HOUSE OF AMAYAH / RESEARCH

HAIR MATERIALS + MECHANISMS DOSSIER

2026 EDITION / OPEN LITERATURE + TEST ARCHITECTURE

A research map of hair-fiber structure, keratin mechanics, water and humidity, cuticle tribology, 18-MEA, thermal exposure, metals and oxidative stress, textured-hair geometry, weathering, computational hair and finished-formula test design.

Purpose: turn literature into better experimental questions without turning third-party papers into unsupported product claims.

WHAT THIS DOCUMENT IS FOR

This dossier is designed as an R&D; orientation layer for House of Amayah and Crown Theory. It does not attempt to be an exhaustive textbook. It prioritizes mechanisms that can change product architecture, testing, segmentation or evidence quality.

> The core rule is simple: **a paper is not a product claim.** A paper can establish a plausible mechanism, a useful endpoint or an experimental precedent. The finished formula must still be tested.

FIVE THINGS THAT CHANGE THE RESEARCH PROGRAM

01 / HAIR IS NOT ONE UNIFORM SUBSTRATE.

Root-to-tip age, prior processing, geometry and environmental history can create materially different test conditions.

02 / WATER IS A MECHANICAL VARIABLE.

Humidity and wet state alter the fiber response, so environmental conditioning belongs inside the protocol, not in the footnotes.

03 / FRICTION IS A HIGH-VALUE BRIDGE METRIC.

It links surface chemistry to combing, tactile feel and cumulative grooming load, while remaining objectively measurable.

04 / TEXTURE IS PARTLY A GEOMETRY PROBLEM.

Curvature and torsion alter contacts and load paths. Sampling only by broad demographic group can hide the physically relevant variable.

05 / CLAIM QUALITY DEPENDS ON EVIDENCE LAYER.

Mechanism literature, ingredient tests, prototypes and final commercial formulas are different evidence classes and should stay labeled as such.

HAIR AS A MATERIAL SYSTEM

HIERARCHICAL STRUCTURE

Human hair is a keratinous composite organized from surface cuticle layers into the cortex and, in some fibers, a medulla. Mechanical response emerges across scales rather than from a single homogeneous material constant. The strongest R&D; implication is methodological: a formulation that changes surface friction may improve combing without materially changing cortical tensile strength, while a treatment that changes water uptake can alter mechanics even when microscopy looks similar.

ROOT-TO-TIP NONUNIFORMITY

Weathering, repeated grooming and environmental exposure accumulate with fiber age. A 2026 arXiv paper on mammalian hair extends the idea further by showing that structural and compositional gradients can exist along individual hairs. For product design, root, mid-length and tip should not be assumed to be equivalent test substrates.

TEST CONSEQUENCE

Segment fibers by location and prior treatment history. Pair single-fiber mechanics with surface-sensitive measurements so that a 'repair' signal can be assigned to a physical layer rather than a generic before/after impression.

SELECTED SOURCES

Hair is a functionally graded composite, not a uniform fiber
arXiv / 2026 - https://arxiv.org/abs/2607.22023

Nanomechanics of single keratin fibres
arXiv / 2007 - https://arxiv.org/abs/0706.0776

MECHANICS, WATER + HUMIDITY

HAIR IS VISCOELASTIC AND ENVIRONMENT-DEPENDENT

Tensile behavior changes with humidity, strain rate and temperature. Water plasticizes keratin-associated structures and changes the energy landscape of deformation. This means that a tensile number without controlled humidity and equilibration history is not fully interpretable.

WET-STATE FAILURE IS A SEPARATE CONDITION

Wet hair experiences altered swelling, friction and chain mobility. A useful protocol separates dry tensile, wet tensile and cyclic grooming rather than assuming one state predicts another.

RECOMMENDED CONTROLS

Condition test fibers at defined relative humidity, record diameter or cross-sectional area, use consistent gauge length and pull rate, and include repeated loading where fatigue is part of the use case.

