



## EPSRC OxpDE CDT Research Case Study Hamza Alawiye (Cohort 3 2016-2020)

### ‘Understanding the wrinkling of elastic bilayers: applying nonlinear analysis and computation’

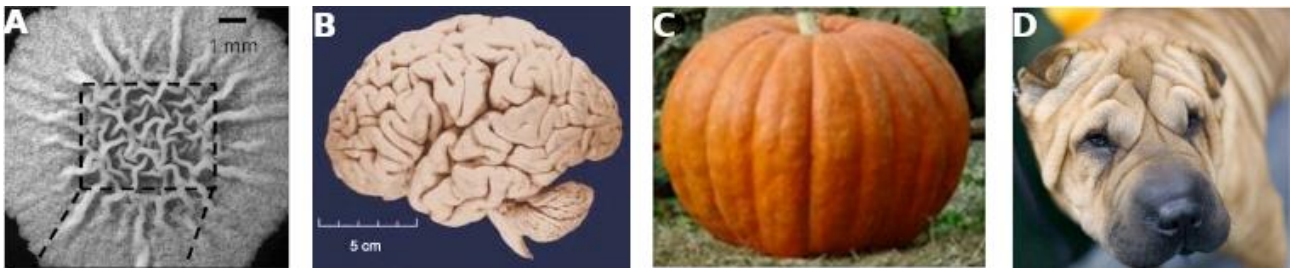


Figure 1: Examples of growth-induced wrinkling across different length scales: (A) a bacterial biofilm, (B) a human brain, (C) a pumpkin skin and (D) a Shar-Pei dog.

Image A from Asally et al. (2012), image B reproduced with permission from Hill & Walsh (2005), image C from Yin et al. (2008)©2008 National Academy of Sciences, image D by Dave Wharton, used under CC BY-SA 2.0

‘Wrinkling’ is a functionally important biological phenomenon that occurs in a variety of contexts and scales. In many cases, the formation of these patterns is driven by growth, whereby the biological tissue starts off smooth and develops wrinkles as it expands.

My research centred around understanding the **mechanics** of wrinkling for materials with a two-layered structure, such as the white and grey matter of the brain, using the mathematical theory of **elasticity**.

The theory of elasticity describes how certain solid materials behave when subjected to forces or tractions, and can be extended to include the effects of **growth** (*‘morphoelasticity’*). In both cases, the mathematics that allows us to calculate the shapes that materials take after applying external forces or internal growth is a system of **partial differential equations** that can be studied using a variety of means. In my thesis, I used a combination of traditional and computer-based methods to compute the critical parameters that dictate **when** wrinkling occurs and **how the patterns evolve** with growth and/or compression.

Understanding **when** wrinkling occurs for materials with different mechanical properties has a number of applications, especially in the context of engineering, where the ability to control the formation of such patterns has been applied to areas like flexible electronics, stimuli-responsive biomaterial design and measurement of material properties. In medicine, we have increasingly become aware that the shapes of many vital organs, including our brains, intestines and skin, are largely determined by these growth-induced mechanical wrinkling processes. Their patterned surfaces are crucial to their function and with a better understanding of how these wrinkled surfaces come to be, we can also begin to better understand how things can go wrong when they develop abnormally.