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The Mathematics of Understanding Disease

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US Department of Homeland Security

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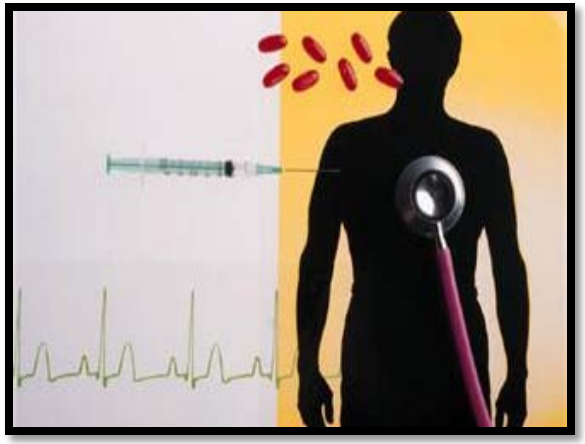
HANDS ON
Real-World Lessons for Middle School Classrooms

By the end of this module, you will …

- Understand how mathematicians and biologists can build mathematical models to simulate disease outbreaks.
- Use real world health data to learn and share something you choose about malaria.



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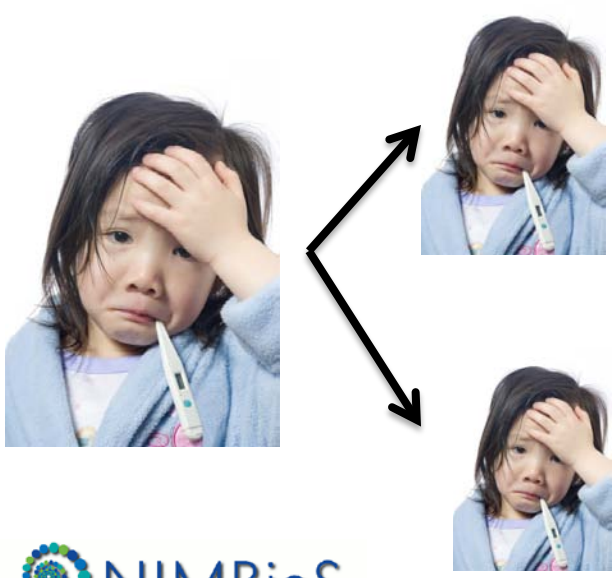
How can we quantify how fast a disease spreads?

Basic Reproductive Number = R_o



- Expected number of secondary cases produced by a single infection in a completely susceptible population.
- If $R_o > 1$, disease spreads

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R_0 for some infectious diseases

- Measles 12-18
- Mumps 4-7
- HIV/AIDS 2-5
- Influenza 2-3

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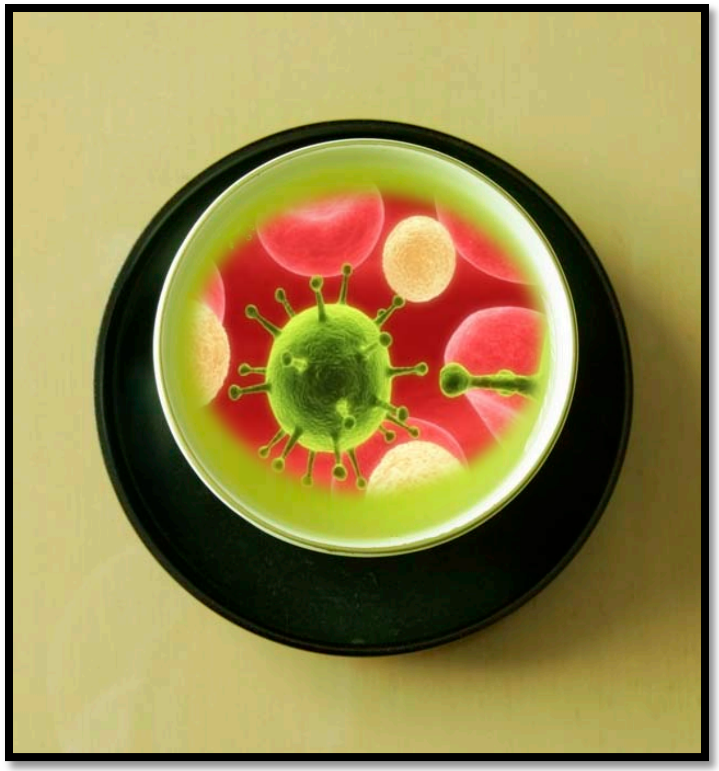
Outbreak in a Cup: Set Up

