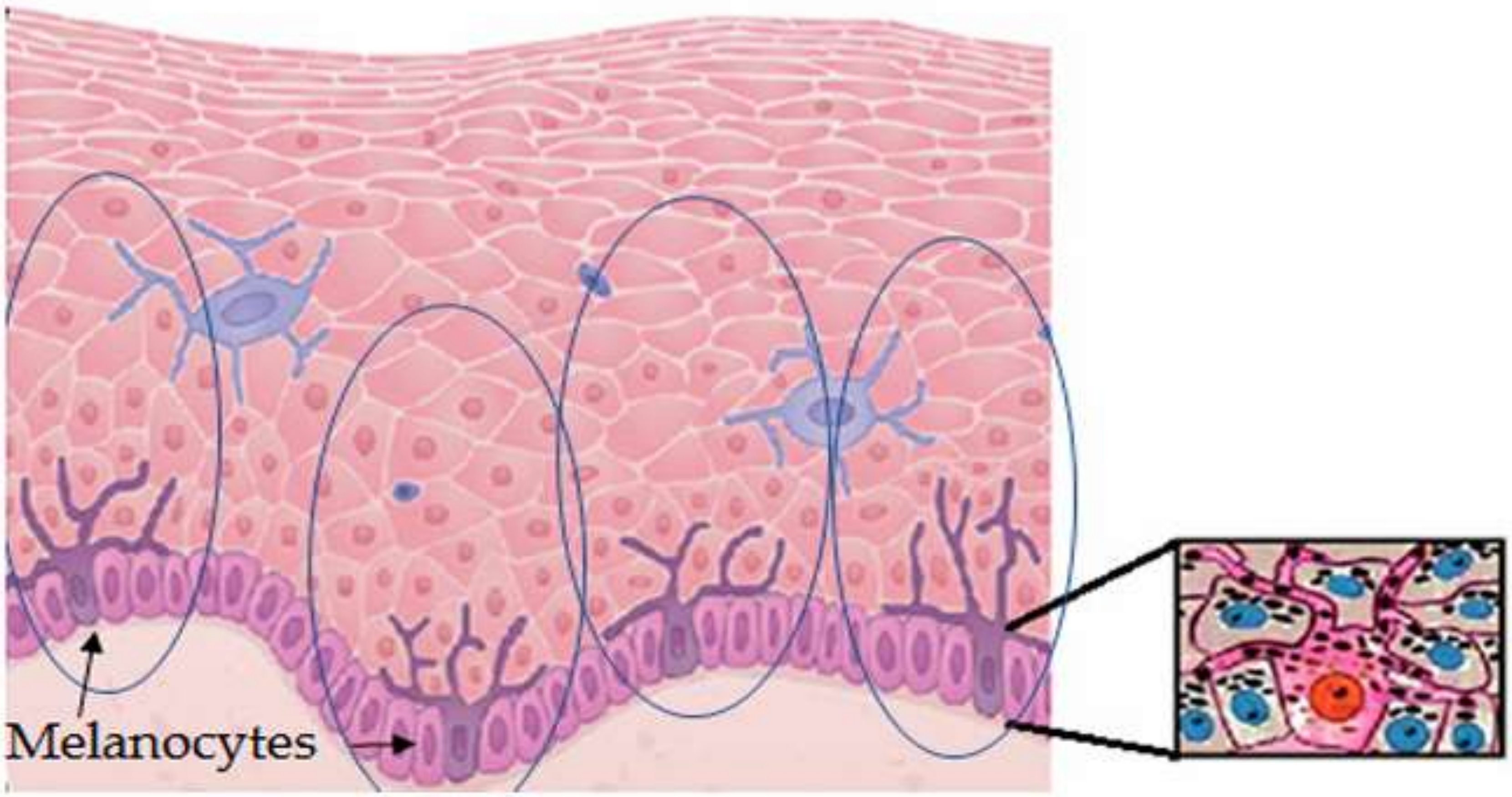
SAI afferent（缓慢适应性机械感受器传入纤维）



Maksimovic S. et al., 2014, *Nature*

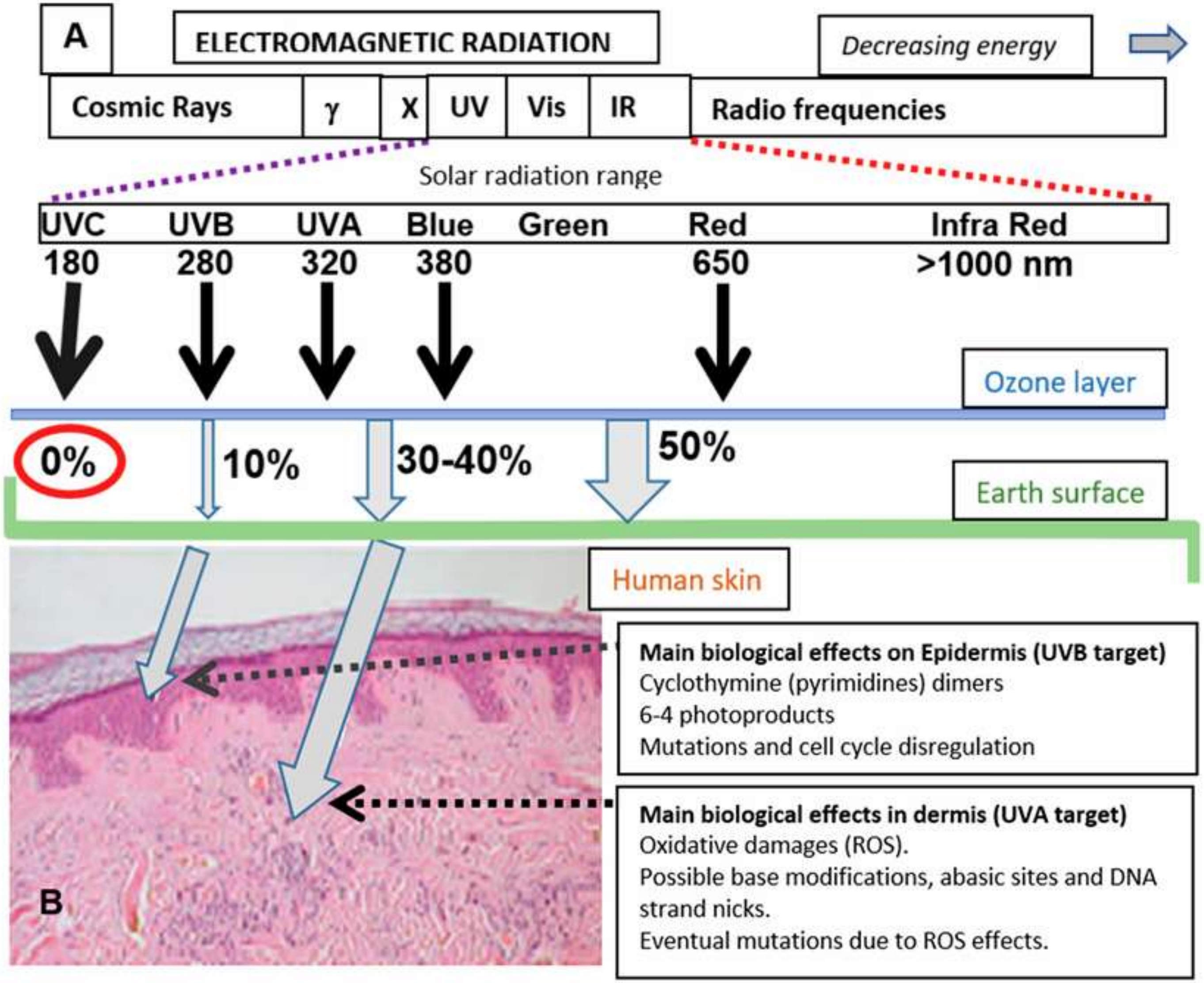
Nakatani M. et al., 2015, *Pflugers Arch*

Graphic representation of a detail of the epidermis.



Solano F. et al., 2020, *Molecules*

Solar radiation reaching Earth’s surface, skin penetrance, and biological effects



防晒产品通常以预防UVB损伤为主，但也应注意**UVA**的影响。

Solano F. et al., 2020, *Molecules*

The Four Major Human Racial Classifications

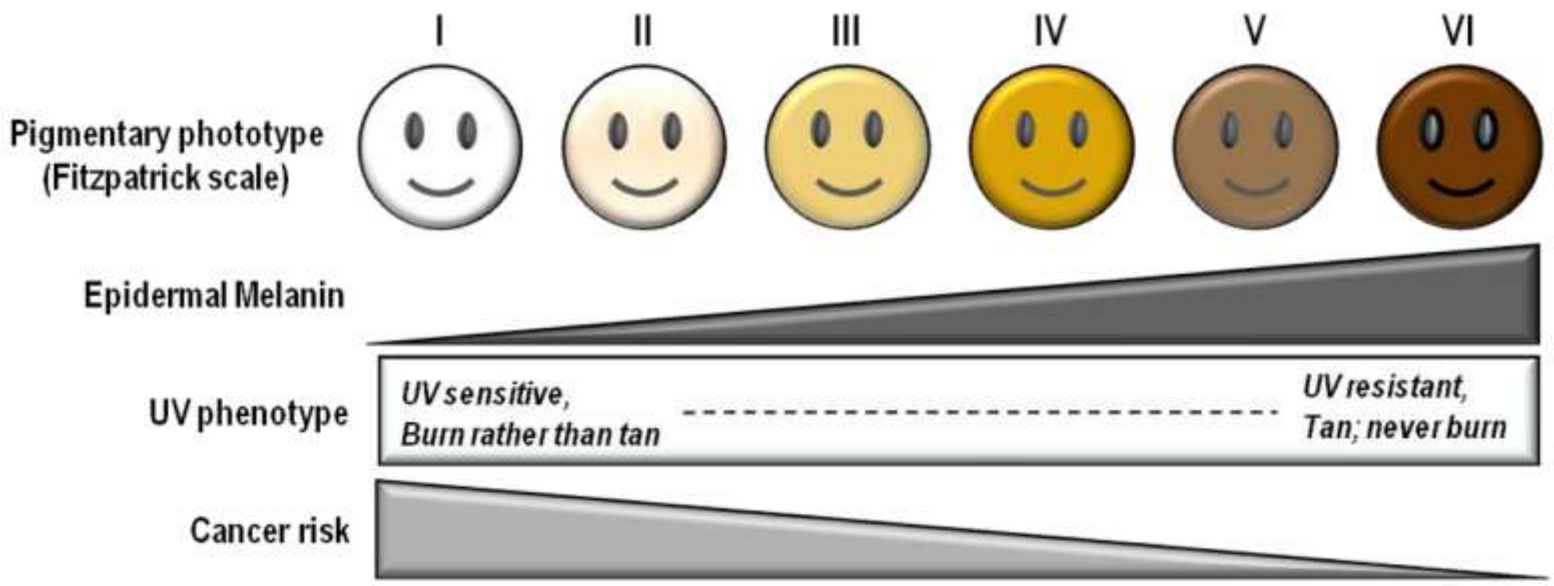
历史上根据体质特征划分的四大人种分类，即白色人种、黄色人种、黑色人种和棕色人种

- **白色人种**: 主要分布于欧洲、西亚和北非等地区，皮肤较白。
- **黄色人种**: 主要分布于亚洲大陆中部、东部和东南亚，也包括部分美洲原住民。
- **黑色人种**: 主要分布于非洲大陆大部分地区。
- **棕色人种**: 通常指澳大利亚原住民及邻近岛屿的居民，其肤色为棕色。

Fitzpatrick scale

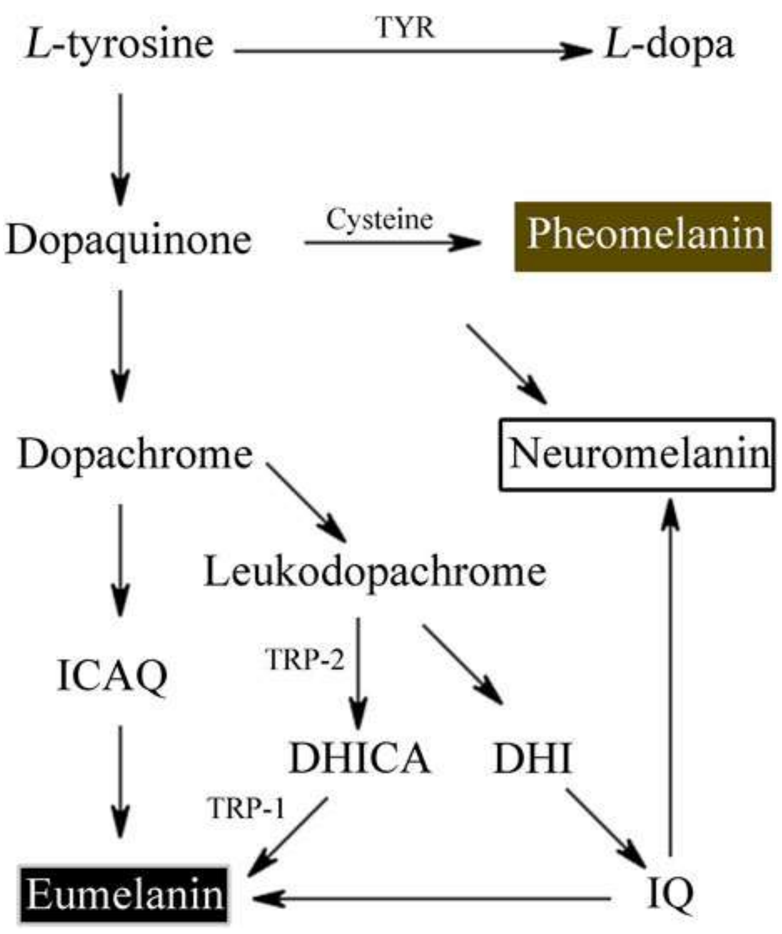
菲茨帕特里克度量（Fitzpatrick scale）是一种人类肤色的分类模式。它是由美国皮肤科医生**托马斯·B·菲茨帕特里克**于1975年发明。

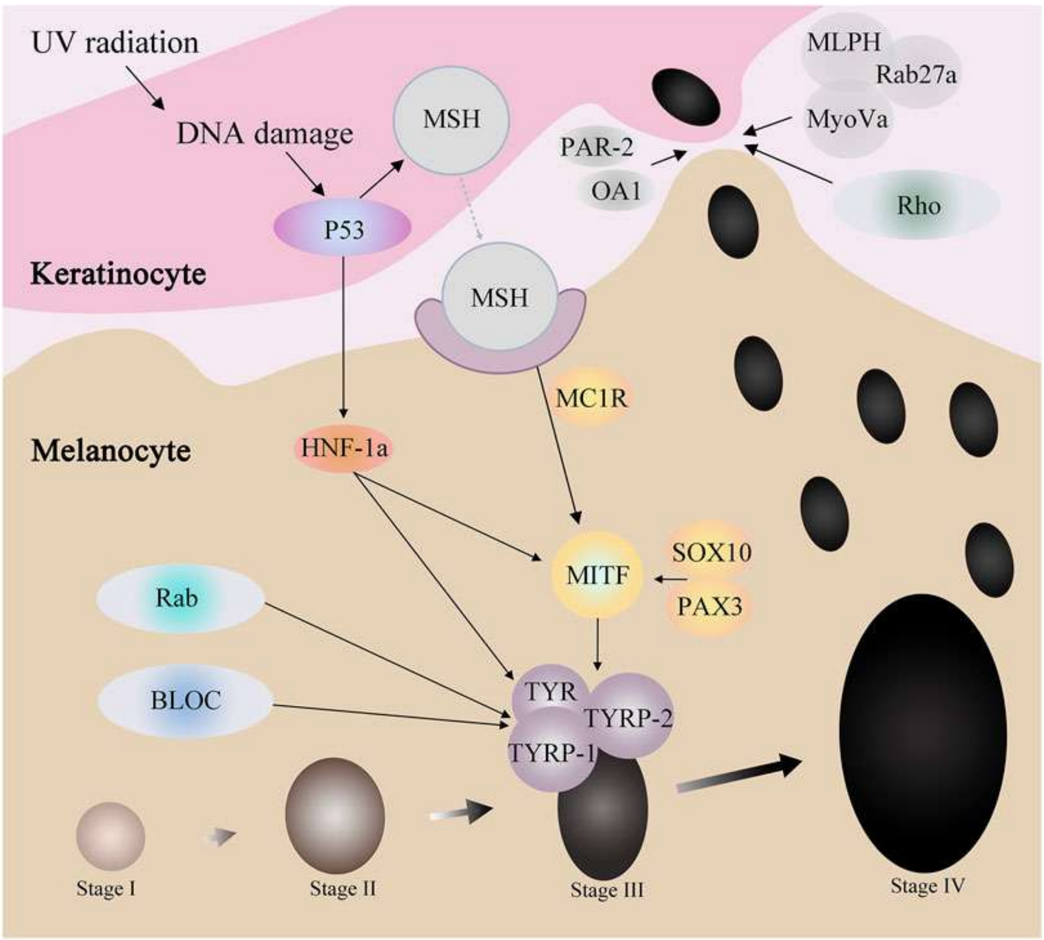
- I型，肤色最白，但有雀斑
- II型，肤色浅，但比I型深
- III型，肤色为橄榄色
- IV型，肤色为棕色
- V型，肤色为深棕色
- VI型，肤色最深



D'Orazio, J. et al., 2013, *Int. J. Mol. Sci.*

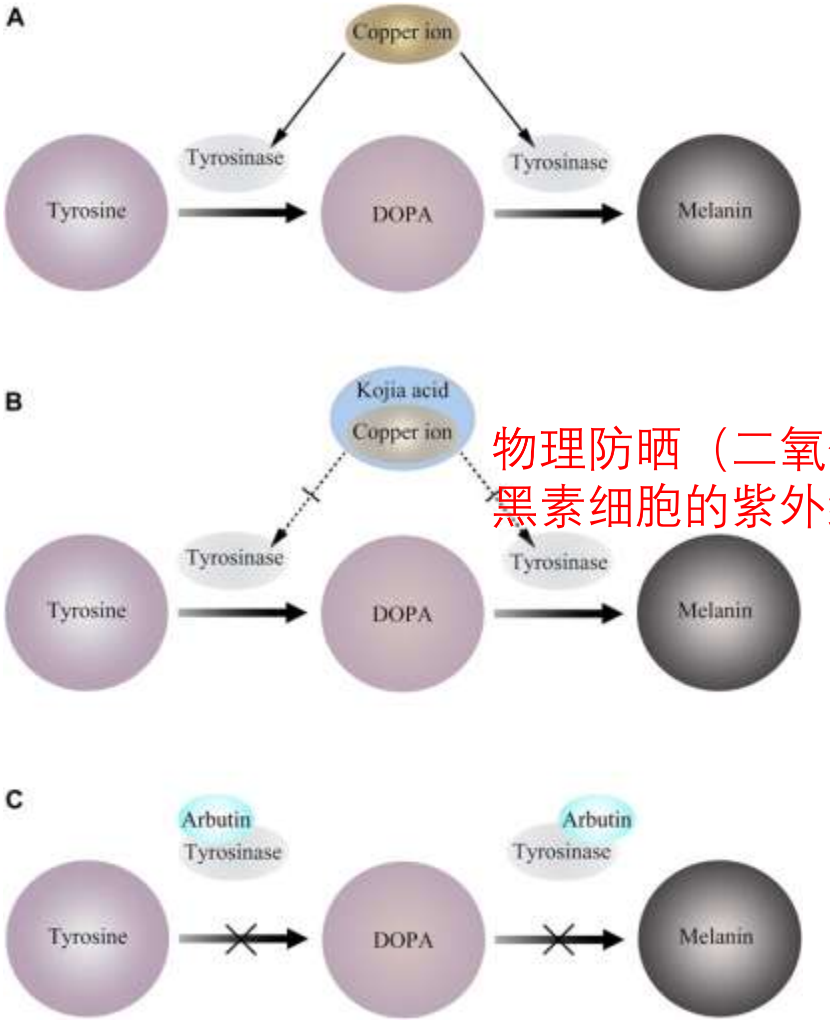
The source of melanin and melanocytes and melanin-related proteins



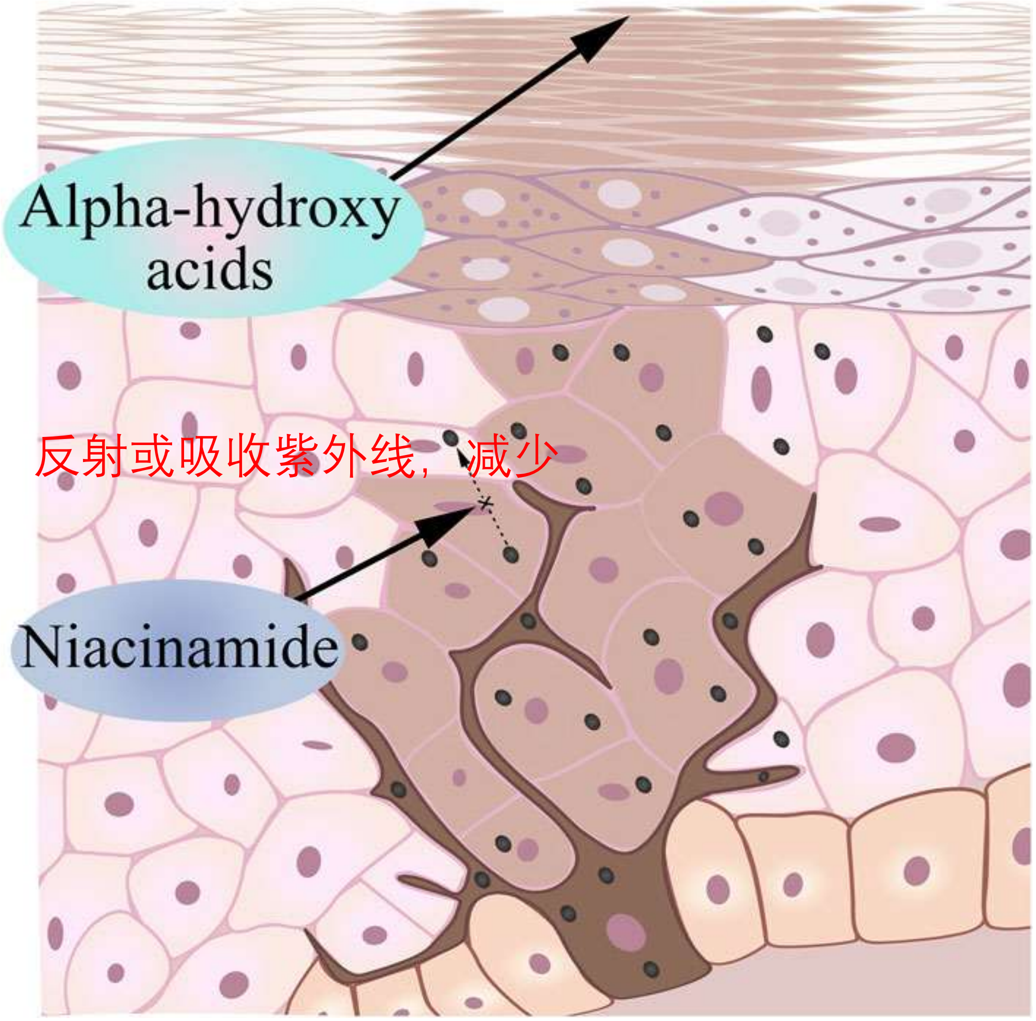


Wang F et al., 2024, *Front Mol Biosci*

Mechanisms of action of popular whitening active agents



物理防晒（二氧化钛、氧化锌）：反射或吸收紫外线，减少黑素细胞的紫外线刺激。



Wang F et al., 2024, *Front Mol Biosci*

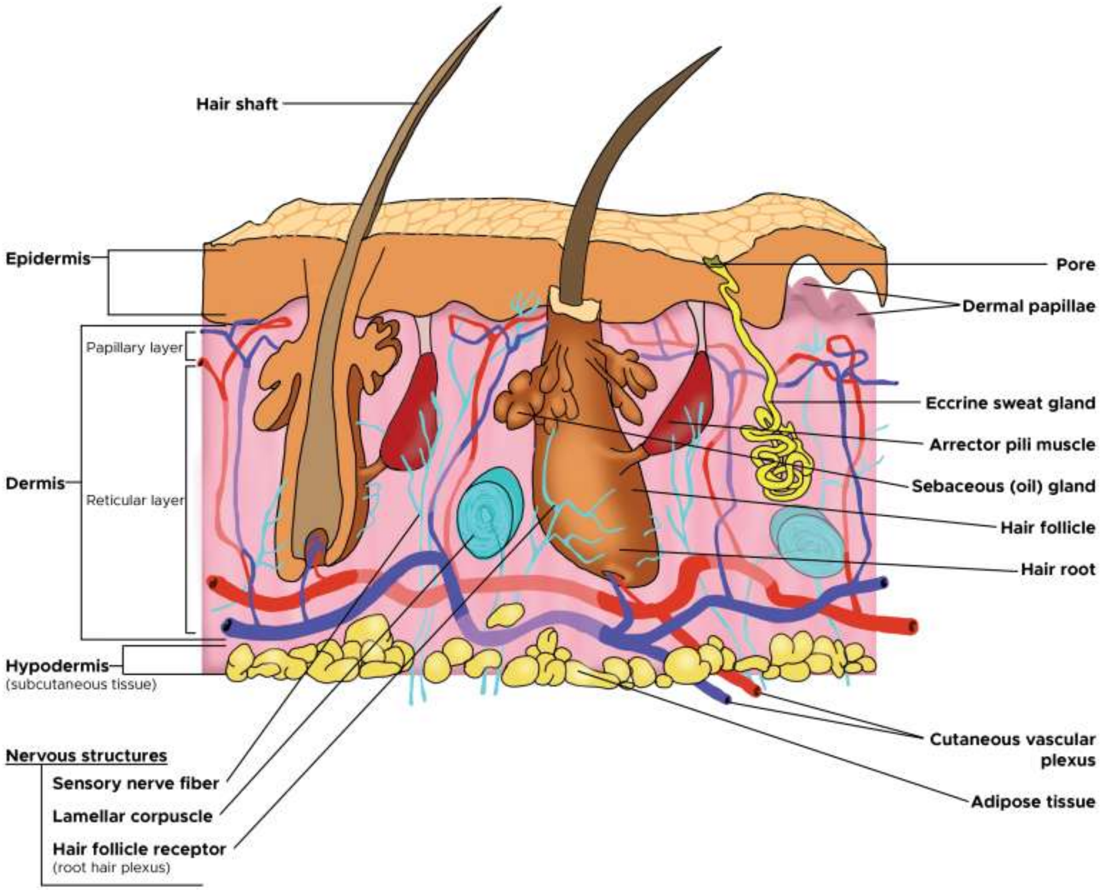
Summary of Epidermal Functions

功能类型	主要承担层/细胞	功能说明
物理屏障功能	角质层（Stratum corneum）	最外层“砖墙”结构（角质细胞 + 脂质基质），防止机械损伤、化学刺激、微生物入侵。
水分屏障（防止失水）	角质层、脂质层	表皮外层含脂质（神经酰胺、胆固醇、游离脂肪酸），防止经皮水分流失（TEWL）。
免疫防御功能	朗格汉斯细胞、角质形成细胞	表皮可识别病原、启动免疫反应；角质形成细胞分泌抗菌肽（如β-defensin）。
光防护功能	黑素细胞及其黑色素	黑素吸收并分散紫外线，保护DNA免受UV损伤。
再生修复功能	基底层干细胞	表皮干细胞不断分裂，替代老化细胞；伤口愈合时可迅速迁移覆盖创面。
感觉功能（间接）	梅克尔细胞、神经末梢	与真皮神经末梢形成复合体，感受触觉与压力。
代谢与吸收功能	角质形成细胞、皮脂膜	表皮可代谢维生素D前体（7-脱氢胆固醇 → 维生素D_3）；部分药物可经表皮吸收（经皮给药）。

