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Systems Biology Education Modules to Promote Computational Thinking in High School Students

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Kelsey Watts is a fourth year Ph.D. student in Bioengineering at Clemson Univerity. She is currently working on developing Systems Biology outreach modules focused on computational skill development for Clemson's Emerging Scholars program.

Dr. Will Richardson, Clemson University

Dr. Richardson received a B.S. in Biological Engineering with high honors from the University of Arkansas in 2007, and a Ph.D. in Biomedical Engineering from Texas A&M University in 2012 with training in the Vascular Mechanics Lab under Dr. Jimmy Moore. His research at Texas A&M developed novel cell-stretching devices for in vitro analysis of cellular responses to spatially varying mechanical strains on 2D and 3D polymer constructs. Subsequent to graduate work, Dr. Richardson was awarded an American Heart Association Postdoctoral Fellowship to work with Dr. Jeff Holmes and Dr. Jeff Saucerman at the University of Virginia in the Cardiac Biomechanics and Cardiac Systems Biology labs. At UVa, he helped develop computational models of cell-matrix mechanobiology in order to understand the processes regulating myocardial infarct scar structure. In 2016, he joined Clemson University Department of Bioengineering as an Assistant Professor and started the Systems Mechanobiology Lab. The lab's expertise is matrix systems mechanobiology, focusing on the use of in silico systems models to identify cell and matrix processes dominating collagen structure regulation, conducted alongside in vitro cell-stretching experiments to test model predictions and engineer designs for fibrotic control in vivo. He has received several honors including the Richard Skalak Best Paper Award from the American Society of Mechanical Engineers, and the University of Arkansas College of Engineering Early Career Award. Dr. Richardson loves exploring the wonders of nature outside the lab as well, especially hiking and camping with his wife and children.

Systems Biology Education Modules

Purpose:

Target Age:

High School

Career opportunities requiring a computational background are on the rise. Because of this, there is a need to incorporate computational thinking development into K-12 education. These skills can be fostered in a multitude of ways that are not just limited to teaching kids to code. In fact, research has shown that hands-on and role-playing activities can increase student motivation and participation in learning computational thinking. The goal of our Systems Biology Education Modules is to expand this concept of using active learning techniques that directly complement coded simulations to a high school level by developing structured lesson plans that could be followed by instructors and students with a minimal computational background.

In-Class Activity

- Hands-on or role-playing activity related to the model
- Can be conducted with inexpensive materials
- Lesson plans provide suggested discussion questions

Goal: increase student buy-in and introduce them to computational and biological concepts

Model Tutorial

- Provides detailed instructions on the development or manipulation of a biological model
- Screenshots of code included

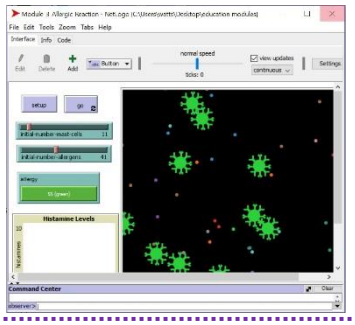
Goal: introduce students to NetLogo* capabilities and syntax as wells as basic computational logic

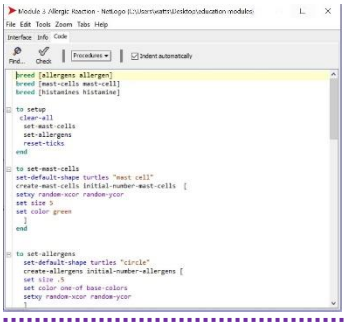
Model Testing and Advancement

- Leads students through steps to create their own strategy to test or improve the model made in the tutorial
- Requires integration of biological and computational concepts

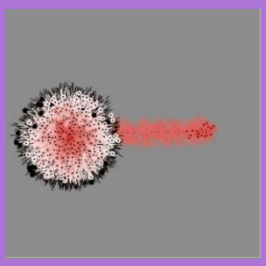
Goal: have students develop their computational skills by manipulating the simulation

*All simulations utilize NetLogo (https://ccl.northwestern.edu/netlogo/) which is an open-source software which allows for simulation development using button and drag and drop components paired with coded scripts



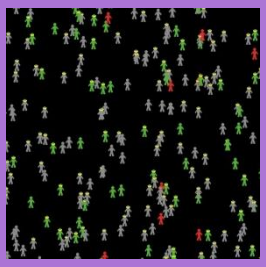


Education Modules



Module 1: Tumor* Growth Simulation & Model Limitations

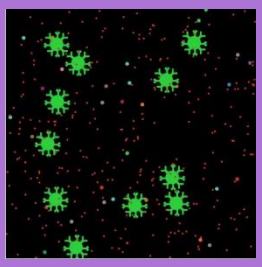
- Biologically- observe the progression and treatment of a disease from a cellular level
- Computationally- gain experience in using a model to test predictions as well as identifying model limitations



Module 2: Virus* Prevention Simulation & Model Inputs

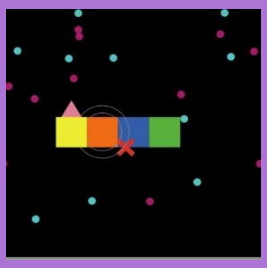
- Biologically- examine population dynamics and viral spread
- Computationally- research and test the effect of input parameters on a model

*Modules 1 and 2 build upon NetLogo's built-in Tumor and Virus models



Module 3: Immune Reaction Simulation & Model Rules

- Biologically- consider how different cells and molecules interact to elicit an immune response
- Computationally- define rules and make assumptions to create an agent-based model



Module 4: Gene Regulation & Stability Using Boolean Logic

- Biologically- exposure to a common model of gene regulation
- Computationally- define rules using Boolean logic and analyze model outputs to identify a system's emergent phenomena

Scan QR code to access a Google Drive with lesson plans and NetLogo simulations

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Special Thanks to