Set up the Initial Conditions:

20 red beans

1 white bean



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Outbreak in a Cup

1. Without looking in the cup, a student from the group selects 2 beans from the cup.
2. If both beans are the same color, simply return the beans.
3. If one bean is red and the other white, remove the red bean and return 2 white beans to the cup.
4. At each time step, record the event that occurs: either no change or a new infection.
5. Repeat the process until told to stop.

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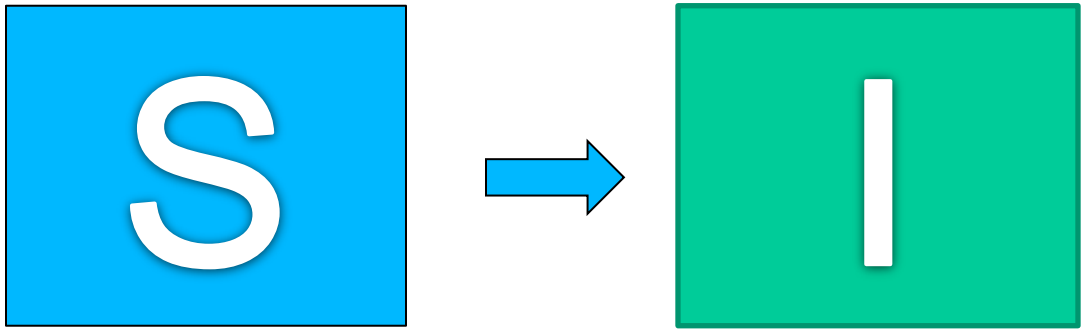
Share!

- Did groups show different patterns in how the outbreaks occurred? Why or why not?
- How is this disease model similar to what happens in the real world?
- What aspects could we add to modify our simple model?
- What would you estimate is the R_0 of this disease?



Susceptible

Infected

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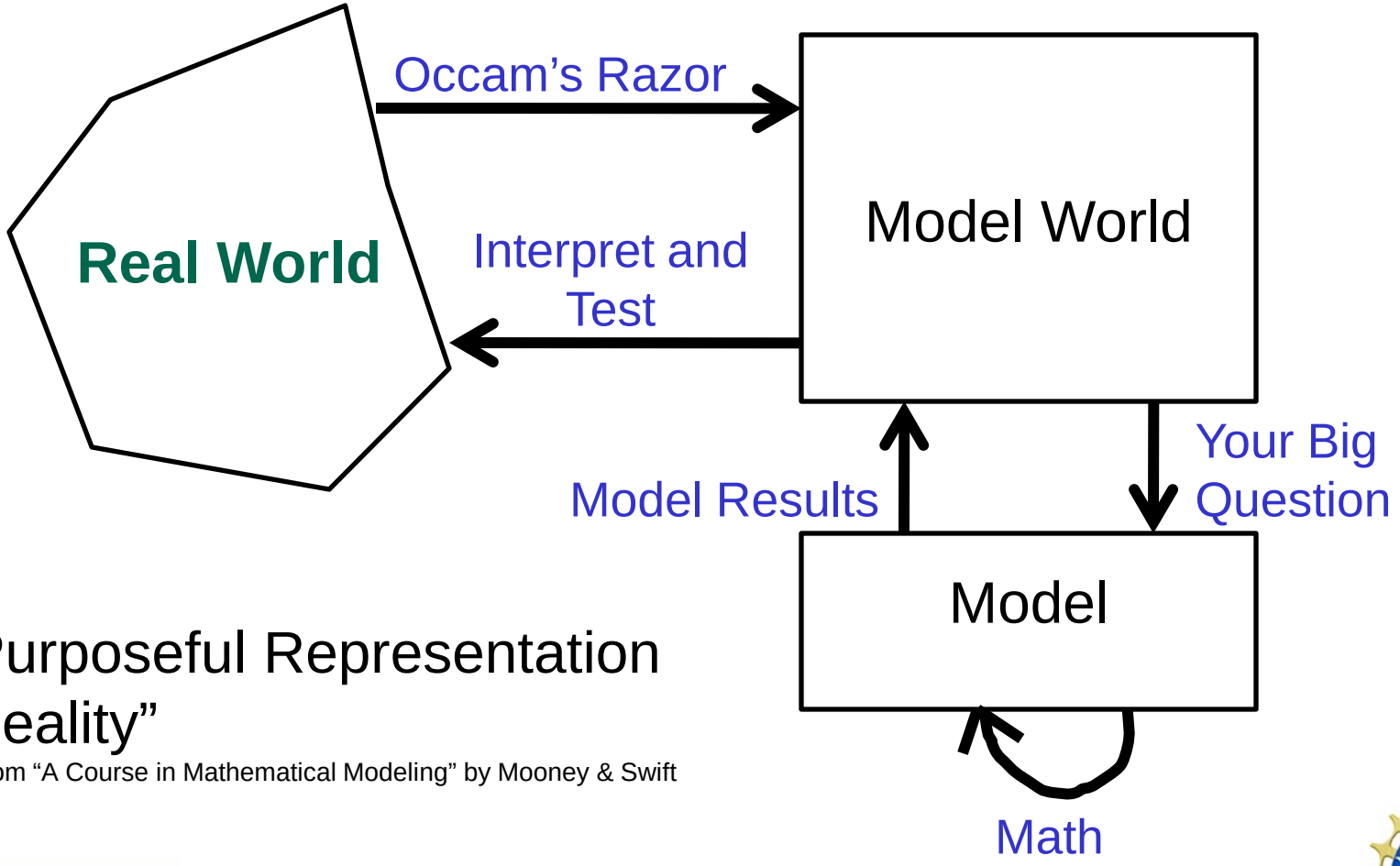
What do we mean by a Mathematical Model?