The Structure of the Dermis

分类	内容说明
层次结构	真皮分为两层，无明显分界: • **乳头层（Papillary layer）**：位于表皮下方，疏松结缔组织，含丰富毛细血管与神经末梢。 • **网状层（Reticular layer）**：位于乳头层下方，致密结缔组织，为真皮主体，含大量胶原纤维与弹性纤维。
其他结构	含毛囊、皮脂腺、汗腺、血管、淋巴管及神经末梢等皮肤附属器。
主要细胞类型	• **成纤维细胞（Fibroblasts）**：数量最多，合成胶原、弹性纤维及基质。 • **肥大细胞（Mast cells）**：含组胺等活性物质，参与炎症与过敏反应。 • **免疫细胞（Macrophages, Lymphocytes, Langerhans cells）**：免疫监视与防御。 • **其他细胞**：少量脂肪细胞与间质干细胞（多见于深层）。
细胞外基质（ECM）	由**胶原纤维、微原纤维、弹性纤维**组成，嵌入透明质酸（Hyaluronic acid）**与**蛋白聚糖（Proteoglycans）中，提供皮肤张力与弹性。
蛋白聚糖分布特点	• 透明质酸、多功能蛋白聚糖：位于真皮与表皮的细胞外基质中。• 双糖链蛋白聚糖、凝溶胶蛋白：仅出现在表皮。
神经与感受器	含机械感受器、痛觉感受器及温度感受器，负责触觉、疼痛与热觉感知。
血管功能	真皮血管网为真皮与表皮提供营养，排除代谢废物，并参与体温调节。

Layers of skin, hair follicles, sweat glands



Summary of Dermal Functions

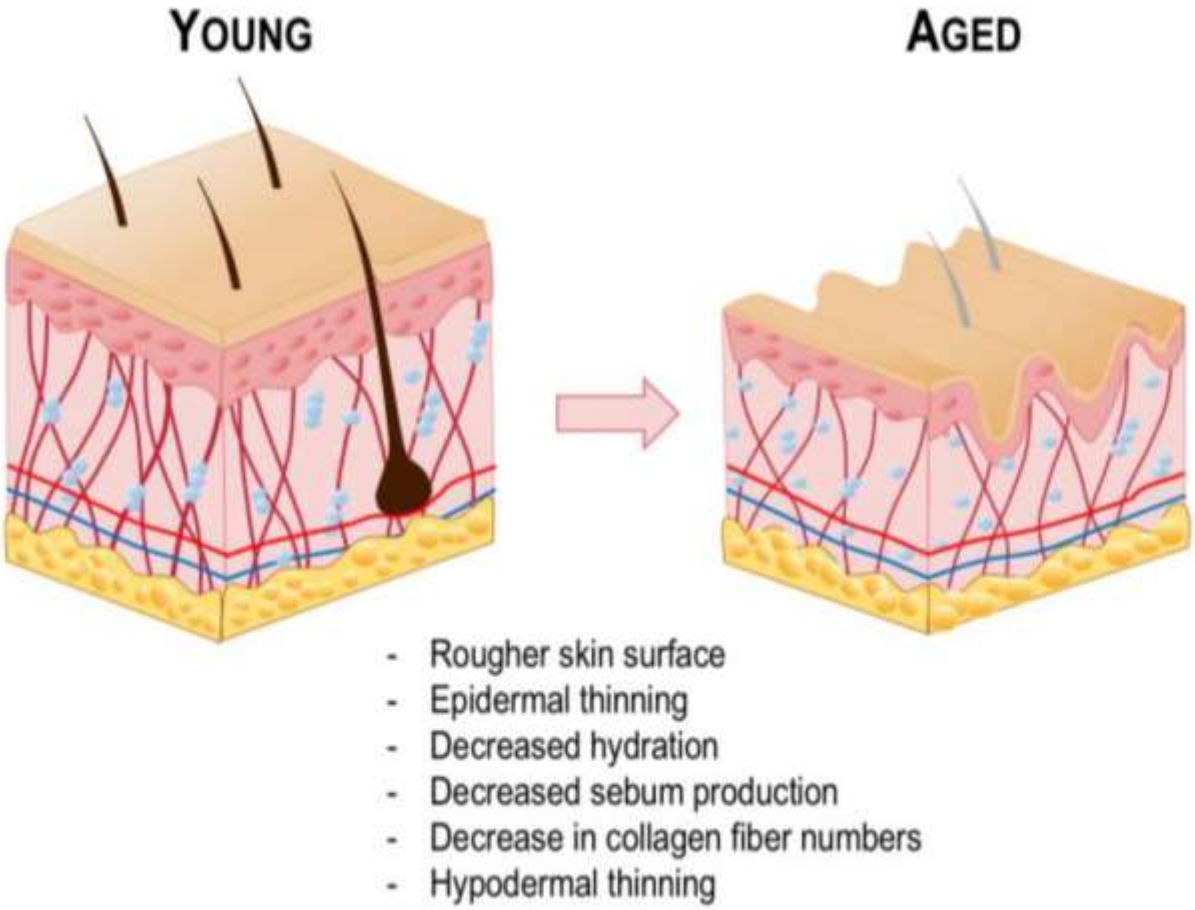
功能类型	主要承担层/细胞	功能说明
支撑与弹性功能	胶原纤维、弹性纤维、成纤维细胞	真皮提供皮肤的机械强度与韧性，维持结构稳定与柔韧性，防止撕裂。
营养供应功能	真皮血管网、乳头层毛细血管	为表皮输送氧气与养分，清除代谢废物，维持表皮细胞生理活动。
感觉功能	神经末梢、触觉小体（Meissner）、压力小体（Pacinian）	感受触觉、压力、温度、痛觉与震动，是皮肤感觉的主要来源。
体温调节功能	血管、汗腺	通过血管扩张/收缩调节散热；汗液蒸发帮助降温。
免疫防御功能	巨噬细胞、肥大细胞、树突状细胞	识别病原体、释放炎症因子、参与皮肤免疫反应与防御。
修复再生功能	成纤维细胞、血管新生细胞、ECM	伤口愈合时合成胶原与基质，促进肉芽组织形成与组织重建。
附属器支持功能	毛囊、皮脂腺、汗腺	为皮肤附属器提供营养与结构支持，参与分泌与再生。

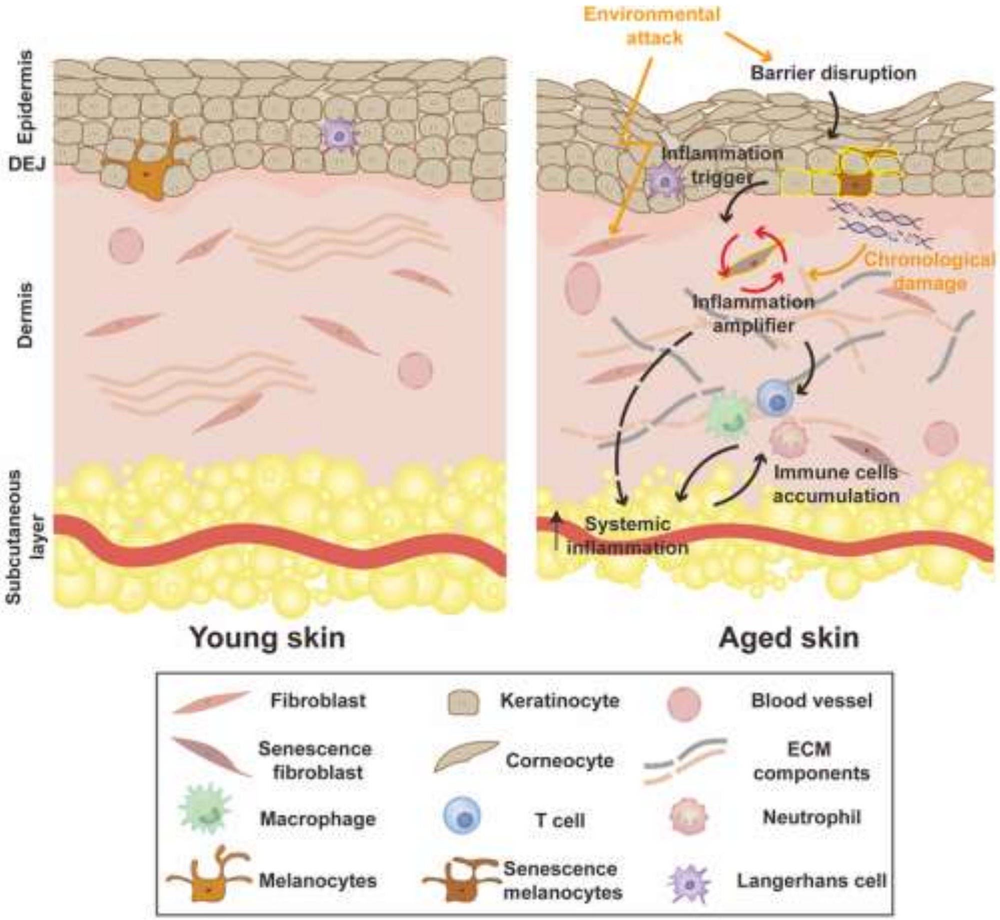
Structure and Function of the Subcutaneous Tissue

组成部分	结构说明
脂肪组织（Adipose tissue）	占主体，分为脂肪小叶（lobules），由结缔组织隔（septa）分隔，富含脂肪细胞（adipocytes）。
结缔组织（Connective tissue）	含大量胶原纤维与弹性纤维，将皮肤与深层结构连接，保持皮肤柔韧与滑动性。
血管与淋巴管（Blood & lymph vessels）	极为丰富，负责营养供应、体温调节及代谢产物运输。
神经（Nerves）	含感觉神经末梢与自主神经，参与触觉、压力觉与血管调控。
皮下筋膜（Superficial fascia）	位于皮下组织深部，与肌肉或腱膜相连，结构因部位和个体而异。

功能类型	功能说明
⚡ **能量储存**	富含脂肪细胞，储存能量
🔥 **保温作用**	防止体温散失
🛡️ **缓冲保护**	吸收外界机械冲击
🔗 **连接作用**	将皮肤与下方肌肉、筋膜相连
💉 **药物吸收**	是皮下注射常用部位

Graphical comparison of the various characteristics of young and aged skin





Sofia Brito et al., 2024, *Pharmaceutics*

Zhang J et al., 2024, *Aging Cell*

Summary

- The skin is the largest organ of the human body, composed of the epidermis, dermis, and subcutaneous tissue: the epidermis is responsible for barrier function and photoprotection; the dermis provides strength, nutrition, and sensory function; and the subcutaneous tissue stores energy, retains heat, and acts as a buffer.
- Its core functions include physical and moisture barrier protection, immune defense, sensory perception, body temperature regulation, and participation in vitamin D synthesis.
- Aging primarily occurs in the dermis (characterized by a decrease in collagen and extracellular matrix/ECM), leading to thinning of the skin and reduced elasticity.

Physiological events in the skin wound healing process

- Types of skin wounds
- Models of skin wound healing
- Physiological processes occurring in wounds

Physiological events in the skin wound healing process

- **Types of skin wounds**
- Models of skin wound healing
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什么是皮肤创伤?

Skin wound：是指皮肤因机械、热力、化学、生物或辐射等因素，导致皮肤结构连续性被破坏。当皮肤屏障被破坏后，伤口被污染和感染的风险大大增加。

4 Main Categories of Skin Wounds

Abrasions
擦伤

Lacerations
撕裂伤

Punctures
穿刺伤

Avulsions
撕脱伤

Physiological events in the skin wound healing process

- Types of skin wounds
- **Models of skin wound healing**
- Physiological processes occurring in wounds

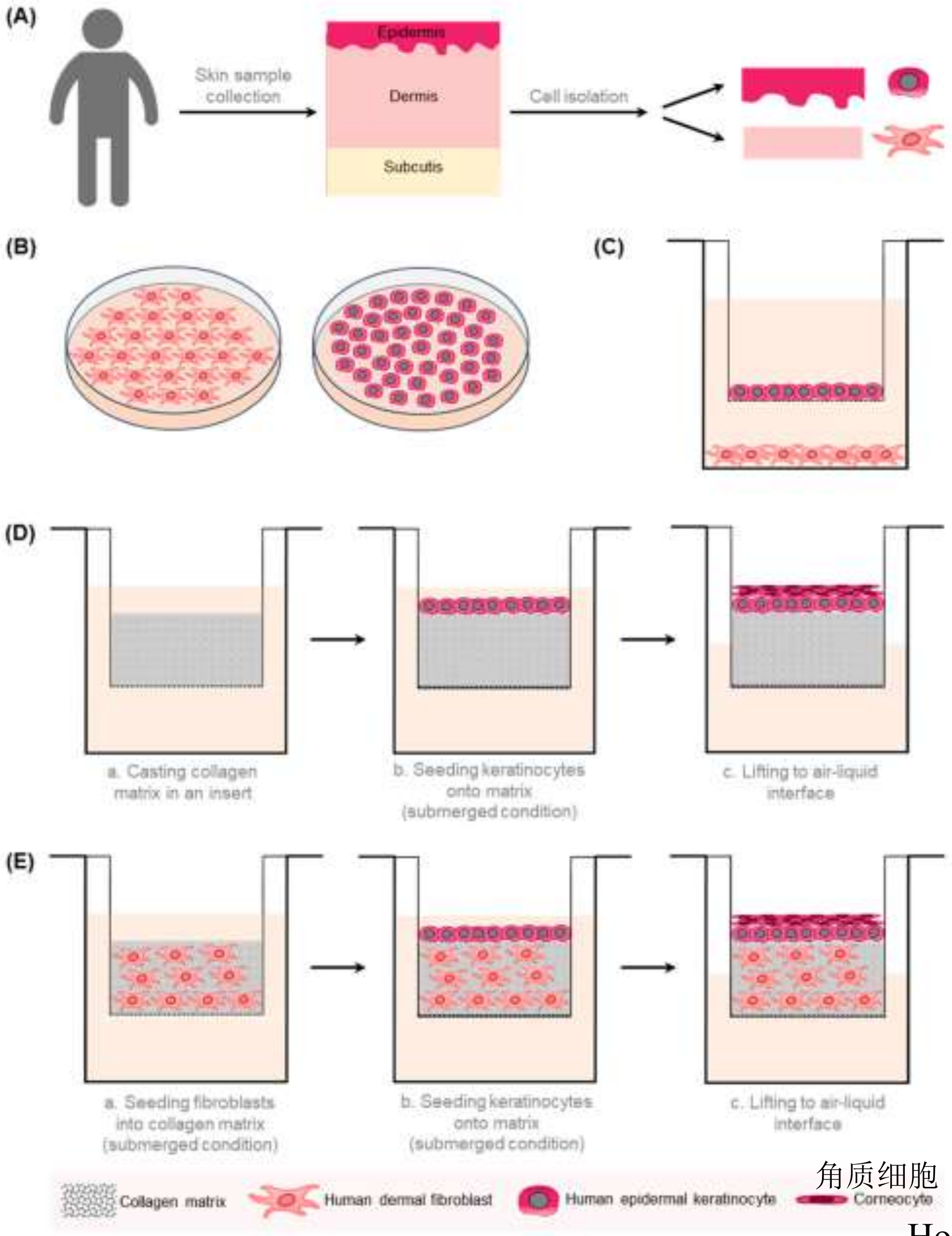
In vitro models of skin wound healing

单培养 (2D)

共培养

组织模型 (3D)

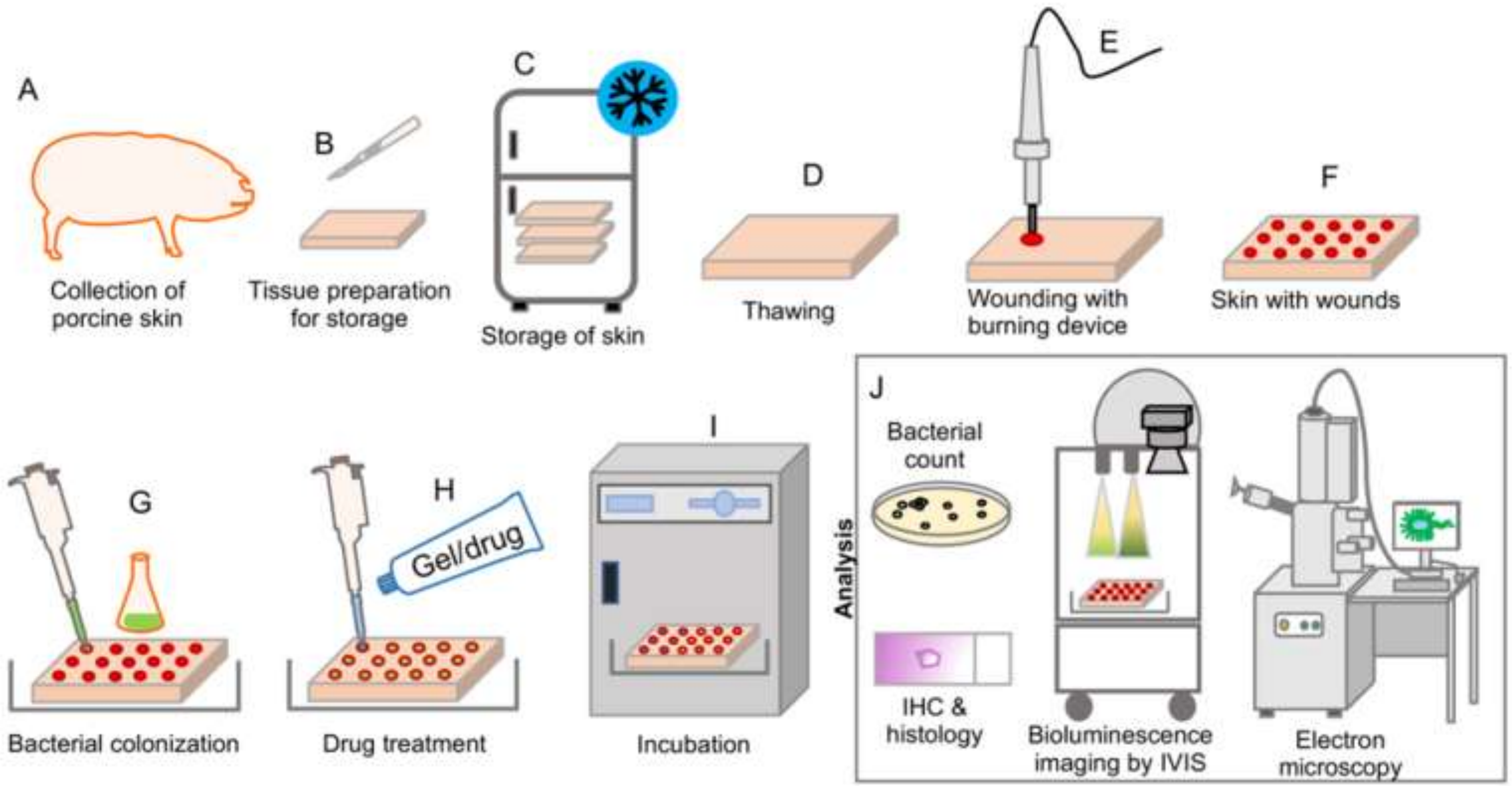
- reconstructed human epidermis (RHE)
- human skin equivalents (HSE)



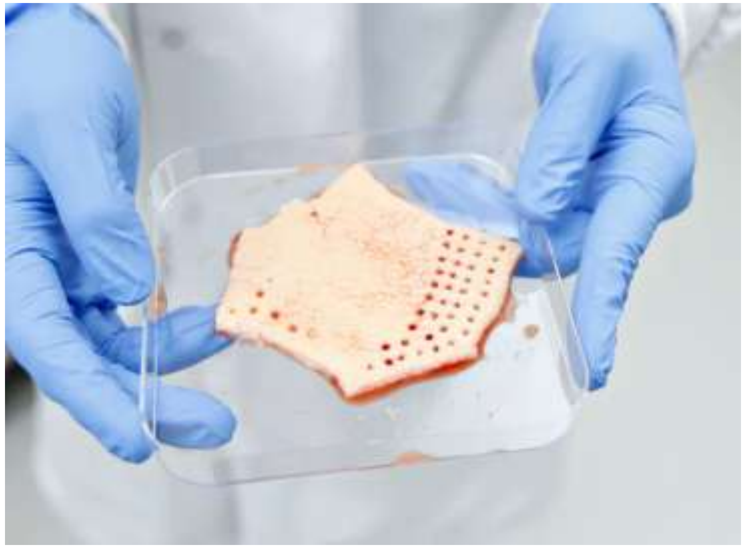
Hofmann E, et al. *Biomedicines*. 2023

体外模型	特点	优点	缺点
单细胞培养	研究**单类细胞**对损伤和应激的基本细胞信号反应。	简单，易于操作，直接反映细胞对损伤的基本反应。	缺乏组织微环境，**没有细胞间相互作用与信号传递**，无法完全复制伤口愈合过程。
共培养	研究角质形成细胞和成纤维细胞之间的**相互作用**。	相对简单易行，允许研究细胞间相互作用与旁分泌。	无法完全复制组织的复杂环境。技术要求与成本也较高。
重建人体表皮（RHE）	具有一定的组织结构，可以在 3D 环境中检测伤口收缩、细胞迁移和相互作用。	改进了组织结构和细胞相互作用的模拟，允许在 3D 环境中研究细胞行为。	**仅含表皮层**，且建立和维护更加复杂，需要专门的设备。
人体皮肤等效物（HSE）	包含**多种细胞类型**，可模拟原生皮肤结构，为组织再生和再上皮化提供研究基础。	**最接近原生皮肤结构和功能**，更好地模拟组织微环境，可研究多种细胞类型及其相互作用。	开发成本更高、更耗时。

