Frottement directionnel du cheveu : perception et frisure

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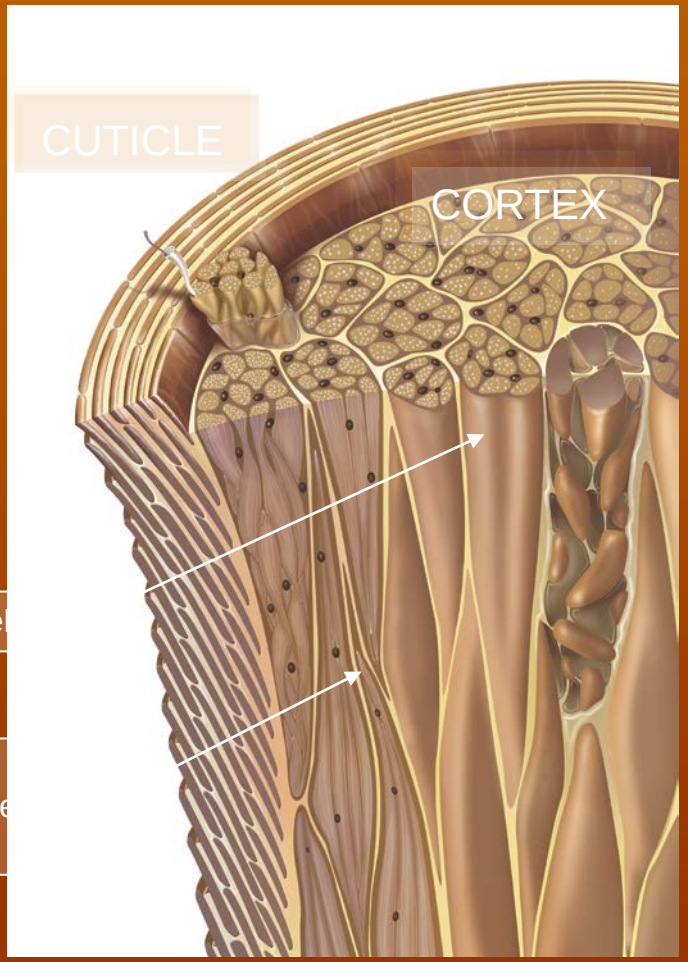
Hair, a bio-composite

From the molecule to the cell:

5 levels of organisation.

- CORTEX
  - Protein alfa hélix
  - Cell membrane complex (lipids
- CUTICLE
  - Exocuticule
  - Endocuticule
  - Cuticle membrane complex (lipids)

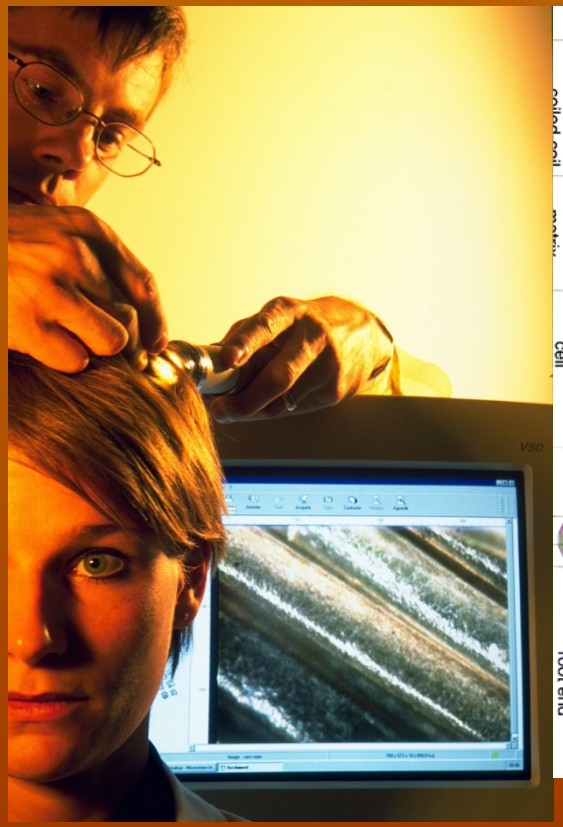


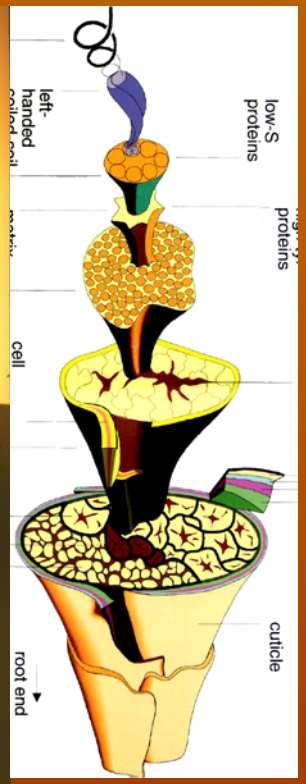
From Feughelman

Hair. A keratin nanocomposite extruded from the skin follicle

- FIRM
- FLEXIBLE
- SOFT, SILKY FEEL
- EASY TO COMB
- MANAGEABLE
- SHINY…

BUT





T. Bornschlögl, L. Bildstein, S. Thibaut · R. Santoprete · F. Fiat · G.S. Luengo · J.Doucet · B. A. Bernard · N. Baghdadli, PNAS, 113, 5940–5945 (2016)

PNAS

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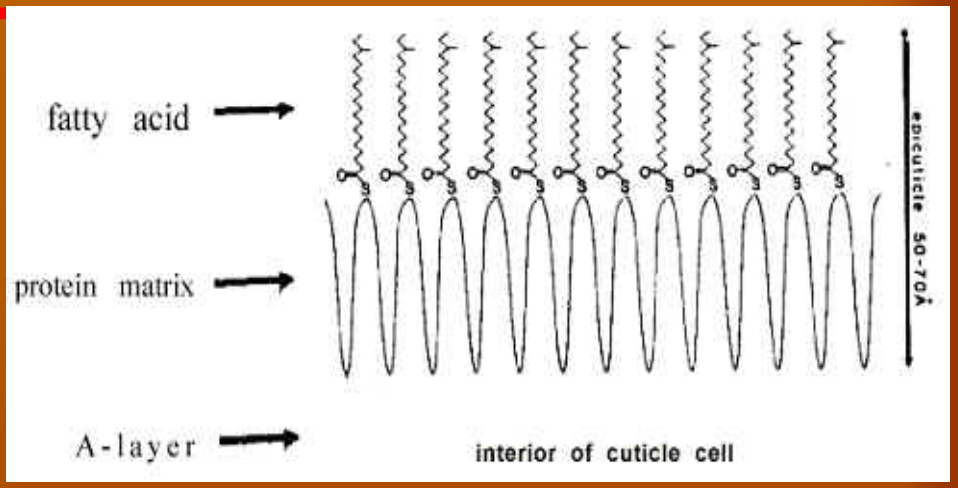
Hair surface structure



Monolayer of 18-methyleicosanoic acid
- Hydrophobicity

Ante-iso branched
- Disrupts packing: low friction

Thio-ester linkage to proteins
- Very sensitive to oxidation

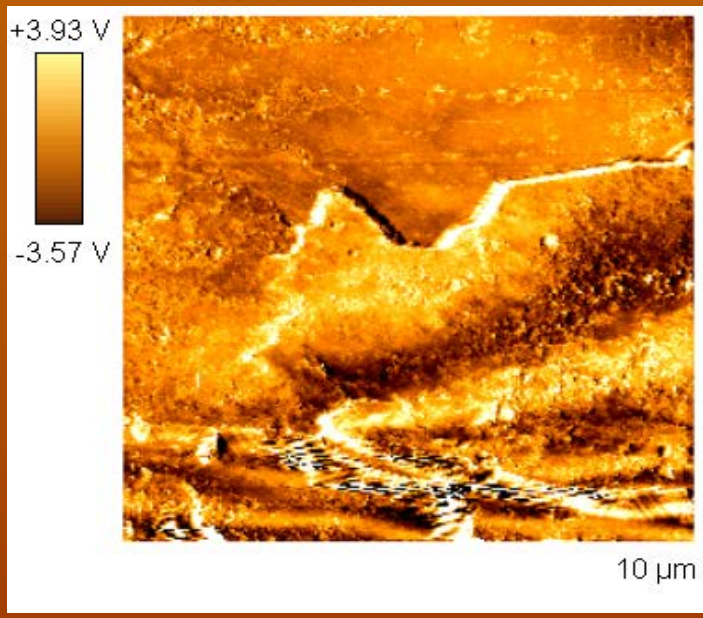
Luengo et al. Macromolecules (1997)
Luengo et al. in Applied Scanning Probe Methods (2004)
Breakspear et al. J. Struc. Biol. (2004)

Loss of Surface Lipids

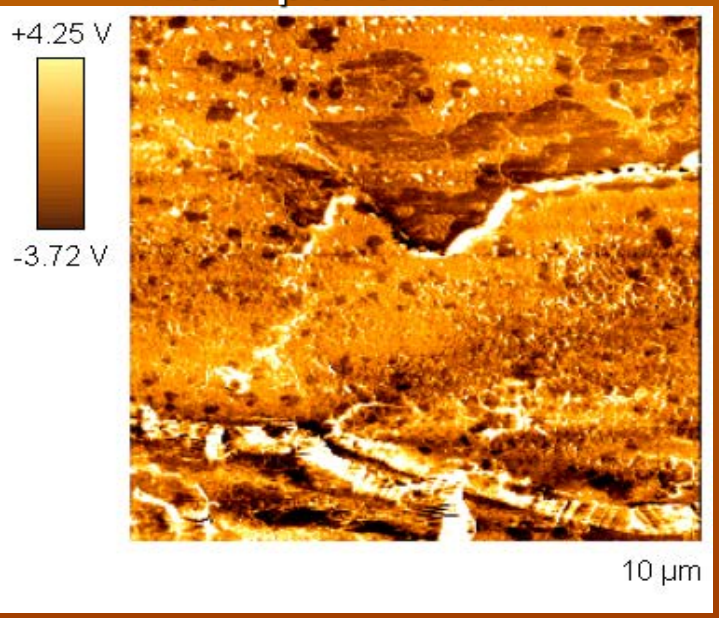
G.S. Luengo, P. Hallegot and F. Leroy, *IFSCC Magazine,* **8**, 269-276, (2005)

S. Breakspear, J. R. Smith* and G. Luengo *, *J. Struct Biol.* **149**, 235-242 (2005)

Natural hair



After lipid removal

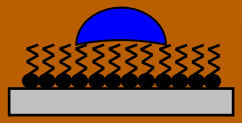


- Friction contrast suggests inhomogeneous covering of hair
- Friction not related to topography
- soft, shiny hair, easy to comb

- Increased mean friction
- Increased heterogeneity
- rough hair, difficult to comb

