Exploring Human Demography

Goals

- Use simulation models of population growth to develop a deeper understanding of the basic principles and concepts of population ecology
- Develop and clarify our understanding of some of the issues surrounding human population growth
- Practice using scientific models to help inform decision-making and policy-making

Introduction

Why are human populations in Africa growing so rapidly, even though life expectancy is shorter than in most other parts of the world? Why do rapidly growing populations have such a large proportion of children? Why is the population of China still growing, even though the Chinese government is enforcing a "one-child per couple" population policy? What kinds of policies could/should be implemented to curb rapid growth?

These are a small sample of the kinds of questions that can be addressed by building and analyzing models of population growth. How would we go about doing this? One important step is to identify the variables that we want to track through time. For example, demographers track the size of populations through time, perhaps divided into population categories, such as gender groups, racial/ethnic groups, or age groups. To track changes in population size, we must look at the processes that could bring about change.

In this simple case, there are only three things that can happen:

- individuals can come into the population via birth or immigration
- they can leave the population through death or emigration, or
- they can move from one category to another (e.g., by getting older, or by having a sex change operation, or by changing their economic status).

That's it! So if we could model the processes by which the number of individuals in each category change, then we could make predictions about the future state of the population. Of course, the challenge is to figure out what influences birth rates, death rates, etc., and that may be very hard, especially when all of the influencing factors may interact in complex ways.

Overview of Activities

During the next two weeks, we will be working through a series of modeling activities using *Demography*, a simulation of population growth in an age-structured population. We will explore the meaning of a variety of concepts related to population growth and challenge our understanding of demographic characteristics of the current human population. We will use these concepts to construct a population policy designed to curb rapid growth in a fictional country.

Demography allows users to graphically enter age-specific fertility and mortality rates for a population, enter an age pyramid for an initial population, and then observe the changes in population size and in the age distribution through time. You can use *Demography* to ask a variety of "what if?" questions, to design and perform your own investigations, to develop a deeper understanding of fundamental population concepts, and to explore the implications of various population policies.

Like all models, the models that *Demography* is based on rely on a number of assumptions. As we learned from Hardy-Weinberg models, this is not always bad. In fact, the whole point of modeling is to simplify in order to concentrate on the few factors that are considered most important for a particular problem, and ignore less important factors that could complicate results. The models that we will be using with *Demography:*

- do not distinguish between gender or any other individual characteristic except age
- do not include immigration or emigration, and
- do not include any elements (such as competition for limiting resources) that would cause growth rates to change with population size.

[*Demography* includes the capabilities to investigate some of these issues. If you should become interested in pursuing something further -- such as the impact of differential abortion or infanticide rates for males and females -- contact one of the instructors for details.]

Activity I -- Constructing Age Pyramids

Age pyramids (which don't always have to *look* like pyramids) are useful graphs for representing the proportions of individuals in a population of different ages. Just to make sure that we all understand how these diagrams are constructed, and how to interpret them, we will begin by constructing an age pyramid diagram for our class.

We will break the population into age groups, in 5-year intervals, recording how many individuals there are in each category for each sex, and record our results on the board. Then we can use these results to construct a bar chart.

60-65		
55-60		
50-55		
45-50		
40-45		
35-40		
30-35		
25-30		
20-25		
15-20		
10-15		
5-10		
0-5		
Age	**M**	**F**

M	**F**

Question: Suppose we hold a class reunion 10 years from now, and everyone brings their families. What would the age pyramid look like then? Draw your prediction below:

60-65		
55-60		
50-55		
45-50		
40-45		
35-40		
30-35		
25-30		
20-25		
15-20		
10-15		
5-10		
0-5		
Age	**M**	**F**

Explain:

Question: What would the shape of the age pyramid for Douglas fir trees in a 150-year-old stand be like?

