Hair Testing: Opportunities & Challenges

Beauty for a New Age

Session 4: Major Advances in Hair Science and Technology

Hair Testing: Opportunities & Challenges

A - very - Personal View

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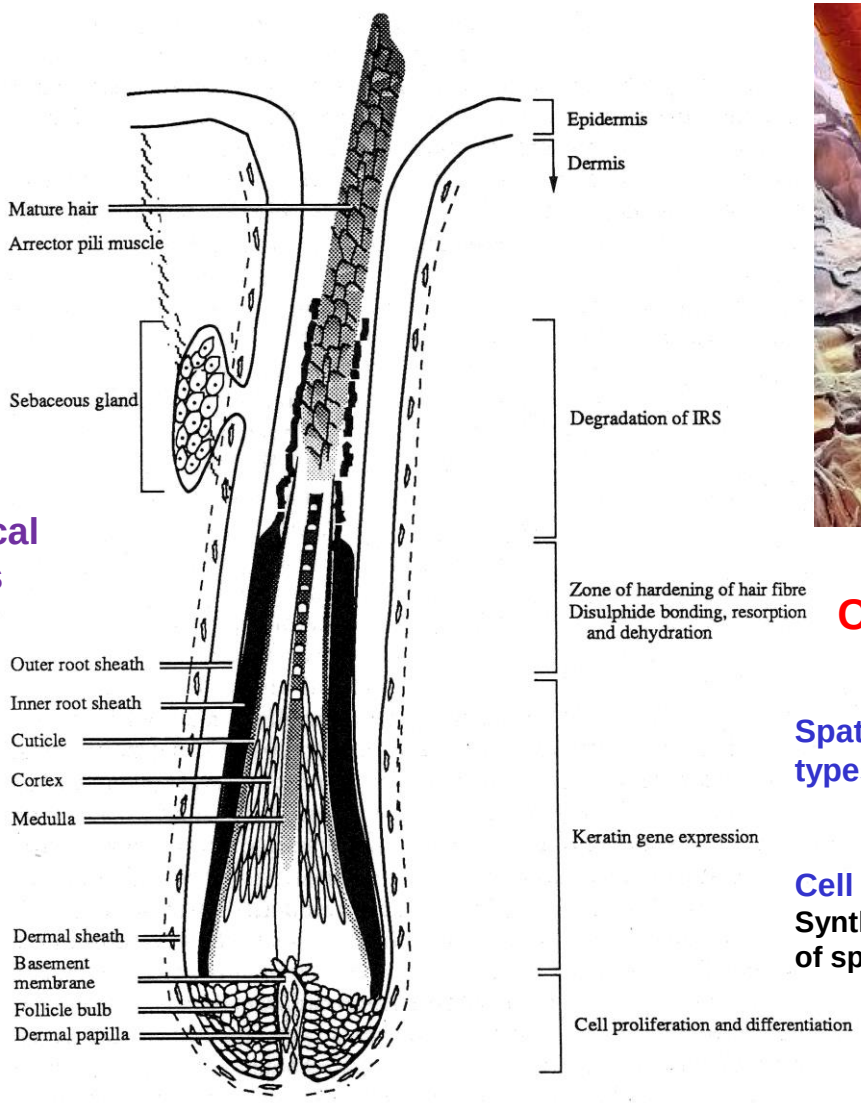
The University of Manchester, UK

F & GW – Consultants, Aachen, GER

Material I: The Two States of Hair



Primary morphological components

Physics & Engineering

Biomaterial

Cell death

Spatial separation of cell types.

Tissue

Cell Differentiation
Synthesis & self-assembly of specific proteins

Life Sciences

BC Powell & GE Rogers in 'Formation and Structure of Human Hair', P Jollès, H Zahn, H Hoecker (eds), Birkhaeuser 1997, p.59-148

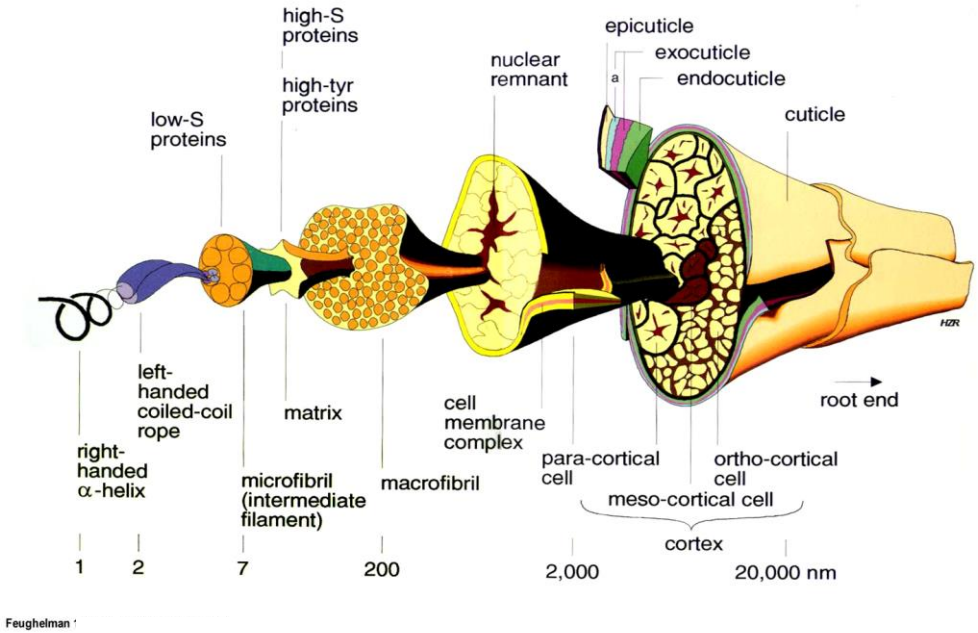
http://naturalnigerian.com/2012/03/hair-101-the-scalp-get-this-right-and-your-hair-will-grow/

