Biophysics of Curly Hair

Link to publication record in Manchester Research Explorer

Citation for published version (APA):
Wortmann, F., & Wortmann, G. (2016). Biophysics of Curly Hair: Why is hair curly, wavy, or straight?.

Citing this paper
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Biophysics of Curly Hair

Why is hair curly, wavy or straight?

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Hair formation

Primary morphological components

Cell death
Spatial separation of cell types.

Cell differentiation
Synthesis & self-assembly of specific proteins

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

http://naturalegions.com/2012/08/10/the-scalp-get-their-right-and-your-hair-will-grow/
Keratin Material: General Morphology of a Fiber

Basic, ethnic hair types

straight  

wavy  

curly
Crimp & fibre morphology in fine wool:
Early investigations

Hypothesis: The side-by-side structure leads to the induction of fibre crimp in Merino wool.

- o-cortex on the outside
- p-cortex on the inside

Other geometries of cell separation lead to less pronounced or no crimp for other types of wool.

Cell fractions change with fibre diameter:
More ortho-, less clear separation – less crimp (Orwin & Woods, 1980)

Hypothesis: The side-by-side structure leads to the induction of fibre crimp in Merino wool.

- o-cortex on the outside
- p-cortex on the inside

Cortical cell distribution in straight & curled Japanese hair

para- ortho-type

Orientation of IFs

Cell cross-section

Bryson et al. observed basically four types of cortical cells:

- A: ortho-type – convex side
- B: ortho/meso-type
- C: para-type – concave side
- D: minor component

Biomechanically, the side-by-side arrangement of o-type & p-type cells will upon keratinisation induce fibre crimp (Munro & Carnaby, 1999)
Wool & hair: Cortex compositions

Thermal analysis (DSC) shows distinct differences for the thermal stability of helical IF proteins in ortho- and para-type cells, leading to unsymmetrical endotherms. The differences between denaturation temperatures are distinct for wool and more subtle for human hairs. Cortical cell fractions are very similar for different hair types and size-wise in line with expectations for coarse wool.

This supports the hypothesis that curl is only related to the lateral segregation of cell types with different types of IF orientation.

IF denaturation & hair self-straightening

Due to the pronounced correlation between straightening effect and helix-content, the mechanism of self-straightening is identified as the alkali-induced denaturation of α-helical segments in the IFs. This in turn confirms the role of IFs and their orientation for maintaining macroscopic hair shape.

Quadflieg & Wortmann, 2011
The role of fibre ellipticity for curl formation

It is intuitively clear that for equal cross-sectional area an elliptical fibre will be easier to bend (across its short axis, $b$) than the equivalent circular fibre.

As a consequence elliptical fibres can form tight curls with only a comparatively low degree of stress-imbalance upon keratinization.

Round fibres for the same pre-condition would just form slight waves.

Role of the follicle form

Hair, emerging from a curved follicle, generally shows retro-curvature.

If this effect is insufficient or absent, dermatological consequences may occur.
Follicle activities

A huge number of processes occurs in the follicle under genetic control.

Those contributing to hair form need to relate to

• IF-aggregation
• lateral cell segregation

Different cortical protein types are formed with lateral segregation.
Langbein, 2003
Other source: Thibaut et al., 2007

Biomechanics of hair forms: Primary cases

straight
straight
wavy
curly

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

Medium ellipticity & biased distribution: Slight/medium curl

High ellipticity & bilateral distribution: Strong curl
Thank you for your attention!