Human Populations: Type I, II, III Survivorship Curves

SC Academic Standards: 4.L.5A; 5.L4A; 6.L.4B; 7.EC.5A,B; H.B.6A,C.

NGSS DCI: 5-ESS3.C; MS-LS2A,C,D; MS-ESS3.C; HS-LS2.A,C.

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.4; S.1A.5; S.1A.6; S.1A.7

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Stability and Change; and Systems Models.

Focus Question(s): How is survivorship of modern Americans different from the survivorship of Americans living in the 1800's? How can survivorship curves be used to predict population growth dynamics?

Conceptual Understanding: Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. Limiting factors include the availability of biotic and abiotic resources and challenges such as predation, competition, and disease.

A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively stable over long periods of time. Fluctuations in conditions can challenge the functioning of ecosystems in terms of resource and habitat availability

Each plant or animal has a unique pattern of growth and development called a life cycle. Some characteristics (traits) that organisms have are inherited and some result from interactions with the environment.

In all ecosystems, organisms and populations of organisms depend on their environmental interactions with other living things (biotic factors) and with physical (abiotic) factors (such as light, temperature, water, or soil quality). Disruptions to any component of an ecosystem can lead to shifts in its diversity and abundance of populations.

<u>Background</u>: **Demography** is the study of population dynamics - how populations grow and decline. The worldwide human population is currently experiencing a population growth phase, and presently is increasing at an **exponential rate** (though it is slowing slightly, human growth rate is still positive). Today, the human population is just over 6 billion people, and is expected to double in about 35 years (300 years ago, the human population used to double every 600 years!) By the year 2050 we could have 10-12 billion people on earth! We are unsure of the **carrying capacity** of the earth; some scientists fear we have already surpassed it.

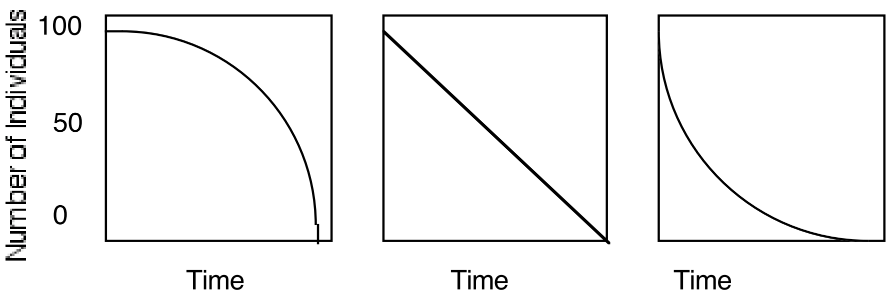
Populations grow as more members are added (through births and immigration) and populations decline as members are deleted (through deaths and emigration). Stable populations have a balance between birth (and immigration) rates and death (and emigration) and are said to have a **zero population growth** rate (G=0, where G is the Growth Rate of a population). Predation and Competition also help to keep population sizes stable.

Today we will look at survivorship / mortality curves, and construct a **static life table**. A **survivorship curve** traces the decline in number, over time, of a group of individuals born at the same time (a **cohort**). It can be thought of as the probability of an individual surviving to various ages, or the average **Life Expectancy. Life expectancy** is different from the **Maximum Life Span** (i.e. the American robin, *Turdus migratorius*, can live to be 7 years old but the probability of a newly hatched robin doing so is less than 1 %. Many live only a year or two. Life **expectancy** is 1-2 years, **maximum** life span is 7 years).

The **life expectancy** of human populations has increased significantly in the past 100 - 300 years due to improved nutrition, preventative medicine, life-style changes, improved sewage control and hygiene and new technologies such as refrigeration and pasteurization. In the early days of Rome, life expectancy was only 22 years! In America in 1900, the life expectancy was about 48 years; in 2010 it was 78.9 years. A Dominican woman lived to a ripe old age of 127 (the maximum human life span). Disease often limited population size prior to the late 1800s. Although reproductive rates were high, child mortality rates were also high, so the population remained relatively steady. With the development of medicine, vaccines, and improvements in sanitation, there was a decrease in infant and childhood mortality. This drop in mortality can be seen as an increase in survivorship. In brief, survival rates are up and mortality rates, especially infant mortality rates, are down: this leads to population growth.

