

Chapter 16

Factors Affecting the Spread of Disease in Human Populations

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Introduction

The subject of this exercise is a computer simulation of human populations. Running the simulation, gathering the data, and graphing the data takes about one and one-half hours. The lab is designed for a sophomore student who has had general biology courses and anatomy and physiology courses. Graphing skills are required. The software programs “Eppie™” and “Cricket Graph™” are run on Macintosh computers. The student should have some knowledge about how to use a computer graphics program and how to write a scientific report. Some experience with the concept of *probability* is also helpful.

Instructor’s Manual

Equipment: Macintosh computer, printer

Supplies: “Eppie” software, “Cricket Graph” (or equivalent), computer paper for printer

Sources:

“Eppie”

Intellimation

Library for Macintosh

PO Box 1922

Santa Barbara, CA 93116-1922

1-800-685-2100

“Cricket Graph”

Cricket Software

40 Valley Stream Pkwy.

Malvern, PA 19355

1-215-251-9890

“Cricket Graph III”

Computer Associates

International, Inc.

One Computer Assc. Plaza

Islandia, NY 11788-7000

1-800-225-5224

Set-Up: Students should work in groups of 2 -3, with one computer per group.

Notes To Instructor

You should make 8 copies of the blank data sheet per student, or ask that the students to make 8 copies before coming to lab.

If your students have a strong math background, encourage them to alter the probabilities that a well person becomes ill, that an ill person dies, and that an ill person becomes well.

The “Eppie” program will graph data as a simulation is run. These graphs can be captured by first depressing the **Caps Lock** key. Then in sequence press down the **Shift** key, the **Open Apple** key, and the number **5** key. The computer screen display will then give four choices for processing the captured graph or animation. Select **Send to Printer** by clicking on this selection with the cursor. Choose the number of copies to print. Then click on the **Print** button with the cursor.

Student Outline

Pre-Test

1. If a disease has human carriers as opposed to non-human carriers (such as mosquitoes) are more or fewer people likely to be infected with the disease?
2. Why are there more people with colds in the winter than in the summer?
3. If you lived in the country rather than in the city would you be more or less likely to contract a disease?
4. If almost everyone in a population is immune to a disease, what is the chance that a non-immune person new to the area will contract the disease?
5. Does one have a greater or lesser chance of contracting a disease, if people can be re-infected with the disease?

Objectives

The objective of this exercise is to show the student that the spread of disease is affected by such factors as: 1) the presence or absence of **carriers**, 2) human population **densities** and **patterns**, 3) **immune** status of the individuals, and 4) **reinfection** status of the individuals.

Introduction

Just as many students may dread going back to school in the fall, many dread contracting their annual “cold.” You may have observed that as the school year progresses, fewer people contract colds. Why does this occur? Have the advancements of our civilization fostered the spread of disease?

Dr. Macfarlane Burnet and David White observed that “Cities are essential to civilization and until well into the nineteenth century, all cities were the spawning ground of infectious disease. Crowded together in such filthy environments, every city dweller was inevitably exposed to infection every day of his life. It is no wonder that the population of cities through history has had to be recruited periodically from the country.” (Black, p. 412)

The spread of disease in a population is affected by many factors. One such factor is the presence in the population of carriers. A **carrier** is someone (or something) that harbors the pathogen and spreads it to other individuals. (**Pathogens** are disease-causing organisms such as bacteria or fungi, or viruses). A carrier may or may not show symptoms of infection. For example, a person can harbor the human immunodeficiency virus (HIV) for years without knowing it, and without showing signs of acquired immune deficiency syndrome (AIDS), the fatal disease caused by this virus. Human carriers can unknowingly transmit the pathogen to other humans. Some pathogens, e.g. cold and flu viruses, are transmitted through the air. Air transmission of the pathogen occurs when an infected person sneezes and a nearby person inadvertently breathes in the contaminated air, or when

two such people kiss. The transmittal of other pathogens require more direct, prolonged, or intimate contact, such as sharing body fluids during sexual intercourse (which is one of the most common means of transmission of HIV). Sometimes the carrier is not human, but rather another organism such as a mosquito. For example, mosquitoes harbor the pathogens that cause malaria which is transmitted to a human via the mosquito's saliva when the mosquito sucks the human's blood. When the carriers are non-human, the disease is sometimes easier to control. For example, one of the factors in finally eradicating the bubonic plague which swept through Europe several centuries ago, was the rising popularity of keeping cats as pets; the cats killed the rats that harbored the bacterium. Disease can spread in the absence of carriers. For example, anyone drinking water contaminated with the *Giardia* protozoan may become ill.

