Biophysics of Curly Hair

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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

Cell proliferation and differentiation


http://naturalnigerian.com/2012/03/hair-101-the-scalp-get-the-right-and-your-hair-will-grow/
Keratin Material: General Morphology of a Fiber

Intermediate Filaments (IF)
Matrix (IFAP, KAP)

Basic, ethnic hair types

straight
wavy
curl
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)

Horio & Kondo, 1953
Mercer, 1954

Cortical cell distribution in straight & curled Japanese hair

Orientation of IFs

para- ortho-type

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)

A: Straight hair
B: High-curvature hair

Convex: Outside curve
Concave: Inside curve

Bryson et al., J Struct Biol 166 (2009) 46-58

Swift, 1997
Kajitura et al, 2006
Nagase et al, 2008
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.

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 IFs.

This in turn confirms the role of IFs and their orientation for maintaining macroscopic hair shape.
The role of fibre ellipticity for curl formation

Asian Hair  European Hair  African Hair

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

Collapse into equilibrium fibre shape upon cross-linking and drying.

Increasing metastability due to cell segmentation

Gel-like, stable, straight 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

http://stylesatlife.com/articles/different-hair-types/
Thank you for your attention!