Material II: Fibre Structure

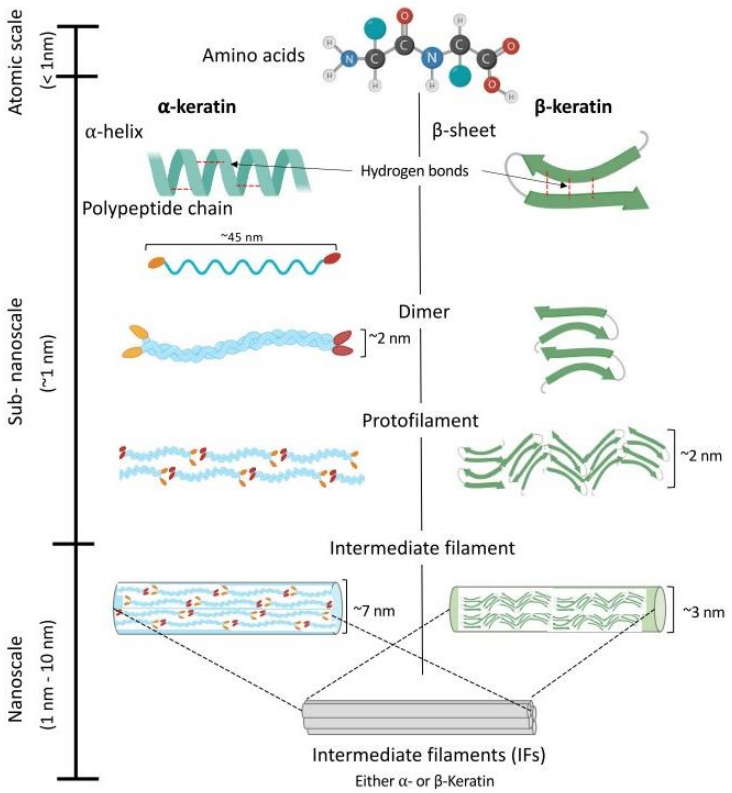
Hair cosmetics deals with the mature, ‘dead’ hair shaft.

The hair shaft is a very complex biological composite material.

The general structural features are consistent across animal hairs.

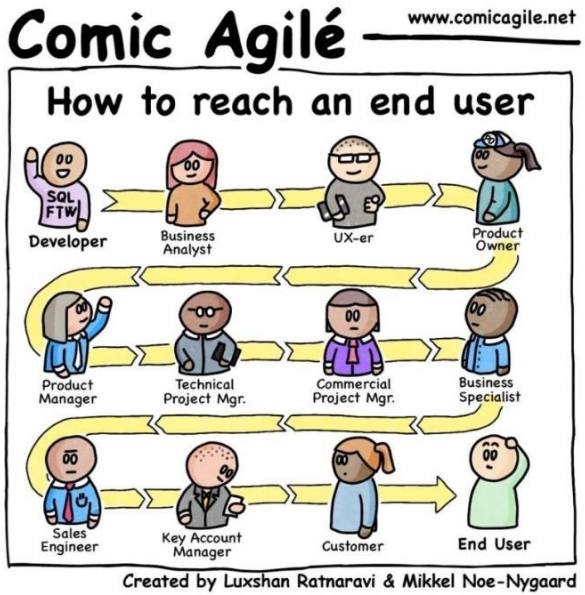


Merino Wool: Feughelman 1997 adapted from Fraser 1981

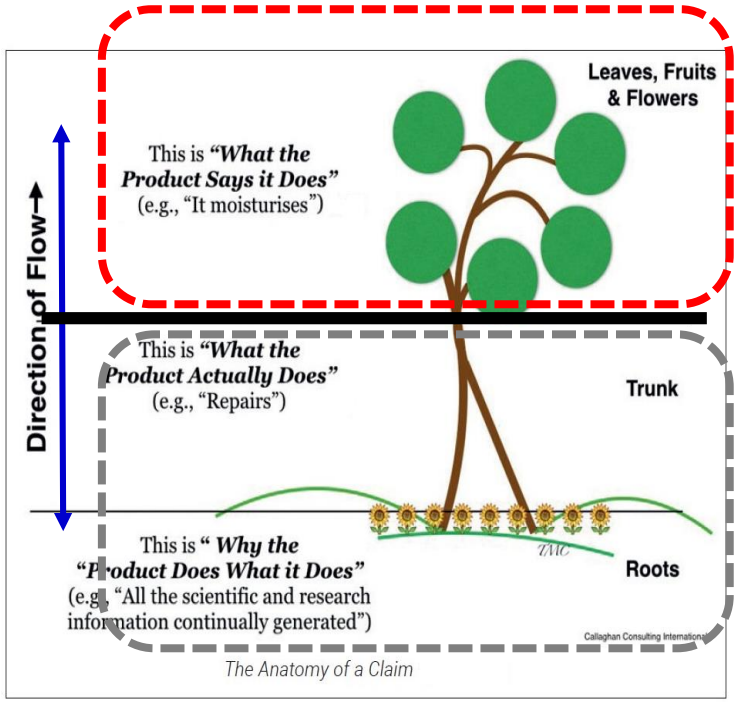


Lazarus, B. S. et al, *Iscience*, *24*(8), 102798 (2021).