Population patterns (exactly where and how people live and interact with others) and densities (how many people are present within a defined area) are also important in the spread of disease. People living in close proximity, such as in the city, are more likely to spread infection than are those living in the country, where there is less person-to-person contact. One's ability to be re-infected is also a factor in the spread of disease. For example, the plaque bacterium usually can cause disease only once in an individual. After the bout with the disease, the person's immune system is able to eliminate the virus upon subsequent exposures to it, without the person suffering any symptoms.

In this exercise, students will investigate some of the factors that affect the spread of disease: 1) the presence and/or absence of carriers, 2) population patterns, 3) population density, and 4) one's ability to be re-infected (one's immune status).

Protocol

Probability is defined as the likelihood that an event will happen over a range of possibilities. In the context of disease, probability measures the reasonable but not certain chance of contracting a disease. This computer simulation will generate data on hypothetical human populations, based on the probabilities you set. Such a simulation can be used to generate valid predictions on the effects of disease. The parameters that are chosen for a given pathogen should reflect known characteristics of that pathogen and how it is normally transmitted. In this exercise, you will be told how to set the parameters. As you perform the simulations, think about which familiar human pathogens may spread according to the particular parameters you set.

In setting probabilities, make sure that a probability is not less than zero and that the total probability of one type changing to another type is not more than one. The rule that probabilities cannot be less than zero cannot be broken, and if you break the second rule, a "bad probabilities" note will appear. One can change the degree of infectiousness by changing **P(well>ill)** and **P(well>carrier)**. Infectious period and recovery period are controlled by **P(ill>well)** and **P(carrier>well)**. Mortality rate is set by **P(ill>dead)** and **P(carrier>dead)**.

How To Use Eppie

1. Turn on the Macintosh computer/monitor, if it is not already on.
2. Open up the **Eppie** program by double clicking on the **Eppie** icon. Click on **OK**.
3. When the program loads on the screen, click on the **Windows** selection of the menu of the screen, drag the cursor to and highlight the **Parameters selection**, then release the mouse button. The following parameters should be set up for all experiments unless one chooses to change these also (**P** is the probability that the person's condition will change; for example, the first **P** listed below indicates the probability that a well person will become ill; $P = 0.05$ means that 5% of the well people in a representative population is likely to become ill):

$$P(\text{Well} \rightarrow \text{Ill}) = 0.05$$

$$P(\text{Ill} \rightarrow \text{Dead}) = 0.10$$

$$P(\text{Ill} \rightarrow \text{Well}) = 0.15$$

$$P(\text{Well} \rightarrow \text{Carrier}) = 0.20$$

$$P(\text{Ill} \rightarrow \text{Carrier}) = 0.00$$

$$P(\text{Carrier} \rightarrow \text{Well}) = 0.10$$

$P(\text{Carrier} \rightarrow \text{Ill}) = 0.10$

$P(\text{Carrier} \rightarrow \text{Dead}) = 0.00$

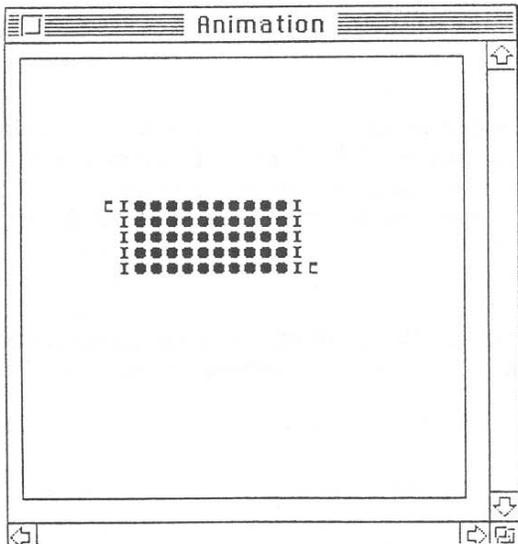


Figure 16.1. Sample Animation Box of Population With Carriers.

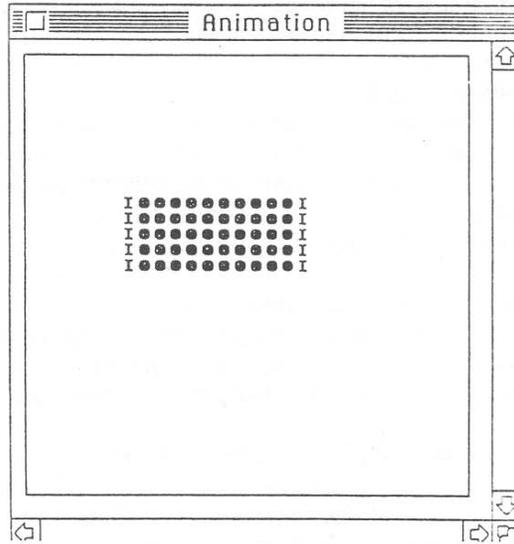


Figure 16.2. Sample Animation Box of Population Without Carriers.

