pH and Thermal Perturbations Disrupt Human Stratum Corneum Lipid Organisation: Biophysical FTIR Spectroscopy Studies

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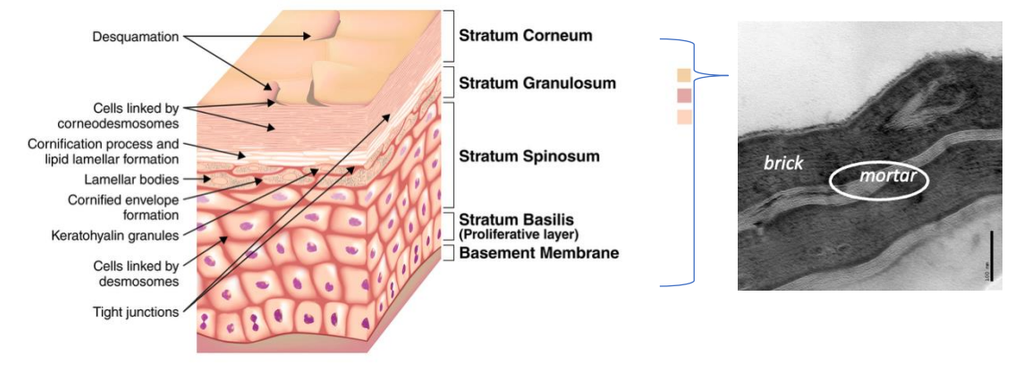
CONTEXT

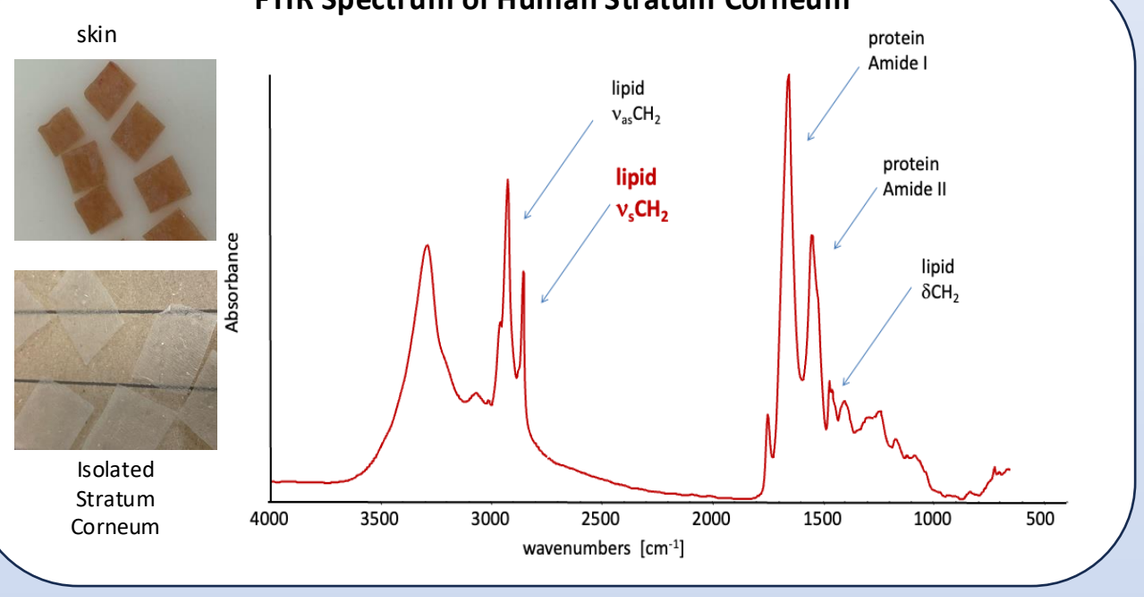
The outer layer of human epidermis, the stratum corneum (SC), which is essential to human terrestrial life, is exposed to physical and chemical challenges which can disrupt its essential barrier function. This can lead to the penetration of allergens and irritants in addition to water loss from the body. Skin cleansing often exposes the SC to alkaline pH and "hot" water while environmental temperatures >40°C are now routine. Both basic pH and increased temperature are associated with decreased skin barrier function. These external stresses are particularly significant for individuals with diminished barrier function due to life-stage or underlying disease.

