Abstract

Topic of this thesis is the investigation of the functional role of biological variability in pattern formation of the slime mould *Dictyostelium discoideum*. It is assumed that individual cell properties, which are constant in time, determine certain properties of excitation patterns during the developmental cycle of *Dictyostelium*. It is postulated that variability has regulatory functions in complex biological communication processes.

To answer this question spatial distributions of cell properties were extracted from excitation patterns of *Dictyostelium* with the help of spatiotemporal filters. During developmental cycle *Dictyostelium* undergoes a transition form the uni- to the multicellular state, mediated by chemotactic cell movement and spatiotemporal excitation waves of cAMP. These waves can be observed as propagating spirals and target waves. Since the properties of the excitation waves determine features of the developing multicellular organism, certain parameters of these patterns are more advantageous than others, in other words: wave properties are linked to a selective advantage. Therefore, it can be assumed that the biological system has evolved regulatory mechanisms to influence the features of these patterns.
The novel conceptual approach of the present thesis consists in studying the correlations between the regulatory principles occurring on the cellular level and the statistical properties of macroscopic aggregation patterns.

Rules of variability involved in pattern formation processes have been analysed numerically by a cellular automaton model and methods to analyse spatiotemporal data sets were applied to simulated patterns. Variability has been implemented as certain system parameters, which were fixed in space. Thus it was shown, that variability has a strong impact on the qualitative features of the simulated patterns. With the help of the mutual information and the fluctuation number, the latter of which estimates directed and undirected changes in state of an element in time and space, the spatial distribution of the underlying variability has been extracted.
To quantify the properties of these patterns, analytical tools to determine the positions of spiral tips and target centres were used, which are based on relative phase information of the single elements. Correlation analyses have revealed statistical probabilities for the development of phase singularities in dependence of the underlying distribution of pacemaker elements.

Next, the numerically established methods were applied to experimental data sets of *Dictyostelium* to visualize spatial distributions of cellular properties. At first, cells were synchronized in their cell cycle and populations of cells of different ages were mixed. This was done following a developmental path where the cells develop in desynchronized manner. This approach provides for a model where cellular heterogeneity is ensured. Pattern quantification was obtained by detection of phase singularities.

The estimation of directed and non-directed changes in spatial and temporal states by the fluctuation number showed that synchronous and non-synchronous cells can be distinguished, and that even the order of synchronisation can be calculated.

Complementary to this experiments where relative cell properties were changed, global properties of the cells were modified chemically. Applications of the observables on corresponding patterns showed no differences between the cells. It is noteworthy that patterns of synchronous cells and mixed cells neither differ in their qualitative features, nor show differing spatial densities in phase singularities. By contrast chemical modification of the cells induces dramatic effects on their patterns.

Correlation analysis between the spatial distribution of the fluctuation number and phase singularities showed positive correlations in many cases before patterns were developed, whereas such correlations could not been found from pure grey values of the patterns or randomly distributed phase singularities. In conclusion, it can be deduced that the symmetry breaking within a cell population happens before coherent wave structures appear and that appropriate mathematical methods can be used to extract such relations.