As human populations progress through time their population growth rates follow predictable patterns called the **demographic transition** (where birth rates are high but death rates are also high at early stages, but by the end of the progression both birth and death rates are low)**.** First world nations have passed through the transition already; many third world countries are in the midst of the transition currently. The goal of many human rights organizations is to help developing countries pass through the transition and enter the 4^{th} , post-industrial, stage, where growth rate is low and stable, leading to a stable (non-growing) population size – the sooner all populations are at ZPG (zero population growth) the better off our world will be as we approach the end of our finite resources. As the United States has progressed through the industrial revolution and the demographic transition model over the last 150 years, changes in the life-styles of citizens have been reflected in their age at death. Factors such as diseases and accidents have changed in their relative impacts. One way to study these changes in human demographic patterns is to visit a local cemetery and collect data recorded on tombstones- from this you can create a survivorship curve.

There are **three typical population survivorship curves**: Type I, Type II and Type III. Humans have a Type I survivorship curve, with low infant mortality and a high probability of living until you are old (at which time the probability of death increases).



Type I (Humans, large mammals) | Type II (songbirds) | Type III (marine invertebrates)

To determine age specific mortality and survivorship curves for a population, ecologists will follow a **cohort** - a group of individuals born within the same time interval (for example, a year, 5 years, or a month, depending on the species we are looking at). The cohort is followed until all members of the cohort are dead; gender and age at death is recorded for each individual. We find that each species has a characteristic life span and survivorship pattern, although few may reach the maximum age.

In this lab we will construct survivorship curves for humans who were born and lived in the 1800s, and for humans who were born and lived in the 1900's (died after 1980). We are **comparing** the survivorship and life expectancies of humans living in the 1800's and humans living in the 1900's.

Materials: Access to a cemetery with tombstones ranging from mid/late 1800's – present day (or obituary pages from newspapers from the 1800's – available on microfiche at your local library – and newspaper obituary pages from the present day. To be able to maintain consistency, it is nice to have newspapers and microfiche from the same region, i.e. if your library only has the state newspaper on microfiche for the 1800s, or the NY Times only, then try to match the present day newspapers and get modern State newspapers or NY Times), semi-log graph paper.

For the **extension**, you will also need bubbles /bubble wands and a stopwatch.

<u>Previous Knowledge:</u> (ecology): There are two different types of strategies that we see in nature for the allocation of energy and resources. Some animals and plants spend most of their energy on reproduction, others on growth. Generally, you aren't both large and very fecund.

Ecologists call this **r vs. k selection** – some organisms (ex., whales, bears, gorillas, annual grasses) have longer lifespans, grow larger, spend a lot of energy growing big, and delay reproduction till later, have only a few young at a time, may reproduce more than once, and often give **parental care** to their fewer offspring. **These organisms are k-selected, and typically have type I** (like humans) or type II (like songbirds) survivorship curves. Other organisms, like dandelion weeds, most frogs, most insects (like the housefly), spend little energy on growth but put the bulk of their energy into reproduction. They have shorter life spans, are often smaller, and generally grow quickly to adulthood, reproduce once – but have lots of well developed offspring, and give little parental care (often dying after reproduction). **These organisms are r-selected and often have a type III survivorship curve.**

