

Journal club

The Human Hair: Structure, Crisis, Regeneration

2026.4.30

Am I bald?



What are the differences between animal hair and human hair?



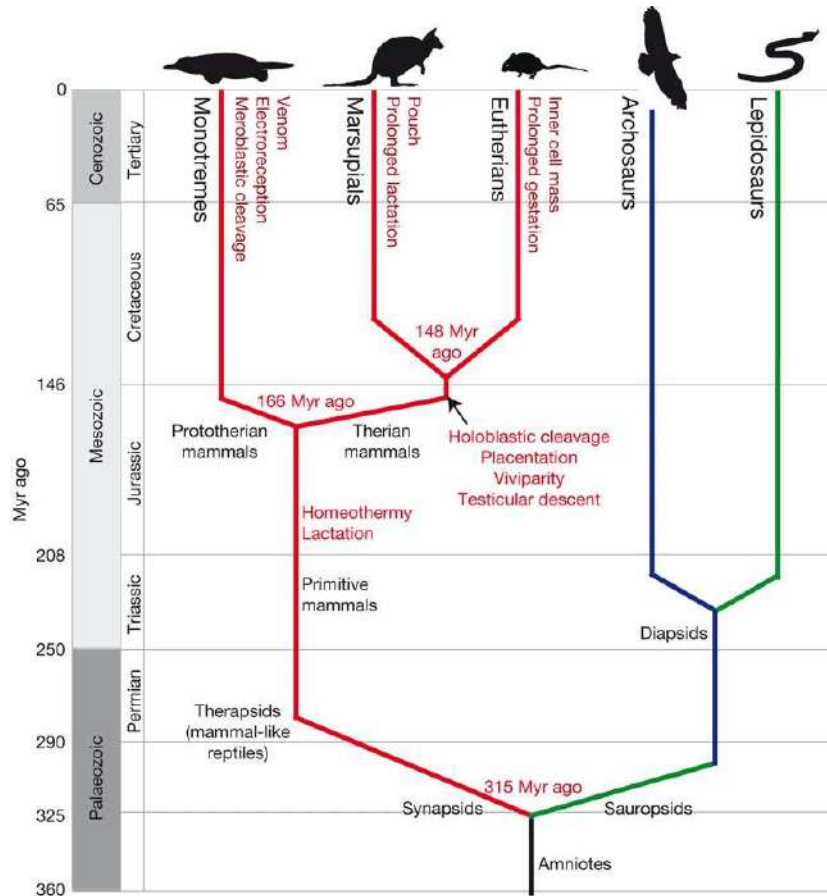
The Human Hair: Structure, Crisis, Regeneration

- Hair Structure: Comparative Analysis Across Animal Species and Humans-LC
- Hair Crisis: Mechanisms of Hair Loss and Graying-ZXX
- Hair Regrowth: Current Interventions, Mechanistic Insights-WJ

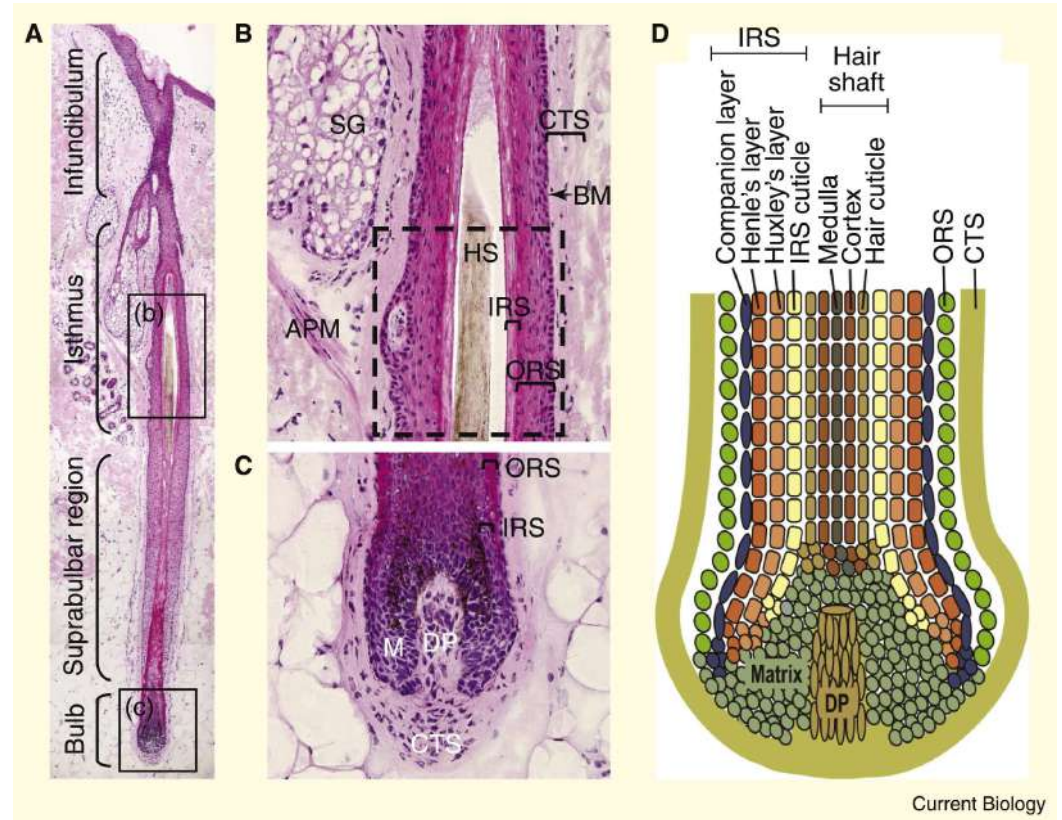
Hair Structure: Comparative Analysis Across Animal Species and Humans

LC
26.4.30

What is hair?

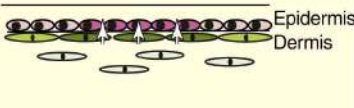
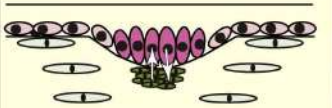
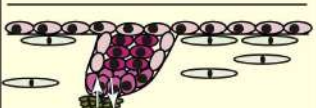
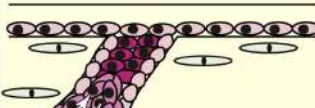
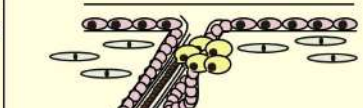


Warren, Wesley C et al. Nature. 2008



Schneider, Marlon R et al. Current biology, 2009

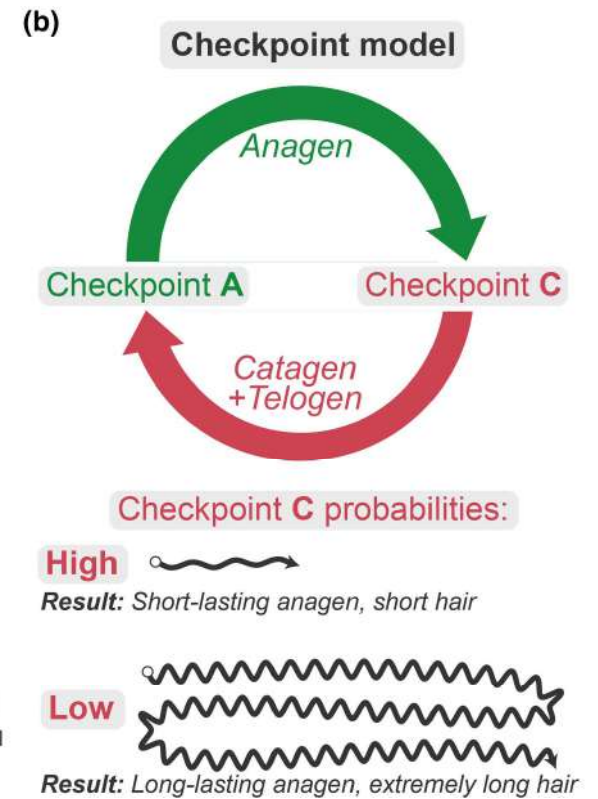
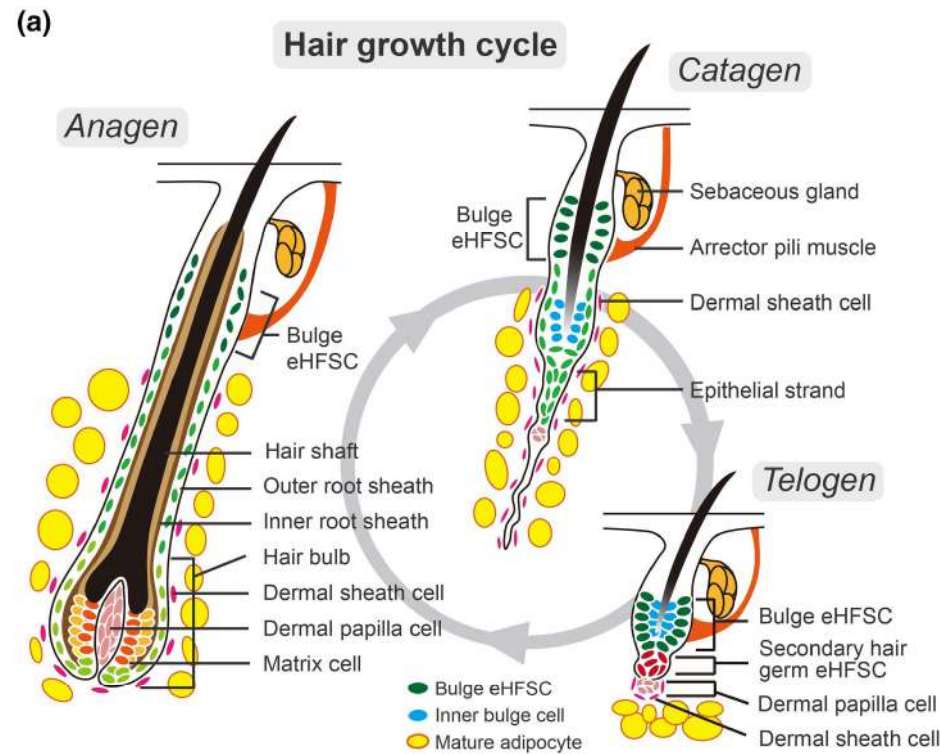
Murine hair follicle development can be divided into three phases: Induction, organogenesis and cytodifferentiation

Induction		Organogenesis		Cytodifferentiation
Stage 0	Stage 1 (placode)	Stage 2 (germ)	Stage 3–5 (peg)	Stage 6–8 (bulbous peg)
				
<p>Interacting gradients of activators and inhibitors creating an inductive field in the epidermis (pre-germ). Specialised dermal fibroblasts gather underneath pre-germ.</p>	<p>Visible hair germ (placode). Promotion of placode growth: <i>Wnt/β-catenin</i>. <i>EdaA1/EdaR/NF-κB</i>. <i>Noggin/Lef-1</i>. <i>CTGF?</i> <i>Ectodin?</i> <i>P-cadherin</i>.</p> <p>Inhibition of placode fate in surrounding cells and placode growth: <i>Dkks (Dkk1, 2, and 4)</i>. <i>BMPs (2, 4 and 7)</i></p>	<p>Proliferation of epidermal hair germ cells: <i>Shh/Smo/Gli2</i>, <i>Wnt (10b,10a)/Lef-1</i>, <i>FGFs/FGF2R-IIIb</i>. <i>TGFβ2?</i> <i>Follistatin?</i></p> <p>Formation of dermal papilla: <i>Shh/Smo/Gli2</i>, <i>PDGF-A</i>.</p>	<p>See Table 2 for molecular controls of ORS, IRS and hair shaft formation, polarity, shaping, innervation etc.</p>	<p>See Table 2 for molecular controls of ORS, IRS and hair shaft formation, polarity, shaping, innervation etc.</p>

Current Biology

Schneider, Marlon R et al. Current biology, 2009

Why does it seem that only human hair keeps growing indefinitely?



Hair length flexibility in animals and in humans upon conditions with altered hair growth

(a) Grey Seal



(b) Malayan Porcupine



(c) Lion, male



(d) Muskox



(e) Hamadryas Baboon, male



(f) Emperor Tamarin



(g) Mantled Guereza



(h) Bornean Orangutan



(i) Cat, Ragdoll



(j) Dog, Lhasa Apso



(k) Dog, Bearded Collie



(l) Cow, Highland cattle



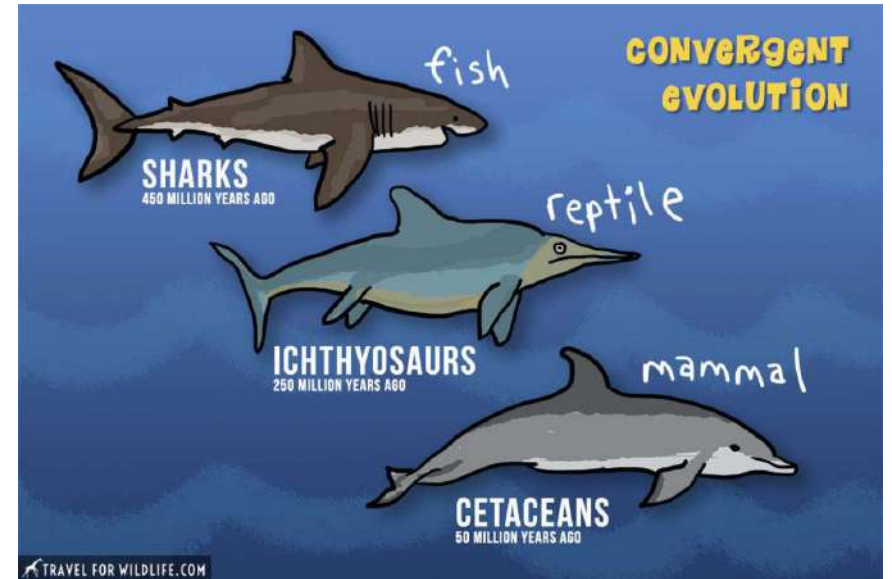
(m) Stump-tailed macaque, old



(n) Short anagen syndrome

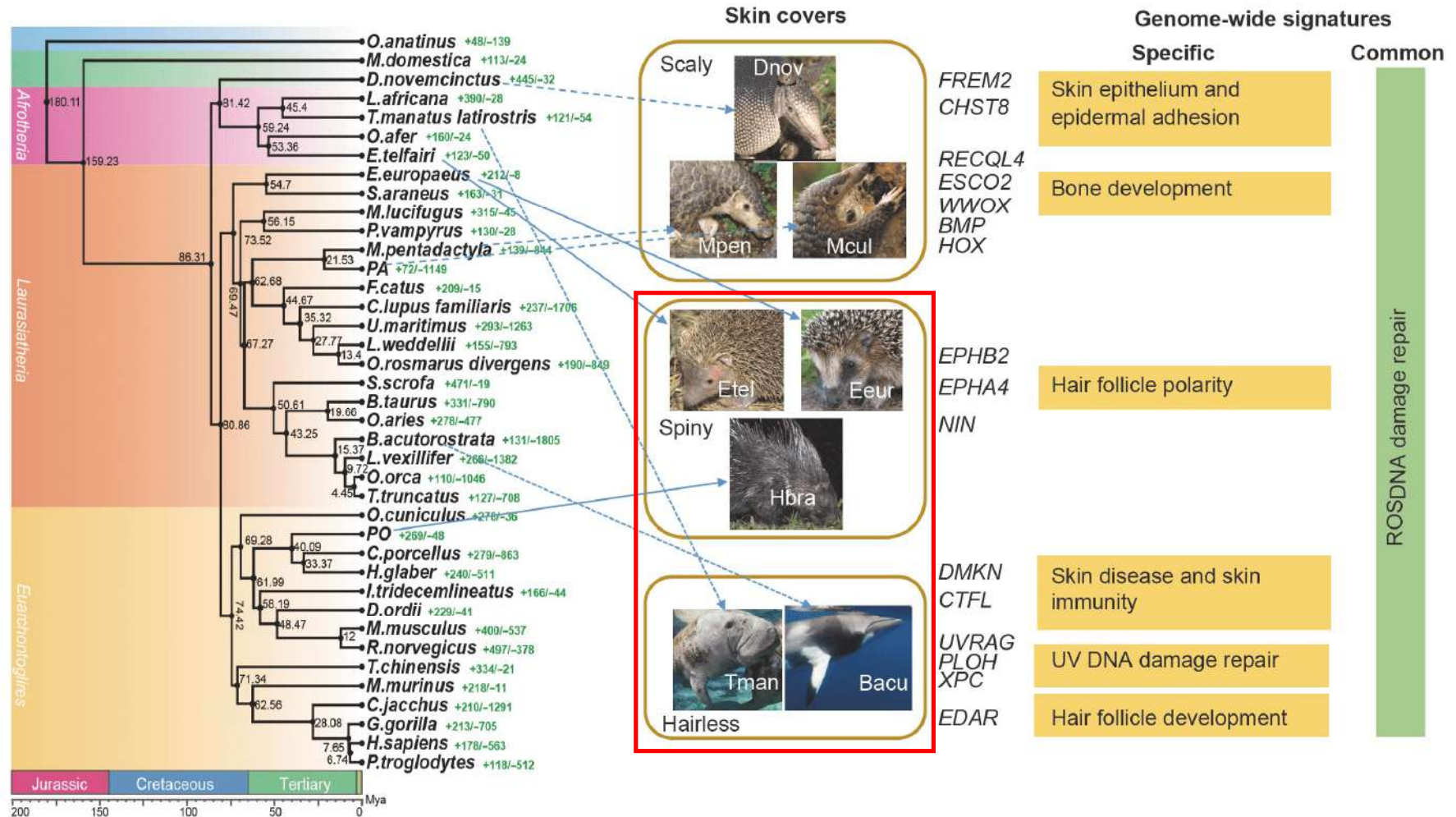


(o) Hairy melanocytic nevus, infant



Convergent evolution

Genome-wide signatures of mammalian skin covering evolution



Part 1

More Than Hedgehogs: The Prickly Ones in Mammals

Animals with spines and quills



Hedgehogs



Porcupines



Echidnas



Tenrecs



Spiny rats

An adult hedgehog has between 5000 and 7000 spines on it's body

Hedgehogs^[1]
 Temporal range: Late Eocene – Recent

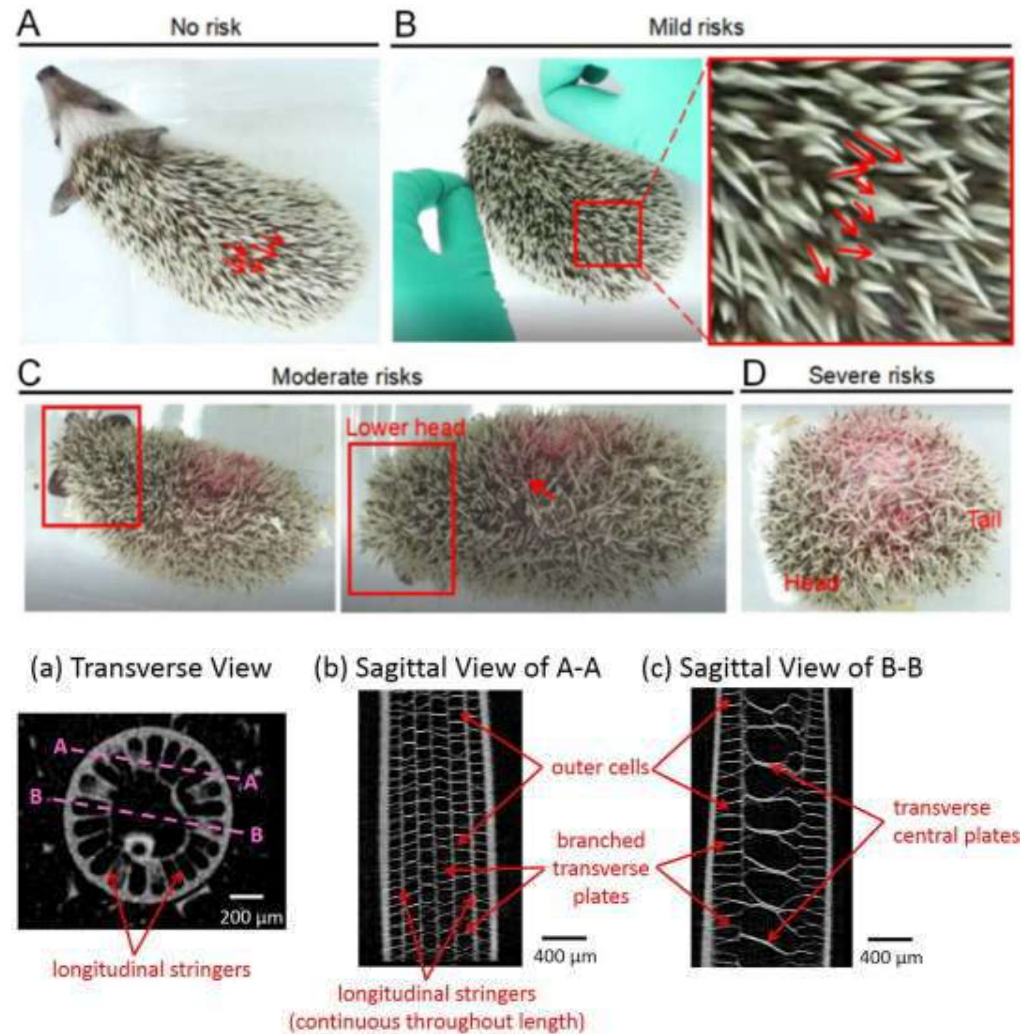
PreC C O S D C P T J K PgN



European hedgehog

Scientific classification

Kingdom: Animalia
 Phylum: Chordata
 Class: Mammalia
 Order: Eulipotyphla
 Family: Erinaceidae
 Subfamily: **Erinaceinae**
 G. Fischer, 1814



Drol, Christopher J et al. *Acta biomaterialia*. 2019

Porcupine quills serve as their essential defense tools

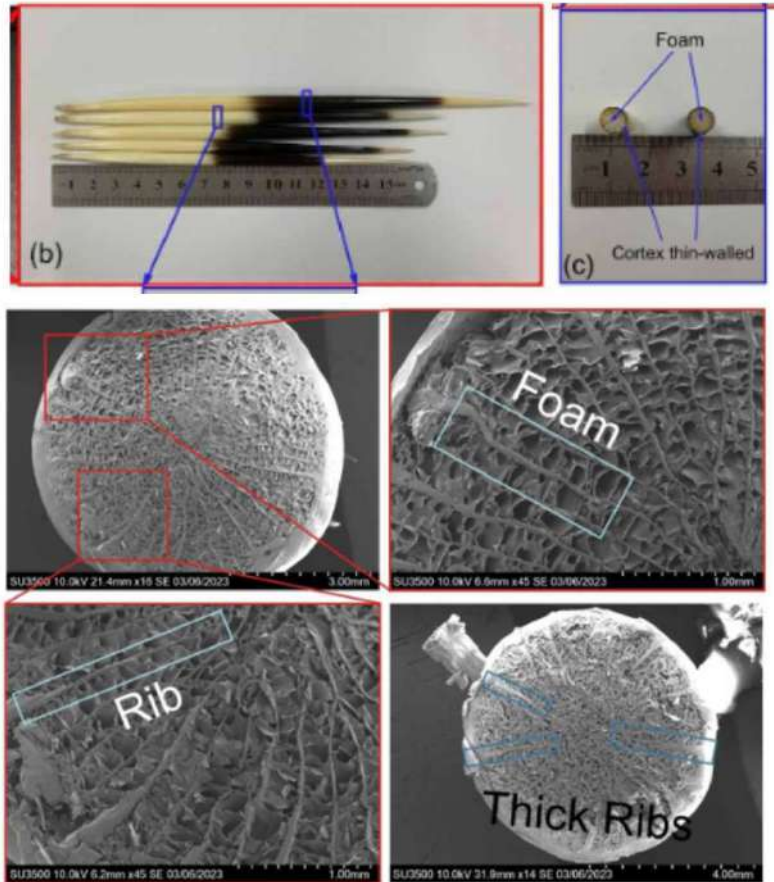
Porcupine



North American porcupine

Scientific classification

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Rodentia
Suborder: Hystricomorpha
Infraorder: Hystricognathi