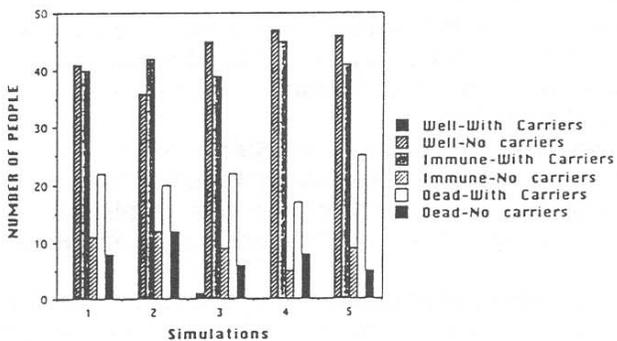


Figure 16.3. Sample Graph Comparing Disease Spread in Populations With/Without Carriers.

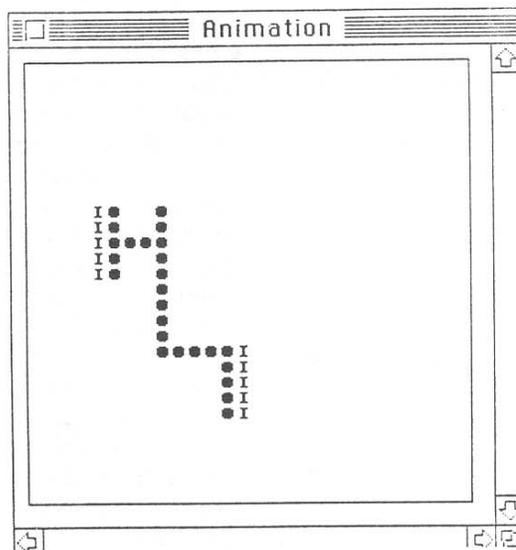


Figure 16.4. Sample Animation Box of Population Pattern #1.

To set up a simulation, click on **Windows** on the menu bar across the top of the screen. Drag the cursor to **Animation** and release the cursor. The **Animation** box will appear. The disease simulation is set up in this box. Round black dots will represent well people; the letter **I** represents ill people; and the letter **C** represents carriers.

Saving Models

To save a model, click the mouse on the **File** menu and drag the cursor to **Save As**. Type in a name for the model used. To save the simulation, drag the cursor to **Text File**. To reopen a saved model, click the mouse on the **File** menu and drag the cursor to **Open**. A prompting message will say that you will lose current data. Click on the **OK** button. To open the data being sought, click **Sample Data** and then, click **Open**.

Printouts of Simulations

To produce printouts of graphs or animations, transfer the information to a program like *MacPaint* or *Excel*. One can also make a copy of a simulation by pressing **Command-Shift-3**. This can then be read by other graphics programs.

Experiment 1: Carriers/No Carriers

This experiment is designed to demonstrate the effects of the presence or absence of carriers in the populations being examined. The simulation assumes the carriers are human, since the “Eppie” program cannot distinguish between humans and non-human carriers.

A. Carriers

1. Click to “on” the **Carriers Allowed** box and click to “off” the **Allow Re-infect** box. **Close the Parameters box** by clicking on the square in the upper left-hand corner.
2. Return to the menu across the top of the screen.
3. Click on the **Windows** selection, drag the cursor to **Model** and release the cursor. Click **Well** cell in the **Model** box.
4. Using the cursor, set up 50 well people in the pattern of a rectangle with 10 rows of five people each in the square under **Animation**. See Fig. 16.1.
5. Click **Ill** cell in the **Model** box.
6. Using the cursor, set up 10 ill people, five on each side of the rectangle of well people, in the square underneath the **Animation** box. Make sure some of the ill people are located next to well people.
7. Click the **Carrier** cell in the **Model** box.
8. Using the cursor, set up two carriers in the **Animation** square. To erase a well, an ill, or a carrier selection, click on the **Empty** cell. Use the cursor to then click on the selection to be erased in the **Animation** box should you want to change or correct your population pattern.
9. Click on the **Run** selection on the menu, and highlight **Start**.
10. After the computer has run the simulation, a box saying **Finished** will appear. Click on the **OK** button. The data will be displayed in both graph and chart form. Record the number of ill, well, dead, and immune people in the chart provided for this exercise.
11. Repeat the simulation ten times; each run or **iteration** represents the data from a different population of people. Record the data each time in the chart provided for this exercise. Then use the cursor to close out each box by clicking on the square in the left-hand corner.