Activity II -- World Population Growth

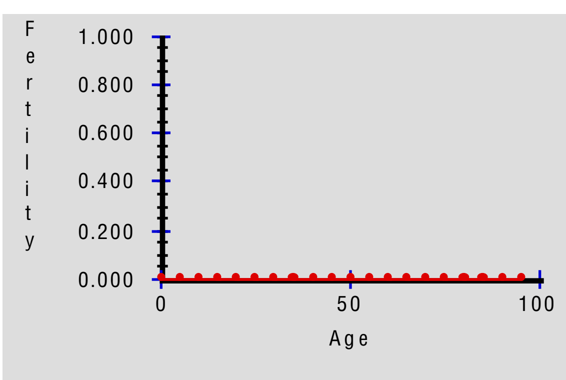
1. Making Some Predictions. Based on your knowledge of the human population, what do you think the current values are for doubling time, total fertility rate, and life expectancy for the world population?

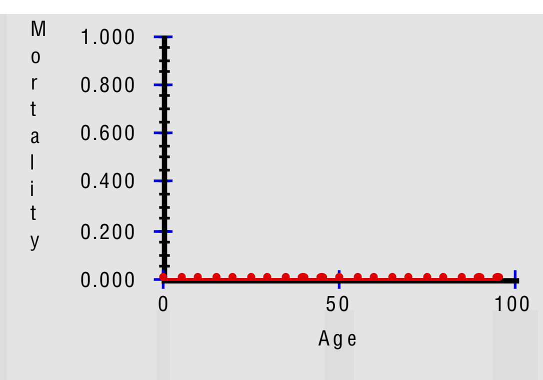
	Definition	Your Estimate	Observed Value (based on your fertility and mortality graphs)
Total Fertility Rate (TFR)	Ave. number of offspring **per female** over her lifetime if she lived through reproductive years		
Life Expectancy	How long an individual can be expected to live, on average		
Doubling Time	The time it would take a population to double, given no changes in age-specific mortality or fertility rates		

For most populations, including humans, birth rates (fertility) and death rates (mortality) vary with age. Using the graphs below, draw your predictions of what fertility and mortality functions should look like. To do this, divide the population into age categories using 5-year intervals (e.g., 0-5, 5-10, 10-15, etc.).

On the “Fertility vs. Age” graph, chart the average number of offspring **per individual** during each five-year interval. For example, suppose that the average individual has 0.5 offspring between the ages of 50 and 55. Then you would enter a fertility rate of 0.5 for age 50.

On the “Mortality vs. Age” graph, plot the proportion of individuals in a given age category that can be expected to die during that interval. For example, if you feel that the probability of dying between ages 50 and 55 is 20%, then you would enter a mortality rate of 0.2 for age 50.





2. Entering Your Data. In the folder called "Human Demog Activity Files", find the file entitled “Activity II” on your computer, and double-click on it. Once *Demography* has started up and the file is displayed on your screen, enter your mortality and fertility predictions in the graphs displayed on the screen. You can manipulate the graphs by just clicking and dragging on any of the points.

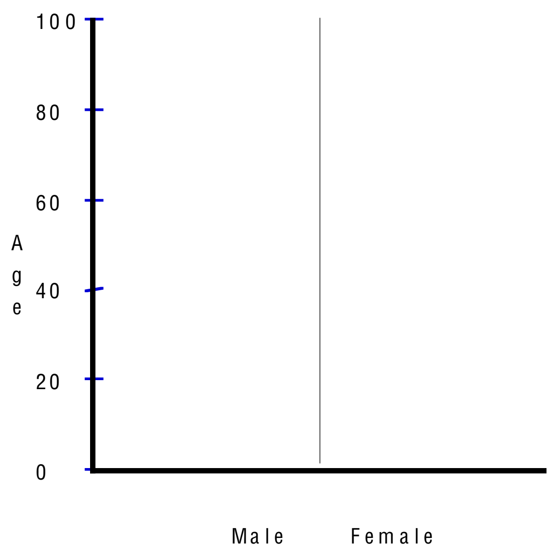
Note that as you change the fertility and mortality graphs, the values for doubling time, TFR and life expectancy automatically change. Enter the observed values in the table on the previous page.

Question: How do the values obtained compare with those predicted? If there are major discrepancies, what kinds of adjustments do you need to make in your predictions?