Ex vivo models of skin wound healing



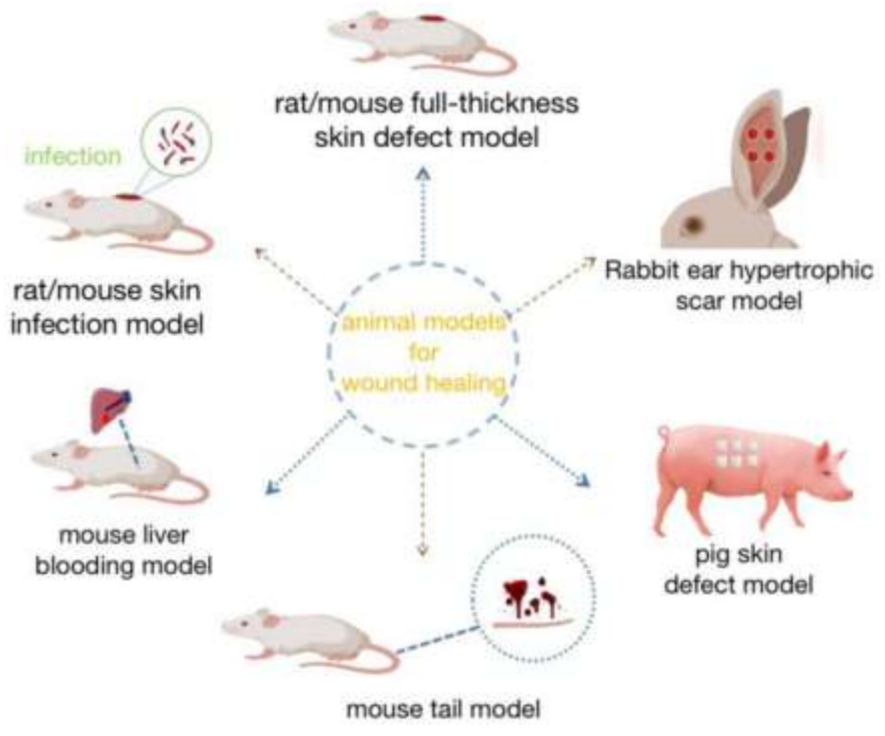
Andersson MÅ, et al. *Int J Mol Sci*. 2021



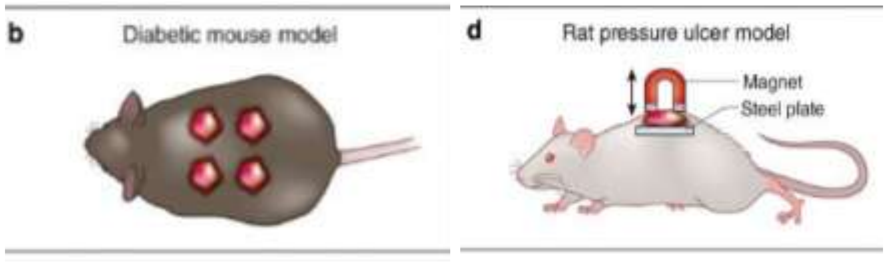
甜甜圈形伤口愈合模型

离体模型	特点	优点	缺点
活组织样本	从生物体获取完整皮肤组织，在体外培养条件下保持细胞活性与组织结构。	保留**皮肤完整结构**及细胞外基质，可研究多细胞相互作用，支持动态监测。	组织活力维持困难，只能**短期观察**。无血流、神经支配、免疫循环，仍不能模拟完整愈合过程。

In vivo models of skin wound healing



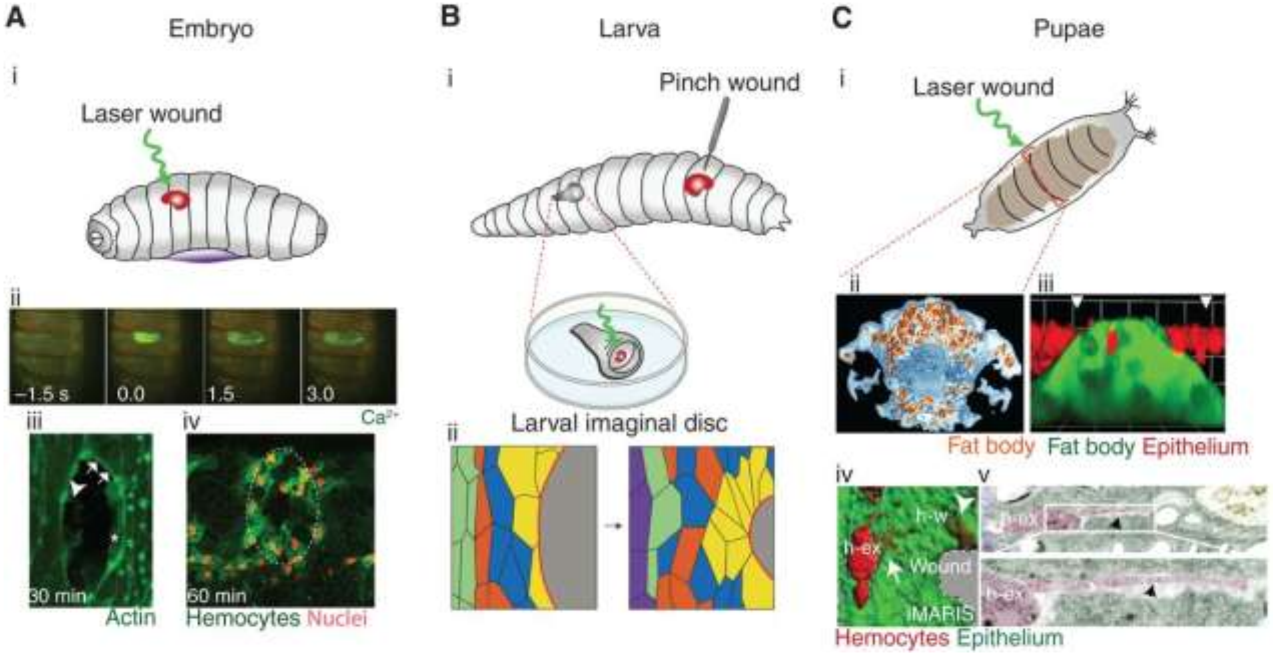
Ma H, et al. *Gels*. 2022

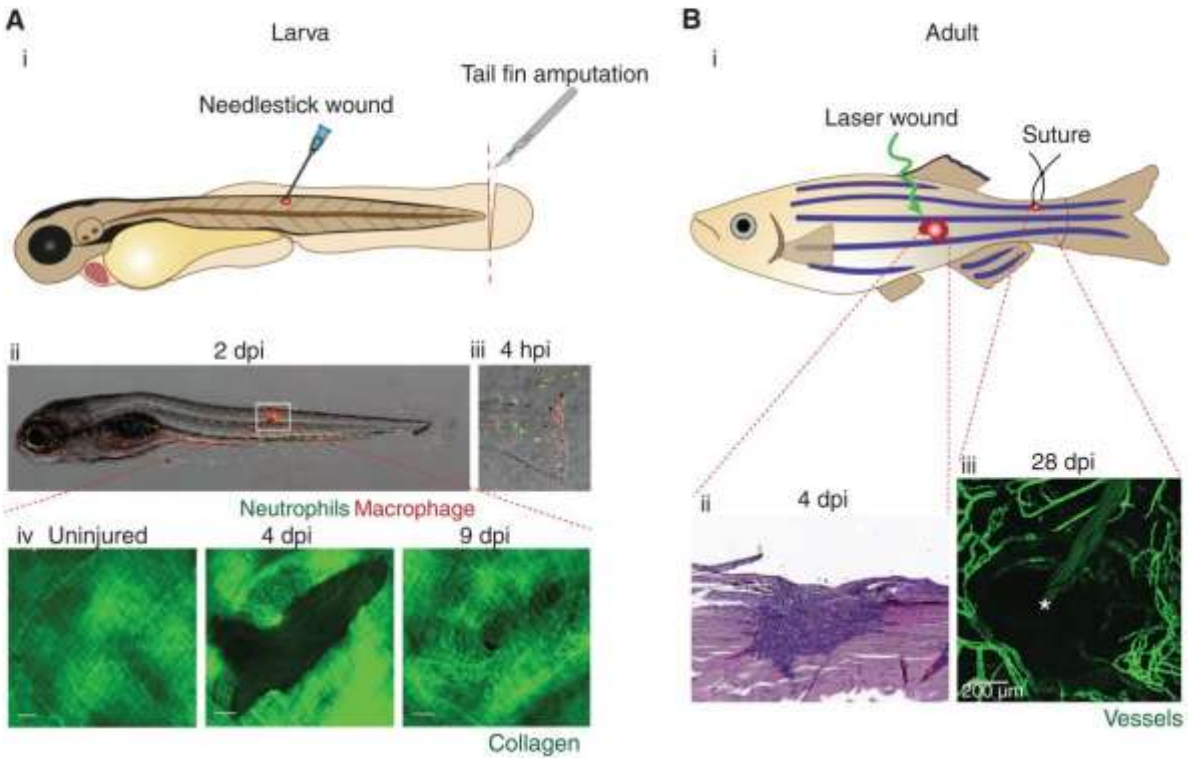


Tan P, et al. *Eur Burn J*. 2021

在体模型	特点	优点	缺点
全层皮肤缺损模型	形成穿透整个皮肤厚度的伤口，**包括表皮和真皮**。	允许调节伤口位置与大小，可利用转基因小鼠以研究特定问题。	由于解剖学和生理差异，愈合机制可能与人类伤口不同。
出血模型	尾巴背面的指定区域完全切除皮肤组织，通常全层切除。**比背部伤口愈合时间更长**。	主要通过再上皮化进行愈合。有利于研究**伤口愈合延迟机制**。	伤口尺寸相对较小、与其他解剖部位相比伤口愈合动力学具有差异。
兔耳增生性疤痕模型	在兔耳上创建全层增生性疤痕伤口，以评估不同治疗的效果。	提供更大的伤口部位，利于观察。易产生增生性疤痕，便于**研究疤痕产生**。	与人类皮肤具有解剖学和生理差异，机制可能与人类伤口不同。
猪皮缺损模型	在猪皮肤的指定区域上进行**全层切除**。	在解剖结构、厚度和愈合机制方面**最接近人类皮肤**。适用于研究更大、更深的伤口。	价格昂贵且遗传异质性高，需要高水平的操作。
皮肤感染模型	在全层或部分厚度伤口上**接种病原菌**，可联合免疫抑制。	模拟感染性、慢性、难愈创面，利于研究材料或药物的**抗菌/促进愈合作用**。	接种量、接种时机需要摸索，健康小鼠对菌抗性高，需免疫抑制或高剂量。
慢性伤口模型	使用糖尿病小鼠或压疮模型模拟**慢性伤口愈合**的复杂性。	操作便利，可通过遗传手段诱导。可模拟人类慢性伤口的某些特征。	不能完全模拟临床慢性伤口特征，**观察周期长**，涉及伦理问题。

Drosophila and zebrafish as in vivo models



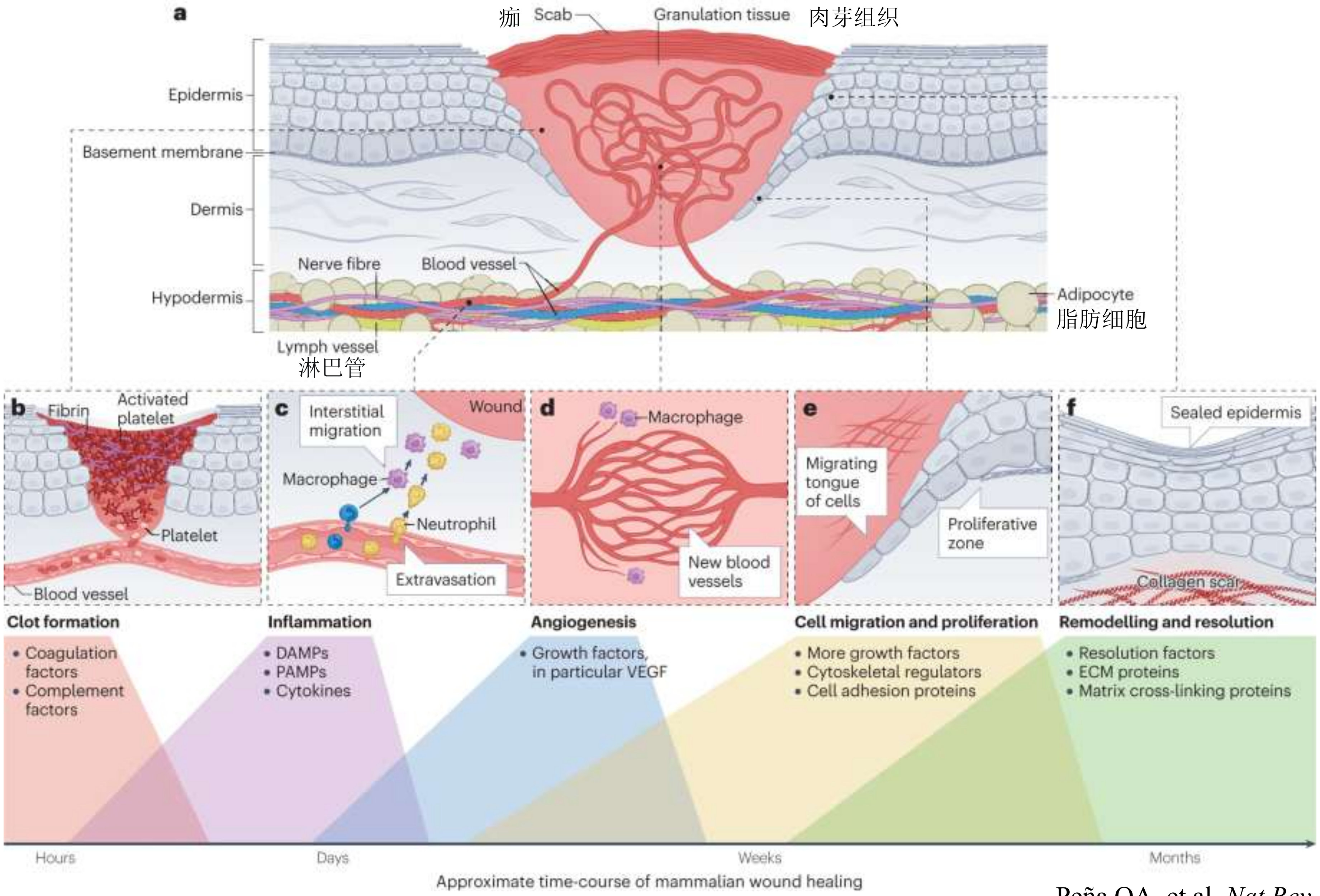


George, A, et al. *Cold Spring Harb Perspect Biol*. 2022

Physiological events in the skin wound healing process

- Types of skin wounds
- Models of skin wound healing
- **Physiological processes occurring in wounds**

The process of skin wound healing

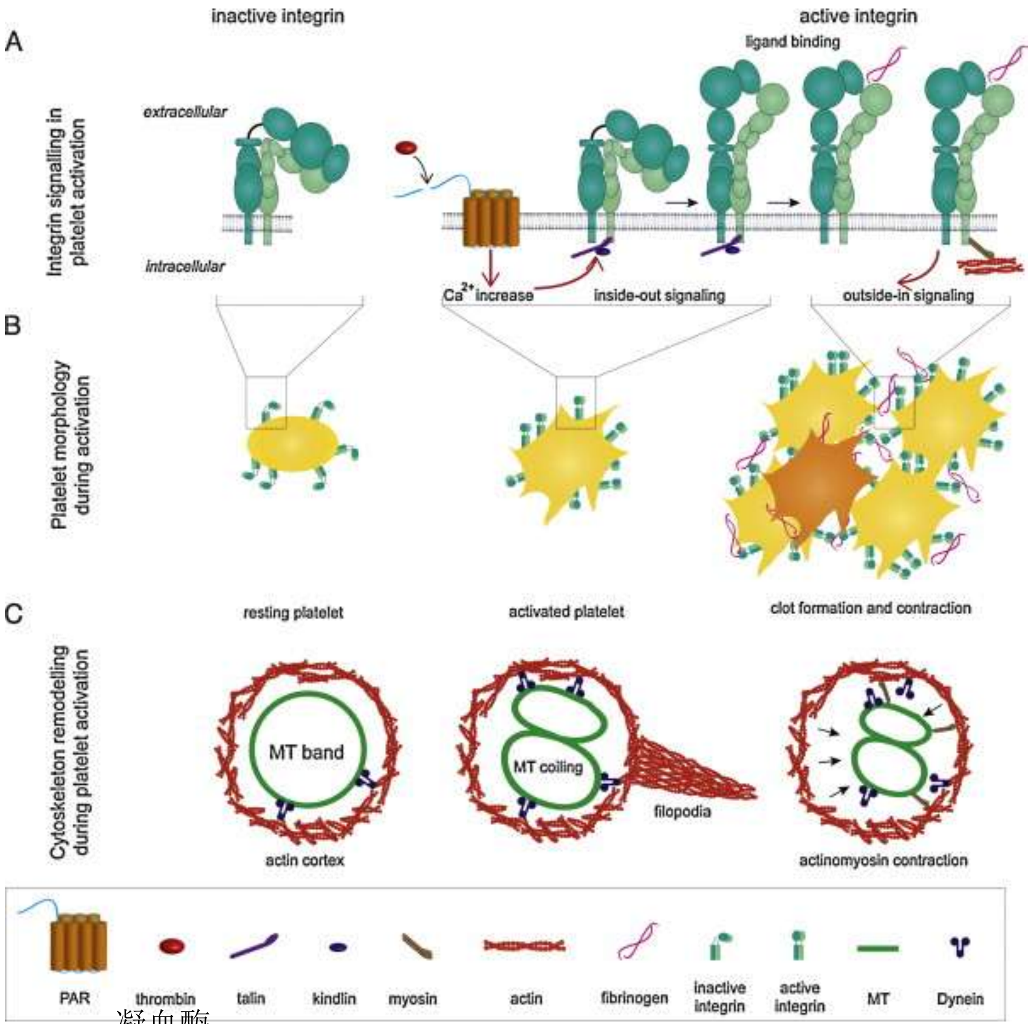


Peña OA, et al. *Nat Rev Mol Cell Biol*. 2024

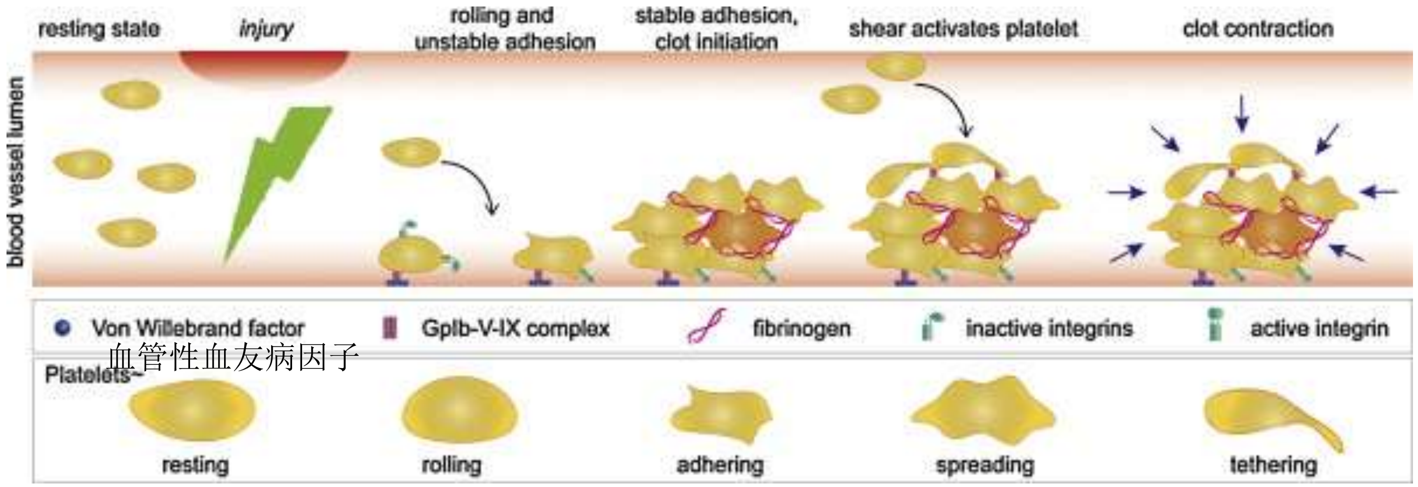

动画科普
如有不适 请线下就医
这是伤口自我修复的神奇过程

• **Hemostasis**

Platelet function and thrombosis（primary hemostasis）



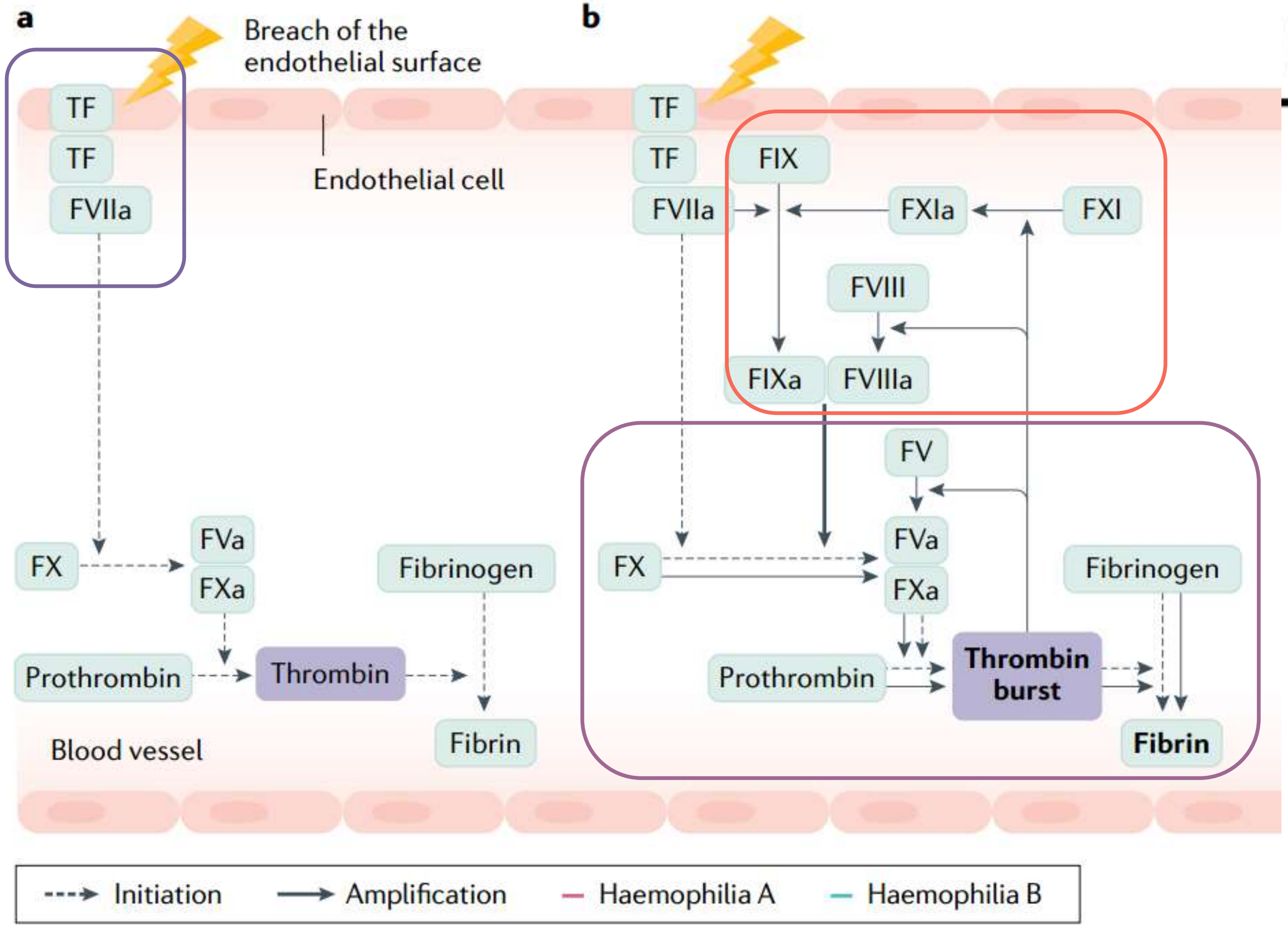
凝血酶

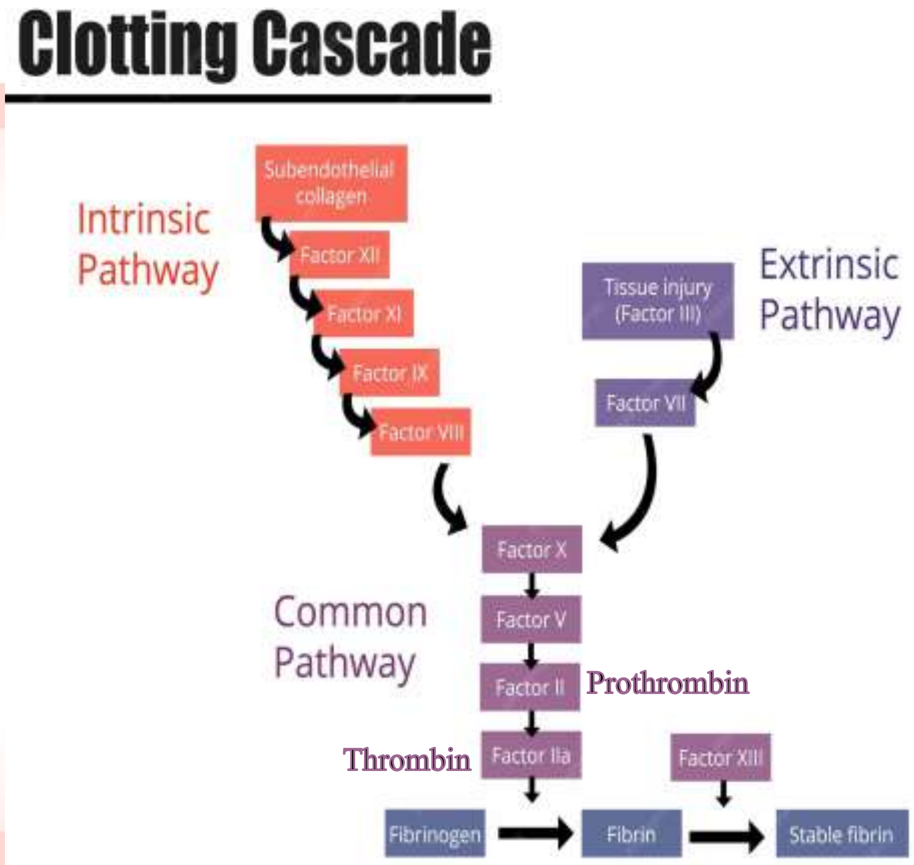


血管性血友病因子

Sorrentino S, et al. *Eur J Cell Biol*. 2015

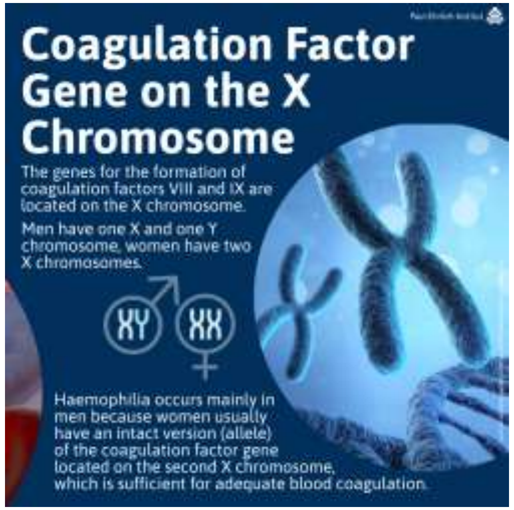
The coagulation cascade（secondary hemostasis）



