Graunt's and Halley's Life Table with ggplot

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Source of Data

Data Input

- **Graunt**'s Life Table

```
rm(list = ls())
graunt <- data.frame(x = c(0, seq(6, 76, by = 10)), lx.17th = c(100, 64, 40, 25, 16, 10, 6, 3, 1))
```

More data

- US 1993 life table for the same age group

```
us.93 <- data.frame(x = graunt$x, lx.93 = c(100, 99, 99, 98, 97, 95, 92, 84, 70))
```

Data Extraction   There are many ways to extract part of `us.93` data frame.

```
us.93["lx.93"]
```

```
##   lx.93
## 1   100
## 2    99
## 3    99
## 4    98
## 5    97
## 6    95
## 7    92
## 8    84
## 9    70
```

```
us.93["lx.93"][[1]]
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```
us.93["lx.93"]$lx.93
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```
us.93["lx.93"]$lx
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93[2]
```

```
##   lx.93
## 1   100
## 2    99
## 3    99
## 4    98
## 5    97
## 6    95
## 7    92
## 8    84
## 9    70
```

```r
us.93[2][[1]]
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93[2]$lx.93
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93[, "lx.93"]
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93[, 2]
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93$lx.93
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

```r
us.93$lx
```

```
## [1] 100  99  99  98  97  95  92  84  70
```

Into one single data frame   Combine two data frames into one single data frame

```r
(graunt.us <- data.frame(graunt, lx.93 = us.93$lx))
```

```
##    x lx.17th lx.93
## 1  0     100   100
## 2  6      64    99
## 3 16      40    99
## 4 26      25    98
## 5 36      16    97
## 6 46      10    95
## 7 56       6    92
## 8 66       3    84
## 9 76       1    70
```

Life Expectancy   The basic principle is that the area under the survival function is the life expectancy.

$X \geq 0$, $X \sim F(x) \Rightarrow X \equiv F^{-1}(U), U \sim U(0,1)$, therefore,

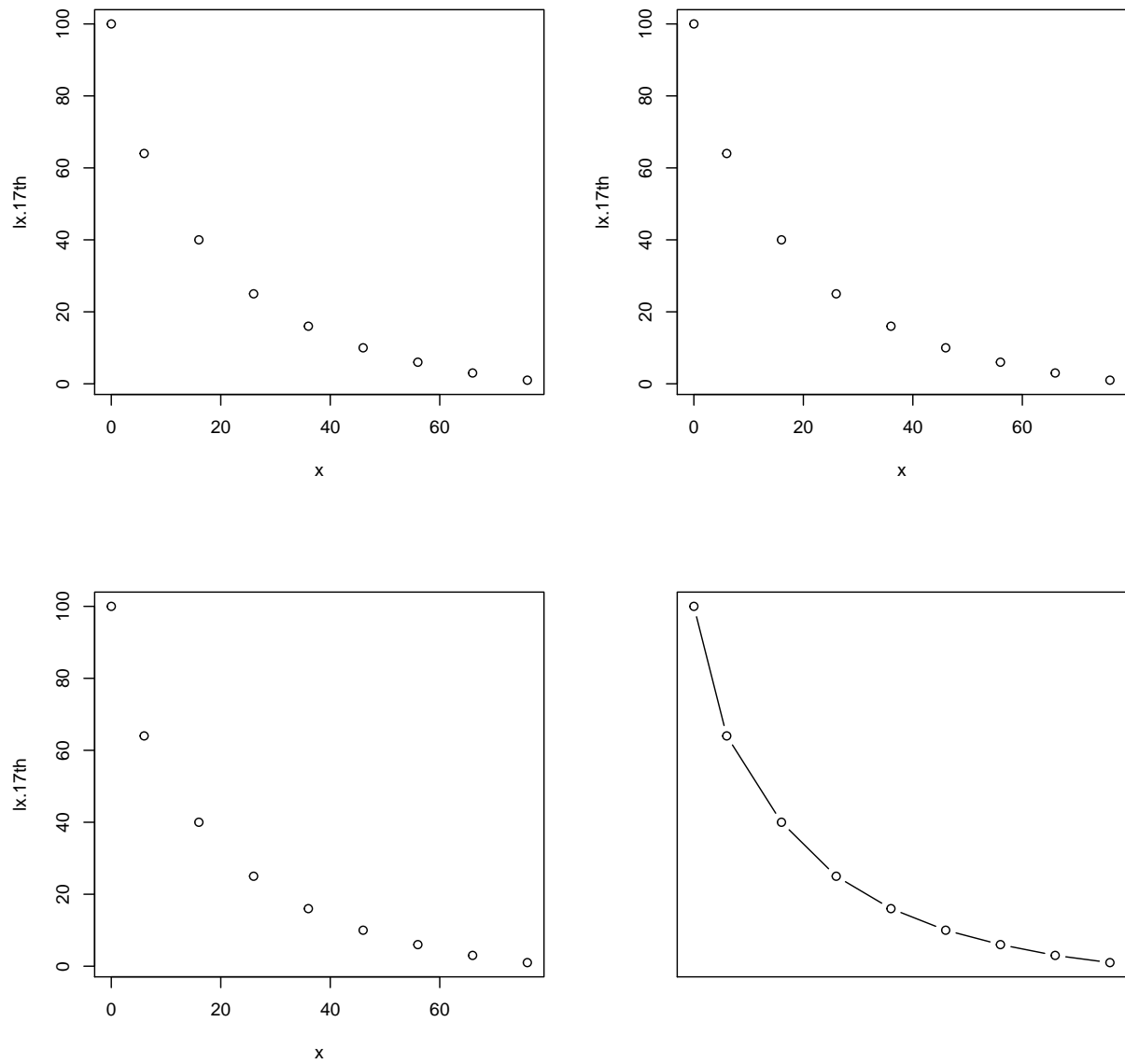$E(X) = E\{F^{-1}(U)\} = \int_0^1 F^{-1}(u)du = \int_0^\infty 1 - F(x)dx = \int_0^\infty S(x)dx$

Step by step approach to draw survival curve

1. Basic plot with points and lines, compare the following threes methods

