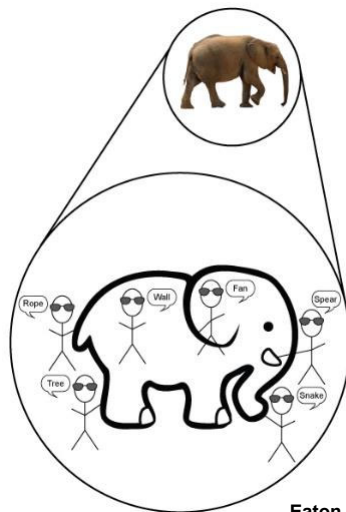


## Think – Write – Pair – Share

- What is a model?
- What is modeling?

**A *model* is a simplified, abstract or concrete representation of relationships and/or processes in the real world, constructed for some purpose**

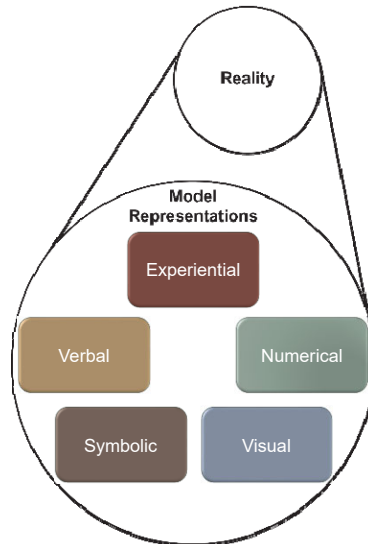


**Models can serve several purposes:**

- Models are used to communicate ideas between scientists.
- Simple, unrealistic models help scientists explore complex systems.
- Models can lead to the development of conceptual frameworks and causal explanations (i.e., understanding)
- Models can make accurate predictions.

Eaton et al. (2016) <https://arxiv.org/abs/1607.02165v2>; Odenbaugh (2005)

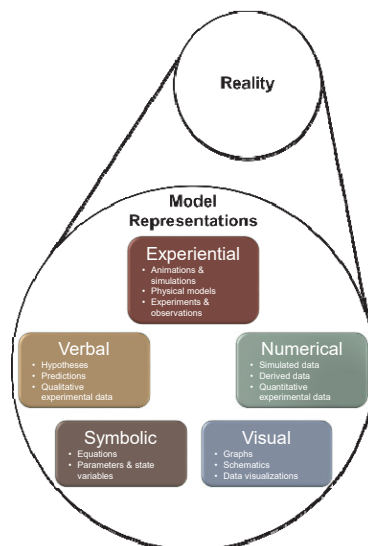
## We aim to be both more expansive and more inclusive of what counts as models



### What's the big deal?

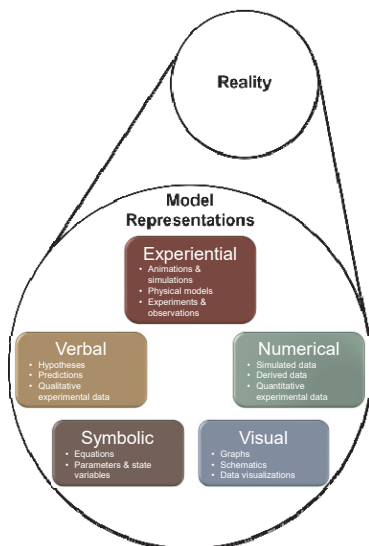
- Models are not *only* formulas.
- Understanding is strengthened when you can make connections between different representations.
- You may prefer working with certain representations, but you will benefit the most from seeing and using multiple representations and from moving between them.

## Verbal Representation



- **Hypothesis:** A mutation in a particular gene will reduce the rate of bacterial growth because the mutation impairs DNA replication.
- **Prediction:** On average global temperature will increase.
- **Assumption:** We assume that the population is well mixed.
- **Simple descriptions of observations:** The rate of increase is decreasing; we observe far more of the blue flower type than the purple flower type.
- **Qualitative data:** Spiciness ratings by tasters of chili peppers.

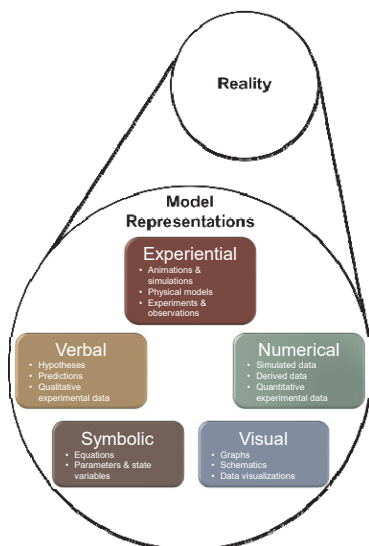
# Visual Representation



- **Graph:** relative growth rate versus population
- **Schematic:** SIR epidemic model; stock-and-flow diagrams
- **Data visualizations:** histograms, scatter plots, infographics, etc.

