Aging in Skin and Hair

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Aging in Skin and Hair: Key Mechanisms

Skin and hair aging result from a synergy of intrinsic factors (genetic, chronological decline) and extrinsic elements (environment, lifestyle). Below are the principal mechanisms contributing to visible and functional changes.

1. **Intrinsic Aging**
   Genetically programmed decline in cellular function over time leads to natural aging of skin and hair.

2. **Extrinsic Factors**
   Environmental stressors like UV rays, pollution, and smoking accelerate skin and hair aging beyond genetic programming.

3. **Oxidative Stress**
   Excessive free radicals cause cellular and molecular damage, driving visible signs of aging.

4. **Glycation**
   Sugar molecules bind to collagen, that decrease skin elasticity and vitality.

5. **Photoaging**
   Chronic sun exposure leads to wrinkles, spots, and loss of skin tone due to cumulative UV damage.

6. **Hormonal Effects**
   Hormonal changes alter hair density and skin structure, contributing to visible aging.

Biochemistry of Reactive Oxygen Species

Types of ROS

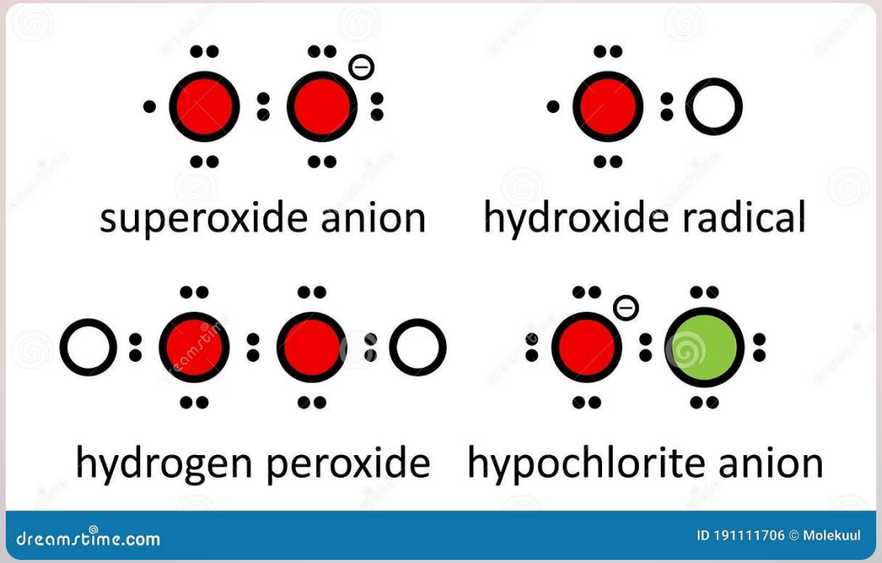
Reactive Oxygen Species (ROS): Superoxide (O_2^-), hydroxyl radicals (OH^-), hydrogen peroxide (H_2O_2)

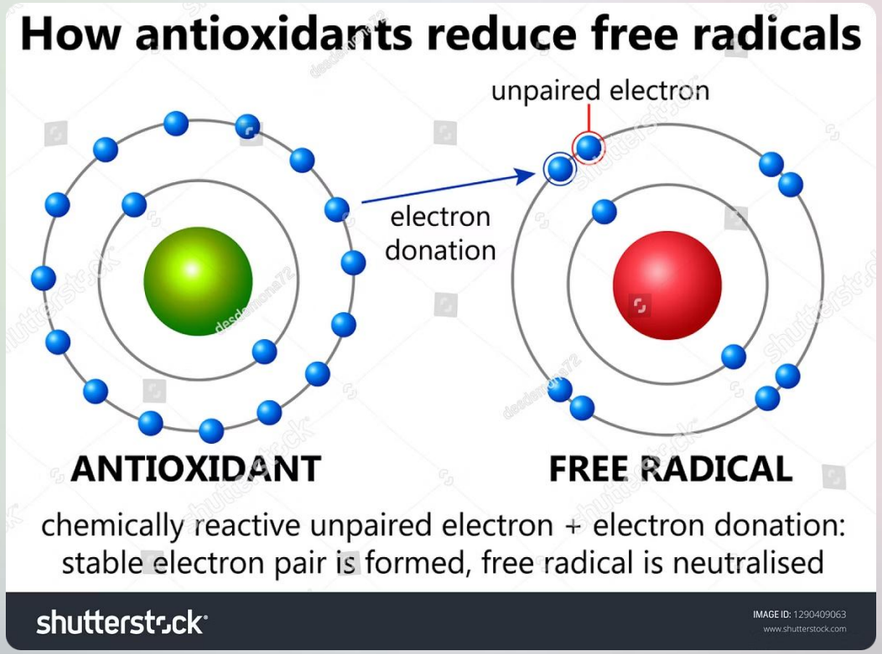
Endogenous Sources

Mitochondrial electron transport chain .