```r
library(extrafont)
```

```
## Registering fonts with R
```

```r
par(family = "Helvetica")
par(mfrow = c(2, 2))
plot(graunt)
plot(lx.17th ~ x, data = graunt)
plot(graunt)
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
```
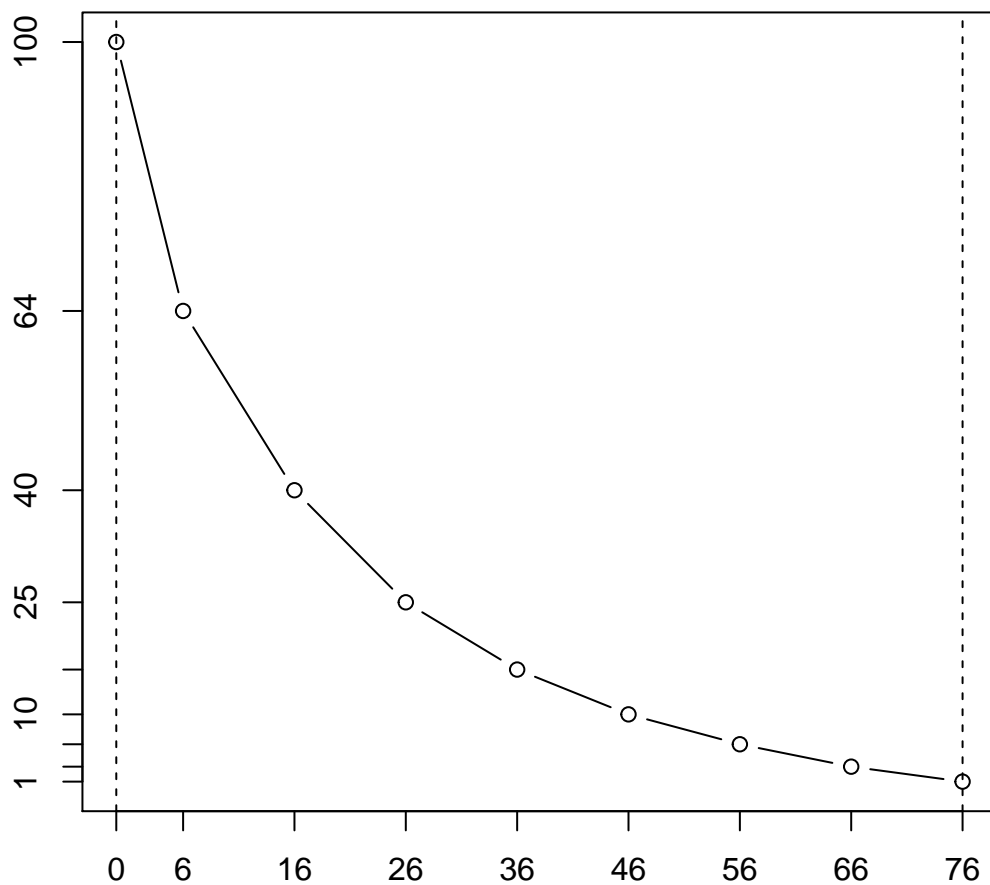
2. Denote the ages and observed survival rates on the axes

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th)
