Activity I: E. Coli Simulator

Developed in Fall 2003 for CD173 at Tufts University, Medford, MA. Please contact Michael Horn (michael.horn @ tufts.edu) for more information.

Summary

In this activity, students will use a computer simulation to explore and chart the exponential growth of a colony of E. coli bacteria. The students will then devise visual representations for their data.
Grade Levels: 6-8

Background

The students should have some basic understanding of cell biology. They should know that cells are the tiny units that make up all living things and that cells are so small we can't see them without the help of a microscope. They should know something about the parts of a cell: the cell membrane, the nucleus, mitochondria, etc. Ideally, they will also have had a chance to see some living cells through a microscope. In addition, the children should have some experience with graphs and charts that describe the relationship between two variables or the change in one variable over time.

Massachusetts Curriculum Framework

6-8 Mathematics

- **6.N.1:** Demonstrate an understanding of positive integer exponents, in particular, when used in powers of ten, e.g., 10^2, 10^5.
- **6.P.4:** Represent real situations and mathematical relationships with concrete models, tables, graphs, and rules in words and with symbols, e.g., input-output tables.
- **6.P.6:** Produce and interpret graphs that represent the relationship between two variables in everyday situations.
- **8.P.EX:** Use tables, graphs, and appropriate technology to explore quadratic and exponential growth patterns.

6-8 Life Science (Biology)

1. Classify organisms into the currently recognized kingdoms according to characteristics that they share. Be familiar with organisms from each kingdom.

2. Recognize that all organisms are composed of cells, and that many organisms are single-celled (unicellular), e.g., bacteria, yeast. In these single-celled organisms, one cell must carry out all of the basic functions of life.

Materials

- large sheets of graph paper

- pens, markers, colored pencils, etc.

- rulers
- Cell Division Simulator software for Windows (http://www.cs.tufts.edu/ mhorn/cd173/)

Procedure

Introduction

Hold a class discussion to introduce the *Escherichia coli* (esh-er-ICK-ee-eh COLE-eye) bacteria and its cell division process. Start by drawing a picture of a single rod-shaped bacteria on the board. Your drawing should be approximately one meter in length. Share some of these interesting facts with the students.

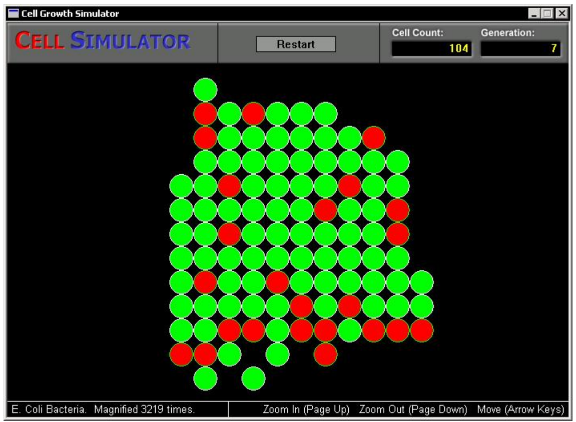
- **How big is it?** In real life a single E. coli bacteria cell is **2-3 micrometers** long. The drawing on the board is **500,000 times** bigger than real life. A student's thumb would be **12.5 miles** long if it were drawn on the same scale.
- **Where does it live?** Every organism has a habitat including E. coli bacteria. It's commonly found in our intestines, although it can also live in water and food. E. coli is necessary for our survival because it helps us break down food into essential nutrients like Vitamin K and B.
- **How many?** Some scientists have estimated that the human intestines produce approximately 20 billion new E. coli cells every single day.
- **Where do they all come from?** Suppose there was a single E. coli cell living on a piece of food that was dropped under your refrigerator. That cell would consume some of the food and grow longer and longer until it eventually split into two cells. Those two cells would continue to consume the food until they split into four cells. And so on. This process is called **binary fission**.

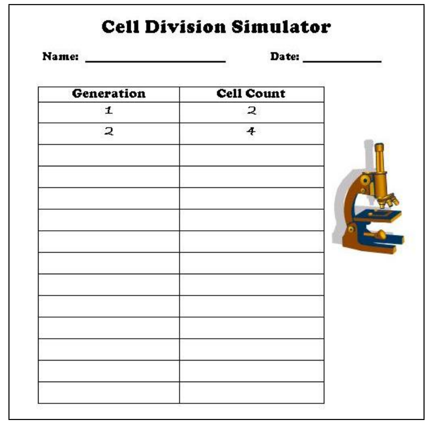
Draw this diagram on the board and have the students fill in the numbers. Each box represents a generation. After one generation there are two cells, after two generations there are four cells, and so on.