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arXiv / 2026 - https://arxiv.org/abs/2607.22023

Nanomechanics of single keratin fibres
arXiv / 2007 - https://arxiv.org/abs/0706.0776

Structure and mechanical behavior of human hair
Journal of the Mechanical Behavior of Biomedical Materials / 2017 - https://pubmed.ncbi.nlm.nih.gov/28183593/

The shape of a ponytail and the statistical physics of hair fiber bundles
Physical Review Letters / arXiv / 2012 - https://arxiv.org/abs/1204.0371

SURFACE LIPIDS, CUTICLE + FRICTION

18-MEA AS A SURFACE VARIABLE

The outer surface of relatively unweathered hair contains covalently attached 18-methyleicosanoic acid. AFM and friction literature associate this layer with hydrophobicity and lower friction. Weathering and aggressive processing can diminish the surface state and expose a higher-friction substrate.

CONDITIONING IS DEPOSITION ENGINEERING

Conditioners can reduce friction through adsorbed materials, but immediate slip does not prove reconstruction of the original surface chemistry. Separate the question 'does the formula reduce friction?' from 'does it recreate a native-like lipid interface?'

DURABILITY MATTERS

A high-value experiment is friction across repeated shampoo cycles. If two formulas give similar first-use combing but one persists through more cycles without unacceptable buildup, that is a different product mechanism and potentially a stronger commercial claim.

SELECTED SOURCES

Understanding and controlling the friction of human hair
Colloids and Interface Science Communications / 2025 - https://pubmed.ncbi.nlm.nih.gov/40782659/

Effect of 18-MEA on hair nanotribology
Journal of Structural Biology / 2005 - https://pubmed.ncbi.nlm.nih.gov/15721577/

Biomimetic barrier recovery on damaged hair
Scientific Reports / 2024 - https://pmc.ncbi.nlm.nih.gov/articles/PMC11550837/

Prevention of lipid loss from hair
Scientific Reports / 2019 - https://www.nature.com/articles/s41598-019-46370-x

THERMAL EXPOSURE

HEAT DEPENDS ON WATER STATE

Classic bubble-hair experiments show that intense focal heating of damp hair can form internal voids and produce brittle fibers. Thermal protocols should therefore treat temperature, contact time and initial water content as coupled variables.

CUMULATIVE HEAT

Repeated straightening or curling cycles can alter cuticle condition and surface friction even when a single exposure looks visually acceptable. Laboratory programs should include realistic repeated styling, cooling and humidity re-exposure.

MEASUREMENT STACK

Combine microscopy, tensile or fatigue testing, combing force and a standardized image pipeline. Avoid using shine alone: optical appearance can change with curvature, films and lighting.

SELECTED SOURCES

Bubble hair from focal heating of damp fibers
British Journal of Dermatology / 1995 - https://pubmed.ncbi.nlm.nih.gov/7857849/

METALS, UV + OXIDATIVE STRESS

COPPER AS AN ACCELERATOR

Hair can accumulate trace metals from water. Published work reports that copper can accelerate UV-associated oxidative damage and protein-loss markers. Chelation strategies such as EDDS and histidine have been studied for reducing uptake and downstream damage in specific shampoo/conditioner systems.

INTERCEPT BEFORE REPAIR

This creates a valuable design distinction: some routines may benefit from reducing a damage amplifier before adding conditioning or reinforcing films. The commercial question is not whether chelation exists; it is whether a finished formula meaningfully reduces relevant metal load under realistic water and wash conditions.

TESTING DIRECTION

Use controlled metal-containing water, matched no-metal controls, ICP-based metal quantification where feasible, protein-loss or oxidative endpoints, and repeated wash/exposure cycles.