B. No Carriers

12. Repeat the simulation using no carriers. To do this drag the cursor under the Windows selection, highlight the **Parameters selection**, then release the cursor. Click on the **Allow Carriers** box to remove the “X.” Be sure when setting up the **No Carriers Allowed** simulation to use the same number of well people (50), the same number of ill people (10), and the same population pattern as before. See Fig. 16.2.
13. Click on the **Run** selection on the menu. After the computer has run the simulation, a box saying **Finished** will appear. Click on the **OK** button. Allow the computer to run the simulation ten times. Record the data in the chart provided for this exercise.

Experiment Two: Population Patterns

Refer to the section “How to Use Eppie” if you need to review. In this exercise, you will determine the distribution pattern of individuals in the population, and observe how this distribution affects the spread of disease. See figures 16.4 and 16.5. You may design a different pattern, if you wish. Be sure to click off the **ALLOW CARRIERS** box.

A. Pattern #1

1. Return to the menu across the top of the screen.
2. Click on the **Well** cell in the **Model** box.
3. Using the mouse button, place 50 well people in a certain pattern in the square under **Animation**.
4. Click on the **Ill** cell in the **Model** box.
5. Using the mouse button, place 10 ill people in a certain pattern in the square underneath the **Animation** box. Be sure some of the ill people are next to well people. See Fig. 16.4.
6. Click on the **Run** selection on the menu, drag the mouse button and highlight **Start** and then release the mouse button.
7. After the computer has run the simulation, a box saying **Finished** box will appear. Click the **OK** button. The data will be displayed in both graph and chart form. Record the data.
8. Repeat the simulation ten times. Record the data each time.

B. Pattern #2

9. Repeat the simulation using a different population pattern being sure to use the same number of well people (50), the same number of ill people (10), and the same parameters as before, but a different population pattern. Try to locate the ill people in a pattern similar to the previous pattern for ill people, but change the distribution of well people. See Fig. 16.5. After the computer has run the simulation, a box saying **Finished** will appear. Click on **OK** button.
10. Allow the computer to run the simulation ten times. Record the data obtained each time, in the chart provided.

Experiment Three: Population Densities

Refer to the protocol for “How to Use Eppie” if necessary. This simulation demonstrates how the number of people per area affects the spread of disease. Be sure to click off the **ALLOW CARRIERS** box.

A. Dense Cluster Population

1. Return to the menu across the top of the screen.
2. Click on the **Windows** selection. Drag the mouse button to **Model** and release the mouse button. Click on the **Well** cell in the **Model** box.

3. Using the mouse button, set up 50 well people in a dense cluster pattern in the square under **Animation**.
4. Click on the **Ill** cell in the **Model** box.
5. Using the mouse button, place 10 ill people in a certain pattern in the square underneath the **Animation** box. Be sure some of the ill people are next to well people. See Fig. 16.7.
6. Click on the **Run** selection on the menu, drag the mouse button and highlight **Start** and then release the mouse button.
7. After the computer has run the simulation a box saying **Finished** will appear. Click on the **OK** cursor. The data will be displayed in both graph and chart form. Record the data.
8. Repeat the simulation ten times. Record the data each time.

B. Sparse Cluster Population

9. Repeat the simulation using a sparse cluster population pattern. Be sure when setting up the simulation to use the same number of well people (50) and the same number of ill people (10), and the same parameters. Try to place the ill people in relatively the same position as in the previous pattern. Be sure that some of the ill people are next to well people. See Fig. 16.8. After the computer has run the simulation, a box saying **Finished** will appear. Click on the **OK** button.
10. Allow the computer to run the simulation ten times. Record the data obtained each time.

Experiment Four: Immune Status

Refer to the protocol for “How to Use Eppie” if necessary. This simulation allows you to compare the spread of diseases depending on probability of re-infection of individuals by the pathogen that causes the disease. Be sure to click off the **ALLOW CARRIERS** box.

