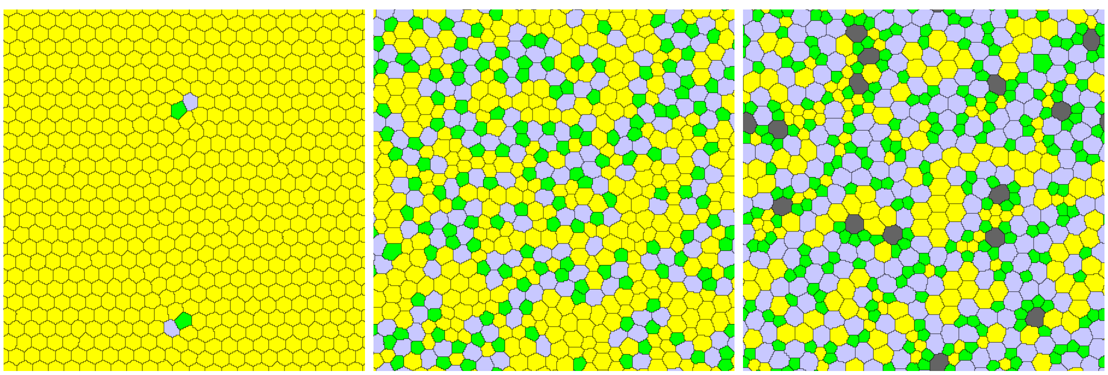
Uncovering shuffling mechanisms

M2 internship and/or PhD thesis

During at least four centuries, cellular patterns ranging from foams to biological tissues have attracted scientists and artists. The fascination they exert lies in the balance between small-scale regularities and global disorder. Mathematical quantitative descriptions of these patterns have alternatively emphasised the cell size, curvatures and angles (*geometry*) or the cell number of sides and neighbour relationships (*topology*), trying to establish correlations.

We propose to use statistical physics to investigate physical mechanisms underlying the observed disorders. We will build upon our two recent successes. First, analytically, within a mean field approximation (top-down approach), we have reproduced without any adjusting parameter the correlation between cell size and number of sides in a shuffled foam [1]. Second, numerically, we have developed a computer simulation (bottom-up approach) of shuffled cellular patterns which is now both realistic (see Figure) and efficient [2]. By combining both approaches, we are now able to investigate in detail the correlations in such systems.



Mixing large and small cells. From left to right : an increasing ratio of large to small size yields an increasing disorder. Colors label the cell side numbers, with hexagons in yellow.

• For an internship : At short term, the candidate will simulate shuffled patterns. She/he will quantify different variables such as size, number of sides, or positional and orientational order in 1, 2, or 3 dimensions. She/he will then quantify the correlations between cells at both small and large scales, first using existing characterisations, and then developing new ones.

• For a PhD : At long term, the candidate will compare mechanical vs thermal shuffling methods. She/he will quantify both the shuffling dynamics and the final shuffled state. She/he will then investigate other shuffling mechanisms such as those acting within biological tissues in response to membrane activity as well as to cell division, birth or death. She/he will study how the correlations and the parameters investigated during the internship evolve, starting from a well ordered hexagonal pattern. Finally, she/he will simulate the mixture of two cell sizes, or the mixture of two cell types, which should display a rich variety of behaviours.

[1] Durand M. & al., "Statistical mechanics of two-dimensional shuffled foams : Prediction of the correlation between geometry and topology", *Physical Review Letters*, **107**, 168304 (2011).

[2] Durand M. & Guesnet E., "An efficient cellular Potts model algorithm that forbids cell fragmentation", *Computer Physics Communications* **208**, 54-63 (2016).

Profile : physicist or engineer ; statistical physics, programming, cross-disciplinary research.

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