Surface of Hair

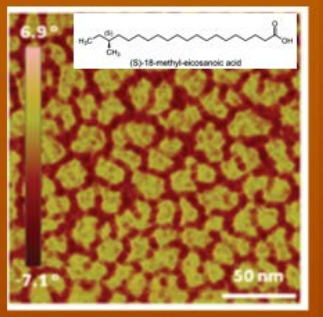
Local surface Energy, wetting



V. Dupres, D. Langevin*, P. Guenoun, A. Checco, **G. Luengo*** and F. Leroy, *J. Coll. Inter. Sci*. 306, 34-40 (2007)

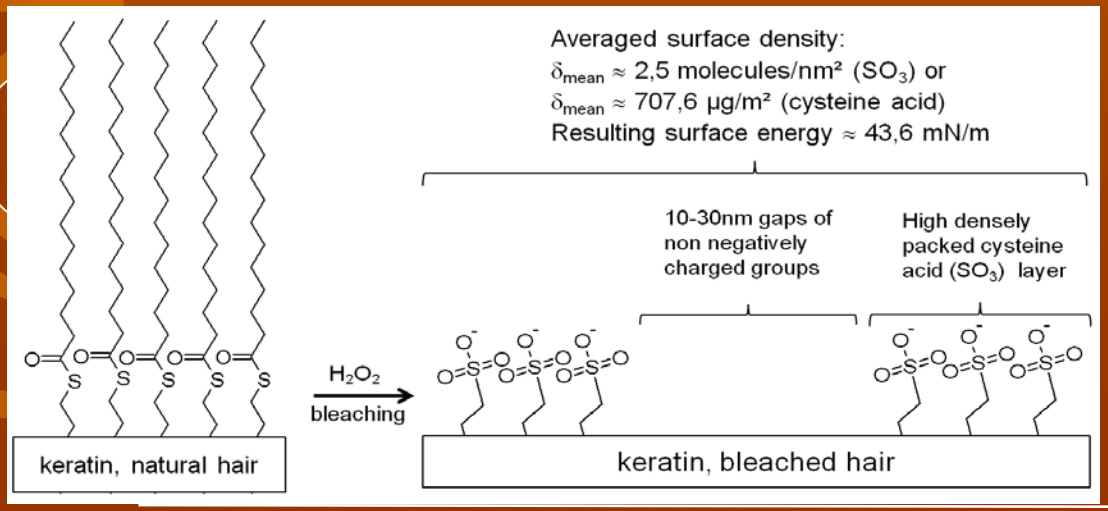
The role of surface llpids on adsorption and tribology

S. Breakspear, J. R. Smith* and G. Luengo *, *J. Struct Biol.* **149**, 235-242 (2005)



Self-assembly of long chain fatty acids

M. Korte, S. Akari, H. Kühn, N. Baghdadli, H. Möhwald and G.S. Luengo *Langmuir* **30,** 12124 (2014)



Determination de densité de SO_3^-

M. Korte, S. Akari, H. Kühn, N. Baghdadli, H. Möhwald and G.S. Luengo *Langmuir* **30,** 12124 (2014)

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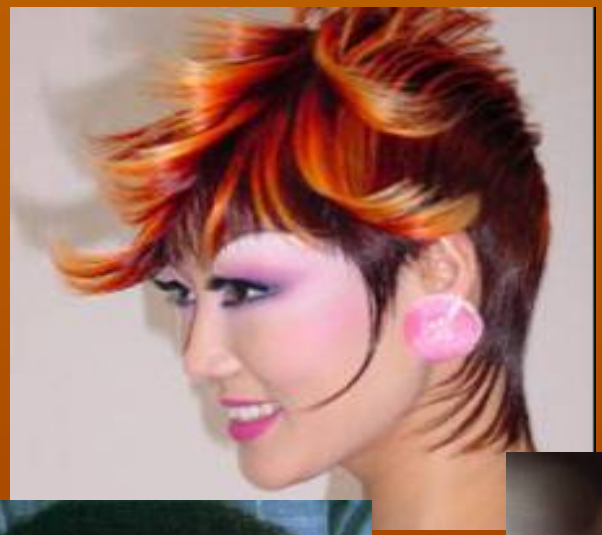
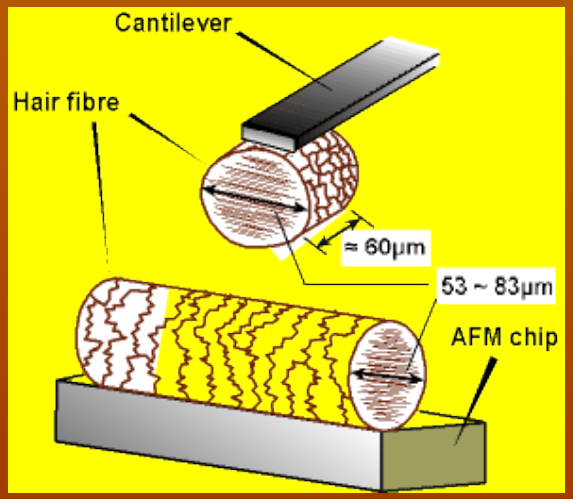
Hair Styling and Fiber Dynamics

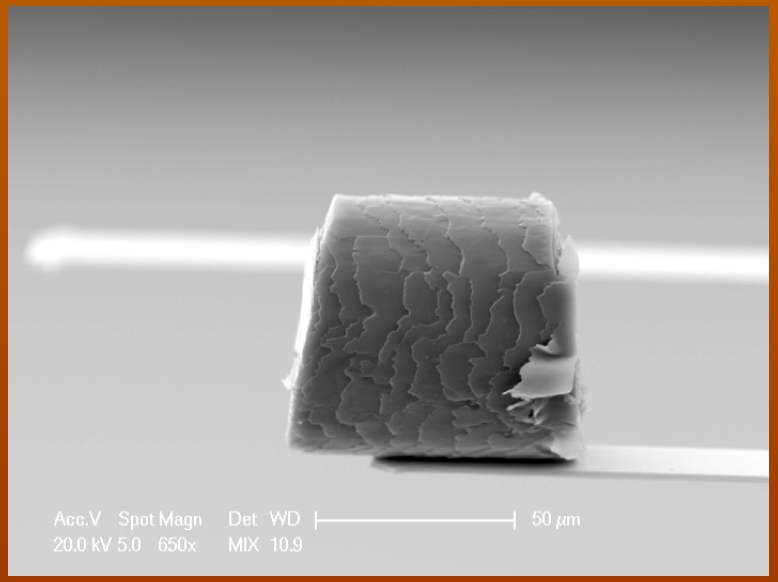
- Contact and Non Contact Forces
  - Electrostatic
  - Van der Waals
  - Capillary
  - Hydrophobic
  - Steric
  - Adhesion and Friction



From fiber tribology to hair shape

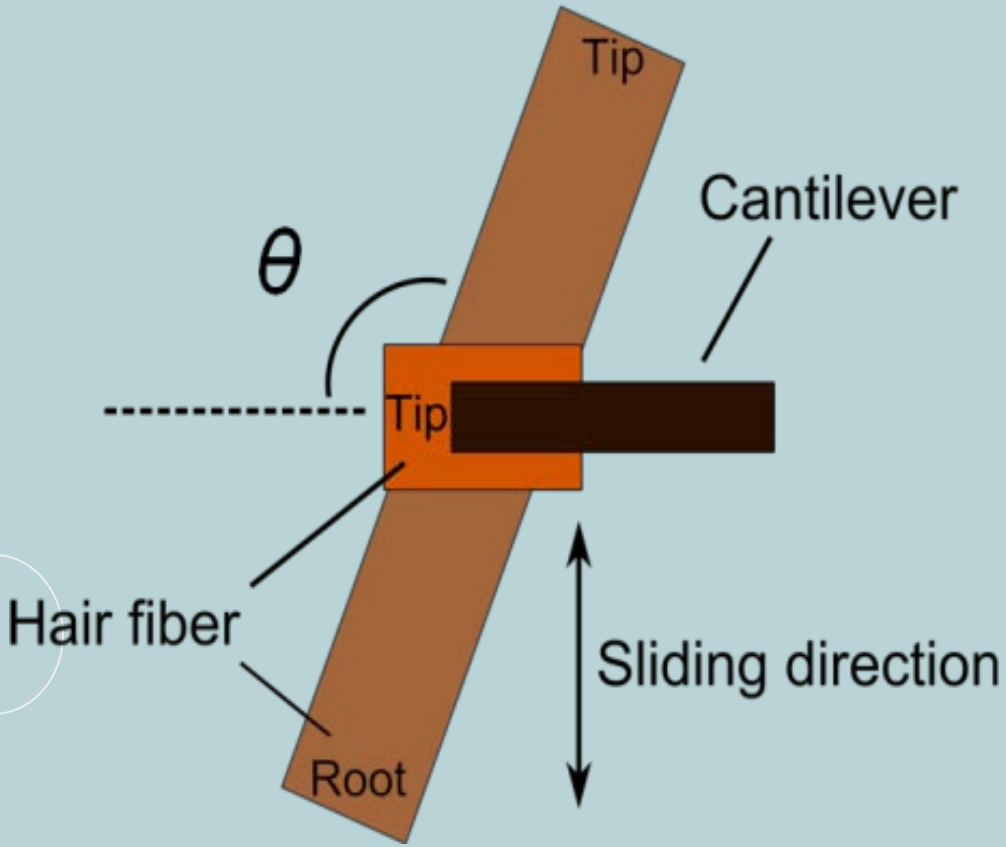
H. Mizuno, G. Luengo et M. Rutland. *Langmuir* **26**, 18909-18915 (2010





(Galliano et al.)

