# Next Frontier & a Mine of Opportunities in Math & Biology

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# Thank you

Robert Palazzo

Yogesh Vohra

Rudi Weikard

Beverly Foster

Cheryl Logan

# Independent Disciplines/Schools/Departments


"well, yes, we could fix it in photoshop, but your arm would still be broken."


"The beauty of this is that it is only of theoretical importance, and there is no way it can be of any practical use whatsoever."

# Statistics Close Relationship

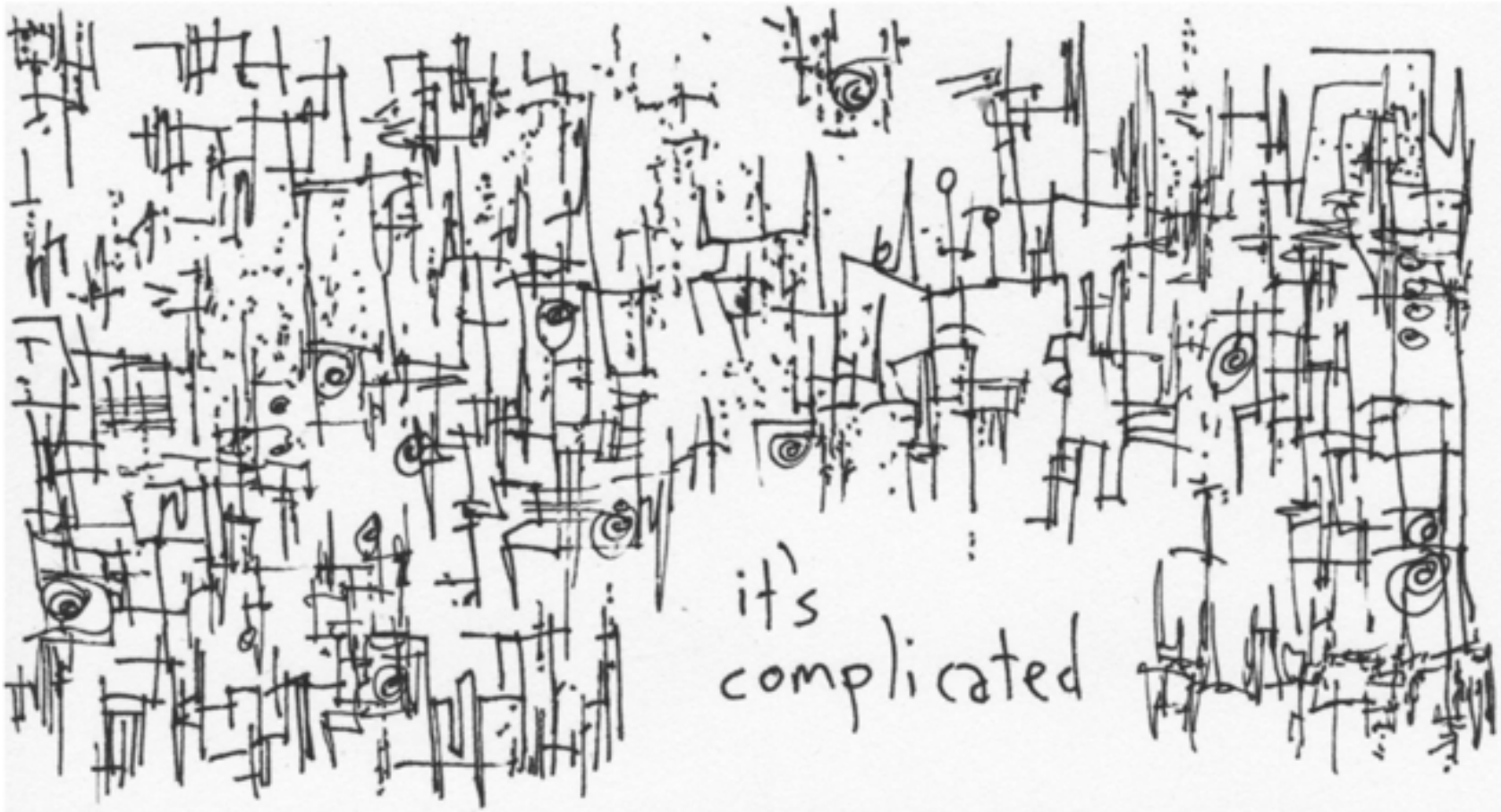

*"I can prove it or disprove it !*
*What do you want me to do?"*

# Overview

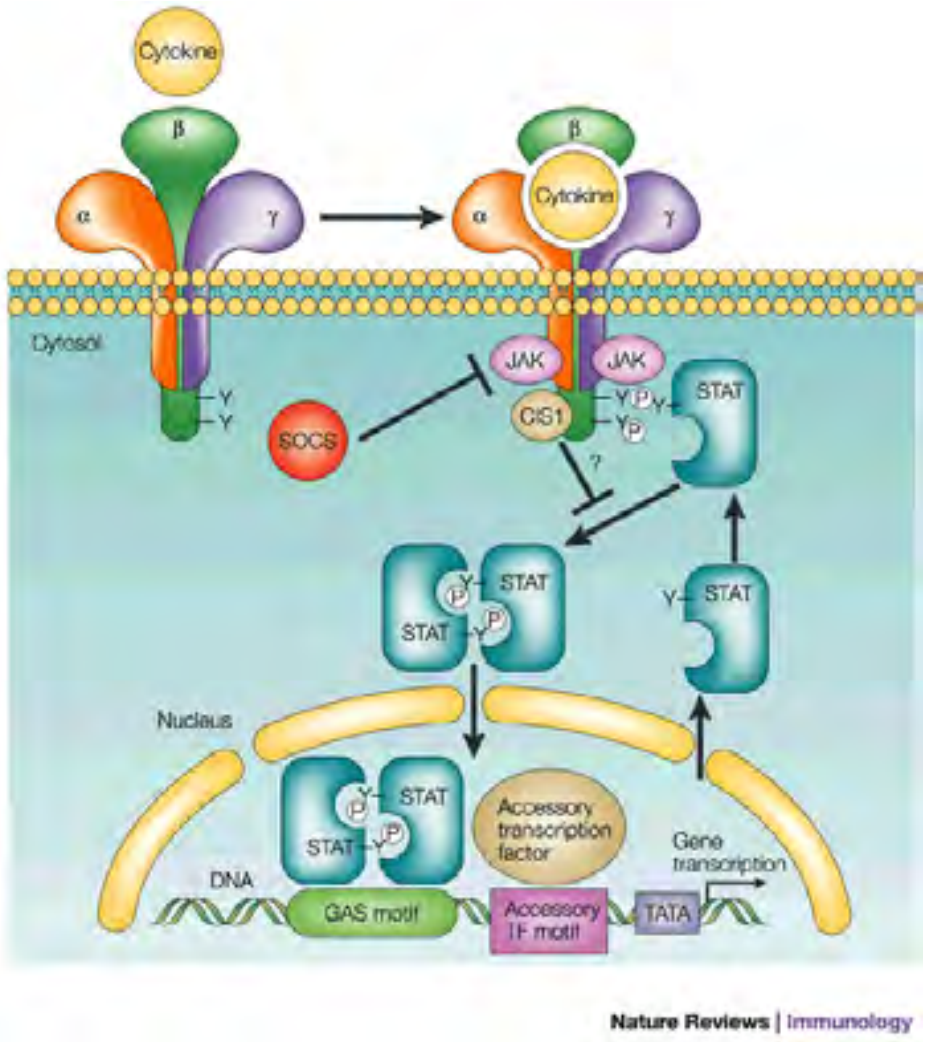
**Mathematical Biology:**

- **Why math for biology/medicine?**
- **Why biology/medicine for math?**
- **Examples.**
- **Suggested Plan.**
- **Concluding Remarks.**

