Lives of Soap Bubbles and People

Teacher Lab Discussion

Overview

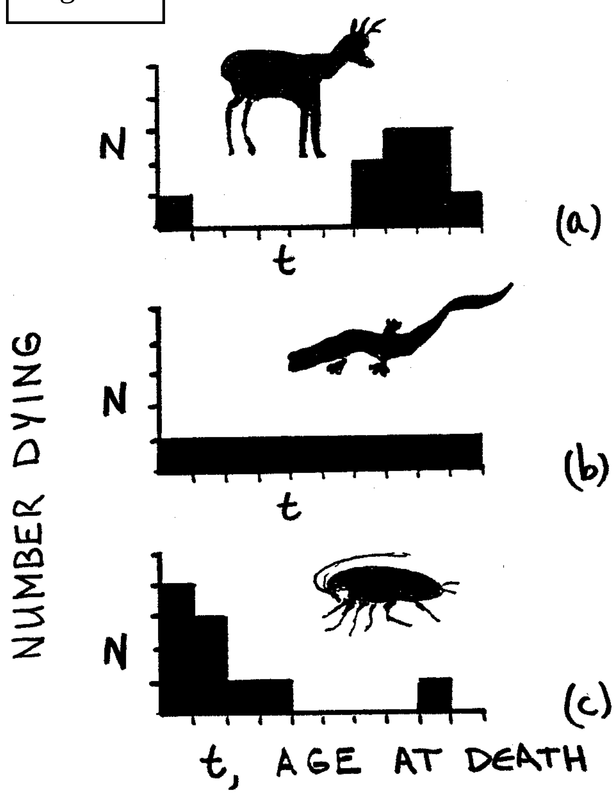
An important problem in biology is trying to understand how long plants and animals live and why they die. In order to do this kind of study biologists often travel great distances and put great effort into collecting population data. For example, one biologist trekked through mountains in Alaska collecting skulls of Big Horn Sheep. He was able to tell how old each sheep was when it died by counting rings of bone in the horns. Then he made a frequency distribution of the number of sheep that died at each age. For humans, the oldest records of life spans have been gathered by going through birth and death records in European churches. We can all study more recent human populations by using local cemeteries. You cannot be afraid of cemeteries if you are a biologist!

Biologists look for patterns in life-span data just as you have looked for patterns in earlier TIMS exercises. To find patterns you need a graph. Since we are looking for patterns in how long individuals live, we need a frequency distribution. Here the manipulated variable is the age at death (**Question 1**) and the responding variable is the number that died at that age (**Question 2**).

Histograms

Thus, the biologists try to determine how many animals died, N, between birth (t = 0) and 1 year, how many between 1 year and 2 years, between 2 years and 3 years, etc. They then plot the time, t, on the horizontal axis and N on the vertical axis. The result is a bar graph with the bars filled in between 0 and 1 year, between 1 and 2 years, 2 and 3 years, etc. An example of one of these filled in bar graphs is shown in Figure 1. This frequency distribution is a bit different from the ones that we have seen earlier. In *Rolling One Die* and *Rolling 2 Dice*, for example, there are no other values for the face numbers besides 1, 2, 3, 4, 5, and 6. There is nothing in between, no 1.5, for example. Thus one obtains a bar graph with the bars as narrow lines around each dice number. But with dying animals, there are numbers in between times. Animals do die at 1.5 years, at 2.25 years, etc. So, to make matters simple, the biologists lump all the data between 0 and 1 year into one bar and draw it as a thick line between t = 0 and t = 1 year and do the same for each subsequent time interval. This is called a histogram.

Figure 1



Let's get some experience with the three basic shapes these histograms have before discussing the children's lesson. Biologists have found that there are three different kinds of lives that animals lead, and these result in three different patterns in frequency distributions of life spans. The first kind of life pattern shown in Figure 1a is for large animals; they have a good chance of living to old age. Animals like elephants, moose, whales, or albatrosses nurture their young until they are old enough to fend for themselves. As adults, they can protect themselves—a healthy adult moose can fend off wolves—so there is little mortality in middle age. But in old age diseases, parasites, and predation result in death. Wolves are only good at killing older moose. For these reasons, deaths tend to occur at the end of the life span of larger animals.

