HARVEY MUDD COLLEGE

Mathematical Biology at Harvey Mudd College

Lisette de Pillis, Mathematics

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Harvey Mudd College: Background

- What we are: Liberal Arts College (of Science, Engineering and Mathematics)
- Curriculum: 1/3 Common Core, 1/3 Humanities and Social Sciences, 1/3 Major
- Majors offered:
  - On campus (9): Math, Bio, CS, Chem, Phys, Eng, Math-CS, Math-Bio, Bio-Chem
  - Off campus (many): All others available

Harvey Mudd College: Background

- Student body size: ~800 students
- Faculty size: ~90 FTE
- Math Department size: 14 fac, 2.5 staff
- Bio Department size: 8 fac, 3 staff
- Faculty teaching load: 3 and 2 (semester system)

The HMC Common Core:

- 1 semester bio: Intro to Biology (lecture)
  - Molecular biology, genetics, evolution
- 4 semesters math (7-week half-courses):
  - Single complex variable calculus
  - Multivariable calculus I & II
  - Linear algebra I & II, discrete dynamical systems
  - Differential equations I & II
  - Probability and statistics

The HMC Common Core:

- 2 semesters chemistry
- 3 semesters physics
- 1 semester computer science
- 1 semester systems engineering

Mathematical Biology Major

- Motivation:
  - Student interest & background
  - Prepare students for interdisciplinary quantitative work in this "Century of Biology"
- Established 2002
- First graduates in 2003

Mathematical Biology Major

- Solid training in both Biology and Mathematics, with Math-Bio bridge
- Students prepared for: industry, biology graduate studies, math graduate studies.
- Senior choices: clinic, bio thesis, math thesis, math-bio thesis

Mathematical Biology Major

- Created & administered jointly by Mathematics and Biology faculty
- Approved by entire HMC faculty vote
- 41 units of 128 to graduate
- Compare:
  - Biology Major: 32 bio + 7 chem = 39 units (plus core of 3 bio units and 8 chem units)
  - Mathematics Major: 33 units (plus core of 13 math units)

Mathematical Biology Major:

Mathematics Requirements

(10 Units beyond 13 core units)

- Discrete Math (lower division) (3 units)
- Analysis I (upper division) (3 units)
- Two Math Electives (upper division) (4 to 6)
  - Examples:
    - Probability
    - Mathematical Statistics
    - Stochastic Processes
    - Advanced Linear Algebra
    - Operations Research
    - Dynamical Systems
    - Partial Differential Eqns
    - Abstract Algebra

Mathematical Biology Major:
Biology Requirements
(15 units beyond core of 3 units)

- Intro Bio Lab (1 unit)
- Choose three (3 units each):
    - Physiology, Ecology, Evolution, Molecular, Neurobiology
- Advanced lab (2-3 units):
    - Ecology, Physiology, or Molecular Biology
- Seminar (3 units; read primary literature)

Mathematical Biology Major: Additional Requirements

- Computation (3 units): Choose one of:
  - Scientific Computing, Numerical Analysis, Algorithms
- Math Forum/Colloquium, Bio Colloquium (1 year each)
- Free Technical Elective (3 units):
  - Eg: Biostatistics, biochem, phys.chem, math as laboratory tool
- Research (6 units, 2 semesters):
  - Math/Bio Thesis or Team Clinic Project
- Mathematical Biology (4): “Bridge” Course

Mathematical Biology Courses (units: 2 + 2)

- Prerequisites:
  - Linear Algebra (1 sem), ODEs (1 sem), Introductory Biology (1 sem): Achieved in the Core
- Course Textbook: *Dynamic Models in Biology,* Stephen P. Ellner & John Guckenheimer
- 2x7 weeks (15 week semester)
- Course style:
  - Traditional & guest lecture, in class exercises, research paper discussion, laboratory exercise, student research paper presentations (compare & contrast)
- Typical class:
  - 10-12 students, various majors (math, chem, bio, physics, eng). Both HMC & non-HMC.