1 Cell	**2 Cells**	**4 Cells**	**8 Cells**
•	••	••••	••••••••

Computer Simulation

- Have the children gather around a computer for a demonstration of the cell-division simulator. The program displays a single green circle. Asks the students to imagine that the green circle represents a single-cell bacteria growing on a piece of food. The cell is magnified **2,220 times** its original size. The simulation displays two numbers labeled *generation* and *cell count*. Both numbers are 1.
- Click on the green circle, and it will *divide* into two red circles. The cell count and generation numbers are now both 2. Explain that you are now looking at the second generation of the cell *colony*. Simulate another generation or two and point out the generation and cell counts as they go along. The program will display the current cell count in a dialog box at the end of each generation.
- Break the students into small groups and have them take turns using the simulation software. Encourage the students to click on the cells to see how many generations they can simulate. One member of each group should be responsible for writing down the generation and cell count numbers.





Cell Division Simulator

Name: ________________ Date: __________

Generation	Cell Count
1	2
2	4

Graphing

- Bring the students back together and ask them to talk about their experiences using the simulator. After a while, the discussion should start to focus on the numbers that the students recorded.
- Ask the students to review what they know about using graphs and charts to represent numbers. They should talk about different kinds of graphs, what they represent, etc. Writes the students' ideas on the board, and draw a few examples together.
- Ask the students to rejoin their groups and work together to create a graph or a chart that represents the numbers they recorded using the simulation software. Give them several large sheets of paper, markers, rulers, and other materials.
- When they are done, have the groups take turns explaining their graphs to the other children.

Activity II: Cell Division Flip-Book

Developed in Fall 2003 for CD173 at Tufts University, Medford, MA. Please contact Michael Horn (michael.horn @ tufts.edu) for more information.

Summary

Time-lapse movies are powerful scientific and educational tools that allow us to see the world in new and exciting ways. In this activity, students will expand their understanding of exponential growth and cell division by creating animated, time-lapse "flip-books" that bring bacterial cell division to life.

Grade Levels: 6-8

Objectives

- Students should deepen their knowledge of bacterial cell division.
- Students should understand how time-lapse movies are created and why they are useful for scientific research.
- Students should further explore concepts of exponential growth.

Background

Students should have a basic understanding of cell biology, bacteria (such as E. coli), and bacterial cell division. They should be familiar with some of the basic terms such as *binary fission*, *prokaryotic*, and *cytokinesis*.

Massachusetts Curriculum Framework

6-8 Life Science (Biology)

2. Recognize that all organisms are composed of cells, and that many organisms are single-celled (unicellular), e.g., bacteria, yeast. In these single-celled organisms, one cell must carry out all of the basic functions of life.

4. Recognize that within cells, many of the basic functions of organisms (e.g., extracting energy from food and getting rid of waste) are carried out. The way in which cells function is similar in all living organisms.

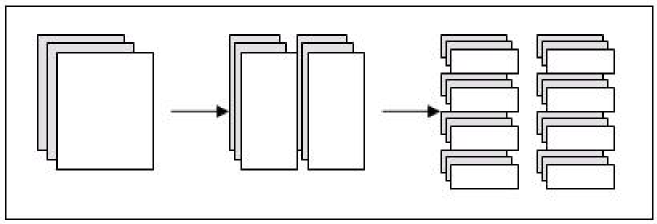
Materials

- 30-40 sheets of white paper
- pencils, colored pencils, markers
- rulers
- glue

- book binding tape
- pictures and diagrams of bacteria and bacterial cell division

Preparation

Cut the stack of white paper into even strips approximately 2 $\frac{1}{2}$ inches wide by 4 $\frac{1}{4}$ inches long according to the diagram below. It is best to use a paper cutter and to cut no more than ten sheets at a time.



Re-combine the strips of paper into stacks of 30-40 sheets and secure each stack with a rubber band.