A. No Occurrence of Reinfection

1. Click off the **Allow Re-infect** box and click off the **Allow Carriers** box. **Close the Parameters** box by clicking on the square in the upper left-hand corner.
2. Return to the menu across the top of the screen.
3. Click on the **Windows** selection, drag the cursor to **Model** and release the cursor. Click on the **Well** cell in the **Model** box.
4. Using the cursor, set up 50 well people in a certain pattern in the square under **Animation**. See Fig. 16.10.
5. Click on the **Ill** cell in the **Model** box.
6. Using the cursor set up 10 ill people in a certain pattern in the square underneath the **Animation** box. Be sure some of the ill people are next to well people.
7. Click on the **Run** selection on the menu, drag the cursor and highlight **Start** and then release the cursor.
8. After the computer has run the simulation, a box saying **Finished** will appear. Click the **OK** cursor. The data will be displayed in both graph and chart form. Record the data.
9. Repeat the simulation ten times. Record the data each time.

B. Occurrence of Re-infection

10. Repeat the simulation but under **Parameters** click on **Allow Re-infect**. Be sure when setting up the record simulation to use the same number of well people (50), the same number of ill people (10), and the same population pattern as before. Be sure some of the ill people are next to well people. See Fig. 16.10. When the computer has run the simulation, a box saying **Finished** will appear. Click on the **OK** cursor.

11. Allow the computer to run the simulation ten times. Record the data obtained each time.
12. Under the **File** menu, drag the cursor to **Quit** selection, highlight it, and release the cursor.

TITLE OF EXPERIMENT— <hr style="border: 0; border-top: 1px solid black; margin: 5px 0;"/> <hr style="border: 0; border-top: 1px solid black; margin: 5px 0;"/>					
Number of Simulations:					
	Well People	Ill People	Immune People	Dead People	Carriers
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Graphing the Data

Follow the instructions in the appendix to this exercise for using “Cricket Graph” to display your data. Suggestions for column headings:

- Column One—Simulation Number
- Column Two—Well People
- Column Three—Ill People
- Column Four—Immune People
- Column Five—Dead People
- Column Six—Carriers

You will have 6 columns of data for each manipulation, and there are a total of 8 manipulations. You can either use columns 1—6 for data from Experiment 1a and the next 6 columns thereafter for each subsequent experiment, or you may create 8 separate files using columns 1—6 in each.

You will be creating bar graphs. To label the horizontal axis, highlight **Simulation Number**. For the vertical axis, highlight **Well People, Ill People, Immune People, and Dead People**.

Suggested title for X-axis- Simulation Number.

Suggested title for Y-axis- Number of People.

Suggested title for the graph for Experiment 1a: A Disease Simulation with Carriers.

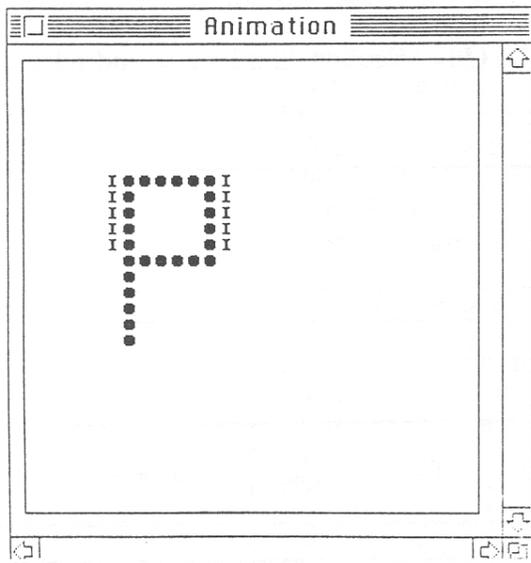


Figure 16.5. Sample Animation Box of Population Pattern #2.

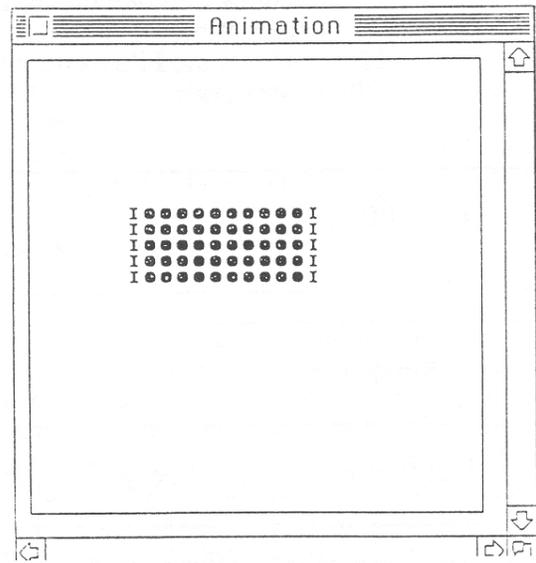


Figure 16.7. Sample Animation Box of Dense Cluster Population.