Hair Cosmetics R&D and Hair Testing

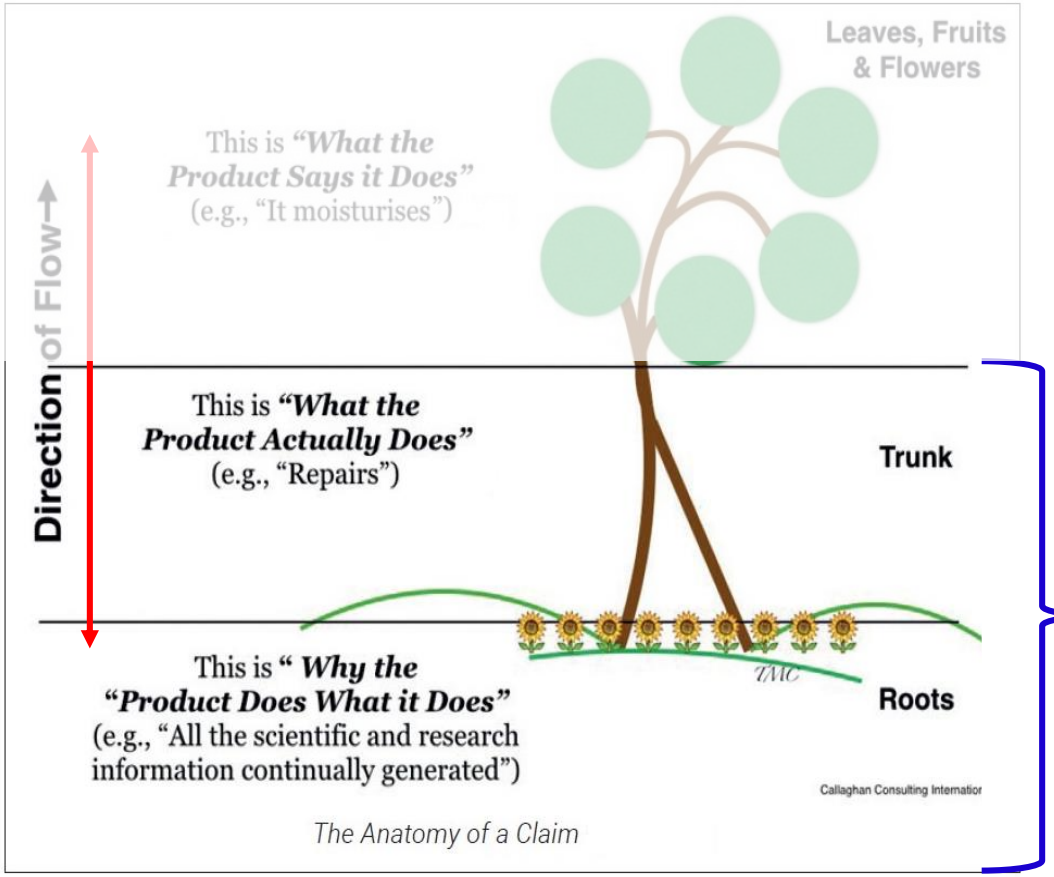


Anatomy of a claim



Adapted from: T M Callaghan, HPC Today 17(3), 11 (2022)

Claims & Laboratory Testing

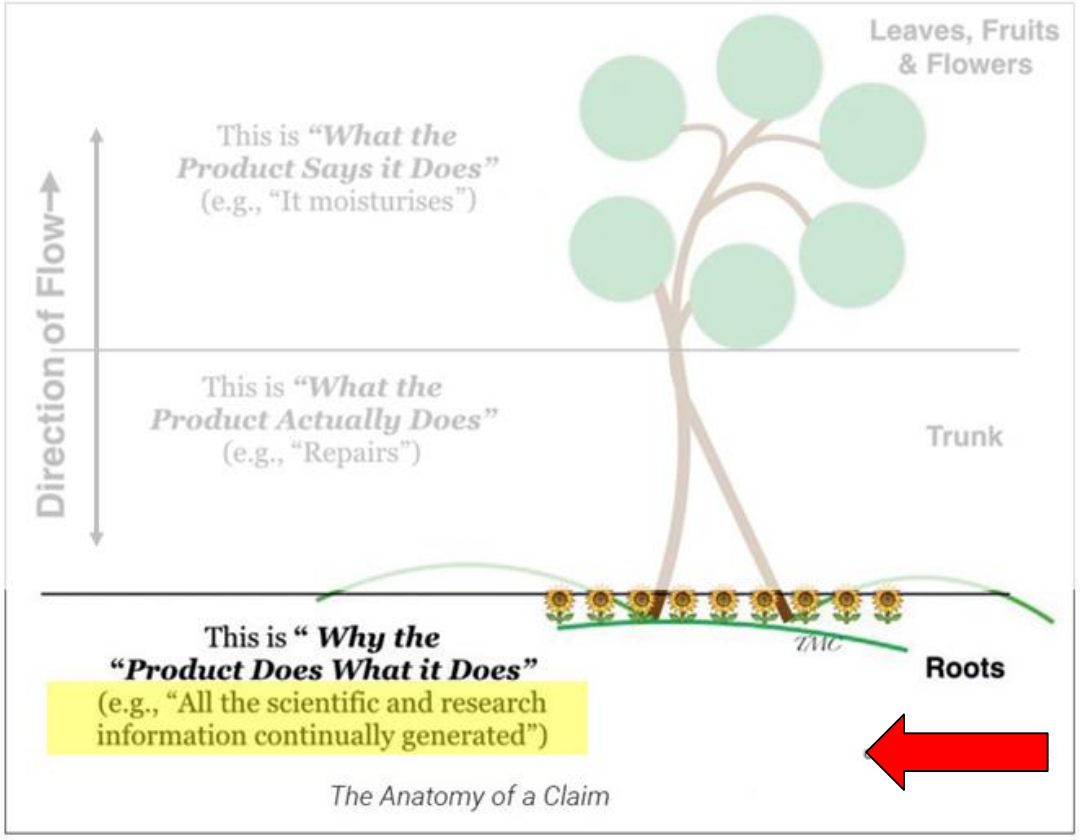


Adapted from: T M Callaghan, HPC Today 17(3), 11 (2022)

Laboratory Tests for Single Hairs & Tresses: An incomplete list

Microscopy: Light, SEM, TEM
Optical Testing
Atomic Force Microscopy
Spectroscopy: FTIR, Raman, NMR
X-ray: Diffraction, Tomography
Chemical & Protein Analysis
Mechanical & Thermal testing
Surface Analysis & Wettability
Sorption, Diffusion & Penetration Studies
Molecular & Statistical modelling
etc, etc, etc

#1 Fundamental Investigations



Adapted from: T M Callaghan, HPC Today 17(3), 11 (2022)

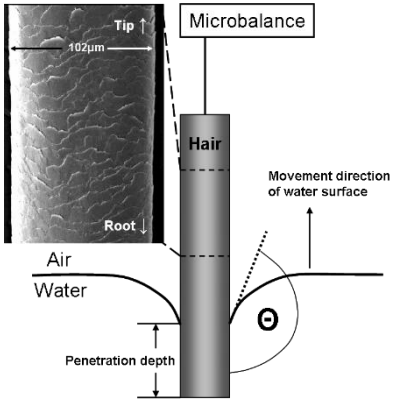
2 case studies

#1 Wettability of the hair surface, using the Wilhelmy method

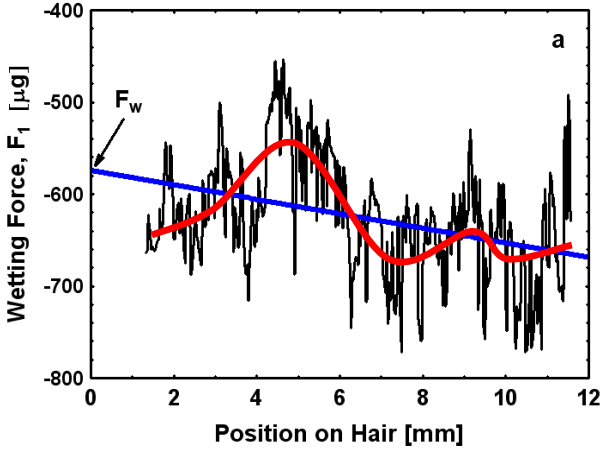
#2 Why is hair curly?