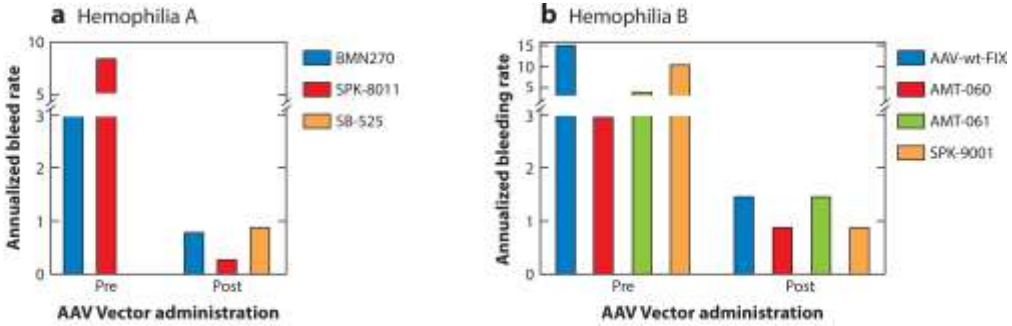


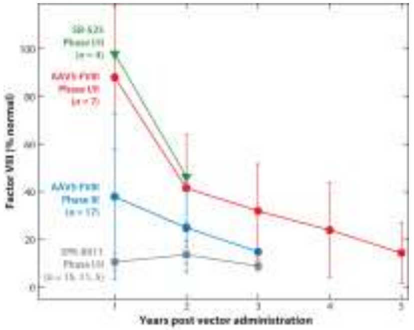
Berntorp E, et al. *Nat Rev Dis Primers*. 2021

Introduction and treatment of hemophilia



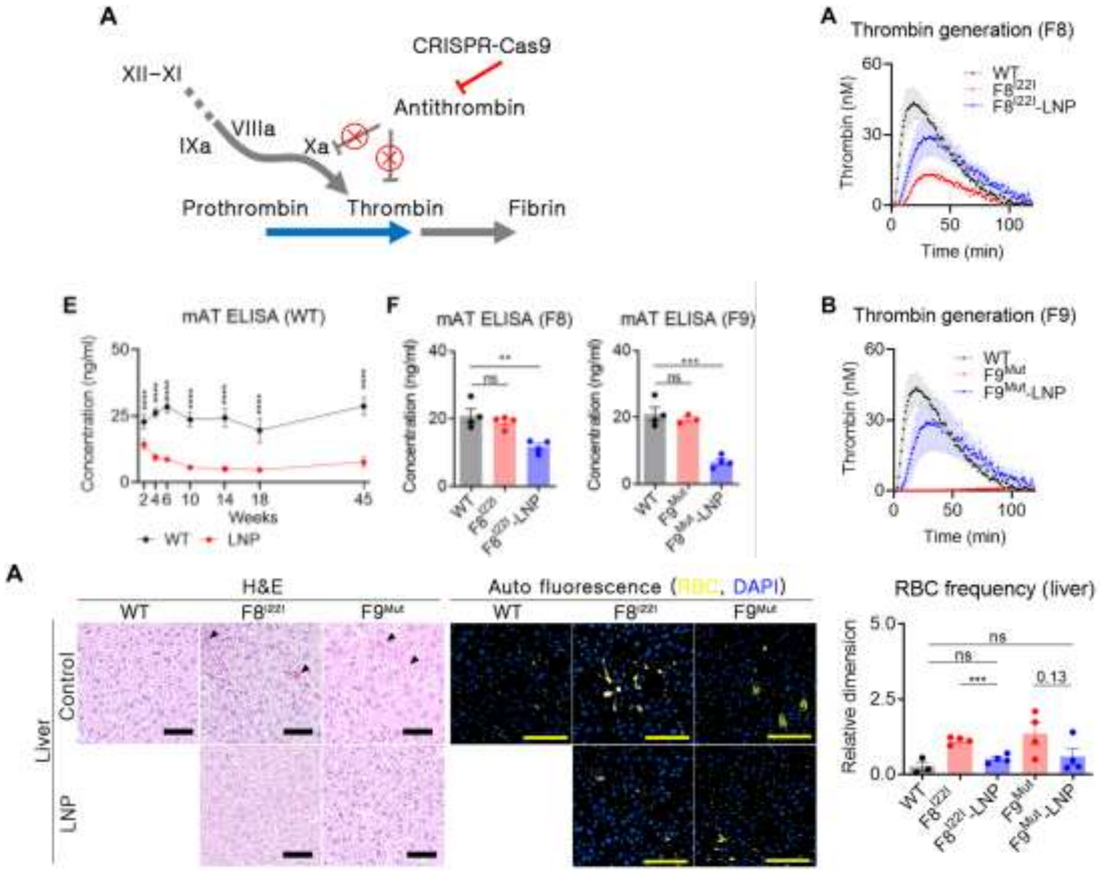
Adeno-Associated Virus (AAV) Gene Therapy





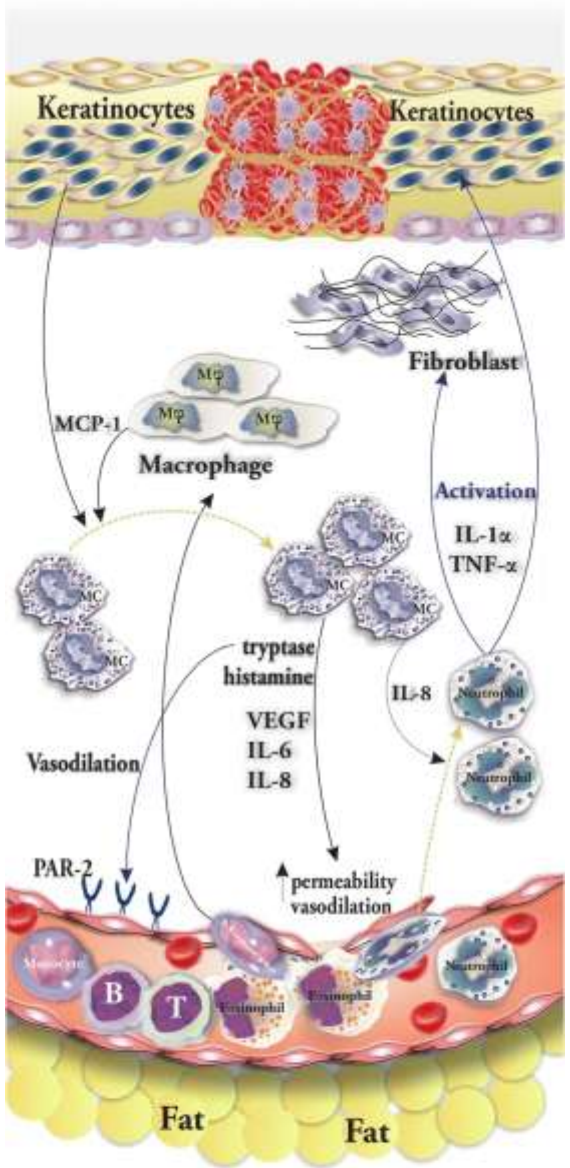
Samelson-Jones BJ, et al. *Annu Rev Med*. 2023

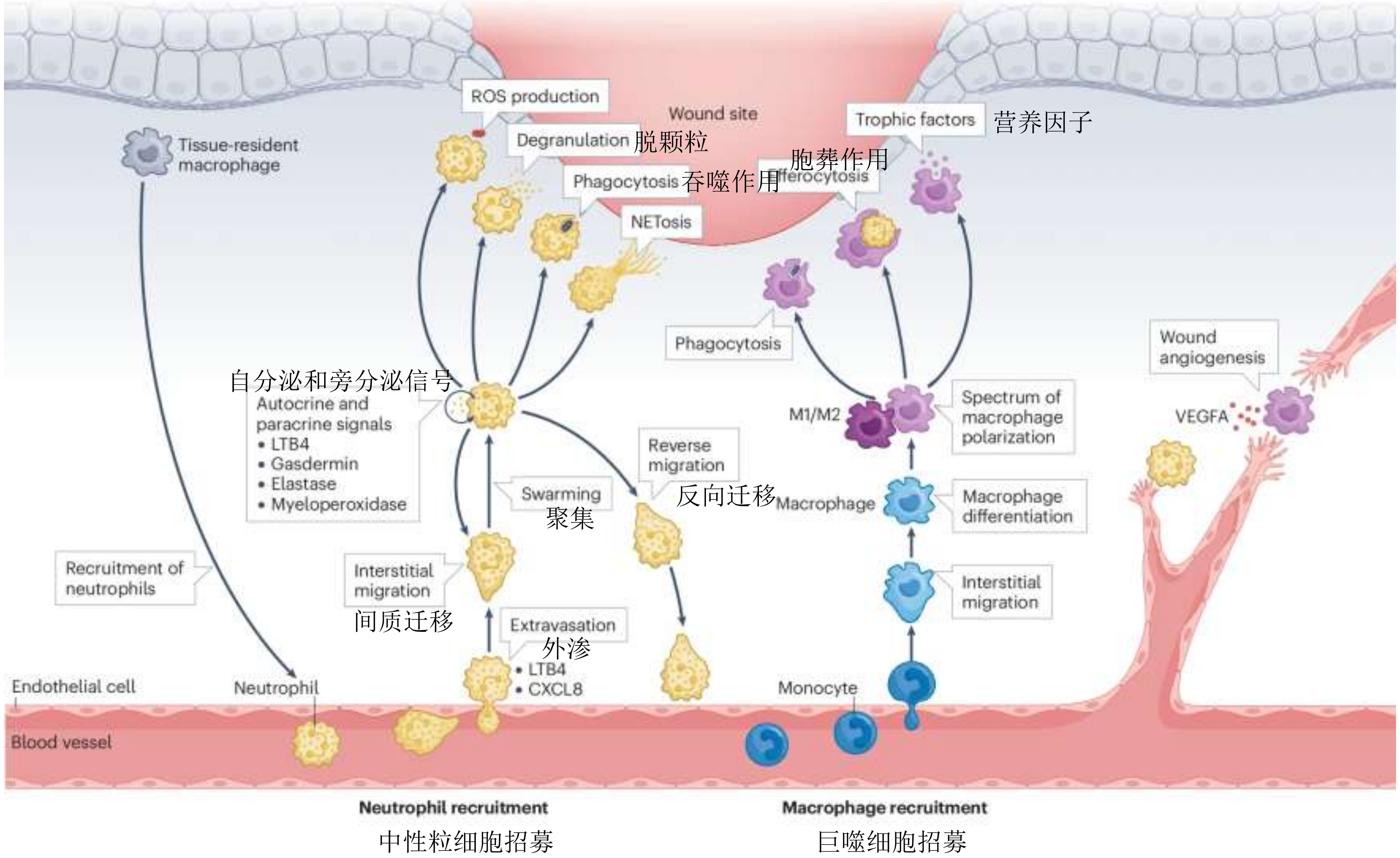
Lipid Nanoparticles (LNP) Delivery



Han JP, et al. *Sci Adv*. 2022

• Inflammation

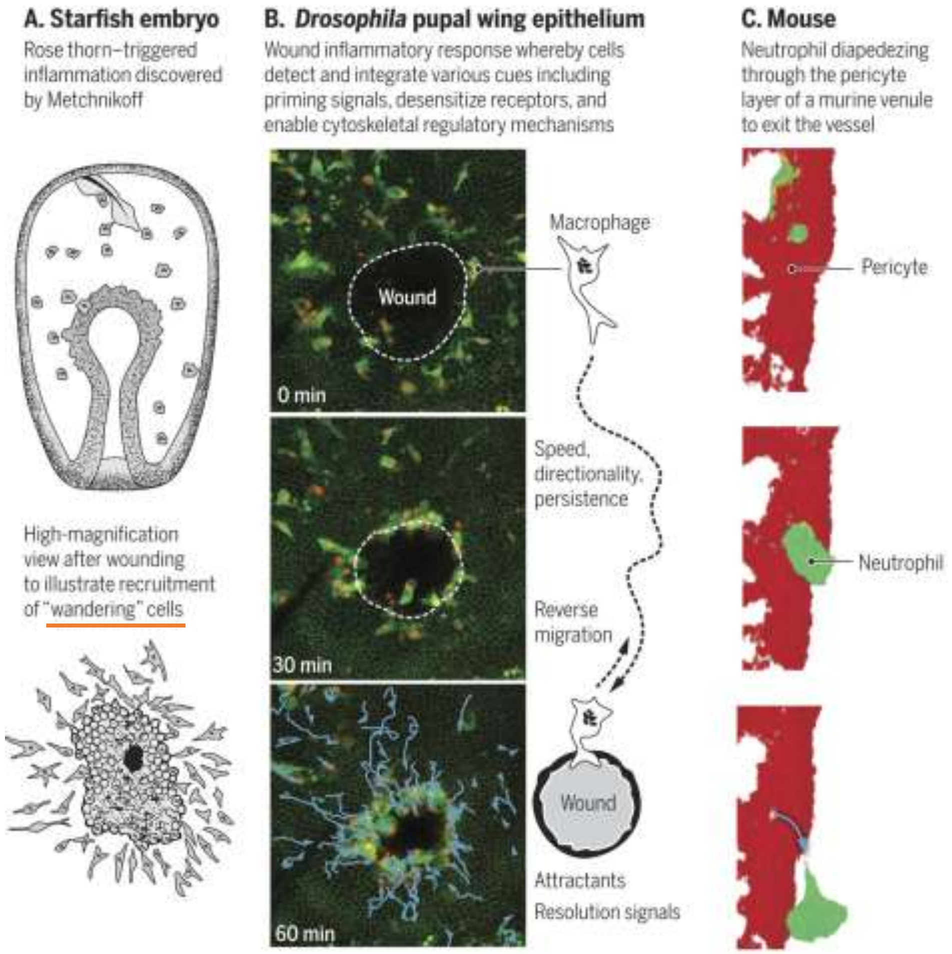




Komi DEA, et al. *Clin Rev Allergy Immunol*. 2020

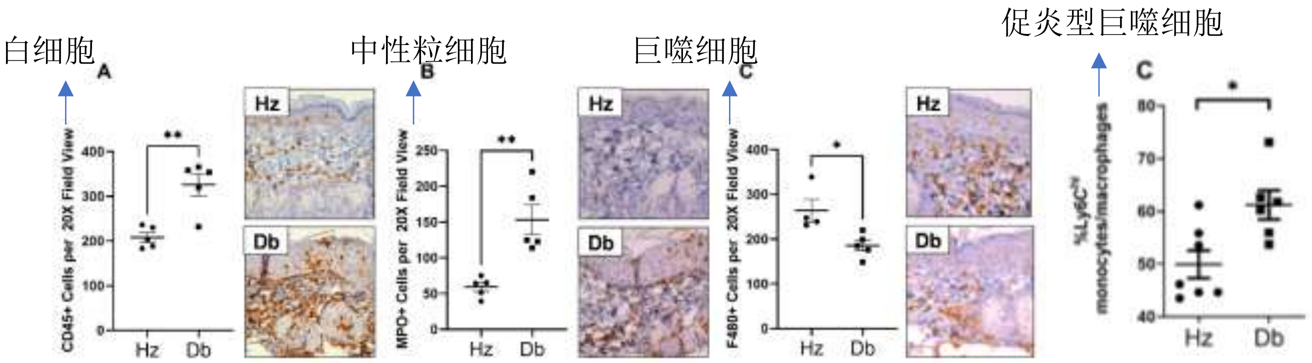
Peña OA, et al. *Nat Rev Mol Cell Biol*. 2024

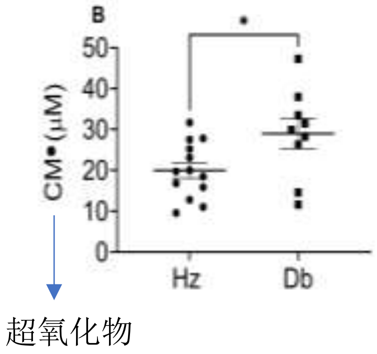
The side effects of long-term inflammation