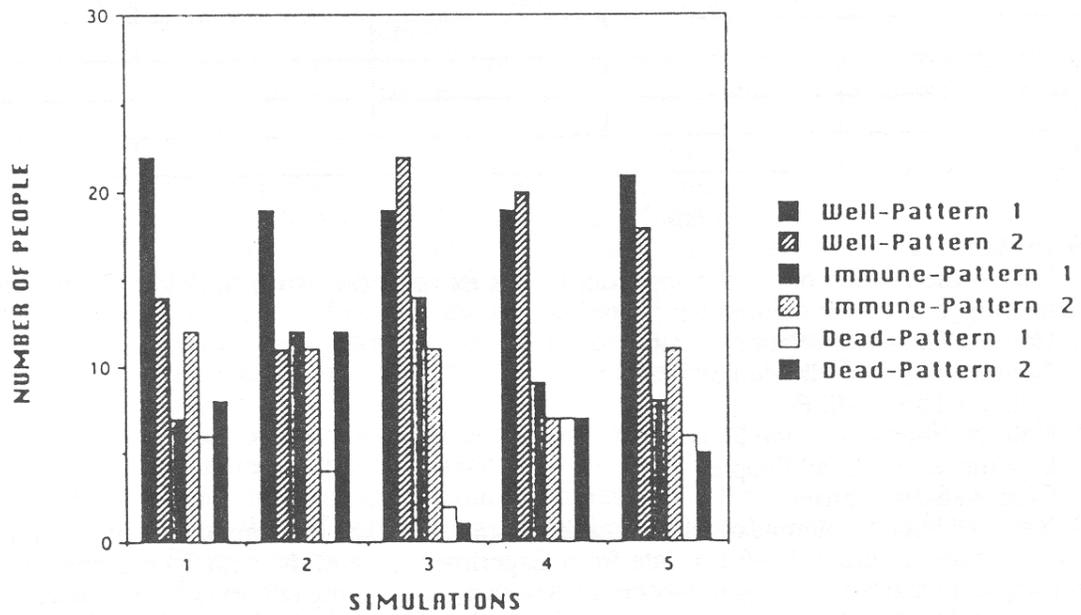


Figure 16.6. Sample Graph Comparing Disease Spread in Population with Pattern #1 and Pattern #2.

Graph the data for each of the 8 manipulations, and print your graphs. See Figures 16.3, 16.6, 16.9, and 16.11 for Sample Graphs.

So What?

An understanding of the way diseases are spread can help to prevent or reduce the incidence of disease. What kinds of measures could be implemented to help reduce the incidence of cholera in a country like India which has a high incidence of cholera? What would you as a public health nurse in a poor rural county advise your patients to do in order not to contract a sexually transmitted disease?

Now What?

You may want to repeat some of the simulations but vary the number of sick people and well people and see how this affects the spread of disease. You can also compare different densities and patterns to see how these affect the spread of disease. You can also change the probabilities under the **Parameters** selection to see how these affect the spread of disease. Some diseases have a high mortality rate. Try changing the probability that an ill person dies from 0.1 to 0.5 and see what happens!

Lab Report:

Write your findings in the form of a short scientific report. Be sure to include your answers to the Pre-test questions, discuss whether your predictions were supported by your data, and provide explanations where appropriate. Identify at least one human disease whose spread corresponds reasonably well to the parameters you set for each of the simulations you ran. Epidemiology reports from the Center for Disease Control in Atlanta, Georgia would be a good reference for disease information. Include in your report a discussion of how you would extend your experiment.

Answers To Pre-Test Questions:

1. Humans and non-humans can be active or passive carriers. Either are a source of infectious organisms. The more carriers there are in a population, the more likely one will be exposed to a pathogen. One's chance of becoming ill or dying from the disease would increase.
2. People stay inside more in the winter than in the summer. Since people are in close contact inside buildings, infectious diseases like the common cold spread faster. Over-heated buildings can dry out respiratory passages, and also make one more susceptible to a cold. The mucus in the nasal passageway helps to trap bacteria and viruses.
3. People living in the city are more likely to contract a disease than people living in the country, since city dwellers are more likely than country dwellers to come in contact with an infectious person.
4. If almost everyone in a community is immune to a certain disease, a non-immune person has little chance of contracting the disease in question.
5. If a person can be re-infected with a disease, then one has a greater chance of contracting the disease. For example, one has a greater chance of contracting a "cold," since people can be re-infected with this disease.

Acknowledgment

I am indebted to Alice Mills for her patience and time spent helping me edit this manuscript.