SELECTED SOURCES

Advanced hair damage model from UV radiation in the presence of copper
International Journal of Cosmetic Science / 2015 - https://pubmed.ncbi.nlm.nih.gov/25923177/

Role of copper in photochemical damage to hair
International Journal of Cosmetic Science / 2013 - https://pubmed.ncbi.nlm.nih.gov/23962007/

UV damage, antioxidants and metal chelators
International Journal of Cosmetic Science / 2020 - https://pubmed.ncbi.nlm.nih.gov/31955440/

TEXTURE, CURVATURE + BREAKAGE

GEOMETRY IS LOAD DISTRIBUTION

Curly and tightly curled fibers experience bending, torsion, inter-fiber contact and knotting patterns that differ from straighter fibers. Reviews caution against treating broad racial categories as a direct material cause; geometry, grooming practices and fiber-to-fiber variability are often the more actionable variables.

BUNDLE BEHAVIOR MATTERS

The ponytail literature demonstrates that a hairstyle is a many-fiber mechanical system involving bending elasticity, gravity, disorder and inter-fiber pressure. Detangling and styling products should therefore be evaluated at both single-fiber and bundle levels.

SAMPLING STRATEGY

Recruit by measurable curl/shape and treatment history, not only demographic labels. When possible, record diameter, ellipticity, curvature, breakage history and routine.

SELECTED SOURCES

Structure and mechanical behavior of human hair
Journal of the Mechanical Behavior of Biomedical Materials / 2017 - https://pubmed.ncbi.nlm.nih.gov/28183593/

Current research on ethnic hair
Journal of the American Academy of Dermatology / 2003 - https://pubmed.ncbi.nlm.nih.gov/12789163/

The what, why and how of curly hair
International Journal of Trichology / 2019 - https://pmc.ncbi.nlm.nih.gov/articles/PMC6894537/

Systems approach to human hair fibers
Frontiers in Physiology / 2019 - https://pmc.ncbi.nlm.nih.gov/articles/PMC6393780/

The shape of a ponytail and the statistical physics of hair fiber bundles
Physical Review Letters / arXiv / 2012 - https://arxiv.org/abs/1204.0371

WEATHERING + CHRONOLOGICAL FIBER AGE

THE OLDEST PART IS THE TIP

A long hair fiber may contain months or years of cumulative abrasion, washing, UV, heat and contact. Root and tip can behave like different test materials even on the same individual.

IMPLICATION FOR 'REPAIR'

If a product acts mainly on highly weathered tips, averaging the full fiber can dilute the effect. Segment-level analysis can reveal where a mechanism is active.

DESIGN OPPORTUNITY

Build products and instructions around fiber age zones: scalp/root environment, mid-length maintenance and high-damage ends. This is more physically legible than assuming every centimeter has identical needs.

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Understanding and controlling the friction of human hair
Colloids and Interface Science Communications / 2025 - https://pubmed.ncbi.nlm.nih.gov/40782659/

Effect of 18-MEA on hair nanotribology
Journal of Structural Biology / 2005 - https://pubmed.ncbi.nlm.nih.gov/15721577/

Biomimetic barrier recovery on damaged hair
Scientific Reports / 2024 - https://pmc.ncbi.nlm.nih.gov/articles/PMC11550837/

Prevention of lipid loss from hair
Scientific Reports / 2019 - https://www.nature.com/articles/s41598-019-46370-x

Chronological ageing of human hair keratin fibres
International Journal of Cosmetic Science / 2010 - https://pubmed.ncbi.nlm.nih.gov/20384898/

DIGITAL HAIR + COMPUTATIONAL PHENOTYPING

HAIR IS BECOMING MACHINE-READABLE

Recent arXiv work reconstructs detailed hair strands from 3D scans or images and models appearance under changing illumination. These systems are built for graphics, but the representations are relevant to future measurement: curvature, strand orientation, density, bundle topology and visible surface response can become structured variables.

IMAGING MUST SEPARATE MATERIAL FROM LIGHTING

Relightable hair models highlight a key problem in consumer testing: perceived gloss, frizz and definition are confounded by illumination. A standardized imaging rig or computational relighting can make visual endpoints more reproducible.

NEAR-TERM USE

Use consistent pose, distance, focal length, light geometry and background. Capture multiple angles and save raw images. Do not let a single hero photo substitute for physical measurement.