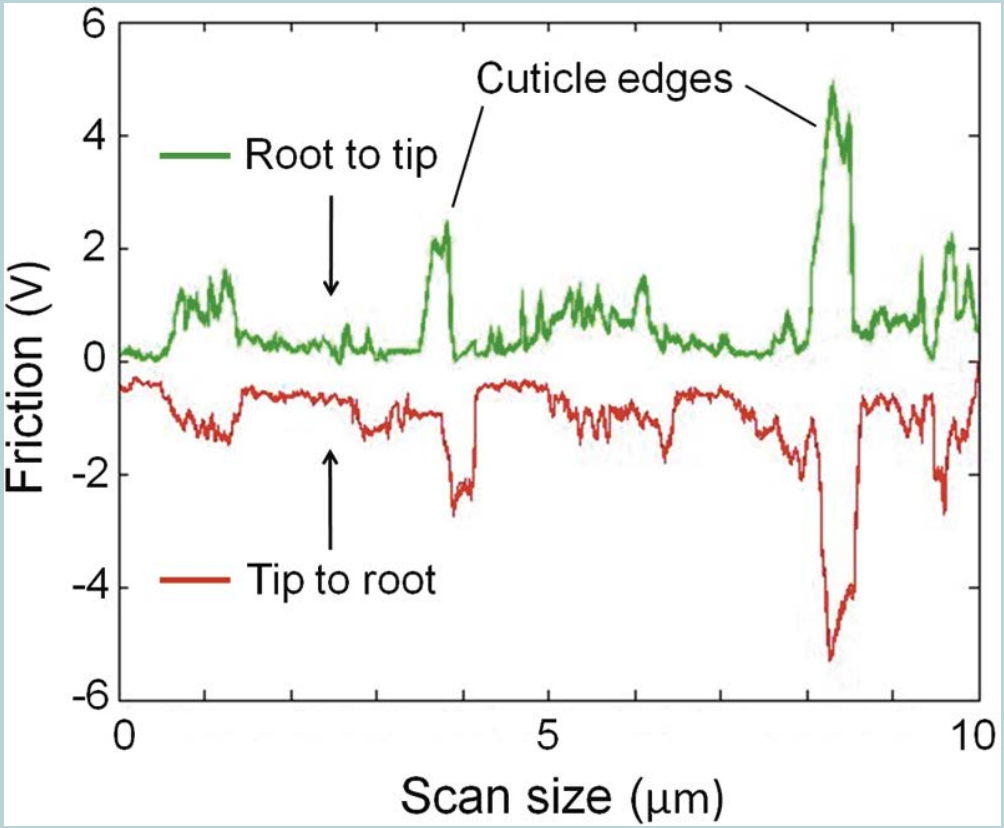
Friction experiments



Sliding velocity 10µm/s
Scan Size 5µm
Load up to 200nN
70% RH

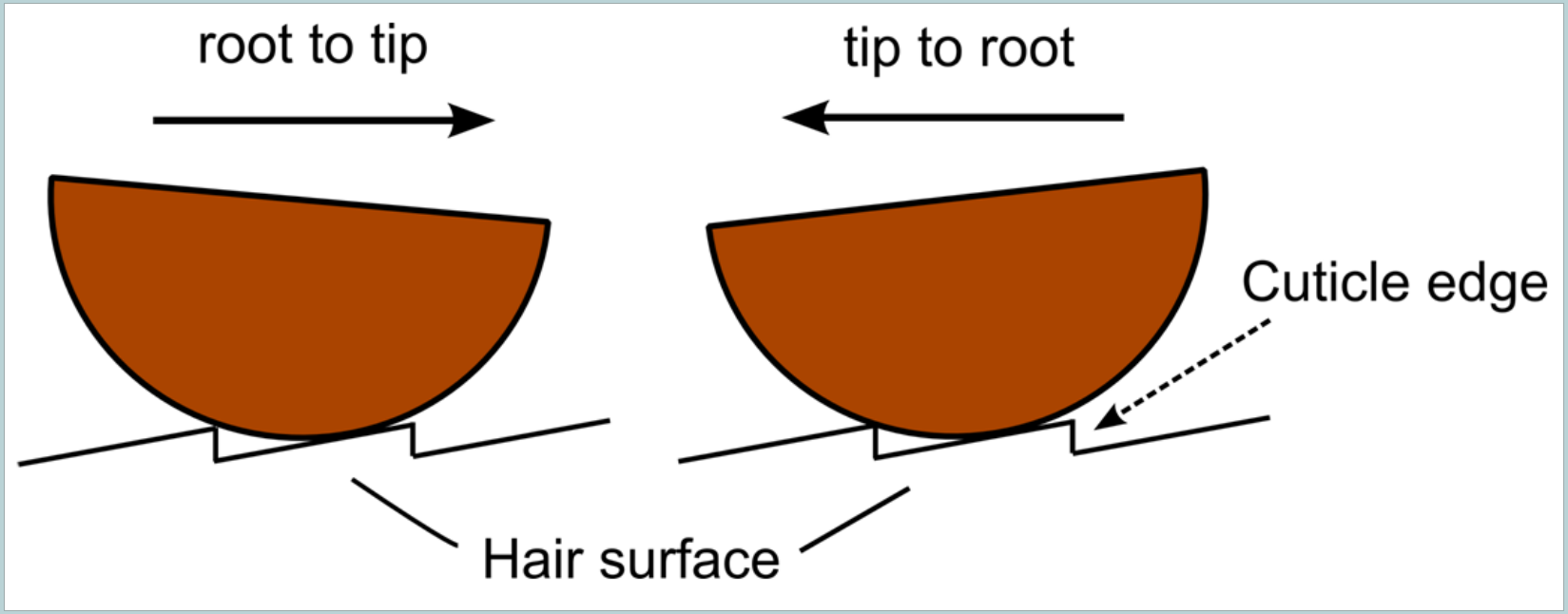
Lower hair can rotate
Sliding direction fixed

Directional effects of friction??

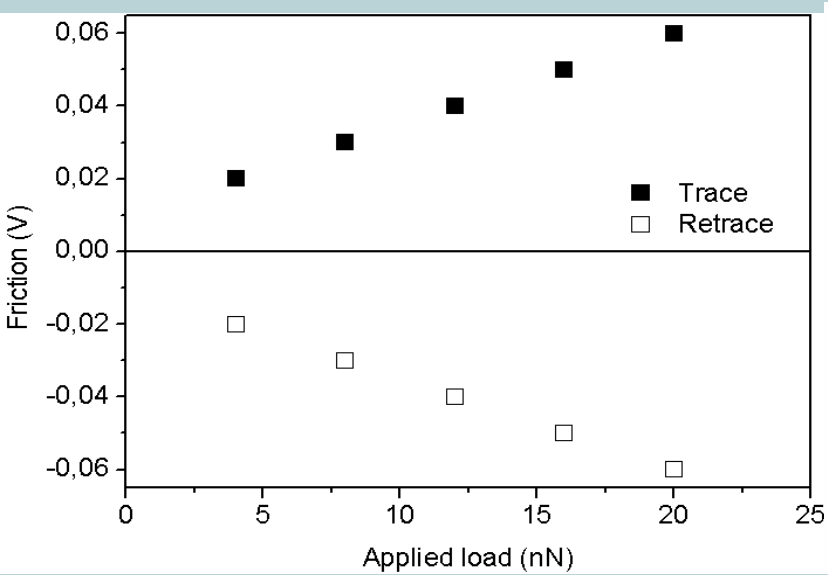


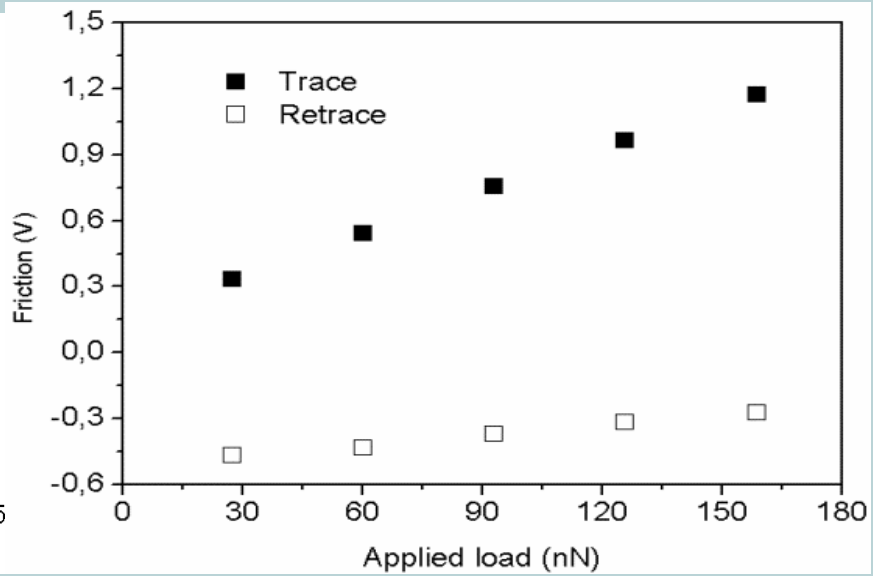
- Roll effect due as one scale slides over an edge of cuticle
- No directional effect in this cross cylinder geometry (compared with a finger or anti-parallel fiber)

Probe Sliding



Probe misalignment effect





Well behaved system

Hair fibre probe

Both arms have positive gradient – physically impossible???!!!!!

Position of the hair fiber is not fully cylindrical/central

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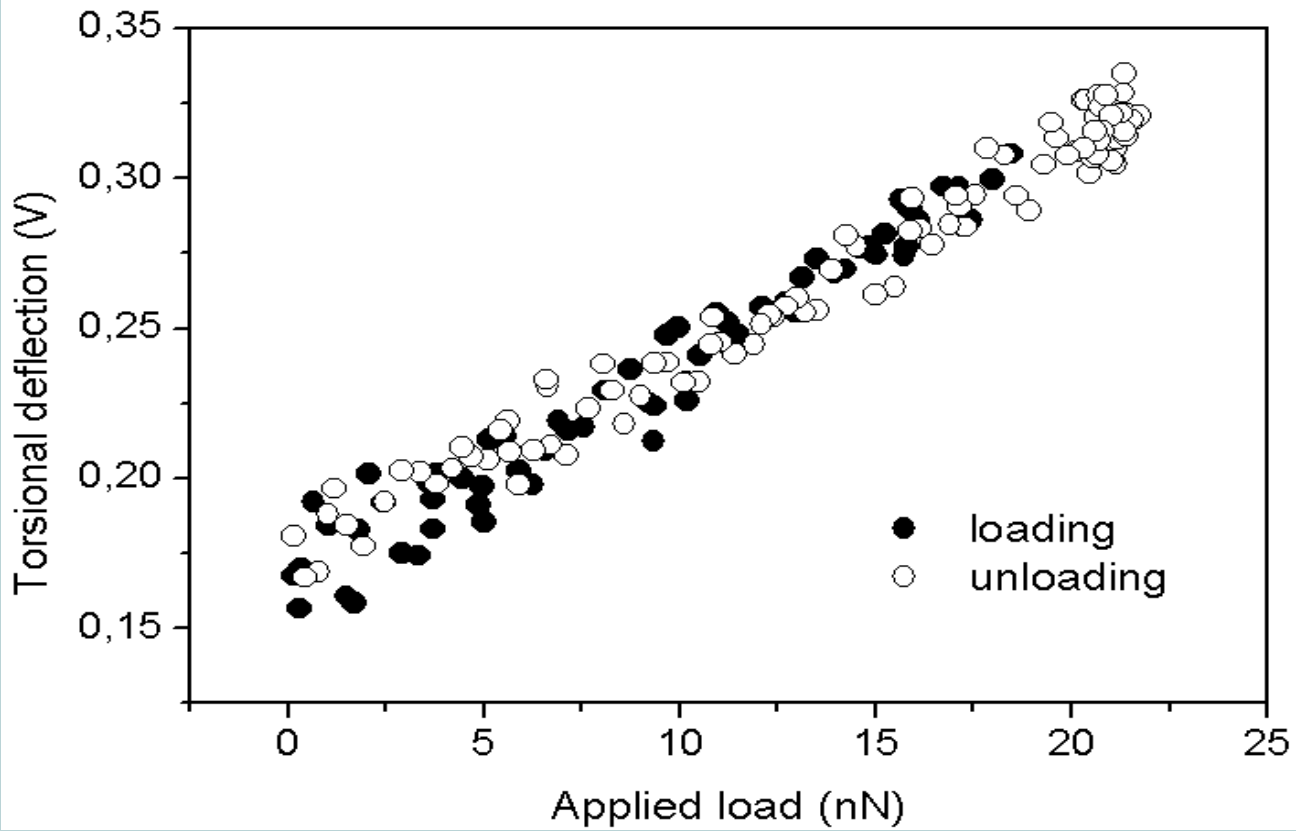
Twist deflection Offset