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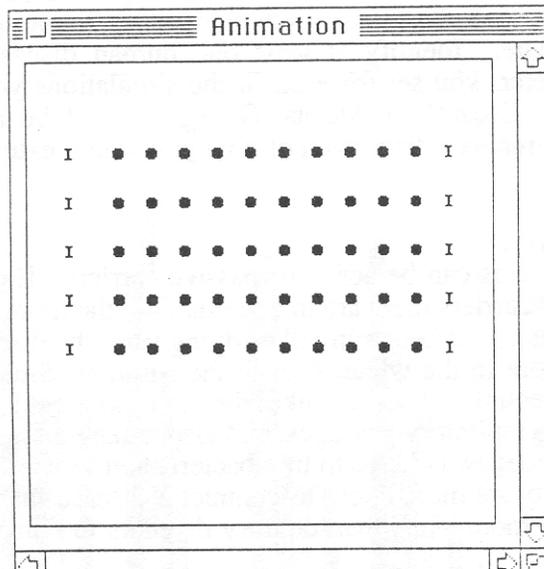


Figure 16.8. Sample Animation Box of Sparse Cluster Population.

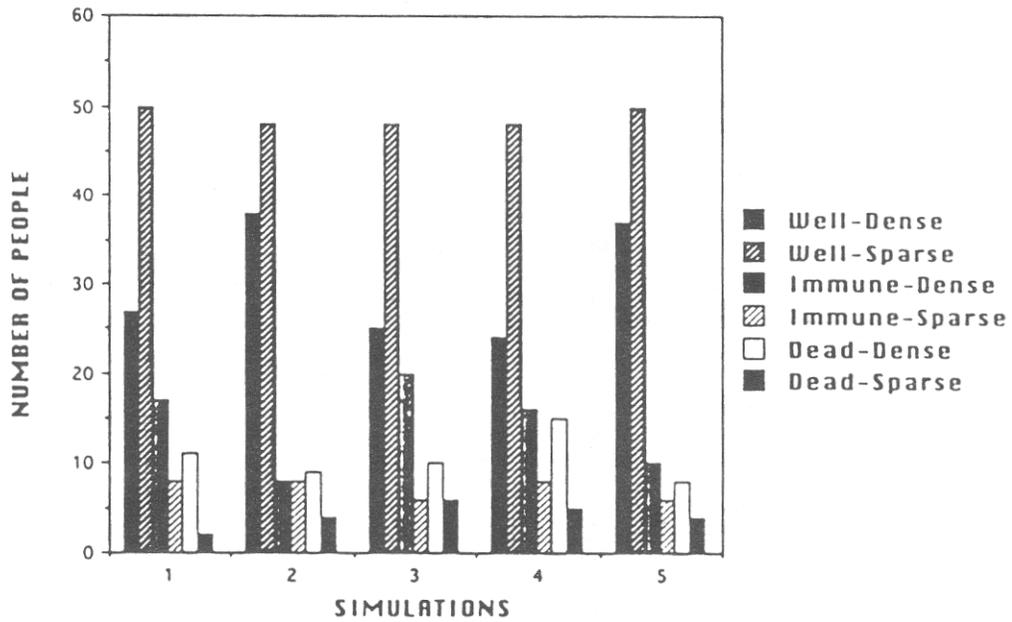


Figure 16.9. Sample Graph Showing Disease Spread in a Dense Cluster and Sparse Cluster Population.

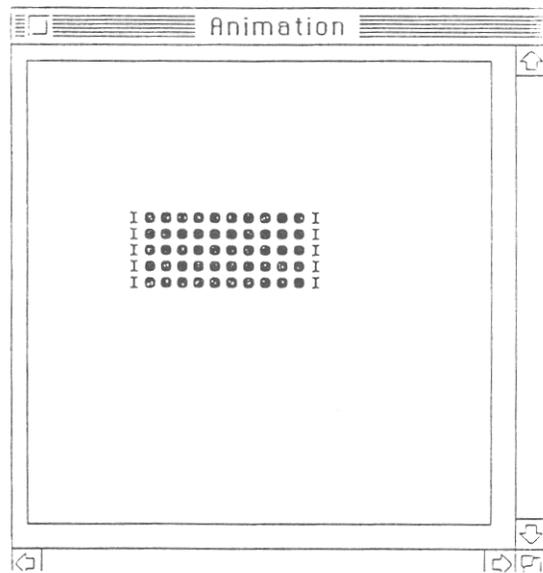


Figure 16.10. Sample Animation Box of a Population Pattern With No Occurrence of Reinfection and With the Occurrence of Reinfection.