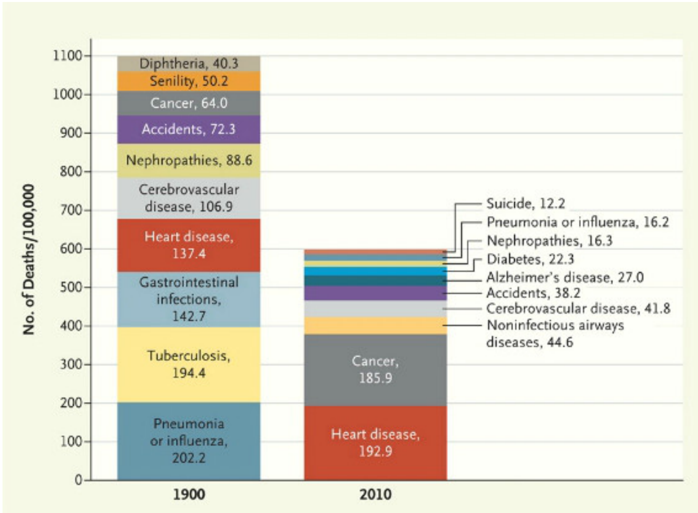
Life history theory, which is more in favor these days than r / k selection, states that natural selection tends to increase **fitness** of any organism (that is, to have reproductive success, so that your genes make it into the next generation, and the next, and so on. This depends on both reproduction and survival of offspring to adulthood. Fitness, essentially, is who can produce the largest number of surviving offspring. We are hardwired (genes) to do this. Life history characteristics, such as age of first reproduction, reproductive lifespan, number and size of offspring, etc, are important and vary from species to species. The variations lead to different allocations of energy / resources (to reproduction? To growth? Time and effort to grow means less available time and effort to reproduce. It is a trade-off). Life history characteristics can change population density and size.

Not every plant or animal fits nicely into r (rate) vs. k (carrying capacity) selection. For example, sequoia trees are very large and very long lived and reproduce more than once in their lifetime - but produce millions of tiny seeds to which they give no parental care, and they have low survivorship to adulthood: it's a mixture of r and k traits, and we see this with a lot of organisms, including sea turtles! And, the theory originally predicted that r-selected species would be found in unstable areas where the environment was very changeable from year to year, so that quick reproduction is an advantage; further that k-selected species would tend to be found in stable environments – however, in all environments you can find a mix of r and k species, and some species that seem to have characteristics of both strategies, like the aforementioned sequoia. Last, it isn't always all genetic either: studies with guppies have shown that the presence of predators can influence the life history traits of prey populations. Predators shifted the prey population toward earlier maturation, more rapid reproduction, and smaller offspring.

<u>Previous Knowledge: (sociology</u>): It's is good to have a little sociological background on your area: There are great variations in life expectancy between different parts of the world, mostly caused by differences in public health, medical care, and diet. The impact of AIDS on life expectancy is particularly notable in many African countries. In the United States, particularly the southeast, in the 1700's there were a couple scarlet fever epidemics (1735-40, 1786); during the civil war (1860-1865) typhoid epidemics and malaria claimed lives; there was a flu epidemic in 1857-59 and in 1918-19 (the Spanish Flu of 1917/18 infected 1/5 of world population, with 3% dying from flu).

And, from Sundstrom, William, et al. "Industrialization and Fertility in the 19th Century: Evidence from South Carolina."
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCIQFjAA&url=http%3A%2F%2Fweb.utk.edu%2F~mwanamak%2FJEHarticle.pdf&ei=0S8sVPDkE4eyyQTQzIG4AQ&usg=AFQjCNFM7BmNn6zy4b1tTO2SFk-YAQin-Q&bvm=bv.76477589,d.aWw

> "By the dawn of the 20th century, fertility rates in the United States had undergone a century of steady decline. In 1800, white American females could expect to bear 7.0 children on average; by 1900, this number was 3.6. The factors behind the 19th century decline have been the subject of a lengthy literature highlighting the importance of intergenerational bequests, the economic value of children, and the cultural context for American family formation.
>
> There are a number of mechanisms by which industrialization may have altered a household's fertility outcome. First, several models of economic growth and fertility decline highlight the role of human capital in increasing the incentives of households to invest in child quality over quantity, thereby reducing the number of children born. Second, industrialization may have induced a rise in the implicit costs of raising children. In particular, industries with high rates of female employment increased the opportunity cost of female time. Under the assumption that the child production process is female time- intensive, this would have reduced the incentive to bear children. Third, the movement away from agricultural and at-home production to centralized production, in addition to more restrictive child labor laws, may have reduced the economic return to children, again lowering parental demand and fertility rates. Fourth, industrialization was associated with increased urbanization and the crowding that occurred may have increased the explicit costs of raising children through higher housing and food costs without an associated increase in the benefit. Finally, the developing economy in the United States witnessed decreases in child mortality rates, especially after 1880."



