Topics in the Mechanics of Soft and Biological Matter

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The subject of these lectures will be recent developments in the Mechanics of Soft and Biological Matter, with special emphasis on the modeling of the elastic properties of polymer networks. These provide the basic architecture for rubber-like solids, one of the key examples of successful application of nonlinear elasticity.

By embedding nematic mesogens in the polymer chains, nematic elastomers can be obtained. These are phase transforming materials exhibiting large spontaneous strains when heated or cooled by few degrees, or when they are exposed to light. The instabilities associated with the non-convexity of the governing energy functionals explain the ability of these materials to respond with large effects to small external stimuli.

Active polymer networks are those in which filaments are allowed to grow by polymerization, or in which motor proteins binding to the filaments force them to slide against each other and the network to deform. Active networks of actin filaments are at the root of cell motility and self-propulsion of microscopic organism. Here a key problem is to understand how, thanks to the interactions with a surrounding medium, a desired positional change can be accomplished by executing a suitable history of shape changes (a stroke). This is a problem of controllability, while searching for strokes that minimize the required energy consumption leads to a problem of optimal control.

A tentative outline of the lectures:

Part 1. Nonlinear elasticity of rubber-like solids.

1.1. Mechanical response of classical elastomers
1.2. Nematic elastomers: material instabilities and soft response

Part 2. Motility at microscopic scales

2.1 Swimming of micro-organisms as a control problem
2.2 Crawling of cells on solid substrates