MTH 995-1, Mathematical modeling of human sensory systems

(TuTh, 2-4pm, Fall 2014)

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Human sensory systems are a part of the nervous system that is responsible for processing of vision, hearing, somatic sensation (touch), taste and olfaction (smell). They consist of sensory receptors, neural pathways, and parts of the brain involved in sensory perception. Human body operates on electricity. Our brain recognizes only electric signals, while external stimuli are chemical, physical, mechanical, thermal, acoustic, and photonic ones. It takes ion channels to transform external stimuli into electric signals. Neurons amplify and preprocess electrical signals before relay and transmit them to the related brain regions. We will try to understand the molecular mechanism of sensory systems, from various sensors and receptors (chemosensor, mechanoreceptor, nociceptor, photoreceptor, thermoreceptor), to second massagers, electrostatic depolarization, ion channel transport, action potential, and neuron transmitters and gene regulation. Molecular mechanism for synaptic plasticity and brain cognition will be discussed as well.

Utility and limitation of classical theories, including Goldman-Hodgkin-Katz equation, Hodgkin-Huxley model, Fitzhugh-Nagumo model and soliton model will be reviewed. We will also discuss a number of deterministic and stochastic models, such as Boltzmann equation, Boltzmann-Vlasov equation, Liouville equation; Zwanzig's equation, Fokker-Planck equation, Brownian dynamics, Langevin dynamics, molecular dynamics, master equation, Poisson-Nernst-Planck equations, Poisson-Kohn-Sham equation, Navier-Stokes equation, elasticity dynamics, Laplace-Beltrami equation, mean curvature flow, Willmore flow, Poisson-Boltzmann equation, Maxwell's equations, wave equation, anisotropic diffusion equation, and generalized Kohn-Sham equation. Multiscale models that couple macroscopic descriptions with microscopic descriptions will be discussed. Emphases will be placed on how to utilize the aforementioned models in a consistent manner for the description of sensory systems. We will make extensive use of fundamental laws of physics via variational approaches to derive governing equations for stimulus receptors, neural pathways and brain perceptions so as to understand sensory transduction from the physical world to the realm of the mind.