http://io9.com/5920871/how-we-died-200-years-ago-compared-to-how-we-die-today

Question 1: Do people living in modern times (1900's) have a longer life expectancy versus people living in the 1800's?

Hypothesis:
Null Hypothesis:

Question 2: In the 1800's, who had a longer life expectancy, men or women?

Hypothesis:
Null Hypothesis:

Procedure: (*Note: you may want to divide the class into 4 groups, one group finds 50 tombstones of males you died before 1900, one group looks for 50 tombstones of females ... and so on).

1. Select 100 tombstones of people (50 males and 50 females) that died before 1900 (so, they lived in the 1800's) and record their ages at death and the sex of the individual.

2. **Next**, choose 100 tombstones of people (50 males and 50 females) who died after 1980 (living the bulk of their life in the 1900's, though some may have lived in the 2000's as well – that's ok) and record their ages at death and the sex of the individual.

3. **Then,** construct a static life table from these data using the attached data sheet. Determine values for the number of individuals who were alive at age 0-9 years (interval 1), 10 - 19 years, 20 - 29 years and so on. Also, determine the number of individuals who died during each interval (the opposite of a

survivorship curve is a mortality curve). A survivorship curve is prepared by plotting the logarithm of the number of survivors against age.

4. **Finally**, Plot the % survivorship versus age intervals for the different populations. (Note: typically this is graphed as $\log_{10}$ (%S) but the curve comes out about the same so you can choose to graph it normally, % S on Y and age interval on X, or use semi-log graph paper with %S on Y and age interval on X.

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column).	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
0-1				
2-9				
10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 1. MALES who died before 1900 (Lived in 1800s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column).	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
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2-9				
10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 2. FEMALES who died before 1900 (Lived in 1800s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Now, **Plot** the survivorship versus age intervals for both males and females who died before 1900 on ONE graph.

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column)	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
0-1				
2-9				
10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 3: MALES who died after 1980 (Lived in 1900s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column).	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
0-1				
2-9				
10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 4. FEMALES who died after 1980 (Lived in 1900s):

What was the average age of death (average life expectancy)? ____________

Maximum life span ?________________

Now, **Plot** the survivorship versus age intervals for both males and females who died before 1900 on ONE graph.

<u>Data Analysis</u>: From the data table, graph %S (Y axis) versus Age Interval (X axis). All 4 data sets should go on the same graph.
Here is a sample of what a completed data table should look like:

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval)	# who died during interval	Survivorship (total # still alive) 50 total:	% Survivorship ((# still alive / total number of people in cohort) x100)
0-1	2 months	1	49	98%
2-9	3, 5	2	47	94
10-19	11	1	46	92
20-29	20	1	45	90
30-39	31, 32, 38	3	42	84
40-49	48, 48	2	40	80
50-59	50, 57	2	38	76

And so on – until you have 50 ages at death

All ages added together =		x	x	x
Average life Expectancy = total of all ages / 50 names		x	x	x
Total	50 ages	50	0	0

Students may find it useful to begin with a data table like the one on the following page.