"A Purposeful Representation of Reality"

Figure from "A Course in Mathematical Modeling" by Mooney & Swift

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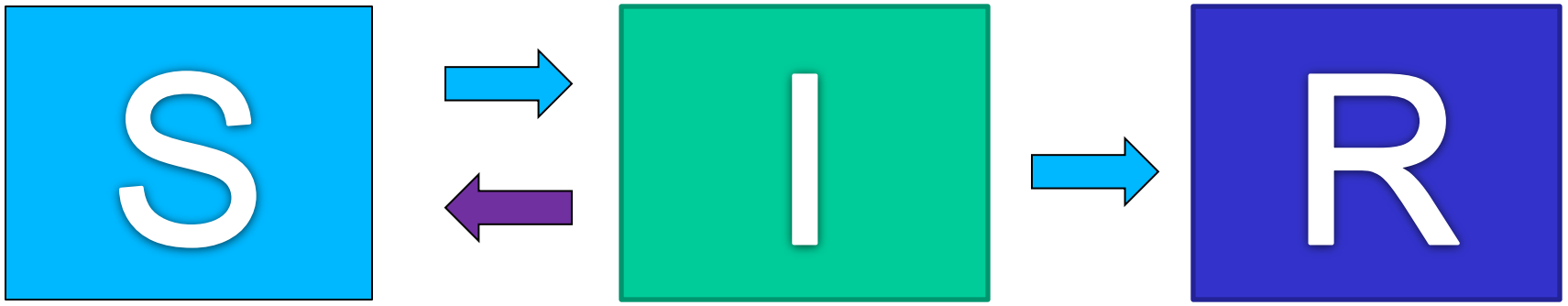
Some ways to add to this model …



Can you think of more?
How would you represent them?
How could you represent these with math?

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What is Malaria?

- **Components** involved in malaria:

  Parasite: Agent that causes the disease

  Human: Host (suffers from the disease)