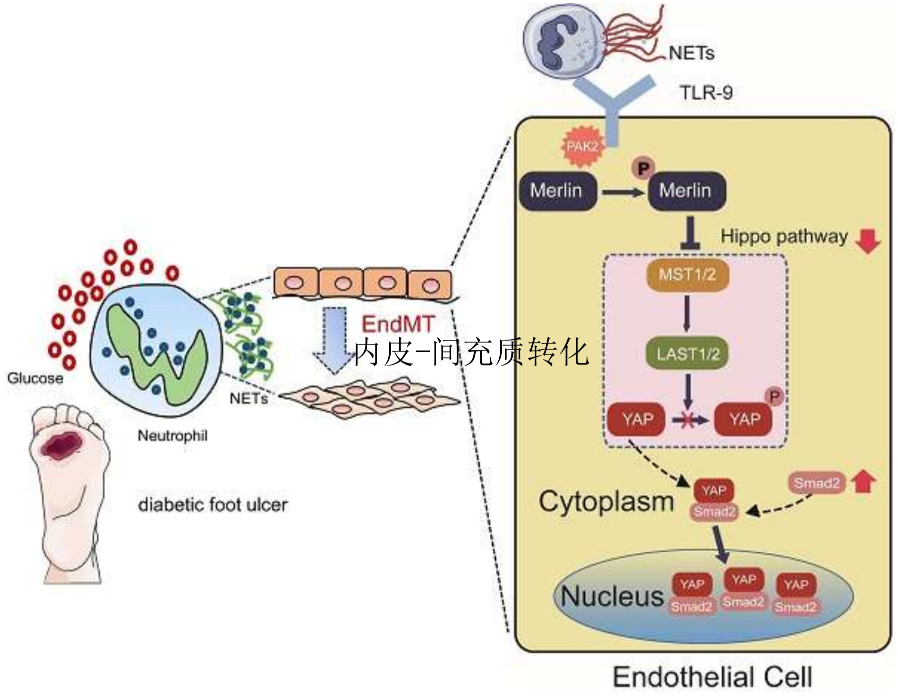


Live imaging of the wound inflammatory response

Eming SA, et al. *Science*. 2017

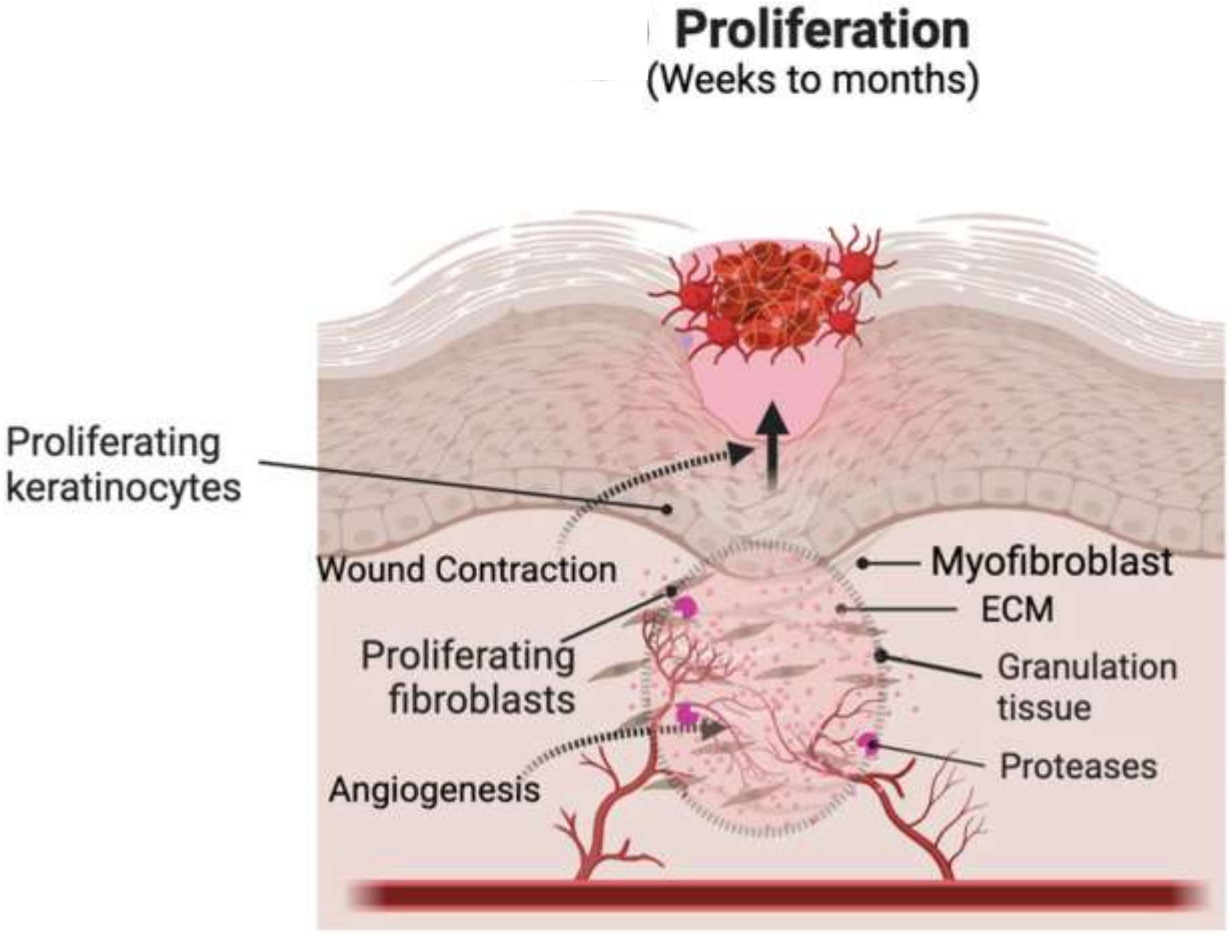






Elajaili H, et al. *Int J Mol Sci*. 2025
Yang SF, et al. *Int J Biol Sci*. 2023

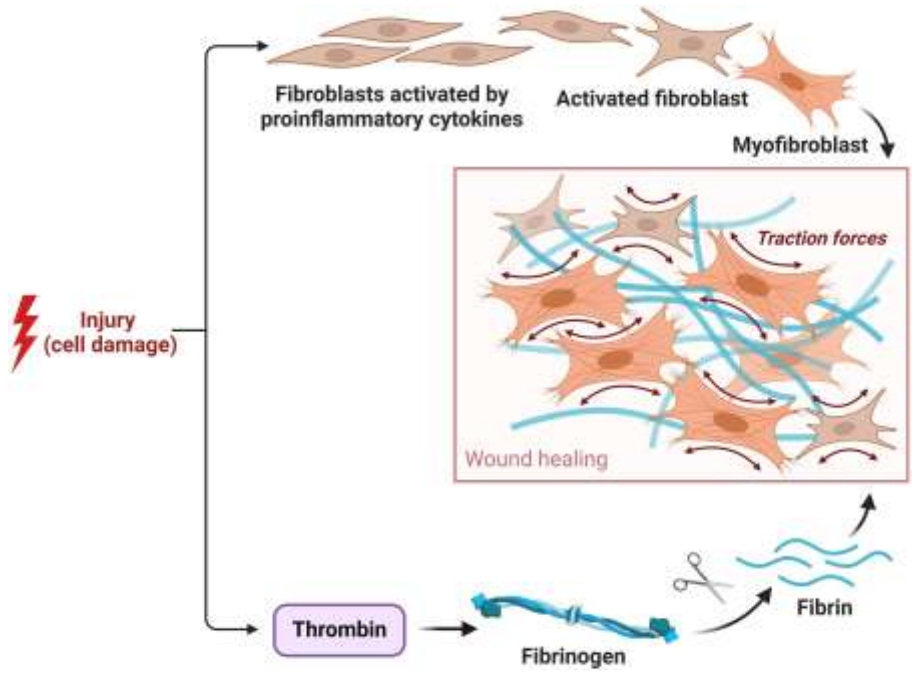
• Proliferation

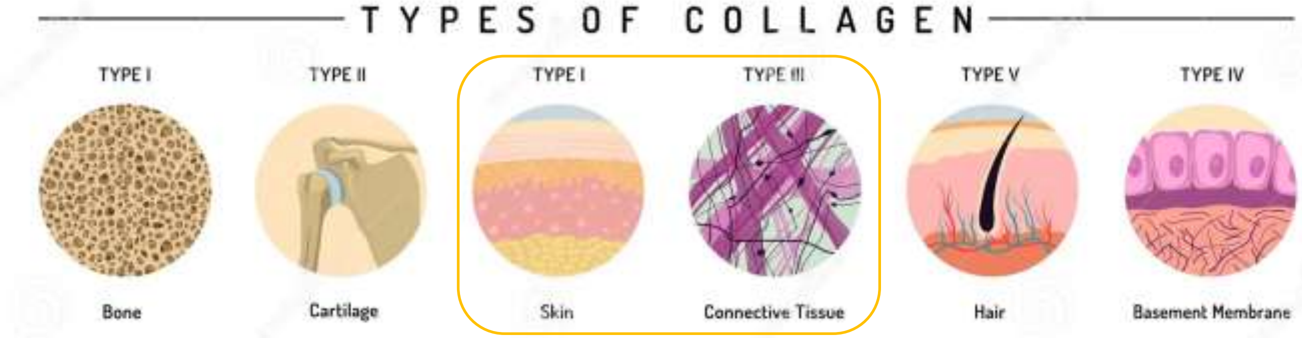


- Granulation tissue formation
- Angiogenesis
- Re-epithelialization

Choudhary V, et al. *Int J Mol Sci*. 2024

The granulation tissue and collagen

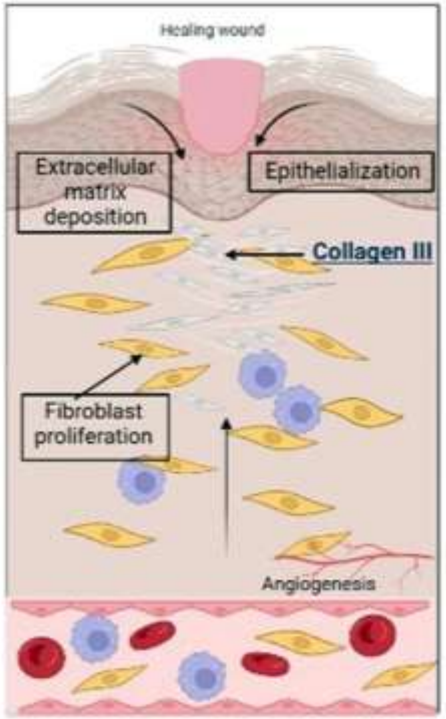




Normal skin：80-85%　10%

difference

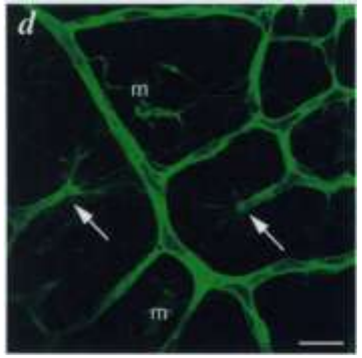
- Type I：纤维粗、交联高、硬度大、低更新率 — 提供抗拉强度和刚性
- Type III：纤维细、交联低、弹性好、高更新率 — 提供延展性与弹性

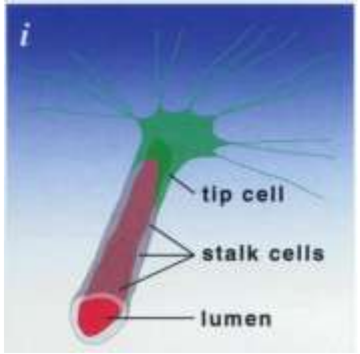


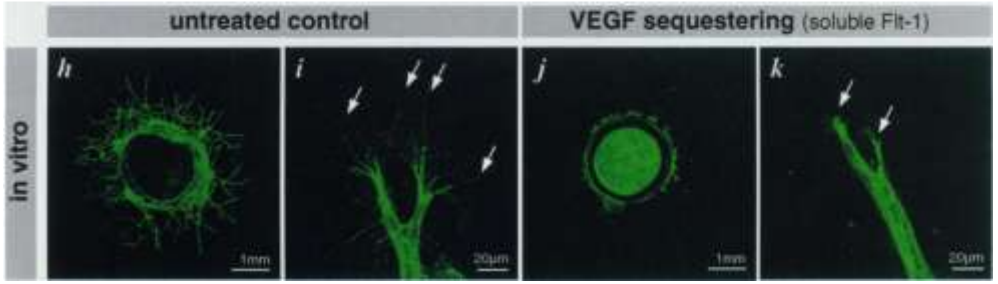
Mamun AA, et al. *Front Immunol*. 2024

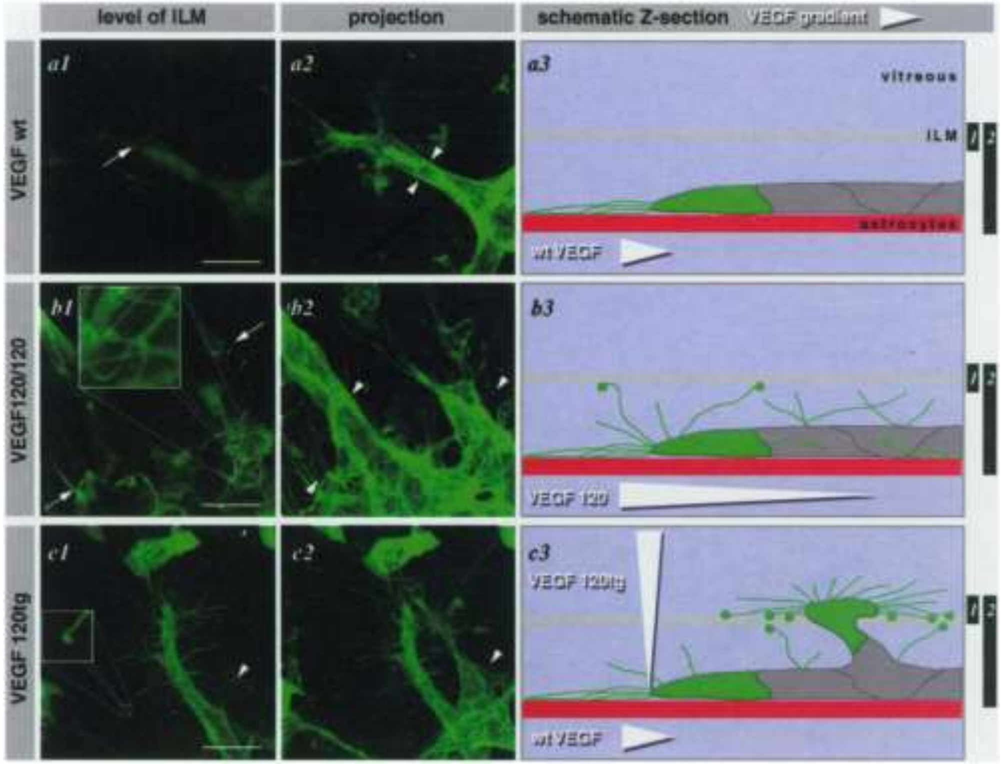
Gajbhiye S, et al. *Biomater Adv*. 2022

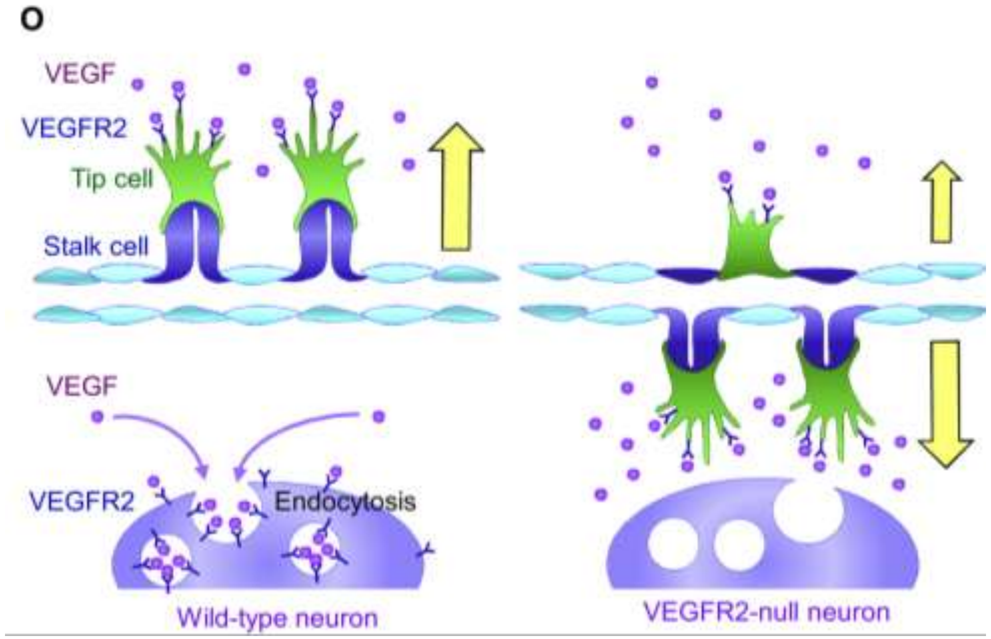
The important role of vascular endothelial growth factor (VEGF) in angiogenesis







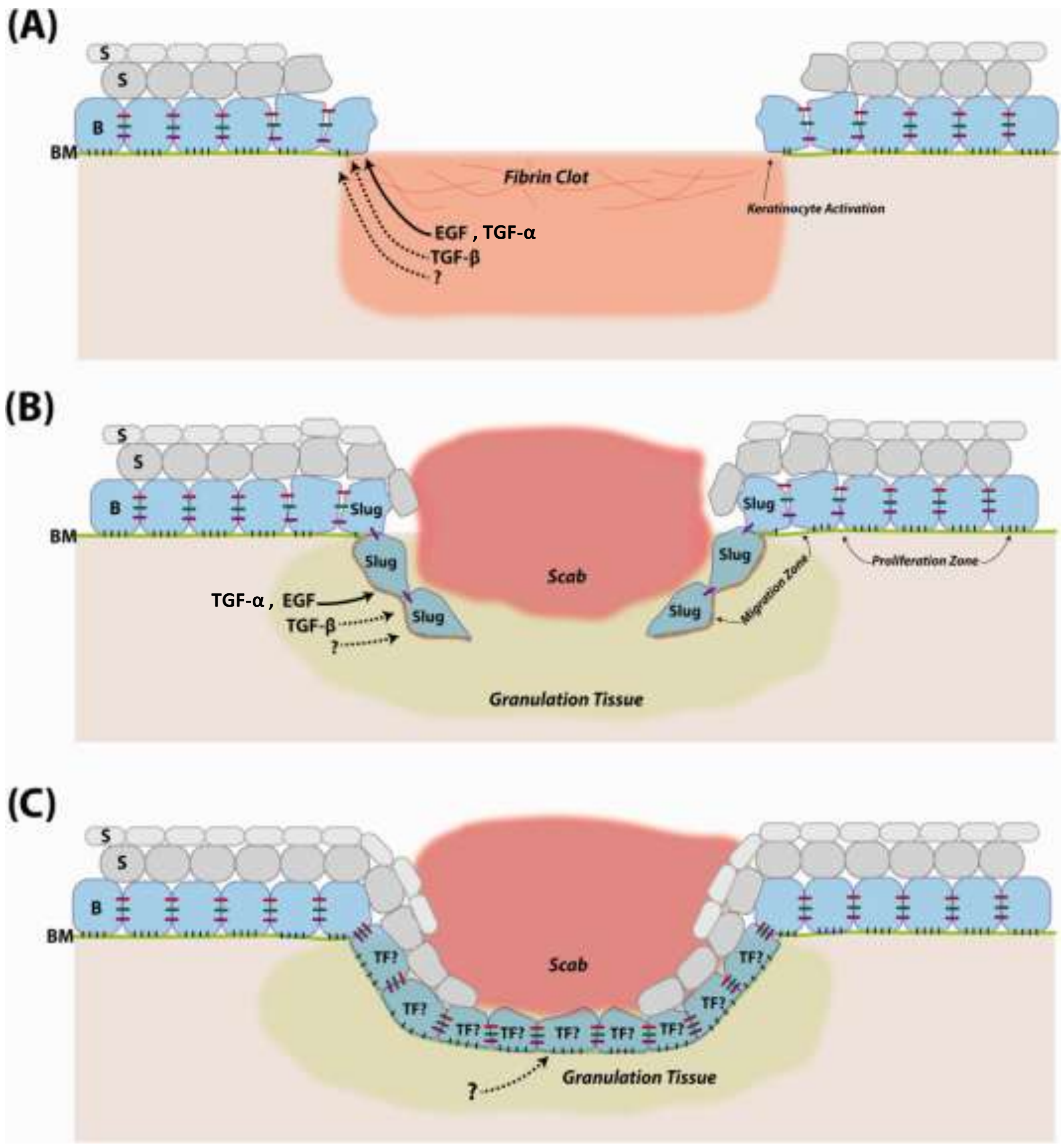


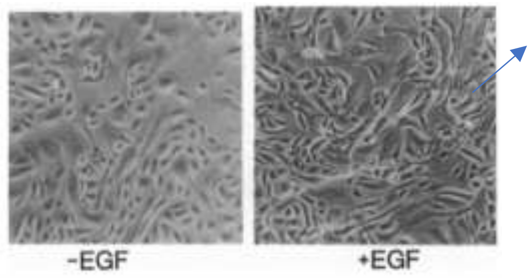


Gerhardt H, et al. *J Cell Biol*. 2003

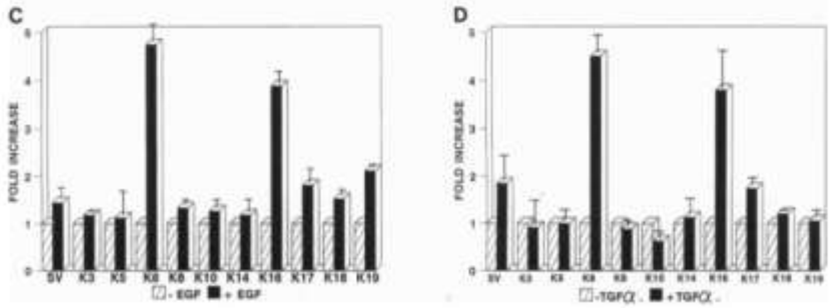
Okabe K, et al. *Cell*. 2014

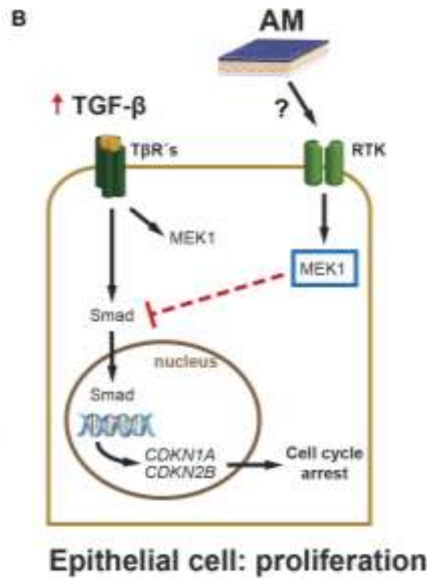
The function of related factors in re-epithelialization

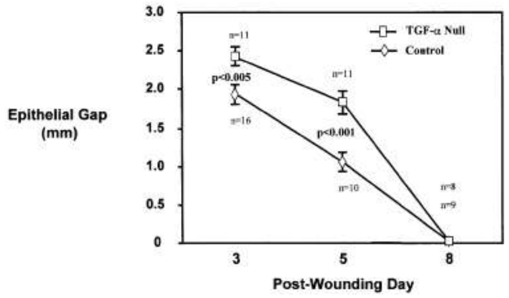


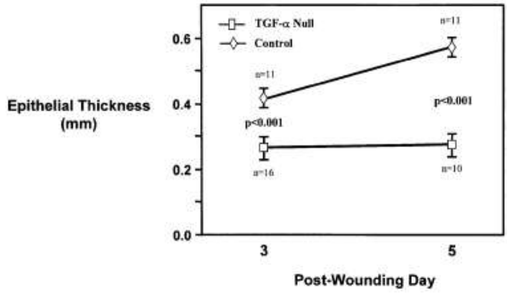


增多、变长、
细胞间边界
更清晰





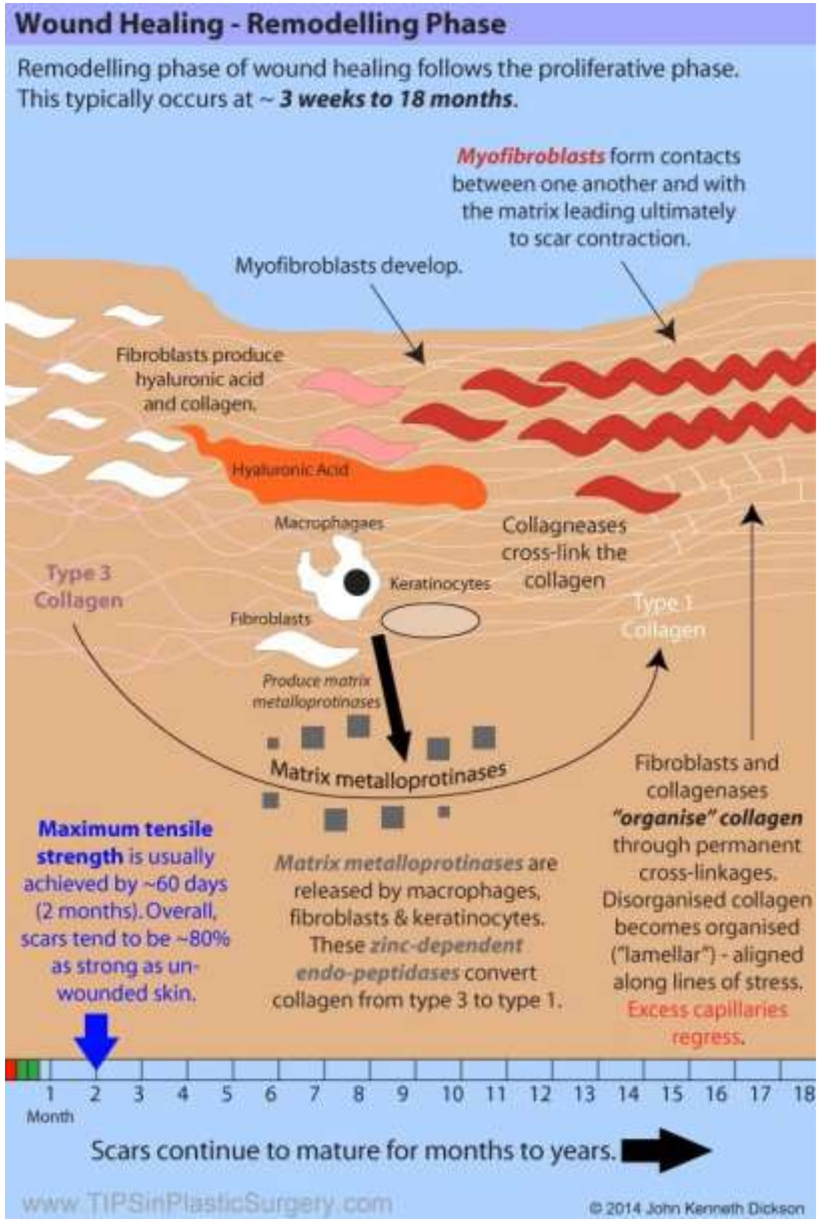




Haensel D, et al. *Dev Dyn*. 2018

Jiang CK, et al. *PNAS*. 1993
Kim, I, et al. *Wound Repair Regen*. 2001
Ruiz-Cañada C, et al. *Front Bioeng Biotechnol*. 2021

- # Remodeling



- **Scar formation**
  - ECM remodeling (Collagen replacement、Apoptosis)
  - Angiogenesis regression

Summary

- Skin wounds are mainly divided into four categories, and they have different degrees of damage to the skin tissue.

- Skin wound healing models can be classified as in vitro, ex vivo and in vivo models and they have different scopes of application.

- Wound healing is divided into four stages, and in each stage, many different cells and factors are involved in regulating the related physiological processes.

  Hemostasis, Inflammation, Proliferation, Remodeling

Thank you!

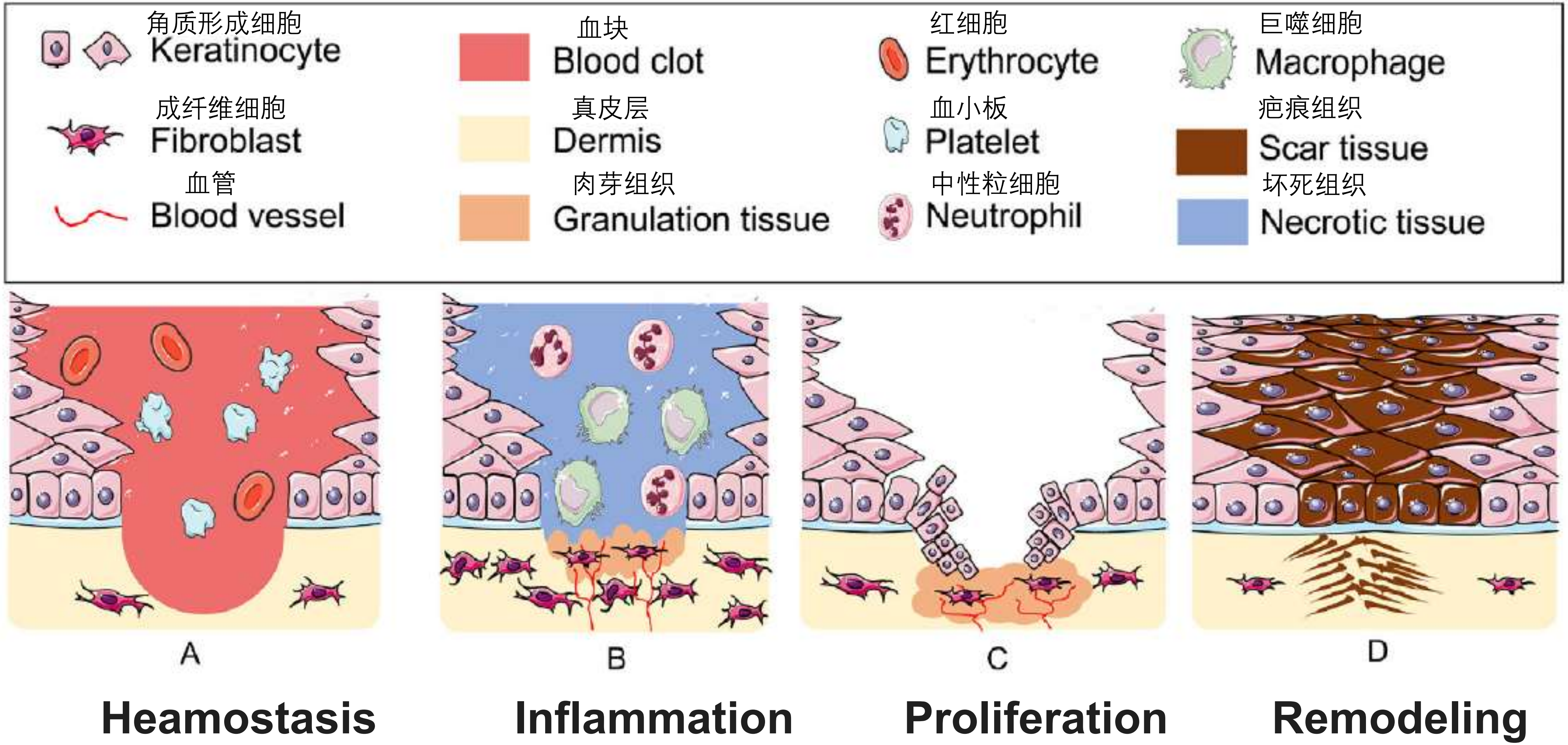
How to accelerate skin wound healing/reduce scarring？

朱培雯

2025-10-30

Humanity's "slow repair"

Normal wound healing process



(Wei Peng, et al. International Journal of Biological Macromolecules, 2022)

The goals of skin wound healing

More efficient

Accelerate healing (quickly stop bleeding and prevent infection)

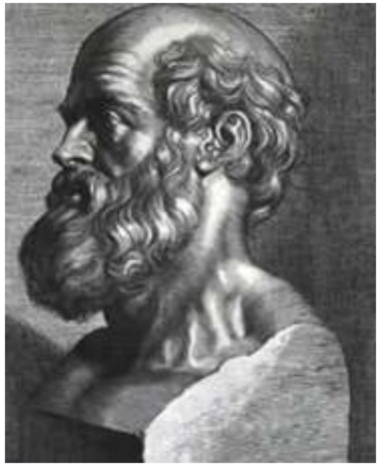
More comfortable

Reduce pain and itching

More beautiful

Reduce scarring

The development history of wound treatment



希波克拉底
（公元前460-370年）

"If the pus is white, and not offensive, health will follow, but if it is sanious and muddy, death is to be looked for."