In Figure 1b is the histogram for middle-sized animals: small birds, frogs, toads, and snakes. The graph is flat for them. This means that they are as likely to live one year as two years or three years. Why? Because they are too small to protect themselves against many predators and accidents, so chance has a much greater effect on how long they live than it does on the lives of large animals.

Small animals such as mosquitoes and house flies, as well as microorganisms, are represented by the bottom graph, Figure 1c**.** Most of them die immediately—fortunately for us! This is because freezing and thawing, rain and drought, as well as chance accidents may kill unprotected small organisms.

Summarizing Figure 1, the graph shows that as a rough generalization the smaller the organism, the more likely it is to die young. In fact, looking at the graph in Figure 1c, you might wonder how small organisms survive. It is because they produce so many more offspring than large organisms.

Now that you are more familiar with how life spans can be plotted as frequency distributions, consider what the children will do in this lesson. In this experiment we will graph the frequency distribution of the number of seconds a number of soap bubbles last. Then, for comparison, we will make frequency distributions of the number of years people live. We will use two populations of people, those who lived before and those who lived after the First World War.

Here is what you should do to get data on soap bubble lives that can be compared with data for humans. The age of a soap bubble will be the time it takes to pop. Our population will be lots of bubbles. We will record how many popped between 0 and 1 second, how many popped between 1 and 2 seconds, how many popped between 2 and 3 seconds, and so on.

Picture, Data Table, and Graph

A drawing of the experiment is shown in Figure 2. The time the soap bubble lives is t, and the number that lived that time is N. The children should work in pairs, one as a timer and the other as the bubble blower. The bubble blower blows a bubble and catches it on the plastic loop or wand that comes in the bottle of bubble fluid. Then, when the bubble

Figure 2

Figure 3

Table I

Bubble	Life Span in seconds
1	8.7
2	1.2
3	9.2
4	11.3
5	8.4
6	7.4
. . .	

is caught on the loop, the timer starts timing. Each pair does this twenty times, recording each time interval in the raw data table shown in Figure 3. This way the children have a permanent record of time intervals just in case something doesn't make sense to you. There is nothing magical about blowing 20 bubbles. We enjoy blowing them (maybe it's the child in us) and the children do too, so why not 30 bubbles, or even 50!

Once they have the raw data each group converts it into a frequency distribution table as shown in Figure 4. Before they do this they must choose the time intervals. The time interval of 1 sec is perfect for the data in Figure 3. But if it's much more spread out—say from 0 to 40 sec, then an interval of 2 sec—or 5 sec might be better. You want the intervals large enough so bars of various heights can accumulate and *not* have one event in each interval. In Figure 4 we can see the histogram building up in intervals 7–8 sec and 8–9 sec. That is what you want.

The data is graphed as a frequency distribution as shown in Figure 5. You can see a pattern: few bubbles die young, most live past middle age and

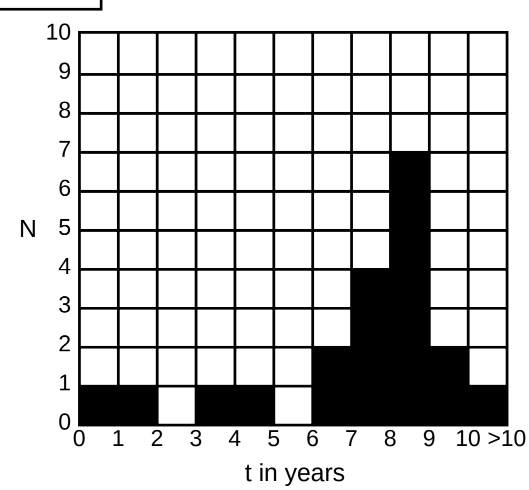
Figure 4

Table II

t Time in seconds	N Number of bubbles popping in the interval	
	Tallies	Total
0–1	/	1
1–2	/	1
2–3		0
3–4	/	1
4–5	/	1
5–6		0
6–7	//	2
7–8	////	4
8–9	~~////~~ //	7
9–10	//	2
>10	/	1

die in the same interval of eight to ten seconds. The most frequent age is between 8 and 9 seconds. Again, the time the bubble lives is the manipulated variable, and it takes on values 0–1, 1–2, 2–3,… 9–10. The responding variable is the number of bubbles in each time interval.