# Short Answer



# JAK/STAT Signalling pathway



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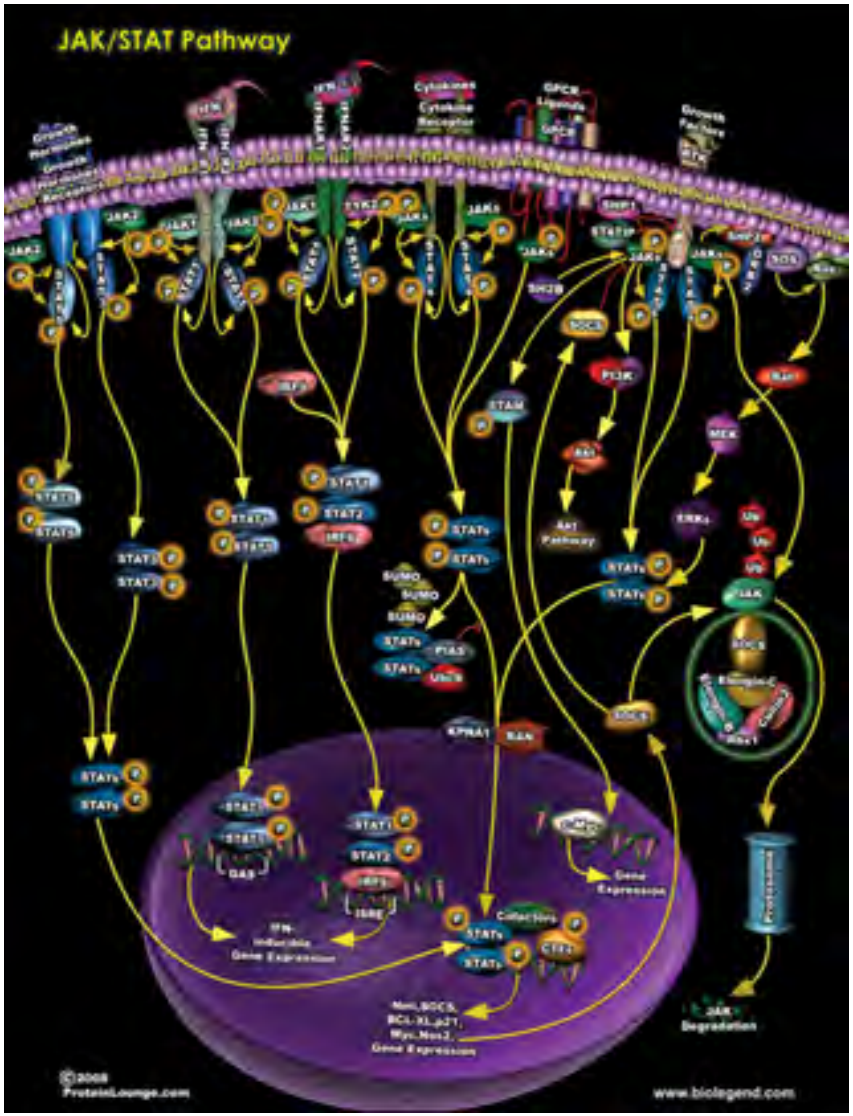
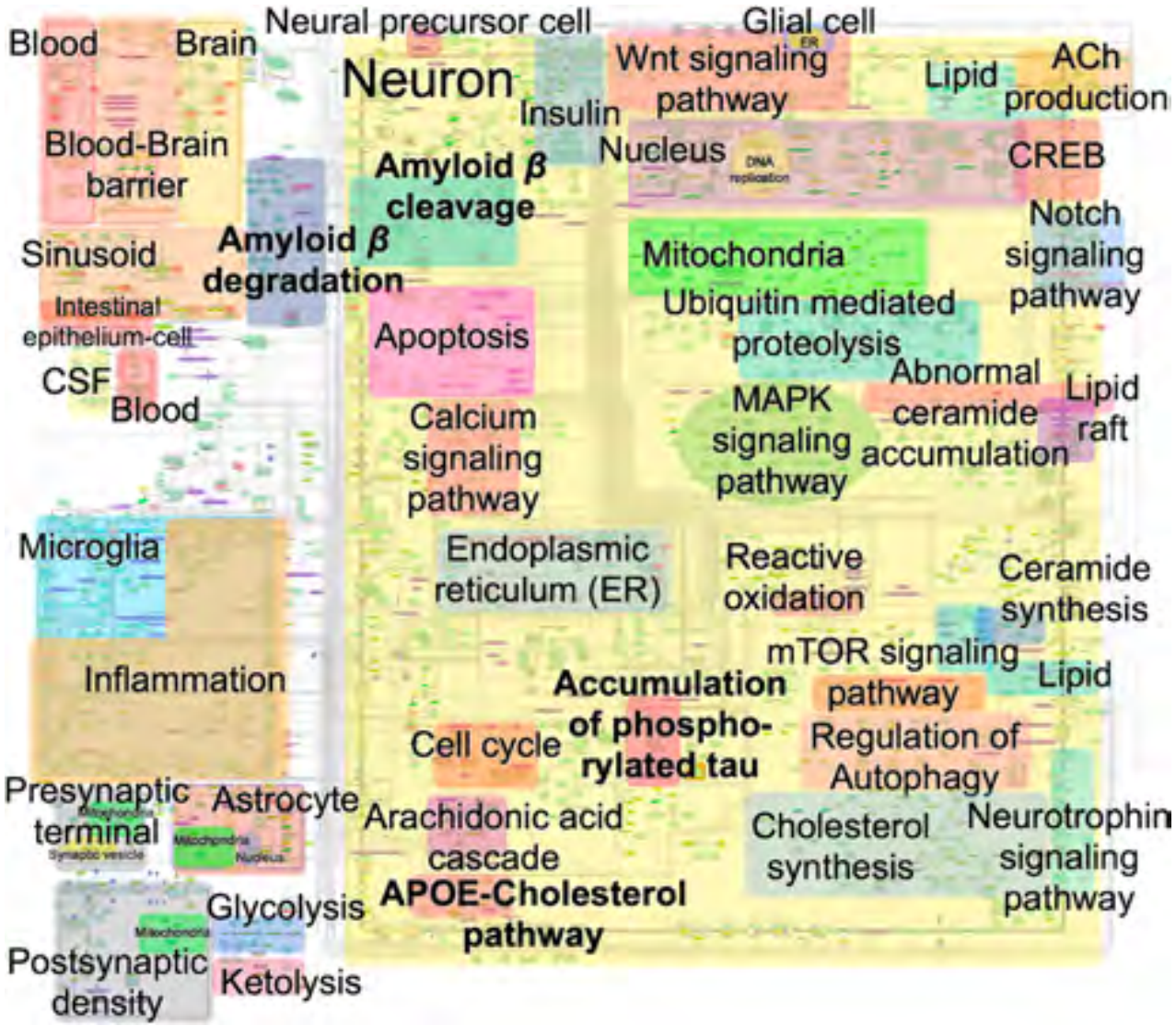


