TU Delft

Bionanoscience Department
Think big about life at the smallest scale

Casimir PhD position

With funding from the NanoFront programme, there are five Casimir PhD positions available in Delft or Leiden for ambitious students who write their own research proposal. In short, these 4-year fully funded positions (salary plus a limited budget for material costs) will be available for the five best students who:

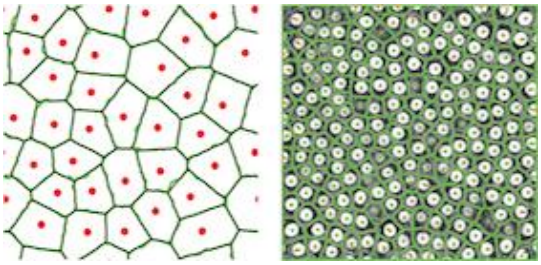
- obtain or have obtained an MSc degree in (Applied) Physics, Nanobiology, or another relevant research field between January 2020 and August 2021,
- send our jury a PhD proposal related to the NanoFront research program, and
- find a supervisor (PI) within our NanoFront program.

The complete guidelines for this competition are available via this link.
Applicants can download a format for the proposal here.

We have room for such a PhD student in the Idema group. Naturally, as the applicant, you can come up with your own suggested project, and we're happy to discuss any topic that would fit our general research scope (see last page). To help you get started, we also have a concrete suggestion, building on projects that have been done in the group in recent years.

Project suggestion: Mechanics of tissue development

During development, tissues undergo large conformational changes. The most striking one is gastrulation, where a spherical or ellipsoidal shaped embryo inverts to become a toroidal shape, creating the intestinal tract. As part of such changes, tissues have to sometimes behave as a solid, and sometimes as a fluid. The characteristic difference between solids and fluids here is their response to shear: solids will elastically deform, while fluids will flow.



Result of a simulation of the existing tissue model (left) and comparison of the predicted Voronoi tessellation to experimental images of early tissue in a Drosophila (fruit fly) embryo (right). Images from Van Drongelen et al. (2018).

In this project, we'll study the mechanics of a developing tissue, built from cells that we describe with a 'sticks and balls' model (where the 'balls' are the nucleus and part of the cortex/plasma membrane, while the 'sticks' are fairly stiff springs that connect the balls to each other, giving the cell rigidity while also allowing it to grow). We already know that this model can correctly predict the geometric pattern of the cells in an actual tissue. Here, we will first actively deform it by shearing, to see whether the resulting tissue is fluid or solid, and which parameters determine that. Second, we will punch a hole in the tissue, and see how it responds, both on short (mechanical response) timescales and on longer ones (where dividing cells can fill up the hole). Third, we will use the newly formed tissue to study development as the tissue differentiates (creating regions with different mechanical properties). We will also look at what happens if one or more cells become tumorigenic, an in particular investigate under which conditions a tumour might grow and eventually metastasize. An interesting option for a side project would be the study of the behaviour of first a single crawling cell, followed by interactions between small numbers of such cells. All these systems can be directly compared to experimental results.

This project can be driven in a mor physics-oriented direction, focusing on the material properties and 'soft matter' aspects (e.g. jamming) of the tissue, or a more biology/medicine oriented direction, focusing on the applications to wound healing, development, and tumour development.

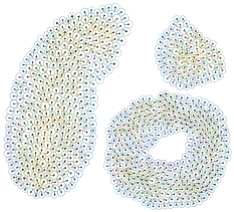
References:

- R. van Drongelen et al., Mechanics of epithelial tissue formation J. Theor. Biol. **454**, 182-189 (2018) / doi 10.1016/j.jtbi.2018.06.002 / arXiv:1705.06205.
- T. Idema, Mechanics in biology, Europhysics News **51/5**, 28-30 (2020) / doi 10.1051/epn/2020504.
- Various BSc and MSc theses from the Idema group (please contact Timon Idema for details).

Idema group – overview

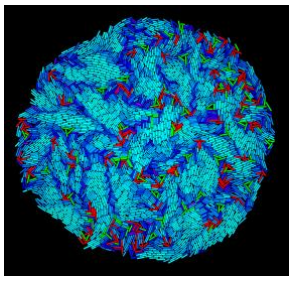
Biology is often highly nonlinear, which is good news for life: many actors together can accomplish what a few cannot, not just for lack of individual strength, but because the whole really is more than the sum of its parts. In our group, we study how collective dynamics of many particles, from protein inclusions in the membrane to growing and dividing cells in colonies, affect the function and behaviour of the living system they are part of.

From single to multicellular behaviour



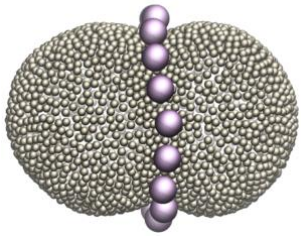
Individual cells and animals behave differently on their own than in a group. Being part of a group is often useful, for protection against outside factors like the weather or predators, or because together cells can achieve more than any single one could alone. We study the collective behaviour of self-propelled soft particles as a model for these systems, looking for a minimal set of rules that allows the cells to create complex patterns.

Development and defects in bacterial colonies and eukaryotic tissues



Many bacteria have rod-like shapes, which extend as they grow, and are halved when they divide. Due to this combination of geometry and growth, a bacterial colony becomes an active material with interesting topological properties, including such features as orientational regions and defects. Similarly, growing and dividing eukaryotic cells form tissues, both healthy and tumour cells. We study the development of both these systems in simulations.

Membrane-mediated interactions



When you put two balls on a mattress, they attract, because they deform the mattress. Two (or more) proteins in a membrane experience similar interactions because of the deformations they impose. Unlike electrostatic interactions, these membrane-mediated interactions are not additive, and can even change sign due to the presence of multiple proteins. Moreover, many membranes in living systems are naturally curved, creating a nontrivial energy landscape that depends on the relative curvature of the membrane and the imposed curvature of the protein. We study the patterns and shapes these membrane/protein compounds form, using both analytical and numerical tools.