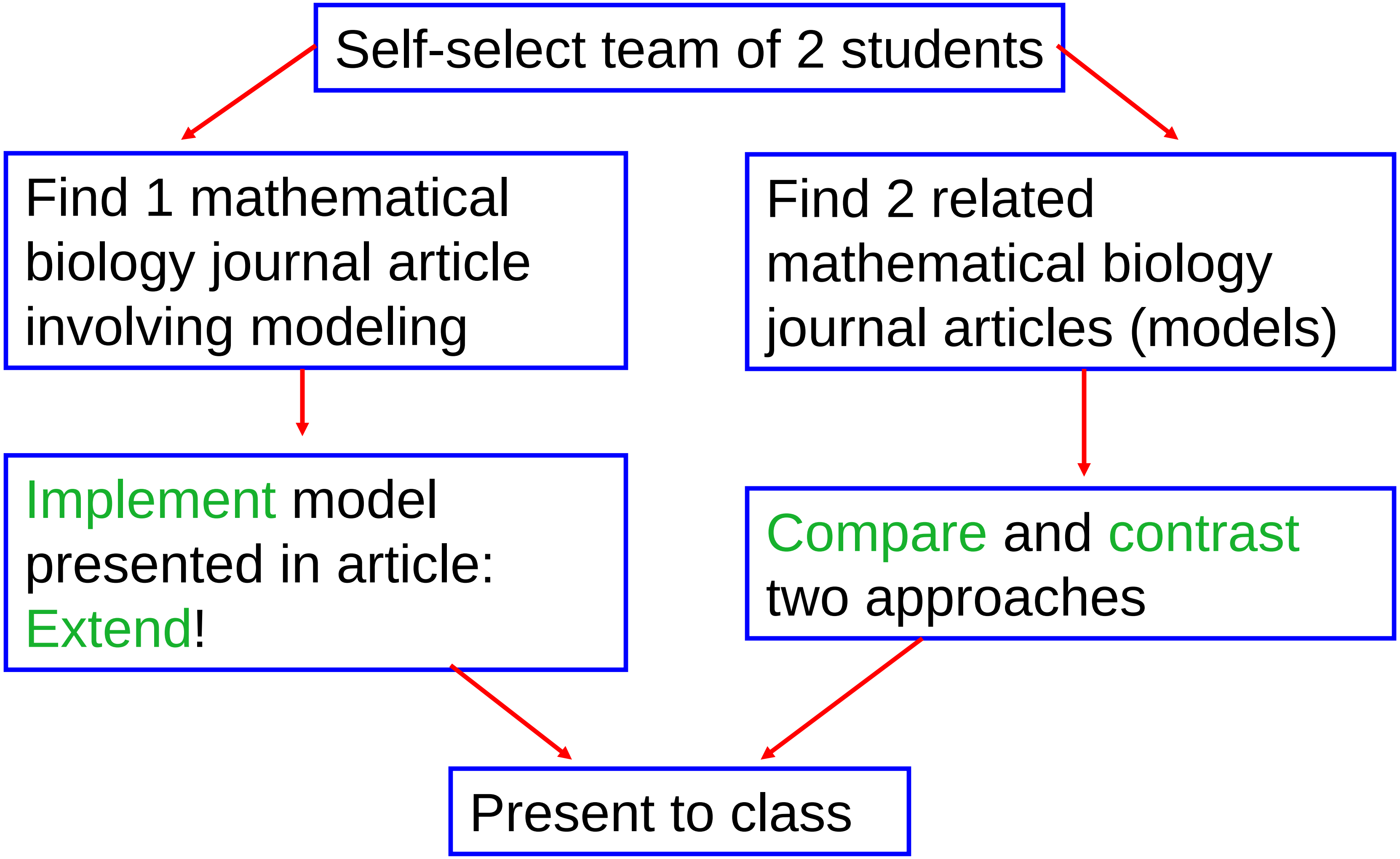
Mathematical Biology: Sample Topics Covered