#1.1 Wettability of the Hair Surface

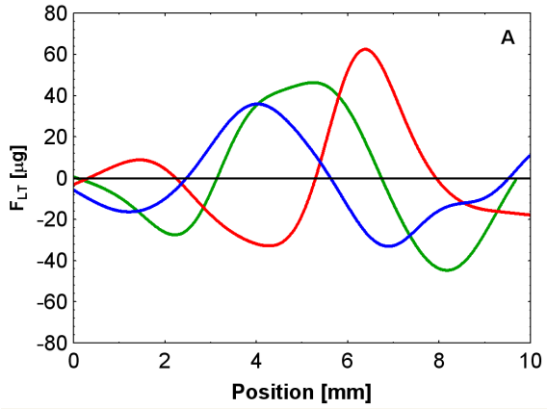
Wortmann, F. J., Wortmann, G., & Schulze zur Wiesche, E. (2010). *Langmuir*, *26*(10), 7365-7369.



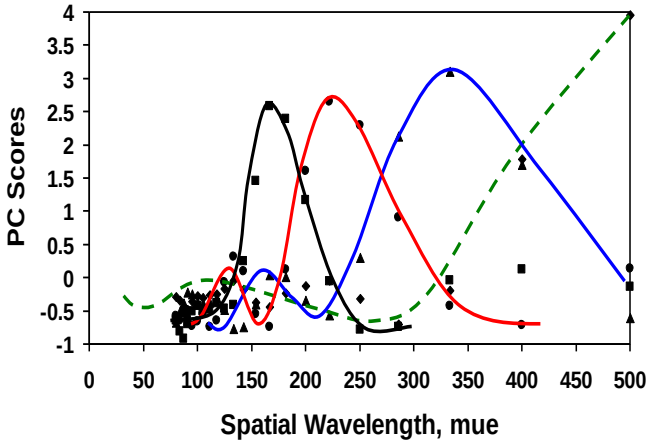
The principle of the Wilhelmy method



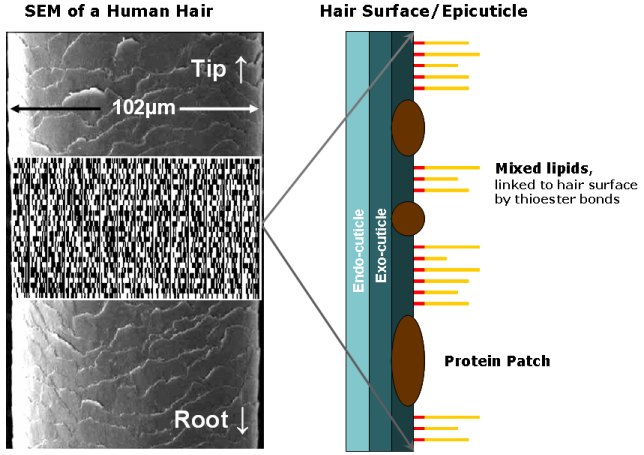
Primary data & baselines



Characteristic baselines for young women

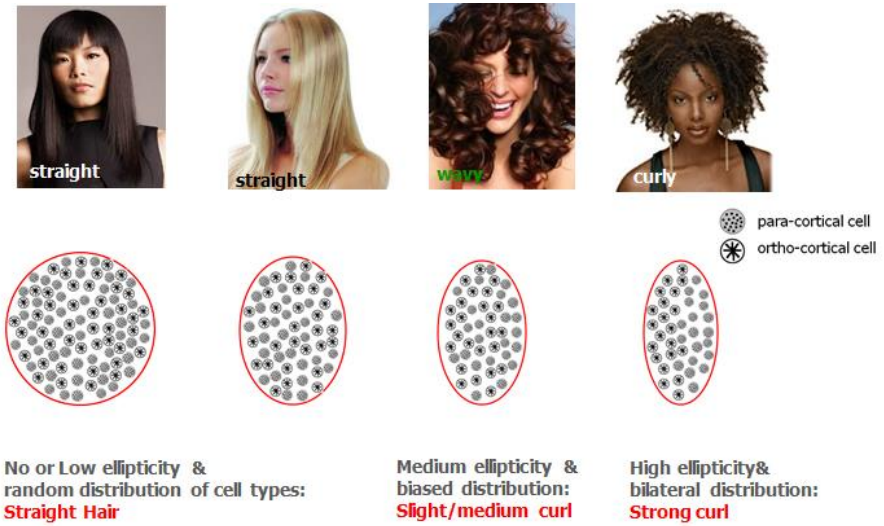


Fourier & Principal Components Analysis: Sleep & wake contributions to the daily changes of surface energy

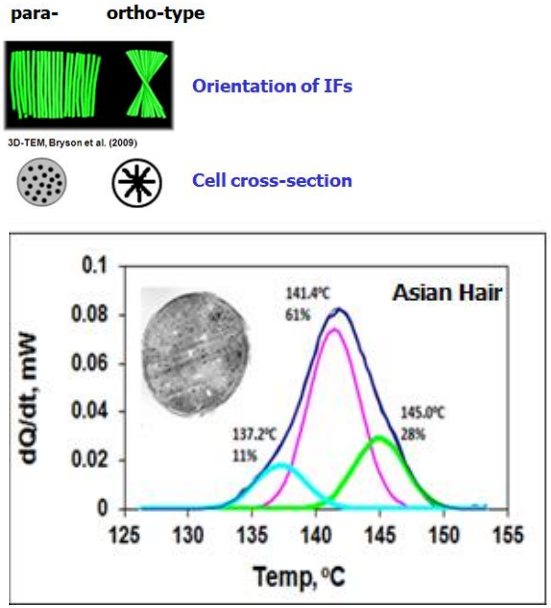


Concept for the dynamics of the surface composition of hair

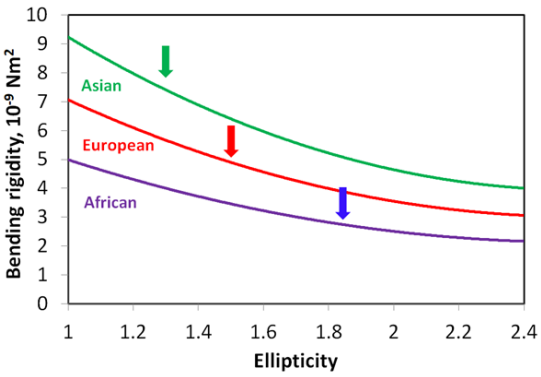
#1.2 Why is hair curly?