SELECTED SOURCES

GeomHair: Reconstruction of hair strands from colorless 3D scans
arXiv / 2025 - https://arxiv.org/abs/2505.05376

GaussianHair: hair modeling and rendering with light-aware Gaussians
arXiv / 2024 - https://arxiv.org/abs/2402.10483

GroomLight: relightable human hair appearance modeling
arXiv / 2025 - https://arxiv.org/abs/2503.10597

Strand-based hairstyle generation via large reconstruction and multimodal models
arXiv / 2026 - https://arxiv.org/abs/2608.13679

FROM PAPER TO FORMULA

EVIDENCE LAYERS

House of Amayah should distinguish at least four layers: mechanism in literature, ingredient-level evidence, prototype-formula evidence and finished-formula evidence. Claims should not jump layers.

PREDEFINE A KILL CONDITION

Before a test, write the result that would cause the formulation hypothesis to be rejected. A research program without a kill condition can become a sequence of post-hoc narratives.

NULL RESULTS ARE ASSETS

A well-designed negative result narrows the search space. Internally preserving null results reduces repeated work and can expose when an attractive mechanism fails under realistic formulation constraints.

RECOMMENDED TEST MATRIX

SURFACE

Dry and wet friction, combing force, contact angle, AFM or high-resolution microscopy when accessible, deposition persistence after washing.

MECHANICAL

Single-fiber tensile, break stress, strain to failure, cyclic fatigue, breakage count under standardized grooming.

CHEMICAL / EXPOSURE

Metal uptake, protein loss, selected spectroscopy, color shift, oxidative markers where scientifically justified.

CONSUMER TRANSLATION

Blind sensory panels, detangling time, routine adherence, styling compatibility and failure-mode logging. Consumer outcomes should be paired with at least one objective endpoint for mechanistic claims.

FRONTIER QUESTIONS WORTH TESTING

SPATIALLY TARGETED CARE

Can a system deliver different deposition or reinforcement to weathered tips versus relatively intact roots without over-coating the full fiber?

GEOMETRY-AWARE CONDITIONING

Can curl geometry and bundle topology predict which conditioning architecture minimizes grooming force without collapsing desired shape?

WATER-QUALITY PERSONALIZATION

Can measured local water chemistry improve selection or frequency of chelation-oriented cleansing compared with a one-size-fits-all routine?

DIGITAL TWIN OF THE ROUTINE

Can image-derived geometry plus structured routine history forecast breakage or reversion risk well enough to change product sequencing?

PERSISTENCE AS A PRODUCT MOAT

Can durable but removable deposition create multi-wash performance without unacceptable buildup, and can that persistence be quantified as a primary endpoint?

CLAIM DISCIPLINE

WHAT THE LITERATURE CAN SAY

The literature can establish that mechanisms exist and that certain measurement endpoints are meaningful.

WHAT ONLY FINISHED-FORMULA DATA CAN SAY

Performance of a commercial product, magnitude of benefit, durability, tolerability and superiority versus another finished system require testing of the actual formula and use protocol.

BOUNDARY

This dossier is a research map, not medical advice, a disease-treatment claim or proof that any House of Amayah product produces the effects described in third-party studies.

APPENDIX A

EXAMPLE FINISHED-FORMULA TEST MATRIX

The matrix below is intentionally method-oriented. Exact protocols require qualified scientific review, validated equipment and predefined statistical plans.

Question	Primary endpoint	Secondary endpoint	Critical controls
Does a cleanser reduce exogenous metal load?	Metal concentration before/after	Protein loss after UV challenge	Water metal level, virgin/processed hair, wash count
Does a conditioner reduce grooming friction?	Wet + dry combing force	Fiber-fiber friction, sensory slip	Hair geometry, damage state, dose, rinse time
Does a treatment improve breakage resistance?	Break count / cyclic fatigue	Tensile stress-strain	Humidity, gauge length, fiber diameter, prior heat
Does a surface treatment persist?	Performance after wash cycles	Contact angle / deposition imaging	Standard shampoo, wash mechanics, time between cycles
Does a heat-protective system help?	Post-cycle breakage / friction	Microscopy + tensile	Temperature, dwell time, water state, repeated cycles

APPENDIX B

THE EVIDENCE LADDER

L0 / Mechanism exists

Independent literature establishes a physical, chemical or biological mechanism.

