MAT 591 Final Projects

Each student is required to write a short paper (about 3-5 pages, in font 11, double spaces) and a five minute presentation plus a 2 minute discussion. The short papers are due on April 20, and the presentations are given on April 22.

Below are the topics of the projects. Each chooses just one topic.

1. In the insulin injection model, can you find an expression of the time at which the peak of insulin concentration is attained? Or, an estimation of the time to peak? If neither of above is obtainable in this short time, fine the time to peak numerically.
2. For the long-acting insulin analogue model, show that the trial solution is globally asymptotically stable.
3. Discuss the law of mass action in the view of stoichiometry when multi molecules of the same species are produced.
4. Explain the built-in memory mechanism in cell development mathematically. (Lewis*, 1977)
5. (For bio majored students) Choose a problem in biology. Develop a mathematical model for the problem. State expected outputs/profiles from the model and then interpret the expected math results into biology. If possible, work with a math majored student on certain mathematical analysis (including numerical analysis). This can become a team project.

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*J. Lewis, J. M. W. Slack, and L. Wolpert, Thresholds in development, Journal of Theoretical Biology, 65(3):579–590, April 1977.

Abstract

The interpretation of gradients in positional information is considered in terms of thresholds in cell responses, giving rise to cell states which are discrete and persistent. Equilibrium models based on co-operative binding of control molecules do not show true thresholds of discontinuity, though with a very high degree of co-operativity they could mimic them; in any case they do not provide the cells with any memory of a transient signal. A simple kinetic model based upon positive feedback can account both for memory and for discontinuities in the pattern of cell states. The model is an example of a bistable control circuit, and transitions from one state to another may be brought about not only by morphogenetic signals, but also by disturbances in the parameters determining the kinetics of the system. This might explain some aspects of transdetermination in insects. An attempt is made to analyse the precision with which a spatial gradient of a diffusible morphogen could be interpreted by a kinetic threshold mechanism, in terms of the length of the field, the steepness of the concentration gradient, and the intrinsic random variability of cells. It is concluded that it would be possible to specify as many as 30 distinct cell states in a positional field 1 mm long with a concentration span of 103. Mechanisms for reducing the positional error are considered.