Exogenous Sources

UV radiation, pollution, cigarette smoke





Antioxidant Defense Systems

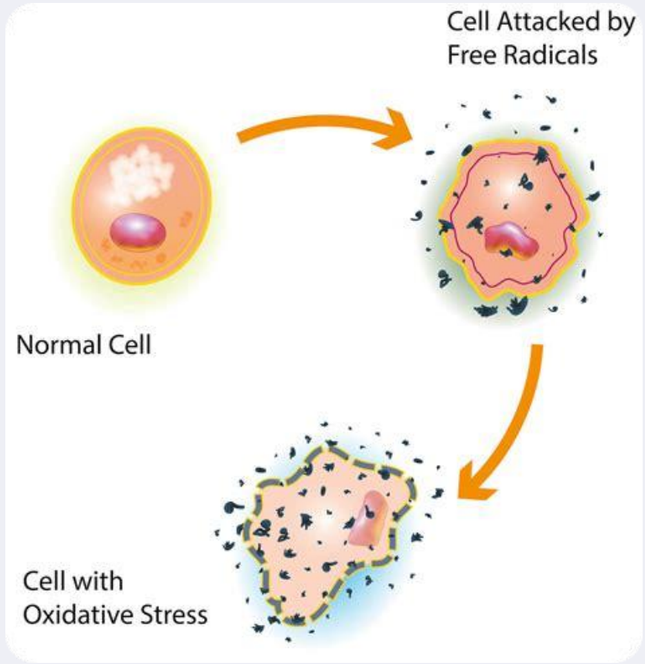
Enzymatic Antioxidants

- Superoxide dismutase (SOD)
- Catalase
- Glutathione peroxidase

Non-enzymatic Antioxidants

- Vitamin C
- Vitamin E
- Glutathione
- Coenzyme Q10

Oxidative Damage to Skin



Collagen Degradation

ROS activate matrix metalloproteinases (MMPs: MMP-1, MMP-3)

Lipid Peroxidation

Damage to cell membranes → inflammation (release of prostaglandins, cytokines)