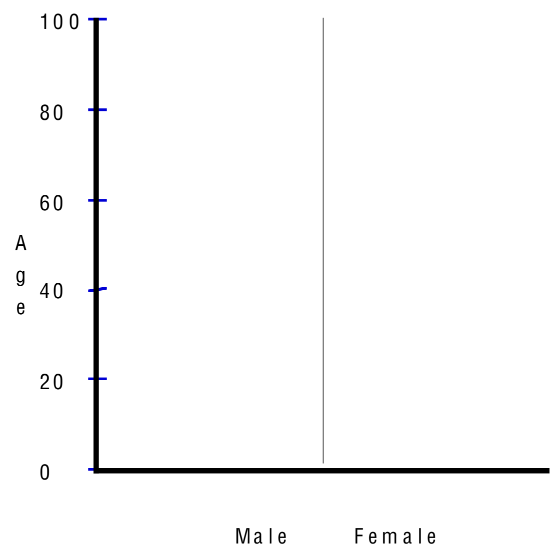
Adjust the graphs until you feel the graphs and the summary statistics match with your understanding of the global population.

3. How Will the Age Distribution Change Through Time? Note the age structure graph. Suppose that the population grew based on the values for fertility and mortality that you have entered. What do you think the shape of the age distribution would be like in 100 years? Draw your prediction on the graph to the left below:

Predicted:



Observed:



You can test your prediction by running the simulation for this period of time. In this activity, the simulation is set to run in 5-year increments. Select “Step” from the “**Control**” menu a few times to see what happens. Then select “100” from the hierarchical “**Go Until...**” menu. You can enter in the observed age distribution to the right of your prediction.

Question: How does the shape of the age distribution graph compare to your prediction? Can you explain any major discrepancies?

4. Understanding Exponential Growth. The initial population was 1000. Given the doubling time of the population based on the fertility and mortality values that you have entered, predict how long should it take for the population to reach 32,000. Run the simulation and compare your prediction with the outcome of the simulation.

Predicted Time to 32,000: ______________________ Observed Time:______________

Question: Can you account for any discrepancies?

Question: What happens to the age pyramid as time goes on? Can you explain why?

5. Data from the Population Reference Bureau. To compare your estimates and results with the model loosely based on 1995 PRB Data Sheets, mark your place by choosing "Set..." from the **Marks** menu, and then go to the mark entitled "PRB Data".

Activity III -- Fertility and Population Growth on "Exponentia"

Two ministers of population for the government of Exponentia, a small island in the South Pacific, are trying to decide how best to limit population growth. One minister, Mr. X, argues that they must convince people to have fewer children; the other (Ms. Y) argues that similar results could be obtained by allowing people to have as many children as they do currently, but convincing people to delay starting their families. Mr. X disagrees. "Delaying reproduction does not cause any decrease in the total number of offspring born," he says, "so how can it affect population growth?"

Question: In the year 2000, the population of Exponentia will be 10,000 individuals. The current Total Fertility Rate (**TFR**) is 6.0 and the age of first reproduction (**A**) is 10. Do you think the population ministers have anything to worry about? Explain.

Question: If these and other demographic factors remain the same, how large do you think the population will be in the year 2100?

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The Prime Minister is fed up with the bickering between his ministers. So he has hired us as scientific advisors. He wants to establish a population policy that will result in a population between 15,000 and 25,000 in the year 2100. He wants us to figure out a way to achieve this goal.

It seems fairly obvious that the more births there are, the faster the rate of growth. But how much faster? Will delaying reproduction affect population growth rates or not? Are there realistic combinations of **TFR** and **A** that achieve the Prime Minister's goals without major disruptions?

Imagine we could set up an experiment with a large number of different islands, all basically identical, and all containing human populations of the same size and demographic characteristics. On each island we specify a unique value for the Total Fertility Rate and for the age of first reproduction (when individuals start producing offspring) to which the island population must adhere. This gives us many possible combinations of TFR and age of first reproduction, and for each of these we could track the population through time to see how fast it grows.

Demography provides us the opportunity to do this experiment as a "thought" experiment without all the hassles of actually doing it "in the field," which would probably not go over very well with the people on the islands, even if we could find a reasonably large number of identical ones. Also, by the time we obtained our results, it would probably be too late to do any good for Exponentia.