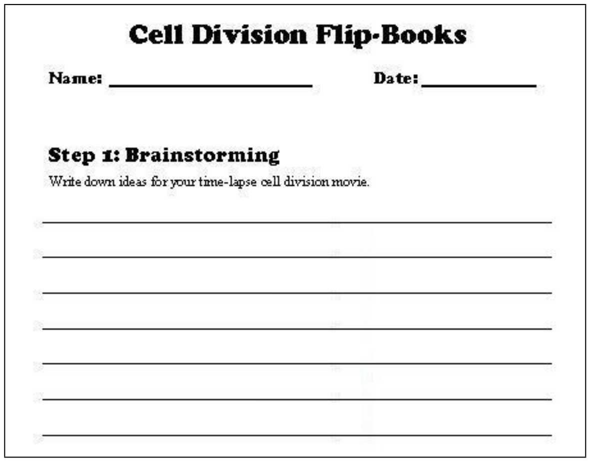
Procedure

Introduction

- Briefly review bacteria and bacterial cell division with the class.
- Introduce the term *time-lapse movie*, and have the class come up with a preliminary definition.
- Show a short time-lapse movie of bacterial cell division. Good time-lapsed movies can be purchased from the *Cells Alive* web site at http://www.cellsalive.com.
- Ask students how they think the movie was made. Make sure to touch on these important concepts:
  - The movie shows an extreme close-up of microscopic life
  - Slow motion vs. fast motion. In this case real life is much slower.
  - Scientists took single pictures at regular intervals and combined them into a movie.

Brainstorming

- Tell the students that they will be creating their own time-lapse movies of cell division.
- Break them into groups of two or three and ask them to brainstorm ideas for their movies. They should write their ideas on the worksheet.
- Emphasize that these will be *very* short movies.
- Distribute plenty of pictures and diagrams of bacteria and cell division to help give the students ideas.



Cell Division Flip-Books

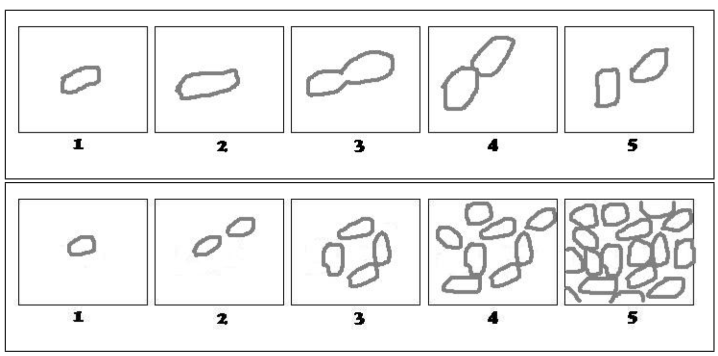
Name: ____________________ Date: ____________

Step 1: Brainstorming

Write down ideas for your time-lapse cell division movie.

Story Boarding

- Explain the concept of a story board. A story board is similar to a comic strip. It helps show what will happen during a movie.
- The first frame is for the beginning of a movie, the last frame is for the end, and the middle frames show what happens in between.
- Do an example story board together as a class, and then have the students break into their groups to create their own. Here are a some examples:



Flip Books: First Draft

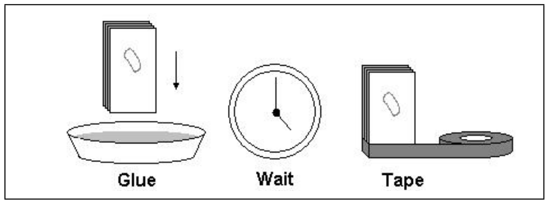
Show the class an example flip book, and explain how each page is only slightly different from the page before it. Pass out one stack of the white paper strips to each group, and have the students work in pencil to draw their movies, frame by frame. Make sure they leave close to 2 inches on the left side of each strip blank for binding. Encourage the students to divide the strips and work on different sections of the animation at the same time. They should test their movie periodically and make corrections as needed.

Second Draft

Once the students have completed the first draft of their flip books, they can begin inking over their pencil drawings and adding color.

Bindings

When the flip-books are complete, they can be bound. Hold the strips of paper together and dip the left side in a 1 inch deep tray of glue. Once the glue has dried, wrap book binding tape around the edge to secure the spine.



Discussion & Sharing

Have each group show their flip-books to the entire class. The students should explain what happens during their movies.

Variations

Similar activities can be done with other materials. For example, students could use play-doh and a digital camera to make clay-mation movies. Students could also work with computer drawing programs and print out each successive frame.