Men who died after 1900

#	Year of Birth	Year of Death	Age at Death	#	Year of Birth	Year of Death	Age at Death
1				26			
2				27			
3				28			
4				29			
5				30			
6				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			

Extensions: Typically survivorship curves are plotted using $\log_{10}$ (%S). I've chosen not to, to save time, and you get a similar curve anyway. You can try graphing your %S on semi-log graph paper to get the "real" experience.
If a cemetery is not available, get modern day newspapers and look for the obituary section. You can also go to a library and look for obituaries on microfiche from newspapers from the 1800's (small print, and not really a "section", so you have to do a bit of scanning, but with a little effort you can print enough "deaths" to have a set for use in the classroom. Be careful though, many of the older obituaries didn't list date of birth, especially for women, and so you can't calculate age at death. For a

time saving last resort, there is a web site with a completed data table for tombstones from Newberry SC (1830s) http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CCoQFjAC&url=http%3A%2F%2Fpeople.cst.cmich.edu%2Fgehri1tm%2FBIO%2520340%2FLab%25207%2520Cemetery%2FCemetery.doc&ei=yiksVO7CFMWgyASDioHABA&usg=AFQjCNFPmTGkl1b7NS8RTTdIbpNIia2-Rg&bvm=bv.76477589,d.aWw

You also could bring into the conversation **r vs. k selection** – some organisms (ex., whales, bears, sequoia) have longer lifespans, grow larger, spend a lot of energy growing big, and delay reproduction till later, have only a few young at a time, may reproduce more than once, and often give **parental care** to their fewer offspring. These organisms are k-selected, and have type I or II survivorship curves. Other organisms, like dandelion weeds and the housefly, spend little energy on growth but put the bulk of their energy into reproduction. They have shorter life spans, are often smaller, and generally grow quickly to adulthood, reproduce once – but have lots of well developed offspring, and give little parental care (often dying after reproduction). **These organisms are r-selected and often have a type III survivorship curve.**

Another fun way to create a survivorship curve is using bubbles. This can illustrate both parental care survivorship curves. A nice write up of this is found at http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CDkQFjAE&url=http%3A%2F%2Fmarshalls-adventures.com%2Fap_environmental%2Funits%2Fpopulation%2Fpopulation%2FBUBBLE%2520SURVIVORSHIP%2520CURVES.pdf&ei=RxMsVNe9IsylyATmgYLoDQ&usg=AFQjCNHEZG1Ghwm2P2LiQtSGOBCj7w1rtQ&bvm=bv.76477589,d.aWw
Use the following data tables to make your graph:

With-out Care	With Care
Bubble number one lived _____ sec.	

Total # of bubbles = _____
Average Age at Death = ____

Total # of bubbles = _____
Average Age at Death = _____

Table 1. Bubble survival rate with and without care.

Age at Death and Survivorship*

Time (seconds)	Without Care	With	Without Care*	With*
Time Zero	X	X	total # bubbles =	total =
0-4				
5-9				
10-14				
15-19				
20-24				
25-29				
30-34				
35-39				
40-44				
45-49				
50-54				
55-59				
60-64				
> 65				

Table 2: Age at Death and Survivorship*

*subtract the number that died in the interval from the total # of bubbles to get how many are still alive (survivorship)

Now make two graphs: one of Age at Death versus Time Interval (bar graph) and one of Survivorship versus Time Interval (Line Graph). Each Graph contains two data sets.

Reflection Questions:

- **What type of survivorship curve (I, II, or III) did you find for your data? What does this reflect?** (Type I)
- **Did your data show a difference in age at death between males and females? For which cohort? Why do you think this happened?**
- **What was the average life expectancy for people living in the 1800's? ________ For people living in the 1900's? __________**
- **Why did American families living in the colonial period want and need to have large families?** (to help work the farm – most people lived on farms and grew their own food (no grocery stores).

  What are some factors that led to low life expectancies in the American Colonial period? (In the 1700's there were a couple scarlet fever epidemics

(1735-40, 1786); during the civil war typhoid epidemics and malaria claimed lives; there was a flu epidemic in 1857-59 and 1918-19 (Spanish Flu infected 1/5 of world population with 3% dying).