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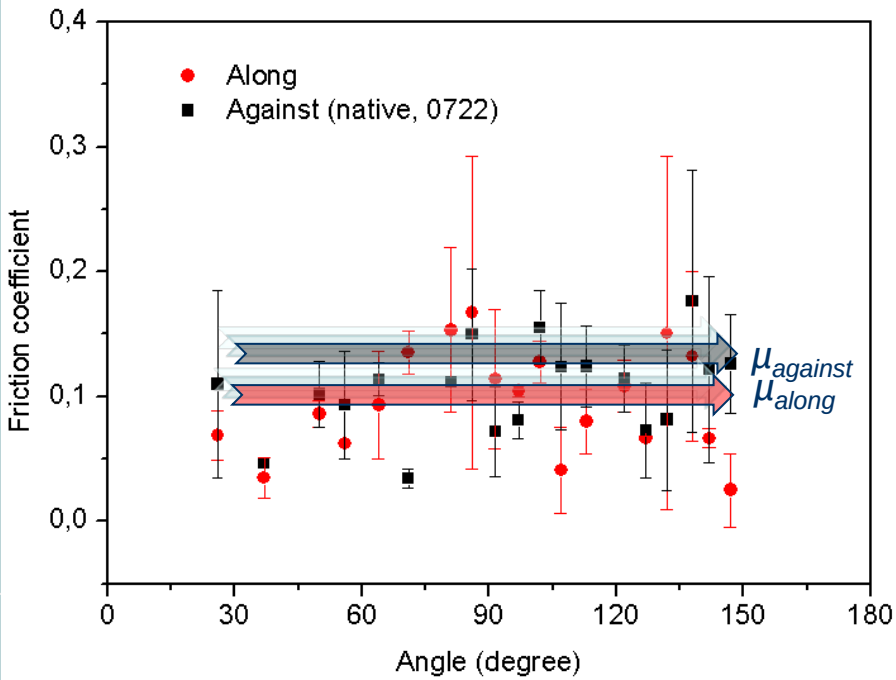
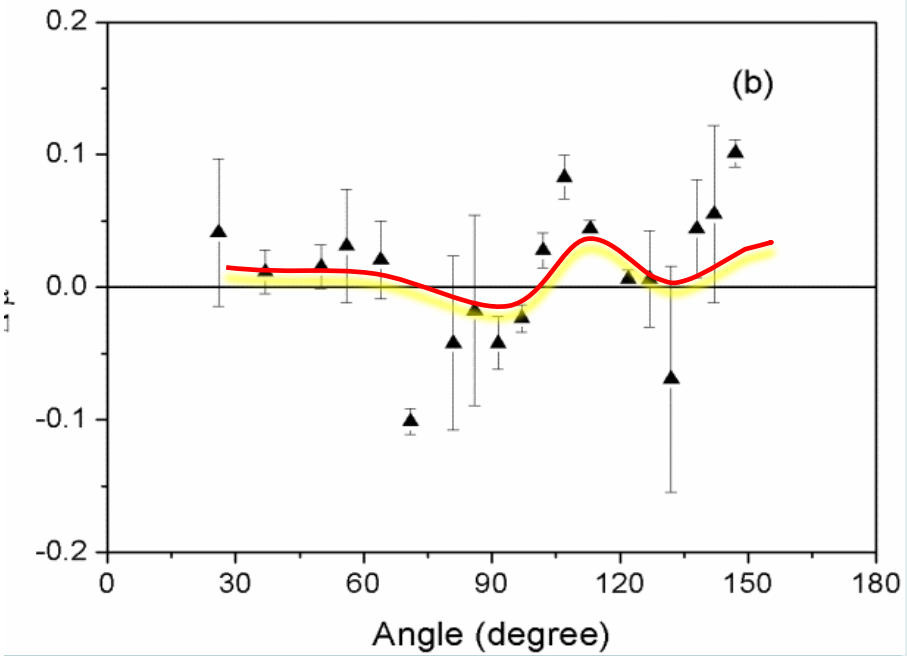
Directional effects - Native hair

H. Mizuno, G.S. Luengo, M. W. Rutland, *Langmuir,* **29,** 5857 (2013)





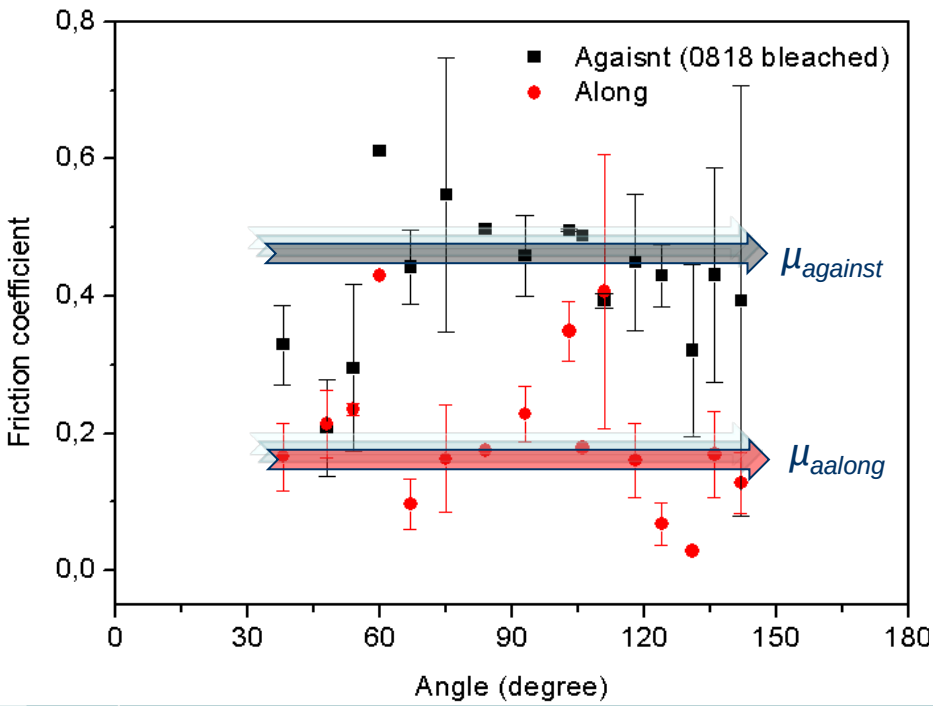
$\mu_{against} \geq \mu_{along}$

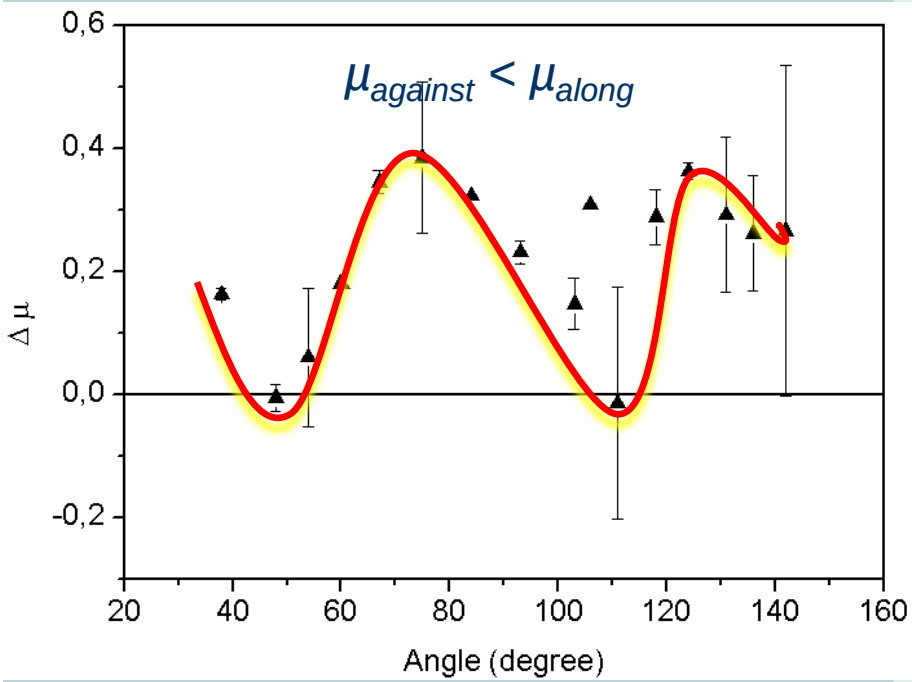
Negligible angular dependence

Interlocking events are rare due to small ratio cuticle step/radious

Directional effects. Bleached hair

H. Mizuno, G.S. Luengo, M. W. Rutland, *Langmuir,* **29,** 5857 (2013)



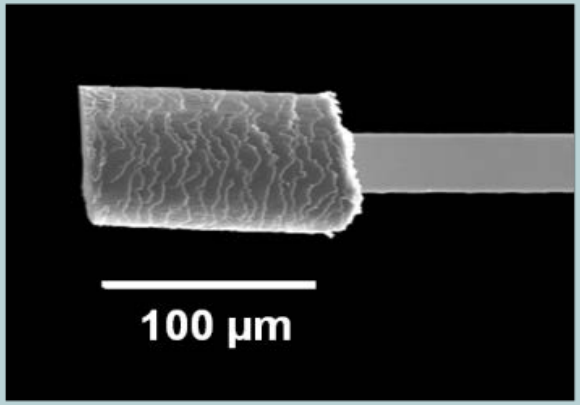


$\mu_{against} > \mu_{along}$

Strong angular dependence

a) Presence of lifted ragged cuticles
b) Probability of antiparallel cuticle-cuticle contact

Interlocking Probability



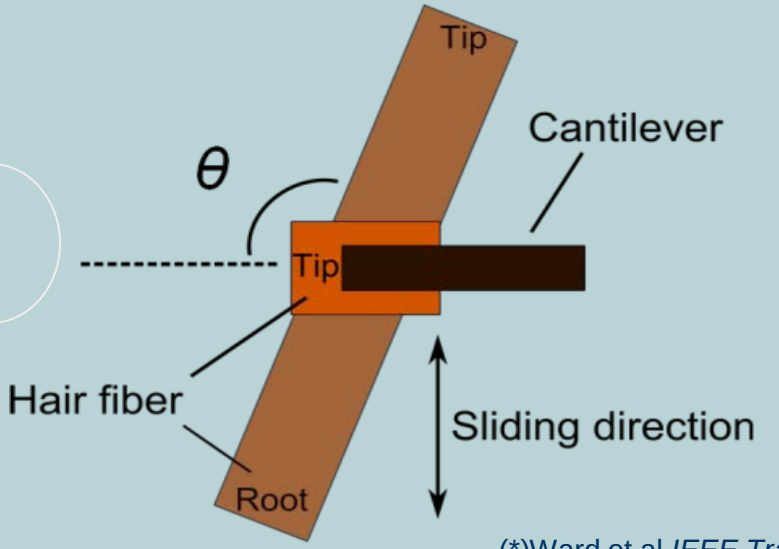
Number of Cuticles visited along the scan length D_0

Effective length of the interacting cuticle at a specific angle

$$P = N_{lower} \bullet L_{eff} =$$

$$[D_0 \bullet \sin(\theta) \bullet Ro] \bullet [L_0 \bullet \cos(\theta)]$$

$$P = C \bullet \sin(2\theta)$$



Highest probability at 45° and 135°
Lowest at 90°

Our results shows a more complex behavior i(max 70, 130° ; min 100°) induced by hair damage

(*)Ward et al.*IEEE Transactions on Visulaization and Computer Graphics* **2007,** *13*, 213