Activity III: Creating Robot Graphs

Developed in Fall 2003 for CD173 at Tufts University, Medford, MA. Please contact Michael Horn (michael.horn @ tufts.edu) for more information.

Summary

In this free-form programming activity, students will express the relationship between the generation of a bacteria colony and its population (number of cells). Students will construct robotic cars using Lego Mindstorms^{TM}. These cars will first read in a generation number and then move a distance corresponding to the number of cells in that generation. Students will write programs in ROBOLAB to control their cars. These programs will also be able to compute base-two exponents using variables and loops.
Grade Levels: 6-8

Objectives

- Students will further explore base-two exponential relationships introduced in Activity I.
- Students will expand their programming knowledge to include loops, variables, and system input.
- Students will explore more advanced robotic concepts such as "gearing-down," axels, and single-motor drives.

Background

Students should have had a basic introduction to Lego Mindstorms, programmable bricks, and ROBOLAB. Students should also have experienced and graphed the exponential growth of E. coli bacteria using the cell simulator in Activity I.

Massachusetts Curriculum Framework

6-8 Technology/Engineering

- **2.1** Identify and explain the steps of the engineering design process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.
- **3.2** Identify and explain the appropriate tools, machines, and electronic devices (e.g., drawing tools, computer-aided design, and cameras) used to produce and/or reproduce design solutions (e.g., engineering drawings, prototypes, and reports).
- **3.4** Identify and explain how symbols and icons (e.g., international symbols and graphics) are used to communicate a message.
- **4.2** Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

6-8 Mathematics

- **6.N.1:** Demonstrate an understanding of positive integer exponents, in particular, when used in powers of ten, e.g., 10^2, 10^5.
- **6.P.4:** Represent real situations and mathematical relationships with concrete models, tables, graphs, and rules in words and with symbols, e.g., input-output tables.
- **6.P.6:** Produce and interpret graphs that represent the relationship between two variables in everyday situations.
- **6.P.EX:** Use physical models to investigate and describe how a change in one variable affects a second variable.
- **8.P.EX:** Use tables, graphs, and appropriate technology to explore quadratic and exponential growth patterns.

Materials

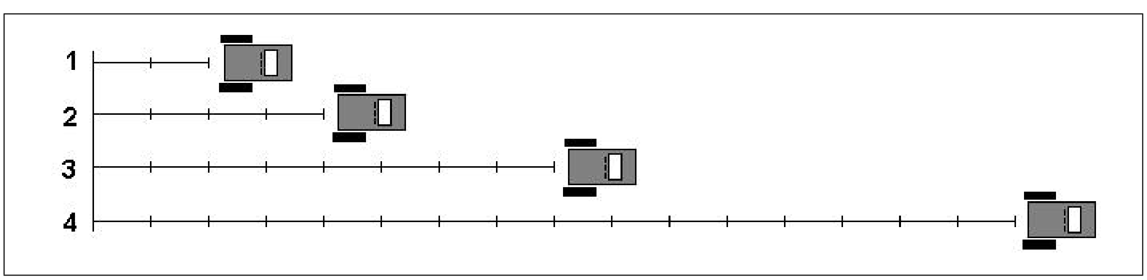
- Lego Mindstorms^{TM} Construction Kits
- ROBOLAB Programming Software
- tape measures

Procedure

Design Requirements

Explain to the students that they will be building robotic cars using Legos that will be able to physically graph the bacterial colony data they recorded in Activity I. Their cars have two basic requirements:

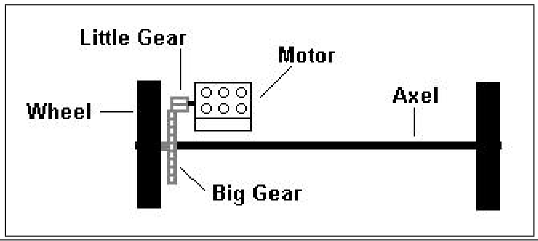
1. A person should be able to enter a generation number by repeatedly pressing one button on the RCX programmable brick.
2. When a person presses a second button, the car will move a certain distance corresponding to the number of cells in that generation. The students should define a unit of measure that represents one cell. This may be an inch, a foot, a car-length, or any other measurable unit that the students choose.