黄天舒. 基于豪猪刺仿生结构抗冲击性能研究.2024

Echidna: The Most Bizarre Mammal

Echidnas
Temporal range: Pliocene–Recent

Prec C O S D C P T J K PgN



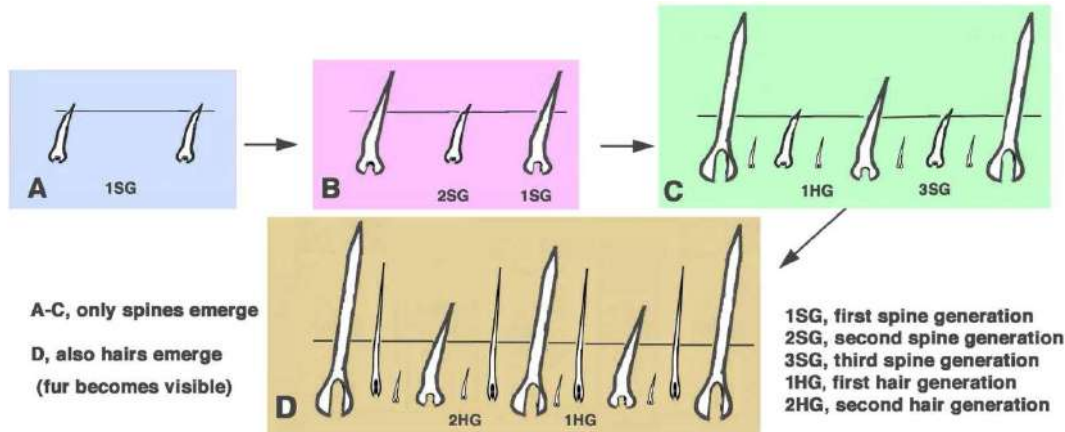
Short-beaked echidna

Scientific classification ✎

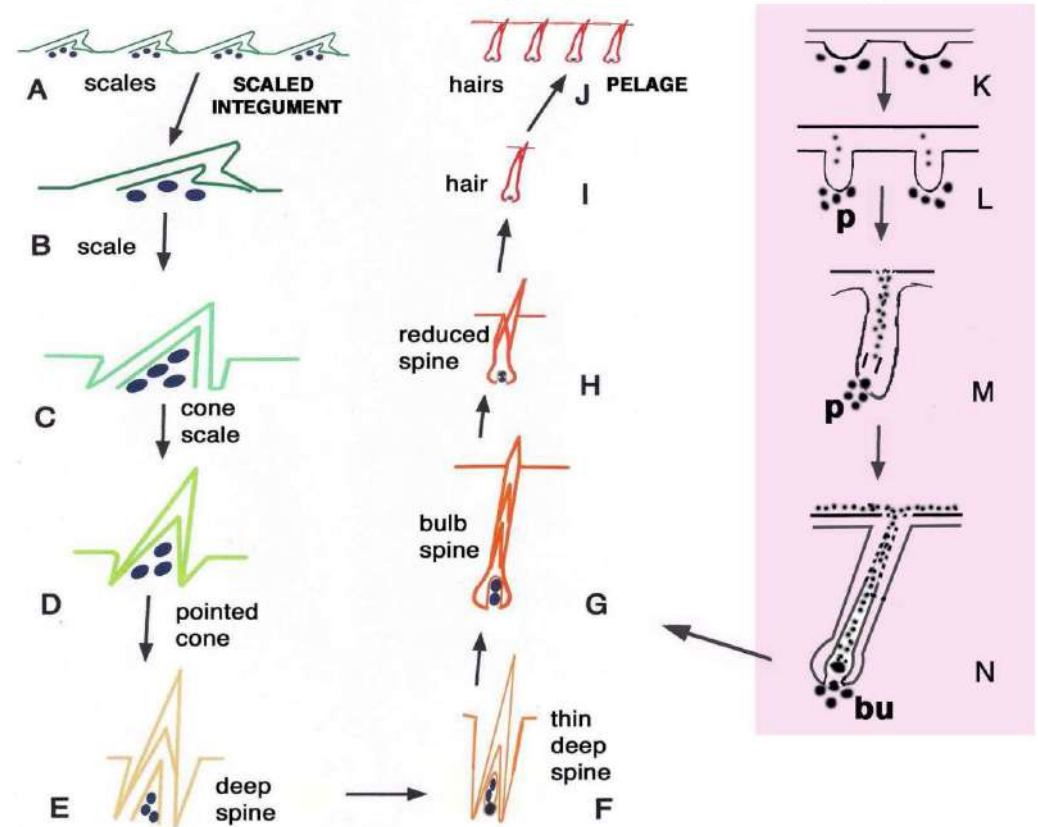
Kingdom: Animalia
Phylum: Chordata
Clade: Synapsida
Clade: Mammaliaformes
Class: Mammalia
Order: Monotremata
Superfamily: Ornithorhynchoidea
Family: **Tachyglossidae**
Gill, 1872



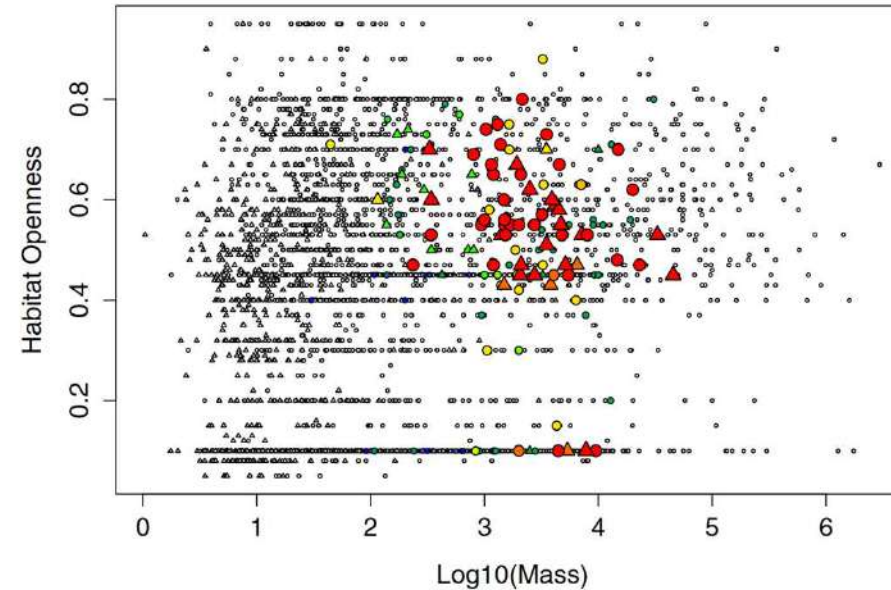
Observations on Fur Development in Echidna (Monotremata, Mammalia) Indicate that Spines Precede Hairs in Ontogeny



Hair evolution from scales through spinesor..... from glands



Living in the danger zone: Exposure to predators and the evolution of spines and body armor in mammals



$$\text{Defense score 1} = \left(\text{Body coverage} + \frac{1}{2} \text{Head} + \frac{1}{2} \text{Tail} + \text{Roll} \right) \times \text{Length} \times \text{Thickness}$$

$$\text{Defense score 2} = (\text{Body coverage} + \text{Head} + \text{Tail} + \text{Roll}) \times \text{Length} \times \text{Thickness}$$

$$\text{Defense score 3} = (\text{Body coverage} + \text{Head} + \text{Tail}) \times \text{Length} \times \text{Thickness}$$

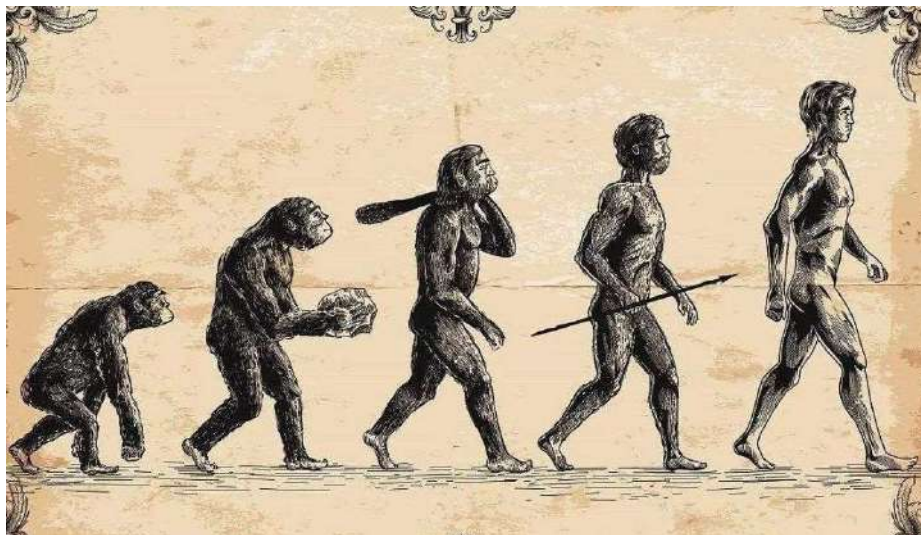
$$\text{Defense score 4} = \left(\text{Body coverage} + \frac{1}{8} \text{Head} + \frac{1}{8} \text{Tail} + \text{Roll} \right) \times \text{Length} \times \text{Thickness}$$

Stankowich et al. Evolution. 2016

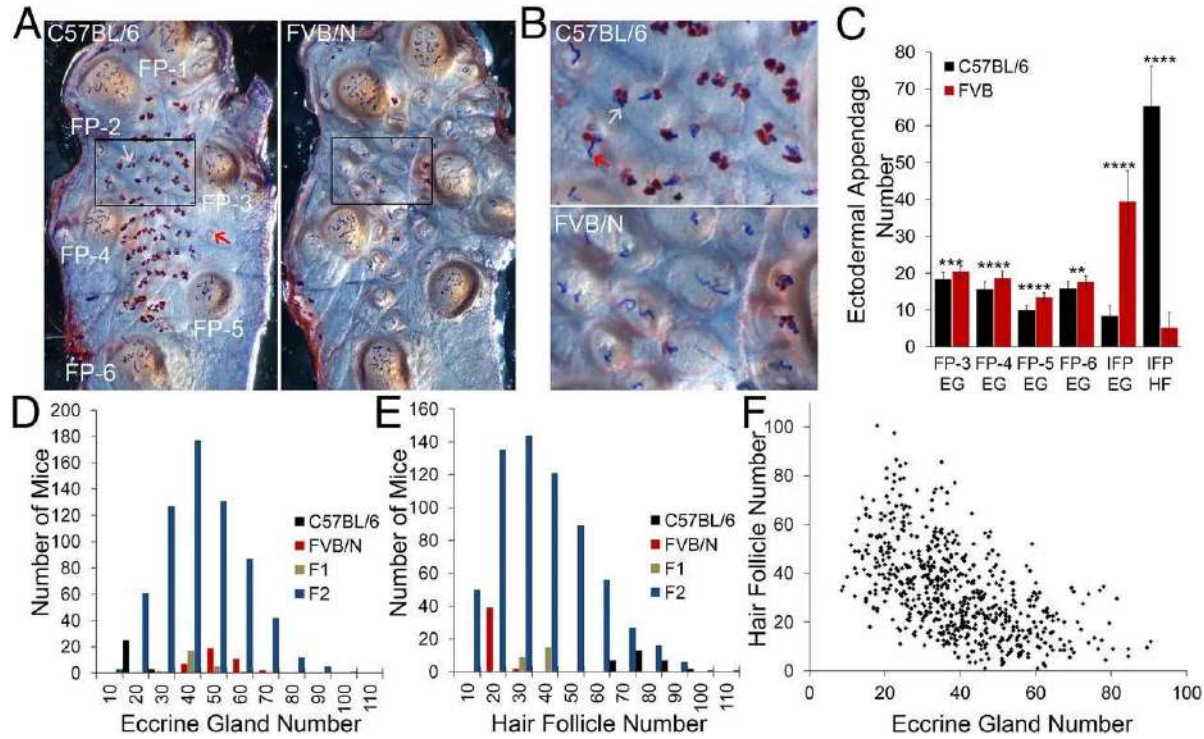
Part 2

Those mammals that chose to “go naked”

Why did humans lose their body hair?

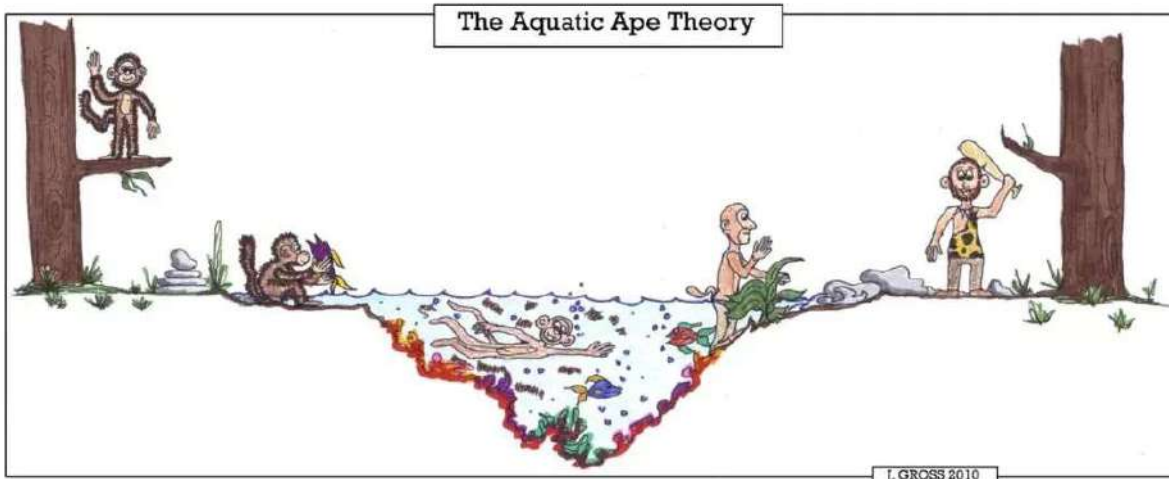


The thermoregulation hypothesis



Kamberov, Yana G et al. PNAS. 2015

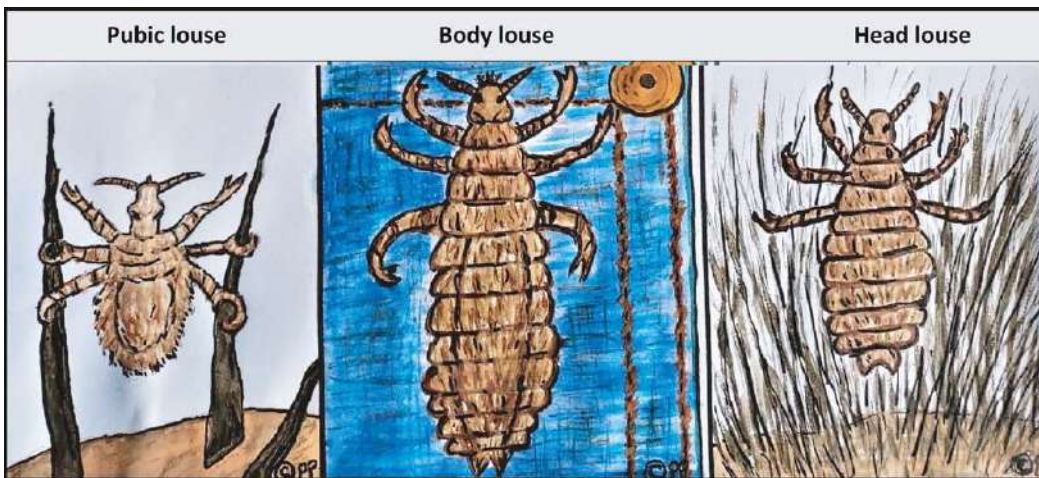
Notley, Sean R et al. European journal of applied physiology. 2024



The aquatic ape hypothesis



The cave ape hypothesis

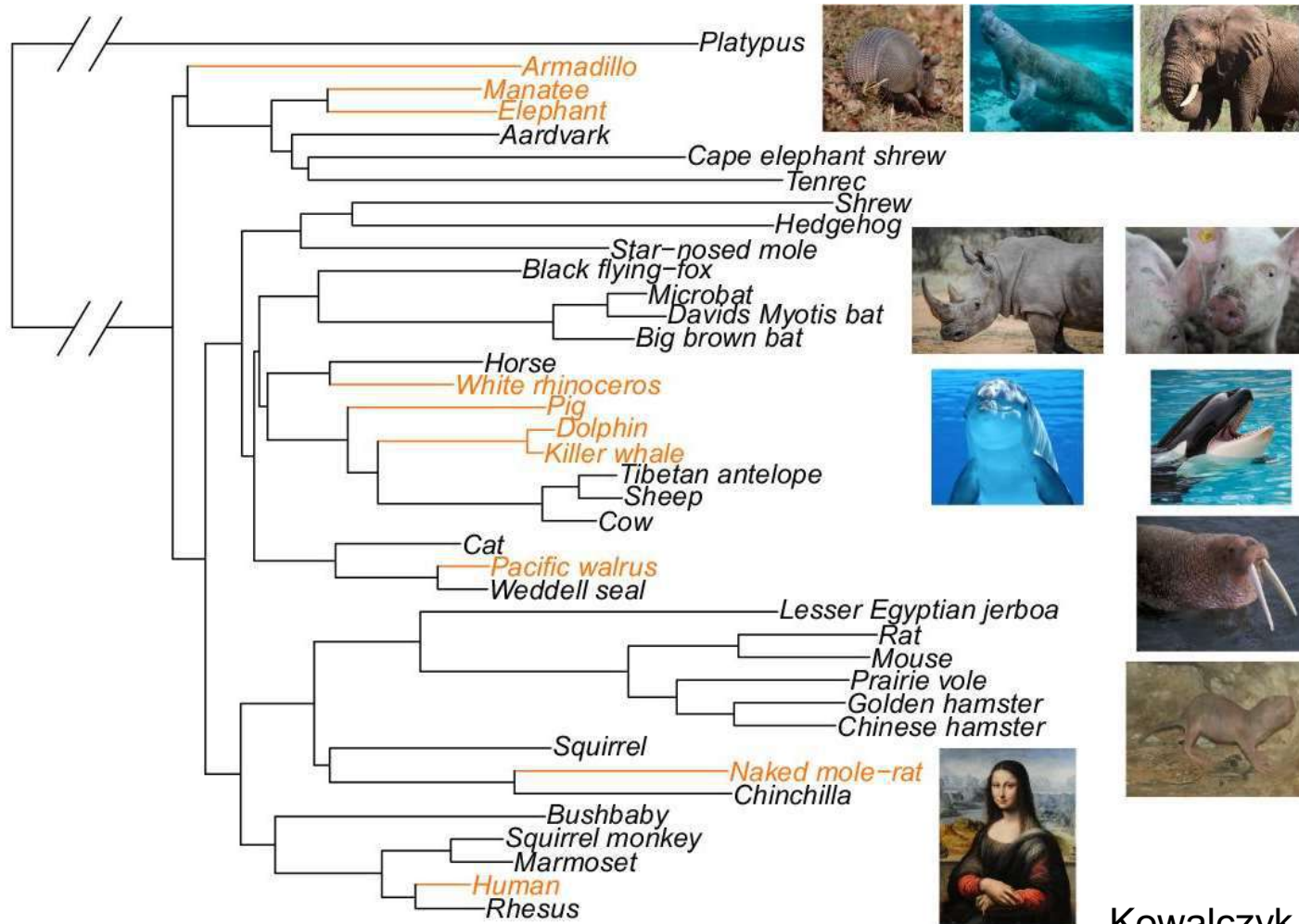


The parasite hypothesis

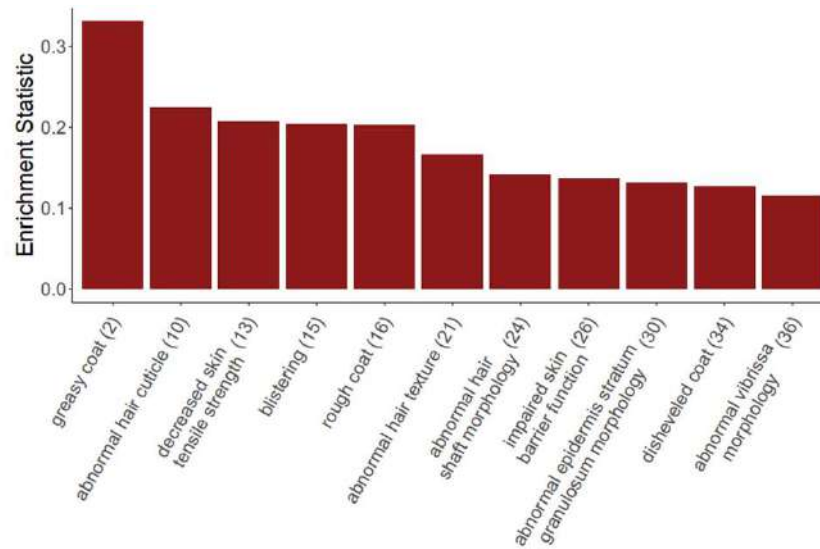
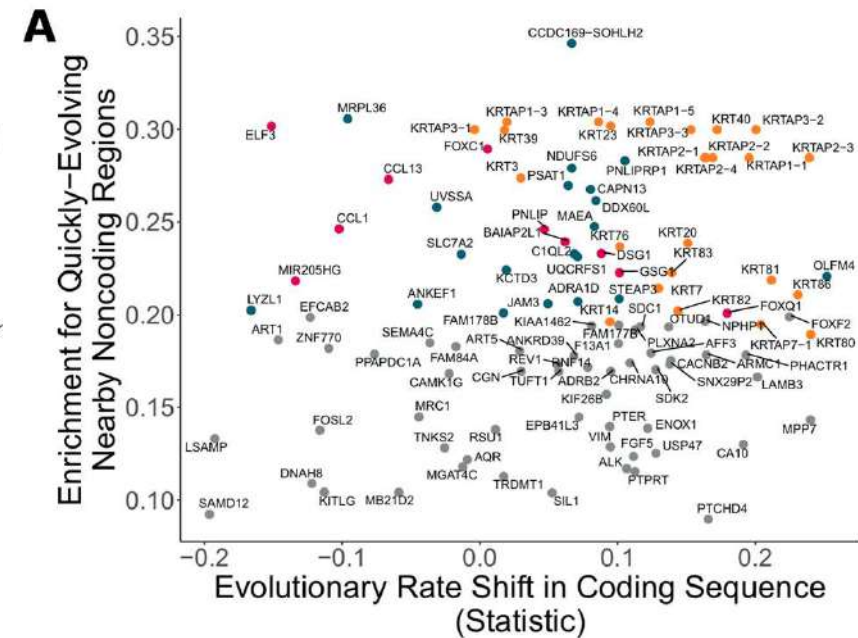
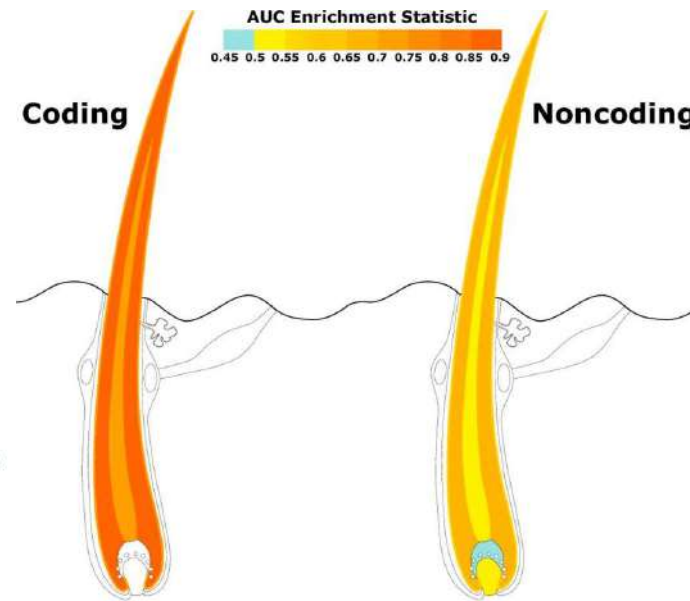
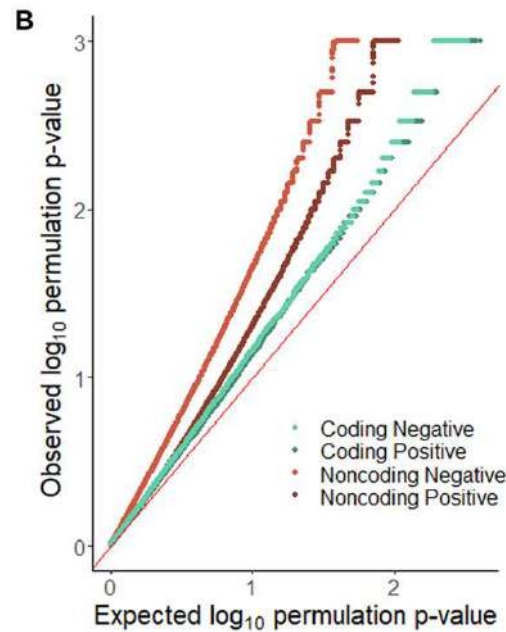