```
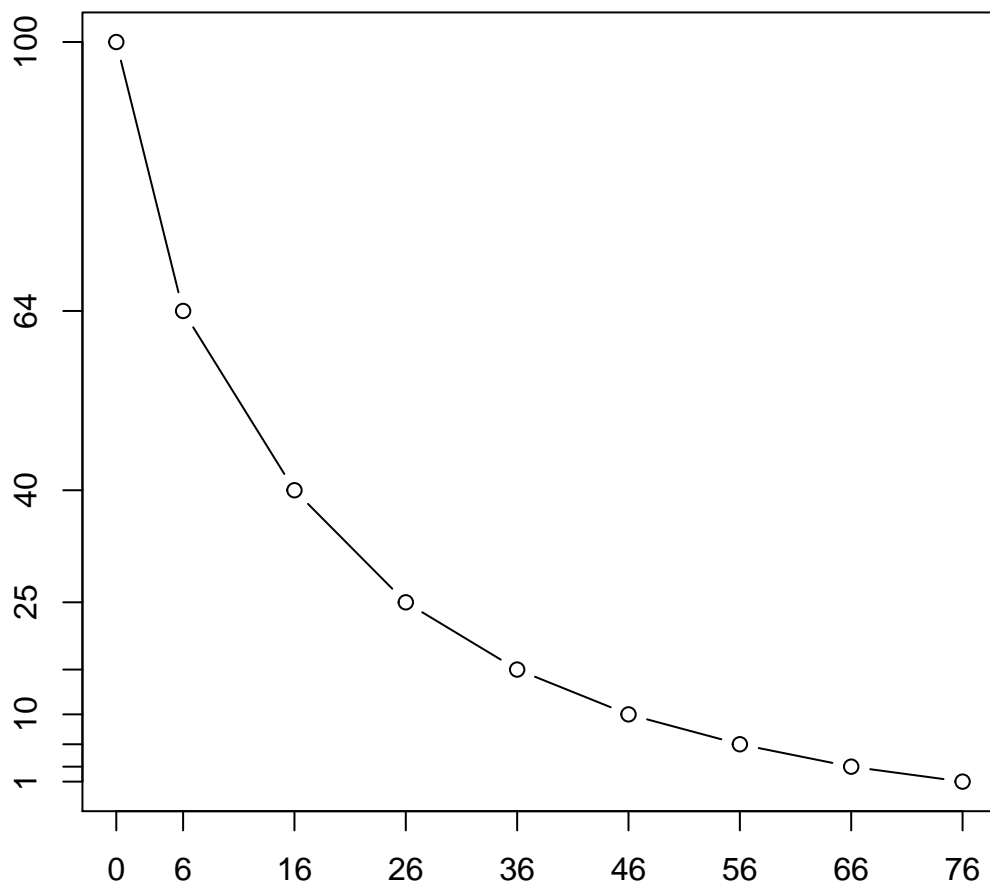
3. Denote the age 0 and 76 by dotted lines

```r
par(family = "Helvetica")
plot(graunt, ann=F, xaxt="n", yaxt="n", type = "b")
axis(side = 1, at=graunt$x, labels=graunt$x)
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
```

```
par(family = "Helvetica")
(graunt.x <- c(graunt$x, 0))
```