血性臭脓

主张"自然愈合力"，反对过度干预

盖伦
（公元129-216年）

Suppuration is a necessary process for healing

→" laudable pus"（有益的脓液）

主张"化脓是愈合的必要过程"

(Jeffrey A Freiberg. J Community Hosp, 2017)

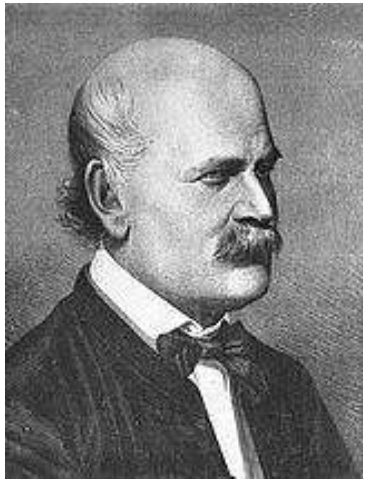
The development history of wound treatment

安布鲁瓦兹·帕雷
（1510-1590年）

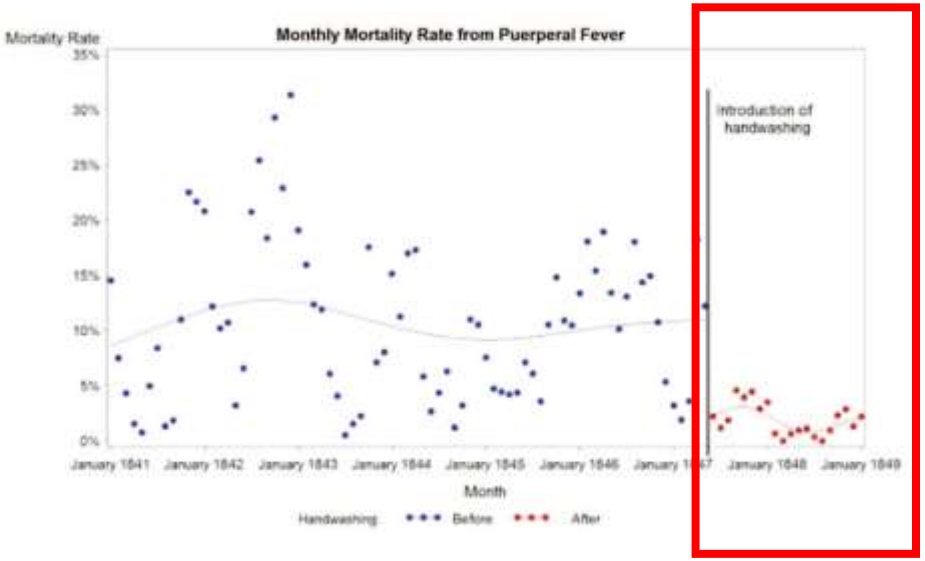
煮沸的油冲烫伤口 ×
温和的蛋黄、玫瑰油和松节油制成的药膏 √

烙铁烧灼止血法 ×
动脉结扎止血法 √

减少痛苦、快速止血



伊格纳兹·塞麦尔维斯
（1818-1865年）



使用消毒液洗手，使脓毒症引发的死亡率急剧下降

消毒液洗手
↓
无菌操作
↓
预防感染

(Pierre La Rochelle, et al. J R Soc Med, 2013)

The development history of wound treatment——Dry healing

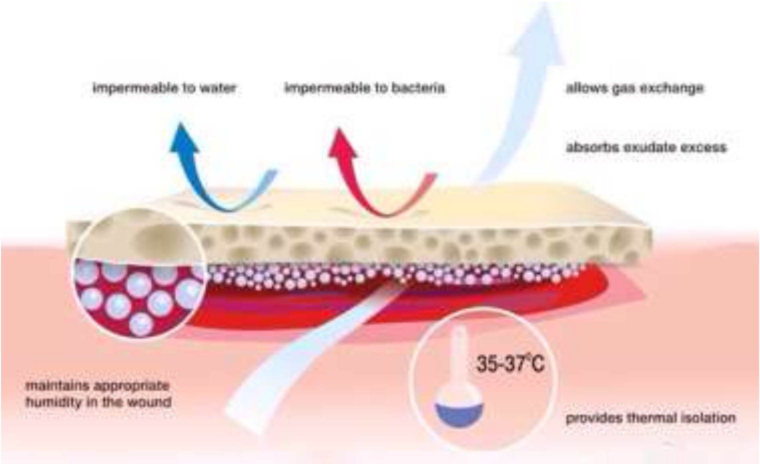
路易斯·巴斯德
(1822-1895年)

约瑟夫·李斯特
(1827-1912年)

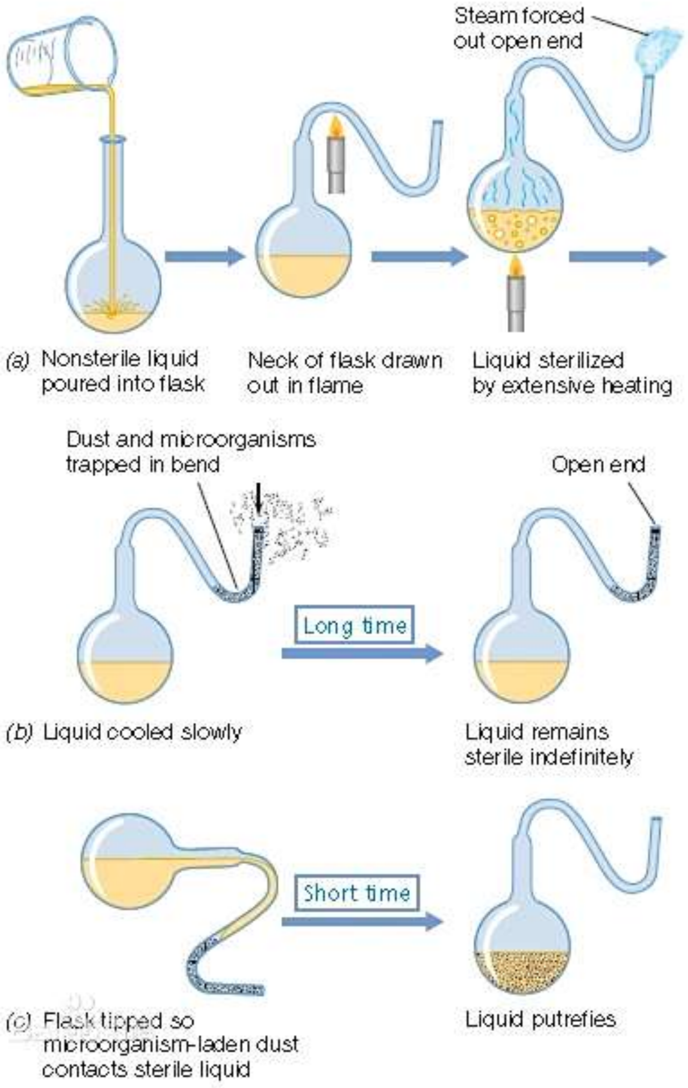
"微生物理论"：腐败和感染是由空气中的微生物引起的，而非自然发生。

巴氏灭菌法

传统敷料——干性敷料（面纱布）覆盖伤口，以保持伤口干燥



将苯酚用于手术器械消毒、外科医生洗手和伤口喷洒，创立了 **"无菌外科术"**



Pasteur's swan-necked flask experiment

Traditional dressings’ obvious shortcomings

1. 它们不能保持伤口湿润，延迟伤口愈合;
2. 伤口肉芽组织容易长入敷料的网状物，更换敷料时容易粘附在伤口上，损伤新的肉芽组织并引起疼痛;
3. 敷料穿透后屏障功能差，易引起外源性感染，止血不良。实验表明，在用生理盐水润湿5 min后，在5层棉纱布组成的敷料中可以发现s型表皮细菌

healing. However, traditional dressings also have obvious shortcomings [40,41]. Such as, (1) they cannot keep the wound moist and delay wound healing; (2) the wound granulation tissue tends to grow into the mesh of the dressing, which tends to adhere to the wound when changing the dressing, damaging the new granulation tissue and causing pain; (3) the barrier function of the dressing is poor after penetration, which tends to cause exogenous infection and poor hemostasis. The experiment has shown that s-type epidermal bacteria can be found in the dressing composed of 5 layers of cotton gauze after being wetted by normal saline for 5 min [42].

(Wei Peng, et al. International Journal of Biological Macromolecules, 2022)

The method of saturating gauze sponges directly in their wrapper was tested to determine strike-through contamination. Contamination occurred in 100% of the uncoated-wrapper sponges, regardless of exposure to Staphylococcus epidermidis or Escherichia coli. Among coated-wrapper sponges, 80% exposed to Staphylococcus epidermidis and 20% exposed to Escherichia coli demonstrated strike-through contamination. Coated-wrapper sponges had a significantly lower rate of contamination than uncoated-wrapper sponges when exposed to Escherichia coli. Occurrence of contamination of all sponges was significantly higher from Staphylococcus epidermidis. The findings render the popular practice of saturating gauze sponges in their wrapper unacceptable.

(D Alexander, et al. Clin Nurs Res, 1992)

The development history of wound treatment—— The Antibiotic Era

The Nobel Prize Physiology/Medicine 1945

Sir Alexander Fleming
1881 - 1955

Sir Howard Walter Florey
1898 - 1968

Ernst Boris Chain
1906 - 1979

Alexander Fleming discovered the antimicrobial properties of penicillin in 1928. Twelve years later, Howard Florey and Ernst Chain developed the processes to produce penicillin in sufficient quantity for it to become widely available

THE BRITISH JOURNAL OF EXPERIMENTAL PATHOLOGY
VOLUME TEN
1929

Reproduced from pages 226–236.

ON THE ANTIBACTERIAL ACTION OF CULTURES OF A PENICILLIUM, WITH SPECIAL REFERENCE TO THEIR USE IN THE ISOLATION OF *B. INFLUENZÆ.*

ALEXANDER FLEMING, F.R.C.S.

From the Laboratories of the Inoculation Department, St Mary's Hospital, London.

Received for publication May 10th, 1929.

ELSEVIER

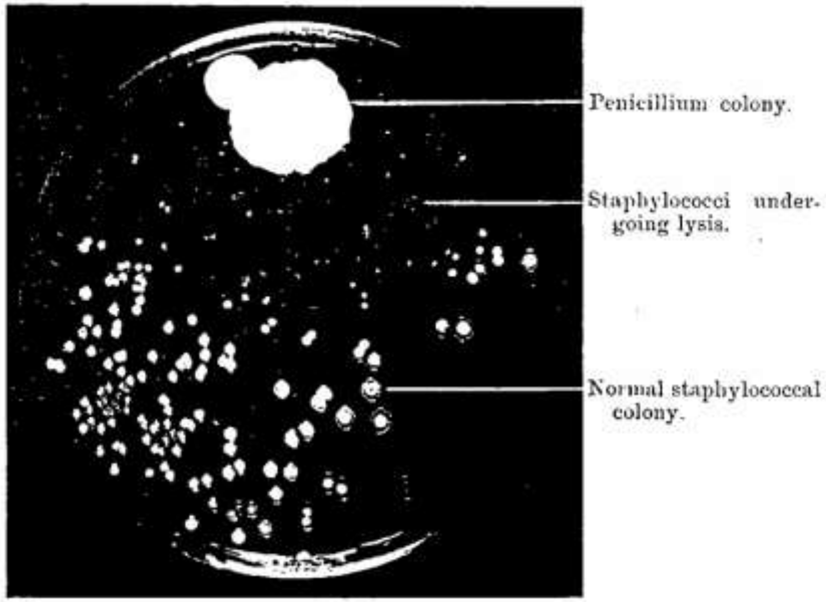
The Lancet
Volume 236, Issue 6104, 24 August 1940, Pages 226-228

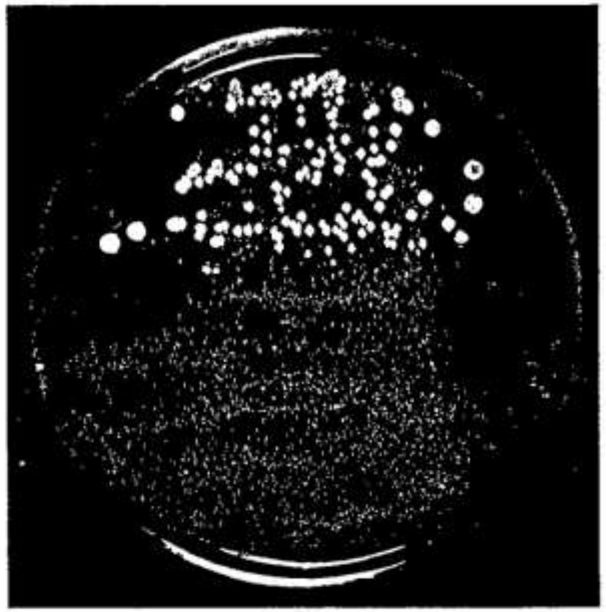
ORIGINAL ARTICLES

PENICILLIN AS A CHEMOTHERAPEUTIC AGENT

E. Chain Ph.D. Cambridge, H.W. Florey M.B. Adelaide, A.D. Gardner D.M. Oxford, F.R.C.S., N.G. Heatley Ph.D. Cambridge, M.A. Jennings B.M. Oxford, J. Orr-Ewing B.M. Oxford, A.G. Sanders M.B. London

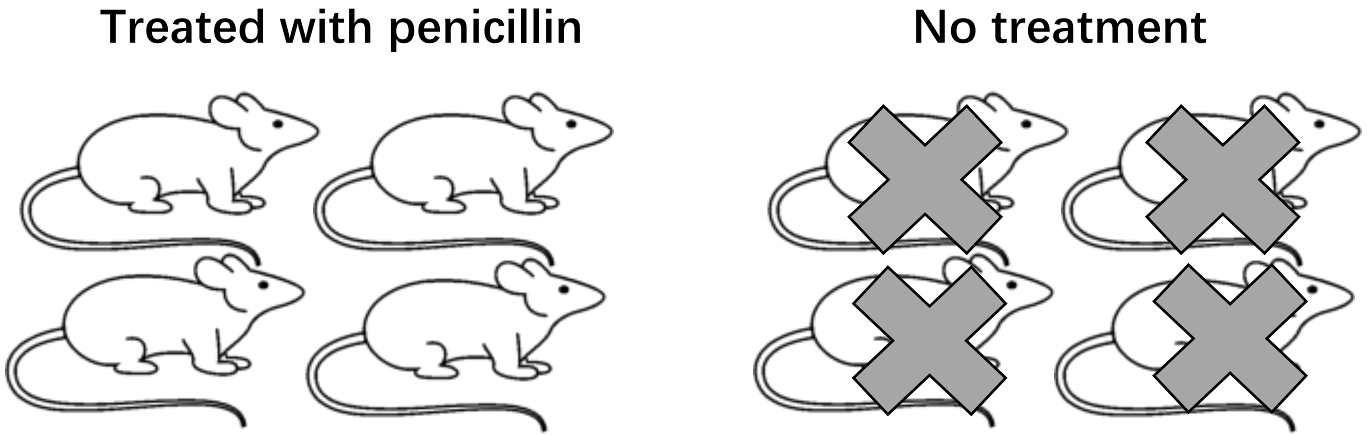
The epoch-making penicillin





(A Fleming. British Journal of Experimental Pathology, 1929)

抗生素的出现，使得人类第一次拥有了能够系统性对抗细菌感染的武器，彻底改变了严重创伤和手术后感染的结局。



《柳叶刀》——
《作为化学疗法的青霉素》

《青霉素的进一步观察》

The development history of wound treatment——Wet healing

Table 1. EPITHELIZATION UNDER NORMAL (DRY) AND EXPERIMENTAL (MOIST) CONDITIONS

Time	Wound	Total length of epidermis (mm. × 10^{-2})	Total length of section examined (mm. × 10^{-2})	Percentage of epidermis
Dry Wounds				
1 day	1	1,608	71,479	2
3 days	7	26,212	77,001	34
5 days	3	55,524	77,504	72
7 days	9	77,902	78,075	100
		Also at 9 and 11 days		100
Moist wounds				
1 day	2	11,327	64,495	18
3 days	8	77,598	78,904	98
5 days	4	71,721	71,721	100
		Also at 7, 9 and 11 days		100

Pig 43. Superficial wounds, 2·5 cm.². Skin depilated with wax 3 days before wound making. 6 wounds, no dressing (dry), 6 wounds covered with polythene film (moist), spaced alternately. Serial sections at 10μ, every fifth section measured.

Table 2. EPITHELIZATION UNDER NORMAL (DRY) AND EXPERIMENTAL (MOIST) CONDITIONS

Time	Wound	Total length of epidermis (mm. × 10^{-2})	Total length of section examined (mm. × 10^{-2})	Percentage of epidermis
Dry wounds				
3 days	3	59,481	102,865	58
	5	32,940	81,635	40
	6	23,224	70,050	33
	8	24,892	66,119	38
	9	23,232	65,183	36
	12	30,254	90,756	33
Total (6 wounds)		194,023	476,608	41 (40·7)
Moist wounds				
3 days	1	83,804	84,410	99
	2	87,120	87,120	100
	4	106,804	106,902	100
	7	101,362	101,574	100
	10	78,045	79,089	99
	11	71,557	76,434	94
Total (6 wounds)		528,692	535,529	99 (98·7)

Pig 47. Superficial wounds, 2·5 cm.². Hair was clipped short immediately before wound making. 6 wounds, no dressing (dry), 6 wounds covered with polythene film (moist), distributed at random. Serial sections at 10μ, every fifth section measured.

(GEORGE D. WINTER. Nature, 1962)

在**湿润密闭环境**下的伤口，其上皮细胞迁移速度比暴露在干燥结痂环境下的伤口快约**2倍**。

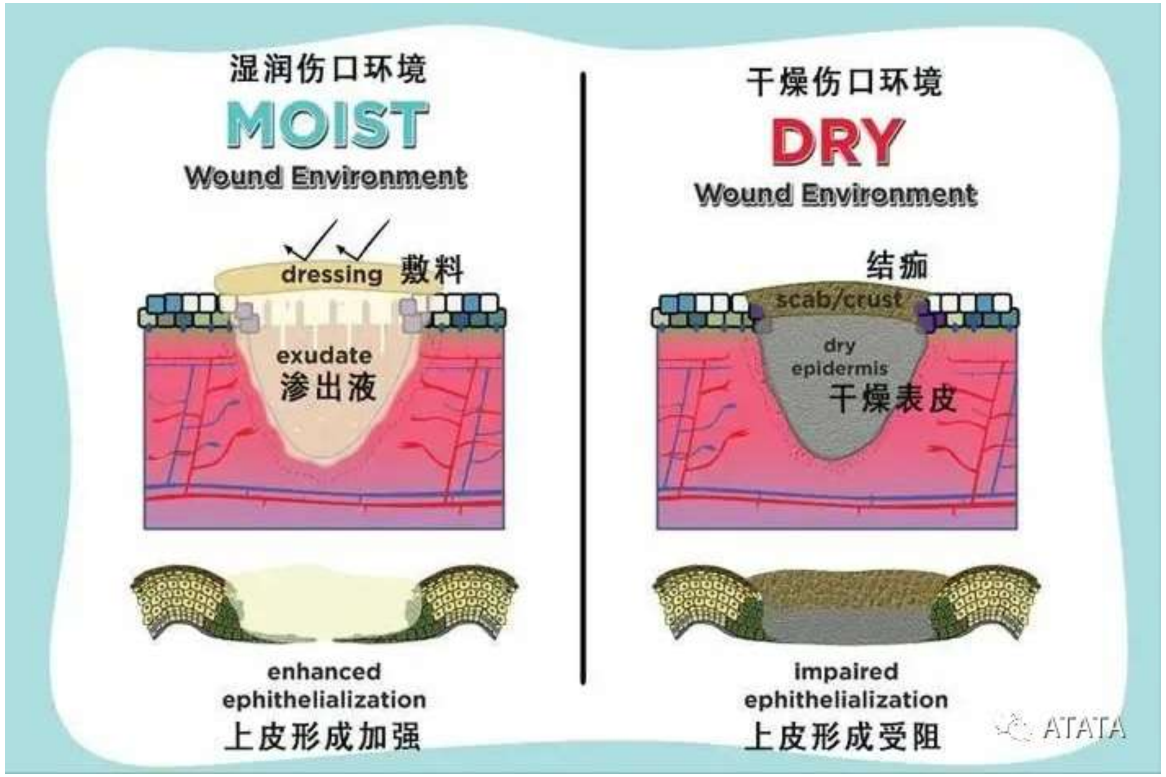
The difference between dry healing and wet healing

细胞在湿润的基质中自由、快速地迁移

保护生长因子和酶活性，促进细胞间通信

保护新生组织，减轻疼痛，炎症期更可控

愈合速度快，疤痕形成减少，舒适度高



细胞需要在干燥的痂皮下或深层艰难迁移

生长因子易失活，细胞间信号传递效率低

换药易导致二次损伤，疼痛剧烈，炎症期可能延长

愈合速度慢，易留疤痕，疼痛感强

Summary：

- **第一阶段：顺其自然**

  错误的化脓理论影响了西方医学长达一千多年。

- **第二阶段：止血、无菌**

  微生物理论提出与无菌术的诞生。在于性愈合理论指导下进行伤口护理。

- **第三阶段：优化愈合微环境**

  抗生素的出现，使得人类第一次拥有了能够系统性对抗细菌感染的武器。

  湿性愈合理论催生了现代伤口敷料的诞生。

Now, we hope to shift the process of wound healing from "passive healing" to "active guided regeneration"

The core of modern wound care is to "create a clean, moist, warm and sealed healing environment"

Questions：

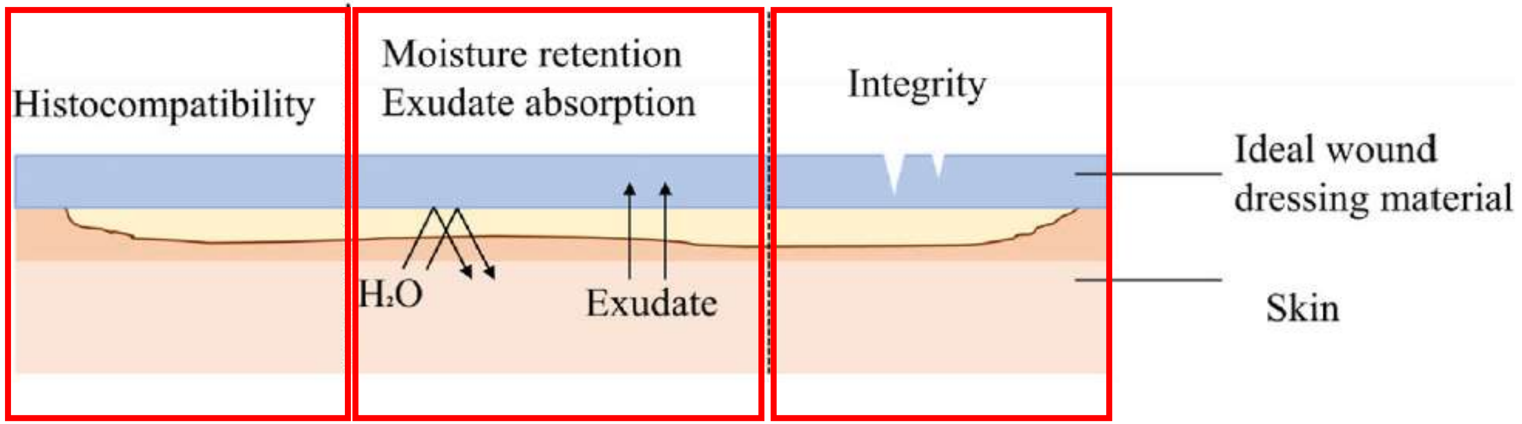
Part 1. What requirements should an ideal skin wound dressing meet?