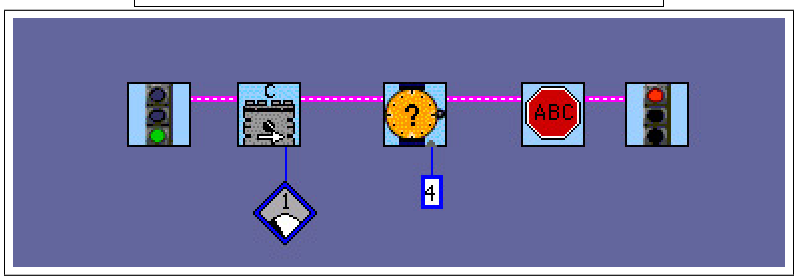


The activity works especially well on tiled floors or using a tape measure so that students can easily gauge the distance their cars have traveled.

Constructing Cars

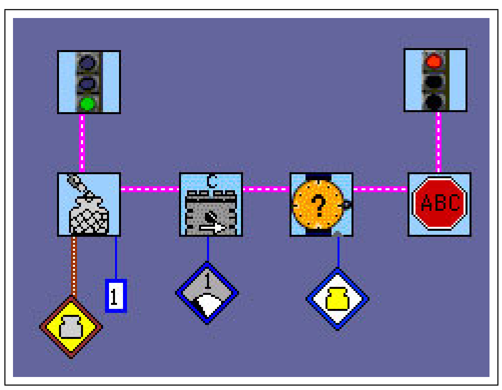
Have the students work in small groups to construct their cars. They can test them using a simple ROBOLAB program like the one listed below which turns motor A at power level 1 for four seconds. Try to have the students build their cars using a single motor connected to a single axel using gears. This will help the cars move slowly in a straight line.





Initial Program

Have all of the students open ROBOLAB Inventor and construct this initial program which illustrates the basic concept of a container.

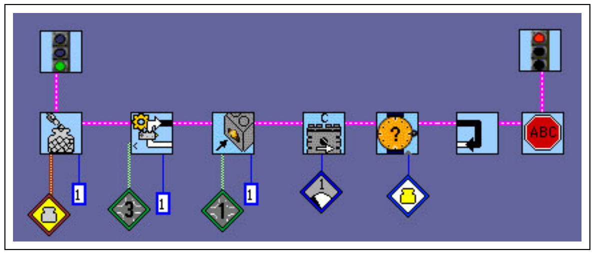


This program first initializes the yellow container with a value of 1. Next it starts the motor and waits the number of seconds stored in the yellow container. Students may have some difficulty understanding the difference between the value of a container and the assignment of a container. It might be a good idea to demonstrate these concepts using actual colored cups and cards with numbers on them. The value of a container is the number you put inside it. The assignment is which cup you put the number into.

Encourage the students to try initializing the container to different values. What happens when the value changes?

Loops

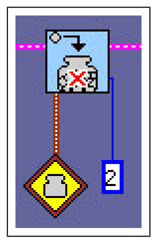
Next have the students write this program using loops.



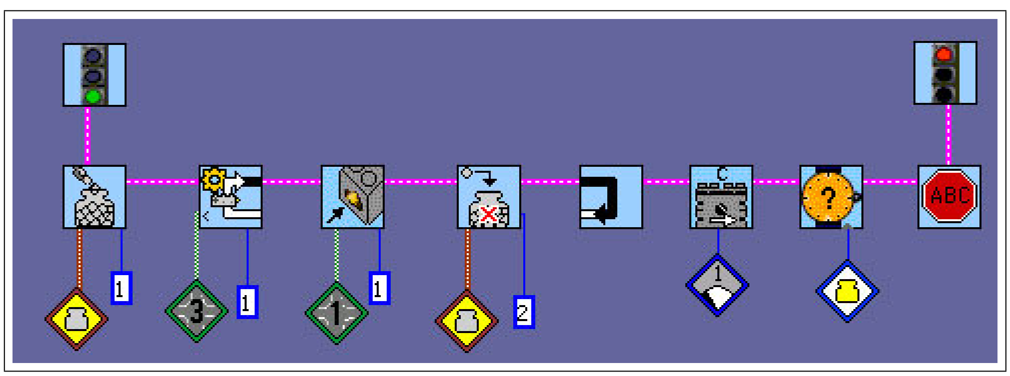
Here we use the *Loop-while-button-clicks-is-less-than* construct. In other words, while the first button hasn't been pressed, wait for the second button to be pressed and then move forward one second. Repeat. There are several new concepts being introduced here, so give the students plenty of time to implement the program, debug their systems, and play around with different configurations.

