

## TEACHER BACKGROUND INFORMATION 

The increase in the size of a population (such as the human population) is an example of exponential growth. The human population grew at the slow rate of less than 0.002 percent a year for the first several million years of our existence. Since then the average annual rate of human population has increased to an all-time high of 2.06 percent in 1970. As the base number of people undergoing growth has increased, it has taken less and less time to add each new billion people. It took 2 million years to add the first billion people; 130 years to add the second billion; 30 years to add the third billion; 15 years to add the fourth billion; and only 12 years to add the fifth billion. We are now approaching the seventh billion!


Bacteria multiply by division; one bacterium divides and becomes two; the two become 4; the 4 becomes 8 and so on. Assume that for a certain type of bacteria the doubling time is 1 minute, Suppose one bacterium is placed in a bottle at 11:00 Am. When the bottle is observed at noon, it is full. This is a simple example of exponential growth in a finite environment, mathematically similar to the exponentially growing human population and its increasing consumption of out finite natural resources. Keep this in mind when considering the following questions about the bacteria:

- At what time was the bottle half full? Answer: 11:59AM
- If you were an average bacterium, at what time would you first realize that consider: At 11:55AM when the bottle was only $3 \%$ filled and $97 \%$ empty, would you be likely to perceive the problem?
- Suppose that at 11:58Am some far-sighted bacteria realize that they are running out of space. With a great expenditure of effort and funds, they launch a frantic search for new bottles. They look offshore and in the arctic and at 11:59 AM they discover 3 new empty bottles. Great sighs of relief come from all the worried bacteria!
- The discovery quadruples the total space resource known to the bacteria. Surely this will solve the problem so that the bacteria can be self-sufficient in space!
- How long can the bacterial growth continue in the quadrupled space resource? Answer: Two more doubling times (minutes)

The following chart documents the last minutes in the bottles:
THE EFFECT OF THE DISCOVERY OF NEW BOTTLES

| TIME | EFFECT |
| :---: | :---: |
| $11: 58$ AM | Bottle \#1 is $25 \%$ full |
| $11: 59 \mathrm{AM}$ | Bottle \#1 is $50 \%$ full |
| $12: 00$ Noon | Bottle \#1 is full |
| $12: 01$ PM | Bottles \#1 and 2 are full |
| $12: 02 \mathrm{PM}$ | Bottles \#1,2,3 and 4 are full |

Quadrupling the resource extends the life of the resource by only 2 doubling times. When consumption grows exponentially, enormous increases in resources are consumed in very short times!

Like the bacteria, the human population is growing, using resources and expelling their by-products at an exponential rate. The maximum population the Earth can sustain at some reasonable average living standard for its inhabitants is called the carrying capacity. The human population today is over 6 billion. The question is: Can we adequately provide the minimal needs for 7 billion people without sacrificing the quality of our environment? Raising their consumption of natural resources to anything approaching that in developed countries may be impossible. Therefore, the population issue, along with many others, must receive our most serious consideration as we plan for the years ahead. If we do not control our global population, natural forces will do it for us.


De fruifful and meltiplign.


Now divide.

## INSTRUCTIONLL ACTIVTTY STAND UP AND BE COUNTED!

OVERVIEW: All population growth, from bacterial division to human procreation are models of exponential growth until natural resources become scarce or diseases or competition start taking a heavy toll. Since the first humans walked the planet, humans have changed ecosystems as they searched for food, fuel, shelter and living space. However, with the start of the Industrial Revolution in the late 1700s, the human influence on the global ecosystem has been seriously increased. A burgeoning human population has modified Earth's ecosystems through advancements in technology and rampant resource consumption. Human destruction of habitats and species through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and, if not addressed, ecosystems will be irreversibly affected.

OBJECTIVES: Students will:

- develop a model of the exponential nature of population growth.
- consider the population growth of plant and animal species and the resultant stresses that contribute to natural selection.


## MATERIALS/ EQUIPMENT

Each group of three or four students will need:

- Approximately 2,000 small, uniformly shaped objects (kernels of corn, dried beans, wooden markers, plastic beads)
- 10 paper cups or small beakers
- A $250-\mathrm{ml}$ or $400-\mathrm{ml}$ beaker


## PROCEDURE:

## PART I: ENGAGEMENT-

1. Initiate a discussion on human population with such questions as:

- How long have humans been on the earth?
- How do you think the early rate of human population growth compares with the population growth rate today?
- Why did this rate change?