- Cancer-Immune modeling. **App:** Wheeler, de Pillis & Radunskaya (*Cancer Res*)
- SIR Models and Vaccination Strategies / Game Theory. **App:** Bauch & Earn (*PNAS*)
- Evolutionarily Stable Strategies (Hawks & Doves)
- Logistic & Age Structured Population Models. **App**: Adolph et al., Desert lizards
- Phenotypic Plasticity. **App:** Padilla & Adolph (*Evol Ecol*): sharp and blunt teeth of snails
- Computational Tools: Matlab with pplane6, ODEArchitect, xppaut

Mathematical Biology: Sample Guest Lecture Topics

- Y. Guo: Neuron modeling, Parkinson's, Deep Brain Stimulation
- A. Gallegos: Uterine Contractions
- S. Blower: HIV/AIDS, Herpes
- M. Stubna: Cardiac Arrhythmias
- L. Li: Ecological Complexity
- G. Dewey: Microarray Analysis
- R. Fister: Optimal Control of Chemotherapy
- A. Sadovsky: Wound Healing
- F. Su: Phylogenetic Trees
- W. Willson: Consumer Resource Models
- T.Jackson,D.Mallet,E.Afenya: Multiple approaches to cancer modeling

Mathematical Biology: Final Class Project



A Tale of Two Futures: HIV and Antiretroviral Therapy in San Francisco

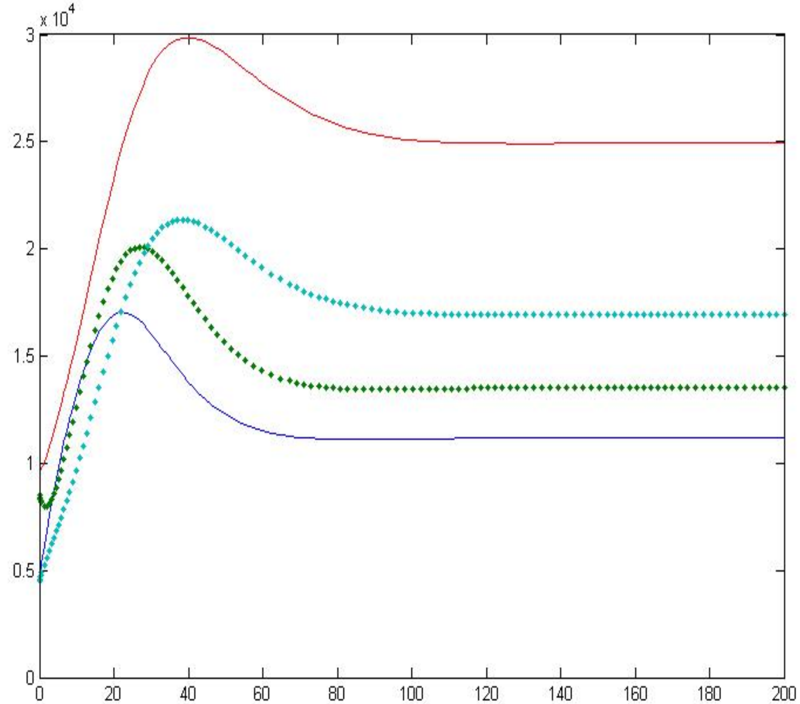
Blower, S.M., Gershengorn, H.B., and Grant, R.M.