The sexual selection hypothesis

The hairless phenotype in mammals arose at least nine independent times along the mammalian phylogeny



Kowalczyk, Amanda et al. eLife. 2022



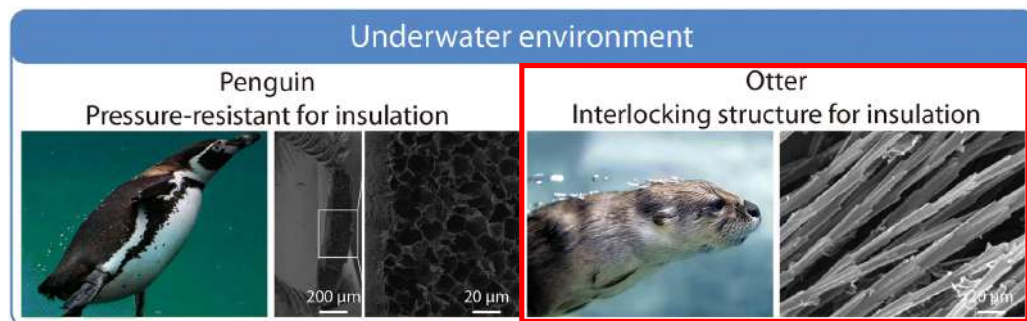
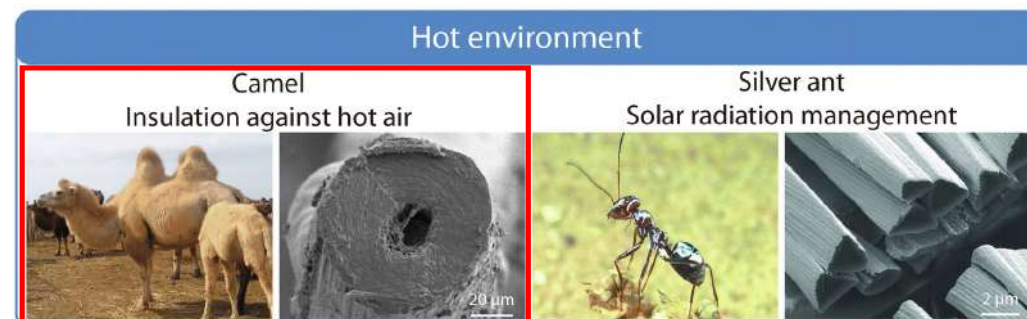
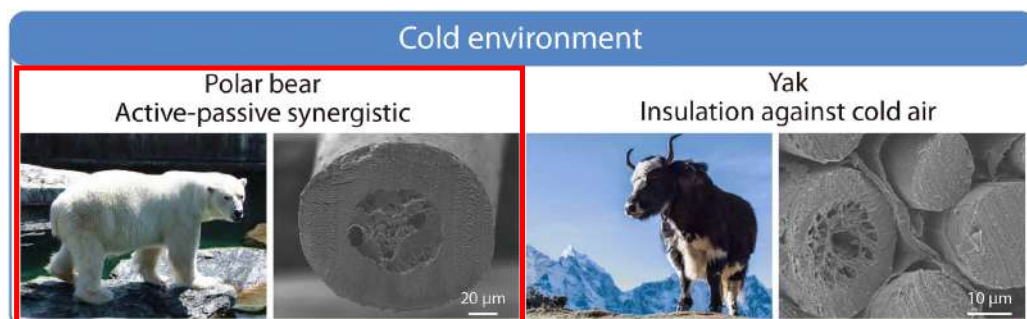
Complementary evolution of coding and noncoding sequence underlies mammalian hairlessness

Kowalczyk, Amanda et al. eLife. 2022

Q3

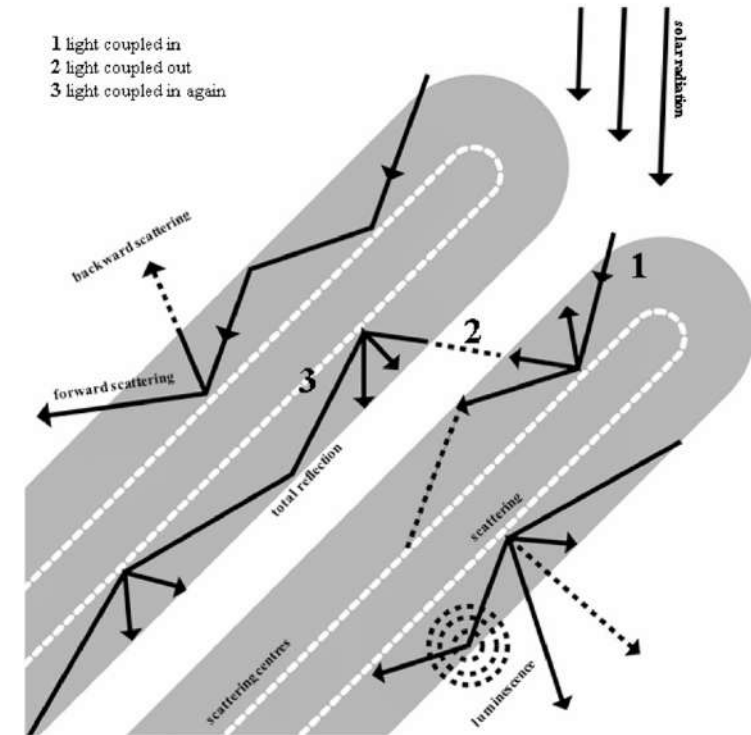
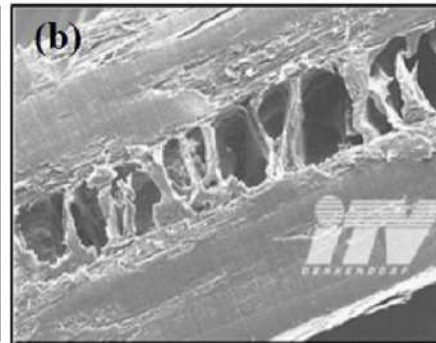
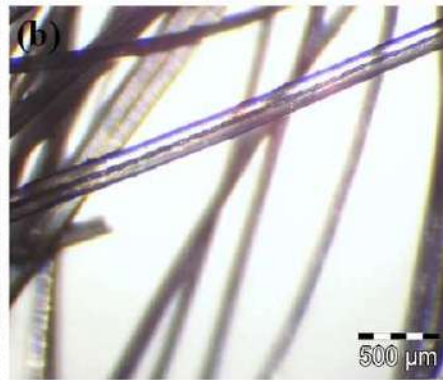
Adaptive evolution of hair in extreme environments

Animals across diverse ecosystems have evolved sophisticated thermal regulation strategies



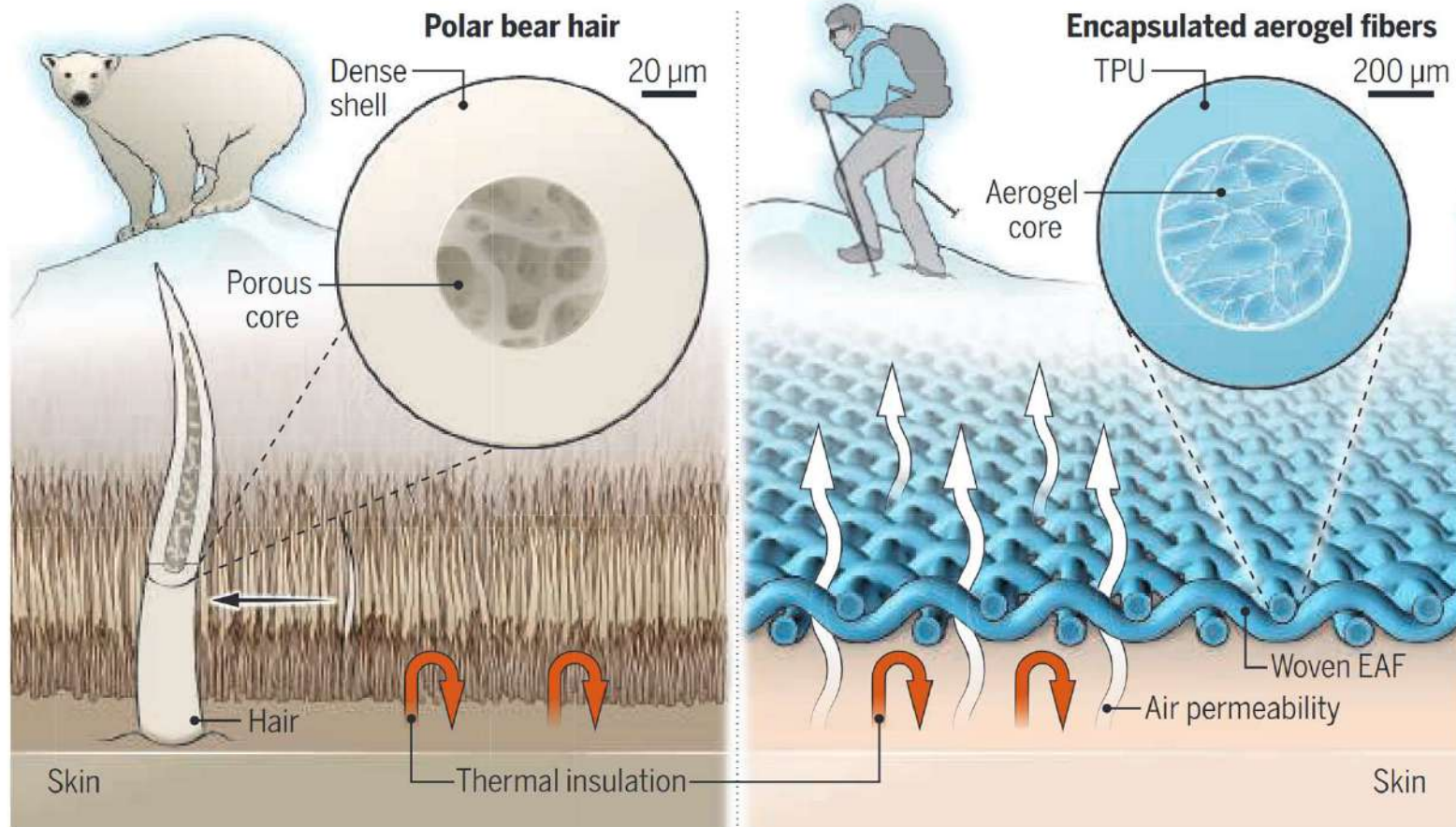
Animal species	Habitat characteristics	Thermal management strategies
Polar bear	Polar regions, extremely cold, ice cover	Core-shell hair, solar light guiding, static air trapping
Yak	High plateau, intense UV radiation, large temperature variation	Crimped underfur, melanin, static air trapping, UV/NIR absorption
Camel	Arid desert, intense solar radiation, large temperature variation	Dual-layered porous fur, solar reflection, nighttime insulation
Silver ant	Arid desert, intense surface and solar radiation, large temperature variation	Triangular cross-section hairs, high vis-NIR reflection, high MIR emissivity
Penguin	Frigid underwater, strong wind, low light intensity	Branched feather structure, waterproof outer layer, static air trapping
Otter	Stable water temperature, high convection	Interlocking waterproof barrier, hydrophobic oil coating, inner downy fur

Polar bear hairs with active-passive synergistic thermal management

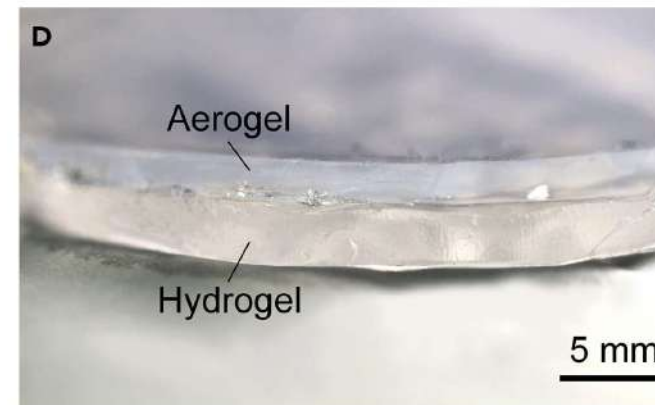
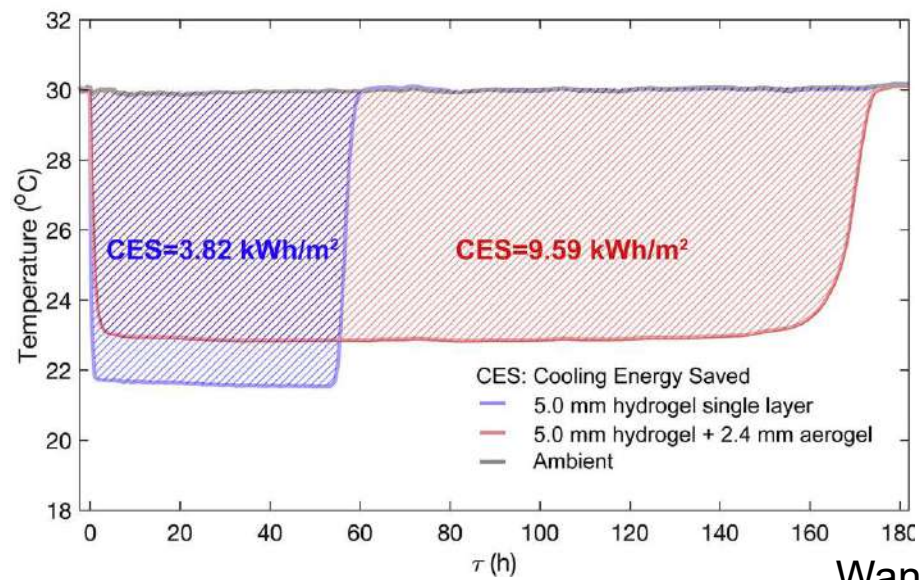
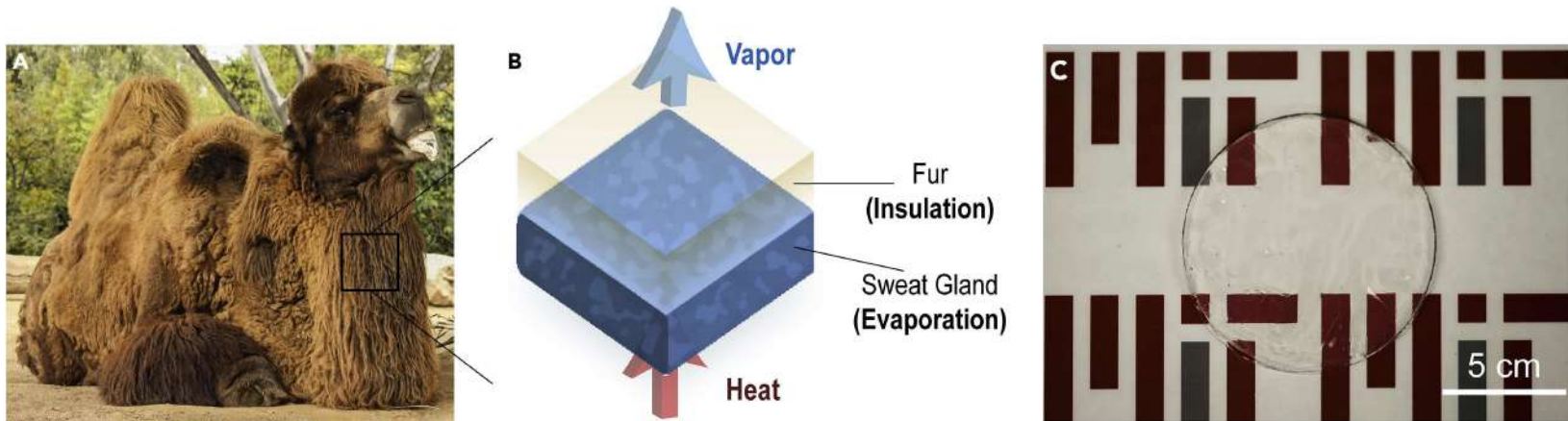


Khattab, Mohammed Qasim et al. 2016

Mimicking polar bear hairs in aerogel fibers

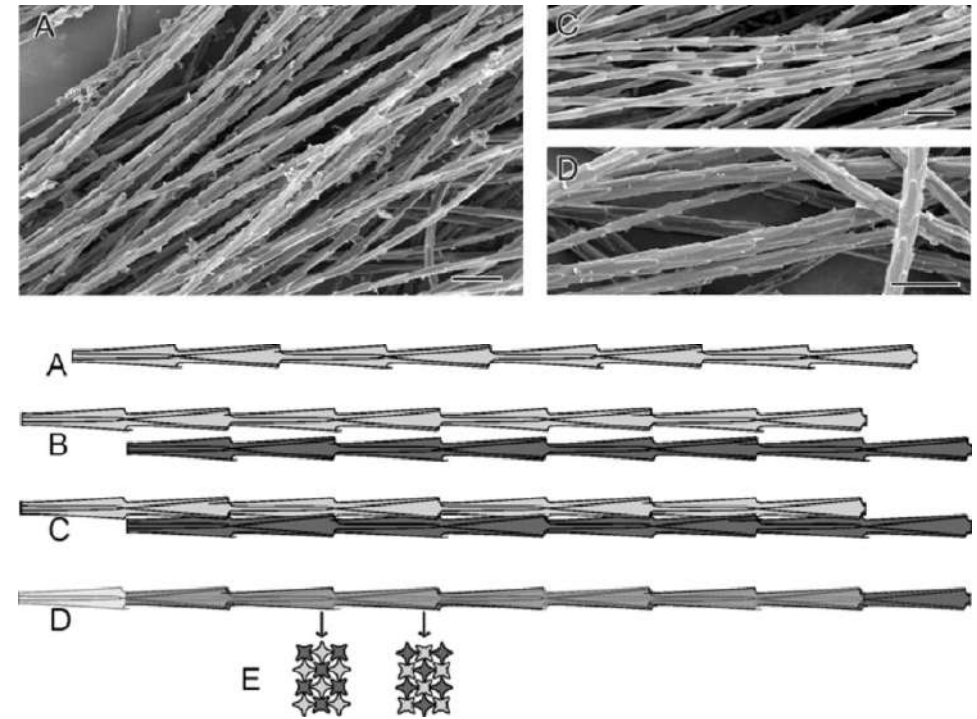
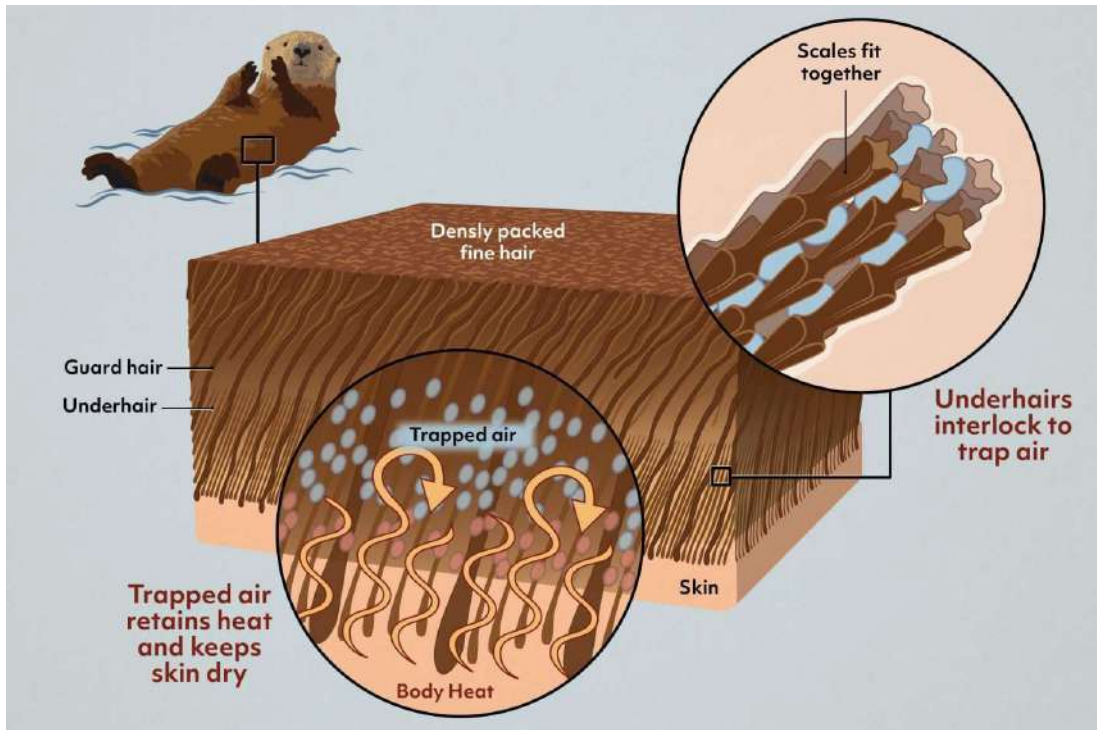


