APES Lab: The Power of Doubling

If you were offered a choice between one million dollars and a penny on the first day of the month, two pennies on the second day, four pennies on the third, and so forth for 30 days, which would you choose? If you calculate this, you will find that the second choice would give you somewhat more than one million dollars! Each day you are doubling a larger number, and although the number of pennies increases slowly at first, it soon reaches over one million dollars. That is the power of doubling, or exponential growth.

Growth is defined as exponential when the increase of a quantity is proportional to the size of the quantity. The quantity may be numbers, as in the numbers of individuals in a population, or some other measure, such as amount of energy consumed. Exponential growth is very slow in the early stages, but quickly accelerates. A frequent measure of exponential growth is **doubling time**, that is, the amount of time required for the quantity to double. The shorter the doubling time, the faster is the rate of growth.

The human population, like all populations of organisms, grows exponentially when unchecked. Although it took 130 years, from 1800 to 1930 for the world population to double, it doubled again by 1975, a mere 45 years. At this rate the world population of 5.5 billion in 1993 would be expected to reach 11 billion by 2035. Different areas of the world, however, have vastly different doubling times. While the doubling time for developed areas in 1993 was 162 years, that for the less developed areas was 35 years.

In this activity, you will demonstrate exponential growth and determine the doubling time and growth rate of a simulated population.

MATERIALS:

2 pennies	approximately 200 dried beans (or dry macaroni)
2 8-oz. Paper cups	graph paper
1 larger paper cup	marking pen

PROCEDURE:

1) Label one small paper cup, "Parents", and the other one "Offspring". Label the large cup, "Bean Pot". Place 10 beans in the "Parents" cup and the rest in the "Bean Pot". Each bean represents an individual in a population.

2) Toss the two pennies. If both pennies show heads, toss again. If both pennies show tails, one member of the population has died and you should remove a bean from the "Parents" cup and put it into the "Bean Pot". If one head and one tail show, a member of the population has had a child. To simulate the birth, take one bean from the "Parents" cup and one from the "Bean Pot" and place them in the cup marked "Offspring".

3) Continue tossing until there are no longer any beans in the "Parents" cup. Count the number of beans in the "Offspring" cup and record the number in Data Table A. The "Offspring" now become the parents, so move all of the beans from the "Offspring" cup into the "Parents" cup.

4) Repeat steps #2 and #3 until you have completed 10 generations.

5) Make a graph of your data, with generation number on the horizontal axis and population size on the vertical axis.

DATA TABLE A:

Generation #	Population Size
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

6) Repeat the activity, only this time assume that when a head shows to the right of a tail, the individual decides not to have a child. In that case, place one bean from the "Parents" cup into the "Offspring" cup, but do not add a bean from the "Bean Pot". If, on the other hand, the head shows to the left of the tail, proceed as you did before, taking one bean from the "Parents" cup and one from the "Bean Pot" and placing them in the "Offspring" cup. Record your data in DATA TABLE B. When you have finished 10 generations, graph your data on the same graph in a different color.

DATA TABLE B:

Generation #	Population Size
0	10
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

FOLLOWUP:

1)   On average, how should the birth rate of this population compare with the death rate?

       How do you know this?

2) From your graph, determine the doubling times for the population at the beginning, the middle, and the end of the graph. Are they all the same? Explain why.

3) Assume that a generation is equal to 20 years. Use the doubling time from your graph to calculate the growth rate of the population, using the formula below:

$$\text{annual growth rate (\%)} \; = \; 70/\text{doubling time (yrs.)}$$

5) Calculate the doubling time and growth rate for the second set of data as you did for the first. Compare the two data sets.

6) Write a short paragraph explaining the implications of this activity for the human population.

Demographic Variable	Country	Data
Birth Rate (annual number of births per 1,000 total population)	World	22
	More Developed	11
	Less Developed	24
	Less Developed (Excl. China)	28
	Africa	38
Death Rate (annual number of deaths per 1,000 total population)	World	9
	More Developed	10
	Less Developed	8
	Less Developed (Excl. China)	9
	Africa	14
GNI PPP Per Capita, 2001 (US$)	World	$7,160
	More Developed	$22,030
	Less Developed	$3,660
	Less Developed (Excl. China)	$3,570
	Africa	$2,120
Population 2025 (projected)	World	7,907,000,000
	More Developed	1,260,000,000
	Less Developed	6,647,000,000
	Less Developed (Excl. China)	5,192,000,000
	Africa	1,289,000,000
Population 2050 (projected)	World	9,198,000,000
	More Developed	1,257,000,000
	Less Developed	7,940,000,000
	Less Developed (Excl. China)	6,547,000,000
	Africa	1,883,000,000

(Adapted from Activity #5, Environmental Science Activities by Dorothy B. Rosenthal, John Wiley & Sons, 1995)