  Mosquito: Vector that transmits the disease from human to human

- **Vector**-borne disease

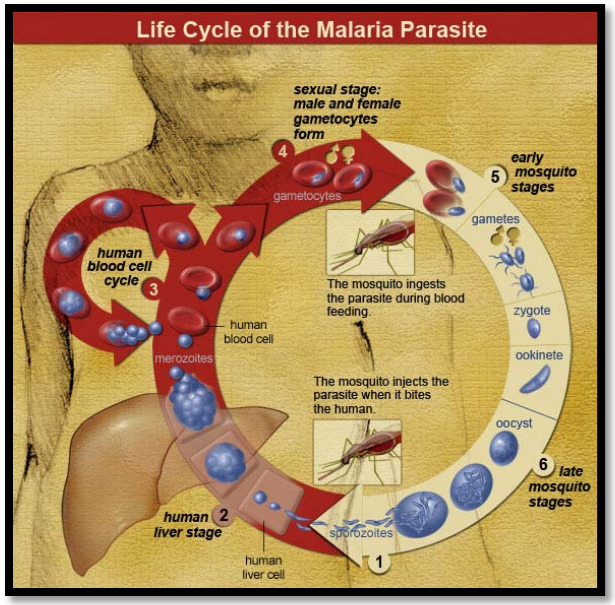
  Cause: *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae, Plasmodium ovale*

  Plasmodium falciparum is the most dangerous species

- **Transmission**: Female mosquito

  Male and female mosquitoes feed on nectar and plant juice

  Female mosquitoes need blood for reproduction



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GAPMINDER: WORLD

- Gapminder is a free data exploration and visualization tool
- Lots of world data from sources such as WHO, FAO, others are loaded into it
- Use it to find your own interesting trends

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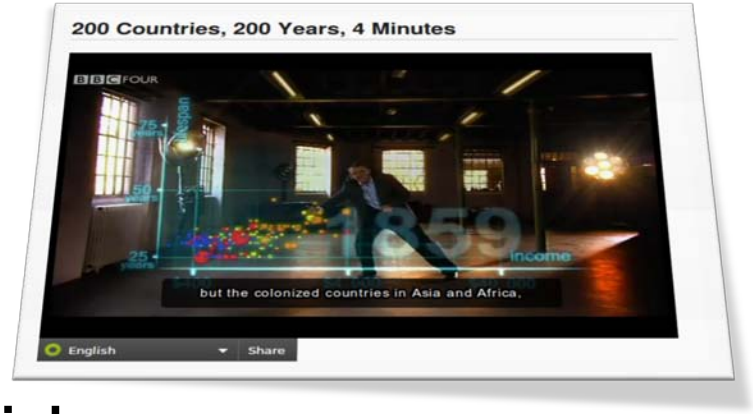
Getting Started



- Watch the introductory video:

http://www.gapminder.org/videos/200-years-that-changed-the-world-bc/

- Open Gapminder World
- Check out the tutorial on the next slide (or click “How to Use”)
- Use the spreadsheet to start thinking about malaria

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Gapminder World Guide

www.gapminder.org/world

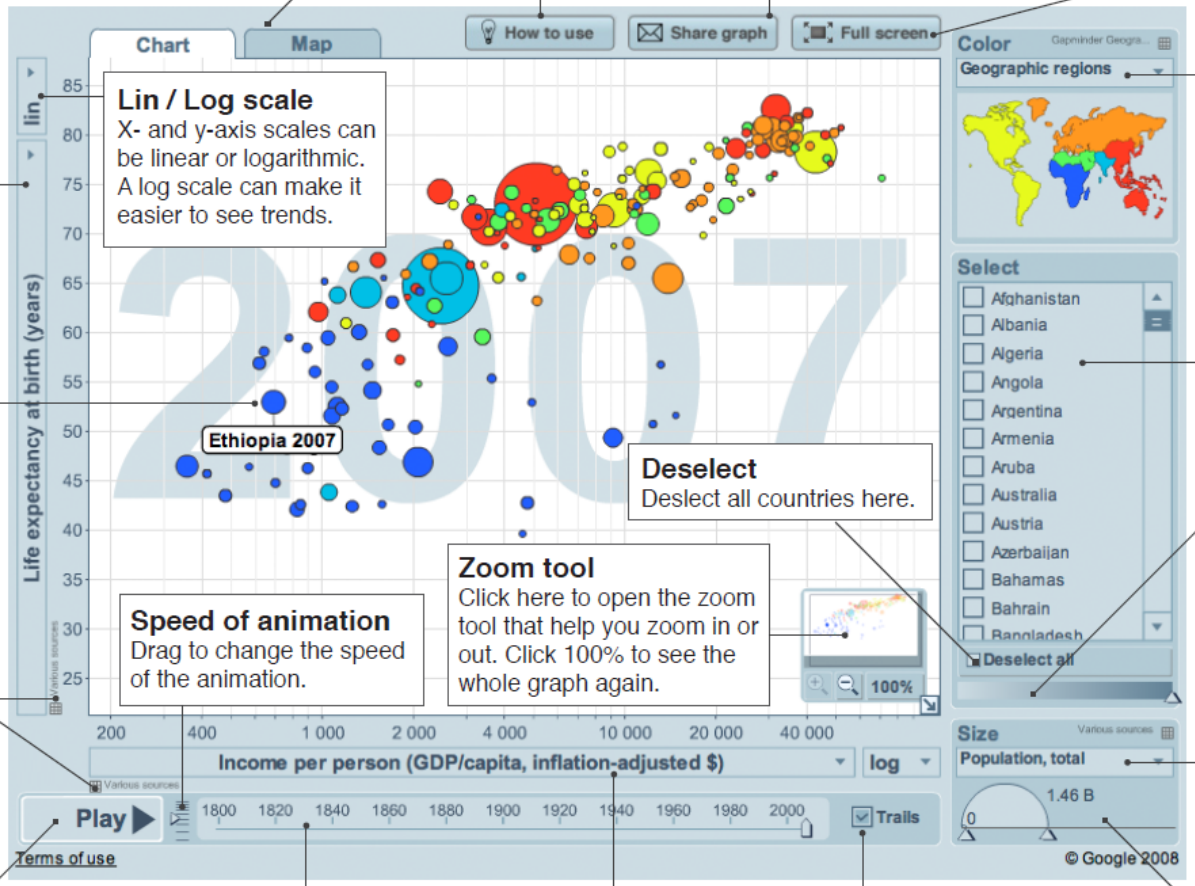
(updated March, 2010)

