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Hair Testing: Opportunities & Challenges

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32nd IFSCC Congress

19 -22 September 2022, London

Beauty for a New Age Session 4: Major Advances in Hair Science and Technology

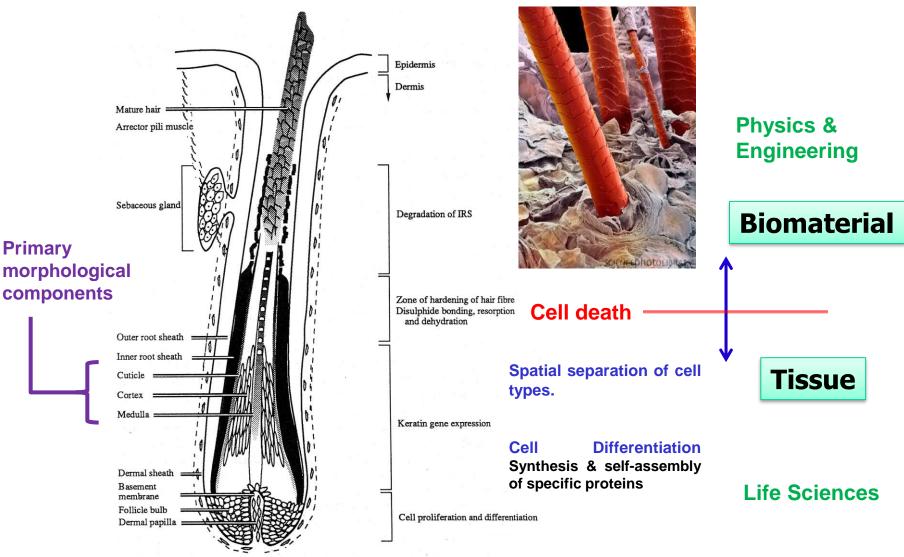
Hair Testing: Opportunities & Challenges

<u>A - very - Personal View</u>

Franz J. Wortmann

School of Natural Sciences, Department of Materials The University of Manchester, UK F & GW – Consultants, Aachen, GER

Material I: The Two States of Hair



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/

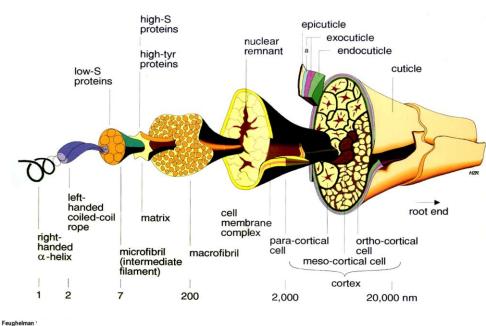
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Material II: Fibre Structure

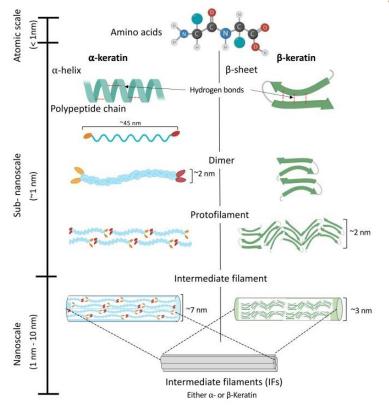
Hair cosmetics deals with the mature, 'dead' hair shaft.

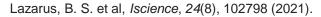
The hair shaft is a very complex biological composite material.

The general structural features are consistent across animal hairs.



Merino Wool: Feughelman 1997 adapted from Fraser 1981





Hair Cosmetics R&D and Hair Testing

Anatomy of a claim Leaves, Fruits & Flowers This is "What the **Product Says it Does**" Flow (e.g., "It moisturises") **Beauty from Concept to Consumer** đ A Series of 4 Educational Workshops at IFSCC 2022 Direction This is "What the **Product Actually Does**" Trunk (e.g., "Repairs") www.comicagile.net Comic Agilé How to reach an end user This is " Why the "P oduct Does What it Does" Roots Ale (e.g., "All the scientific and research information continually generated") SQL Callaghan Consulting Inter Business Analyst Developer The Anatomy of a Claim Adapted from: T M Callaghan, HPC Today 17(3), 11 (2022) Commercial Project Mgr. Product Technical Business Project Mgr. Specialist 00

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Custome Created by Luxshan Ratnaravi & Mikkel Noe-Nygaard