EXPERIMENTAL APPROACH

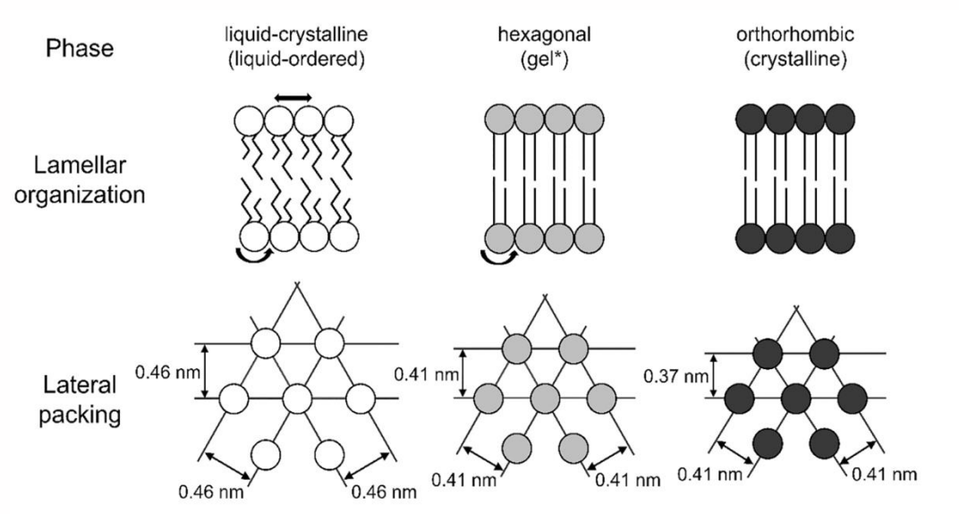
Biophysical Fourier transform infrared (FTIR) spectroscopy methods allow for the direct measurement of inter- and intra-molecular lipid organisation in the SC in a variety of experimental skin systems from *in vitro* models to human *in vivo* studies. Stratum corneum (SC) sheets were isolated from 2 cm^2 pieces of human skin by a standard trypsin separation method. SC sheets were sandwiched between ZnSe infrared windows and mounted in a temperature-controlled transmission holder. Spectra of SC were acquired as a function of temperature and time (depending on the experiment).



A common analogy for the SC is a brick wall as it consists of terminally differentiated cells (bricks) embedded in a lamellar lipid matrix (mortar) as indicated in the electron micrograph of SC.



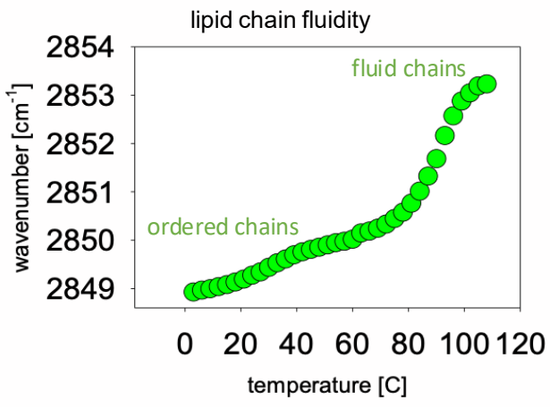
MEASURING LIPID INTER- AND INTRA-MOLECULAR ORGANISATION IN HUMAN STRATUM CORNEUM



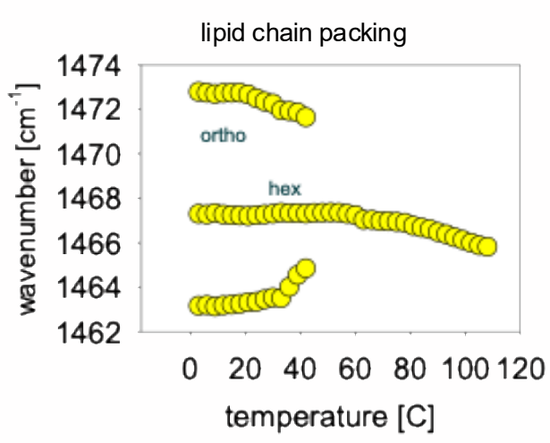
Lipid chain CH_2 vibrations are sensitive to molecular organisation and dynamics:

Conformational order (fluidity) is measured via changes in the methylene stretching frequencies.