L1 / Ingredient signal

A specific ingredient or material demonstrates an effect in a relevant model.

L2 / Prototype signal

A development formula produces the target endpoint under controlled testing.

L3 / Finished formula

The commercial or near-commercial formula reproduces the effect at intended use levels.

L4 / Use durability

The effect survives realistic washing, heat, humidity, layering or routine conditions.

L5 / Consumer translation

The objective endpoint corresponds to a meaningful improvement in blinded or structured user testing.

> A strong claim should identify which rung supports it. The most common failure is silently jumping from L0 or L1 directly to a consumer-facing L5 statement.

APPENDIX C

SOURCE INDEX

Primary-source links used in the website research library. Source selection favors papers that alter a mechanism, measurement strategy or research direction. It is not exhaustive.

01. **Hair is a functionally graded composite, not a uniform fiber** - arXiv / 2026
https://arxiv.org/abs/2607.22023

02. **Nanomechanics of single keratin fibres** - arXiv / 2007
https://arxiv.org/abs/0706.0776

03. **Structure and mechanical behavior of human hair** - Journal of the Mechanical Behavior of Biomedical Materials / 2017
https://pubmed.ncbi.nlm.nih.gov/28183593/

04. **Current research on ethnic hair** - Journal of the American Academy of Dermatology / 2003
https://pubmed.ncbi.nlm.nih.gov/12789163/

05. **The what, why and how of curly hair** - International Journal of Trichology / 2019
https://pmc.ncbi.nlm.nih.gov/articles/PMC6894537/

06. **Systems approach to human hair fibers** - Frontiers in Physiology / 2019
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07. **Understanding and controlling the friction of human hair** - Colloids and Interface Science Communications / 2025
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08. **Effect of 18-MEA on hair nanotribology** - Journal of Structural Biology / 2005
https://pubmed.ncbi.nlm.nih.gov/15721577/

09. **Biomimetic barrier recovery on damaged hair** - Scientific Reports / 2024
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10. **Prevention of lipid loss from hair** - Scientific Reports / 2019
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18. **GroomLight: relightable human hair appearance modeling** - arXiv / 2025
https://arxiv.org/abs/2503.10597

19. **Strand-based hairstyle generation via large reconstruction and multimodal models** - arXiv / 2026
https://arxiv.org/abs/2608.13679

20. **The shape of a ponytail and the statistical physics of hair fiber bundles** - Physical Review Letters / arXiv / 2012
https://arxiv.org/abs/1204.0371

APPENDIX D

OPEN R&D CAPTURE TEMPLATE

Use this before adding a new mechanism to the roadmap.

OBSERVATION

What repeated behavior, failure mode or measurement triggered the question?

MECHANISM

What physical or chemical mechanism could plausibly generate it?

PRIOR ART

What has already been demonstrated, and on which substrate?

NOVELTY GAP

What important combination, boundary condition or application has not been adequately tested?

EXPERIMENT

What is the smallest decisive test?

PRIMARY ENDPOINT

What number or observable changes if the mechanism is real?

KILL CONDITION

What result causes the idea to be rejected or materially revised?

COMMERCIAL BRIDGE

If it works, what product architecture, routine or market behavior changes?

CLAIM BOUNDARY

What would still remain unsupported even after a positive result?

READ THIS BEFORE USING THE DOSSIER

This document is an independent synthesis for research planning. It is not medical advice, does not diagnose or treat hair or scalp disorders, and does not demonstrate efficacy of any House of Amayah or Crown Theory product. Third-party names and source marks are used for attribution only; no affiliation or endorsement is implied.

Where the website links to arXiv, PubMed, PMC, Nature or other publishers, readers should inspect the original paper, methods, population, substrate and limitations before operationalizing a conclusion.

> The most valuable use of the dossier is not to repeat its conclusions. It is to turn each section into a sharper experiment.