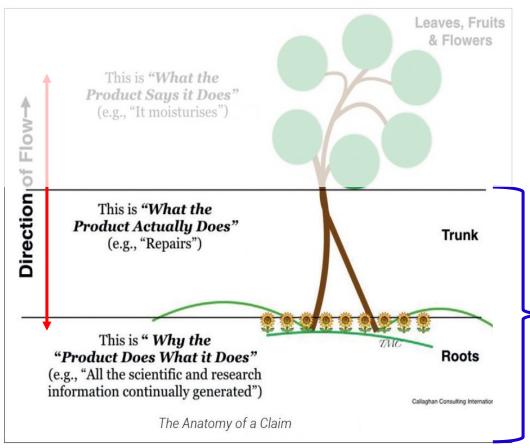
End User

Sales

Engineer

Key Account Manager

Claims & Laboratory Testing



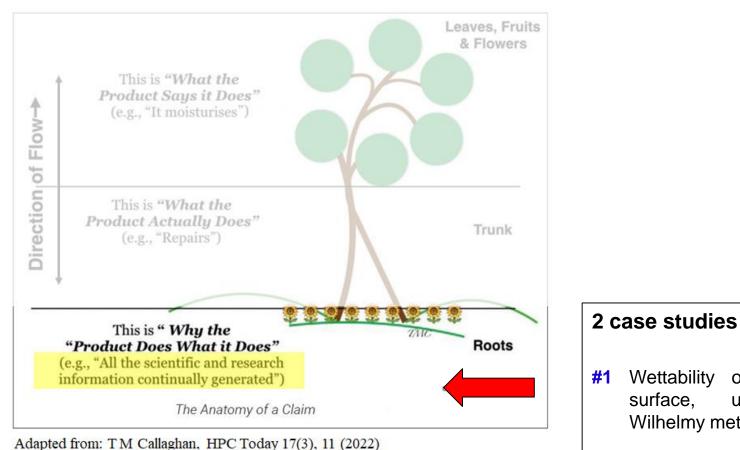
Adapted from: T M Callaghan, HPC Today 17(3), 11 (2022)

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

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#1 Fundamental Investigations



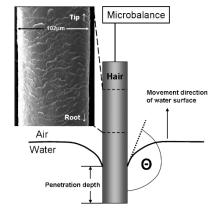
Wettability of the hair using the Wilhelmy method

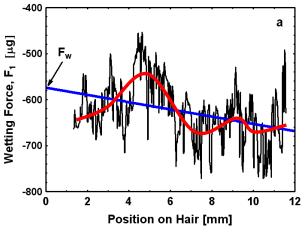
#2 Why is hair curly?

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#1.1 Wettability of the Hair Surface

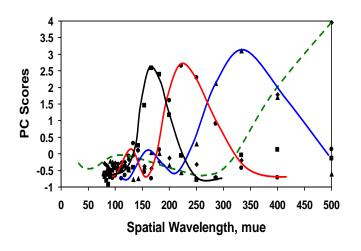
Wortmann, F. J., Wortmann, G., & Schulze zur Wiesche, E. (2010). *Langmuir*, *26*(10), 7365-7369.



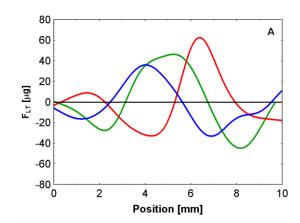


The principle of the Wilhelmy method

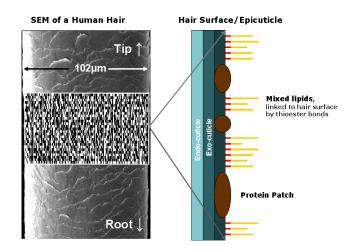
Primary data & baselines



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



Characteristic baselines for young women



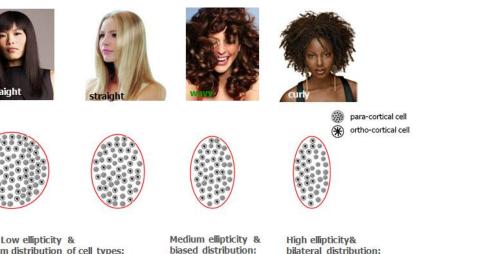
Concept for the dynamics of the surface composition of hair

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#1.2 Why is hair curly?

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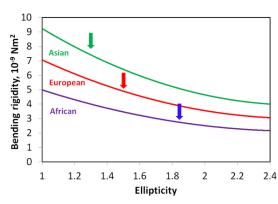


No or Low ellipticity & random distribution of cell types: **Straight Hair**

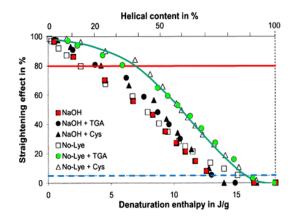
biased distribution: Slight/medium curl

Strong curl

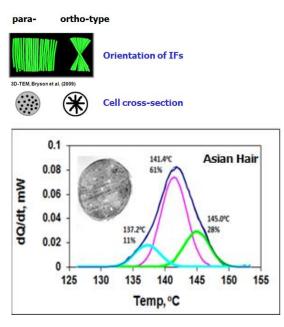
- 1 Curl formation depends, primarily, on the lateral segregation of ortho & para-cortical cells.
- 2 There is no role of follicle shape or mechanical processes.