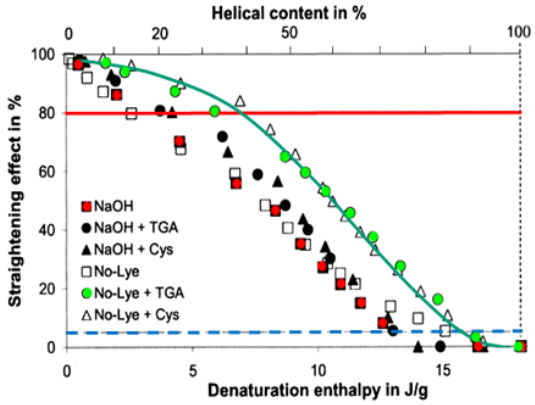
1 Curl formation depends, primarily, on the lateral segregation of ortho & para-cortical cells.
2 There is no role of follicle shape or mechanical processes.



o/p-cell fractions are essentially equal across hair ethnicities



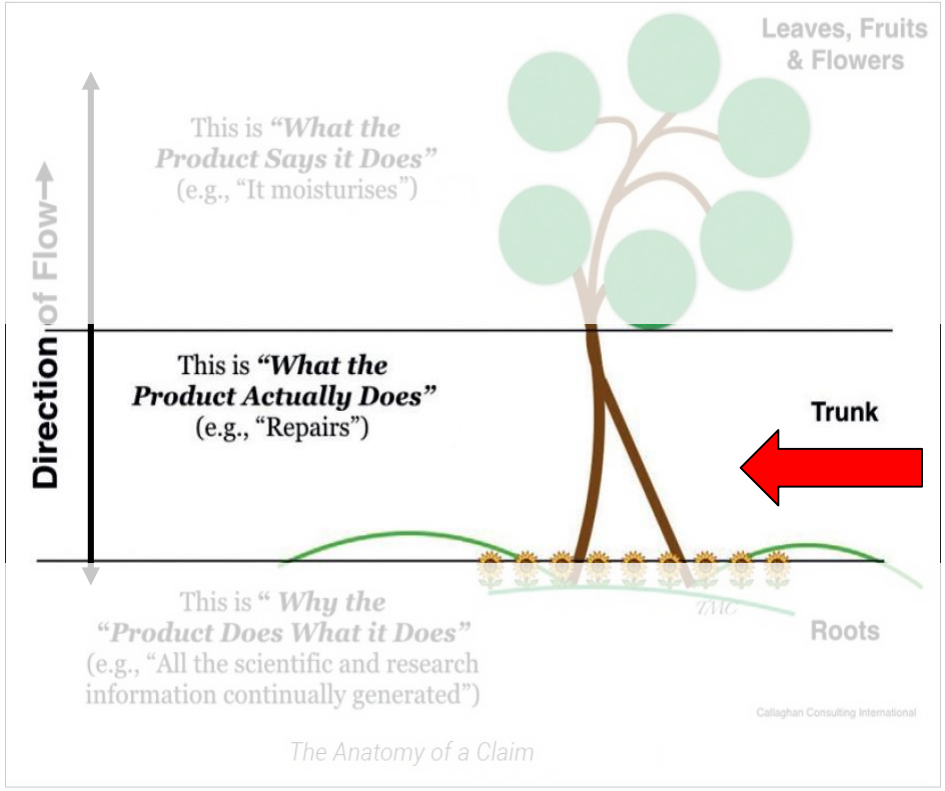
Ellipticity plays a strong synergistic role for curl formation



IFs form the scaffold for a natural curl

Wortmann, F & G (2018). *EXD 27*(3), 292-294.
Wortmann, F & G, Sripho, T. (2020. *EXD 29*(3), 366-372.
Wortmann, F; Quadflieg, J; Wortmann, G (2022). *EXD 31*(2), 257-258.

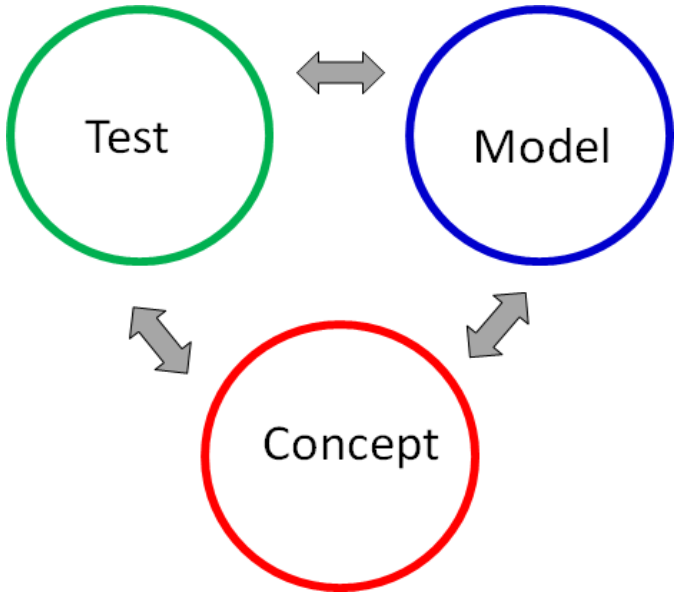
#2 The Focus of Usual Testing



The successful implementation of the scheme requires the synergistic interaction of three fundamental aspects of hair testing.

This may be (usually) a top-down or (sometimes) a bottoms-up approach

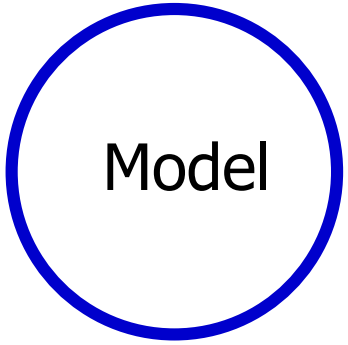
Formalization



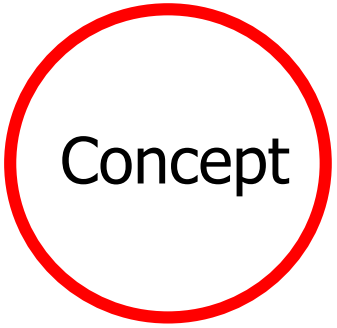
However – what comes first? Claim or Test?

