# Lab exploration 8: Self-organizing systems III: Cascades
# Math 309 Fall 2022
# Deadline: class 30 November

- Conduct experiments as indicated.
- **Journal entry.** Respond to each of the "journal queries." Using *concise and clear sentences*, incorporate data, symbols, and illustrations into your text. Have an audience in mind. Focus on *developing* an explanation or argument that stems from your simulations.
- Submit 300-400 words double-spaced to te Beachboard dropbox.
- **Recommended.** Work in groups of 2 or 3. Submit one journal entry for the group.
- **Suggestion.** Before running the simulations, read the "What is it?" and "How it works" sections under the Info tab.

**Model: Sandpile.** (Location: Models Library/Chemistry & Physics.)

The model simulates the dynamical behavior of an idealized 3-dimensional sandpile: when the number of grains on a cell reaches four, a slide occurs in which the four grains are distributed to the four adjacent cells. The grains-per-patch value determines how many grains of sand are placed on each cell when setup uniform is selected. Note that each cell gets the same initial number of grains. The color of a patch—from dark to light—indicates the number of grains it contains—from 0 to 3.

## 8.1 Journal query.

Start with each cell having no grains and run the process with drop-location: random selected. Let things run until some significant slides (called avalanches in the model) occur. (Since this can take a large number of steps—equal to the number of grains placed, you might want to speed up the process.) You can see the slides by switching on animate-avalanches. Check the plots of Avalanche sizes. How closely do the data conform to a power law?

## 8.2 Journal query.

Put three grains on each cell and set the process to drop grains on the cell at the center. Before hitting go once, try to predict what will happen when the grain drops. Continue to drop grains manually and look for patterns to emerge. Does it make sense to call the state of the system *critical* at this stage? Is the behavior here similar to what takes place when water freezes?

**For fun:** In automatic drop mode, let the process continue for many steps—say around 10,000.

## 8.3 Journal query.

Start again with a uniform distribution of three grains. Now drop grains randomly and repeat for many steps and slides. What sort of configuration eventually emerges? Briefly explain.

**Model: Virus.** (Location: Models Library/Sample Models/Biology.)

Here we have a simulation of virus transmission. There are three states in which an agent can be: 1) healthy and susceptible to infection, 2) infected (sick), and immune (previously infected and recovered). Note that immunity wanes after one year—an immune agent returns to the healthy but susceptible state. Infected agents either recover or die. The parameter variables are:

> infectiousness: the chance that an infected agent will transmit the virus to a healthy agent if they occupy the same patch (one of the cells into which the space is divided)

chance-recover: the probability that an infected agent will recover and acquire temporary immunity

duration: how long it takes an infected agent either to recover or die.

When the model starts, there are a select number of agents (number-people) ten of whom are randomly selected to be infected. The agents move about and interact in a random fashion.

Set infectiousness at is maximum value (99%), chance-recover at its minimum (0%, meaning that no infected agents recover), and duration at its minimum (0 weeks, meaning that infected agents recover immediately).

### 8.4 Journal query.

Begin with 300 agents and run the model. What happens? Why?

### 8.5 Journal query.

Gradually increase the duration setting until the population reliably dies out (say for five consecutive runs). Call the threshold value of duration that you've found $D$.

### 8.6 Journal query.

With duration set at $D$, gradually decrease the initial number of agents until the entire population is healthy—the infection is eradicated. Briefly explain what property of the system is responsible for the emergence of this state. What does the model suggest regarding behavior during an epidemic or pandemic?

### 8.7 Journal query.

What's an unrealistic feature of the model?

**Model: Fire.** (Location: Models Library/Earth Science.)

The model follows a simple rule for the spread of a forest fire: if an unburned tree is next to a burning tree, the unburned tree burns. Also, once a tree burns, it doesn't burn again. When the simulation is initialized, every cell is randomly selected as either a tree or empty (empty spaces don't burn) according to the value of density.

### 8.8 Journal query.

Beginning with the density low, gradually increase—by increments of 5%—the value until a density $C$ is reached where the fire reliably burns at least 80% of the forest. (Make several runs for each density value and then average the fraction burned.) Plot the averaged burn-fractions as a function of density up to $C$. Describe the behavior of the burn-fractions when the density gets close to $C$. Does this seem to involve a critical transition?

### 8.9 Journal query.

How does the dynamics of fire propagation compare to that of sand-slides?

### 8.10 Journal query.

To what extent might the fire model indicate how a disease spreads. What's the key parameter here? What's an important property of a transmissible disease that the fire model omits?