Figure 5



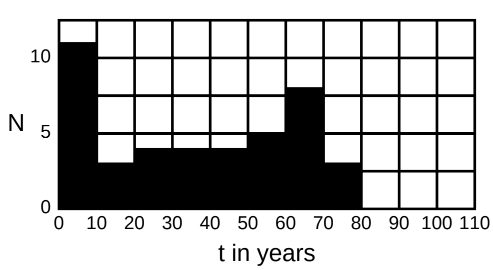
Why use soap bubbles? First, because they last such a short time children can see the process that leads to the graph. And second, the frequency distribution for soap bubble lives is the same as that for people who lived after the first World War. For these reasons, the soap bubble graph will help the children understand the cemetery data better. Is there any similarity in whatever makes soap bubbles pop and whatever makes people die? No. Both seem to wear out, but in different ways. If you watch a soap bubble closely, a thin film of fluid seems to be running down the side until the bubble is so thin it pops. Apparently each bubble is "born" with a thick enough film to live past middle age. But part of the film runs down the side of the bubble after it is blown, so the film gets thinner and thinner. Finally, the film gets so thin that it ruptures, and the bubble pops. This seems to be the reason that similar-sized bubbles pop after the same length of time, thus giving a similar frequency distribution to lives of people. So soap bubbles appear to age as do people whose hearts and lungs "wear out" also.

The real biology begins when you ask your students to prepare frequency distributions of how long people lived before and after the First World War. If you can visit a cemetery and collect your own data all the better, but if you cannot, the children are given data from a Chicago cemetery for these two periods. Below is the completed data table and graph for each period (Figure 6).

Figure 6

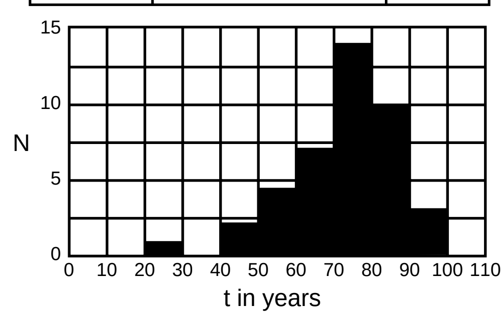
BEFORE WORLD WAR I

t Life span in years	N Number of people who die in time interval	
	Tallies	Total
0–10	𝍸 𝍸 /	11
10–20	///	3
20–30	////	4
30–40	////	4
40–50	////	4
50–60	𝍸	5
60–70	𝍸 ///	8
70–80	///	3
80–90		
90		



AFTER WORLD WAR I

t Life span in years	N Number of people who die in time interval	
	Tallies	Total
0–10		0
10–20		0
20–30	/	1
30–40		0
40–50	//	2
50–60	////	4
60–70	𝍸 //	7
70–80	𝍸 𝍸 ////	14
80–90	𝍸 𝍸	10
90	///	3



Before World War I many people died as children, and if they survived childhood they had a high and constant chance of dying at any age, like in Figure 1b. Few lived to old age. After World War I we get a distribution more like that of large animals, as seen in Figure 1a, and like that for soap bubbles. Why the difference? Before the First World War, window screens to keep out disease-carrying insects, and disinfectants and soap were not much used. Thus, before the war people lived without the benefits of public health, and therefore had a constant high risk of dying at any time of their lives. For this reason, the frequency distribution of life spans of people who lived before the First World War is similar to that for small birds and frogs (Figure 1a). In contrast, after the First World War use of these public health practices became common, and most people lived to old age.

Supplemental Activity

Soap bubbles simulate the frequency distribution of life spans for large animals including people who lived after the First World War. You can use dice to simulate the frequency distribution of life spans for organisms that have a constant chance of death, including people who lived before the First World War and medium sized-animals (Figure 1c).