Camel hairs with thermal insulation



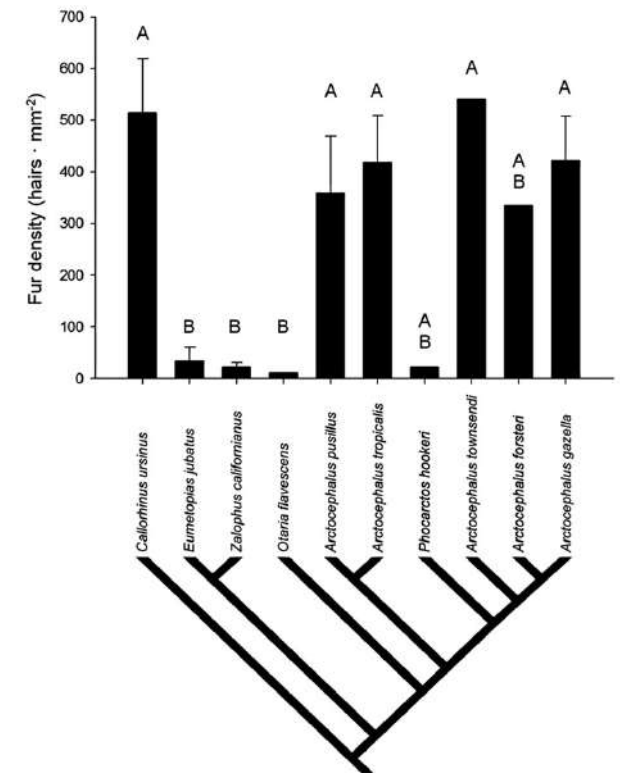
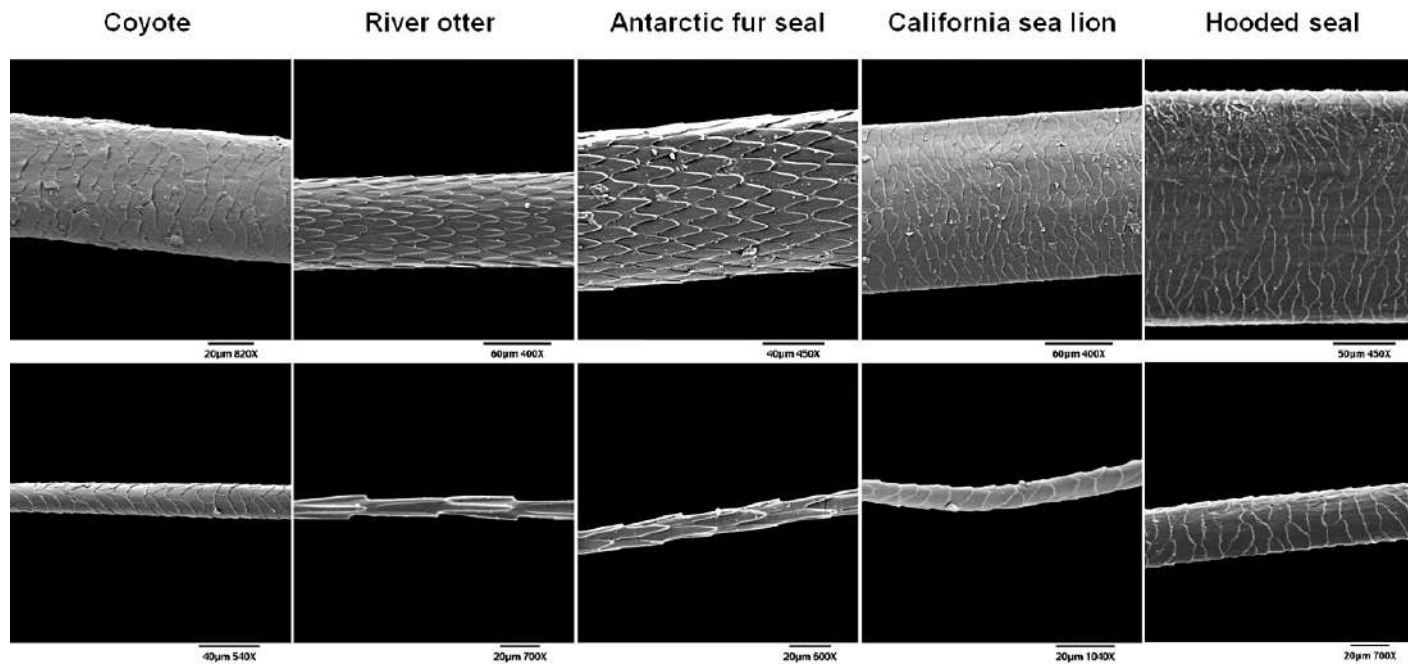
Wang, Tong et al. Nanophotonics (Berlin, Germany). 2023

Otter fiber with pressure resistance



Kuhn, Rachel, and Wilfried Meyer. *Zoological science*. 2010
John W Weisel et al. *Canadian Journal of Zoology*. 2005

Morphological and thermal properties of mammalian insulation: the evolution of fur for aquatic living



Hair cuticle, Circularity, Lengths, Fur density, Air trapped in the fur

Take home message

1. The spines of hedgehogs, porcupines, and echidnas are the result of **convergent evolution**, used for attack and defense. Research has found that mammals of **medium body size, inhabiting open habitats and with an insect-dominated diet**, are most likely to evolve spines or body armor.
2. Explanations for why humans lost their body hair include **the thermoregulation hypothesis** and the parasite hypothesis, among others. The convergent evolution of the hairless phenotype manifests as independent yet complementary accelerations of evolutionary rates in **coding and non-coding regions**.
3. **Animals from different habitats achieve synergy of multiple functions**—such as thermal insulation, radiation regulation, moisture management, and solar-thermal utilization—through the hierarchical structure of hair, spanning from nano to macro scales.

To Bald or Not to Bald: A Scientific Journey into Hair Loss

ZXX
26.4.30

Hair loss is commonly observed

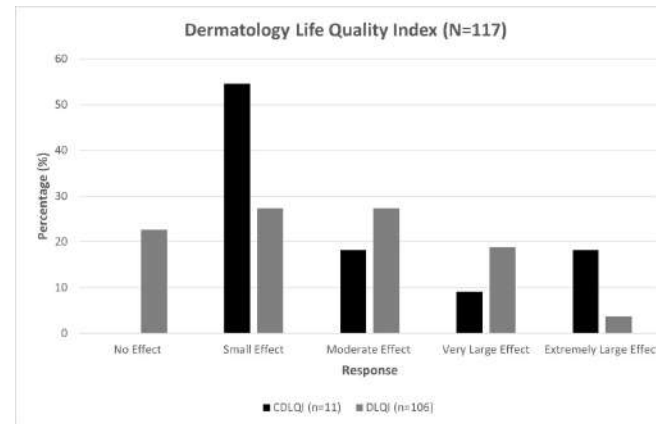


(艾媒咨询,2024-2025年中国头皮疗养行业发展趋势分析报告, 2025)

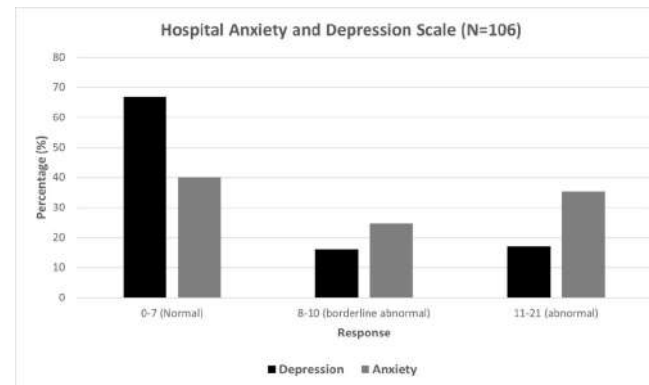


脱发人群：**3.4 亿**，其中 20-35 岁群体占比 **70%**，30 岁前脱发者更是高达**86%**

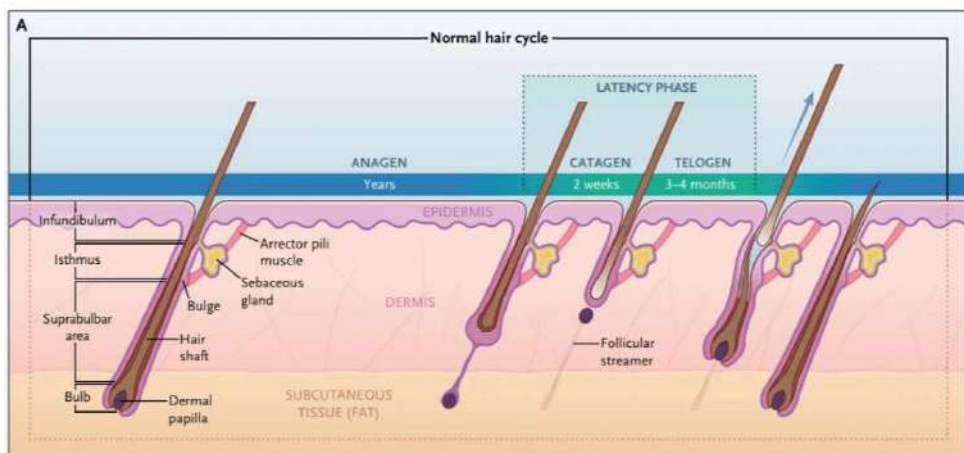
(中国头皮健康产业联盟, 2025中国头皮健康产业白皮书, 2025.)



(Anthony Justin Gilding, et al, JMIR Dermatology,2022)



Is your hair loss considered alopecia?



方法一、数掉落头发

每天大约掉多少根头发？

- A、50根以下
- B、50-100根
- C、100根以上

方法二：拉发实验方法

用拇指和食指轻拉一束（50-60根）头发，掉多少根？

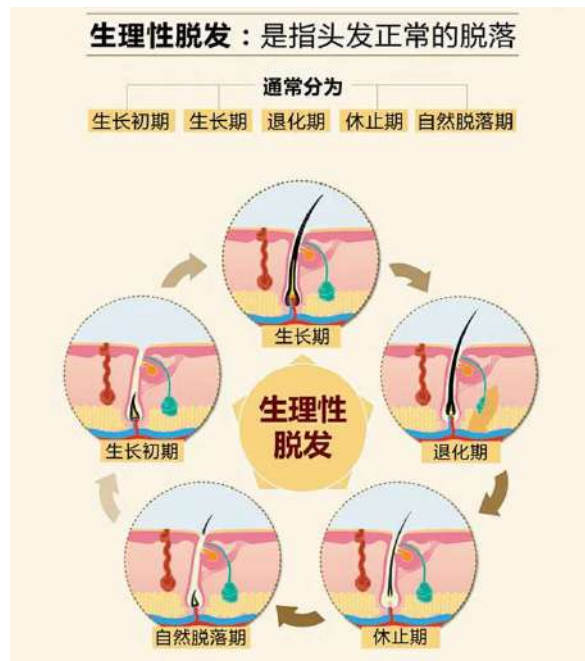
- A、6根以下
- B、6根以上

单手测发际线图示



卫健委发布的脱发人群调查显示，我国脱发人群已经超过2.5亿
2019年，阿里健康大药房脱发产品成交金额增速230%

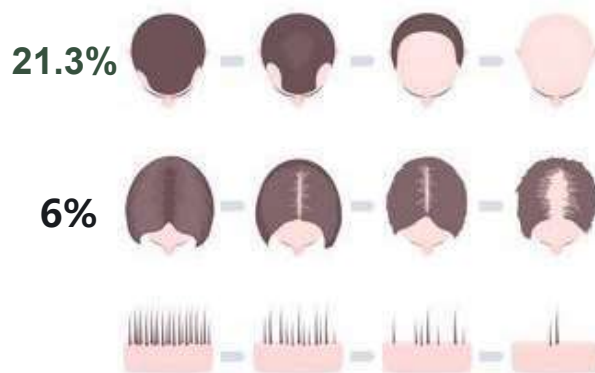
Type of hair loss



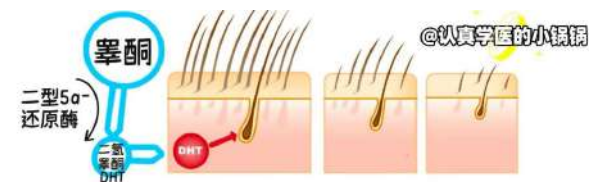
影响因素：营养不良、压力大、熬夜……

可自行调整恢复

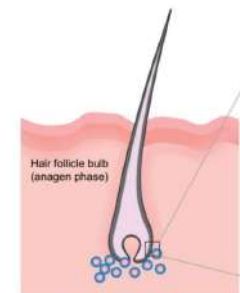
病理性脱发：由于毛囊受损而造成的头发非正常脱落的异常状态。



雄激素性脱发 (AGA)



斑秃 (AA)



需就医

Part I What environmental factors can lead to hair loss?

1.1 Seasonality of hair loss:



1.1 Seasonality of hair loss:

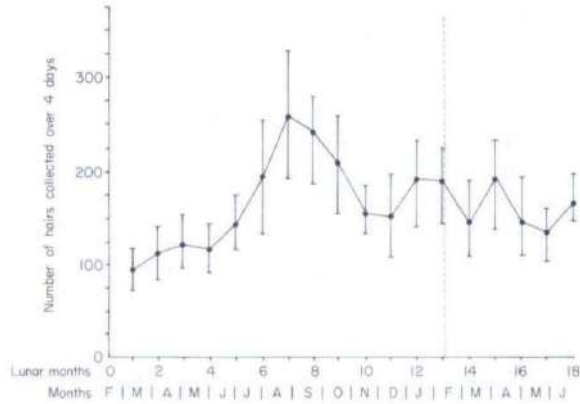
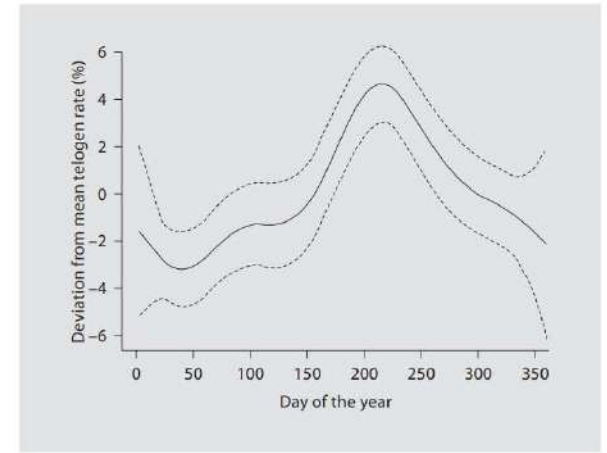
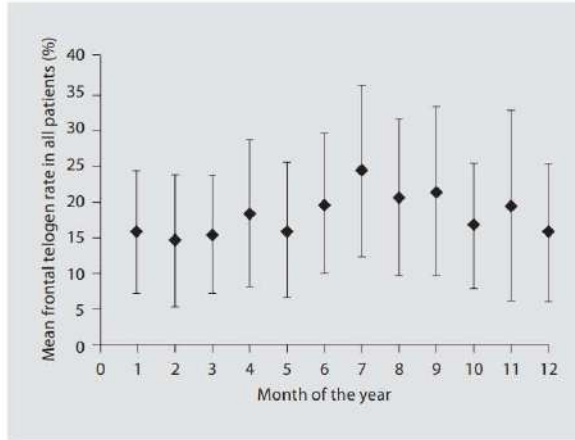
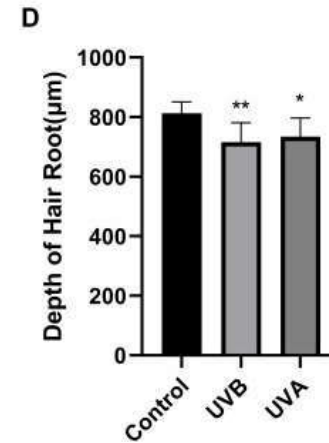
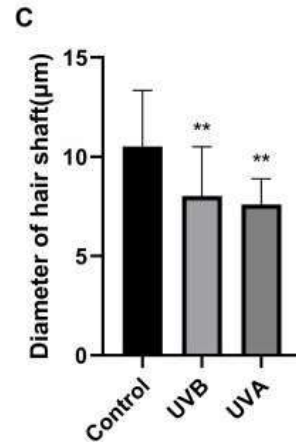
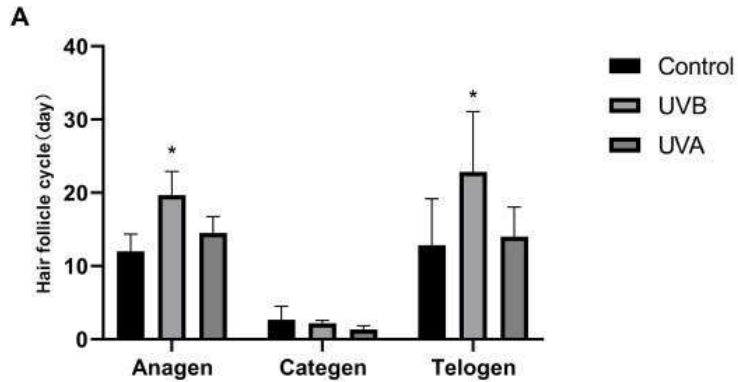


Figure 3. Number of hairs shed from the scalp in 14 Caucasian men over a 4-day period in each lunar month (mean ± SEM).

(RANDALL, et al. British Journal of Dermatology 1991)



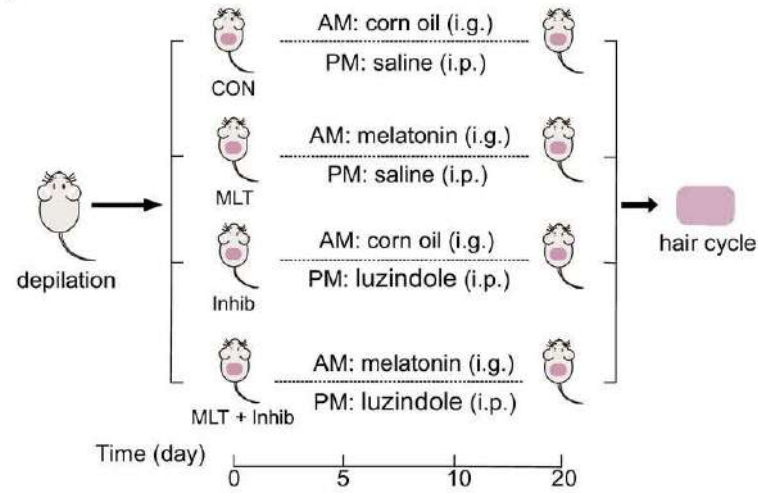
(Kunz, M., et al. Dermatology 2009.)



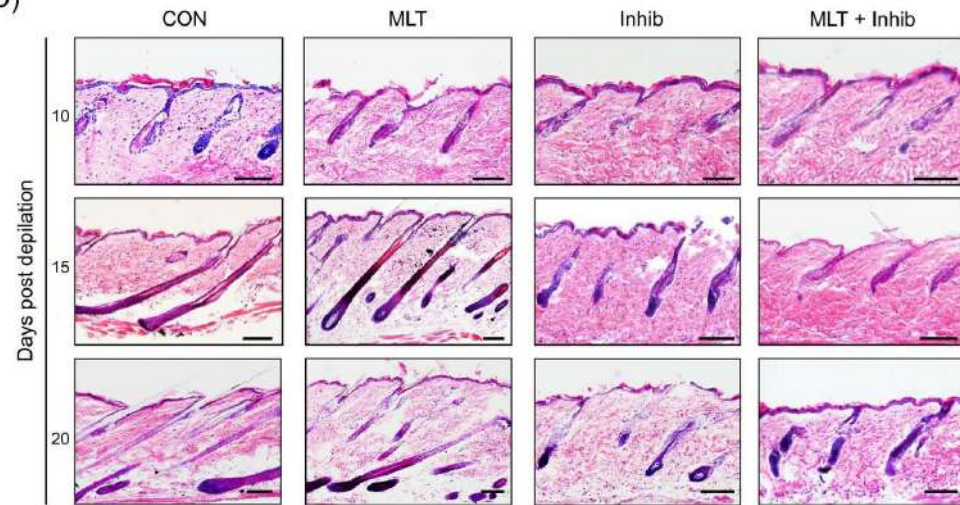
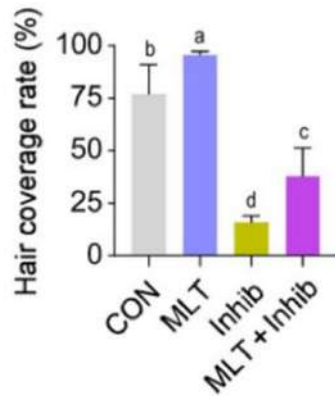
(Zhai X, et al. Clin Cosmet Investig Dermatol 2021)

1.1 Seasonality of hair loss

(A)



(D)



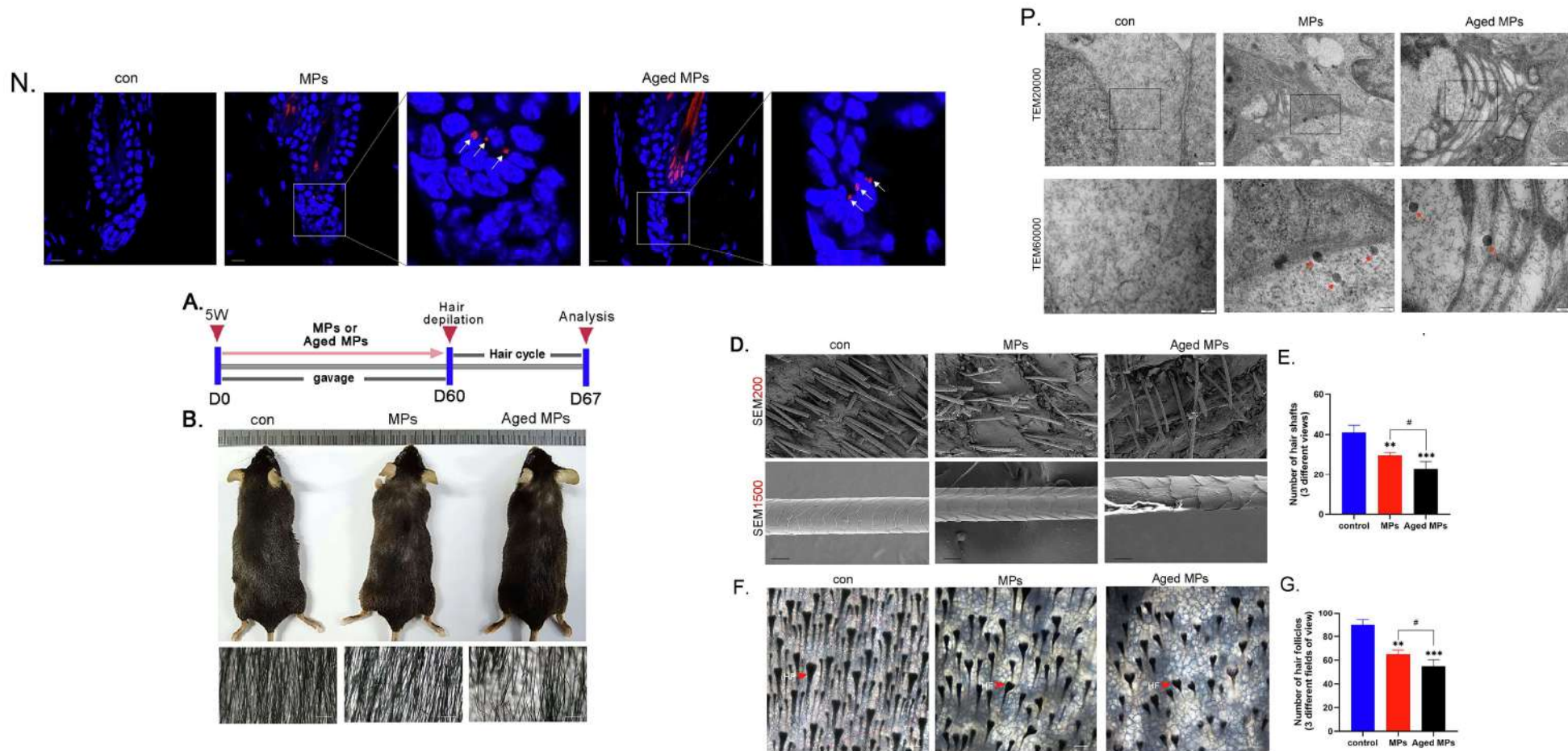
(Niu Y-L, et al. Cell Prolif 2024.)