Presented & Extended by: Christoph Rau and Micki Kaye

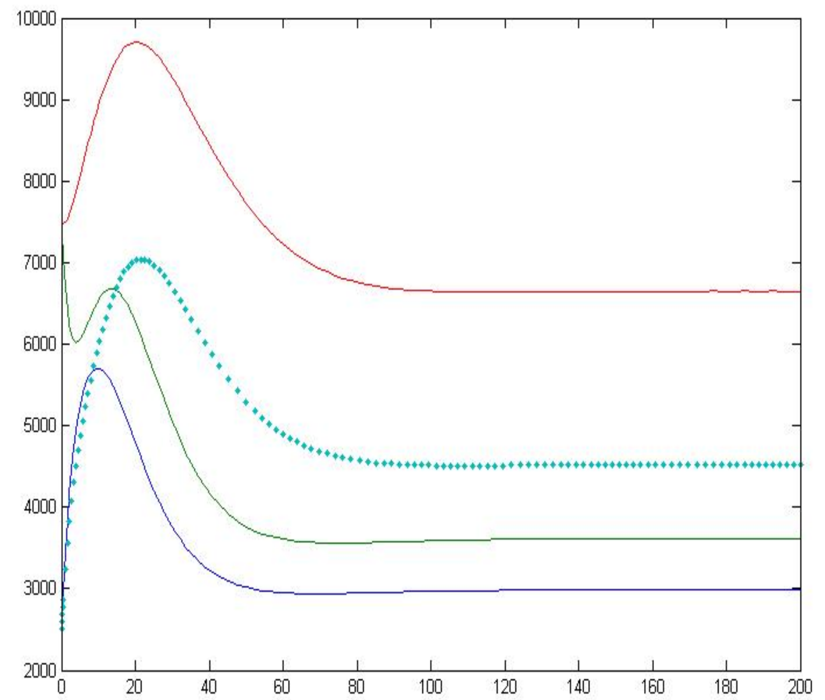
Math 119

4/24/06

Christoph and Micki's Extension: Get NY Data, Compare to SF. What happens?



NEW YORK



SAN FRANCISCO

Mathematical Biology: Recent Student/Fac Research

- De Pillis & Gu & Fister: *Optimally controlling combination immuno-chemotherapy in cancer models*. 2 Summers, 12 students
- Adolph & Hardin: *Statistical estimation of physiological performance*. 2 students.
- Yong: *Mathematical model for nutational movement of plant cotyledons*. 1 student.
- Jacobsen: *Modeling ecological invasions on dynamic habitats.* 2 students.
- Bassman: *Multidisciplinary study of structural development in tendril-bearing plants.* 1 student.
- Bechtel: *Identifying Oscillating gene expression transcripts in microarray time series data.* 1 student.

Math/Bio Students: Where are some of them now?

- Erin Bodine, 2003 (PhD program, Mathematics/Mathematical Ecology, Univ. of Tennessee, Knoxville)
- Tara Martin, 2004 (PhD program Systems Biology, Harvard)
- Trevor Pickering, 2005 (PhD program Bio Stats, USC),
- Lori Thomas, 2005 (PhD program, Biological Oceanography, joint MIT-Woods Hole)
- Sean Fogarty, 2006 (PhD program, Animal Behavior, UC Davis),
- James Moore, 2007 (PhD program, Mathematical Biology, University of Utah)
- Victor Camacho, 2007 (PhD program, Mathematical Biology, University of Utah)
- Ryan McCarthy, 2007 (PhD program, Plant Biology, Univ. of Georgia)
- Christoph Rau, 2007 (PhD program in Molecular, Cell and Developmental Biology, UCLA.)

Future Plans

- Computational Biology (HHMI Funded)
  - New faculty member: Eliot Bush
  - Experimental year-long *core* course combining introductory biology and introductory computer science
- Claremont Center for the Mathematical Sciences (CCMS)
  - 4 areas of Concentration, including *Computational & Mathematical Biology*

Funding

- W.M. Keck Foundation
- Howard Hughes Medical Institute (HHMI)
- National Science Foundation (Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences - UBM)

HARVEY MUDD COLLEGE

Thank you for listening!

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Sample In-Class Exercise

Lotka-Volterra Competition Equations

For 2 competing species, we'll use the following notation:

Species 1: N_1, K_1, r_1 Species 2: N_2, K_2, r_2

1. Write down the **logistic equation** for Species 1 (ignoring Species 2 for the moment).

2. Suppose that we now **add some individuals** of Species 2, who compete for resources with Species 1. **What effect** will they have on the population dynamics of Species 1? **Will the effect** of each individual of Species 2 be equal to that of Species 1? **What features** of the biology of these two species will determine this?

3. Try to **modify your logistic** equation for Species 1 so that it includes the effects of Species 2. (Hint: think about how we included the effects of Species 1 on its own growth rate.) **Etc...**