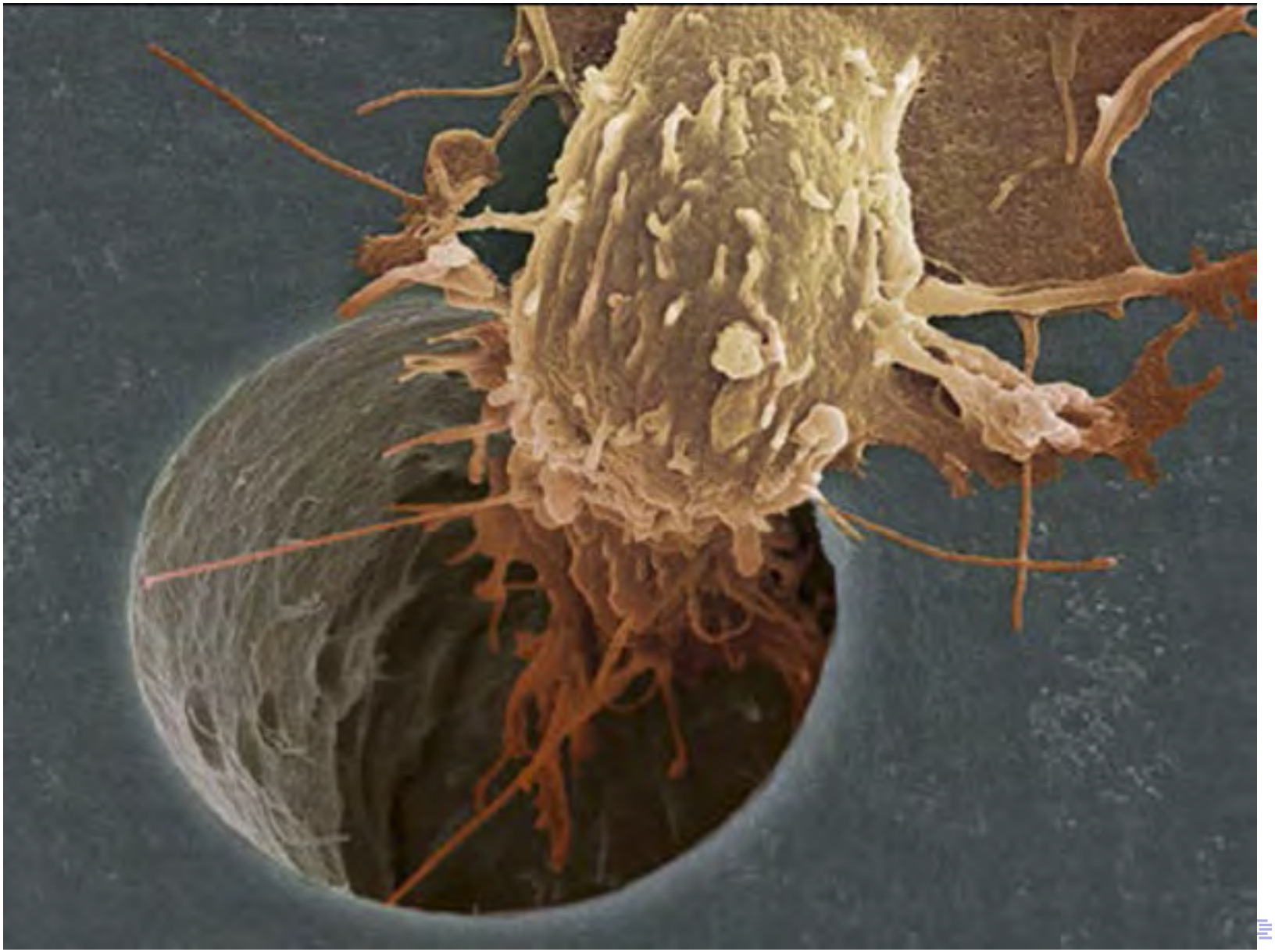
# Signalling in Alzheimer's Disease