1.2 Microplastics can induce hair loss

微塑料：指直径小于5毫米的塑料颗粒，更小尺寸的还有微米、纳米级的微塑料



1.2 Microplastics can induce hair loss

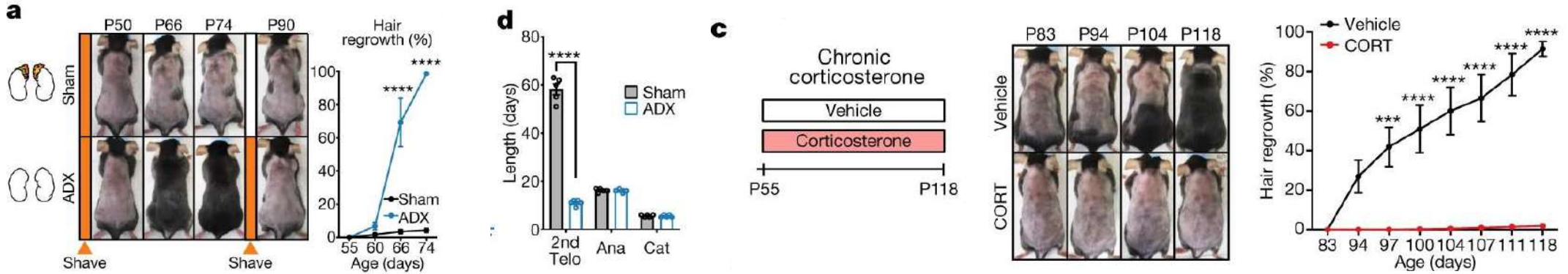


MPs treatment caused alopecia and hair structural damage in mice, and the toxic effect caused by aged MPs was more obvious.

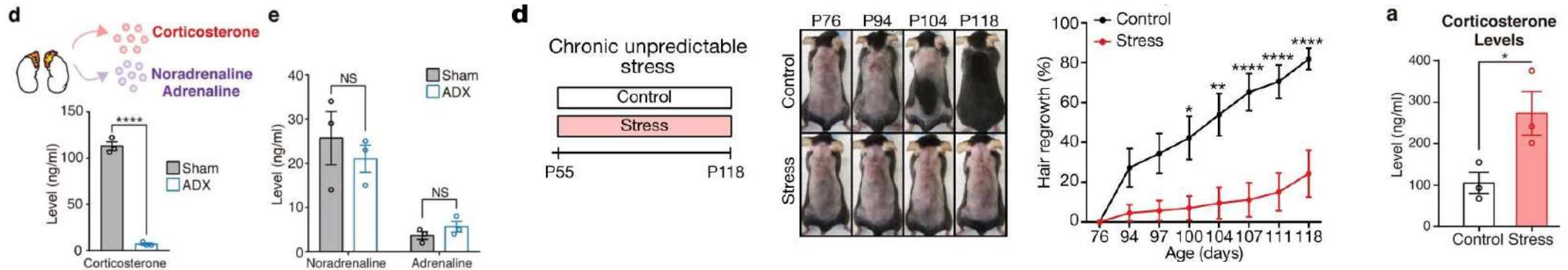
(Li Q, et al. Environment International 2024.)

Part II What daily activities or habits contribute to hair loss?

2.1 Stress-induced chronic hair loss



Which hormone is exerting this effect?



Corticosterone is a systemic 'brake' signal that inhibits hair follicles from entering the growth phase

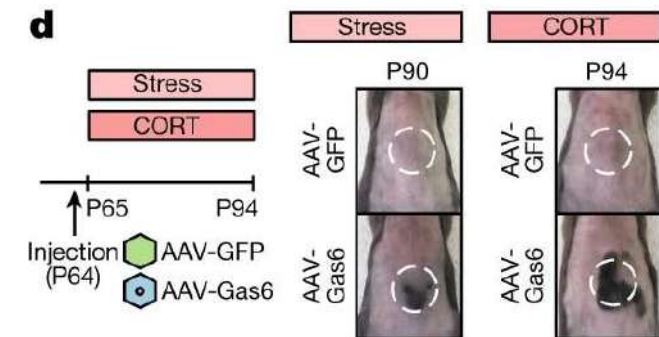
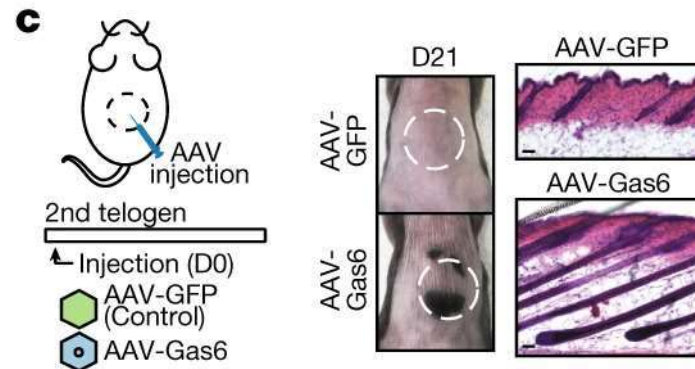
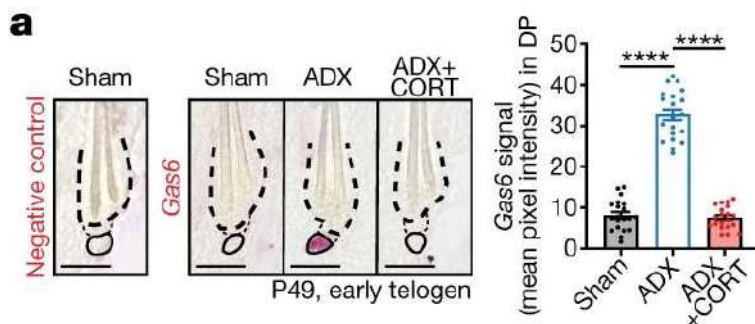
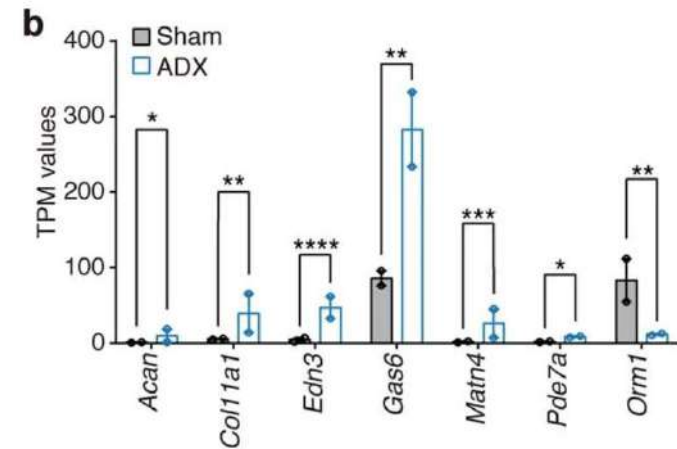
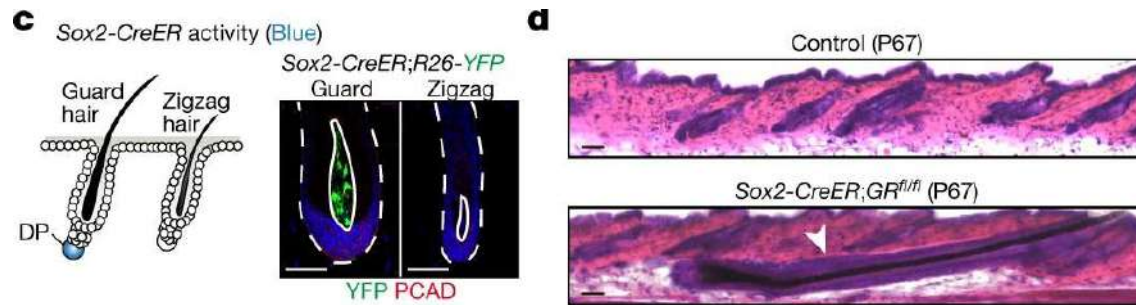
(Choi, S., et al. *Nature* 592, 428–432, 2021)

2.1 Corticosterone acts on the DP to regulate HFSC quiescence.

Which cells does corticosterone act on?

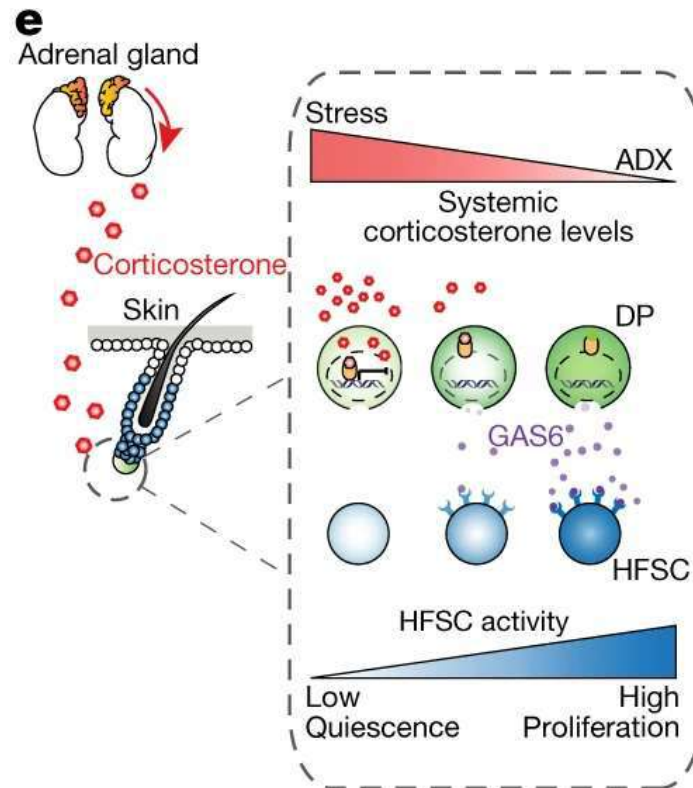
真皮乳头细胞 (DP) 是围绕毛囊干细胞 (HFSC) 的异质性细胞群

After DP receives the corticosterone signal, through which specific molecules does it affect hair follicle stem cells?

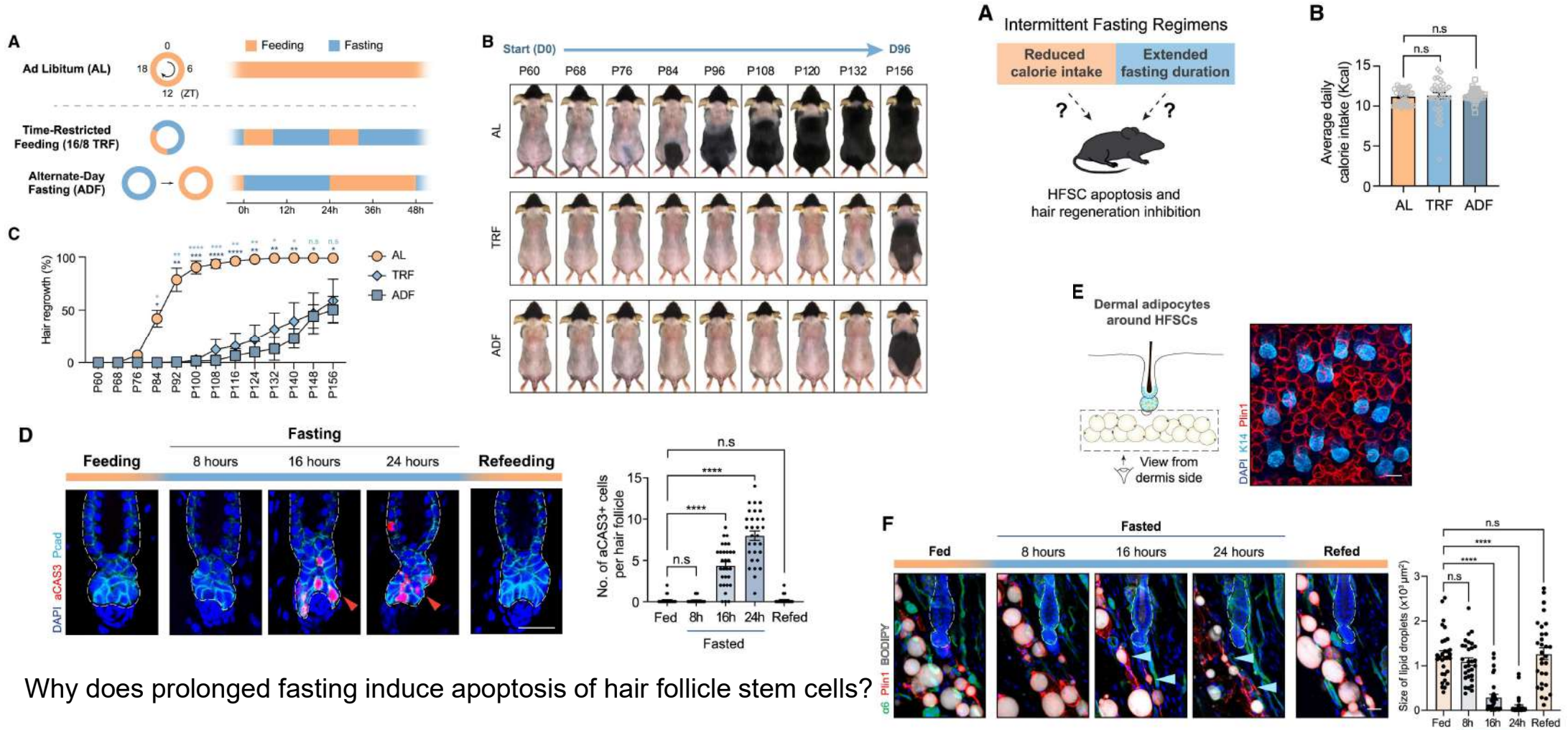


(Choi, S., et al. *Nature* 592, 428–432, 2021)

2.1 Gas6 overexpression counteracts the inhibitory effect of corticosterone.



2.2 Intermittent eating inhibits hair follicle regeneration



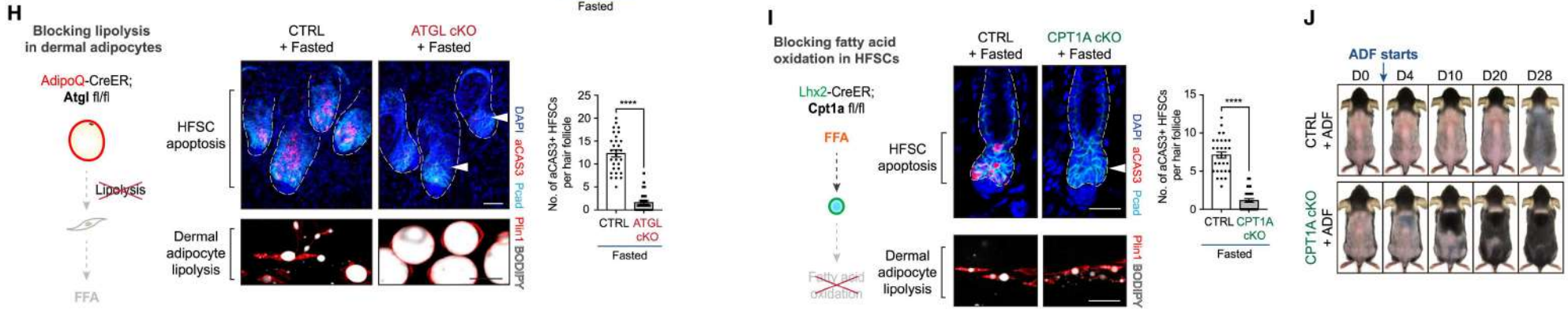
Why does prolonged fasting induce apoptosis of hair follicle stem cells?

There is a close correlation between lipolysis in dermal adipocytes during fasting and apoptosis of HFSCs.

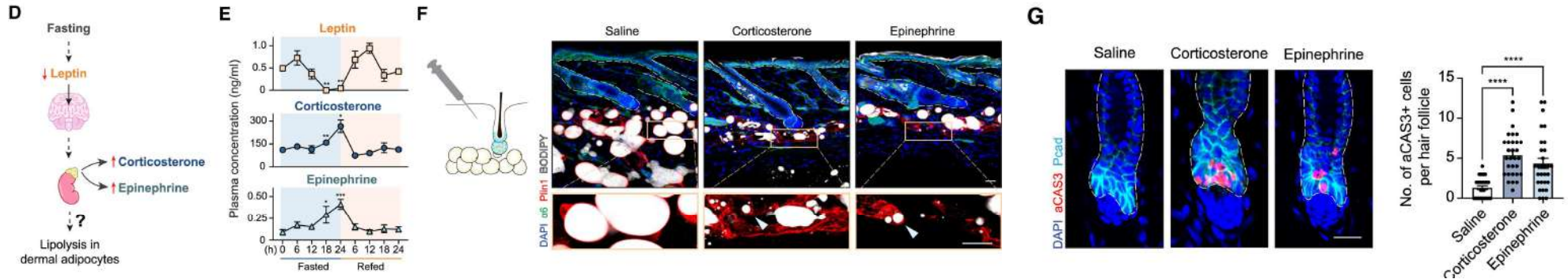
(Chen H, et al. Cell 2025)

2.2 Intermittent eating inhibits hair follicle regeneration

What is the specific relationship between fat breakdown and stem cell apoptosis?



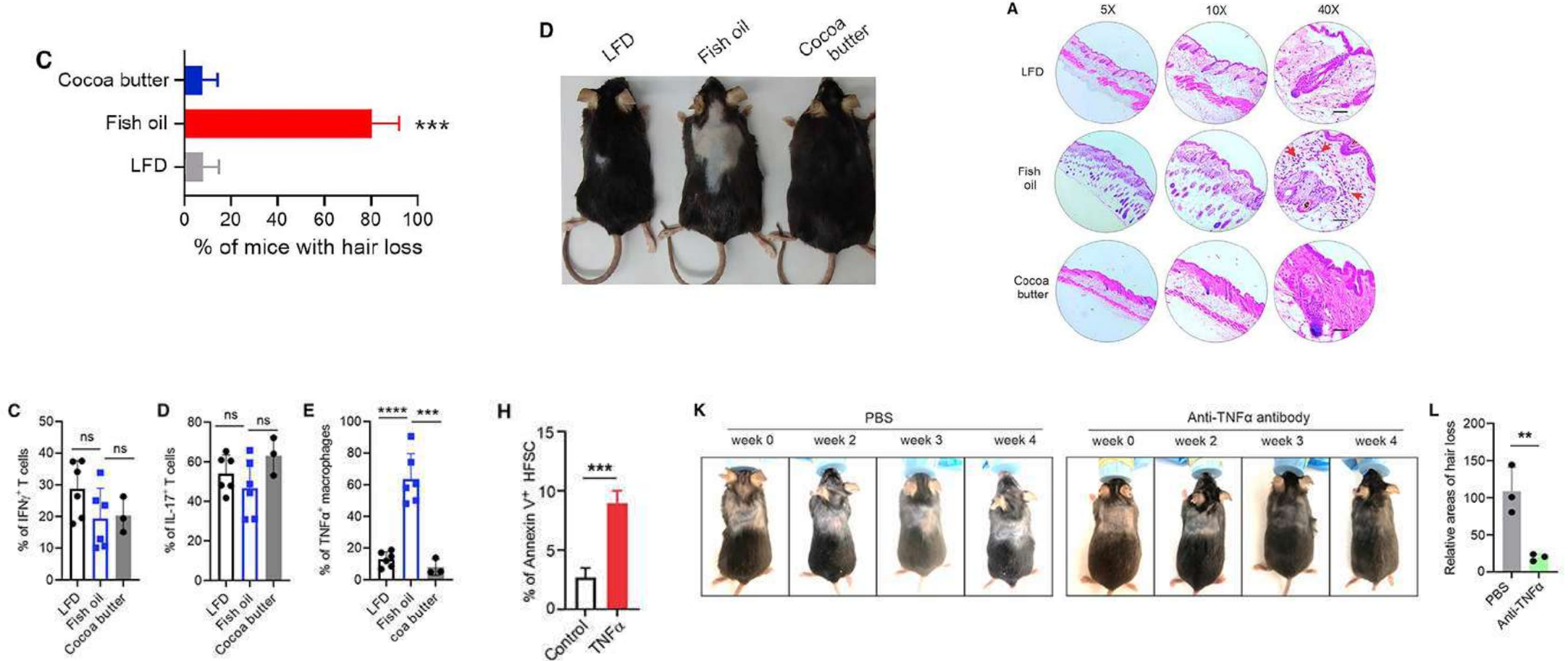
How does fasting induce lipolysis and ultimately lead to the apoptosis of hair follicle stem cells?



Extended fasting activates the adrenal glands to release lipolytic hormones, which signal through adipocytes in the niche to eliminate activated HFSCs and inhibit hair follicle regeneration.

