

Mathematical Résumé

1 Coursework (University of Chicago)

- **for M.S.**

Measure Theory, Real & Complex Analysis, ODEs/ Dynamical Systems/ Hydrodynamics; Mathematical Physics; Geometry of Manifolds.

- **for qualifying exams**

Bifurcation Theory; Dynamical Systems; Equivariant Bifurcation Theory; Representation Theory of Finite Groups.

- **other**

Mathematical Biology; Computational Neuroscience

2 Teaching (University of Chicago)

- **as undergraduate instructor**

Elementary Functions and Calculus; Multivariate Calculus with Applications to the Social and Biological Sciences; Linear Algebra.

- **as teaching assistant for M.S. program in financial mathematics**

Mathematical Foundations of Option Pricing; Numerical Methods for PDEs ; Neural Networks for Optimization

3 Research (University of Chicago & Salk Institute for Biological Studies)

- **cortical development**

In my Ph.D. thesis, *Order and Disorder in Visual Cortex: Spontaneous Symmetry-Breaking and Statistical Mechanics of Pattern Formation in Vector Models of Visual Cortex*, I applied equivariant bifurcation theory to pattern formation problems with special symmetry properties particular to the visual cortex. I formulated a detailed biophysical model for the development of ordered connectivity in the retino-cortical nerve pathway and proved that it could be reduced to a well-known class of ad hoc models for pattern formation

that had been previously proposed (a variation of the Heisenberg XY magnet model from condensed matter physics). In addition I used statistical tools such as Monte Carlo simulation to study the dynamics of the XY model in comparison with the symmetry-breaking analysis.

- **geometric visual hallucinations**

In addition to my thesis work I also applied equivariant bifurcation ideas to the formation of cortical activity patterns underlying geometric visual hallucinations. This work was done in collaboration with Bressloff, Cowan, and Golubitsky. Among other things we discovered that the structure of the orientation-specific connectivity of the cortex naturally gives rise to the so-called *pseudoscalar action* of \mathbf{E}_2 , on $\mathbf{R}^2 \times \mathbf{S}^1$, as well as the standard scalar action.

- **spike-time reliability**

To study the robustness of neural spike-timing patterns I have used a combination of computational and analytic techniques. Simulating noisy integrate-and-fire neurons is done with a stochastic forward Euler method; we are adapting basic techniques from stochastic processes for the analysis of how noise influences bifurcations of neural oscillators (e.g. Gardiner's *Handbook of Stochastic Methods*).

- **signal-transduction networks**

To develop a platform for the analysis and simulation of biochemical reaction networks I have adapted existing finite-element PDE techniques to solving a new class of *boundary-coupled reaction-diffusion equations* with novel boundary conditions. This kind of problem should play a prominent role in analyzing biochemical network dynamics of all sorts, currently an area of major biological interest.

In addition to deterministic methods for solving boundary-coupled PDEs I am developing an approach to stochastic PDEs based on the partition of unity method underlying the classic finite element technique. This approach promises to advance our understanding of stochastic partial differential equations.

I have also been adapting the probability-theoretic tools of information theory to the biochemical context, in preparation for the analysis of biochemical signal-transduction "circuits" as communications channels.

4 Publications

- "Reliability and Bifurcation in Neurons Driven by Multiple Sinusoids", **Peter J. Thomas**, Paul H. E. Tiesinga, Jean-Marc Fellous and Terrence J. Sejnowski, *Neurocomputing in press*.

- “Establishing Direction during Chemotaxis in Eukaryotic Cells”, Wouter-Jan Rappel, **Peter J. Thomas**, Herbert Levine and William F. Loomis, *Biophysical Journal* **83**, 1361-1367, September 2002.
- “What geometric visual hallucinations tell us about the visual cortex”, P.C. Bressloff, J.D. Cowan, M. Golubitsky, **P.J. Thomas** and M.C. Wiener, *Neural Computation* **14**, 473-491, 2002.
- “Geometric visual hallucinations, Euclidean symmetry, and the functional architecture of striate cortex”, P.C. Bressloff, J.D. Cowan, M. Golubitsky, **P.J. Thomas** and M.C. Wiener, *Phil. Trans. R. Soc. Lond. B* **356**, 299-330, 2001.
- “Scalar and pseudoscalar bifurcations motivated by pattern formation on the visual cortex”, P.C. Bressloff, J.D. Cowan, M. Golubitsky and **P.J. Thomas**, *Nonlinearity*. **14**, 739-775, 2001.
- “Uniform fan-out constraints couple orientation and retinotopic distortion maps”, **P.J. Thomas** and J.D. Cowan, *Society for Neuroscience Abstracts*, 2001.
- “Reliability, precision and the neuronal code”, P.H.E. Tiesinga, **P.J. Thomas**, J.M. Fellous and T.J. Sejnowski, *Society for Neuroscience Abstracts*, 2001.
- “Order and Disorder in Visual Cortex: Spontaneous Symmetry-Breaking and Statistical Mechanics of Pattern Formation in Vector Models of Cortical Development”, **P.J. Thomas**, *Dissertation, University of Chicago Department of Mathematics*, August 2000.
- “Symmetry analysis of cortical-map formation via spontaneous symmetry-breaking”, **P.J. Thomas** and J.D. Cowan, *Society for Neuroscience Abstracts*, 2000.
- “A Resonance Effect for Neural Spike Time Reliability”, J.D. Hunter, J.G. Milton, **P.J. Thomas** and J.D. Cowan, *J. Neurophysiol.* **80**, 1427-1438, 1998.
- “Mature rat testis contains a high molecular weight species of phosphatidylinositol transfer protein”, **Thomas P.J.**, Wendelburg BE, Venuti SE, Helmkamp GM Jr., *Biochim Biophys Acta* **982**(1):24-30, June 26, 1989