**Title: Hacking virus spread – modeling COVID (or other disease) spread with mathematical SIR model**

SARS-2 or COVID-19, has spread all around the world and the cases have accumulate over time, but how, and can we use math to understand and predict the trends? In this lesson students will use a computer simulation of the mathematical SIR model to understand how transmission and recovery rates affect the number of people who get infected and when. There are 2 versions/tracks. One in which students will change parameters on an interface to see how the plots change (grades 6-8/no coding experience *1-1.5 hours*). The second version/track has code which students can review and manipulate to explore how to build the model for themselves (grades 9-12/coding experience *1.5-2 hours*).

See <https://github.com/jennifer-bio/workshops> for maintained lesson plan and source code

**What standard(s) does this address?**

|  |  |
| --- | --- |
| NGSS Performance Expectation  *Write it out, not just the #.* | CCC4: Systems and System Models  **Energy:**  Develop a model to describe unobservable mechanisms. **(MS-PS3-2)**  Create a computational model or simulation of a phenomenon, designed device, process, or system. **(HS-PS3-1)**  **Ecosystems:**  Growth of organisms and population increases are limited by access to resources. **(MS-LS2-1)**  Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support**. (HS-LS2-1), (HSLS2-2)** |

**Keywords:**

Viruses, infectious disease, epidemiology, math models, R, coding, SIR, COVID-19, grades 6-8, grades 9-12, virtual lab

**Learning Objectives:** What will the students be able to do or demonstrate after this lesson?   
After completing this lesson, students will be able to:

* Describe SIR model and how it relates to disease rates in a population
* Test how parameters effect a model
* Illustrate how limited resources (susceptible population) reduces growth rate of virus population (number of infected individuals)
* Recognize R code and understand some of basic pieces of syntax (version 2)

**Lesson plan outline:**

* Engage 10 min
  + SARS-2 or COVID-19, has spread all around the world and the cases accumulate over time, but how, and can we use math to understand and predict the trends?
    - <https://vac-lshtm.shinyapps.io/ncov_tracker/>
      * Optional: Outbreak comparisons – flu has more cases, SARS-1/Ebola have more deaths per case, but SARS-2 has the most fatality because it combines many cases with medium fatality rate
* Explore 15 min
  + Play around with the parameters – how much of the population is infected? How does the transmission rate change this, infectious period?
  + Simple version but is less clear about what each line is <https://bjornstad.shinyapps.io/ch2sir/>
    - S: susceptible
    - I: infectious
    - R: removed
  + You could use <https://alhill.shinyapps.io/COVID19seir/> which is used latter and has more clear labels
* Explain 20-30 min
  + Review basic epidemiology (ie you can only get sick from virus if you have been exposed ect.) and SIR model
    - See tutorial of <https://alhill.shinyapps.io/COVID19seir/>
    - Written
      * <https://towardsdatascience.com/infectious-disease-modelling-beyond-the-basic-sir-model-216369c584c4>
      * <https://towardsdatascience.com/infectious-disease-modelling-part-i-understanding-sir-28d60e29fdfc>
    - Video (for teachers or calc/preclac)
      * <https://www.youtube.com/watch?v=NKMHhm2Zbkw>
      * (I have not found an accurate video for younger students)
* Elaborate 20/45min
  + **Version 1 - Estimating parameters**
    - Modeling works by making assumptions as to the most important factors in a situation and building the model structure from that, here that would be the SIR model structure. The next step is to fit the parameters to evidence from the past, that is what students will do for this activity. The last step in modeling is to use the parametrized model with the chosen parameter values to predict what will happen in the future – an extension of this activity would ask students to look at the results they might get from a vaccine (preventative strategy)
    - At <https://alhill.shinyapps.io/COVID19seir/>
    - The default parameters are for all of the US, try to set up the parameters that reflect India in this plot <https://ichef.bbci.co.uk/news/800/cpsprodpb/18018/production/_113282389_doubling_coronavirus_measures_india-nc.png> from <https://www.bbc.com/news/world-asia-india-53284144>
    - If including preventative strategies: The default parameters are for all of the US, try to set up the parameters that reflect Germany in this plot <https://www.janheiland.de/post/covid-19-trends/featured.png> from <https://www.janheiland.de/post/covid-19-trends/> (hint put in preventative strategy in march)
  + **Version 2 - Coding:** Walk through the code, try changing the parameters, or adding more events
    - <https://mybinder.org/v2/gh/jennifer-bio/workshops/master?filepath=SIR_model_R.ipynb> **OR** <https://mybinder.org/v2/gh/jennifer-bio/workshops/HEAD> (click on SIR\_model\_R.ipynb)
      * Note this can take a while to load so have students open it at the start of the explain portion, they may need to try different browsers if it is not working – chrome seems to work better than firefox
      * If students have jupyter set up on their computers they can get the source code from <https://github.com/jennifer-bio/workshops>
      * the default parameters are NOT real values
* Evaluate
  + Challenge/reflection problems for students such as:
    - Why is social distancing important? (versions 1 and 2) How would you include social distancing in the model? (version 2)
    - If a vaccine works 90% of the time – what proportion of people need to get the vaccine?
    - What questions do you have about how viruses spread
    - What is missing from this model – what could change the results of this model but was not included (for example this model assumes that all susceptible people are equally likely to interact with infectious people however some people interact with others much more than other people, some people are sick and infectious longer than others ect)
    - What does the following code do (version 2)

y = 0

for (x in c(1, 2, 3, 4, 5)){

y = y + x

}

return(y)

**Appendix:**

Teacher and precalc/clac SIR model introduction

<https://www.youtube.com/watch?v=NKMHhm2Zbkw>

Pre-biology course virus background:

Immune system reading background: <https://www.thepartnershipineducation.com/resources/immune-system>

Intro to viruses video:

<https://www.youtube.com/watch?v=8FqlTslU22s>

during/post biology course:

virus video:

While the information in the video is accurate to the best of my knowledge I recommend a reminder before showing that this video focuses on critical infections and only about 5% of cases are critical infections, this is not the course of the disease for most people so please do not panic

<https://www.youtube.com/watch?v=5DGwOJXSxqg>

Optional advanced/challenge

how this kind of model is actually being used – this is science that is currently being developed so I would not expect anyone to understand much, but there are some figures that are somewhat approachable it might be interesting as a challenge problem

[*https://www.medrxiv.org/content/10.1101/2020.06.23.20138099v2.full.pdf+html*](https://www.medrxiv.org/content/10.1101/2020.06.23.20138099v2.full.pdf+html)