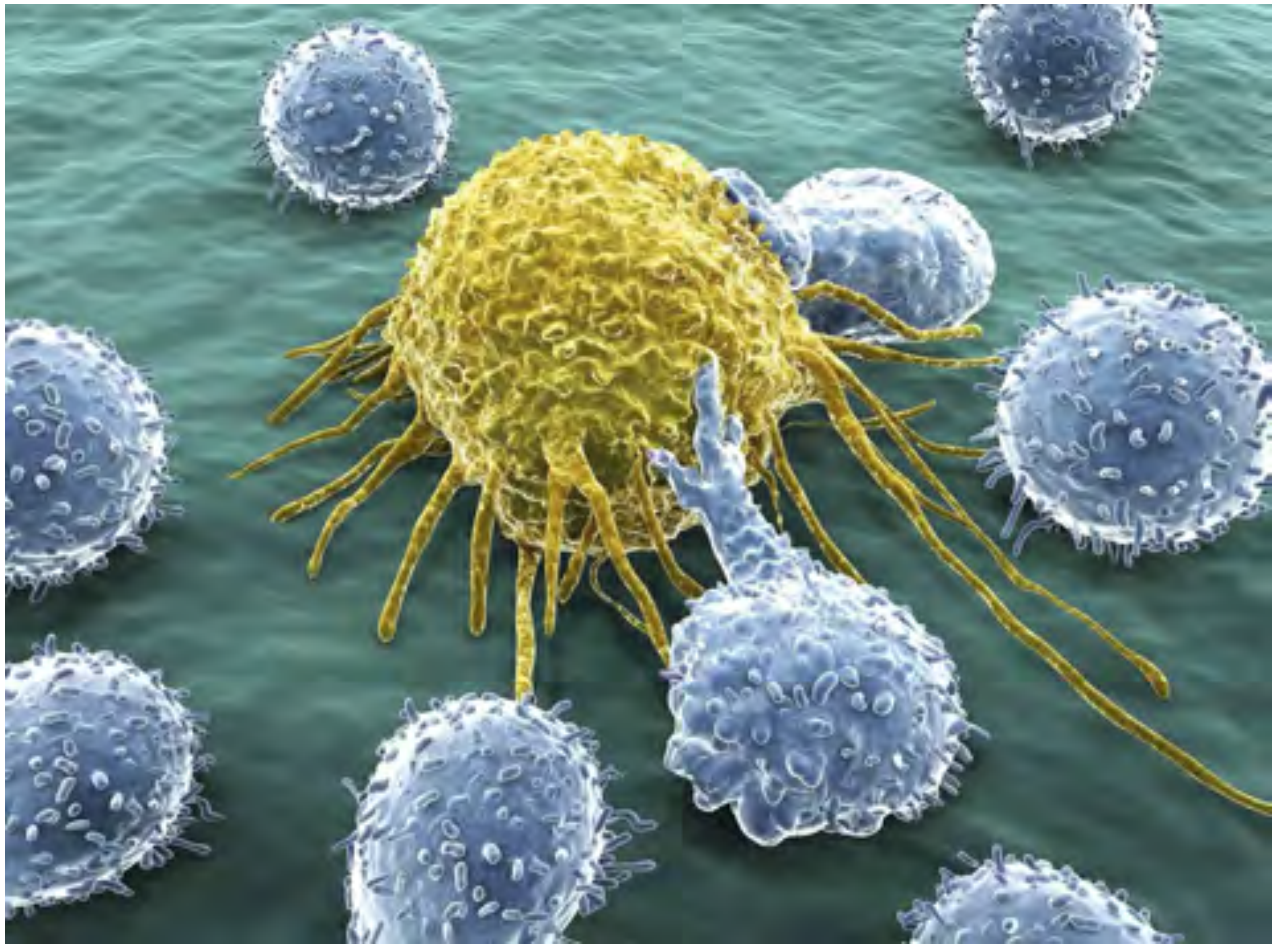

Mizuno *et al.* BMC Systems Biology 2012, **6**:52.