DNA Damage

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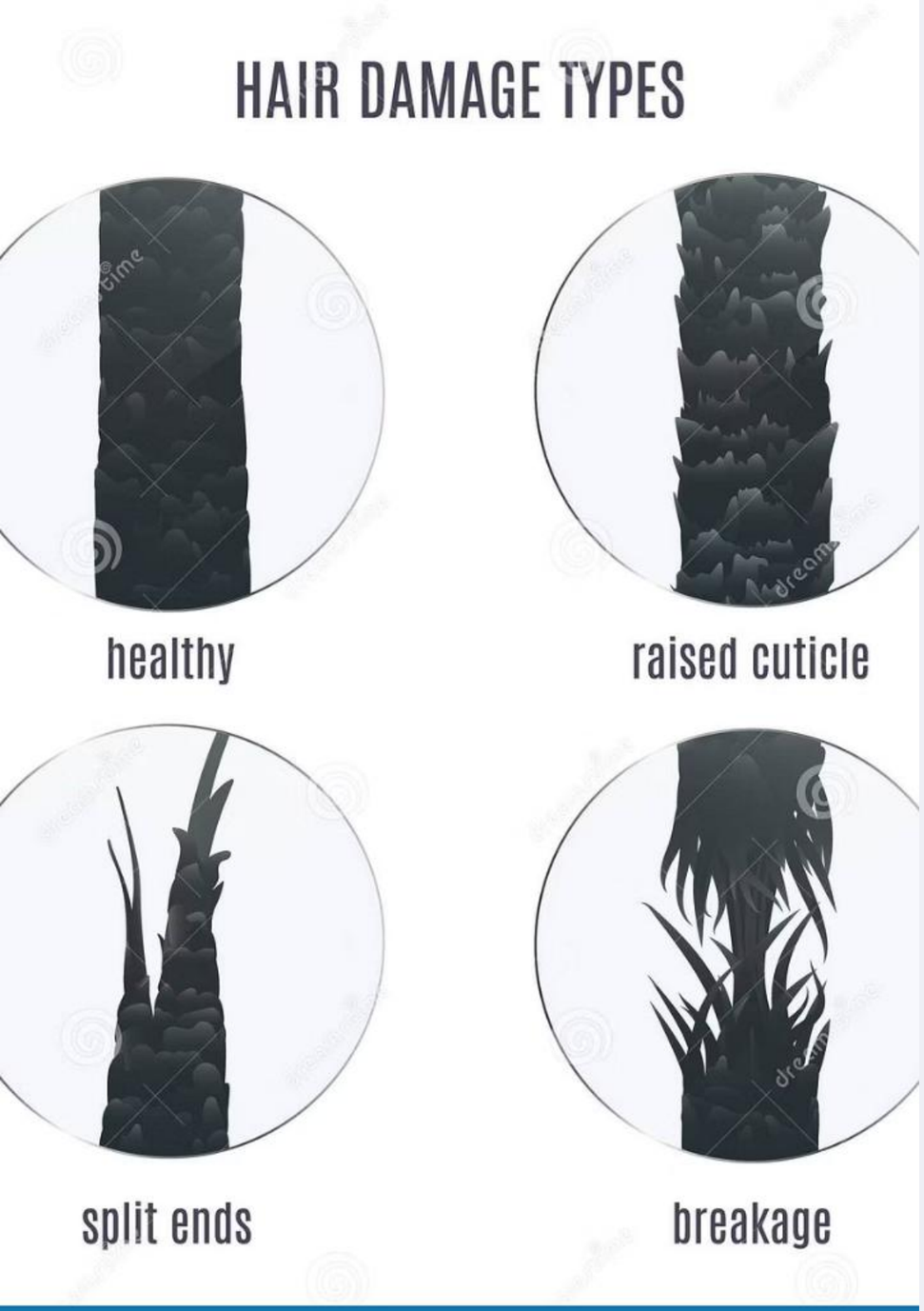
mutations, impaired repair (↓ BRCA1)



Oxidative Damage to Hair

Melanocyte Apoptosis

ROS ↑ melanocyte stem cell depletion → graying

Keratin Damage

Disulfide bond oxidation → week hair

Photoaging: UV Radiation Types

UVA (320–400 nm)

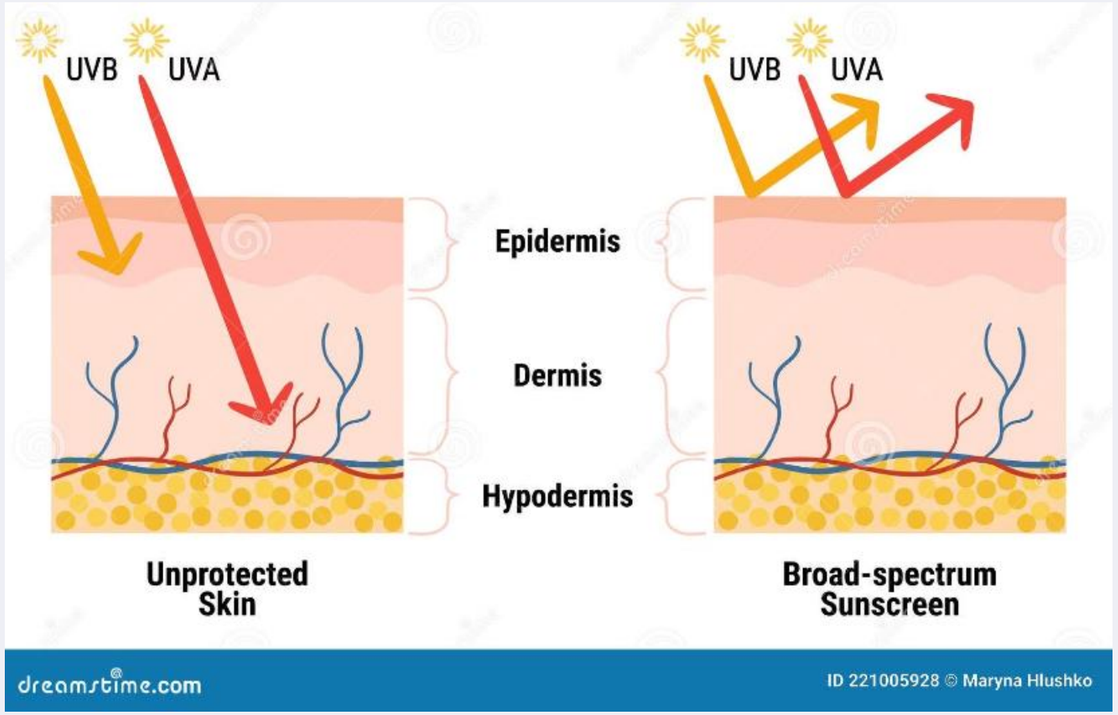
Penetrates dermis → ROS generation, lipid peroxidation

