Physiological simulations of neuronal color coding in honeybees

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Abstract: Biological systems have developed by evolution, i.e. by genetic mutations and selection of organisms according to their macroscopic properties. This allows that even in complex biological systems, only a few physiological elements can determine the specific macroscopic behaviour of the entire system. Additional physiological elements may play only a secondary (rudimentary) role (as e.g. the energetic metabolism with respect to the electrical properties of neurons) or are used for additional macroscopic behaviours of the system which can be independently described. In this respect, physiologically adequate simulations appear to be indeed possible for specific purposes without the necessity of a complete description including all physiological elements of the biological system.
To obtain a physiologically adequate model,
1) one has to start with the simplest model possible, in order to avoid "trivial" mathematical models which posses as many variables (n) as measured data points available, which always allows perfect fits by e.g. polynoms of ninth degree.
2) In simulations with this model, critical predictions are then derived which
3) have to be tested further in critical experiments.
4) According to the outcome of these critical tests, the model will be modified in order to describe the physiological results even more adequate. This leads
5) to an iterative process in which the model becomes as complex as necessary for the given purpose and thus becomes physiologically adequate in the sense described above.
As examples for the power of this approach, the results of five different physiological simulations related to the neuronal colour vision system and the colour choice behaviour of the honeybee are presented:
1) the steady state model of neuronal colour coding and colour choice behaviour,
2) the simulation of the noise properties of the neuronal colour coding system and colour choice behaviour,
3) the temporal model of the membrane potential of photoreceptors,
4) the temporal simulation of neuronal colour coding, and
5) the simulation of co-evolution of neuronal colour coding systems of insects and light reflection spectra of plants.
Although the examples are descriptions on very different systems levels, i.e. on the molecular, organismic, and ecological level, all five examples clearly demonstrate 1) that physiological simulations of complex biological systems as perceptual neuronal systems, can indeed be systematically developed, even on PC's, according to the method described above, 2) that the results give additional insight into the "mechanics" of the neuronal sy-stems, and 3) that physiologically adequate models can even be used as biological explanation models.