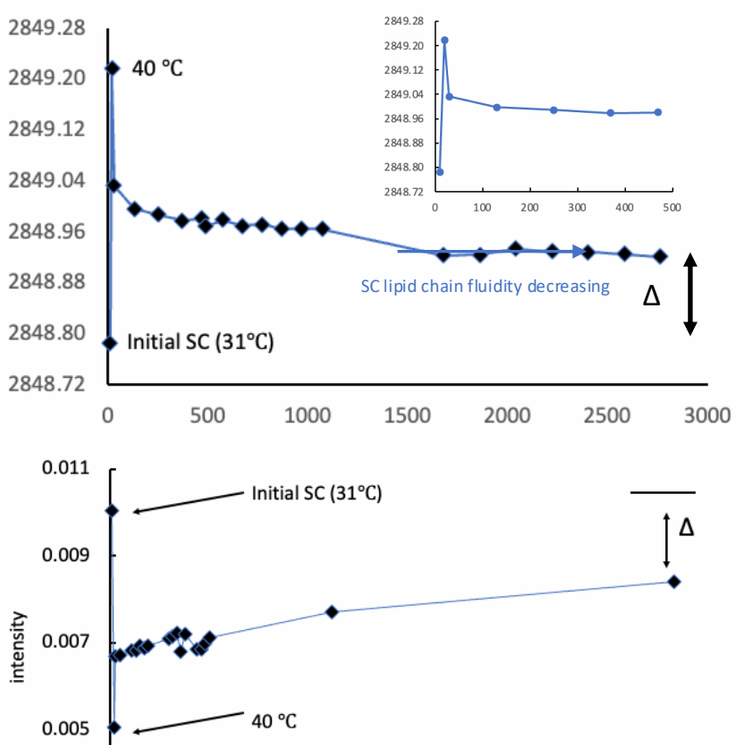
Chain packing (inter-molecular organisation) is measured via splitting in methylene rocking or scissoring vibrations.



The lipid lamellae of healthy human SC consists of fully conformationally ordered chains (no fluidity) at skin physiological temperatures (32°C).
A packing transition around 40°C is indicated. Chain fluidity begins above 60 °C.

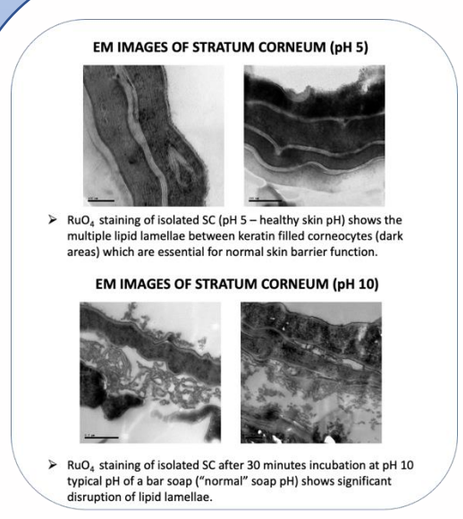


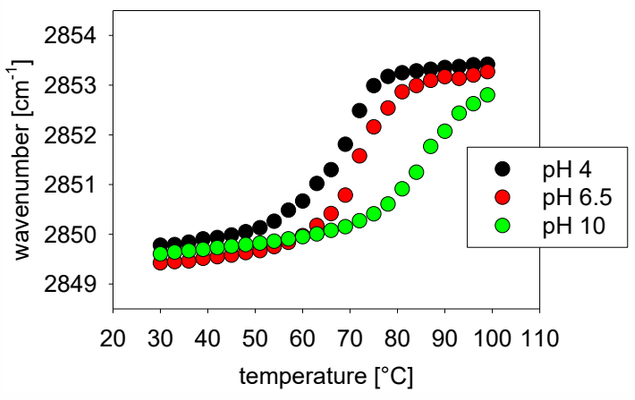
Orthorhombic (crystalline) and hexagonal chain packing is observed at skin physiological temperatures. All orthorhombic lipid packing collapses at 40°C in human SC.



Exposing human SC to 40°C disrupts orthorhombic packing and decreases chain conformational order. Neither parameter returns to baseline after 20 hours.

Skin barrier function compromised for >20 hours following a routinely encountered thermal perturbation (40 °C)





Exposing human SC to pH 6.5 and 10 results in a progressive higher lipid Tm compared to pH 4 (close to SC physiological pH). Skin cleansing with soap bars exposes skin to pH 9 -10.

Exposure to basic pH results disrupts SC lipid organization by selectively removing cholesterol and shorter chain lipids from the SC effectively changing the composition of SC and altering the molecular organisation of SC lipids. This leads to compromised skin barrier function and dry skin.

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