2. Tell students that this investigation represents a model of population growth rates.

PART II: EXPLORATION: Have student groups complete the following activities.

1. Place the glass beakers on their desks.
2. Begin by placing two objects (e.g., corn or plastic beads) in it. [The beaker represents the limits of an ecosystem or ultimately the earth.]
3. Place 10 cups in a row on their desk.

- In the first cup, place two objects.
- In the second cup, place twice as many objects as the first cup (four).
- Have students record the number of objects on the outside of the cup.

4. Continue this procedure by placing twice as many objects as in the former cup, or doubling the number, in cups 3 through 10.

- Be sure students record the numbers on the cups.

5. Take the beaker and determine its height.

- Have students indicate the approximate percentage of volume that is without objects.
- Record this on the table as 0 time.

6. At timed intervals of 30 seconds, add the contents of cups 1 through 10 .

- Students should record the total population and approximate percentage of volume in the beaker that is without objects.

7. Students should complete the procedure and graph their results as total population versus results.

Note: Students may question the need for the 30 -second intervals. The length of the time interval is arbitrary. Any time interval will do. Preparation of the graph can be assigned as hork.


Figure 1--Sample population growth graph

|  | TABLE 1 <br> POPULATION GROWTH |  |
| :--- | :--- | :--- |
| Time <br> Internal | Population | Percentage of empty <br> volume (400-ml beaker |
| 0 | 2 | $99 \%$ |
| 1 | 4 | $99 \%$ |
| 2 | 8 | $99 \%$ |
| 3 | 16 | $98 \%$ |
| 4 | 32 | $97 \%$ |
| 5 | 64 | $95 \%$ |
| 6 | 128 | $93 \%$ |
| 7 | 256 | $88 \%$ |
| 8 | 512 | $80 \%$ |
| 9 | 1024 | $70 \%$ |
| 10 | 2048 | $50 \%$ |
| 11 | 4096 | $0 \%$ |

## RANGE OF RESULTS

The mathematics involved in answering the questions may challenge some students. Assist students when necessary to enable them to accomplish the objectives of the investigation. Table 1 shows the population and the percent of the beaker's volume without objects. A typical student graph is shown in Figure 1.

## PART III: EXPLANATION -

- Ask the students to explain the relationship between population growth and biological evolution in populations of microorganisms, plants, and animals.
- Through questions and discussion, help them develop the connections stated in the learning outcome for the activity. Evolution results from an interaction of factors related to the potential for species to increase in numbers, the genetic variability in a population, the supply of essential resources, and environmental pressures for selection of those offspring that are able to survive and reproduce.


## PART IV: ELABORATION -

1. Begin by having students explain the results of their activity.
2. During the discussion of the graph, have the students consider some of the following:

- Are there any limitations to the number of people the earth will support?
- Which factor might limit population growth first?
- How does this factor relate to human evolution?
- Are there areas in the world where these limits have been reached already?
- Have we gone beyond the earth's ideal population yet?
- What problems will we face if we overpopulate the earth?
- How might human influence on, for example, habitats affect biological evolution?
- What factors enabled the rapid growth of the last decades and century?

Note: Students' answers to these questions will vary, depending on their background and information. The outcome, however, should be an intense discussion of some vital problems and should provide opportunities to introduce some fundamental concepts.

## PART V:EVALUATION -

1. Human population on the earth is thought to have had a slow start, with doubling periods as long as 1 million years. The current world population is thought to be doubling every 37 years. How would this growth rate compare with the rates found in your investigation?

Answer: Both the population in the investigation and on the earth increase in a geometric progression. This means the graphs have the same shape. You can substitute 37 years for every 30 -second interval and the numbers will represent actual world population growth. The slope of the graph would remain the same.
2. What happens to populations when they reach the limits to growth?

Answer: The populations stop growing because death rates (or emigration) exceed birth rates (or immigration).

## Notes:

1. Investigating the Earth.
2. Thomas Malthus. 1993. Essay on the Principle of Population. Geoffrey Gilbert, ed. Oxford: Oxford University Press.