Testing Hair & its `Environment`

General requirement for a test:
Accuracy & Precision:
Without precision data no comparative statement, eg between Sample A vs B, can validly be made.
Case: Fatigue-failure Testing.



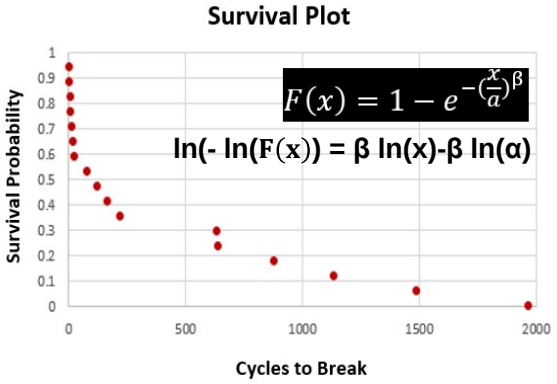
Lack of data precision – if unavoidable - is not necessarily a disadvantage, if you got a good structural / physical / statistical model.
Case: Hair Torsion

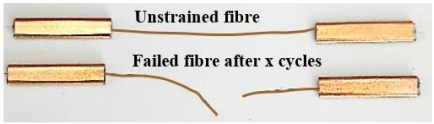


Established academic and commercial concepts usually provide the context for testing. However, testing and data analysis may also lead to the need to reconsider such concepts. This provides challenges as well opportunities.
Case: pH-adjustment of Hair

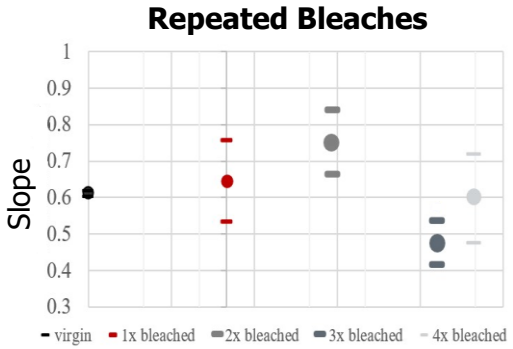
#2.1Constant Strain Fatigue-Failure testing

Test

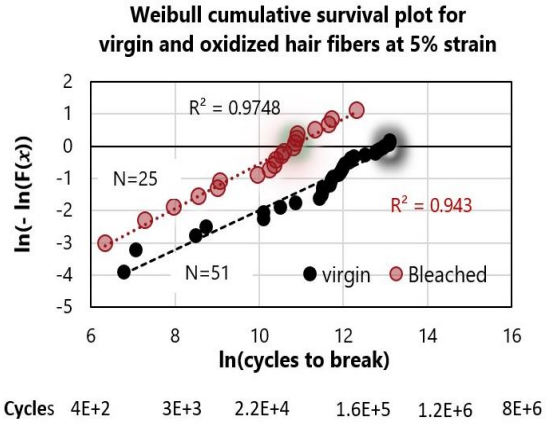




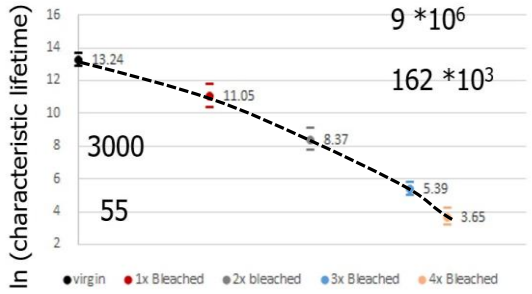
Weibull model: Survival probability follows a simple exponential decay



Failure kinetics/mechanism essentially does not change with repeated oxidations.



The properties of a linear regression enable the determination of the confidence limits of the parameters & thus the statistical comparison of sample performances.



ln(characteristic lifetime) follows simple (1st order?) kinetics. Precision constant.

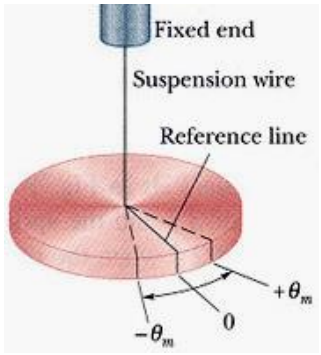
Model approach enables

- *dealing with incomplete data*
- *reduced test times & sample sizes*
- *enables valid comparison of samples*
  - *enables experimental design*

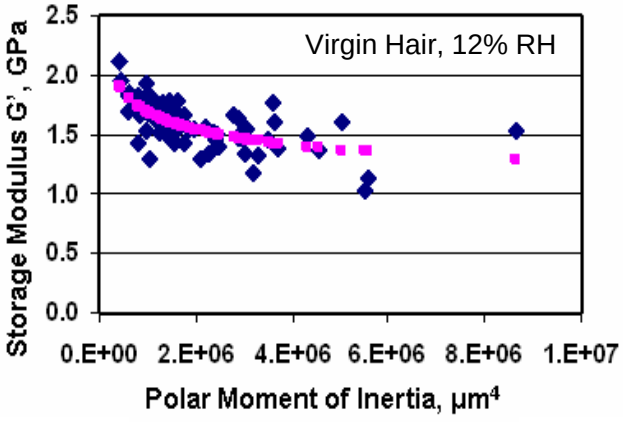
Berriche, L et al; TRI Hair Conf 2022

#2.2 Torsional Testing of Human Hair

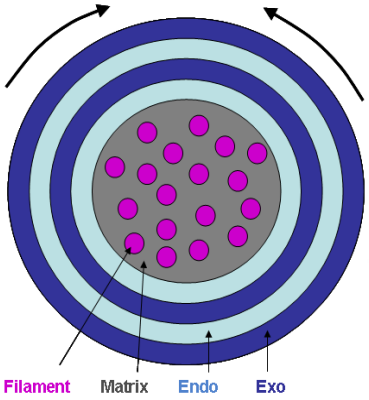
Model



The torsional pendulum

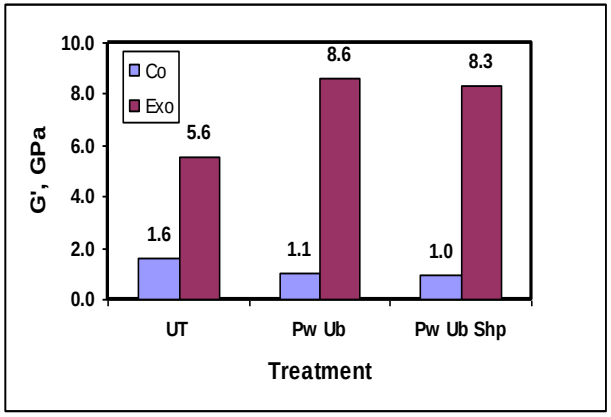


Torsional modulus changes with PMI. G' is not a material constant.