# Targeting & Time-Varying Networks

# Cells Migrate



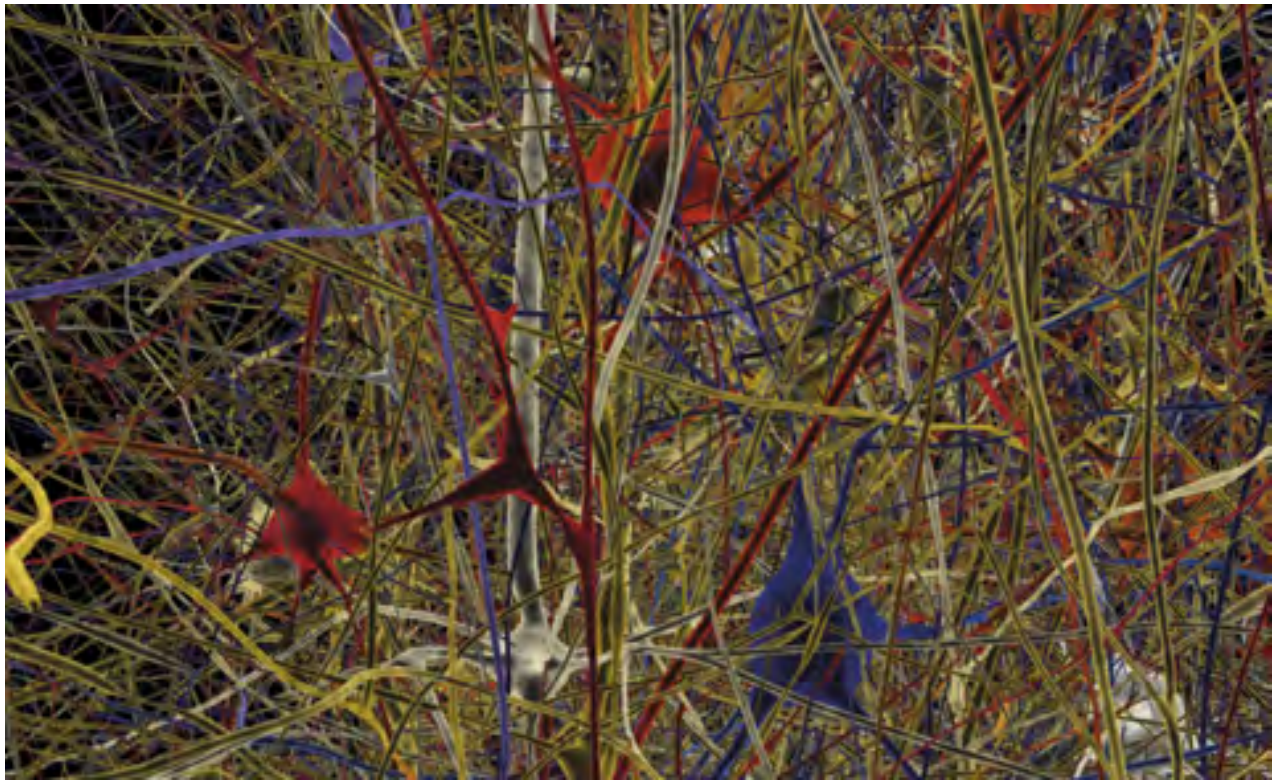
# Cells Communicate



# Cells Interact

# Human Brain Project: Neuron

# Human Brain Project: Synapses



# Human Brain Project: Supercomputer

# Remarks

**Is it Hopeless?**

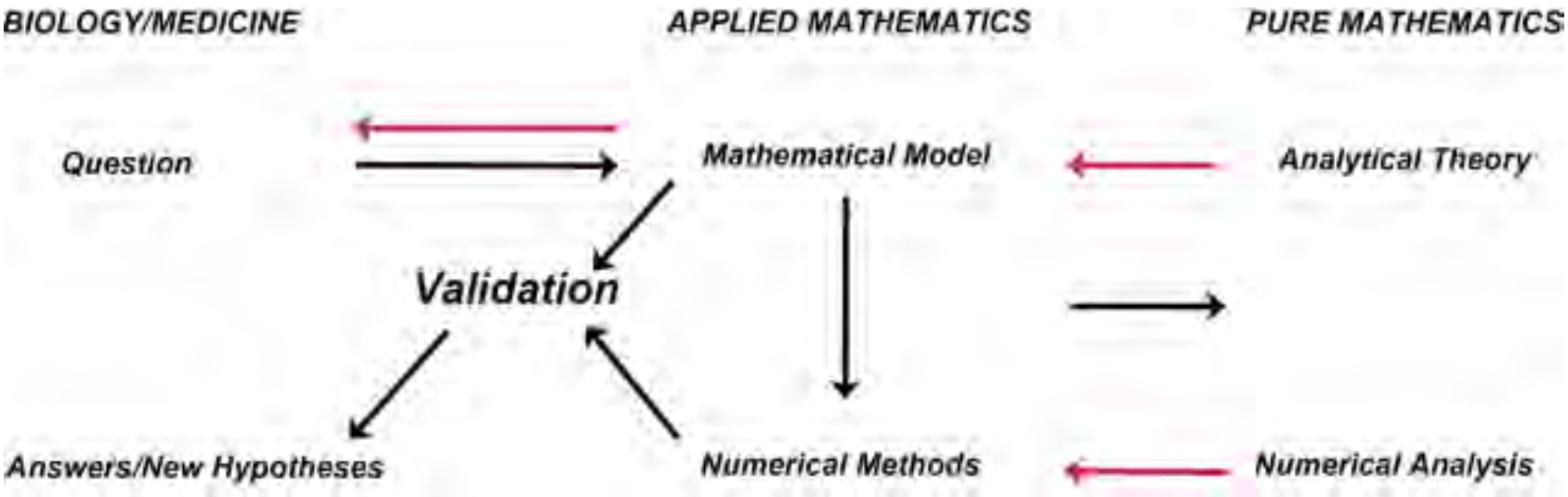
# Remarks

- It is awesome,
- the Next Frontier and a mine of opportunities.

# Remarks

- Mathematics deals with time-varying systems (dynamical), and large dimensional and infinite objects.