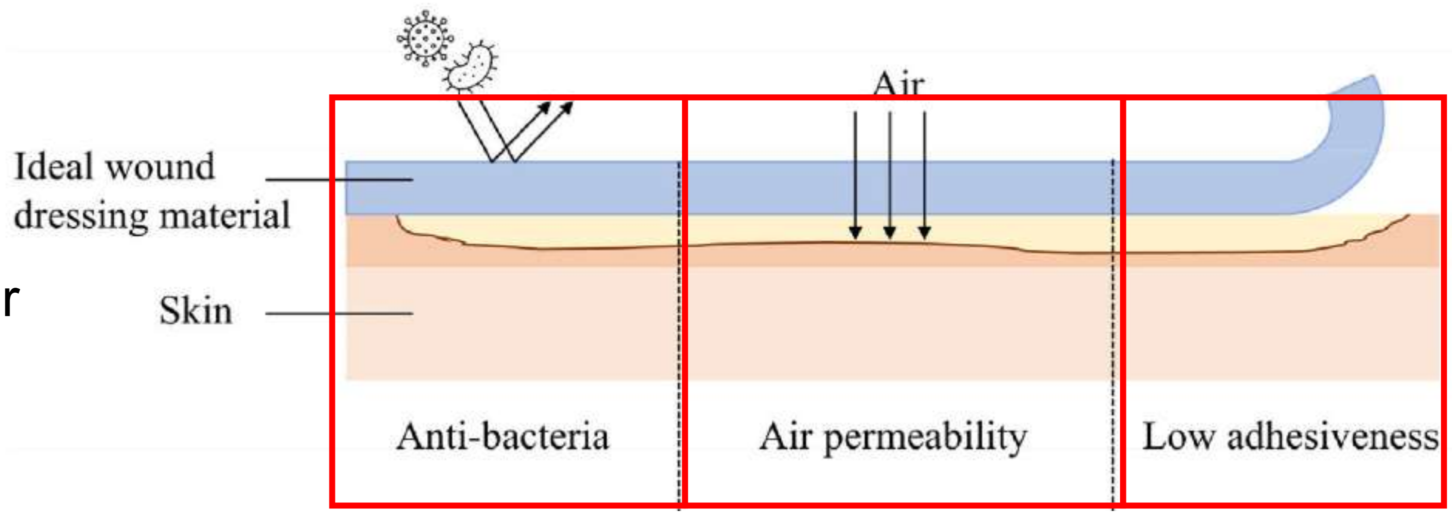
Part 2. At present, what are the new types of wound dressings used in clinical wound healing?

Part 3. How to reduce itching or improve the appearance of scars?

Ideal skin wound dressings' requirements

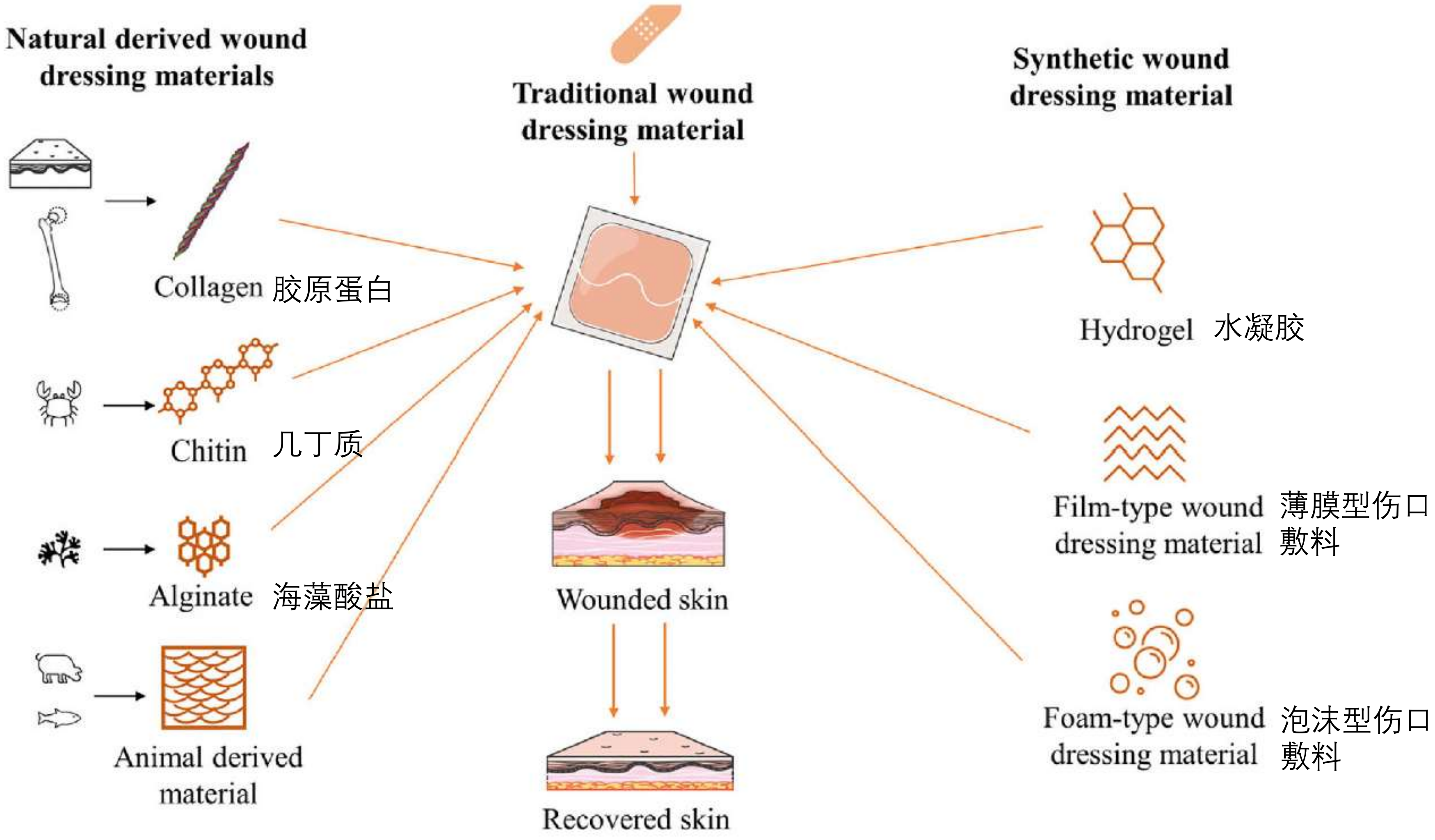
(a) Histocompatibility, toxicity, and inflammation free;
(b) Moisture retention and exudate absorption;
(c) Mechanical properties similar with human skin which keeps its integrity;
(d) Protection against secondary infection;
(e) Suitable pore density allowing air permeability;
(f) Low adhesiveness that prevents wound trauma at dressing removal.





(Wei Peng, et al. International Journal of Biological Macromolecules, 2022)

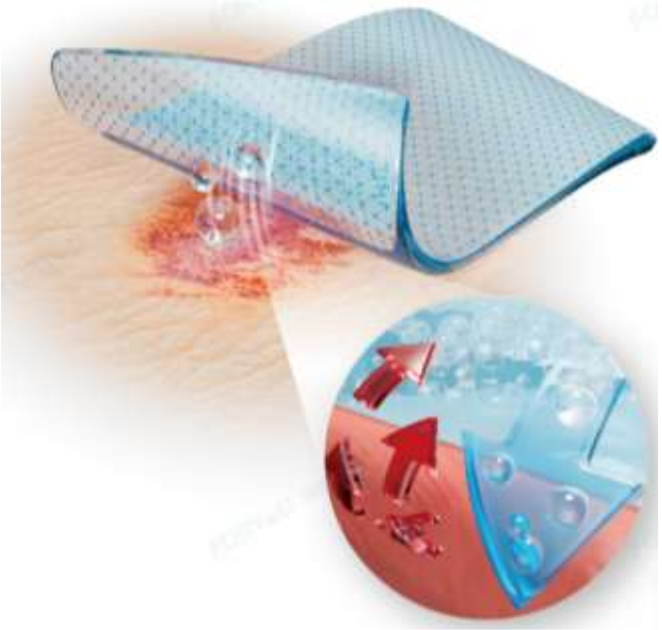
The Classification of different wound dressing materials



(Wei Peng, et al. International Journal of Biological Macromolecules, 2022)

Hydrogel: "Hydrating and Debridement Engineer"

水溶性高分子材料或其单体经特殊工艺加工而成的一种不溶于水的胶体物质，具有三维网络结构。

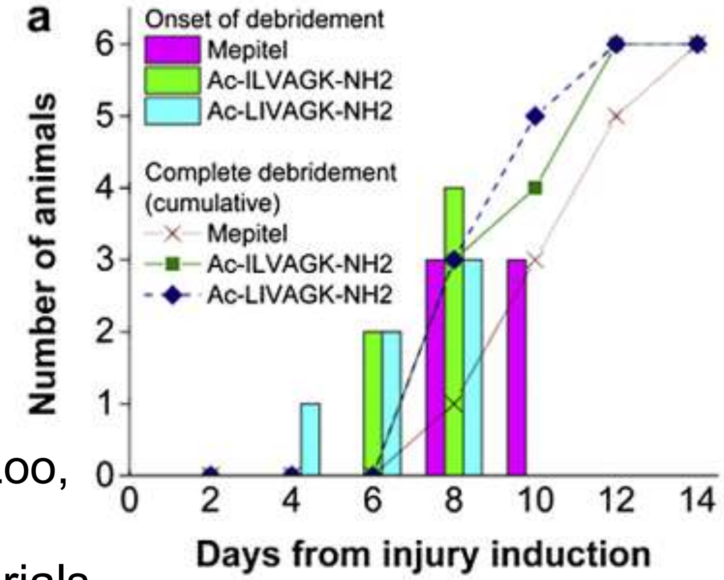


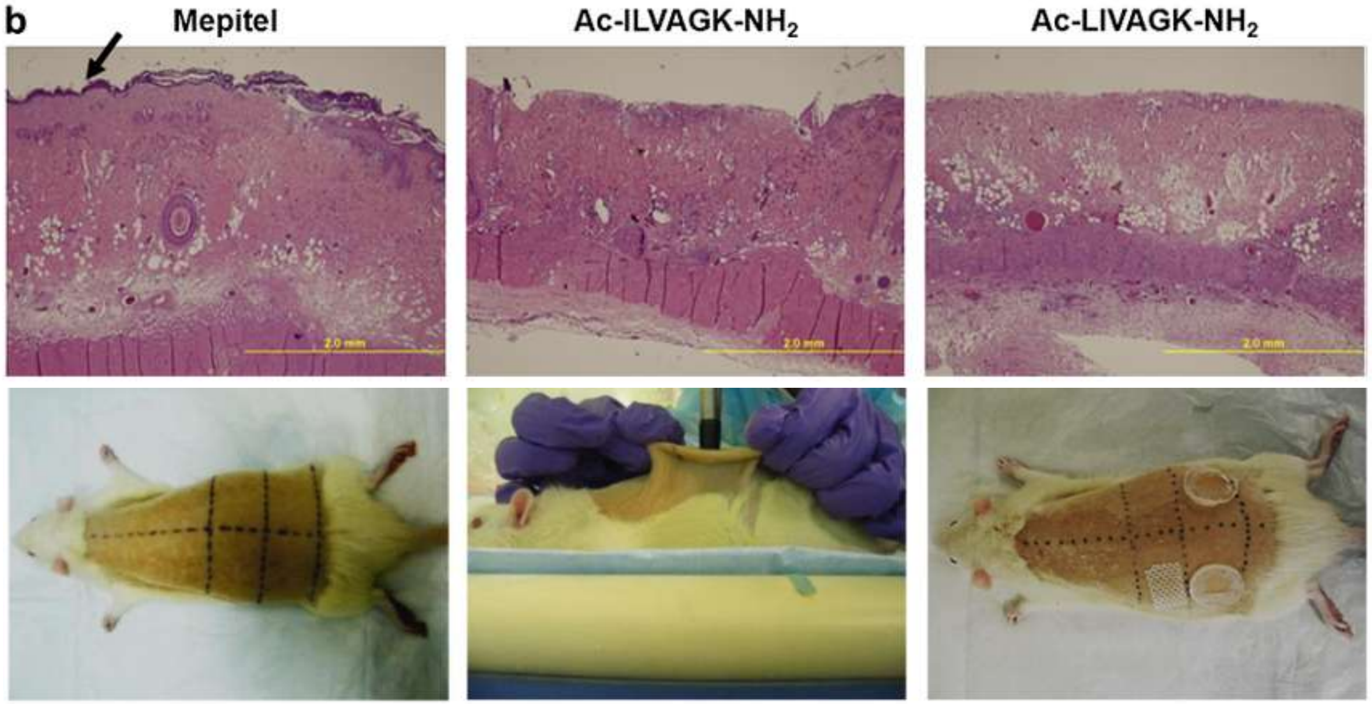
最适合的伤口类型：

- **干燥或有坏死组织/黑痂的伤口**
- **部分或全层厚度的烧伤**
- **疼痛明显的伤口**（其清凉感有镇痛效果）
- **用于清创阶段的黄色腐肉伤口**

Hydrogel Dressings for Autolytic Debridement

水凝胶

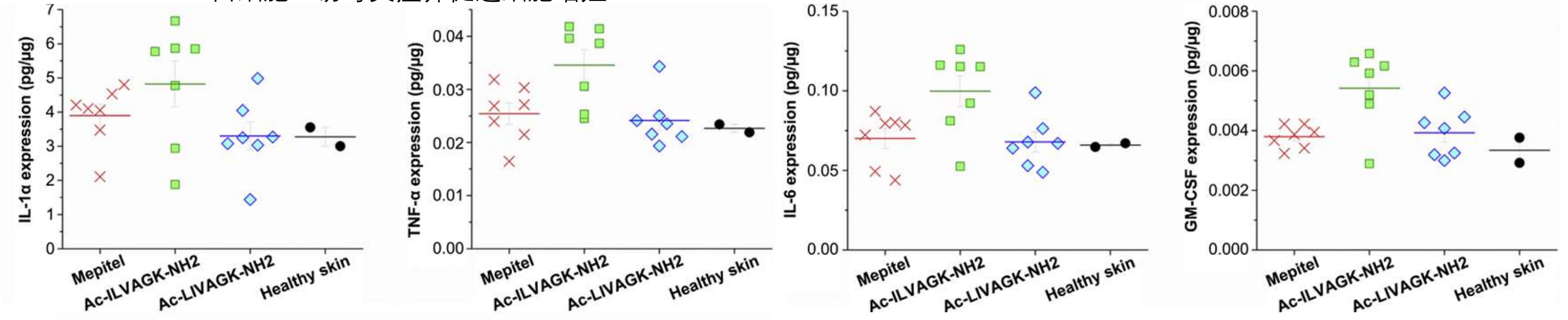




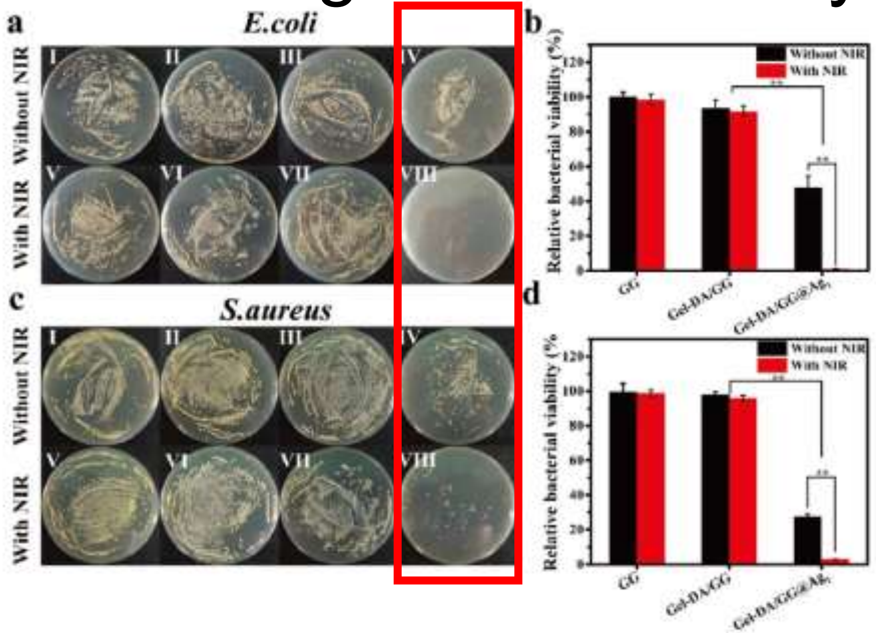
(Yihua Loo, et al. Biomaterials. 2014)

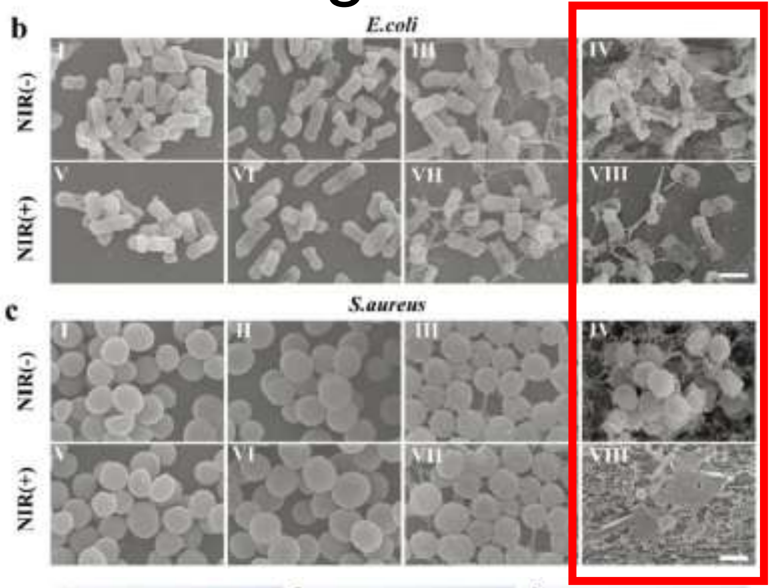
白细胞—诱导炎症并促进细胞增殖

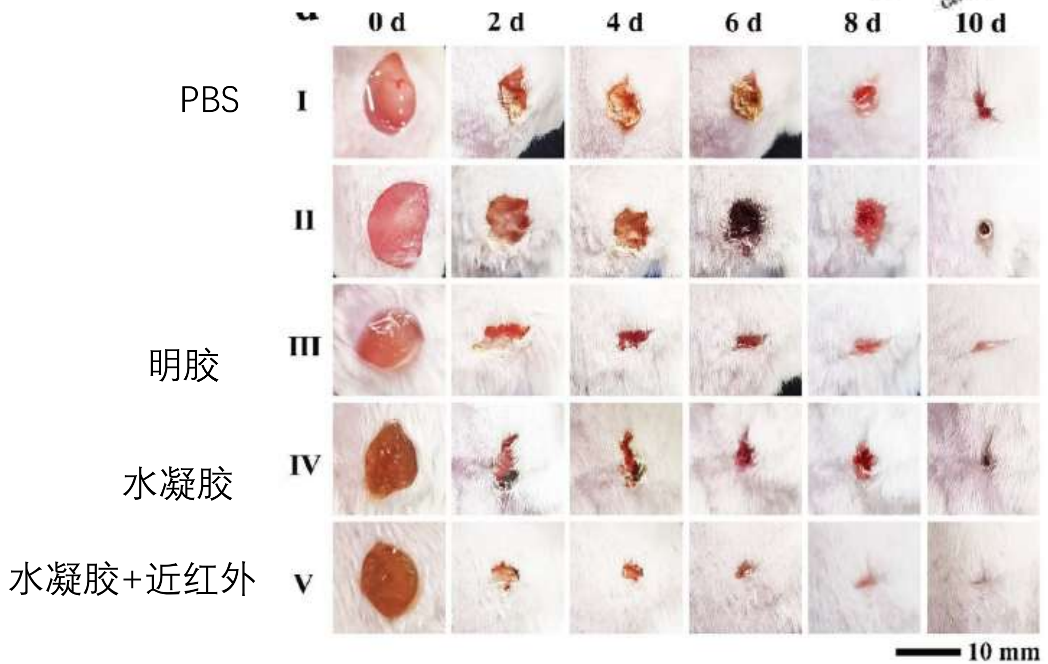
巨噬细胞—选择性溶解和清除坏死组织

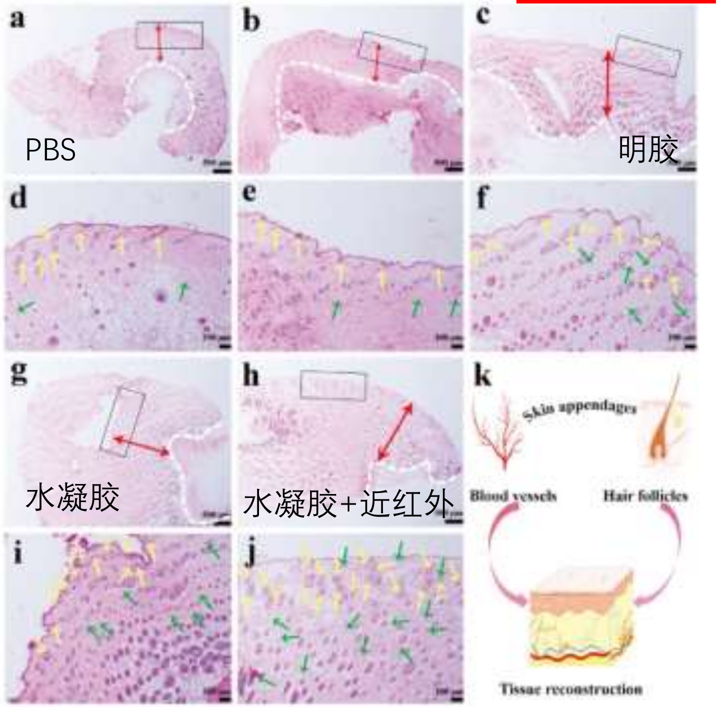


Hydrogel Dressings for Effectively Accelerating Wound Healing









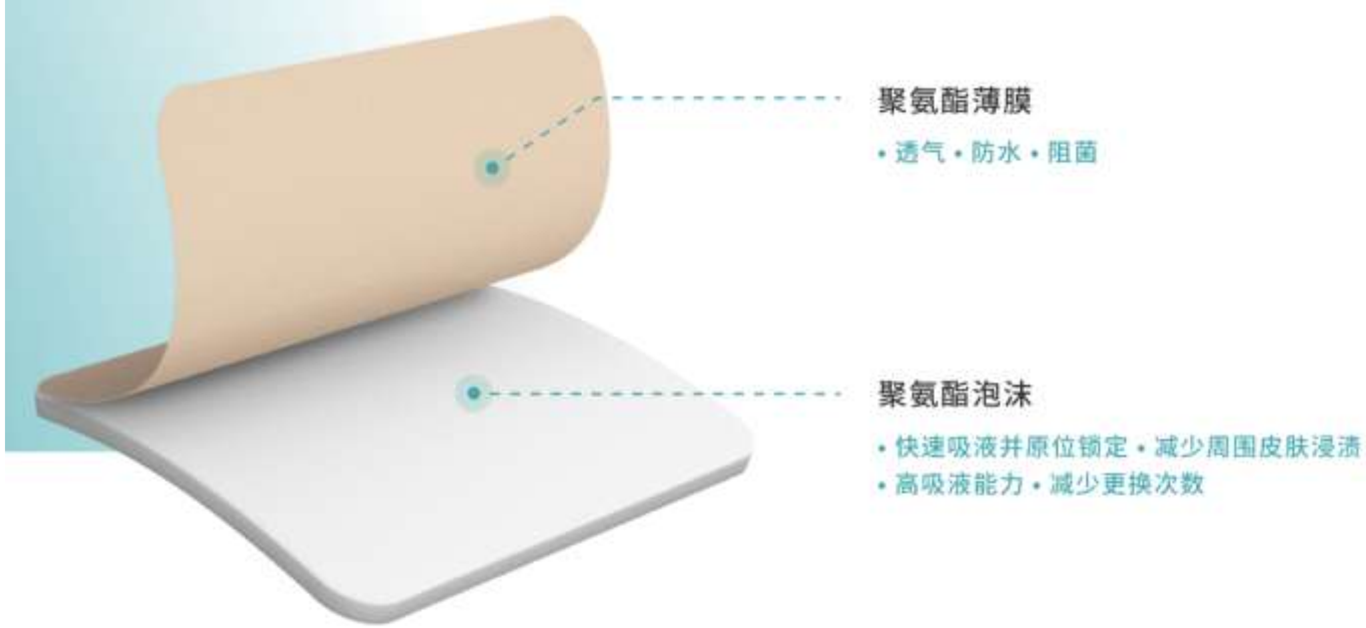
(Hui Zhang, et al. Adv. Funct. Mater. 2021)

Foam-type wound dressing material: "Absorption Buffer Guardian"

