Introduction to Mechanics of Swelling

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Programme by days

lecture 1. Introduction to Foundational Physics of Mechanics of Swelling

- Material that swell: hydrogels & water (yes), rubber & water (no); which are the differences ?
- Short overview of basic thermodynamical issues: mixing and elastic energies.
- Flory-Huggins mixing energy, neo-Hooke and Arruda-Boyce elastic energies: from statistical to continuum mechanics.

lecture 2. Basic elements of mechanics of swelling

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- Gel body and body configurations: spatial and material description of mechanics.
- State variables and balance equations of forces and liquid mass.
- From the mixing and elastic energies to chemical potential, liquid fluxes and stresses.
- Boundary and initial conditions of the mechano-diffusion problem.

lecture 3. The free-swelling problem

- The equilibrium free-swelling state: controls and characteristics.
- Pressure balance and imbalance: osmotic versus mechanical pressure.
- An example of confined swelling.

lecture 4. The traction problem

- From the dry to the wet Rivlin traction problem: controls and characteristics
- Some comments on stability of solution: the role of the Flory-Huggins parameter.
- The uniaxial traction problem: controls and characteristics.

lecture 5. Swelling in active gels

- Which are active gels?
- The change of paradigm in the control of the solution.
- The free-swelling problem revisited.

References by lectures

lecture 1.
- M. Doi - *Soft Matter Physics*. Cambridge University Press, 2013 (Chapter 3).
- L. Teresi - *Gel Dynamics*. Internal Report, 2016.

lecture 2.
- A. Lucantonio, P. Nardinocchi, L. Teresi - *Transient analysis of swelling-induced large deformations in polymer gels*. Journal of the Mechanics and Physics of Solids 61 205-218, 2013.

- S.A. Chester, L. Anand - *A coupled theory of fluid permeation and large deformations for elastomeric materials.* Journal of the Mechanics and Physics of Solids 58, 1879Ð1906, 2010.
- M.E. Gurtin, E. Fried, L. Anand - *The Mechanics and Thermodynamics of Continua.* Cambridge University Press, 2010.

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- F.P. Duda, A.C. Souza, E. Fried - *Solvent uptake and cavitation.* Journal of the Mechanics and Physics of Solids 59 2341-2354, 2011.
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- R.S. Rivlin - *Stability of pure homogeneous deformations of an elastic cube under dead loading.* Quarterly Appl. Math. 32(3), 265-271, 1974.
- P. Nardinocchi and L. Teresi - *On the active response of soft living tissues.* J. Elast. 88, 27-39, 2007.
- P. Nardinocchi and L. Teresi - *Actuation performances of anisotropic gels.* Journal of Applied Physics 120, 215107, 2016.
- M. Fujine, T. Takigawa, and K. Urayama - *Strain-Driven Swelling and Accompanying Stress Reduction in Polymer Gels under Biaxial Stretching.* Macromolecules 48, 3622-3628, 2015.

lecture 5.

- Y. Ideses, V. Erukhimovitch, R. Brand, D. Jourdain, J. Salmeron Hernandez, U. R. Gabinet, S. A. Safran, K. Kruse, and A. Bernheim-Groswasser - *Spontaneous buckling of contractile poroelastic actomyosin sheets.* Nat. Commun. 9, 2461, 2018.
- J. Prost, F. Julicher and J-F. Joanny - *Active gel physics.* Nature Physics 11, 111-117, 2015.
- M. Curatolo, P. Nardinocchi, and L. Teresi - *Dynamics of active swelling in contractile polymer gels.* J. Mech. Phys. Solids 135, 103807, 2020.