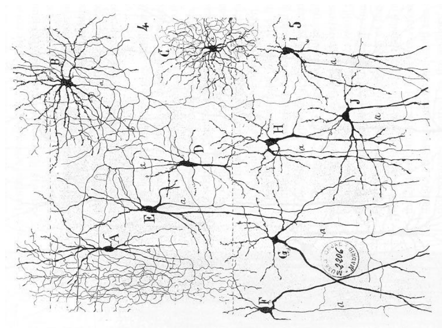
Special course: Network Dynamics and Synchronization Theory

Networks pervade all areas in nature and technology, from statistical physics over engineering to biology, and from small to large scales. They coordinate complex interactions on the level of cells, of organisms and of society. Dynamically interacting units in such networks include wind turbine generators, neurons, or pacemaker cells in the heart. When such units oscillate, they may exhibit *synchronization* — a self-organizing principle that may be seen in a large variety of systems, e.g. pendulum clocks, Josephson junctions, pedestrians on a bridge, circadian clocks in the brain, and wireless networks.

This special course aims at introducing advanced students to the world of network dynamics, with a particular focus on coupled oscillator networks. The course introduces the student to network theory and to the concept of network dynamics, i.e., the theory of dynamics on and of networks. The main focus of the course is on coupled oscillator networks and synchronization dynamics in complex networks, including dimensional and mean field reduction methods, and discuss extensions of these to include dynamics on an of networks.

The detailed content and form of the course will vary based on the interests of the participants.

$$\frac{\mathrm{d}}{\mathrm{d}t}\theta_i = \omega_i + \sum_{j=1}^{N} K_{ij}\sin(\theta_j - \theta_i) \quad \frac{\mathrm{d}}{\mathrm{d}t}K_{ij} = g_{ij}(t, K_{ij}, (\theta_{i\in[N]}), (\theta_{j\in[N]}))$$



What you will learn about:

- Classification of complex network structures and network dynamics
- Applications in biology (neuronal networks, vascular networks, fireflies, ...) and technology (Josephson junction arrays, MEMS arrays, power grids structures, wireless networks,...)
- Elements of network theory and introduction to complex network structures (Erdösz-Renyi, Barabasi-Albert, Watanabe-Strogatz)
- Dynamics *on* networks:
  - Kuramoto model
  - Networks of coupled Theta neurons
- Exact mean field reduction techniques
- Synchronization manifolds
- Synchronization patterns and chimera states
- Master stability function, graph Laplace spectra
- Continuous graph descriptions (graphon limits)
- Dynamics *of* networks (first unrelated to oscillators)
- Introduction to adaptive dynamic networks, including neural networks
- Applications of coupled oscillator networks in science and technology
- Co-evolutionary networks / adaptive dynamics networks

Practical information

- Taught during spring semester 2020
- MSc/PhD level
- 5 ECTS
- Course responsible: Erik A. Martens
- **Sign up: write email to eama@dtu.dk**