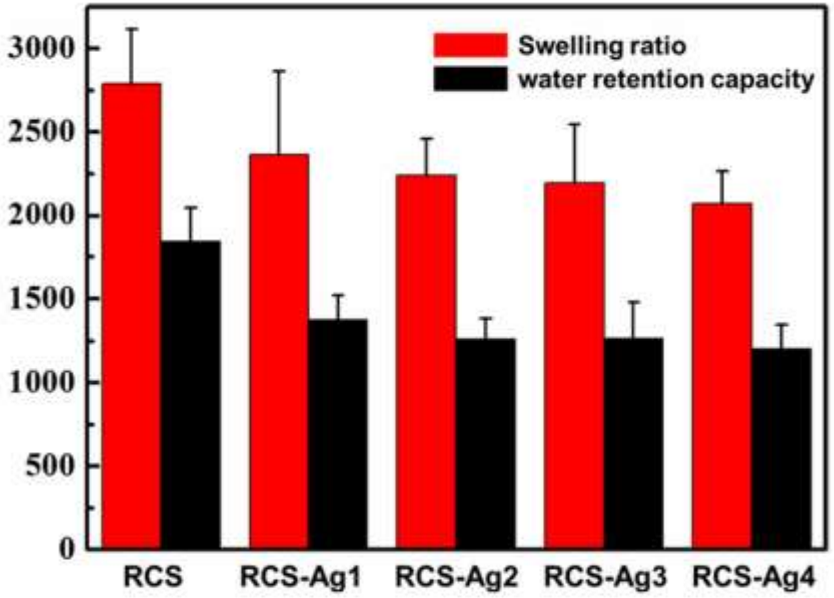
泡沫型伤口敷料是由泡沫聚合物（如聚氯乙烯或聚氨酯）和有机硅组成的片状敷料。它们有许多空隙，有弹性和透气性，不粘性，轻便舒适。

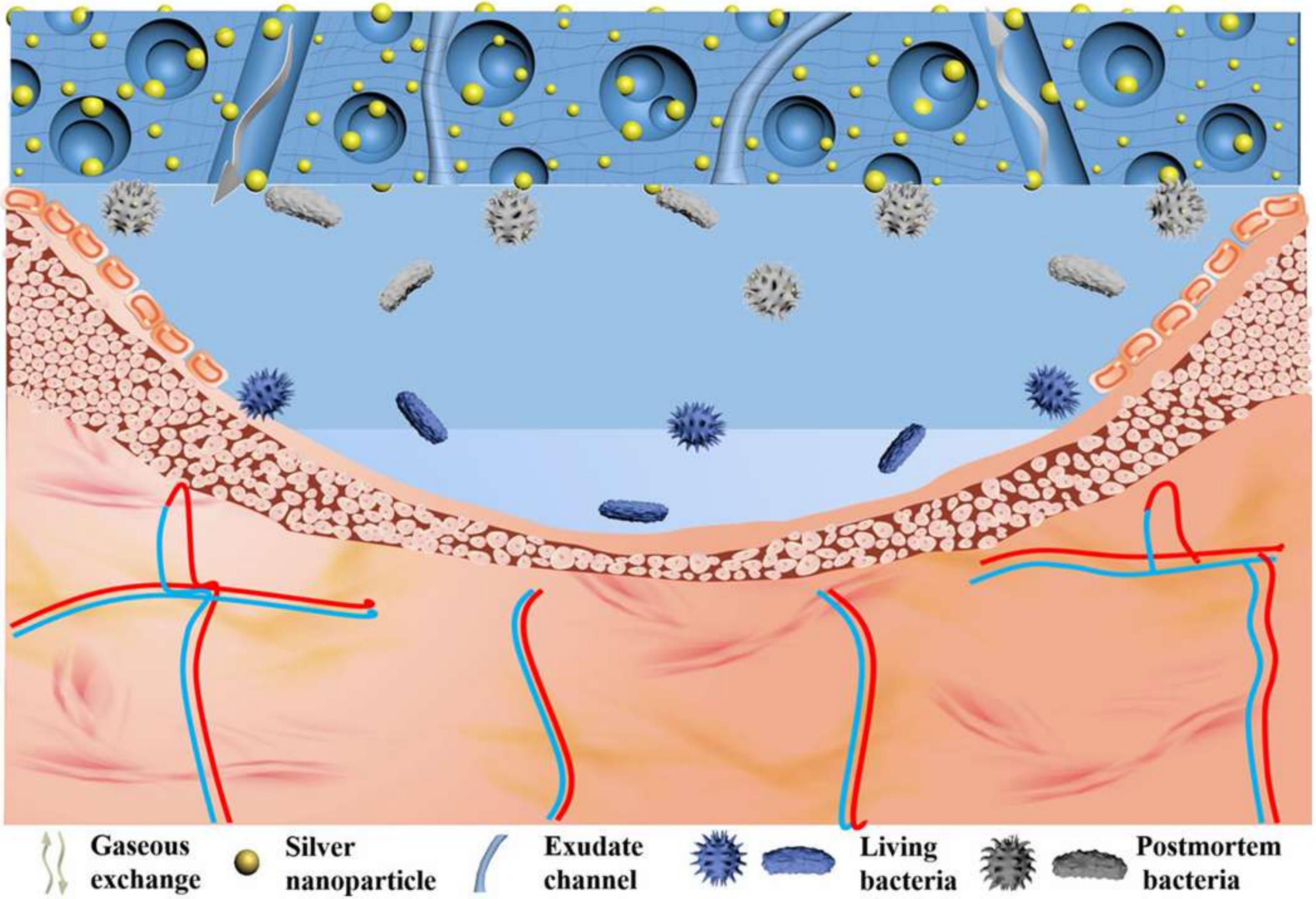
最适合的伤口类型：

- **中至大量渗液的肉芽期伤口**
- **周围皮肤浸渍高风险伤口**
- **需要缓冲保护的伤口**
- **部分厚度烧伤**（渗液多时）。



The Advantages of Foam wound dressings





（1）纤维素海绵丰富的微孔和纳米孔为足够的透气性和渗出液吸收提供了通道。

（2）纤维素海绵具有良好的溶胀性能，具有优异的生物相容性，可保持伤口湿润的环境并吸收渗出液。

(Dongdong Ye, et al. Cellulose, 2016)

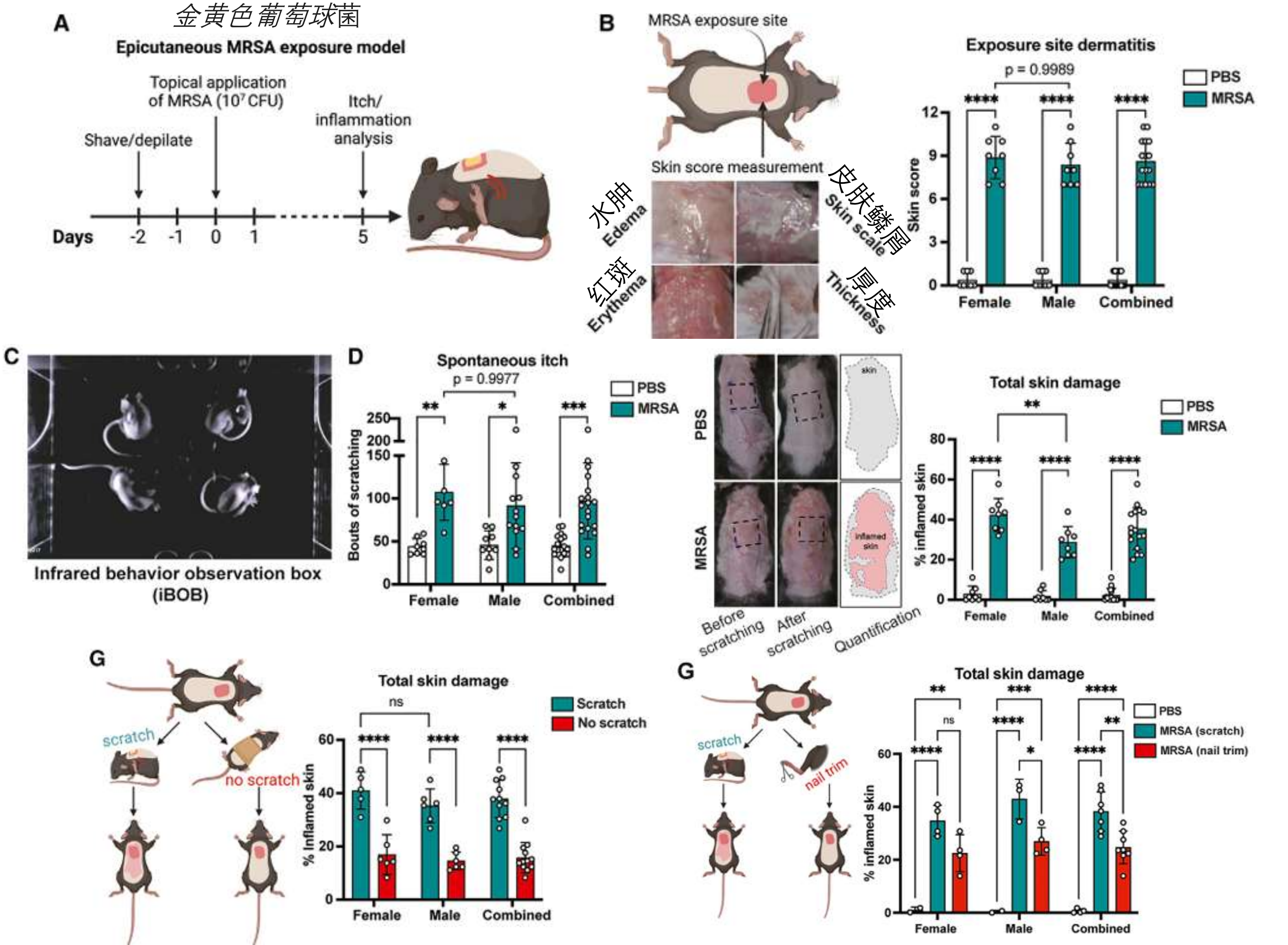
Film-type wound dressing material: "Transparent Breathable barrier"

薄膜型伤口敷料是由聚乙烯(PE)、聚氨酯(PU)等高分子复合材料在一侧覆盖脱敏医用胶粘剂制成，主要用于静脉注射和导管放置部位等浅表伤口、褥疮早期阶段、预防辐射损伤。也可用作敷料的外层保护膜。

最适合的伤口类型：

- **表浅、渗液极少的伤口**
- **缝合或钉合后的清洁手术切口**
- **静脉留置针的固定与保护。**
- **作为二级敷料**：用于覆盖在水凝胶等无粘性的初级敷料之上，起到固定和密封作用。

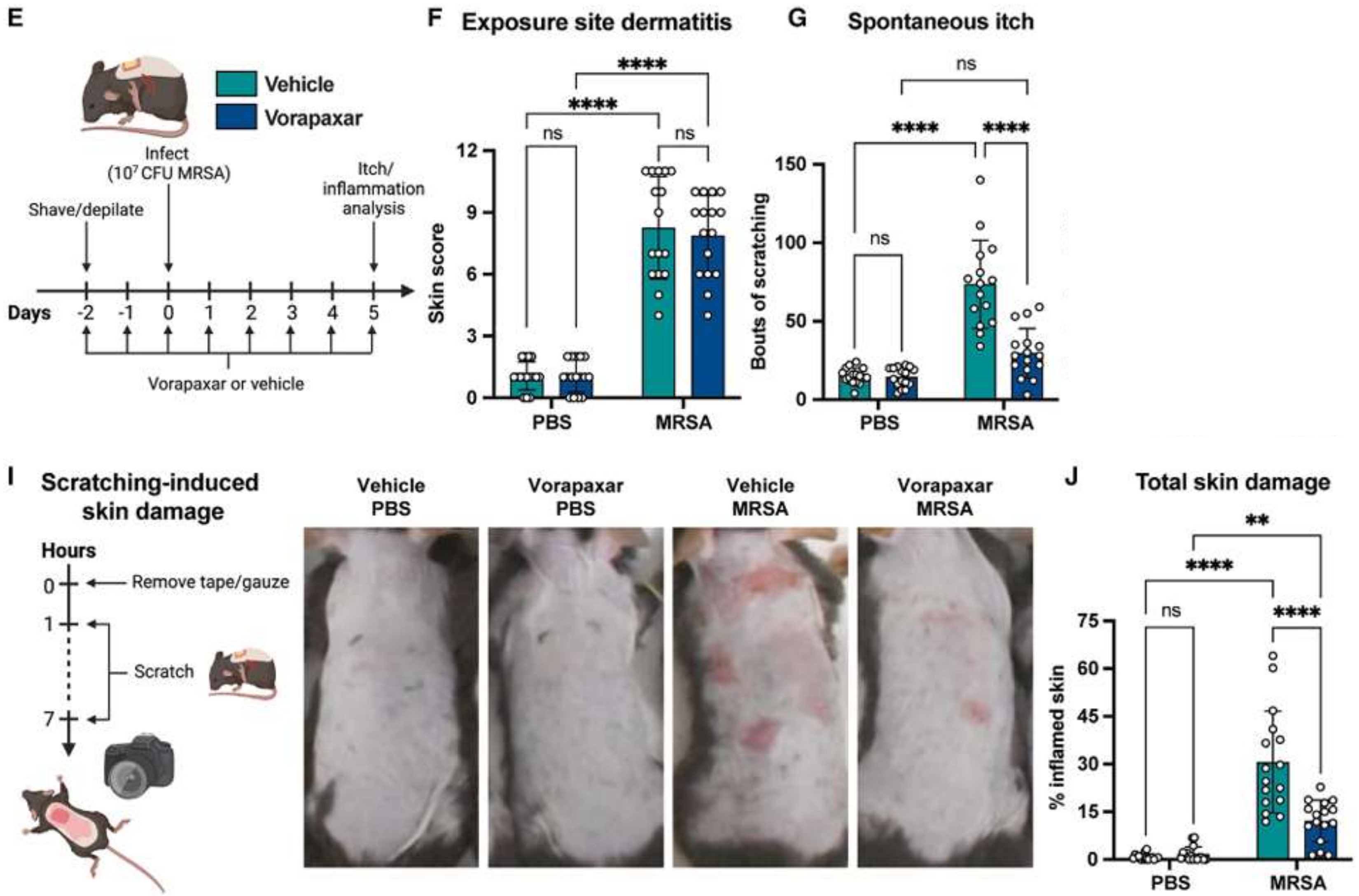
Reducing scratching can help with wound healing



(Liwen Deng, et al. Cell, 2023)

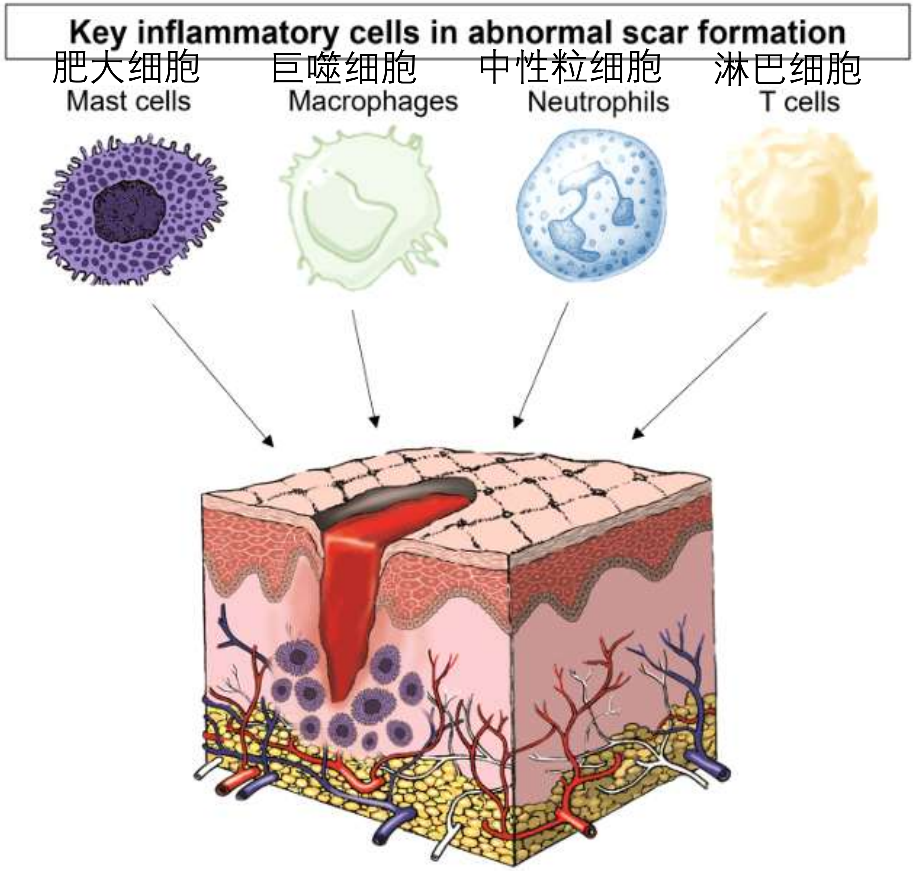
Pharmacological inhibition reduces S. aureus itch and skin damage

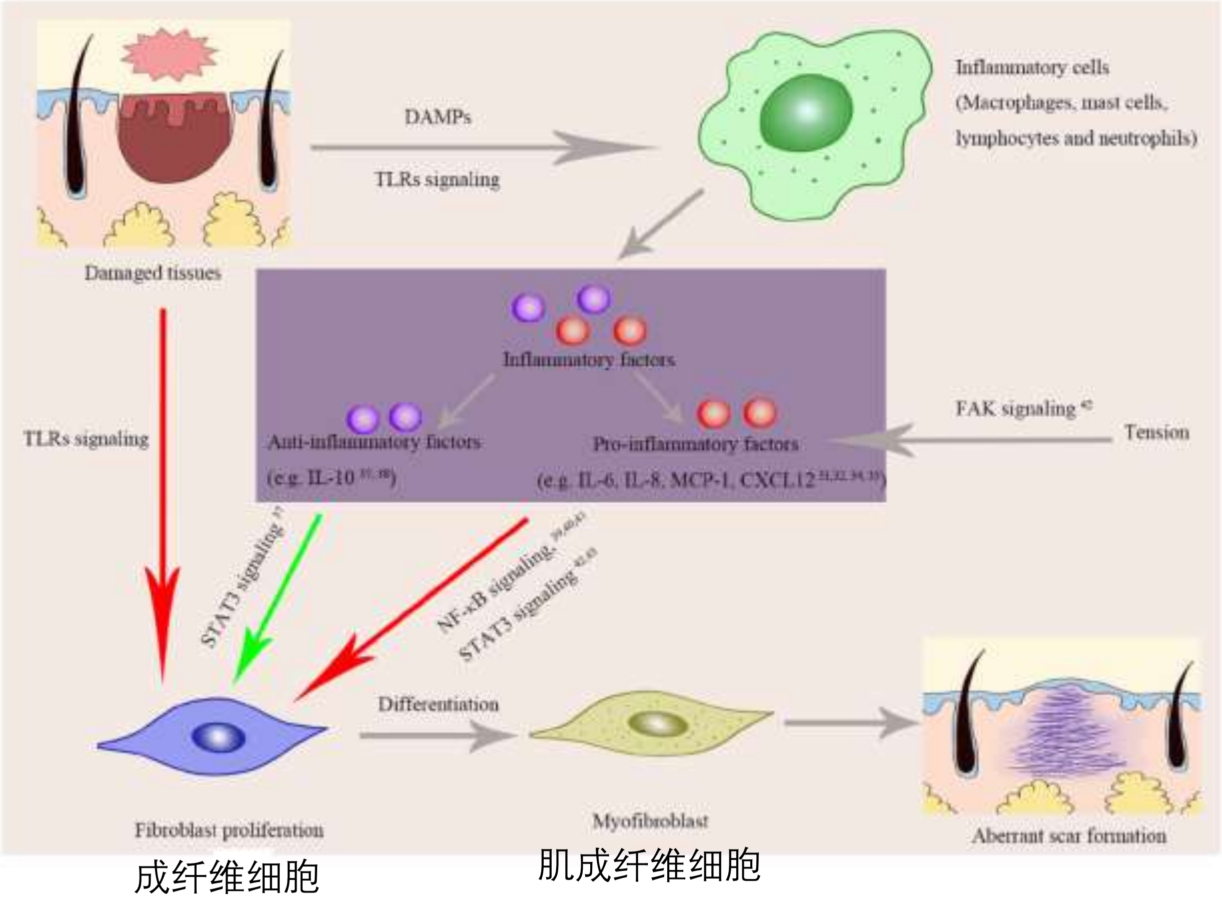
Vorapaxar 降低血栓性心血管事件风险的药物。



(Liwen Deng, et al. Cell, 2023)

The Key Inflammatory Cells in Scar Formation





(Ud-Din S, et al, Front Immunol, 2022)

(Zheng-Cai Wang, et al, Front Immunol, 2020)

Treatments for Scar through Suppressing Inflammation

抑制淋巴细胞的活性

促进肥大细胞的稳定

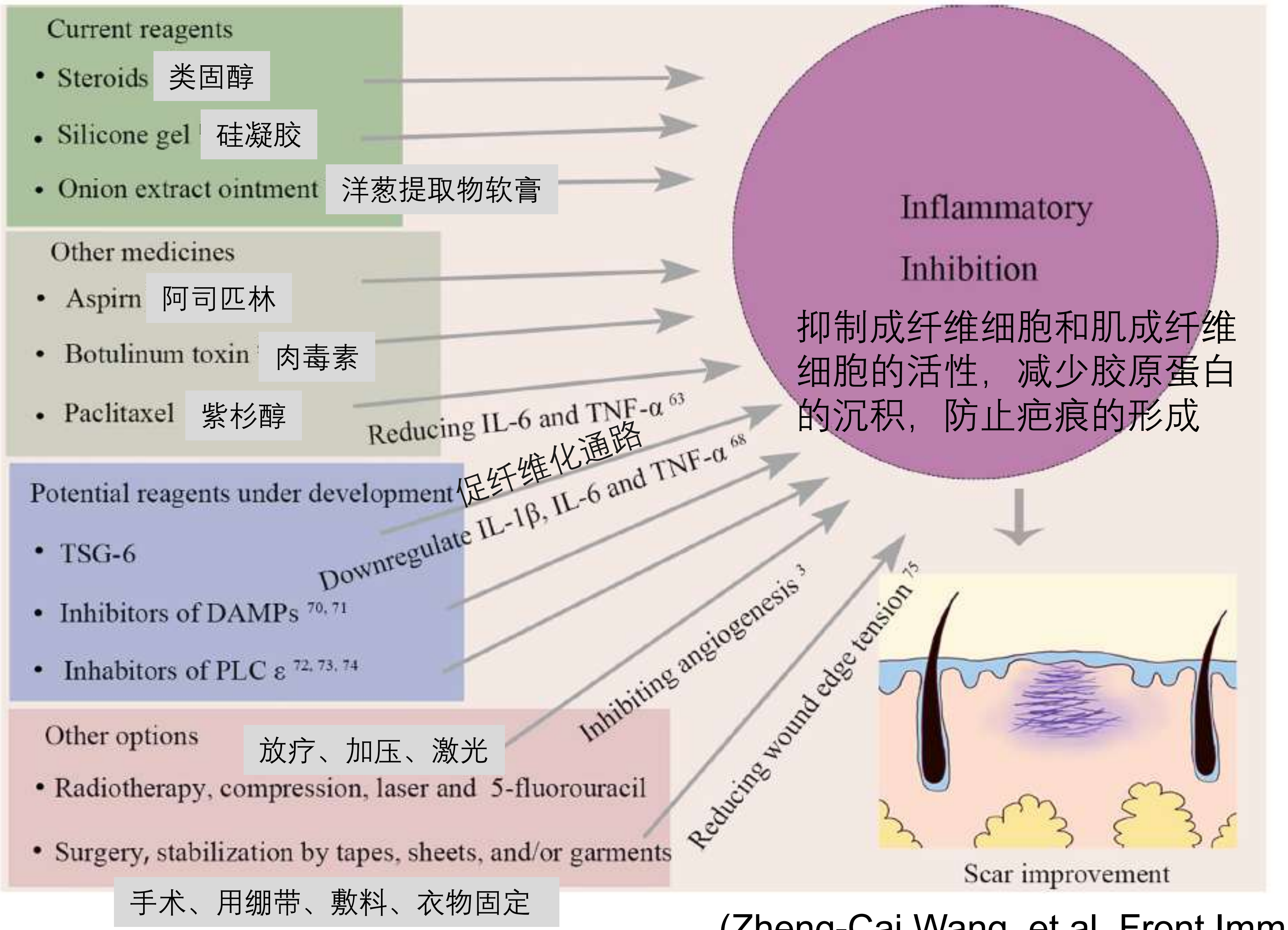
通过调节JNK/STAT-3 信号抑制大量炎症因子产生和释放

阻断乙酰胆碱的释放、抑制巨噬细胞等免疫细胞的活化

阻断 STAT-3 信号传导来抑制 NF-κB 通路的促炎因子

抑制血管生成来减轻炎症

减少伤口边缘的张力来减少伤口区域的炎症



(Zheng-Cai Wang, et al, Front Immunol, 2020)

Take-home message

1. 伤口处理的发展历史是从控制感染到优化愈合的过程。
2. 快速愈合的关键是创造一个干净、湿润、温暖和密封的愈合环境。

水凝胶适用于干燥坏死伤口——补水清创
泡沫型伤口敷料用于中重度渗液——吸收保湿
薄膜型伤口敷料用于表浅伤口——密闭透气

3. 通过药物抑制可减少金黄色葡萄球菌瘙痒引发的皮肤损伤。
4. 许多疤痕疗法以针对炎症细胞为目标，通过控制炎症，抑制纤维化进而改善疤痕效果。

Wishing a happy, long and healthy life!