(Chen H, et al. Cell 2025)

2.3 Fish oil and high-fat diet can induce hair loss

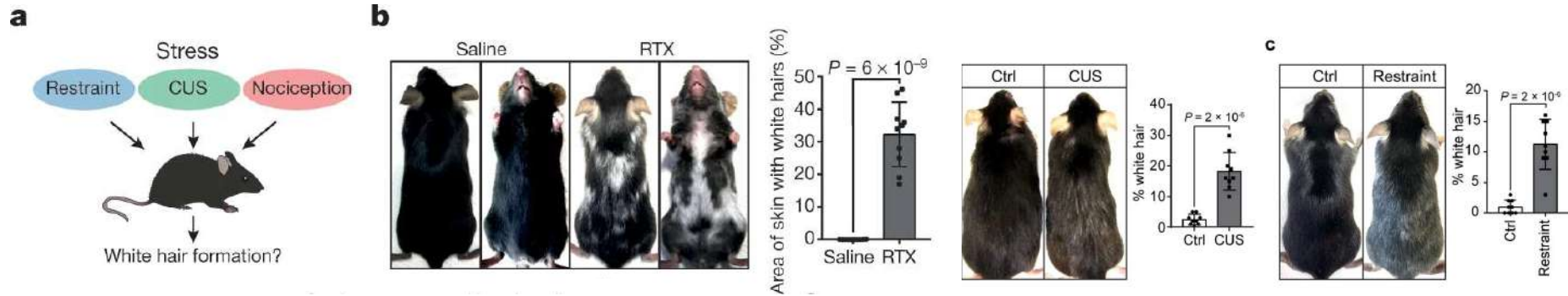


TNF- α signaling generated by dermal CD207⁺ macrophages represented a main molecular mechanism underlying fish oil HFD-induced murine hair loss.

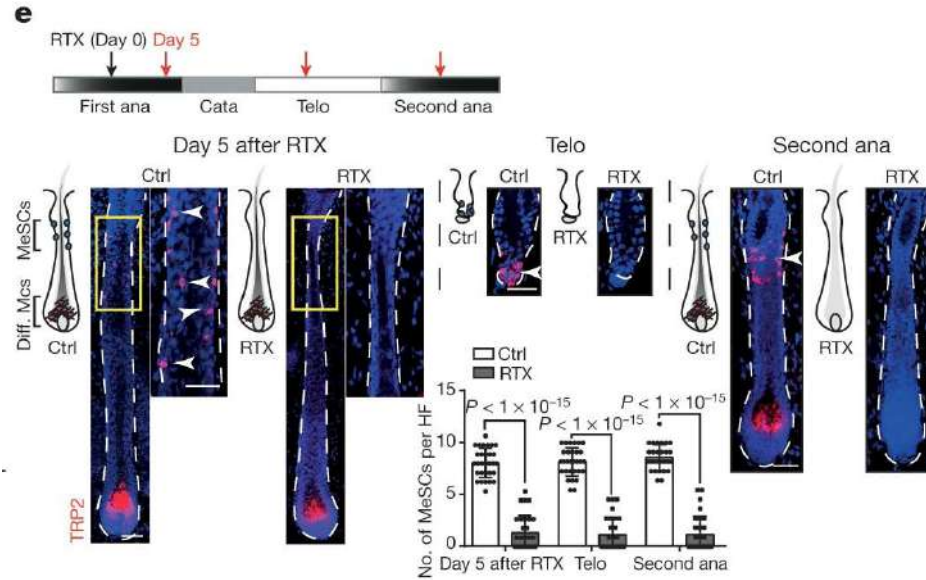
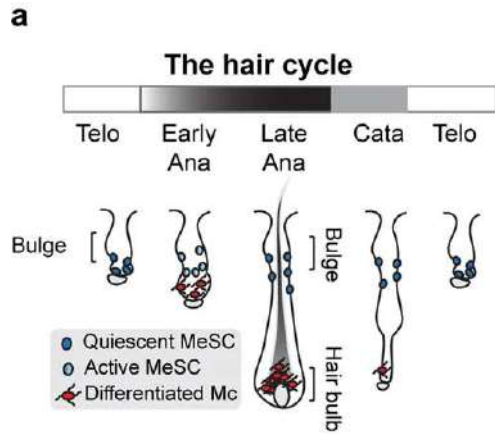


Part III Does hair turning white overnight really exist?

Stress-induced white hair



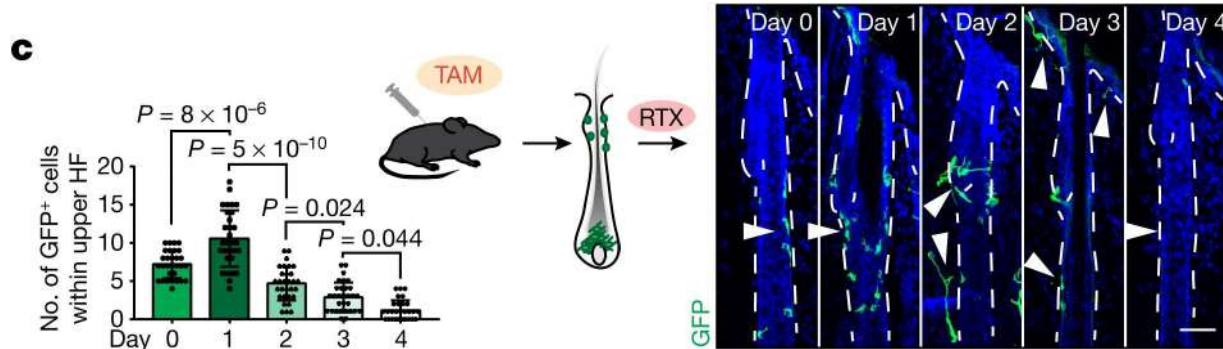
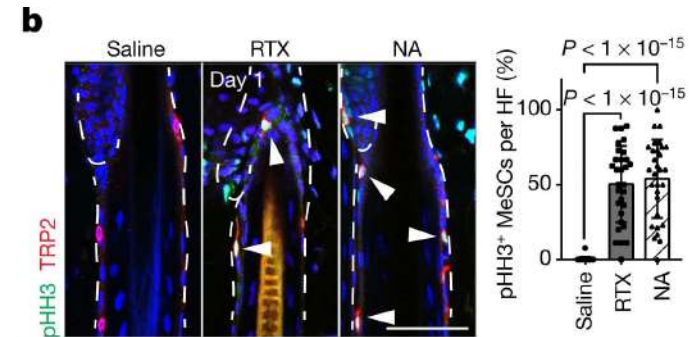
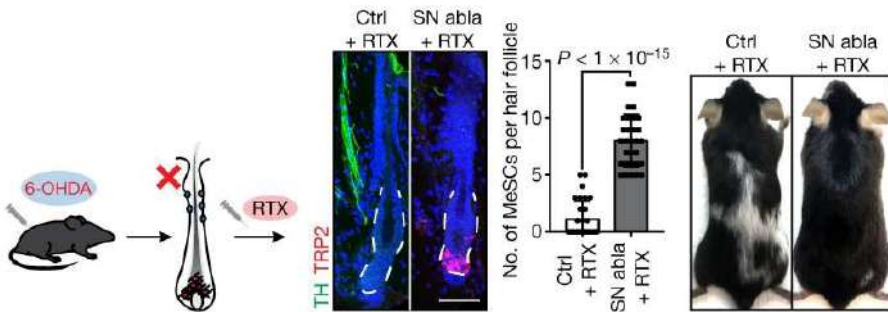
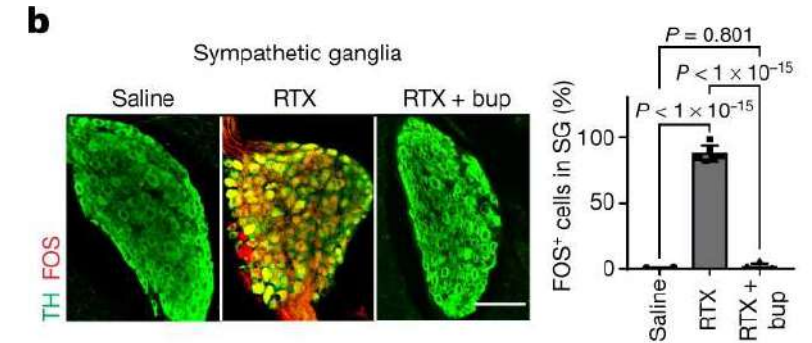
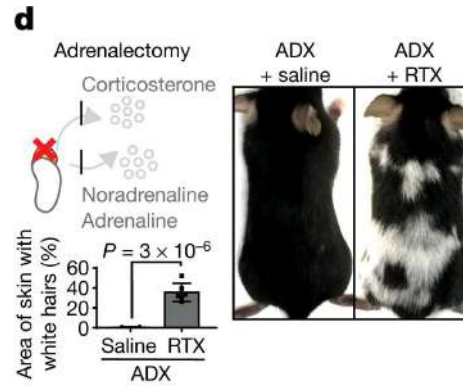
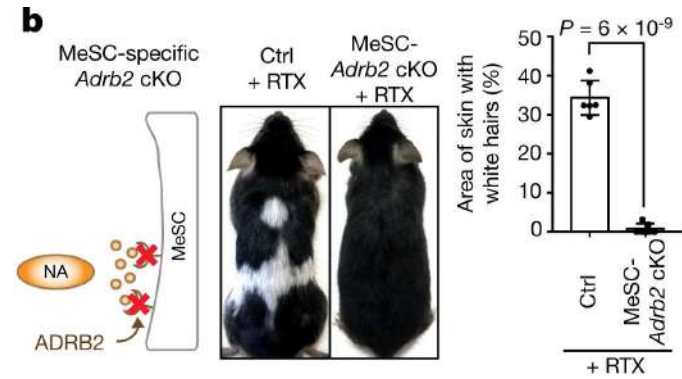
Why does hair turn white?



Stress leads to loss of MeSCs.

(Zhang B, et al. Nature 2020.)

Stress-induced white hair



MeSCs undergo rapid proliferation followed by differentiation and migration, which leads to their loss from the niche.

(Zhang B, et al. Nature 2020.)

Take-home message

1. Intense ultraviolet radiation and prolonged sun exposure during summer, coupled with microplastic pollution, can lead to hair loss.
2. Under stress conditions, corticosterone levels rise, subsequently inhibiting CAS6 secretion and prolonging the quiescent phase of hair follicle stem cells.
3. Prolonged fasting promotes fat breakdown, thereby inducing apoptosis of hair follicle stem cells.
4. A high-fat diet rich in fish oil can lead to hair loss.
5. Stress can lead to premature depletion of MeSCs, subsequently resulting in hair whitening.

Hair Regrowth: Current Interventions, Mechanistic Insights

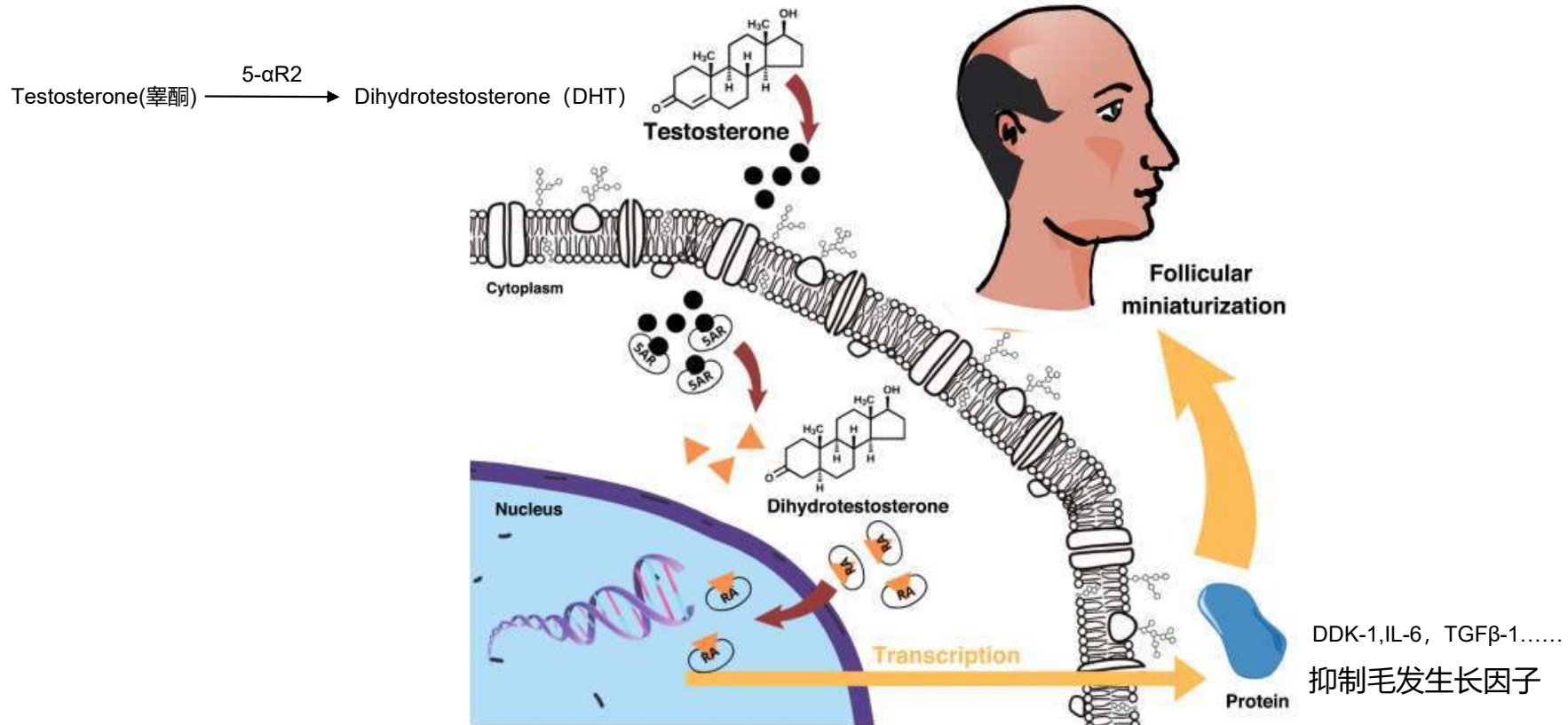
WJ
2026.4.30

Part1. An Introduction to Medical Interventions for Pathological Alopecia



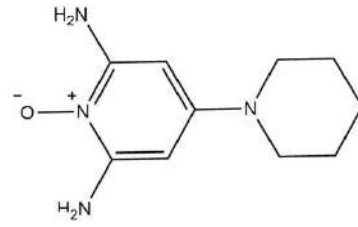
Male androgenetic alopecia

Androgen-dependent molecular signaling pathway in the dermal papilla cells



Cortez GL, et al. An Bras Dermatol. 2025.

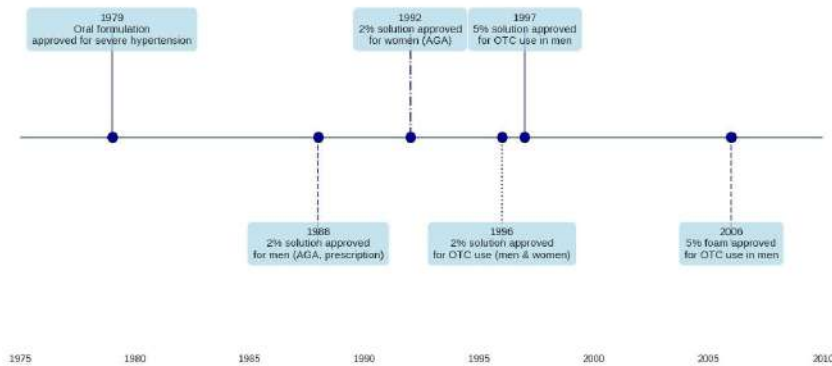
Minoxidil for Hair Loss Disorders



6-(1-哌啶基)-2,4-嘧啶二胺-3-氧化物

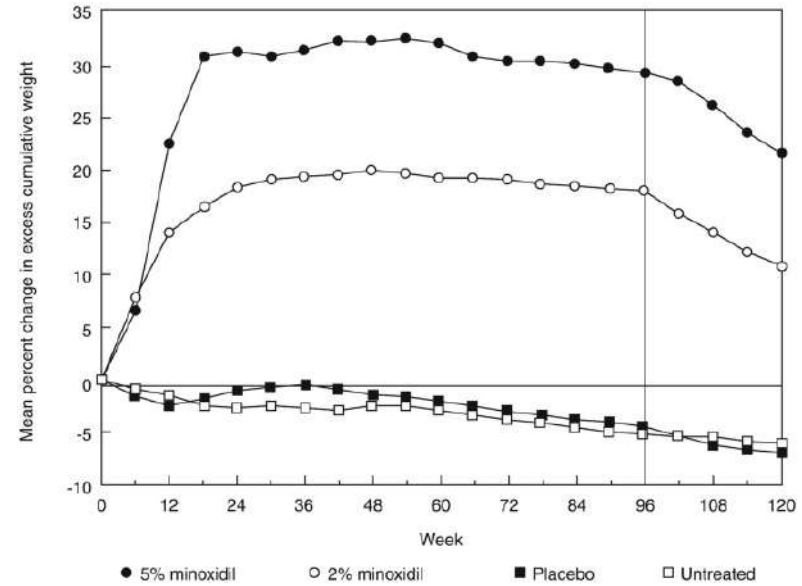
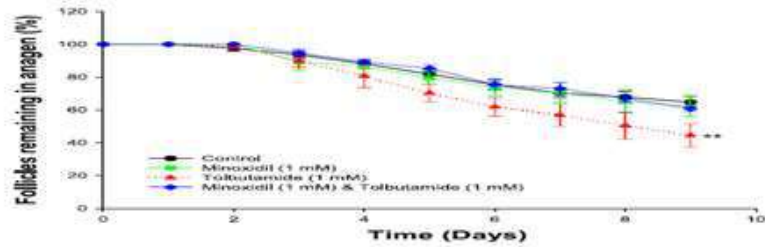


FDA Approvals Timeline for Rogaine® (Minoxidil)

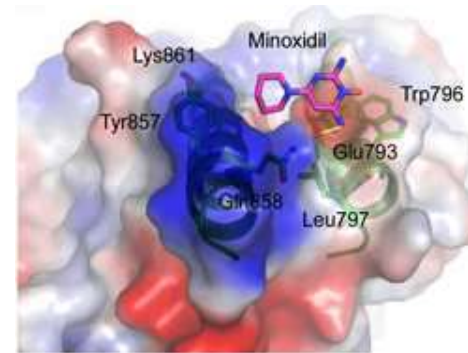
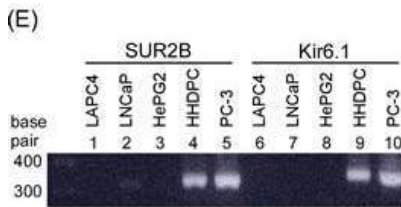
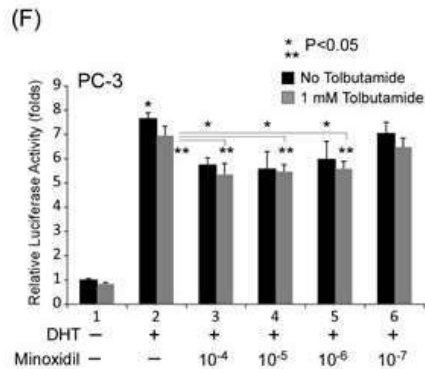
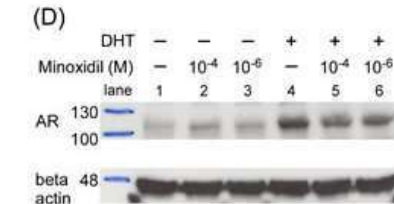
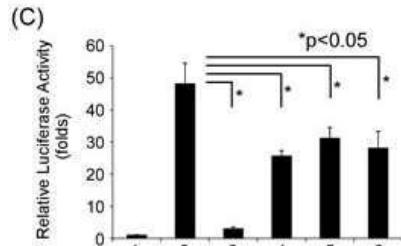


Anastassakis K. Androgenetic Alopecia From A to Z. 2022.

Minoxidil promotes hair growth



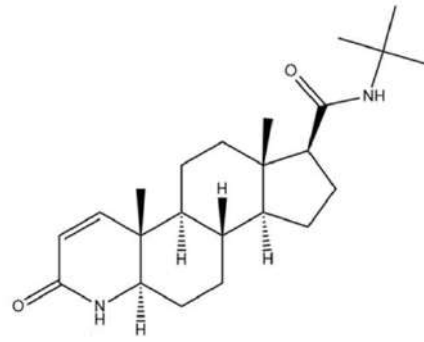
16h



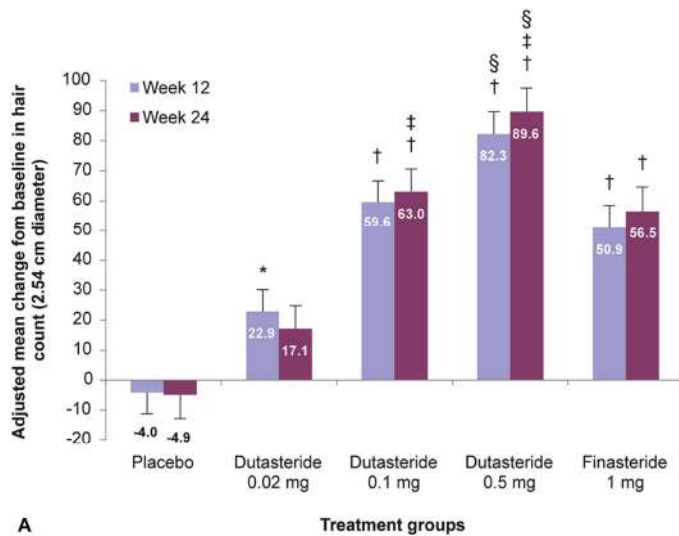
Valerie A. Randall¹, et al. The FASEB Journal. 2008.

Anastassakis K. Androgenetic Alopecia From A to Z. 2022.

Anti-androgen Drugs for Hair Loss Disorders



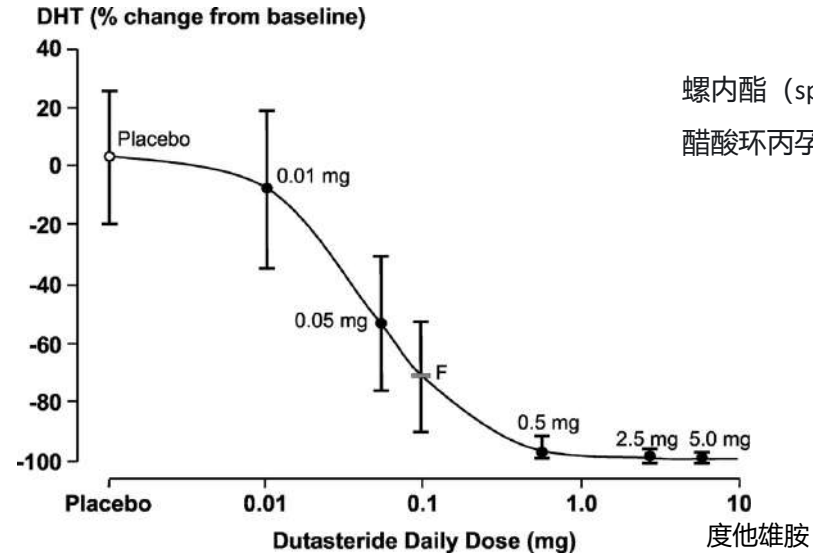
4-氨基甾体化合物



A

Treatment groups

Gubelin Harcha W, et al. J Am Acad Dermatol. 2014.