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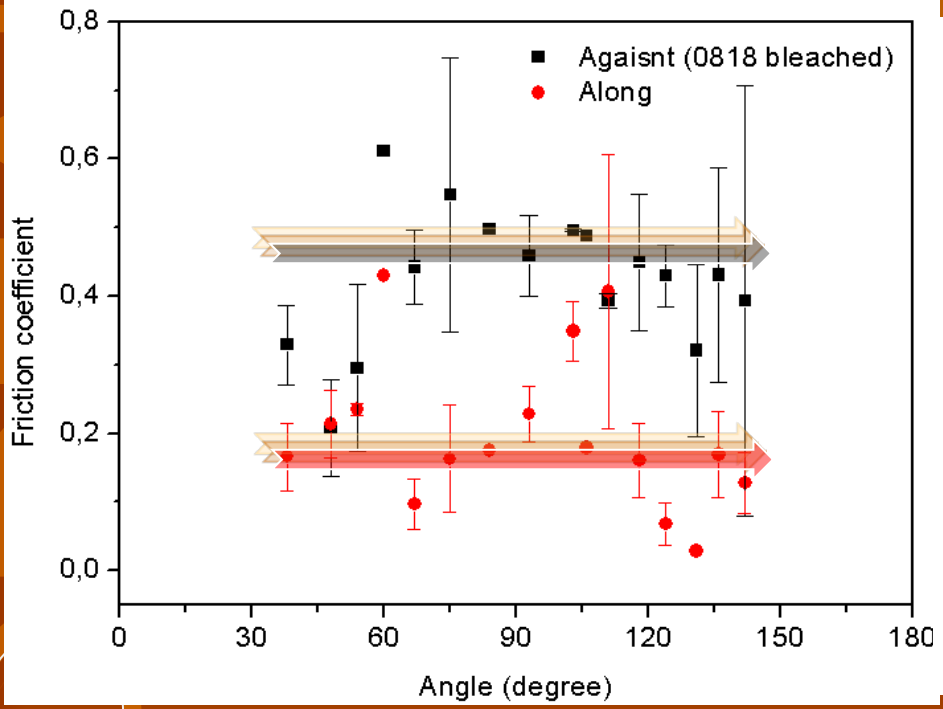
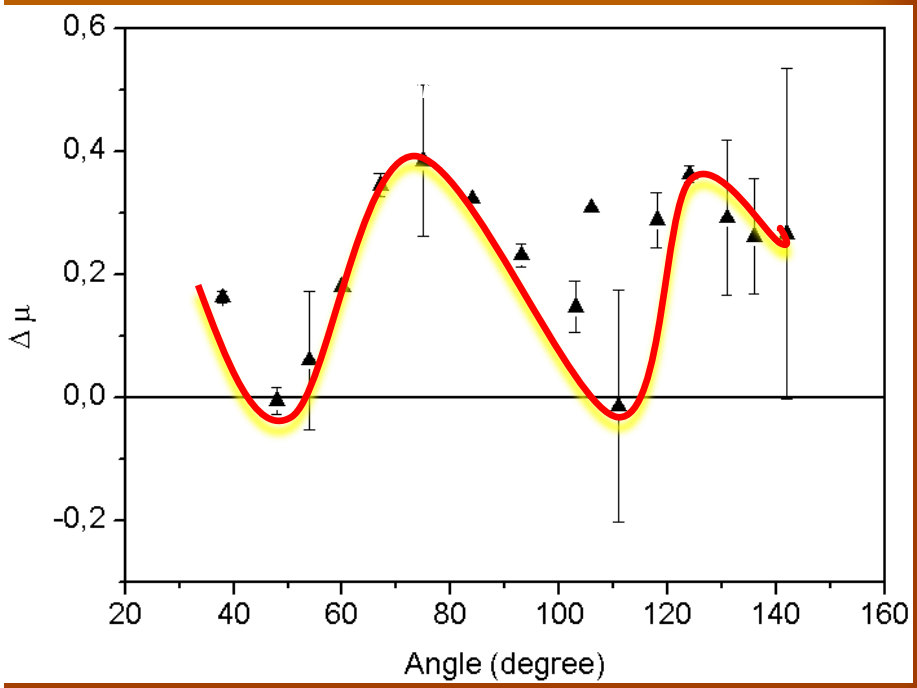
Directional effects. Bleached hair

H. Mizuno, G.S. Luengo, M. W. Rutland, *Langmuir,* **29,** 5857 (2013)





Strong angular dependence

$\mu_{against} > \mu_{along}$

a) Presence of lifted ragged cuticles
b) Probability of antiparallel cuticle-cuticle contact

KTH VETENSKAP OCH KONST

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HAIR SENSORY: Moment of truth

Wet Sensory

Combing sensory

Final Result

Dry sensory

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Psychotribology of hair . Environmental aspects

Lisa Skedung, Kathryn Harris, Elizabeth S. Collier & Mark W. Rutland (RISE)
Mara Applebaum, Andrew Greaves & Gustavo S. Luengo (L'Oréal)

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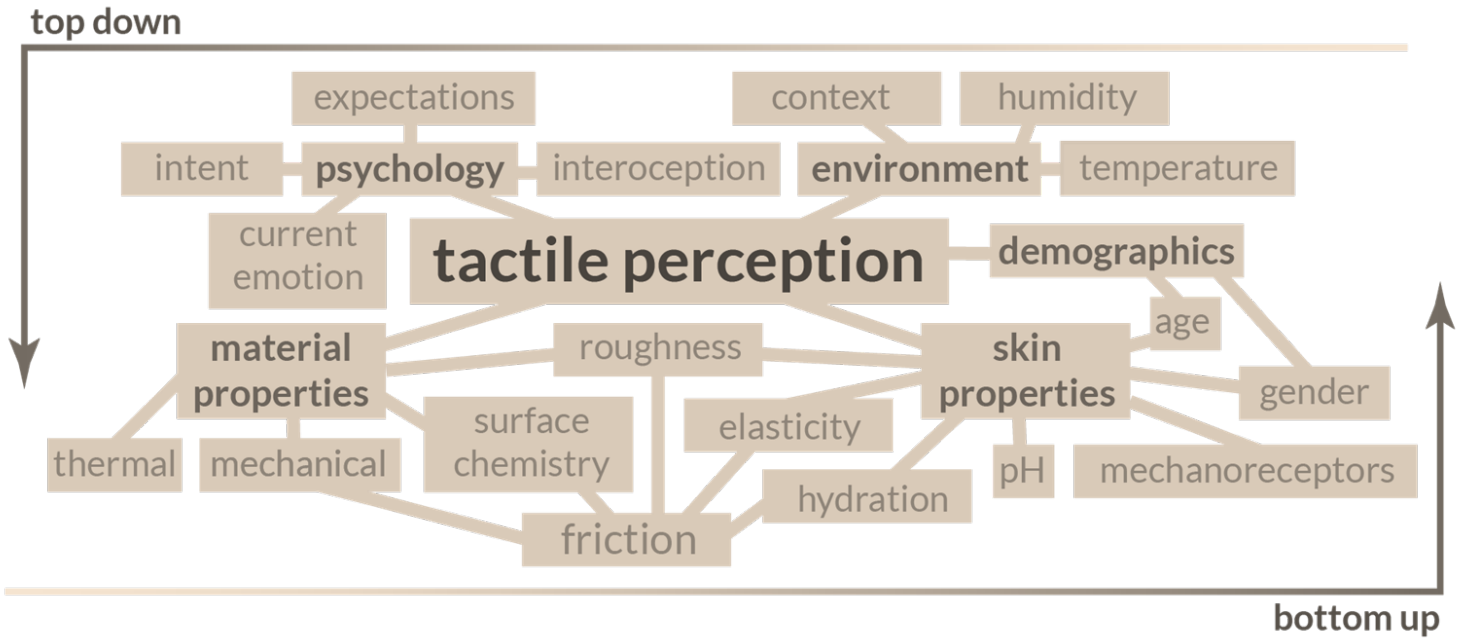
Tactile perception



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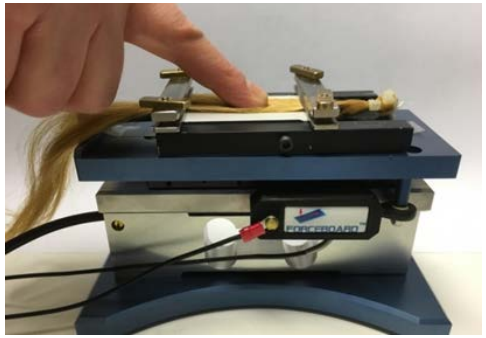
Three hair studies including…

Hair swatches

Tactile friction

Perception evaluation



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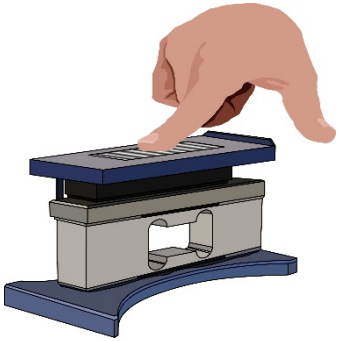
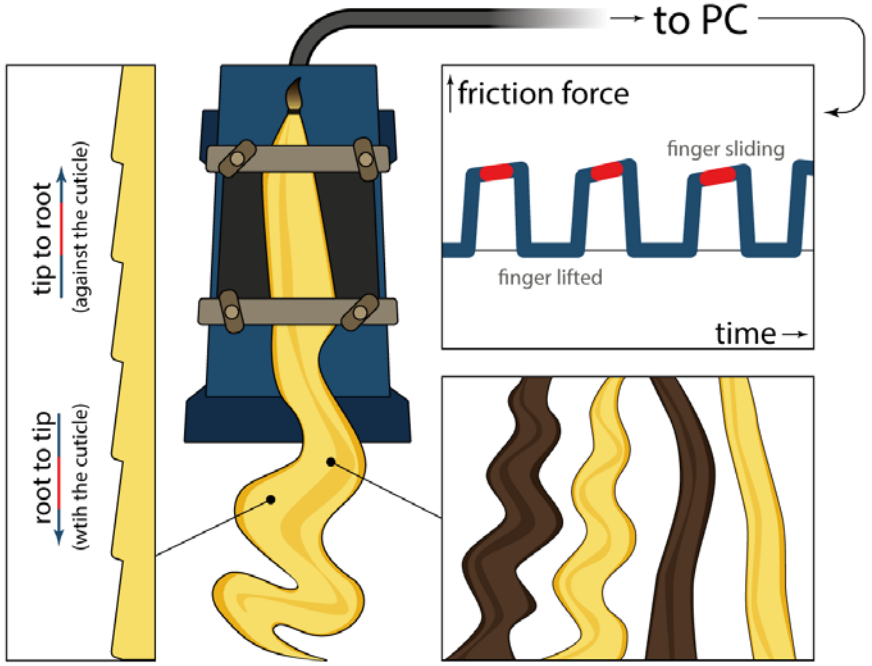
Tactile friction on hair





- Applied load and friction force continuously recorded at 100 Hz
- 10-15 strokes per measurement
- Separate measurements in root-tip and tip-root direction

<u>4 hair samples</u>
Straight bleached
Straight unbleached
Curly bleached
Curly unbleached

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Samples

The samples were four types of hair tresses:

