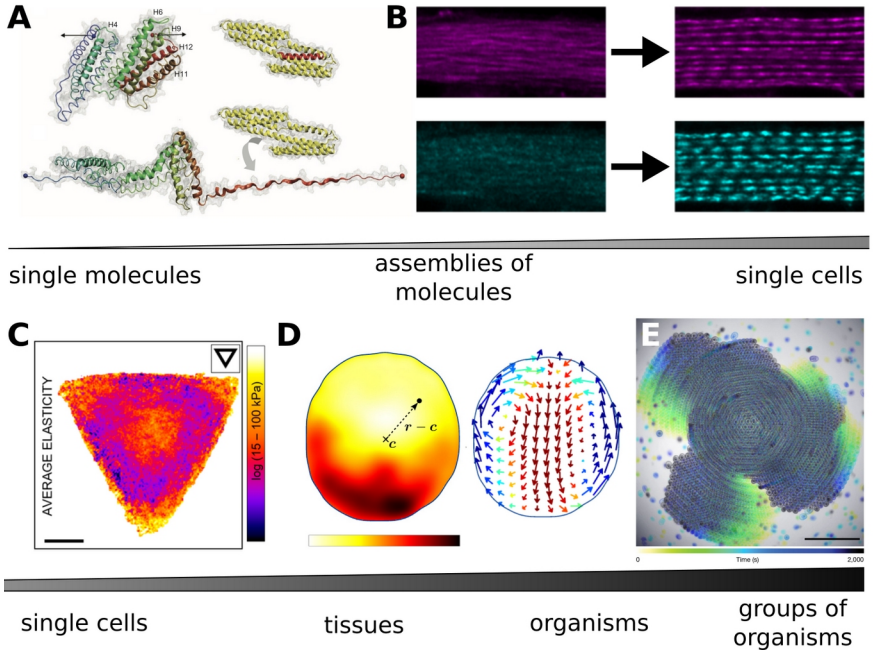
Mechanics and microstructure of living matter across length scales

Organizers: Matthias Merkel (CPT, Marseille), Felix Rico (DyNaMo, Marseille)
Support: Division of Physics and Life of SFP, GDR Quantitative Approaches of Living Systems (AQV)
Invited speaker: Alexander Mietke (Oxford, UK)

Biological systems can display different kinds of microstructure. For instance, molecules in cells, cells in tissues, and organisms in their swarms are often arranged in a disordered manner. Yet, there are also many examples of ordered microstructures (e.g. polar, nematic, or crystalline - Figures D, E). The goal of this colloquium is to present the state of the art in understanding the interplay between such microstructure and mechanics ranging from the single-molecule scale to the scale of groups of organisms.

One example on the molecular scale are structural changes of certain proteins in response to externally applied forces, which in turn facilitates binding of other proteins, an essential step in the formation of cell adhesion complexes (Figure A). Another example is the emergence of the crystalline structure of muscles, where mechanics has been proposed to play an important role (Figure B). On the cellular and tissue scale, cell mechanics both adapts to external structure (Figure C) but also feeds back on pattern formation. For instance, the polarization of cell aggregates is promoted by tissue flows created by cellular interaction forces (Figure D). However, mechanics can also organize groups of living organisms. For instance, star fish can form chiral active crystals, whose dynamics is determined by hydrodynamic interactions between individuals (Figure E).

The goal of this mini-colloquium is to exchange about the different ways in which living matter can be organized by mechanics. How do structure and mechanics interact with each other in living matter? Are there common principles that appear across the different length scales?



(A) Part of the molecule talin, which unfolds upon force application, allowing for the binding of the molecule vinculin (del Rio et al, *Science*, 2009). **(B)** Fluorescence microscopy image of a muscle cell. Shown here are actin (magenta) and myosin (cyan). The images on the right were taken 8 hours after those on the left, showing the emergence of crystalline (sarcomeric) structure. (Kolley et al, *PRX Life*, 2024). **(C)** Spatially dependent Young's moduli within a single cell, measured using Atomic Force Microscopy. The cell is attached to a triangle-shaped, adhesively coated region (Rigato et al, *ACS Nano*, 2015). **(D)** Left: distribution of the protein T/Bra in a cell aggregate. Right: tissue flows in the aggregate, promoting a polarized T/Bra distribution (Gsell et al, *bioRxiv*, 2023). **(E)** Swimming starfish, which form an active, chiral crystal (Tan et al, *Nature*, 2022).