UVB (290–320 nm)

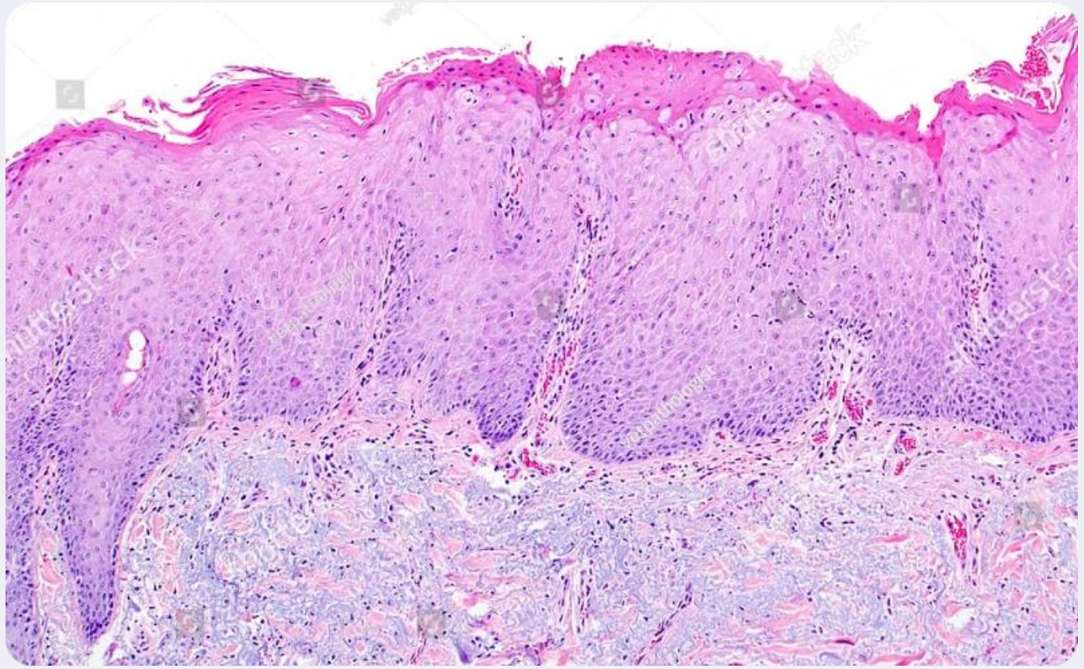
Epidermal damage → sunburn, DNA mutations

Molecular Mechanisms

DNA Damage, Melanocyte Stimulation



Clinical Features of Photoaging



Skin Changes

- Wrinkles (dynamic → static)
- Solar elastosis (yellow, thickened dermis)
- Telangiectasias (broken capillaries)
- Actinic keratosis (pre-cancerous lesions)

Hair Changes

- UV-induced melanin degradation → fading, dryness
- Cuticle damage → split ends

Photoaging vs. Intrinsic Aging

Feature	Intrinsic Aging	Photoaging
Skin Thickness	Thinning epidermis/dermis	Thickened, leathery texture
Pigmentation	Uniform pallor	Mottled dyspigmentation
Wrinkles	Fine lines	Deep, coarse wrinkles

Clinical Interventions for Oxidative Stress

Topical Antioxidants

Vitamin C (L-ascorbic acid): Boosts collagen, regenerates vitamin E

Niacinamide (vitamin B3): ↑ reduces ROS

Oral Supplements

Polyphenols (green tea)