When you toss a die, there is an equal chance that any of the six sides will face up. If you assume that the number facing up after each toss of a die is the age at which death occurred, a plot of the frequency with which each side faced up will have a similar number of deaths at each age, which is very much like the situation for people who lived before the First World War.

In order to do this, have the children toss a die and read the number on the face. Each face of the die has the same chance of being up, so the six bars of the frequency distribution should be the same height, much as you see for pre-World War I humans. The children did this experiment way back in the 3rd grade in *Rolling One Die.* You might want to supplement this experiment with the basic graph of that exercise. If you add this to the lesson, have each child roll the die about 20 times and record which number between one and six comes up. Have the class then combine all of their data into one big frequency distribution of how many times one comes up, two comes up, and so on. The distribution will be flat, just like the one for small animals (Figure 1a).

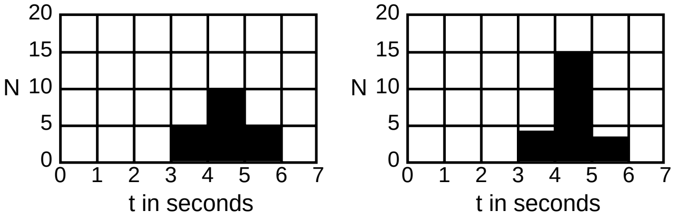
Comprehension Questions

We start out in **Question 3** with a general exercise about the experiment. By counting the height of all the bars the children should find that there were 420 bubbles blown by the class. Since there were twenty students in the class, each child blew 21 bubbles, assuming all blew the same number. This is a good assumption since this is the way your class did the experiment. The most likely length of time one of the bubbles lived is between 38 and 40 seconds.

In **Question 4** we ask the children to look at their data and compare it to the class described in **Question 3**. Assuming a distribution like that in Figure 5, the most common length of time your bubble lived is between 8 and 9 seconds. Under these conditions, your bubbles did not live as long as those in **Question 3**. How might you account for the difference? You might tease the children and say that the other class had more girls and they blow better bubbles. We hope the children will see that this is a ridiculous answer. A more likely possibility is a difference in type of fluid used. This will determine the surface tension of the liquid and, thus, how big the bubble will be, how thick the film will be, and therefore how long the bubble will live. A nice science fair project would be to see what to change in bubble-blowing mixtures to change average lifetimes.

The answer to **Question 5** is not meant to be exact. The children should distribute their twenty bubbles

Figure 7



so that there is a peak in the frequency distribution between four and five seconds. Two possibilities, both correct, are shown in Figure 7.

Lives of Soap Bubbles and People is a wonderful experiment for exploring probability. **Questions 6, 7, 8,** and **9** are in the nature of a review for the children.

In **Question 6a,** we want to know the experimental probability that one of their bubbles will live longer than the most frequently occurring time interval. Using the data in Figure 5, there are three bubbles out of the twenty that live longer than 8–9 sec. Therefore

$$P_{Exp}(> 8 - 9) = \frac{3}{20} \times 100$$
$$= 15\%$$

The experimental probability of living shorter than 8–9 sec is (**Question 6b**)

$$P_{Exp}(> 8 - 9) = \frac{10}{20} \times 100$$
$$= 50\%$$

while the experimental probability of living exactly 8–9 sec is (**Question 6c**)

$$P_{Exp}(> 8 - 9) = \frac{2}{20} \times 100$$
$$= 35\%$$

Should the numbers add up to 100%? The answer to **Question 6d** should be a resounding yes. Why? Not because 15 + 50 + 95 = 100. That is not a physical reason. Rather you want the children to see that they are using *all* the data and so the bubble *must* have burst in one of the intervals and so the measured probability is 100%.