- Problems from biology/medicine are novel in mathematics.
- Problems from biology/medicine require close collaboration within various disciplines in mathematics and with biology.

# Suggested Plan



# Network Model

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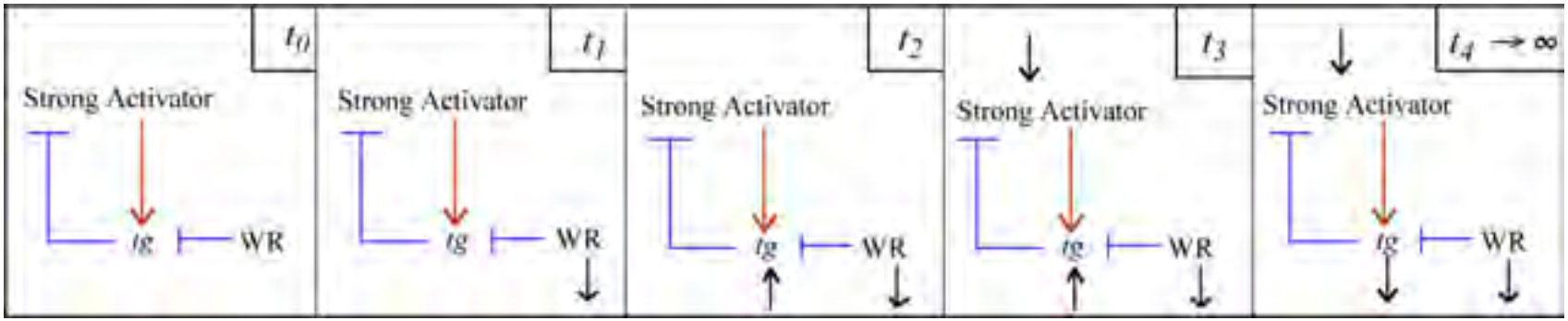
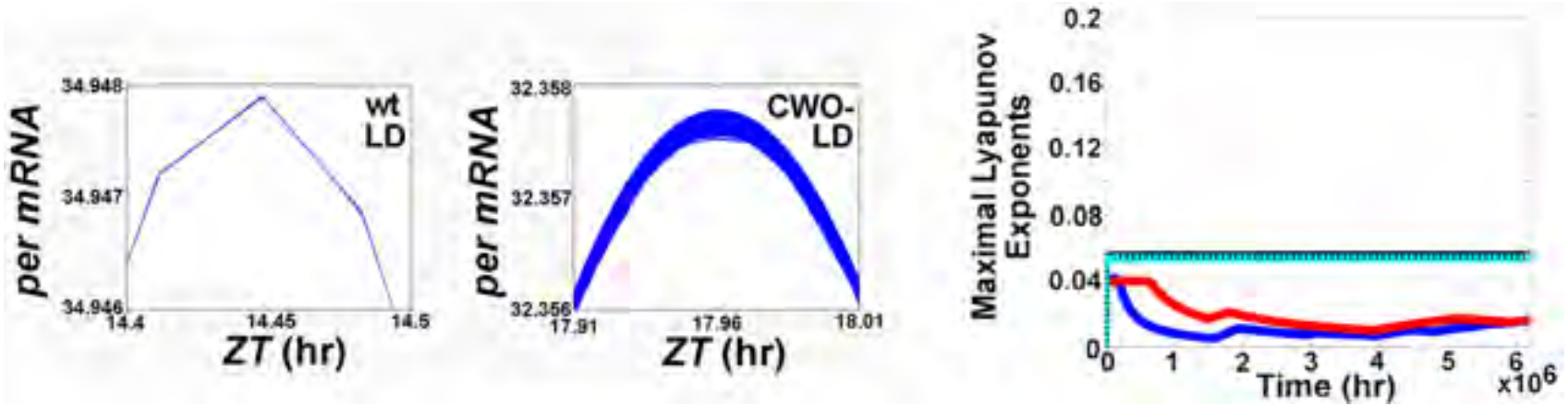
- **Model application: discovering the time-varying molecular networks of the Drosophila embryo** (Khan *et al.*, EURASIP J Bioinform Syst Biol. 2014).