Chart / Map
Select between Chart view and Map view.

How to use
Click to open video tutorial about the interactive functions.

Share graph
Creates a short URL to the graph you've created. Share it with friends.

Full screen
Click to toggle full-screen. Graph will cover the whole screen. ("Lecture mode")



Color
The countries on the graph are color-coded by continent. Click to choose another indicator for color.

Y-axis
Click here to select indicators for the y-axis.

Lin / Log scale
X- and y-axis scales can be linear or logarithmic. A log scale can make it easier to see trends.

Select countries
Click boxes to select specific countries. (You can also click the bubbles.)

Name of country
Hover mouse pointer over bubble to reveal the name.

Deselect
Deslect all countries here.

Opacity
Drag to adjust visibility of non-selected countries.

Zoom tool
Click here to open the zoom tool that help you zoom in or out. Click 100% to see the whole graph again.

Sources
For information about the sources, click the small text next to the axis.

Speed of animation
Drag to change the speed of the animation.

Size indicator
The size of the bubble normally represents the population of the country. Click here to make the size show another indicator.

Play / Stop
Click Play/Stop to control the animation. (How the graph changes over time.)

Time
Click and drag to change year.

X-axis
Click here to select indicators for the x-axis. You can also choose to display **time** on this axis.

Trails
Click Trails to follow a selected country while the animation plays.

Bubble size
Change the size of the bubbles here.

Adapted from an original idea by wwww.juicygeography.co.uk

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From Gapminder World Website

Share Your Findings

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Effects of Malaria

- Effects range from mild to fatal, including cerebral malaria
- About 1.24 million deaths in 2010 (Murray et al. 2012)
- In Africa, a child dies every 45 seconds of Malaria
- Malaria prevalence is high in developing countries due to:

  poverty,

  human behavior,

  poor sanitation,

  inadequate drainage,

  drug resistance, etc.
- Malaria has a negative impact on economic growth.
- People moving from regions without malaria to regions where it is present are more at risk

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For This Module & More …

- Website: www.nimbios.org
- Sign up for our bimonthly email newsletter
- Check our blog

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Acknowledgements

Disease modeling activity adapted from:

- Jungck, J.R., Gaff, H. and A.E. Weisstein. 2010. Mathematical Manipulative Models: In Defense of “Beanbag Biology”. CBE-Life Sciences 9(3): 201-211.

Slides on Malaria disease adapted with permission from:

- Dr. Calistus Ngonghala, NIMBioS postdoctoral researcher

And for the excellent data tool, video, tutorial resources:

- Dr. Hans Rosling and www.gapminder.org

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