Setting up coordinates for `polygon()` (Clockwise)

```
##  [1]  0  6 16 26 36 46 56 66 76  0
```

```
(graunt.y <- c(graunt$lx.17th, 0))
```
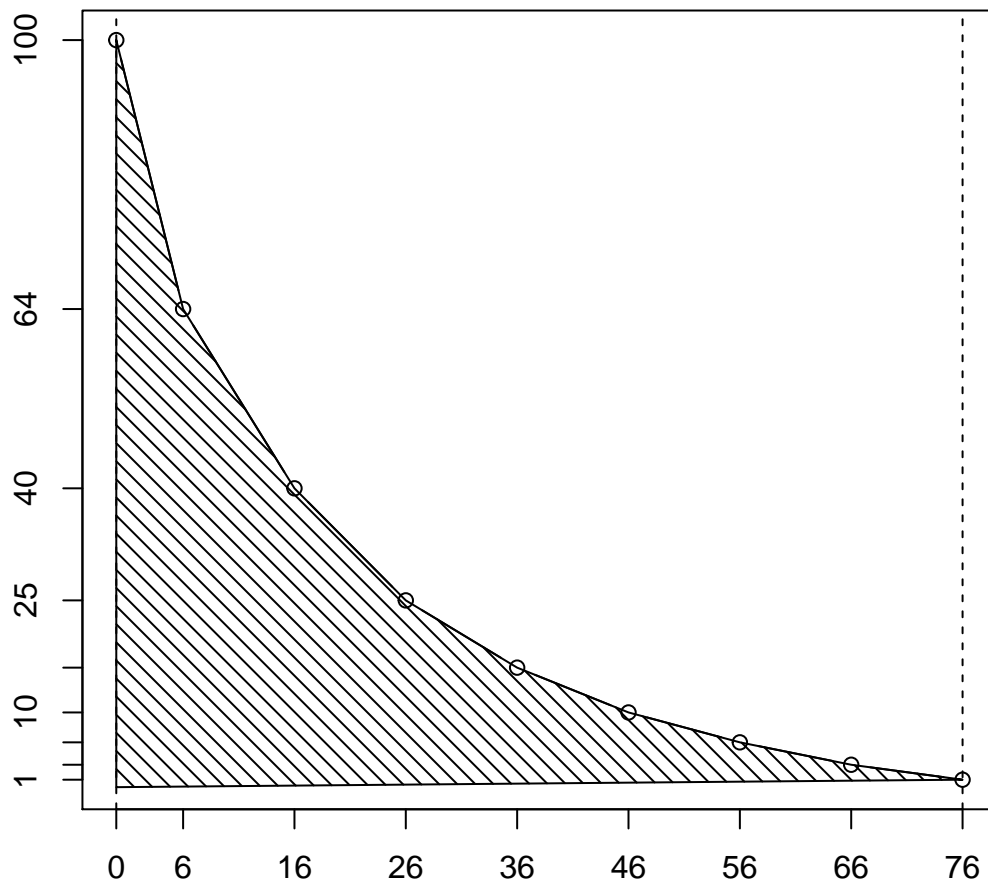
```
##  [1] 100  64  40  25  16  10   6   3   1   0
```

4. Shading

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
polygon(graunt.x, graunt.y, density = 15, angle = 135)
```
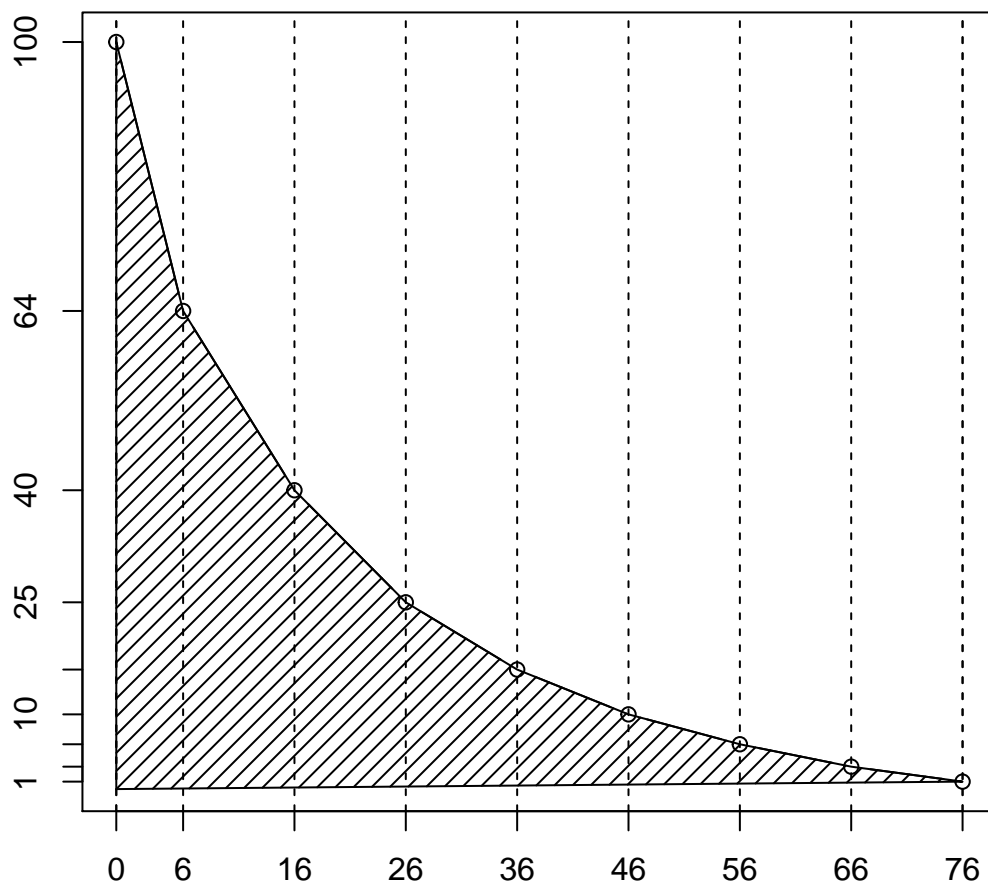

5. Grids

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
polygon(graunt.x, graunt.y, density = 15)
abline(v = graunt$x, lty = 2)
```