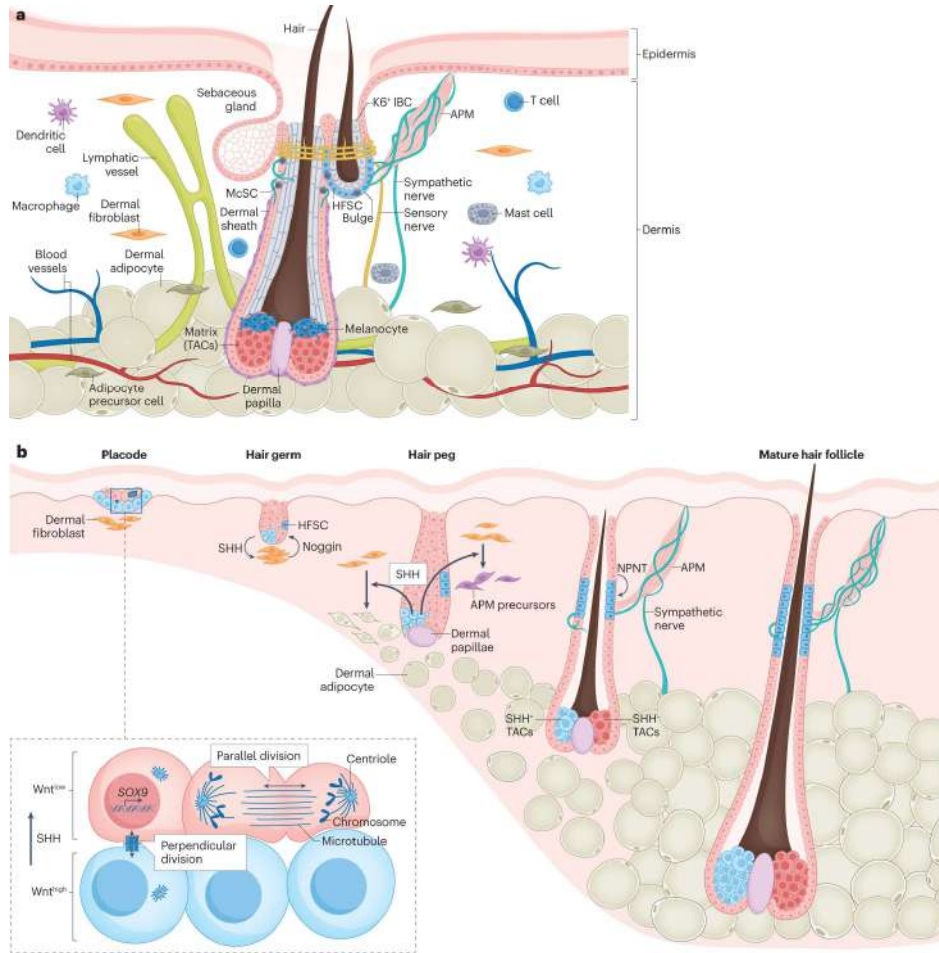
螺内酯 (spironolactone)

醋酸环丙孕酮 (cyproterone acetate, CPA)

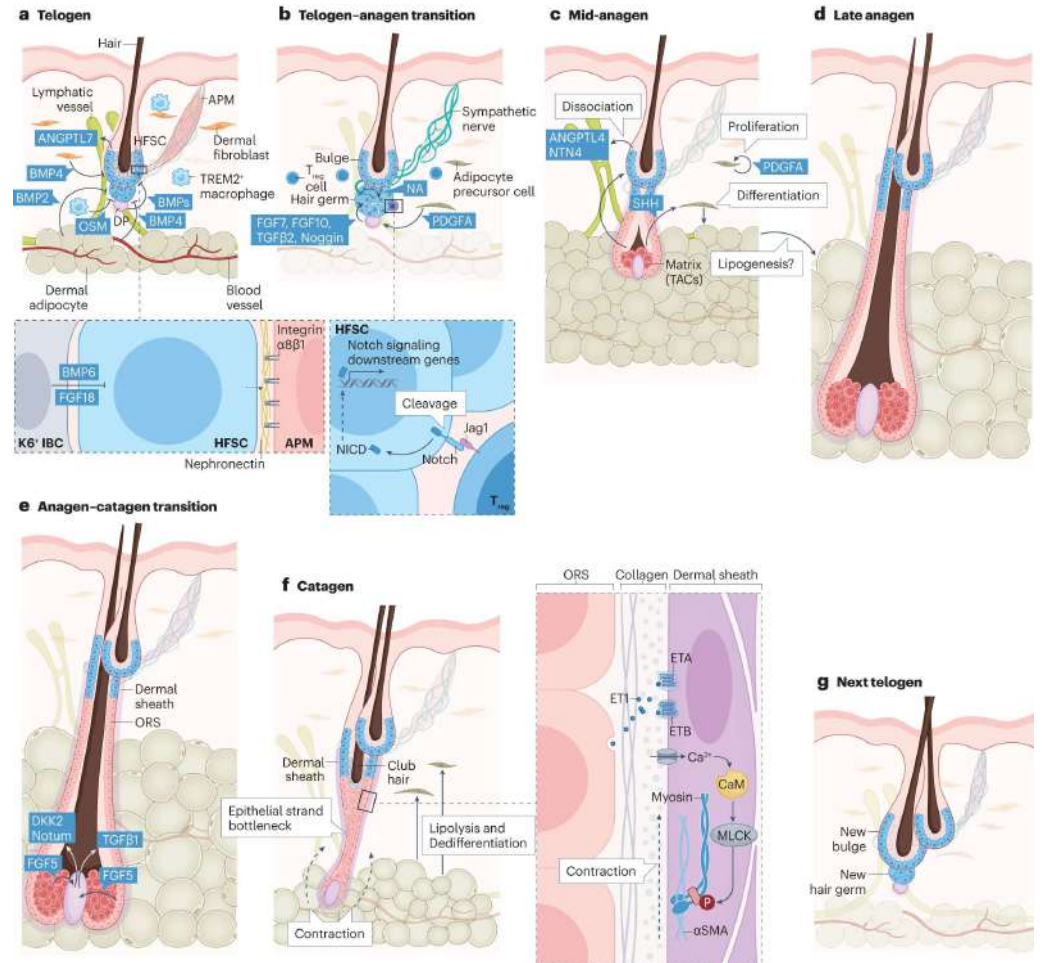


Sujit J.S Shanshanwal. Indian Journal of Dermatology, Venereology, and Leprology.2017.

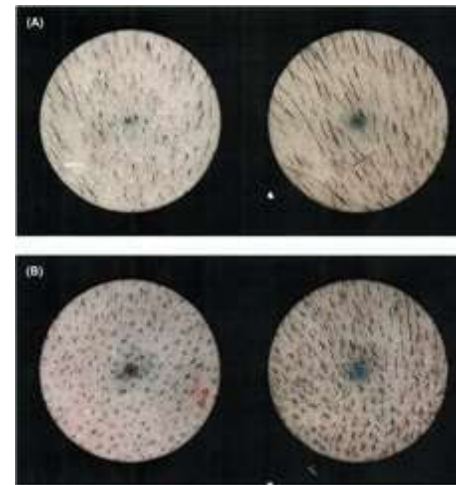
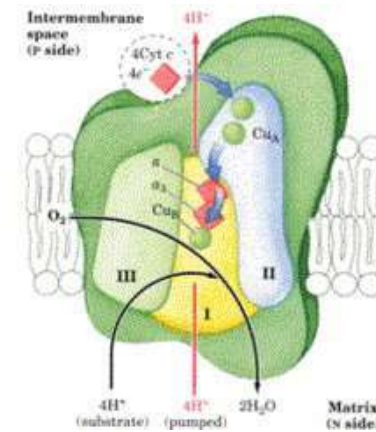
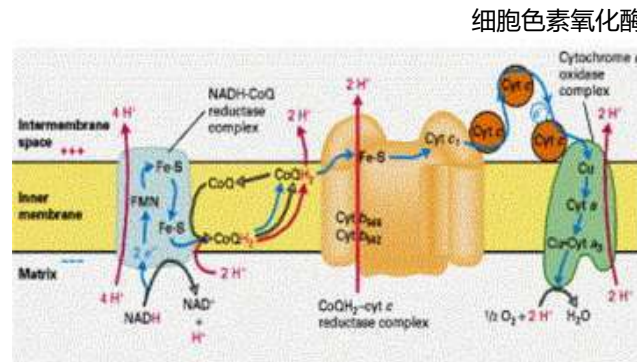
Establishment of the niche surrounding hair follicle stem cells.



上皮细胞不对称分裂



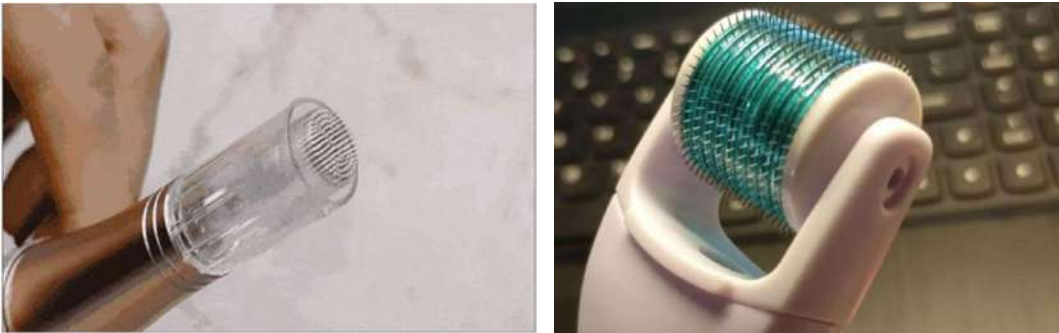
Low-Level Laser (Light) Therapy (LLLT)



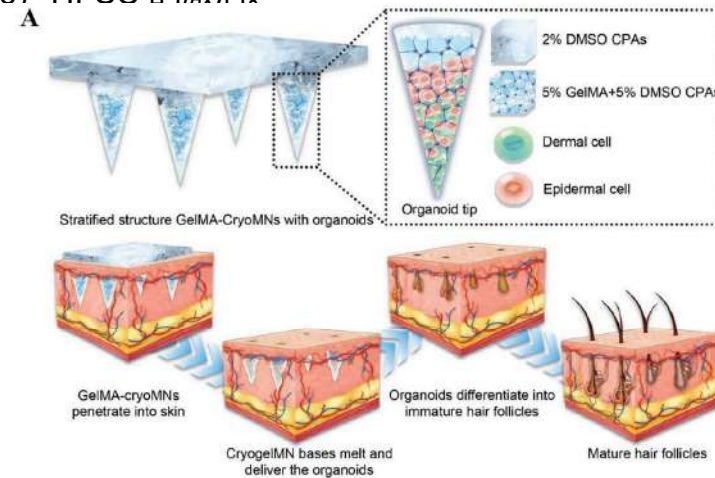
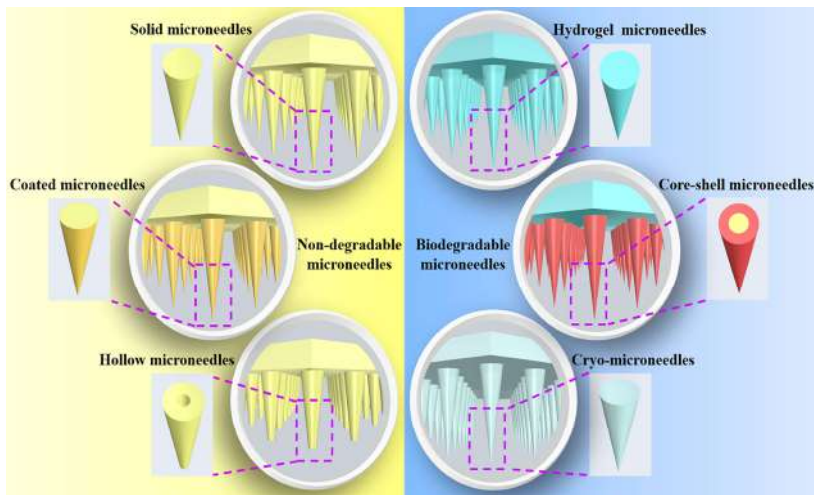
Patricia BSBA, et al. Dermatologic Surgery. 2017.

Eells JT, et al. Mitochondrion. 2004.

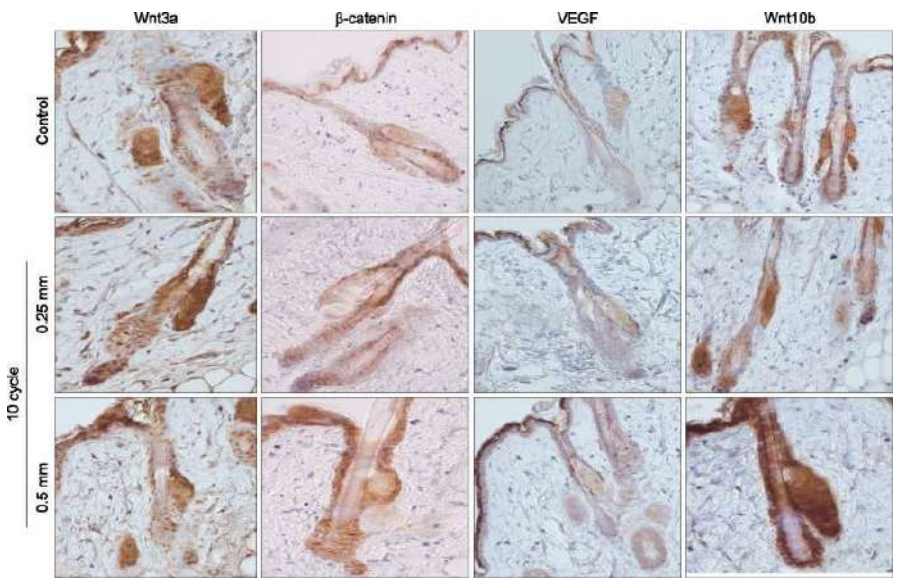
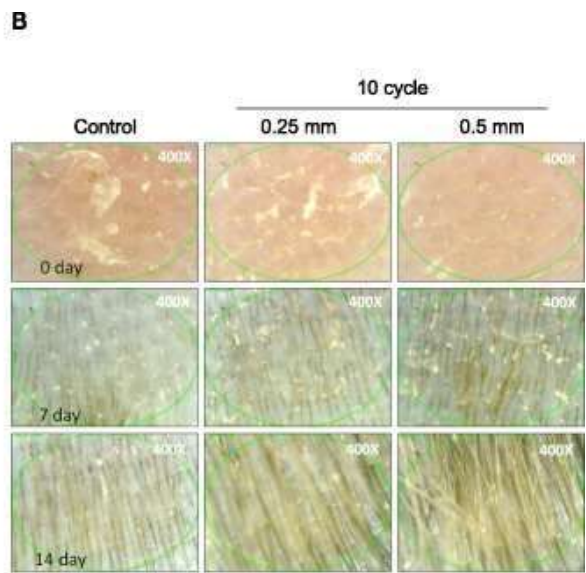
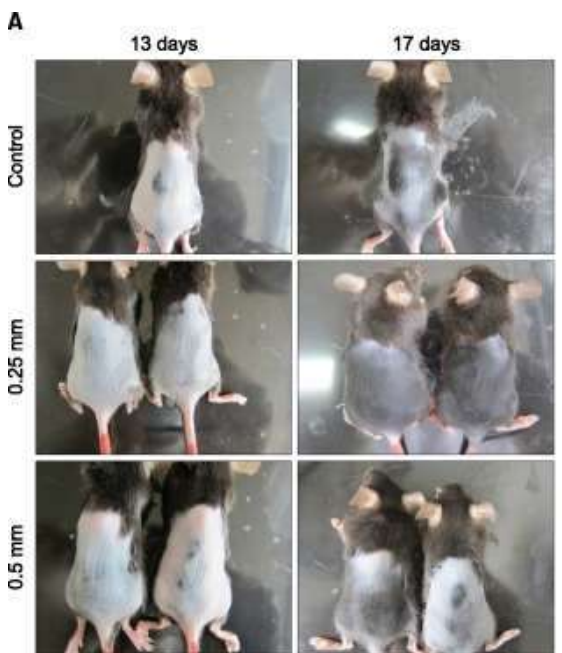
Microneedle-mediated therapies



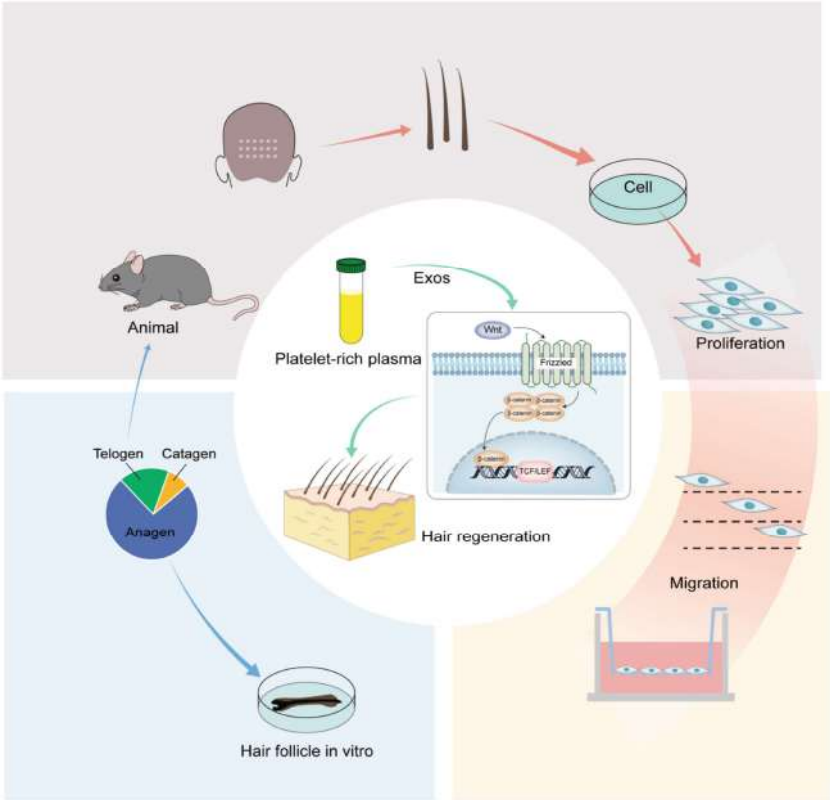
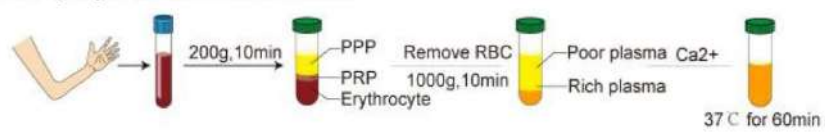
- (1) 刺激胶原蛋白的生成和促进血液循环;
- (2) 激活生长因子;
- (3) 促进药物吸收;
- (4) 调节头发生长周期;
- (5) 改善头皮微环境;
- (6) HFSC 的激活.



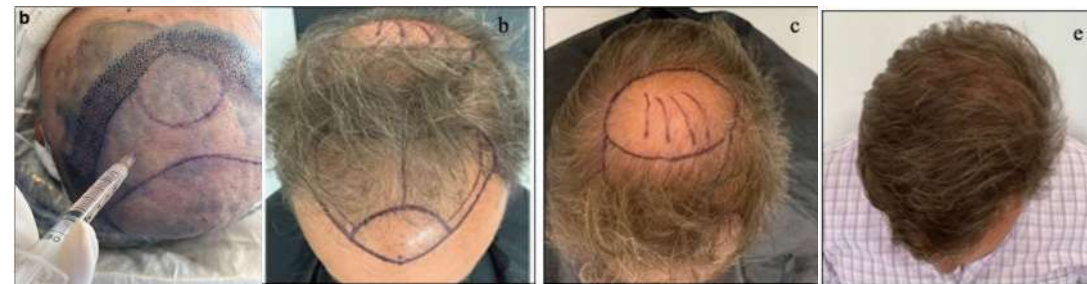
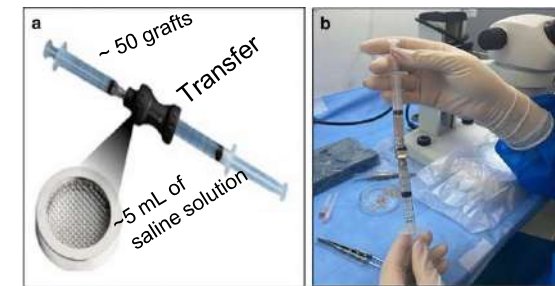
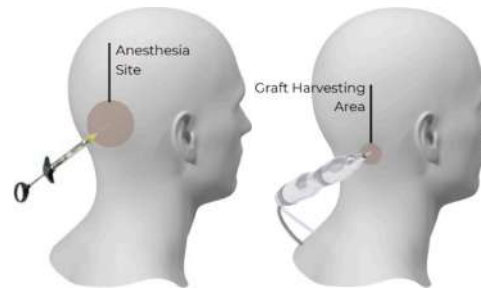
Repeated microneedle stimulation induces hair growth



Platelet-Rich Plasma (PRP) Therapy for Hair Regrowth



Hair Transplantation



autologous MSCs

follicular unit transplantation (FUT)
follicular unit extraction(FUE)

Combination of Drugs and Physical Methods

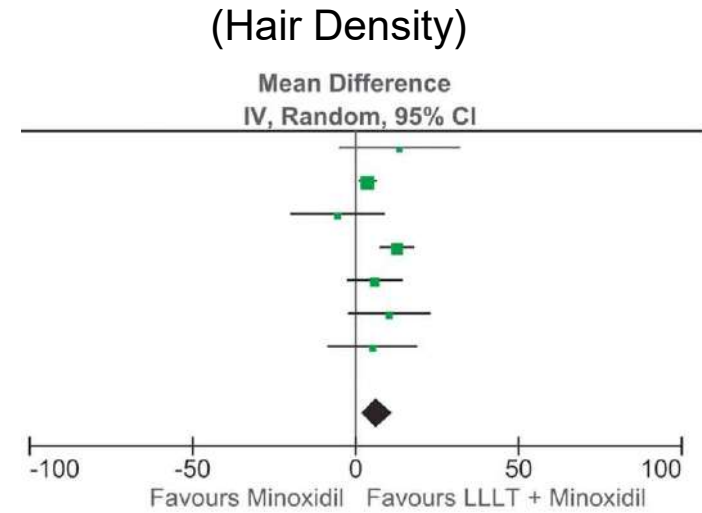
(a) Group 1 5% minoxidil



(b) Group 2 microneedle treatment



(c) Group 3 microneedle combined 5% minoxidil.



Mawu, F.O., et al. Lasers Med . 2025.

Linlin Bao, et al. JOURNAL OF COSMETIC AND LASER THERAPY. 2020.