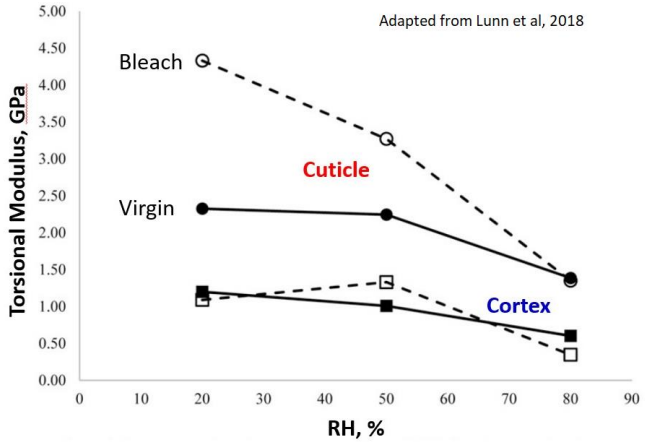


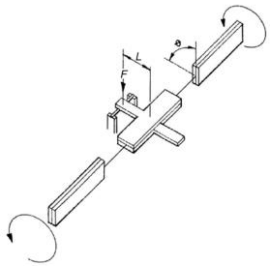
$$G^* = (G^*_{co} I_{co} + G^*_{cu} I_{cu})/I$$

co = cortex
cu = cuticle



Torsional modulus contributions of cortex and cuticle can be separated.



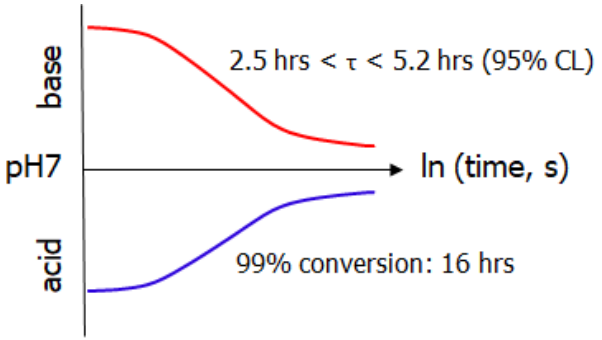


Torsional moduli of cortex and cuticle change with humidity with a strong effect of chemical pre-treatment.

Wortmann, F & G et al (2010) TRI Conf; Wortmann, F & G. et al (2014). *J Cosmet Sci*, *65*(2), 59-68
Lunn et al (2018). *J Cosmet Sci*, *69*(5), 383-396.

#2.3 pH-Adjustment of Human Hair (HCl & NaOH)

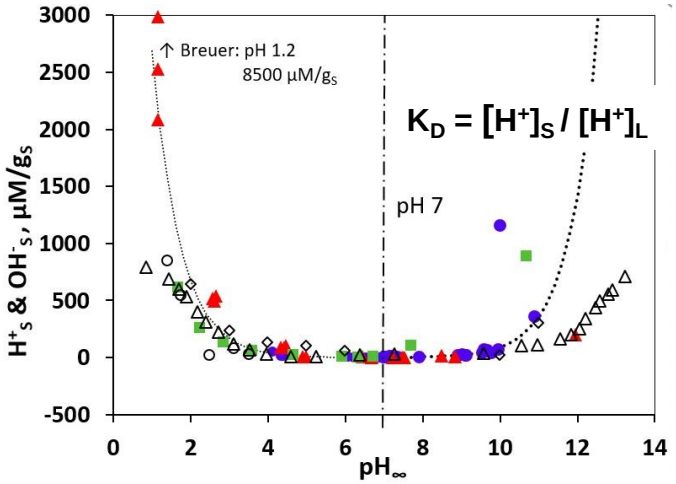
Concept



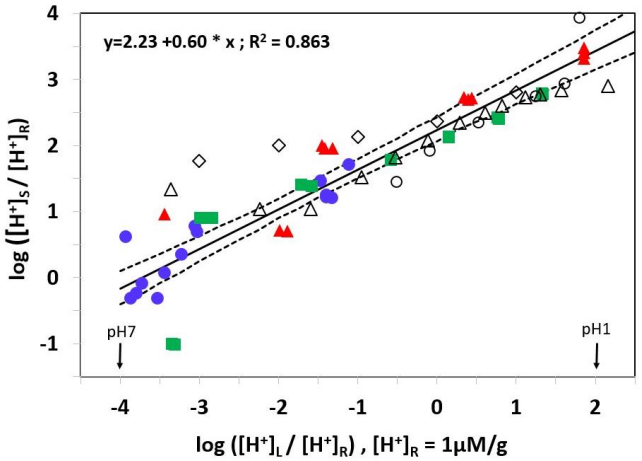
Acid : $pH(t) = pH_\infty - (pH_0 - pH_\infty)\ exp\ (-t/\tau)$

Alkali : $pH(t) = pH_\infty + (pH_0 - pH_\infty)\ exp\ (-t/\tau)$

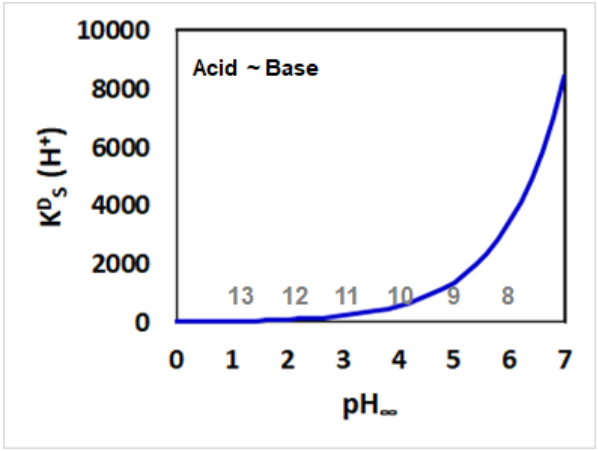
pH-adjustment follows essentially equal1st-order kinetics for acid and base.