Ellipticity plays a strong synergistic role for curl formation



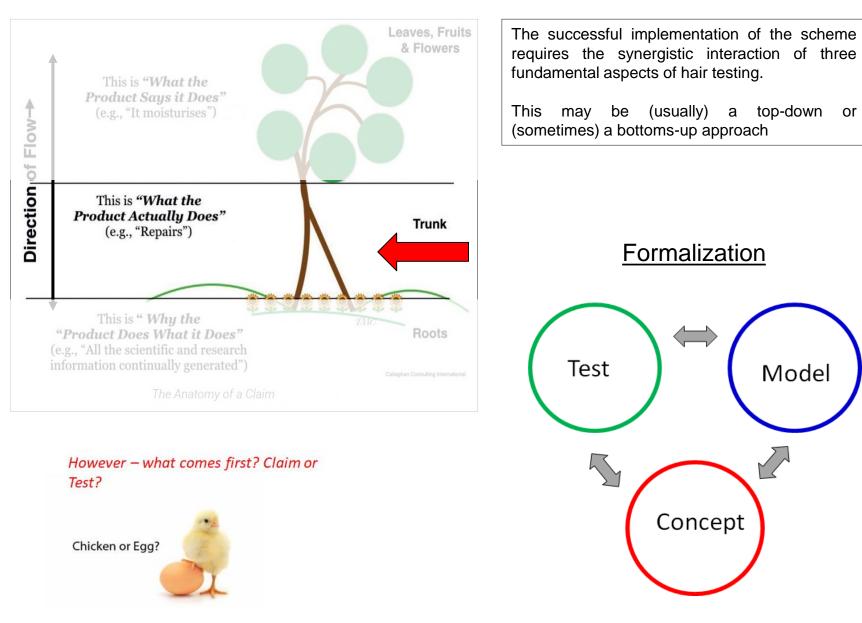
IFs form the scaffold for a natural curl



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

> 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



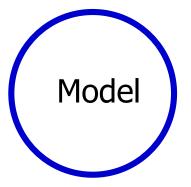
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Testing Hair & its `Environment`

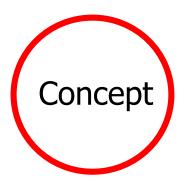


General requirement for a test: Accuracy & Precision: Without precision data no comparative statement, eg between Sample A vs B, can validly be made. Case: Fatigue-failure Testing.



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

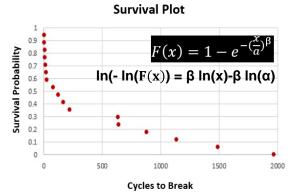
Case: Hair Torsion



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

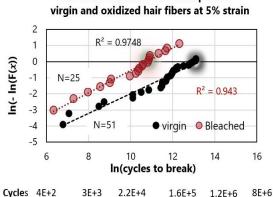
#2.1Constant Strain Fatigue-Failure testing





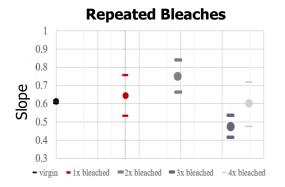


Weibull model: Survival probability follows a simple exponential decay

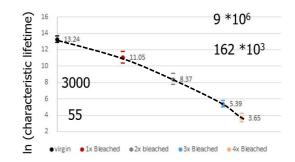


Weibull cumulative survival plot for

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



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



In(characteristic lifetime) follows simple (1st order?) kinetics, Precision constant,

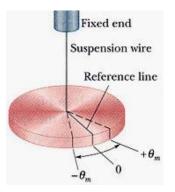
Model approach enables

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

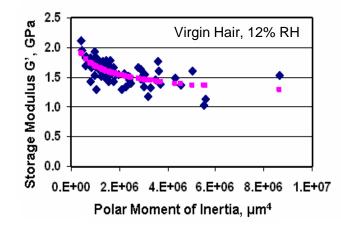
Berriche, L et al; TRI Hair Conf 2022

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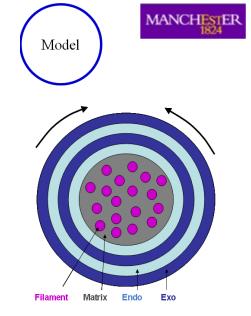
#2.2 Torsional Testing of Human Hair



The torsional pendulum

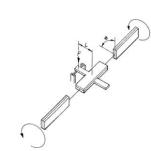


Torsional modulus changes with PMI. G' is not a material constant.

