M2 INTERNSHIP PROPOSAL

Laboratory name: Physics of Cells and Cancer
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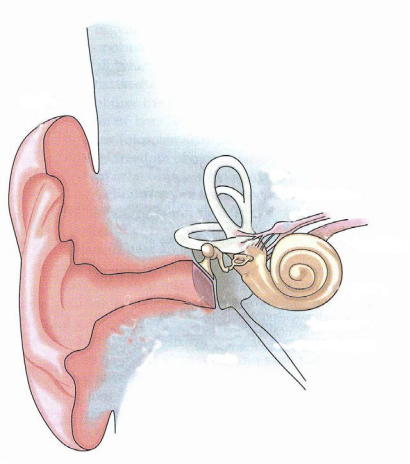
Thesis possibility after internship: YES

Sound emission by coupled critical oscillators in a nonlinear model of the ear's cochlea



Sounds are detected and amplified in the inner ear's cochlea by active mechano-sensory hair cells. The hair cells are each tuned to a characteristic frequency of the sound input and spatially distributed in the organ according to a frequency map. Our working hypothesis (1) is that each hair cell operates as a critical mechanical oscillator poised near the onset of an oscillatory instability—a Hopf bifurcation. Because of lateral coupling via hydrodynamic and viscoelastic interactions, sound stimuli evoke nonlinear traveling waves that reach a frequency-specific position in the cochlea where the local oscillators are brought into active resonance. We have recently developed a numerical model of the cochlea based on a string coupled critical oscillators that are organized according to the frequency map of the cochlea (2). The model is able to reproduce the cochlear response to pure tones at varying sound-pressure levels. The objective of the traineeship will be to study how coherent reflections of the traveling waves within the cochlea may give rise to active sound emissions by the ear, called oto-acoustic emissions, which are well characterized experimentally but still poorly understood.

The theorerical work will be performed in collaboration with Carles Blanch Mercader (PCC), Jean-François Joanny (Collège de France) and Frank Jülicher (MPIKS, Dresden). It will involve both analytical and numerical studies, for which prior experience with the Python programming language is required. The trainee will also be exposed to the experimental work on single hair-cell mechanics routinely performed in the team.

KEYWORDS: hearing, coupled oscillators, bifurcation theory, nonlinear waves, out-of-equilibrium physics, numerical simulations.

REFERENCES:

1. A. J. Hudspeth, F. Julicher, P. Martin, A critique of the critical cochlea: Hopf--a bifurcation--is better than none. *Journal of neurophysiology* **104**, 1219–29 (2010).
2. Ver Hulst H, Blanch-Mercader C, Martin P, Nonlinear tuning from coupled critical oscillators in a travelling-wave model of the cochlea. (2024) DOI: 10.5281/zenodo.13342229.