In **Question 7** we try to predict for the class the number of bubbles that live for exactly the lifetime of your most frequently occurring interval. The answer will depend upon the class size. Say there are 15 groups and each blows twenty bubbles. Then

$$N_{Tot} = 15 \text{ groups} \times \frac{20 \text{ bubbles}}{\text{group}}$$
$$= 300 \text{ bubbles}$$

Your expected probability is 35%.

$$\therefore N(8–9) = 300 \times .35$$
$$= 100 \text{ bubbles}$$

In **Question 8** we ask the children to do a mini-experiment and collect the data for the entire class. They should *not* need your help to do this. Treat this as an open-ended exercise. Let them set up the data tables and collect the data. The answer to **Question 8a** may be yes or no. Only the experiment will give the answer. In **Question 8b** the children are asked to see how close their previous prediction was. Let's say for the class

$$N(8–9) = 140 \text{ bubbles}$$

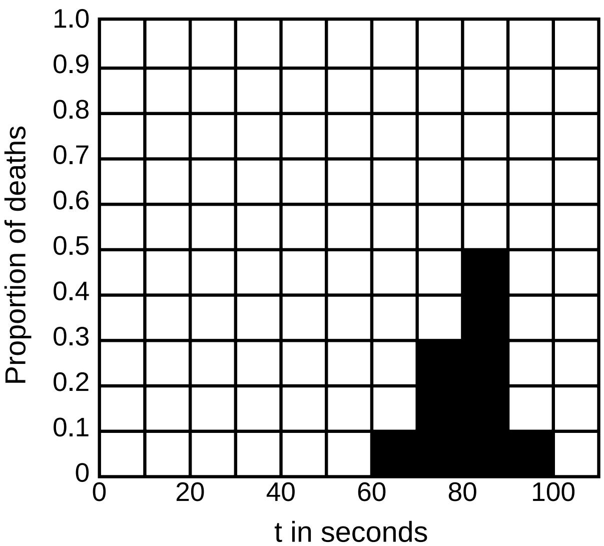
Then "how close" is *not*

$$\Delta = 140 - 105 = 35 \text{ bubbles}$$

We need a percent comparison. See if they will remember this. Don't tell them. What they should find is

$$\% \text{ Diff.} = \frac{\Delta}{140} \times 100$$
$$= \frac{35}{140} \times 100$$
$$= 25\%$$

Figure 8



So, their answer would be "my prediction was within 25%, which isn't too bad."

Question 9 could be a homework assignment. Remember, median is one-half up or down the data sample. They found in Question 3 that N_{tot} = 420 bubbles, so halfway is 210. Counting up from the bottom (t = 0) the 210th bubble falls in the interval between 30 sec and 32 sec, so that is the median lifetime. The answer to **Question 9b** is

$$P_{Exp}(> 40 \text{ sec}) = \frac{N(> 40)}{N_{Tot}} \times 100$$
$$= \frac{80}{420} \times 100$$
$$= 19\%$$

We now ask four questions that deal with the cemetery data. For the data before World War I (**Question 10**), the age at which the largest number of people dies was between birth and nine years. This is obviously and tragically very young. But when we compare soap bubbles in **Question 11** with the cemetery data, we find that soap bubbles are more like the data after World War II. In both cases there are almost no early "deaths" and both peak at a later time.

Now the important question: Why are the two cemetery data sets so different? It might prove interesting to let the children answer **Question 12** without your intervention. Then, based on their answers which they could present to the class, you could generate a discussion about the toll of disease because of the lack of public health measures.

The final question in this group, **Question 13**, asks what the frequency distribution would look like if people are kept alive into their seventies and eighties. The distribution is shown in Figure 8. What we probably have here is a natural limit to the age of humans. If we remove all disease, accidents, and war, senescent death remains. Most population biologists believe that the human life span will not be extended, but rather, more and more individuals will survive to that limit.

Summary

Using soap bubbles we explore a wide range of population biology phenomena. For both animals and humans a histogram type frequency distribution gives us great insight into the external conditions affecting lifetimes. The use of cemetery data is a good field exercise to augment the data given in the experiment.

The experiment also adds histograming to the students' analytical tools. Much like their previous work with bar graphs, they can apply basic probability ideas to the analysis of the data.

Materials per Team

- bubble solution
- bubble wand
- stopwatch