治疗手段	适用目标	作用机制	效果	不良反应/注意事项
外用米诺地尔 (2%/5%)	雄激素性脱发 (AGA, 男/女)、斑秃辅助	钾通道开放, 促进血管内皮生长因子 (VEGF) 表达, 延长毛囊生长期	增加毛发密度和直径 (有效率 40-60%); 需持续使用, 停药后效果逐渐消失	头皮轻度瘙痒、接触性皮炎; 多毛症 (罕见)
口服非那雄胺 (1mg/日)	男性AGA	抑制II型5 α -还原酶, 降低血清和头皮DHT约60-70%	延缓脱发进展, 部分患者出现中等程度毛发生长; 停用后脱发复发	性欲减退、勃起功能障碍 (约1-2%)、射精障碍; 极少数抑郁、男性乳房发育
外用非那雄胺 (0.25%喷雾)	男性AGA (希望降低全身副作用)	局部抑制头皮5 α -还原酶, 减少DHT生成, 全身暴露量极低	疗效与口服相当, 但血清DHT抑制程度显著降低	局部刺激; 性功能障碍发生率接近安慰剂
螺内酯 (口服, 80-110mg/日)	女性型脱发 (FPHL)	雄激素受体拮抗剂+轻度醛固酮拮抗; 减少雄激素对毛囊的抑制	81%患者出现毛发生长; 联合米诺地尔优于单用	月经紊乱 (约7.9%)、高钾血症、低血压、乳房胀痛; 老年患者需监测血钾
低能量激光治疗 (LLLT)	AGA (男/女) 辅助治疗	光生物调节: 细胞色素C氧化酶吸收光子 \rightarrow ATP \uparrow \rightarrow 促进毛囊生长期转换; 部分波长抑制5 α -还原酶	联合米诺地尔增加毛发密度 (MD +6.62根/cm ²); 患者满意度高	轻度自限性头皮瘙痒、刺激; 无严重不良事件
微针疗法	AGA (联合米诺地尔或单独)	微创形成皮肤通道促进药物吸收; 直接激活Wnt/ β -catenin、上调VEGF等促生长因子	联合米诺地尔总有效率92.42% (vs 78.79%); 女性型脱发90%可测量改善	暂时性点状出血、红斑、疼痛; 不当操作可致感染或瘢痕
富血小板血浆 (PRP)	AGA、斑秃、休止期脱发	血小板释放多种生长因子 (PDGF, TGF- β , VEGF等) 刺激毛囊真皮乳头细胞和干细胞	增加毛发密度和厚度 (荟萃分析SMD 3.39和2.78), 减少拉发试验脱发数	注射局部短暂疼痛、肿胀; 活化PRP比非活化更有效; 缺乏统一制备标准
植发 (FUE/FUT)	稳定期AGA (供区毛囊充足)、瘢痕性脱发	供体优势理论: 枕部毛囊对DHT不敏感移植后保持持久存活	永久性改善脱发外观; 自然生长, 无需药物维持	术后暂时性红肿、结痂、毛囊炎、供区瘢痕 (FUT线状、FUE点状)

Is it really useful?



生姜擦头皮真的能长头发吗？



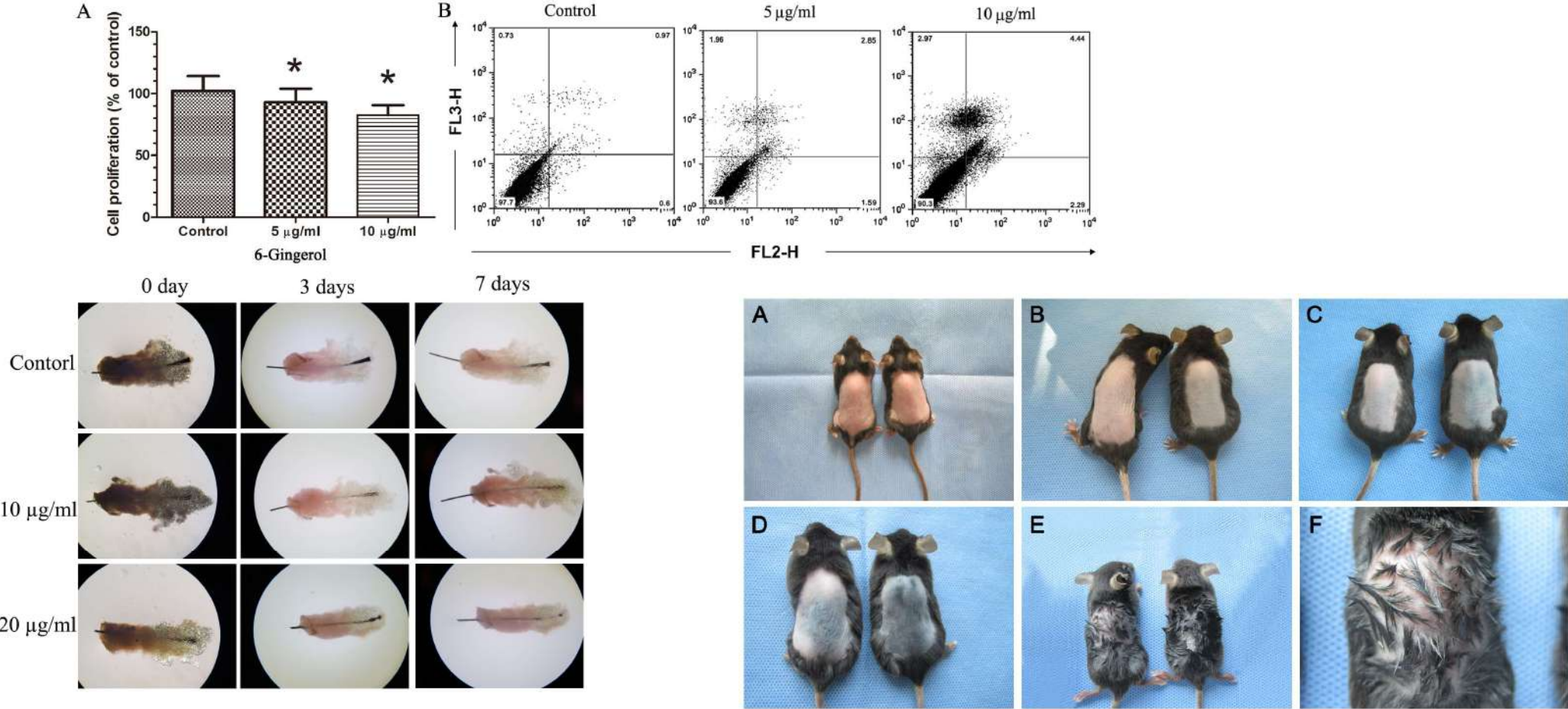
何首乌生发



咖啡因助生发？

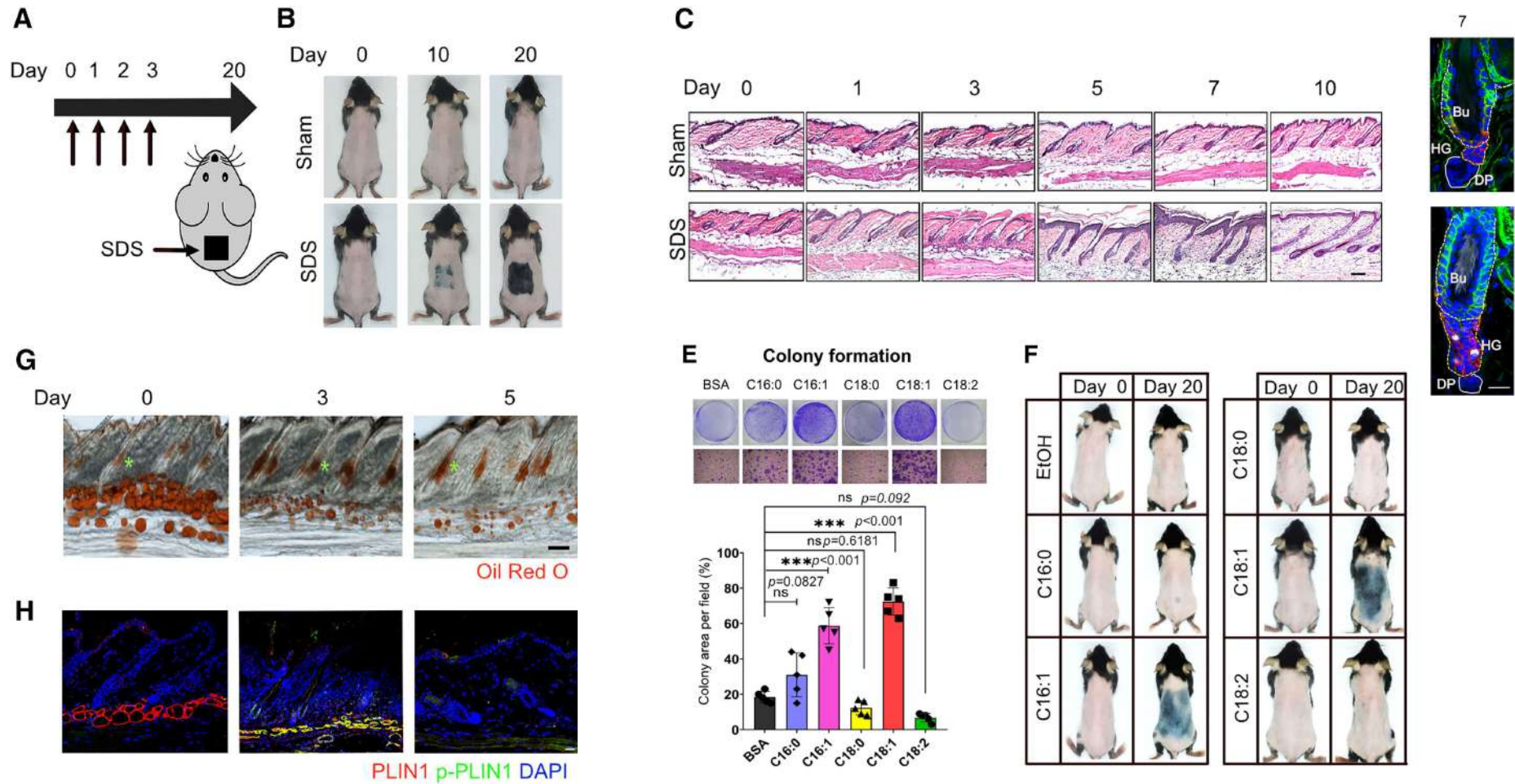
1. 机制是否合理？（停留时间是否足够吗？能否作用于毛囊干细胞？）
 2. 是否有高质量临床证据？
 3. 是否有监管机构批准？（FDA、NMPA？）

6-gingerol has no effect on promoting hair growth

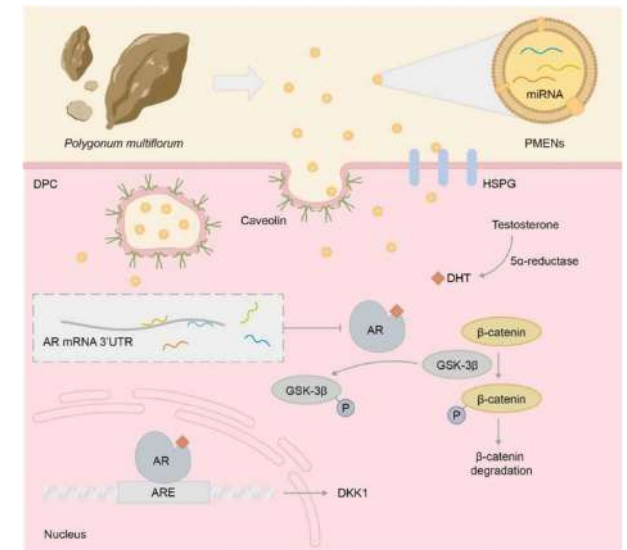
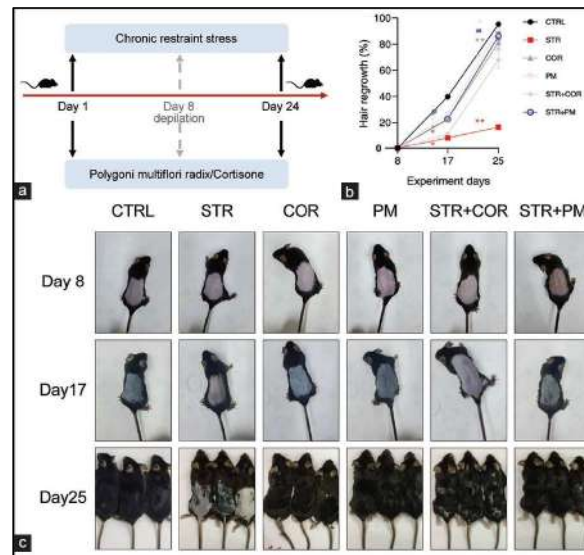
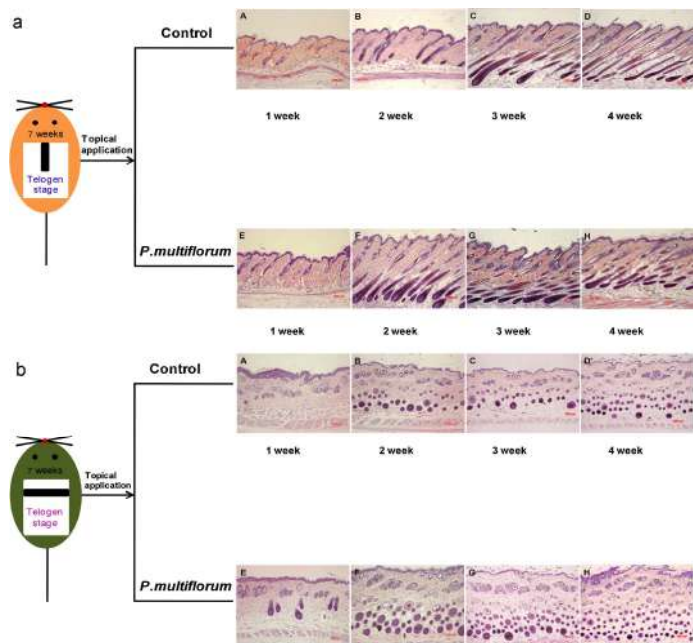


Miao Y, et al. PLoS One. 2013.

Wound-induced hair neogenesis (WIHN)



Polygonum multiflorum extract promote hair growth by inducing anagen phase of hair follicles.

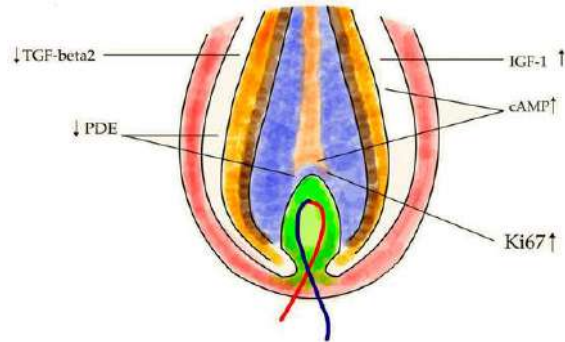
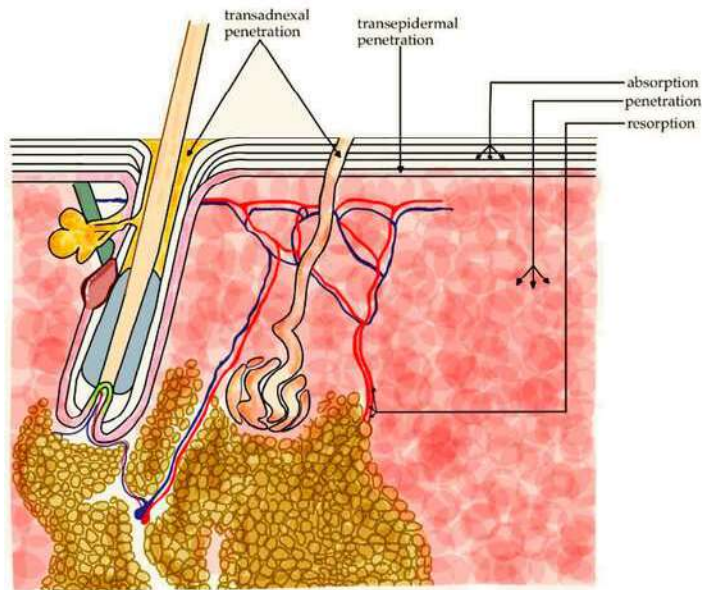


Liqin Zhang, et al. Pharmacological Research. 2025.

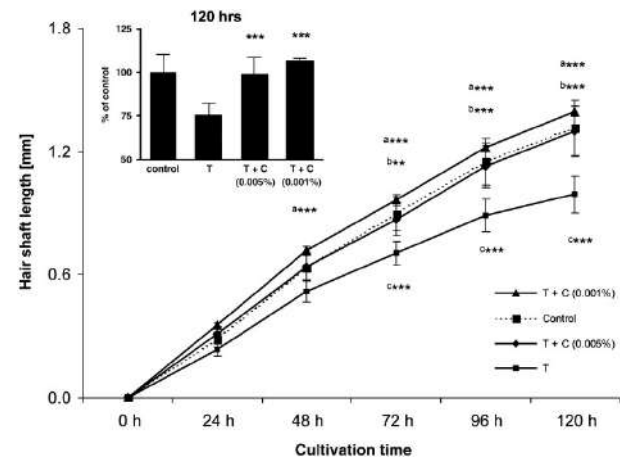
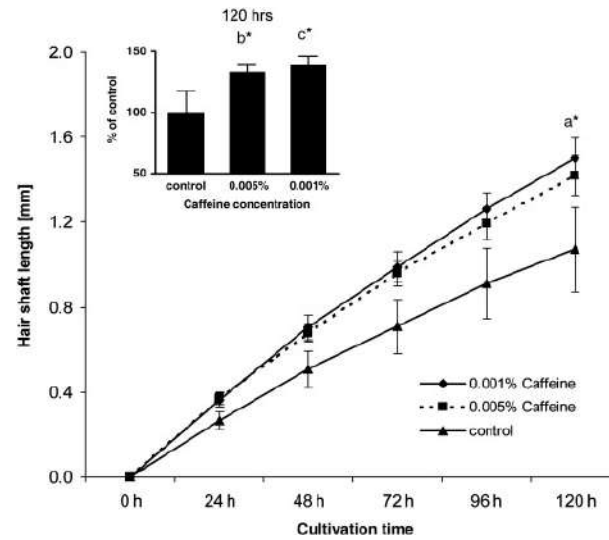
Yuan Gao, et al. World Journal of Traditional Chinese. 2025.

Dong Ki Park, et al. Journal of Ethnopharmacology. 2011.

Caffeine's Effects on the Growth of Hair.



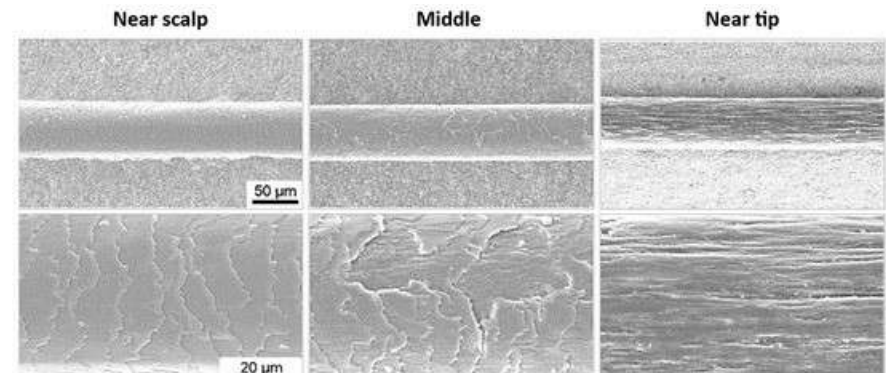
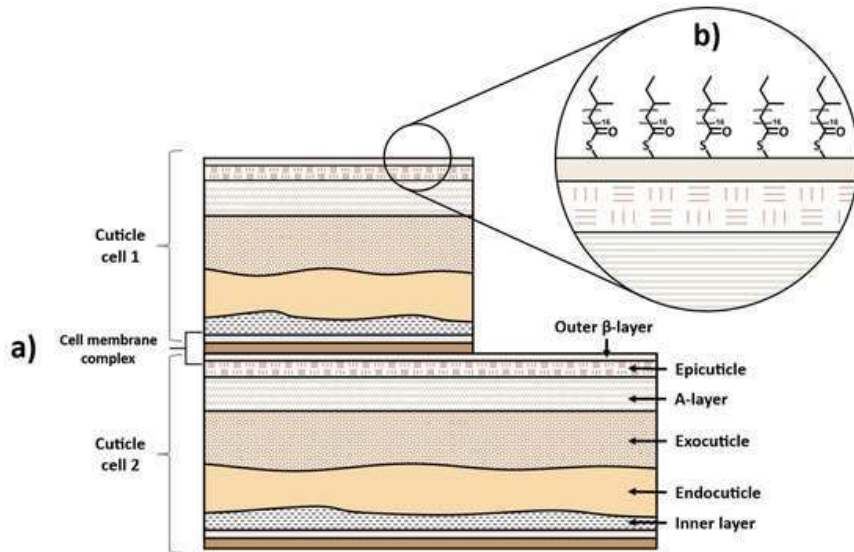
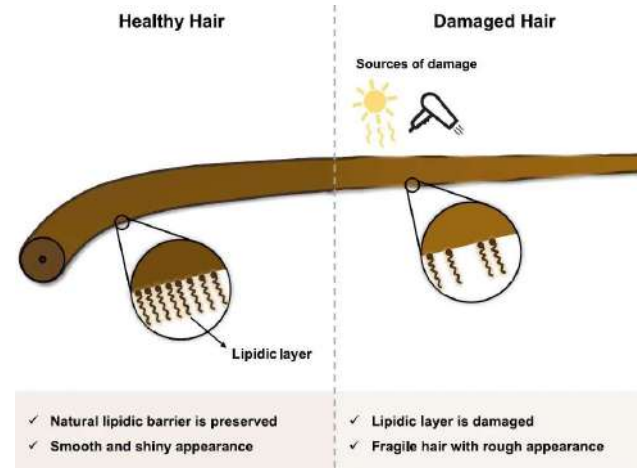
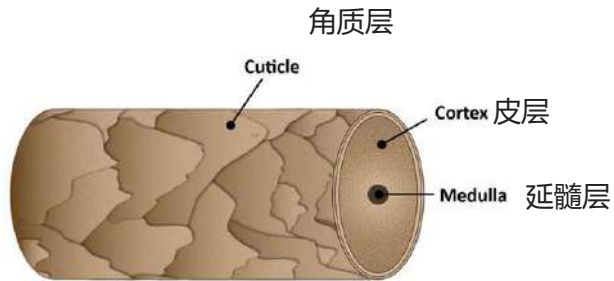
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Part2. Daily maintenance methods for telogen effluvium

Hair Structure and Chemical Composition



Tips

基础营养支持

- 每日摄入60-80g蛋白质（头发主要成分）
- 补充含铁、锌、维生素D

头皮环境优化

- 油脂平衡、微生物菌群生态平衡（限制性马拉色菌）
- 避免频繁染烫，洗头水温不超过40°C
- 休止期头发根部脆弱，过度牵拉或刺激会加重脱发
- 适当按摩头皮

缓解压力

- 适度运动
- 冥想

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Take home message

1. **Timely medical intervention is required for pathological alopecia.** Since therapeutic efficacy varies among different regimens, combined multiple interventions are generally applied in conventional treatment protocols.
2. **Telogen effluvium is a temporary and reversible** form of hair loss without follicular damage, which can be ameliorated through long-term daily maintenance and care.

THANKS

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