In *Demography*, you can specify how many offspring organisms have and when they have them by manipulating the graph of Fertility vs Age (see Figure 1). Two arrow keys in the tool bar at the top of the graph can be used to shift the whole graph to the left or right, advancing or delaying reproduction without influencing the shape of the curve. The other arrow key can be used to multiply all the values in the curve by a specified amount. This can be used to change **TFR** without changing the shape or the position of the curve.

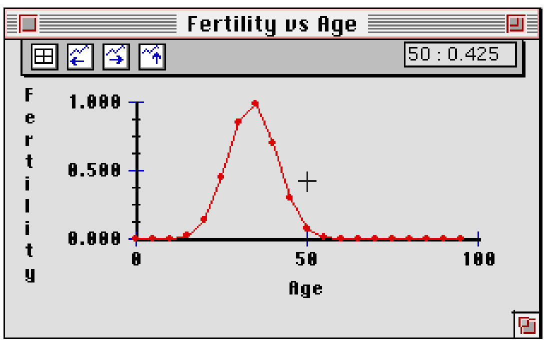


Figure 1. Fertility as a function of age in the computer program, Demography. Note the arrows in the tool bar at the top left of the window.

Our experiment will consist of setting up populations that are identical in every way except for our two independent variables (**TFR** and age of first reproduction, **A**). If *Demography* is still open, close your current document (save it to a floppy disk if you wish to keep your work), and open the file named "Exponentia" (found in the folder called "Human Demog Activity Files",) which we will use as a starting point.

For each combination of **TFR** and **A**, we will obtain a value for doubling time of the population, and we will track population growth, noting the population size and the "% juvenile" after 100 years (% juvenile represents the proportion of the population under age 15; even though the summary chart says "%", the value is actually given in proportions). We will fill in this chart below. Rather than all of us doing all of the simulations, we can divide up the workload and collate all our results**. Each group in the class will be assigned a single row to work on. Your lab instructors will describe an efficient way to obtain your results.**

Total Fertility Rate-> Age of First Reproduction		**1.5**	**3.0**	**4.5**	**6.0**
10	DT				
	Size				
	<15				
15	DT				
	Size				
	<15				
20	DT				
	Size				
	<15				
25	DT				
	Size				
	<15				
30	DT				
	Size				
	<15				
35	DT				
	Size				
	<15				
40	DT				
	Size				
	<15				
45	DT				
	Size				
	<15				

Question: What combinations of **TFR** and **A**, *if any*, will accomplish Exponentia's goals? (Highlight the appropriate cells in the table.)

Question: Was Ms. Y correct about the impact of delaying reproduction? Explain why or why not.

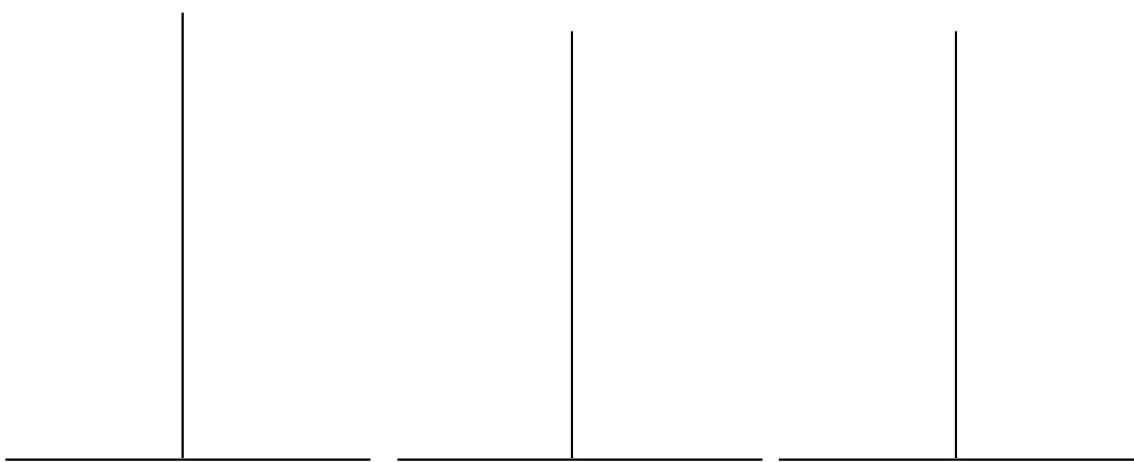
Activity IV. How Age Distributions Change Through Time