- **Why are life expectancies throughout the world so different?**
  (There are great variations in life expectancy between different parts of the world, mostly caused by differences in public health, medical care, and diet. The impact of AIDS on life expectancy is particularly notable in many African countries).

Models and Explanations: In this lab we explored survivorship curves and population growth rates. **A student who demonstrates understanding** of these concepts can explain why population growth rates are different today than they were over 100 years ago, and can explain why modern Americans have a Type I survivorship curve. This student can also, given some life history details of an organism, such as size, reproductive patterns, fecundity, and life span, predict if the species will show a Type I, II, or III survivorship curve.

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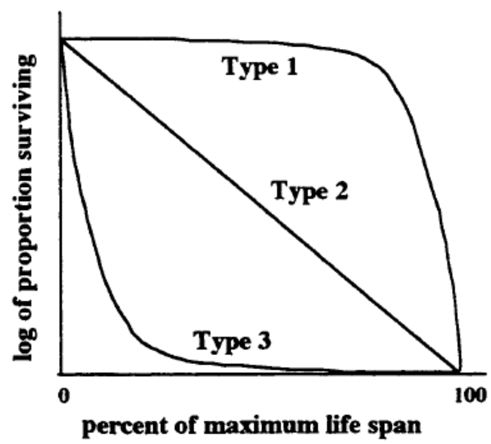
<u>**Student Worksheet:**</u>

As the United States has progressed through the industrial revolution over the last 150 years, changes in the life-styles of citizens have been reflected in their age at death. Factors such as diseases and accidents have changed in their relative impacts. One way to study these changes in human demographic patterns is to visit a local cemetery and collect dada recorded on tombstones.

By collecting information on the year of death for all individuals who died in the same time period you can produce a graphical representation of their survivorship called a survivorship curve. For this exercise three time periods will include all individuals born before 1901, all individuals born between 1901 and 1944, and all individuals born from 1945 to the present.

For the numerous species studied, the curves usually fit one of three general shapes (Figure 1). Human survivorship typically fits a type 1 curve. However, slight, but distinct, differences can be seen when survivorship curves from separate human communities are compared, and when cohorts from different time periods for a single community are compared, as you will see during this lab.

FIGURE 1. Three types of survivorship curves: Type 1 shows low initial mortality and many individuals living to old age. Type 2 shows a steady death rate. Type 3 shows high initial mortality with few individuals living to old age.



<u>**Reflection:**</u>

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- **What was the average life expectancy for people living in the 1800's? _______ For people living in the 1900's? _________**

- **Why did American families living in the colonial period want and need to have large families?**
  What are some factors that led to low life expectancies in the American Colonial period?
- **Why are life expectancies throughout the world so different?**

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10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 1. MALES who died before 1900 (Lived in 1800s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column).	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
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40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 2. FEMALES who died before 1900 (Lived in 1800s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Now, **Plot** the survivorship versus age intervals for both males and females who died before 1900 on ONE graph.

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column)	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
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20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 3: MALES who died after 1980 (Lived in 1900s):

What was the average age of death (average life expectancy)? ____________

Maximum life span ?________________

Age Interval (years)	Age at Death (years) (List the separate ages of death for each individual who died in this age interval. The total goes in the next column).	# who died during interval	Survivorship (# still alive)	% Survivorship (# still alive / total number of people in cohort) x100
0-1				
2-9				
10-19				
20-29				
30-39				
40-49				
50-59				
60-69				
70-79				
80-89				
90-99				
100+				
TOTAL	50	50	0	0

Table 4. FEMALES who died after 1980 (Lived in 1900s):

What was the average age of death (average life expectancy)? ___________

Maximum life span ?_______________

Now, **Plot** the survivorship versus age intervals for both males and females who died before 1900 on ONE graph.

Men who died after 1900

#	Year of Birth	Year of Death	Age at Death	#	Year of Birth	Year of Death	Age at Death
1				26			
2				27			
3				28			
4				29			
5				30			
6				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			

Semi-log graph paper. Graph Age interval on the X and %S on the Y.