Perception tests: Experimental protocol

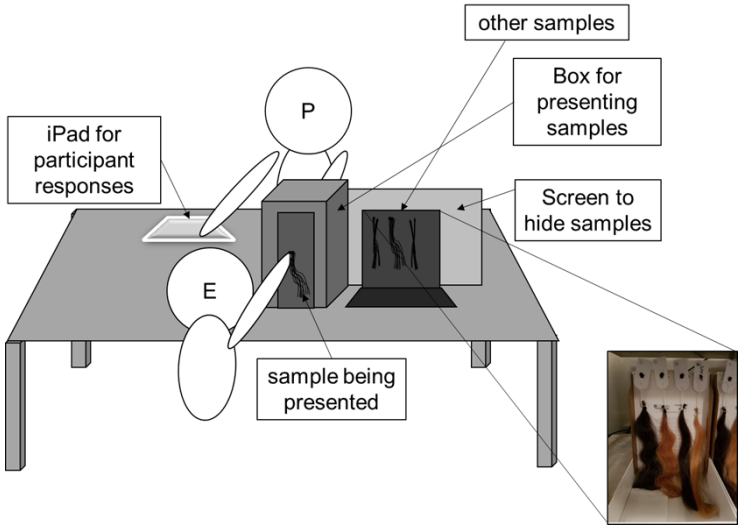
RISE recruited 5 participants per climate condition

1. Participant reads and signs consent form
2. Measure participant's skin hydration (index finger)
3. Participant completes questionnaire about their hair care routine and rates how pleasant their own hair feels to touch [0 (unpleasant) to 100 (pleasant)]
4. After 15 minutes measure participant's skin hydration again
5. Begin perception task 1: similarity rating task
6. After perception task 1, offer a short break to participant
7. Begin perception task 2: descriptor evaluation task
8. Rate pleasantness to touch of their own hair again

Similarity scaling and attribute scaling

5 participants per climate condition
Similarity scaling (0% to 100%)
Attribute scaling on a VAS-scale (0 to 100)

4 climate conditions
T: 30°C % RH: 80%
T: 30°C % RH: 20%
T: 15°C % RH: 80%
T: 15°C % RH: 20%



Attributes
Slipperiness
Stiffness
Softness
Smoothness
Volume
Electrostaticity
Clumping
Pleasantness
Frizziness
Fly-away
Shape recovery
Strand alignment

- There were 4 hair samples, giving 16 possible pairs of combinations, including presentation order (e.g., 1-2, 2-1).
- All combinations were presented four times, giving a total of 64 trials per participant.
- Trial order was randomised for each participant

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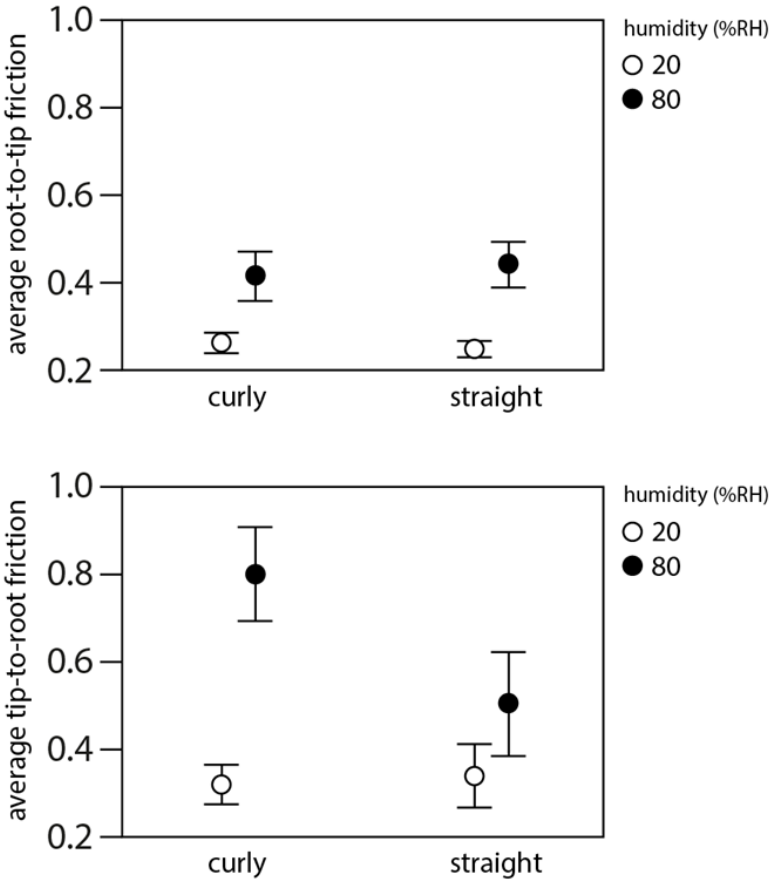

Friction results

- Higher tactile friction in the tip-to-root than the root-to-tip direction on all hair samples ($p < .001$) .
- Greater effect of humidity than temperature on tactile friction.
- The tip-to-root tactile friction for curly hair increased to a greater extent in higher humidity than straight hair ($p < .001$).

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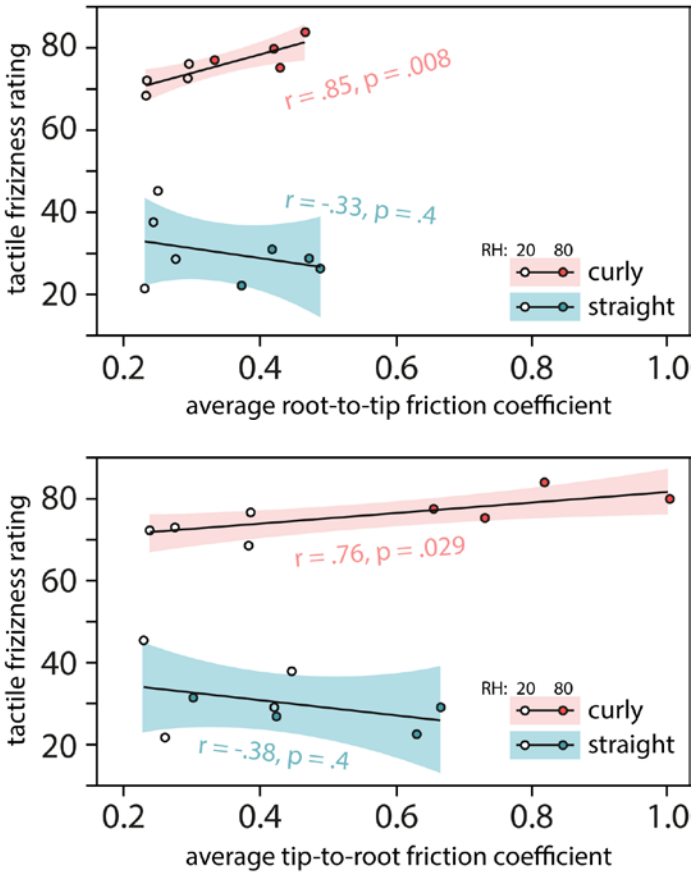

Perception results

- Similarity ratings did not differ significantly across the four environmental conditions possibly because hair shape (straight or curly) remained a salient cue in all conditions.
- Straight hair was rated more slippery, smooth, and more pleasant than curly hair, while curly hair was rated as stiffer, more voluminous, clumpier, having more fly-aways (all $p < .05$) and more frizzy ($p < .001$)..
- Frizziness ratings of curly hair correlated positively with root-to-tip and tip-to-root tactile friction, which was not found for straight hair.

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Conclussions

- curly hair more susceptible than straight hair to perceivable changes in texture.

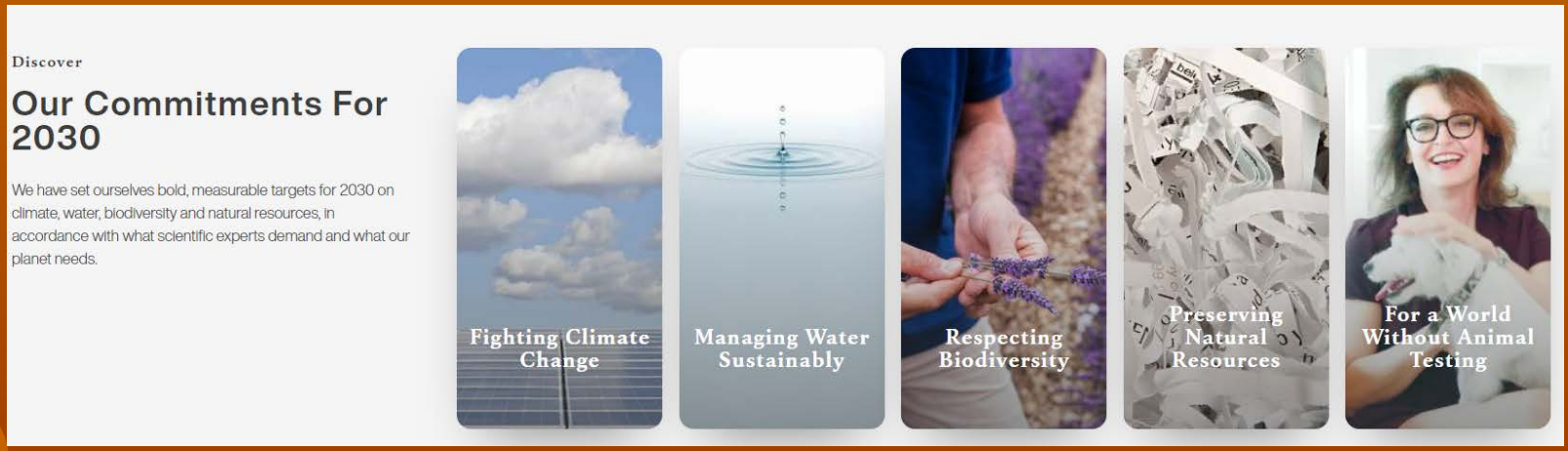
- Increased friction of the hair (especially for the curly hair in the tip-to-root direction) may hinder the ability of the hair strands to return to an ordered state after disruption and the curly morphology may exacerbate the effect of increased resistance to reordering as a consequence of a higher friction coefficient.

- although higher humidity, often portrayed as immediately caus-
- ing wild and frizzy hair, affected the tactile friction coefficients for both straight and curly hair, it did not appear to affect tactile perception of frizziness directly or consistently

- relationships between tactile friction and perceived frizziness were detected only in the case of curly hair.

L’Oréal for the Future

- our sustainability commitments for 2030



https://www.loreal.com/en/commitments-and-responsibilities/for-the-planet/

Acknowledgements

Short and Sweet

PERCEPTION

A Curly Q: Is Frizz a Matter of Friction?

Perception
0(0) 1–5

DOI: 10.1177/03010066211024442
journals.sagepub.com/home/pec
SAGE

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Vulgarisation/News

La psychophysique au service des cheveux frisés, une autre vision de la frisure !

