What is the Mathematical Contest in Modeling?

- Students compete in teams of three to solve modeling problems.

- Teams choose between two problems and have four days to come up with their models and write up their solutions.

- Teams may use any inanimate sources of help, but they can’t talk to anyone about the problems except their teammates.

- Winning group from Temple’s Competition Thursday, Nov. 6-Monday, Nov. 10 will participate in International Competition (Feb 5- Feb 9 2015)
Members of the Team

You will need a variety of skills on your team. While everyone will do a little bit of everything, it’s best if you match jobs to people’s skills. You will need:

- Researcher - to find data relating to your problem and existing models
- Programmer - to write code for simulations
- Head writer - to make sure the paper is well-written and that the explanation is as clear as possible
- Motivator - to keep everyone excited and working when you are tired and frustrated
- Pragmatist - to deal with deadlines, plan meal/sanity breaks, and point out practical details, like don’t decide to change your OS in the middle of the contest
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Important Reminder about Jobs

Even with these jobs, remember that to be successful everyone needs to do a little bit of everything.

Specifically, **EVERYONE** needs to write and help run programs to get data.
The Key to Teamwork
Your team must work well together to do well.

- Make decisions by consensus not by majority
  - You don’t want to have a problem that not everyone wants to work on or an approach someone doesn’t believe in.
  - If you don’t all agree, take the time to talk and listen until you come to a consensus.
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- Everyone should always be working on something important to the problem.

- Make sure everyone understands the mathematics.
  - If you can’t explain it to each other, you probably won’t be able to explain it to the judges.
How to Get Started

- If you have a choice of problems, spend a few minutes deciding as a team which problem to do.
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- If the problem is very broad with many possible problems, choose one that you think you can solve.
- Once you have some ideas, do research to learn as much as you can about the problem.
- Look for background data and mathematics that seems to apply.
What to Do Next

- Come up with a model. Simple is okay.
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- If you think your model is too simple, you can begin to add more complexity.
- Add complexity to the model in small steps, making sure the model works at each step.
- You’ll need to run your model many times with various parameters to be able to test it and compare to other models.
The Problem

The CDC has asked you to develop a strategy to model the outbreak of virus X in Philadelphia. Analyze your model and propose a strategy to combat the spread of the virus.
Considerations

Things to consider:

- Population (approx. 1.5 Million people)
- Probability of virus contraction via contact with infected.
- Study the disease: airborne? physical contact? blood?
- Geography, climate
- Survival/Mortality rates
How can we model the spread of the disease?

- Can we determine a function $I(t)$ that tells us the number of people infected with Virus X at time $t$?
How can we model the spread of the disease?

- Can we determine a function \( I(t) \) that tells us the number of people infected with Virus X at time \( t \)?
- How does \( I(t) \) change with time? What is \( I'(t) \)?
A Simple Ansatz

Suppose that $I'(t)$ is proportional to $I(t)$.

\[ I'(t) = rI(t) \]
\[ I(0) = I_0 > 0 \]

The constant $r$ is called the rate of infection.
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Is this realistic?
Adding Complexity to the Model

Populations of susceptible, $S(t)$, infected, $I(t)$, and recovered, $R(t)$, people.
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SIR Model

Susceptible
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**SIR Model**

Susceptible $\rightarrow$ Infected
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**SIR Model**

Susceptible $\rightarrow$ Infected $\rightarrow$ Recovered

How do these functions change with time?
Setting up the Equations for this Model

How do $S(t)$, $I(t)$, $R(t)$ change with time?

- Members of the susceptible population leave by becoming infected.

\[ S'(t) < 0 \text{ and } S(0) \geq S(t). \]

The susceptible population declines at a rate, $r$, proportional to the interaction between the infected population and the susceptible population.

\[ S'(t) = -rSI. \]

The infected population grows via this same interaction with the susceptible population.

\[ I'(t) = rSI. \]

The infected population declines at rate, $a$, proportional to number of infected people.

\[ I'(t) = rSI - aI. \]

The number of recovered people grows via the infected population becoming recovered.

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System of ODES

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\[ I'(t) = rSI - aI \]
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\[ S(0) = S_0 > 0 \]
\[ I(0) = I_0 > 0 \]
\[ R(0) = 0 \]

\( r > 0 \) infection rate.
\( a > 0 \) infection removal rate.

Note that
\[ S'(t) + I'(t) + R'(t) = 0 \implies S(t) + I(t) + R(t) = N \]
\( R(t) > 0 \) implies \( R(t) \) is increasing.