The Prime Minister is ready to adopt population policies to achieve his goals, based on our recommendations. Now he wants to know how he should plan for government services in the future. For example, he needs to know how much of his limited resources to put into health care, how much into schools, and how much into social security. So he needs data not only for overall population size, but also for the distribution of population into different age groups. To prepare the population for the new programs that he hopes to implement, he wants to be able to compare two scenarios:

- Scenario One -- The status quo. What will the population size and age distribution of the population be like in 100 years if things continue the way they are?
- Scenario Two -- The new policy. What will the population size and age distribution be like in 100 years if the new policy is adopted?

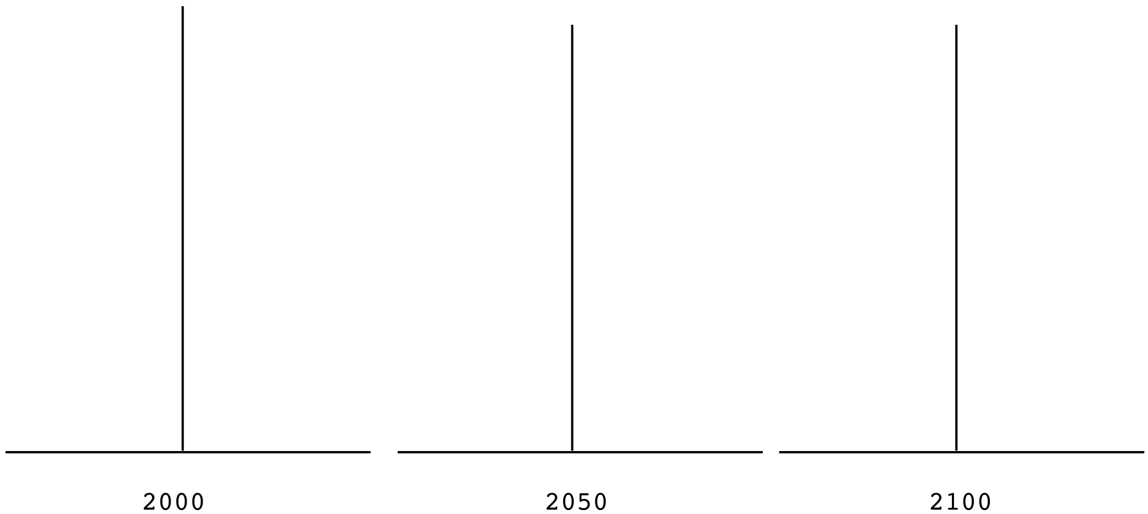
In the folder called "Human Demog Activity Files", open the file called Activity IV. Notice that there are two “Marks” available from the **Marks** menu, called “status quo” and “new policy.” Go to “status quo.” In addition to a Population Size vs Time graph, a Current Age Distribution graph should also be displayed. Otherwise the conditions are the same as the initial conditions for the Exponentia file that you worked with in Activity III. Note the initial age distribution of the population.

NOTE: You may draw graphs of Population Size vs Time on graph paper (available in the lab), or you may cut and paste graphs from *Demography* into an MS Word document, which can then be printed. You may also cut and paste the age pyramids into a Word document , you may use graph paper, or you may draw them below.