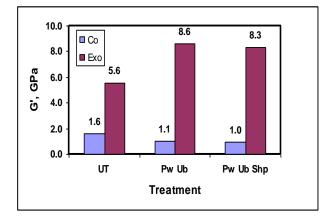


 $G^* = (G^*_{co} I_{co} + G^*_{cu} I_{cu})/I$ co = cortex

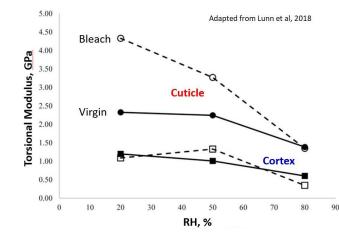
cu = cuticle



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



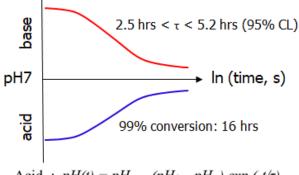
Torsional modulus contributions of cortex and cuticle can be separated.



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.

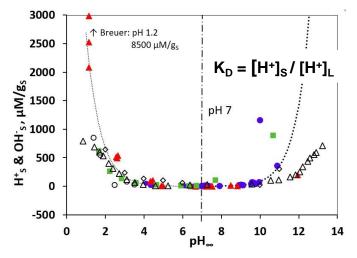
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#2.3 pH-Adjustment of Human Hair (HCI & NaOH)

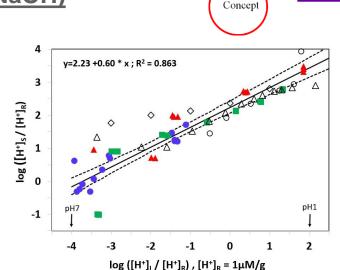


Acid : $pH(t) = pH_{\infty} - (pH_0 - pH_{\infty}) \exp(-t/\tau)$ Alkali : $pH(t) = pH_{\infty} + (pH_0 - pH_{\infty}) \exp(-t/\tau)$

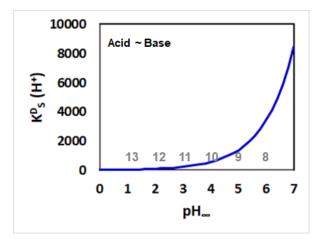




Experimental & literature data (hair & wool) follow the expected U- shaped curve. Equilibrium uptake in experimental pH-range is questionable.



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.

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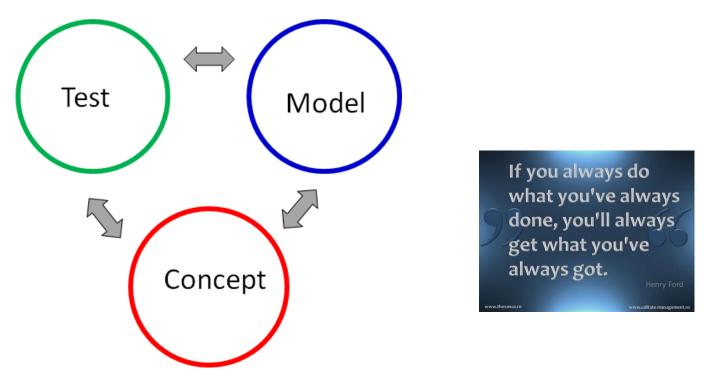
Conclusions

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

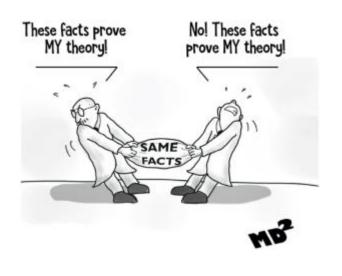
Structural & physical / mathematical **models** as basis for optimum yield of information from testing.



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



CORE PRINCIPLES IN RESEARCH



OCCAM'S RAZOR

"WHEN FACED WITH TWO POSSIBLE EXPLANATIONS, THE SIMPLER OF THE TWO IS THE ONE MOST LIKELY TO BE TRUE."

Researcher



OCCAM'S PROFESSOR

"WHEN FACED WITH TWO POSSIBLE WAYS OF DOING SOMETHING, THE MORE COMPLICATED ONE IS THE ONE YOUR PROFESSOR WILL MOST LIKELY ASK YOU TO DO."

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

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

Acknowledgements

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Leila Berriche (Uni Hamburg/Henkel)

and a large number of more indirectly involved former and current students, as well as numerous collaborators and sponsors in the international cosmetic industry.

Thank you for your attention!