Design and Implementation

The students should now have almost all of the tools necessary to write their programs. One final piece is the *Multiply Into Operator*. The operator shown below multiplies the value in a container by 2.



Here is what a finished version of the program *might* look like. This is only one of many, many possible solutions. As much as possible, let the students devise their own solutions.



Wrap-up & Discussion

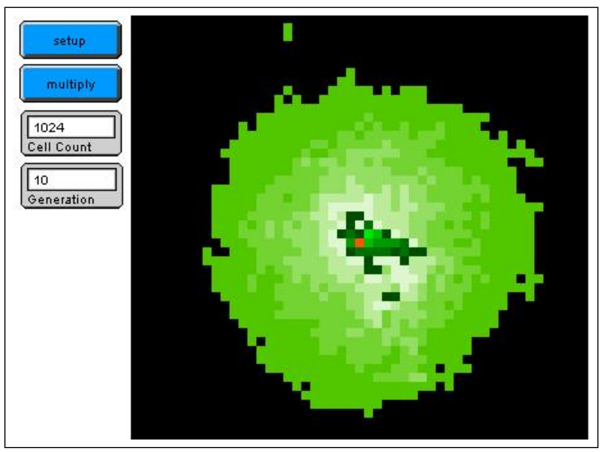
The students should test their cars and programs for several generations. They'll quickly discover that there isn't enough room in the classroom to do more than seven or eight generations. If some groups finish early, suggest extension activities or design enhancements. Finally, have each group explain their robot designs and programs and give a demonstration.

Activity IV: StarLogo E. coli Simulator

Developed in Fall 2003 for CD173 at Tufts University, Medford, MA. Please contact Michael Horn (michael.horn @ tufts.edu) for more information.

Summary

StarLogo is a programming environment that allows students to explore decentralized phenomena, such as a flock of birds, traffic jams, and the growth of bacteria colonies. In this activity, students will create their own versions of the cell growth simulator from the first activity using StarLogo and recursive programming.
Grade Levels: 6-8



Objectives

- Students will further explore base-two exponential relationships introduced in Activity I.
- Students will be introduced to new programming techniques such as recursion.

Background

Students should have some familiarity with the Logo programming language and preferably experience using StarLogo. Students should also have had the opportunity to use the cell simulator from Activity I and to have seen a time-lapse video of cell division from Activity II.

Materials

The StarLogo programming environment (http://education.mit.edu/starlogo/)

Procedure

Introduction

Introduce students to the StarLogo programming environment. Have them do the following:

1. Create a new project.
2. Execute some of the basic setup commands using the *Observer Command Center*. Important commands to try are: `clear-all` and `create-turtles`.
3. Send a simple command to all turtles using the *Turtle Command Center*. For example, try `fd 10`. What happens?

Procedures & Recursion

Show the students how to write procedures for the Observer and for the Turtles. For example, here's a simple setup procedure for the Observer:

```
to setup
clear-all
create-turtles 1
end
```

And here's a simple turtle procedure:

```
to circle
pd
right 15
fd 1
circle
end
```

These procedures can be invoked by simply typing `setup` or `circle` in the Observer Command Center or the Turtle Command Center. Notice that the `circle` procedure contains a line that also says `circle`. Thus, when `circle` is invoked, a turtle moves right 15 degrees, forward 1, and then it does it all over again, forever. When a procedure invokes itself like this one, it's called recursive.

Hatching & Exponential Growth

So what does this all have to do with exponential growth? Well, in StarLogo, turtles have a useful command called `hatch.` This command causes one turtle to divide into two identical turtles. Sound familiar? After hatching, you can have the new turtle can follow some commands. For example:

```
to divide
hatch [ right random 180 find-empty-spot ]
end
```

This procedure causes one turtle to hatch another turtle. The new-born turtle then turns right between 0 and 180 degrees and moves to an empty spot. The `find-empty-spot` command might look something like this:

```
to find-empty-spot
setc red
if count-turtles-here = 1
[ setc green stop ]
right random 10
fd 1
find-empty-spot
end
```

Believe it or not, with that procedure your students will have a completely functional cell simulator. Every time they invoke `divide` in the Turtle Command Center, the population of the turtles (or E. coli bacteria) will double in number. It's easy to set up a monitor to display the current number of cells using the built-in `count-turtles` command.