- La perception de notre chevelure passe non seulement par nos prunelles, mais aussi par la caresse ! Alors que la brillance est une composante purement visuelle, la douceur une dimension tactile, qu'en est-il de la frisure ?
- La Recherche L'Oréal s'est intéressée à la perception de la frisure des cheveux en étudiant la possible relation entre notre sensation au toucher et la facilité de glissement de nos doigts sur la surface des cheveux.
- Des panelistes ont évalué tactilement des mèches de cheveux, raides ou frisés, placées dans des boîtes noires et exposées à diverses conditions de température et d'humidité. En parallèle, a été mesuré le frottement généré par le passage de leurs doigts sur ces mèches*.
- Dans le cas des cheveux bouclés, un lien a été clairement établi entre la perception de la frisure au toucher et le frottement tactile. La plus forte augmentation de leur friction tactile en milieu humide versus celle des cheveux raides, témoigne de leur plus grande sensibilité à cette condition ambiante.
- Cette étude exploratoire, menée en collaboration avec l'institut de Recherche RISE, ouvre de nouvelles pistes pour le développement de produits capillaires destinés aux cheveux bouclés.

Design and method

- The design of the perception portion was a full factorial between-participants experiment
- Tactile friction tests done using a ForceBoard (2 trained operators)
- Four climate conditions are tested
  - Temperature 30°C – Relative Humidity 80%
  - Temperature 30°C – Relative Humidity 20%
  - Temperature 15°C – Relative Humidity 80%
  - Temperature 15°C – Relative Humidity 20%

+ ambient conditions (23°C-30% RH; friction tests only)

- The tests were run in a climate controlled laboratory
  - The tress samples were placed in lab late afternoon evening before testing

Image showing the climate controlled lab in which the experiments were conducted

Visual Changes

RH: 20%

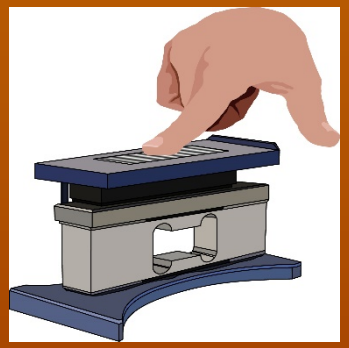
RH: 80%

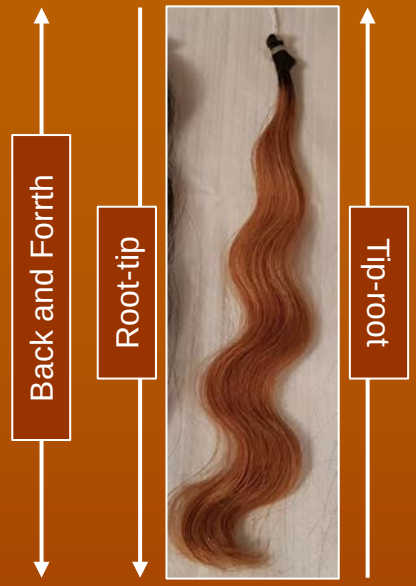
T=15° C

T=30° C

Friction tests

- Tactile friction measurements were conducted using a ForceBoard.
- In each climate condition the following measurements were taken:
  - Tip-root direction (15 cycles)
  - Root-tip direction (15 cycles)
  - Forward-backwards (15 cycles)
- Each of these measurements were repeated twice by two operators
  - BF measurements completed only once
- The operators were trained RISE staff with previous experience of using the ForceBoard.





The friction measurements were carried out on a different set of samples than those used in the perception tests.

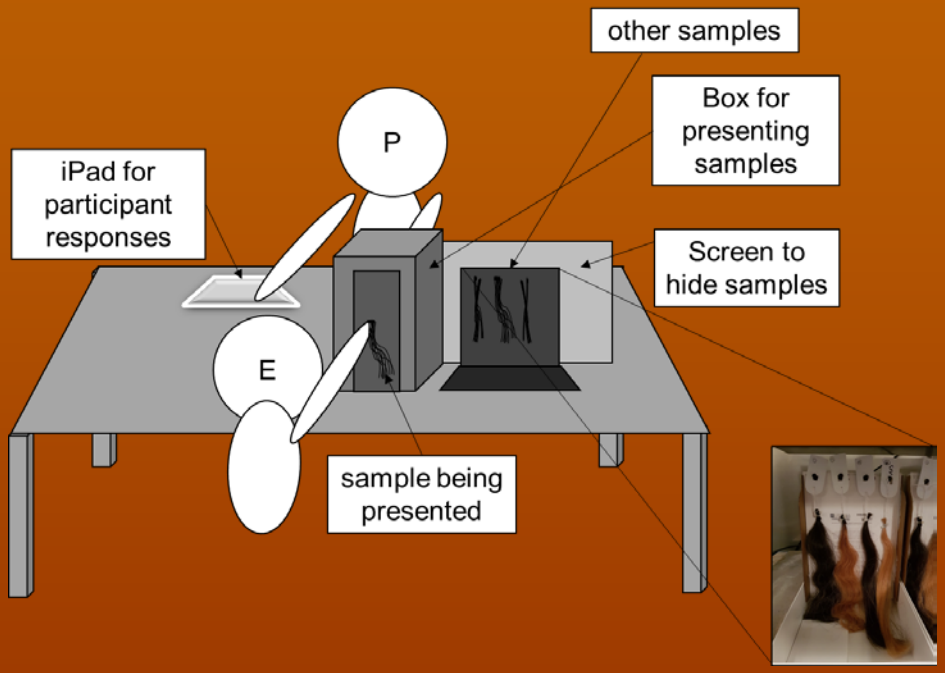
Experimental set-up: both perceptual tasks

The participant (P) sat opposite the experimenter (E) at a table and placed their hand inside an open-ended box. The side of the box facing the participant was covered by a curtain whilst the side facing the experimenter was fully open.

This allowed the experimenter to present the tresses inside the box without the participant seeing them.

The participants made their responses in both tasks on an iPad, which they used with their dominant hand. They touched the tresses with their non-dominant hand.

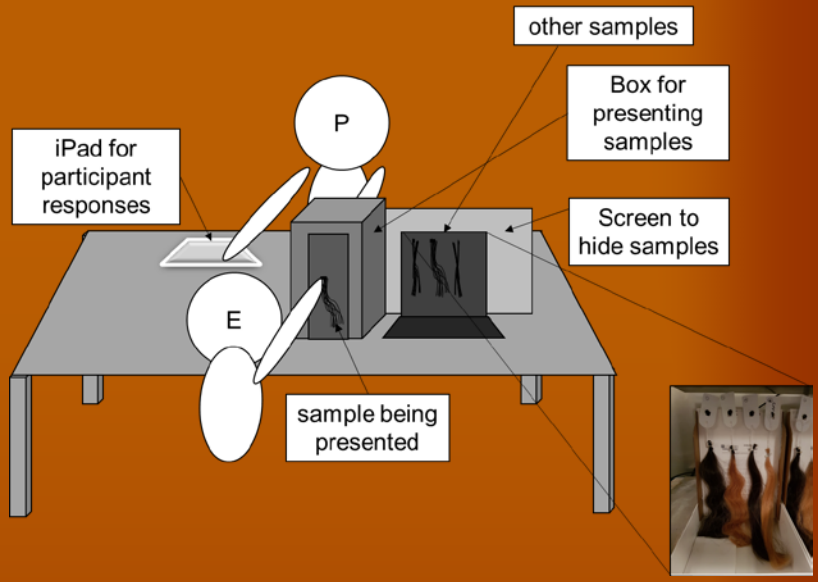
One set of samples was used by 2-3 participants.



Similarity rating task

- Participants reached into the box and touched one tress, followed by a second tress
- On the iPad, they moved a marker on a scale to rate how similar the two tresses felt

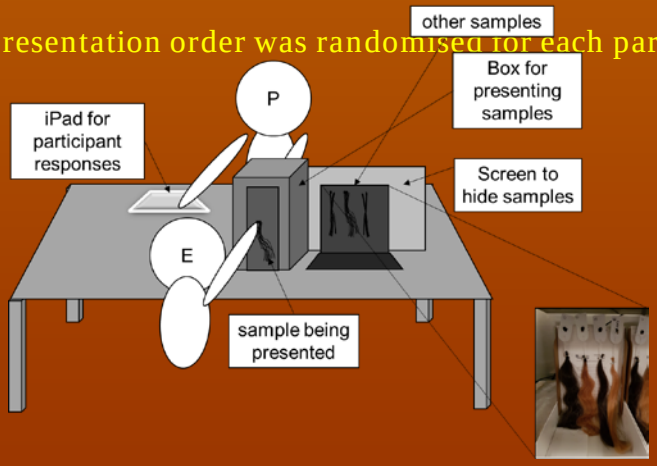
- They were instructed to assess the tresses as a whole and consider all factors they considered relevant



- There were 4 hair samples, giving 16 possible pairs of combinations, including presentation order (e.g., 1-2, 2-1).
- All combinations were presented four times, giving a total of 64 trials per participant.
- Trial order was randomised for each participant

Descriptor evaluation task

- Participants placed their hand inside the box and touched **one** sample at a time
- They then rated it on several descriptors using the iPad on scales from 0 (not very much) to 100 (very much)
- The task was completed for each of the four samples
  - Presentation order was randomised for each participant

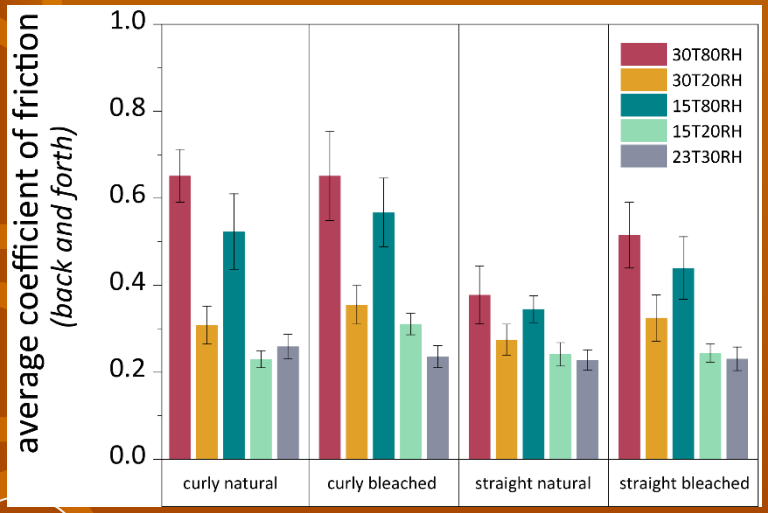


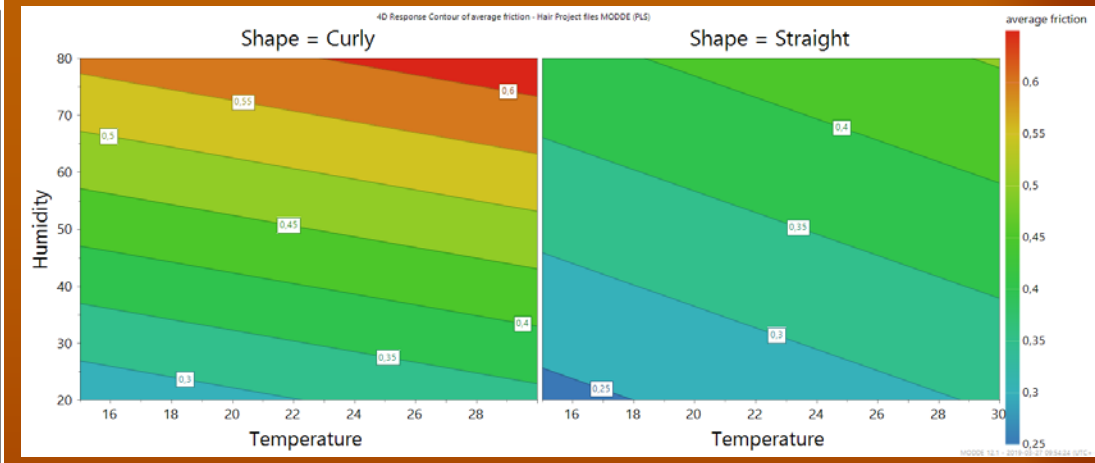
The descriptors were:

- Slipperiness
- Stiffness
- Softness
- Smoothness
- Volume
- Electrostaticity
- Clumping
- Pleasantness
- Frizziness
- Fly-away
- Shape recovery
- Strand alignment

These 4 descriptors were assessed visually at the end of the task

Effect of climate on back and forth tactile friction



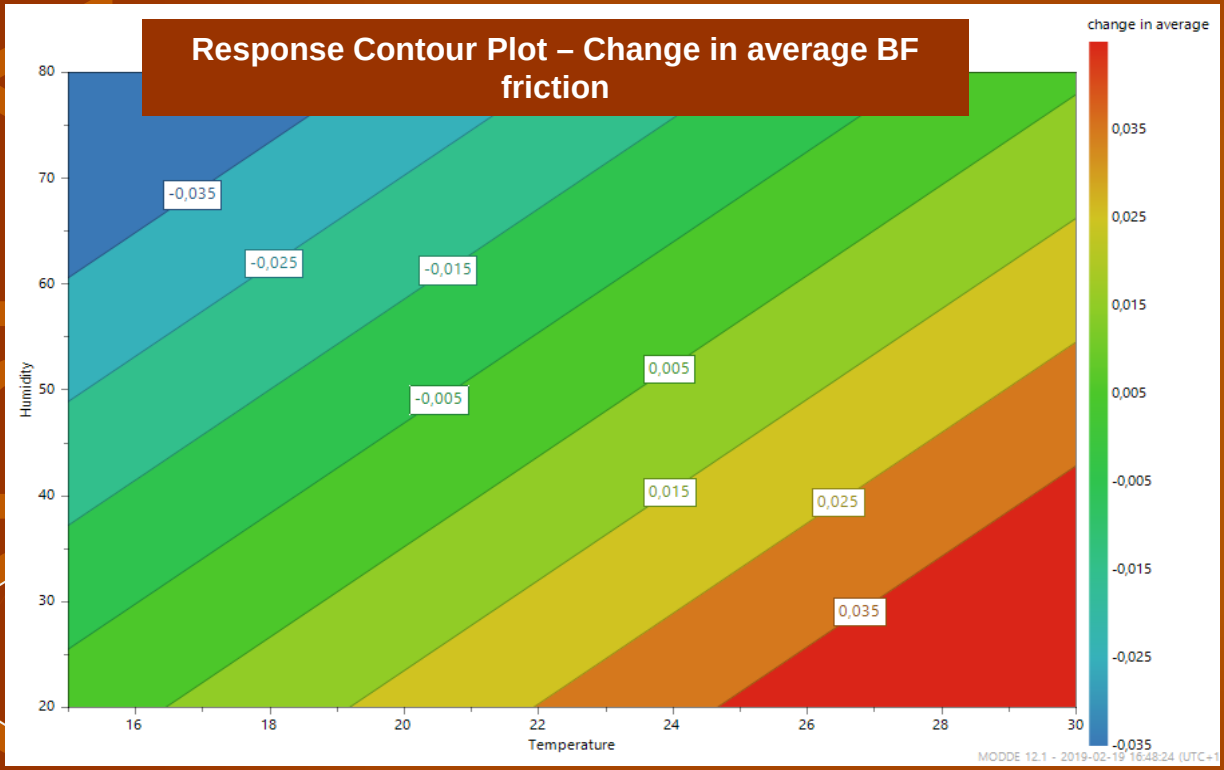


- Mechanical properties of skin vary with temperature
- The dew point at 15° C is between 31-36% RH
- The dew point at 30° C is around 73% RH

Contour plot showing the influence of temperature and humidity on curly and straight hair samples. Change in colour from blue to red indicates an increase in back and forth friction.

L'ORÉAL

Change in average friction (first two – last two cycles)



Increasing the temperature leads to a decrease in friction over cycles

Increasing the humidity leads to an increase in friction over cycles

- Mechanical properties of skin vary with temperature
- The dew point at 15° C is between 31-36% RH
- The dew point at 30° C is around 73% RH

L'ORÉAL

average tactile friction was higher in the tip to-root direction than the root-to-tip direction (p<.001)

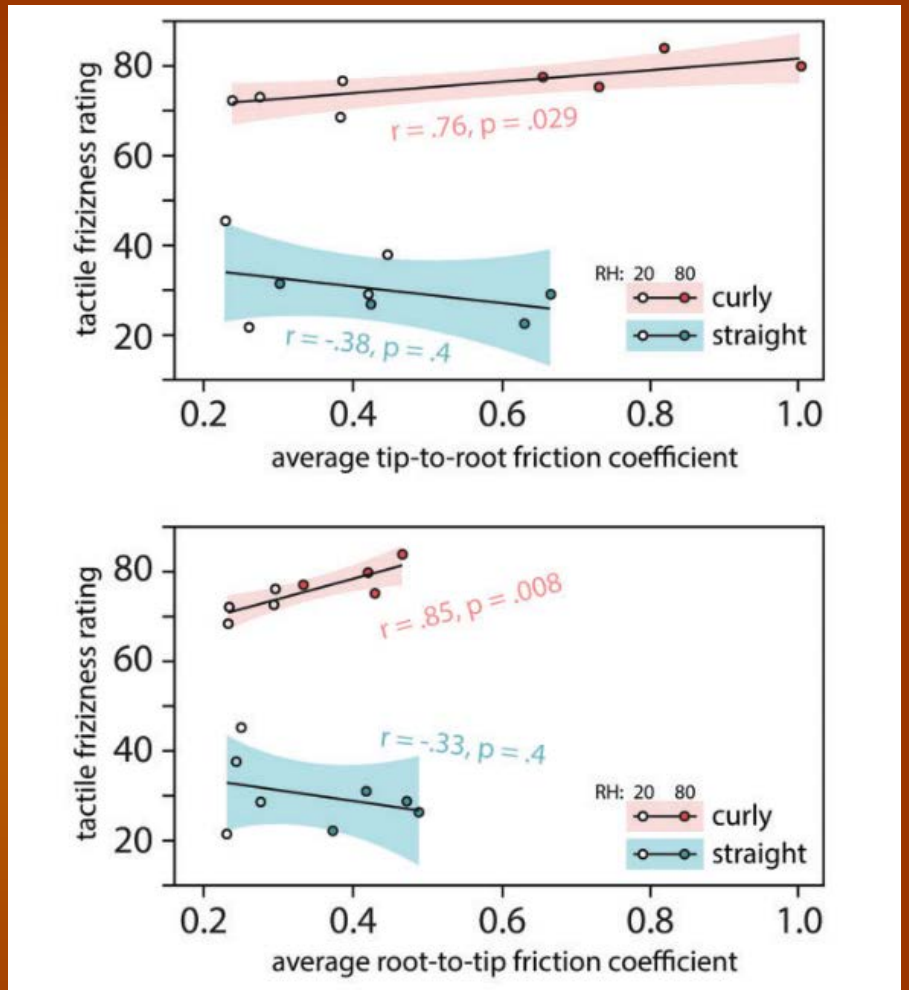
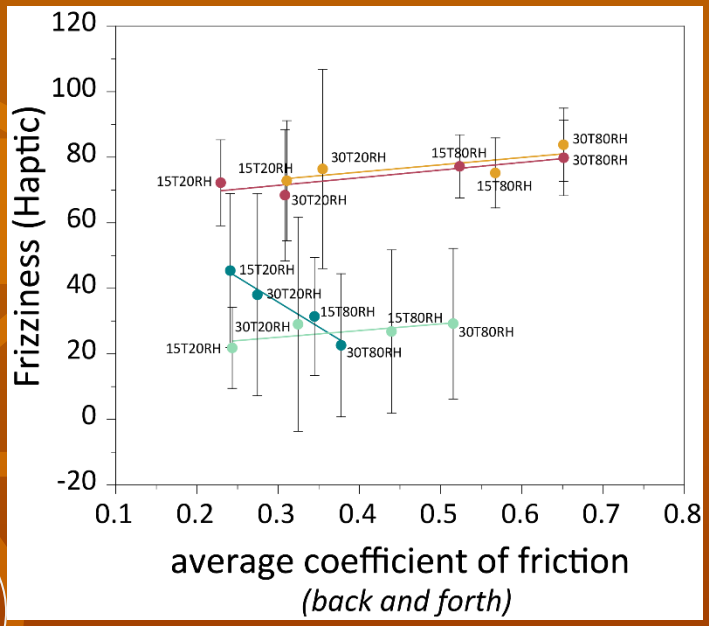
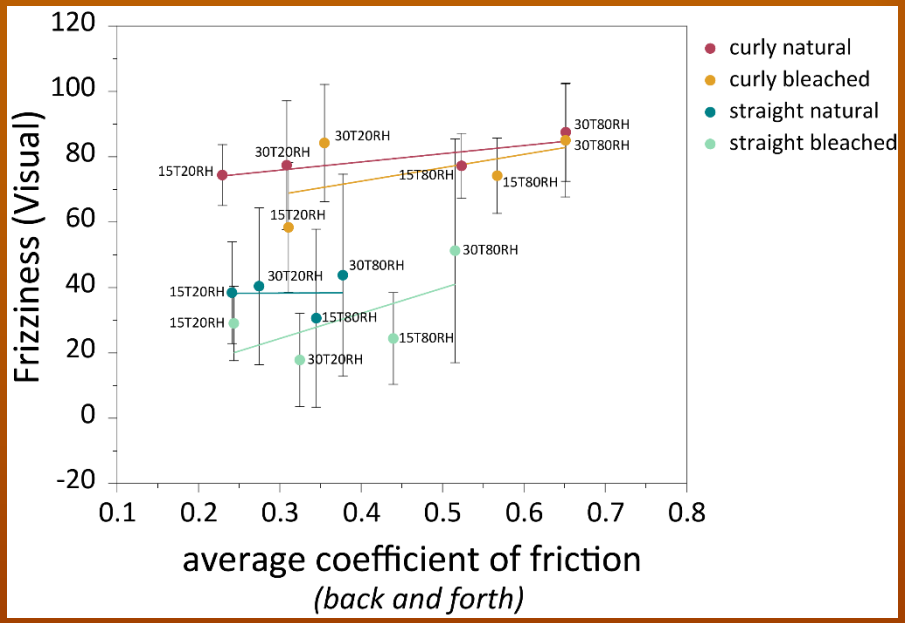


Figure 2. Mean frizziness ratings of straight and curly hair by touch against tip-to-root (top) and root-to-tip (bottom) tactile friction, with 95% confidence intervals shaded. Points represent average values for each combination of temperature, humidity, and treatment (8 points per hair shape).

Relationship between BF friction and frizziness by touch and vision





Mixed analyses of variance (within: hair shape and treatment, between: temperature and humidity) were used to analyze the perceptual data.