# Suggested Resolution of Paradox



# Jitter and Chaotic Dynamics

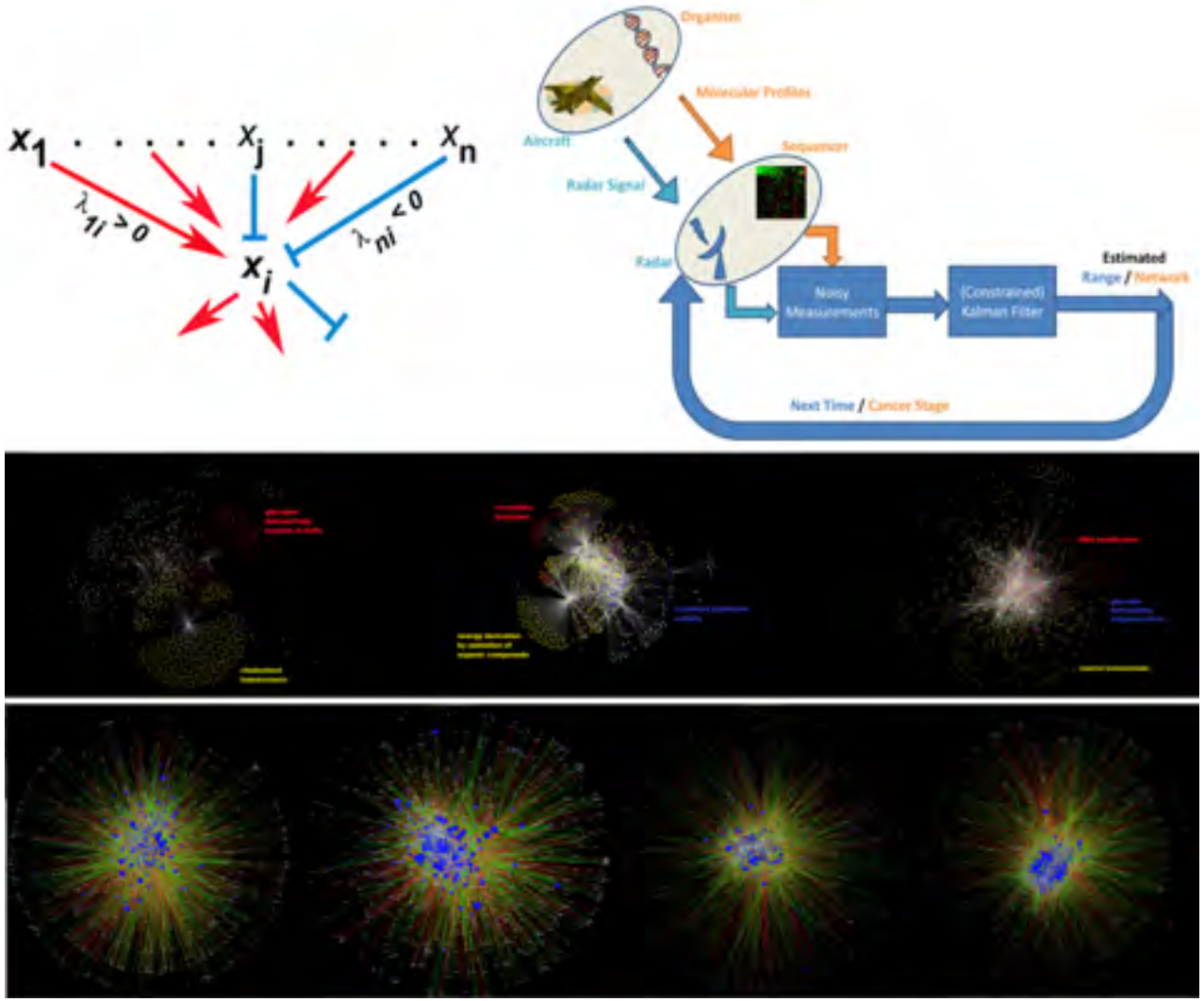


# Counter-Example of The Kaplan-Yorke Conjecture

Table 1 The Fractal/Box-Counting and Kaplan-Yorke Dimensions of the wt and *cwo*-Mutant Models in LD and DD Conditions.