Sun Protection

Sunscreen

Broad-spectrum (UVA/UVB) with zinc oxide/titanium dioxide

Behavioral

Avoid peak sun hours (10 AM–4 PM), hats/UV-protective clothing

Hair-Specific Therapies and Emerging Treatments

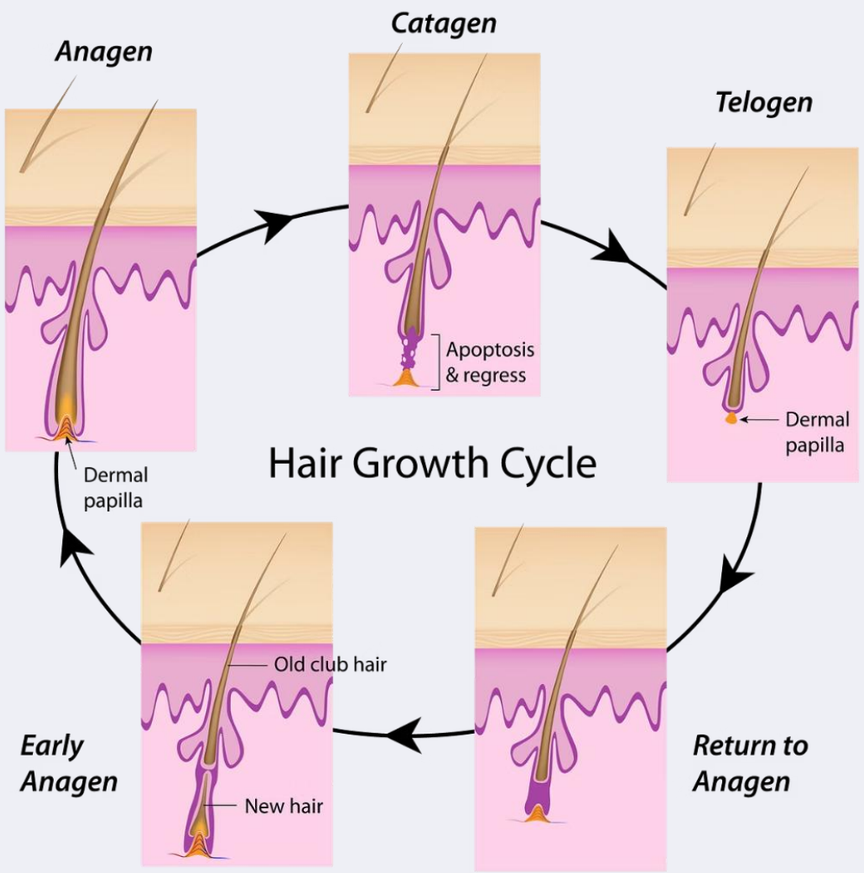
Hair-Specific Therapies

- Topical Minoxidil: ↑ Follicle blood flow
- Antioxidant Shampoos: Caffeine, rosemary oil (↓ oxidative stress)

Emerging Therapies

PRP , MESOTHERAPY , EXSOSOM

- Stem Cell Therapy: Follicle stem cell activation (experimental)



Hair Growth Cycle and Aging Effects

Anagen (2–6 years)

Aging effect: Duration shortens → hair becomes shorter and finer

Molecular drivers: Reduced Wnt/β-catenin signaling and BMP inhibition

Catagen (2–3 weeks)

Apoptosis-driven regression; accelerated by oxidative stress

Telogen (3–4 months)

Aging effect: Prolonged telogen → increased shedding (e.g., "senescent alopecia")

Key mediators: Increased TGF-β, FGF5

Clinical Management and Future Directions

Hair Thinning Therapies

First-line: Minoxidil, Finasteride, Spironolactone (women)

Advanced: Platelet-Rich Plasma (PRP), Low-Level Laser Therapy (LLLT)

Gray Hair Management

Cosmetic: Temporary dyes (ammonia-free for sensitive scalps)

Emerging: Topical antioxidants, stem cell injections, oral L-Tyrosine

Holistic Approaches

Diet: Iron, zinc, biotin, vitamin D, antioxidant-rich foods

Lifestyle: Smoking cessation, stress management

Future Directions

Stem cell therapy, JAK/STAT inhibitors, CRISPR gene editing