Experimental & literature data (hair & wool) follow the expected U- shaped curve. Equilibrium uptake in experimental pH-range is questionable.



H^+ and OH^- -absorption (for the specific conditions) show the same two-parameter physi-sorption isotherm (Freundlich)



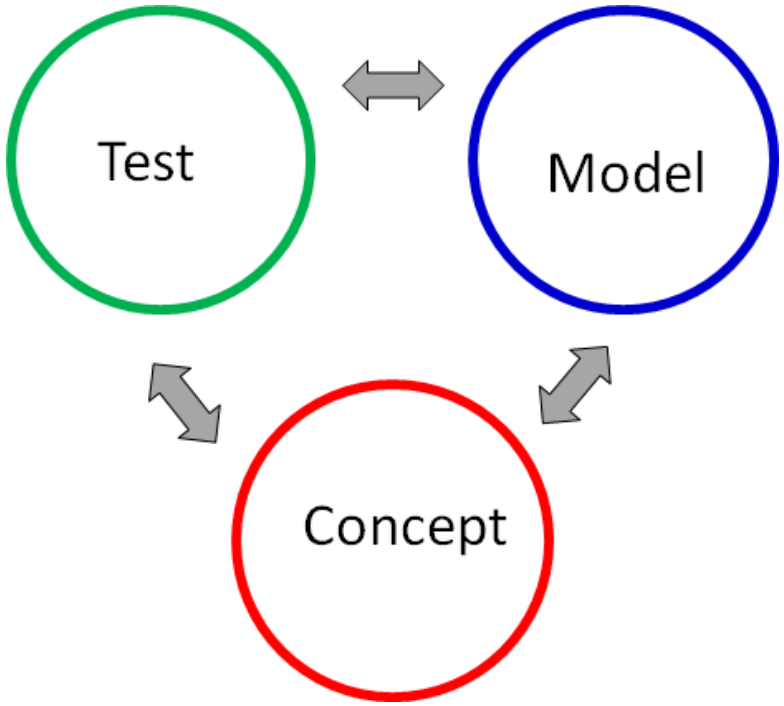
The absorption for H^+ and OH^- is especially biased towards hair in the mid pH-range. No special pHs or roles of specific amino acids. No diffusion barrier.

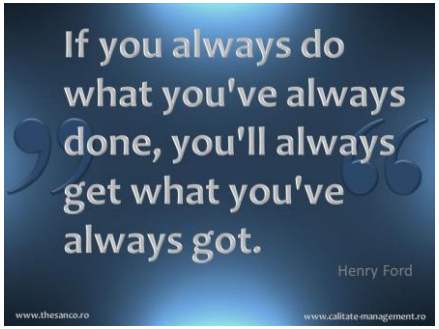
Wortmann, F & G et al, 2022 in prep

Conclusions

***Test**: Accuracy & Precision*
Experimental Design
Minimal & high-throughput testing

*Structural & physical / mathematical **models** as basis for optimum yield of information from testing.*

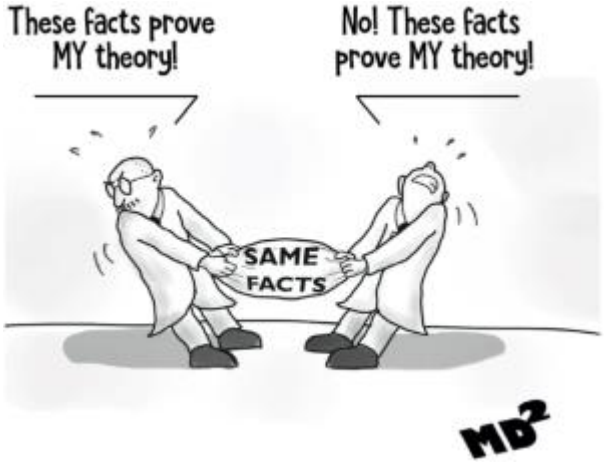


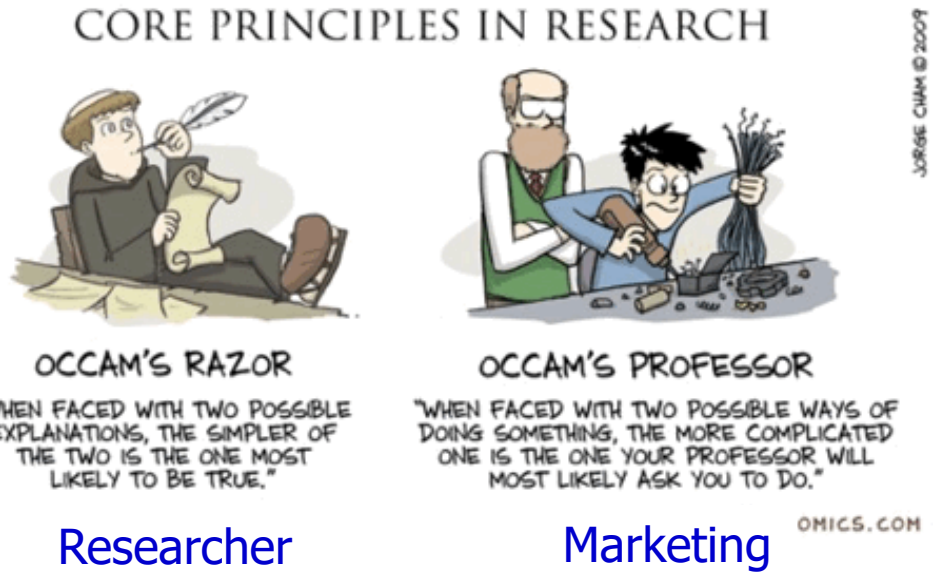


*Which fundamental or strategically important **concepts** are supported or challenged by the data?*

Epilogue: Conflict of Goals

Over- and under-interpretation of tests/models/concepts: Challenges & Opportunities





Researcher Marketing

www.nature.com/articles/s41565-022-01166-5

https://i.pinimg.com/originals/f0/99/6a/f0996abbfcb2f0e9644c839686f4bb9f.gif

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Jutta Quadflieg (DWI, 2003)

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Natalja Focht (UoM/Henkel, 2016)
Katie Hardie (UoM, 2017)
Thomas Davies (UoM, 2019)
Therakanya Sripho (UoM, 2019)

Leila Berriche (Uni Hamburg/Henkel)

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Thank you for your attention!