Microbes live in fluctuating environments that are often limiting for growth. They have evolved several sophisticated mechanisms to sense changes in important environmental parameters such as light and nutrients, after which they swim or crawl into optimal conditions. This combination of sensing changes in the immediate environment and transducing these changes to the motion organisms, allows for movement in a particular direction: a phenomenon known as “chemotaxis” or “phototaxis.” Using time-lapse video microscopy we have monitored the movement of phototactic bacteria, i.e., bacteria that move towards light. These movies suggest that single cells are able to move directionally but at the same time, the group dynamics is equally important. The various patterns of movement that we observe appear to be a complex function of cell density, surface properties and genotype. Very little is known about the interactions between these parameters.

In this talk, we will present a hierarchy of new models for phototaxis that were constructed based on the experimental observations. The first model is a stochastic model that describes the locations of bacteria, the group dynamics, and the interaction between the bacteria and the medium in which it resides. The second model is a new multi-particle system that is obtained from a discretization of the first model. Our third model is obtained as the continuum limit of the second model, and as such it is a system of nonlinear PDEs. Our main theorems clarify the sense in which the system of PDEs can be considered as the limit dynamics of the multi-particle system.