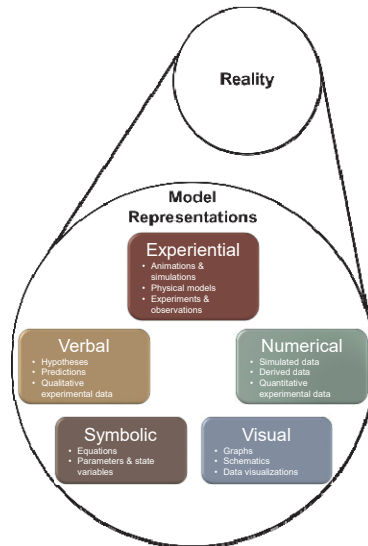
# Symbolic Representation

a.k.a. mathematical model



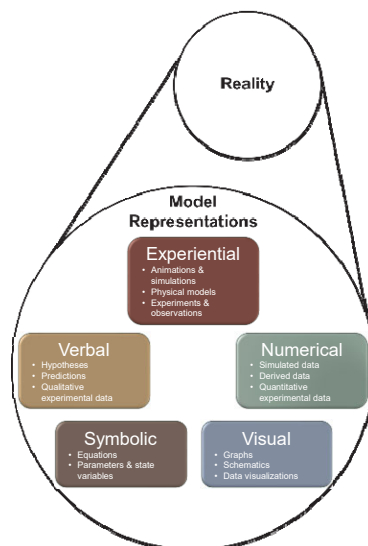
- **Equations:** Discrete difference equation for geometric growth  $x_{n+1} = \lambda x_n$  and continuous differential equation for exponential growth  $dP/dt = rP$
- **Parameters:** If in HWE,  $p$  = frequency of one allele,  $p^2$  = frequency of homozygotes for that allele
- **State variable:**  $P(t)$  = population at time  $t$  (in years)
- **Equation (stats):** linear regression
- **Equation (stats):** probability distribution

# Numerical Representation

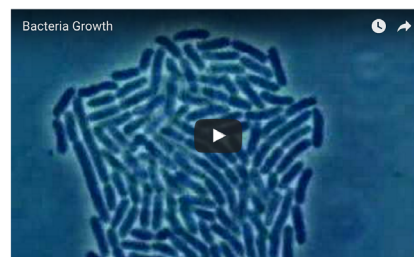


- **Simulated data:** Numbers of infected individuals calculated from a Symbolic epidemic model
- **Derived data:** low density growth rate and carrying capacity calculated from plotting relative growth rate versus population for logistic growth
- **Quantitative Experimental Data:** Measured population counts from experiments

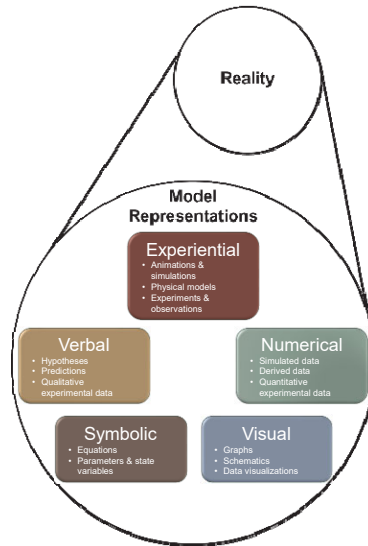
# Experiential Representation



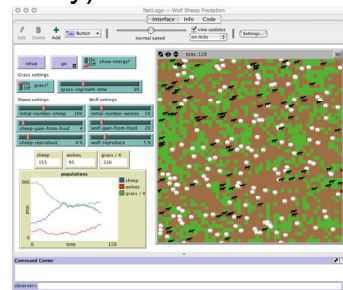
- **Animations & simulations:**  
A video of bacterial growth; beanbag biology; virtual laboratories (e.g, SimBio, the BUGBOX-predator virtual laboratory)



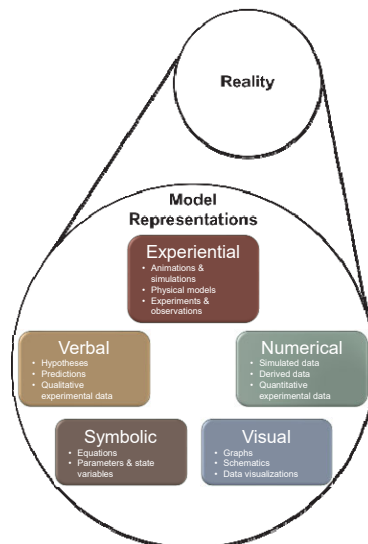
# Experiential Representation



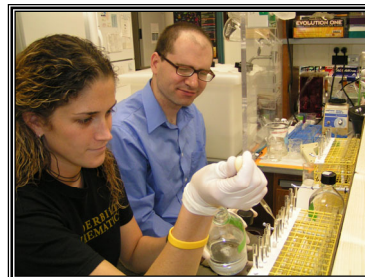
- **Animations & simulations:**  
A video of bacterial growth; beanbag biology; virtual laboratories (e.g, SimBio, the BUGBOX-predator virtual laboratory)



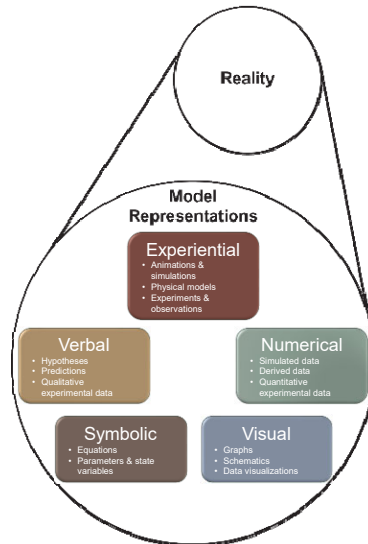
# Experiential Representation



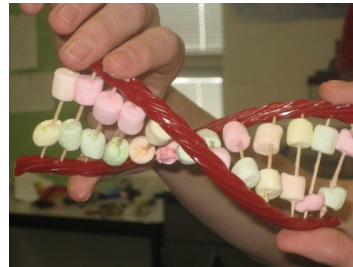
- **Experiments & observations:**  
measure bacterial growth in the laboratory



# Experiential Representation



- **Physical model:** structure of DNA



## The Process of Modeling Is the Process of Science