\( R(t) \) can be ignored since \( R'(t) \) depends on only \( I(t) \).

Given \( r, a, S_0, I_0 \), can we predict when there will be an outbreak of Virus X?
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**Given** \( r, a, S_0, I_0 \), can we predict when there will be an outbreak of Virus X?
Let’s set:

- The total population of Philadelphia $N = 1.5 \times 10^6$.
- The infection rate $r = 10^{-4}$.
- The infection removal rate $a = 10$.
- $S_0 + I_0 = N$, initial population consists of susceptible and infected people.
Observed Behavior

Initial conditions: \( I_0 = 3 \times 10^4, \ S_0 = N - I_0. \)
Parameter values: \( r = 10^{-4}, \ a = 10. \)
Changing Parameters

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Parameter values: $r = 10^{-5}$, $a = 10$. 
From these initial experiments we have observed that different parameter choices produce different model behaviors.
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*When does the infection grow?*
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When does the infection grow? $I'(t) > 0$

$$I'(t) = I(rS - a)$$
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*When does the infection grow?* \( I'(t) > 0 \)

\[
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\]

\[
\begin{align*}
I'(t) > 0 & \quad S > a/r \\
I'(t) < 0 & \quad S < a/r
\end{align*}
\]
Discussion

- How realistic are the assumptions?

SIR Model

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- How can we make things more complex?

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- Only one example of what you can do. You’re free to make completely different choices with your problem.

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[J.D. Murray, Mathematical Biology I: An Introduction]
The end result of the contest is a paper that is submitted to the judges.

The challenge is to convey all of your mathematics clearly in this paper.
Key Points about the Paper

- It must be easily skimmable.
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- It can be useful to put lists in bulleted or numbered list format.
Parts of the Paper

- Summary
- Introduction
- Assumptions
- Model Design
- Model Testing and Results
- Strengths and Weaknesses
- Future Work
- Conclusion
- References
- Appendices
Most important part of your paper as it may be the only part the judges read on their first pass.
Summary

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- Draw attention to what you’ve done. Why is what you’ve done interesting?
Good to write this piece early to make sure that everyone is on the same page.
Introduction

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- Restate the problem as you interpret it. Many problems are very broad leaving you to interpret the goal and the piece you will attack.
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Include your research into the background on the problem.

If you have found traditional approaches to the literature, mention them and why you’ve chosen to use them or try something else.
Assumptions

- State all assumptions you are making that affect the model.
- Justify your assumptions.
- Clearly list all variables you will be using.
Model Design

- A Big Section
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- Fully explain the reasoning behind your models and what the models are doing. It is easy to gloss over this part, but this is a MODELING competition, so this part is important.
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- Explain in words, figures, or flow charts all algorithms for which you create computer code.
Implement your algorithm to determine results.
• Implement your algorithm to determine results.

• Run the models under a variety of parameters.
Results

- Implement your algorithm to determine results.
- Run the models under a variety of parameters.
- Use these results to answer the specific questions asked in the problem.
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Use data to back up your answers. Present data in tables or graphs.
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- Present data intelligently. Do not present all data generated.
- If you have multiple models, be sure to compare the results from each.
Testing Your Models

This section can come either before or after the results.

- Test your models with real data, if possible. If real data is not available, generate data sets with which to test.

- Analyze the error. Does your model match reality? Did your implementation introduce error?

- If you do not have the data or methods available to test the models, explain how the model could be tested.

- Lots of data available on the internet for many problems.
Strengths and Weaknesses

- Discuss the strengths and weaknesses of your models and your solution approach.

- Might include limiting assumptions you wish you didn’t have to have.

- Should really be a summary of things you’ve already said.
Future Work

- Can be used to explain what you would do if you had more time, more computing ability, more data, etc.
- Shows you are looking at the big picture.
Conclusion

- Sum up the main results from the results section.
- Refer back to numerical results when drawing conclusions.
- Must cite all sources you use
- Include references to the list of references in the text of your paper
- Likely to include sources with background material on the problem and mathematical sources.
Appendices

This is where you place things that don’t fit in your paper including

- Computer Code
- Large Data Sets
- For large data sets, include histograms, descriptive statistics, etc.
Temple Competition

- Competition at Temple
  
  8 pm November 6 - 4:30 pm November 10

- Winner will go on to compete at International Competition in February

- Teams of 3

- Consult any inanimate objects, but may not talk to anyone outside your group or an instructor

- Have fun!!!!