| | wt LD | wt DD | *cwo*-Mutant LD | *cwo*-Mutant DD |
|---|---|---|---|---|
| Kaplan-Yorke | 4.3521 | 5.0085 | 5.3962 | 6.1017 |
| Box-Counting | 1.2345 | 0.8983 | 0.8793 | 0.8961 |

# Time-Varying Networks



# Some Theoretical Results

**Theorem**

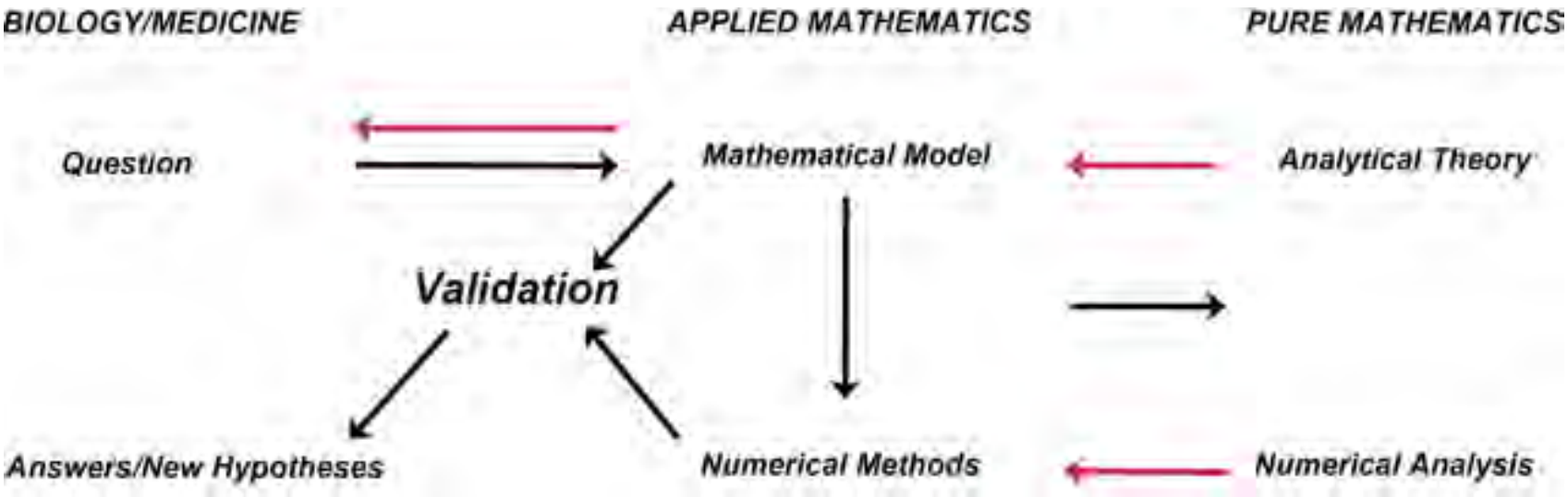
*Consider a system $S^n$ and assume that $\boldsymbol{A}$ is LDS and $x_i(t_0) \in \prod_{i=1}^{n}(-\gamma_i, \mu_i), \forall i$, then*

1. *$\boldsymbol{\sigma}$ is GAS if $\boldsymbol{\sigma} \in \prod_{i=1}^{n}[-\gamma_i, \mu_i]$,*
2. *a critical point on the boundary is GAS if $\boldsymbol{\sigma} \notin \prod_{i=1}^{n}[-\gamma_i, \mu_i]$.*

**Theorem**

*Consider a complete network with three vertices, which includes at least one positive edge. If $\boldsymbol{A} \in P$ and $\boldsymbol{A}$ is not D-stable, then the system admits a nonconvergent bounded trajectory.*

# Suggested Plan



# Collaborators and Students

- Nidhal Bouaynaya
- Uppender Manne
- Jerry Bona
- Sebastian Kadener
- Elizabeth Scribner
- Amanda Rehm

# Grant Support/Funding

- NSF/NIGMS
- NSF
- NIH
- Societies
- Burroughs-Wellcome: Education

# Tomorrow's Talks

- **Philip Maini:** *"Modelling Collective Cell Motion in Biology."* **CH274, 8:00 am.**
- **Jim Keener:** *"Using Mathematics to Understand Biological Processes".* **BEC 256 School of Engineering, 11:00 am.**
- **Emmanuele DiBenedetto:** *"On the Local Behavior of Non-Negative Solutions to a Logarithmically Singular Equation."* **CH452, 2:30 pm.**