2000 2050 2100

Scenario One - Status Quo

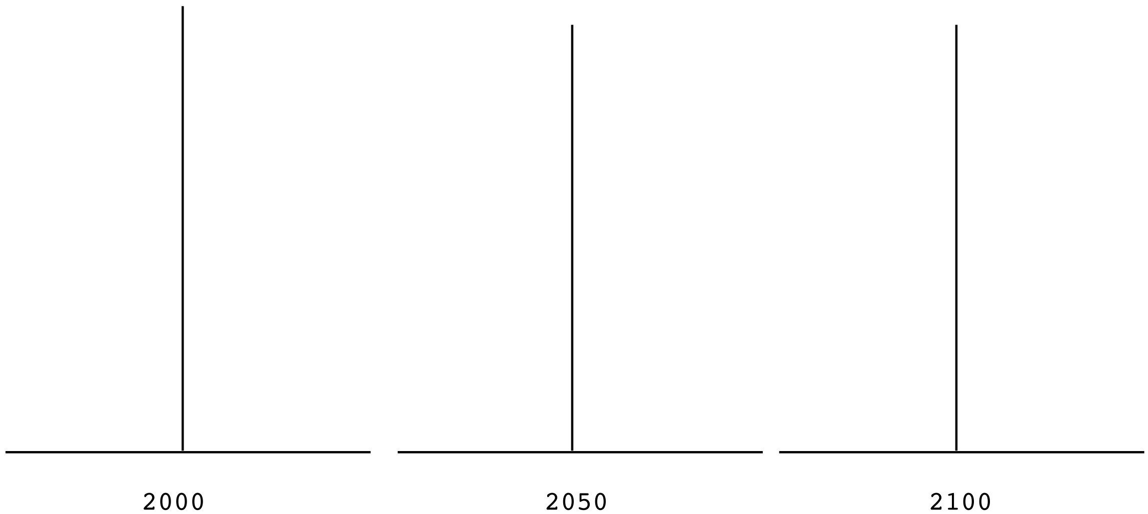


Scenario Two – Pruthu’s Policy

Question: Describe and *explain* the differences between the age distributions for the two scenarios.

After the Prime Minister makes his plan public, the loyal opposition counters with a plan of their own. Concerned that the population is already too large, and convinced that something more drastic needs to be done, they propose to adopt a modification of China’s “one child per couple” policy which would effectively reduce TFR to 1.5.

Question: Accurately describe and explain what would happen to population size and to the age distribution of the population if this policy were implemented along with policies that delayed reproduction until age 30 (see “Mark” labeled “One child”). Use graph paper to draw the population graph, or cut and paste into a Word document.



Scenario Three - One child per couple

Question: The Prime Minister argues that such a plan would necessarily involve coercion, and would have severe negative consequences both for family life and for the economy. What do you think his rationale is?

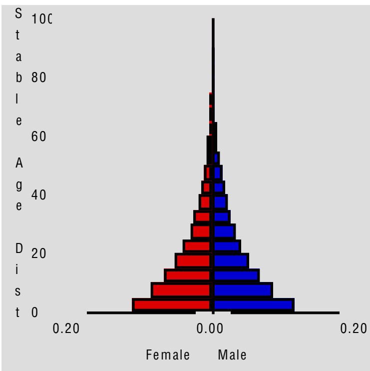
The opposition counters that these are simply prices that society needs to pay to prevent destruction of the island and a decrease in everyone's quality of life. Yet another opposition party favors doing nothing. They argue that population measures will be ineffective because environmental degradation on the island is due to other causes, and they contend that people are our most important resource.

Question: Based on the predictions of these models, which scenario would you choose if you were the one making the decision? Why?

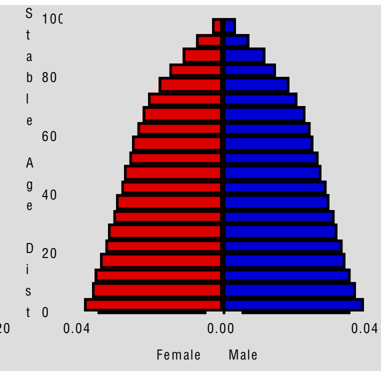
Activity V -- Stable Age Pyramids

In Activity IV, we discovered that after a number of time intervals, the proportion of individuals in each age class reaches an equilibrium (called a "stable age distribution"). Demographers recognize that populations growing at different rates will have stable age "pyramids" that differ in shape. In fact, the stable age distribution for a population can be determined solely from its fertility and mortality functions. (You can use *Demography* to help convince you of this, if you are skeptical.)

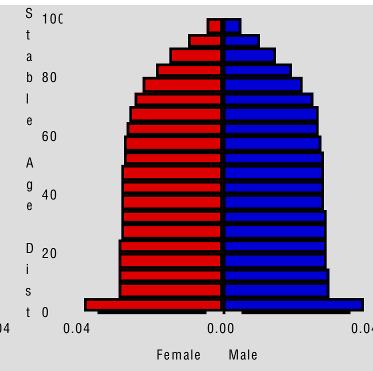
Consider the shapes of the following age "pyramids". Your task in this activity is to construct fertility and mortality curves that will produce each of these pyramids. Some are easy; some are challenging. As you do this activity, you should be developing hypotheses to explain why certain fertility and mortality combinations yield particular shapes for the stable age distribution.



