Interview with Jean-François Rupprecht (CPT, Marseille, France)

- Could you briefly describe your academic background and experience ? What led you to interdisciplinary research ?

“Choisir, c’est renoncer” as we sometimes hear; maybe interdisciplinary research was my way to defeat such odds. Maybe I wouldn’t be doing research at all if I had not grew up under the pristine skies of the French Alps. I spent nights starring at the Moon craters, planets and stars. My young attraction to astronomy could explain why, ten years later, when I got the question “what scientific field do you find particularly inspiring?” at the very end of my Ecole Normale Supérieure oral examination, I answered “astrochemistry”. Since the examiner positively nodded, it was probably not a bad answer; it was a sincere answer too (I rushed to related courses) yet I still had a tough time choosing in which field I would go on for my PhD. One day during my M2 in Theoretical Physics, urged by a procrastination moment, I googled the name of Steven Weinberg — a Nobel price awardee but also author of one of the standard textbook of Quantum Field theory I was supposed to study — and I found the following interview of him:

“When I was teaching at the Massachusetts Institute of Technology in the late 1960s, a student told me that he wanted to go into general relativity rather than the area I was working on, elementary particle physics, because the principles of the former were well known, while the latter seemed like a mess to him. It struck me that he had just given a perfectly good reason for doing the opposite. It really was a mess in the 1960s, but since that time the work of many theoretical and experimental physicists has been able to sort it out, and put everything (well, almost everything) together in a beautiful theory known as the standard model. My advice is to go for the messes - that’s where the action is.” Steven Weinberg[1].

I took this advice literally. And so I choose courses related to Statistical Physics — which, by definition, is all about messes. Statistical Physics was famously initiated by Boltzmann, who was trying to find universal laws emerging from the random motion of individual gas particles. In its current form, modern Statistical Physics focuses on the emerging collective properties of individual agents- not just gas particles, but also sheeps in a herd or traders in the global stock market. As such, Stat. Phys. has been applied to almost any fields, from Economy to Biology- sometimes revealing recurrent features behind these fields.

I did my PhD with Raphael Voituriez and Olivier Bénichou in Paris VI. We worked on random search process; the question there is: how long does it take for a random walker to find a particular region of space? The question had been formulated by Lord Pearson in 1907, who was interested in malaria propagation in British colonies: how long does it take for an infected mosquito, exploring space randomly, to locate its next victim? A first educated guess was provided by Lord Rayleigh, yet neglecting the role of spatial boundaries (e.g. the limit of the city, etc...).
During my PhD, I addressed that point and found that some geometry could significantly reduce the search time (even though the searcher is perfectly random). I also had a project on cell motility. I should mention that many cells, in particular immune cells, do not stay still and crawl around; they move in random directions but with some persistence. A team at the Institut Curie had organised the first World Cell Race; they had analysed the thousands cell trajectories gathered during the Race, and what they had found was strikingly robust: the faster the cell, the longer it would take to flip direction — and that for any eukaryotic cell. With Raphael, we got to explain all experimental features within a single theoretical framework- that was particularly satisfying to me! I then went on with a one year project with Lydéric Bocquet. We worked on magnetotactic bacteria, a fascinating class of micro- organisms which can orient their swimming direction along the Earth magnetic field lines — it is still not so known what is the evolutionary advantage provided

---

[1] Nature 426, 389 (2003) doi:10.1038/426389a

by following magnetic lines. What we showed is that these bacteria can exhibit a diverging “susceptibility” under which they will flow together even if they are far from each other. Around that time, I also had the great chance to meet Jacques Prost, who was thinking about recruiting a new post-doc for his joint appointment at the Mechanobiology Institute, in Singapore. He was also thinking about a fluctuating active gel theory, and I embarked on the project. Active gel theory is a hydrodynamic approach that include mechanical contributions related to energy consumption; it is generic, meaning that the same set of equations can describe the large-scale properties of the intracellular medium (composed of myriads of molecular motors) or that of epithelial tissues (composed of thousands of cells). Active gel theory had been successfully applied to several systems, ranging from cell division to embryogenesis. Working in parallel on a variety of subjects ranging from molecular motors to tissue mechanics, I had a very enriching experience during these 3 years spent in Singapore.

- What led you to CENTURI ? Could you describe us your research projects and perspectives within CENTURI ?

I had been acquainted with some of the work of several groups that are now within CENTURI for quite some time: my first exposure dates from my M1, in 2010; I participated to a CIRM summer school organized by the Math department of ENS about the math/biology interface- a course worth 6 ECTS, aka academic credits.

From the Mechanobiology Institute in Singapore, I had a privileged view on many aspects of the research achieved within CENTURI groups. As I became more familiar with the concepts of signalling and mechanical transduction, I found many opportunities of collaborations with groups in CENTURI, working on cellular adhesion for example. In particular, several groups at the Institut de Biologie du Développement Marseille are top-notch experts in imaging techniques of Drosophila embryonic development and master the most recent techniques in microscopy, which enable to image the whole embryonic development of a Drosophila embryo at unprecedentedly high resolution, both spatially (sub-cellular) and temporally (seconds). I think that interpreting this new data requires new theoretical approaches to understand the relation the biochemical activity (at the cell level) and the global embryonic properties.

My CENTURI research proposal at bridging gaps between cell molecular biology and the physics of large scale embryonic flows, in particular through the development of new conceptual and computational tools. Particularly central is the role of fluctuations, form which I believe that we can extract lots of information about the system under study.

I am also particularly enthusiastic by the opportunity of joining a theory lab such as the CPT. I’m really looking to expand the scope of my theoretical expertise. It is also great to have Matthias Merkel and Hervé Rouault as office mates, who have a great experience in the tissue mechanics fields; but I’m also looking forward to have interactions with other CPT members- to name a few, Xavier Leoncini and Alain Barrat; epithelial tissues have been described as active nematics, showing glassy features, thus I think there is plenty of room for collaboration on these subjects.

- What are your first impressions about CENTURI ?

I’ve only recently joined, but I certainly have a good feeling about it!
In particular, there are groups who are working on interested in probing the mechanical properties of tissues, and so I’m particularly eager to interact on this subject.