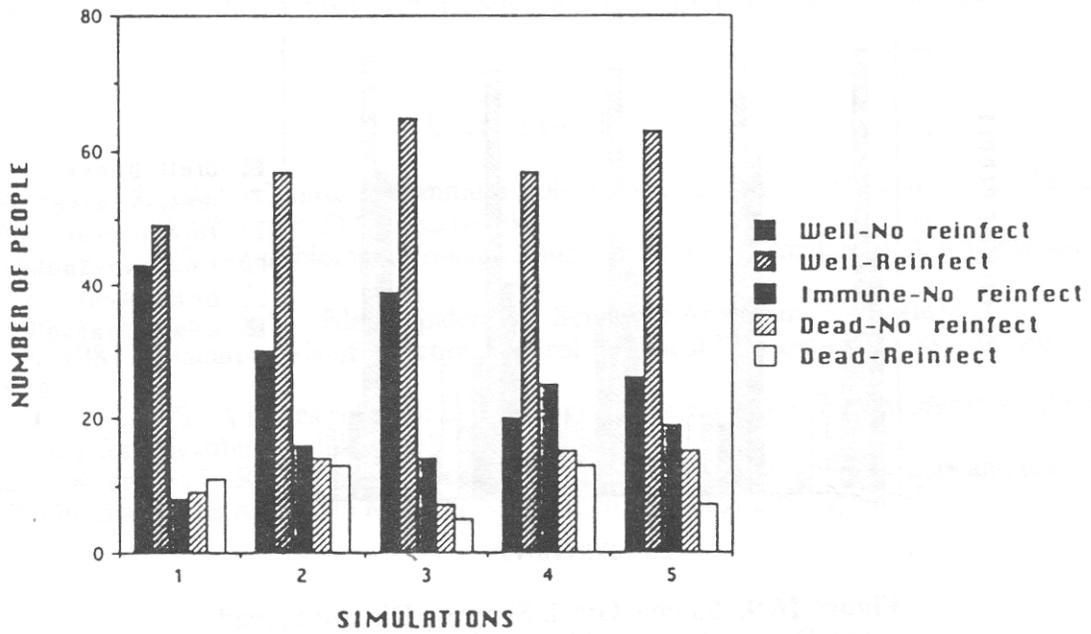


Figure 16.11. Sample Graph Showing Disease Spread in a Population With No Occurrence of Reinfection and With the Occurrence of Reinfection.

Appendix A
Using Cricket Graph 1.3.2 To Display Data

1. Turn on the Macintosh computer and monitor. When the software icons appear, double click on **Cricket Graph**.
2. When the data chart appears, click on **Column One** and type in an appropriate heading for the data. Click on the first cell under that column and record the data. Click on the next cell in the same column or hit the **Enter** key and record the next data point for that column. Continue in the same manner to record the rest of the data for that column.
3. Click on **Column Two**, type in an appropriate heading, and enter data as before.
4. To display the data, highlight **Graph** on the menu across the top of the screen, drag the cursor to the appropriate graph icon.
5. The graph will then appear. Under **Categories**, highlight **Simulation Number**. Under **Values**, highlight the headings for your columns.
6. Click on **New Plot**. The graph should appear.
7. Click on **Untitled Graph Number One**. Select the **Delete** key.
8. Click on **Goodies** on the menu across the screen; drag the cursor to **Show Tools** and release the cursor. Highlight **A** on the **Tools Box**; click the cursor where the title was or double click on the **“Untitled Data.”**
9. Type in the title of the lab exercise or experiment. Select the font, style, size, and position (horizontal or vertical) of the lettering to be used. Click on the **OK** box. The title should appear across the top of the graph. The title can be centered by using the cursor to click on the title, holding the cursor down, dragging the title to the appropriate place, and then releasing the cursor. Click the cursor on the edge of the dotted line, which will then disappear.
10. To label the vertical axis, click on the title on the vertical axis. Select the **Delete** key. Highlight **A** on the **Tools Box** and click the cursor where the title was or double click on **“Well People.”**
11. Type in the title for the vertical axis same way as in #9.
12. Highlight the **File** selection of the menu across the top of the screen. Drag the cursor to **Print** and release the cursor. A display of the graph will appear. Click the **OK** box. Click on the **Copies** box. Select the **Delete** key. Type in the number of copies desired. Make sure the printer is on. Click on **Print**. Retrieve your printout from the printer.
13. To close the graphics on the screen, click on the small box in the upper left-hand corner. Click on **YES** if you want to save your graph. Click on **NO** if you do not want to save your graph.
14. The data chart will appear. To close the data chart use the cursor to click on the small box in the upper left-hand corner. Click on **YES** if you want to save your data. Click on **NO** if you do not want to save your data. To close out the program, drag the cursor down under **File** of the menu across the top of the screen. Highlight **Quit**.