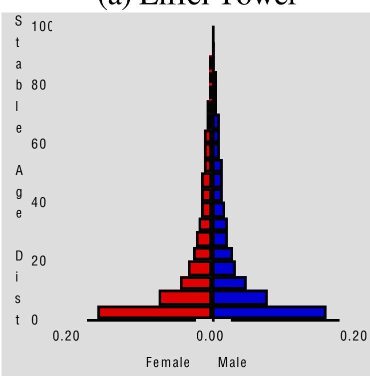
(a) Eiffel Tower



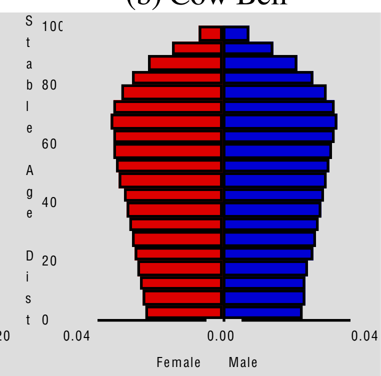
(b) Cow Bell



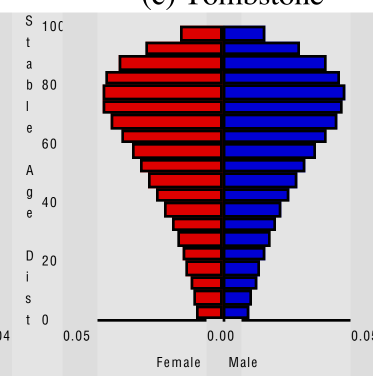
(c) Tombstone



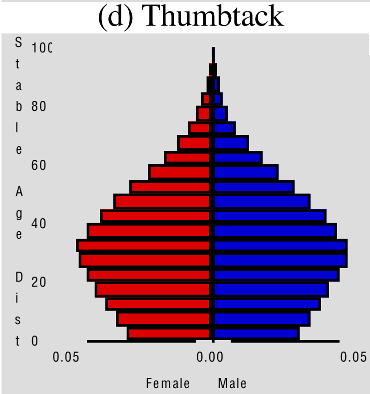
(d) Thumbtack



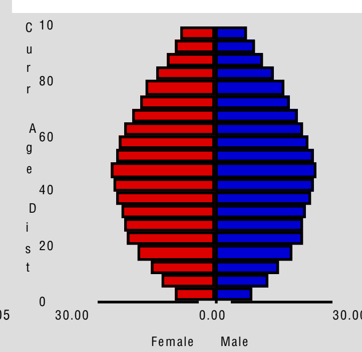
(e) Mummy



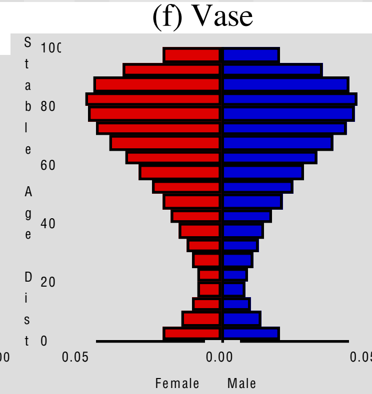
(f) Vase



(g) Taj Mahal



(h) Football



(i) Tornado

Question: Briefly describe the characteristics of the fertility and/or mortality curves that lead to each of these stable age distributions. For example, what differences in fertility and mortality lead to a tornado instead of a vase? Is a tornado (or a vase) even possible? What kinds of doubling times do you get for various shapes?

(a) Eiffel Tower	**(b) Cow bell**	**(c) Tombstone**
(d) Thumbtack	**(e) Mummy**	**(f) Vase**
(g) Taj Mahal	**(h) Football**	**(I) Tornado**

Question: Which of the above shapes are likely to characterize

- Rapidly growing populations?
- Slow-growing populations?
- Declining populations?

Note that some shapes might fit into more than one category.