6. Title, x-axis label, and y-axis label

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
polygon(graunt.x, graunt.y, density = 15)
abline(v = graunt$x, lty = 2)
main.title <- "Graunt's Survival Function"
x.lab <- "Age (years)"
y.lab <- "Survival Rates (%)"
title(main = main.title, xlab = x.lab, ylab = y.lab)
```

Graunt's Survival Function
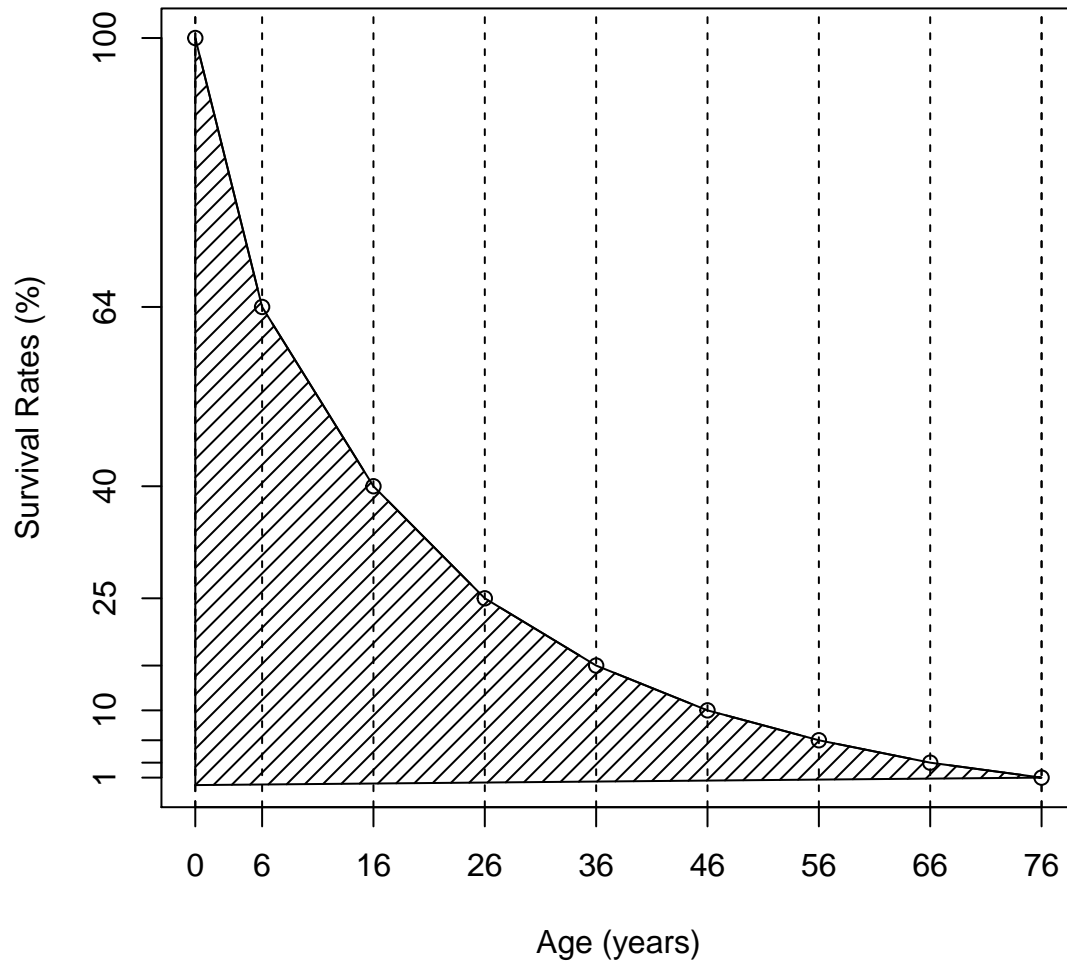
Area under the curve

- The area under the curve can be approximated by the sum of the areas of trapezoids, therefore the area is
  - $\sum_{i=1}^{n-1}(x_{i+1} - x_i) \times \frac{1}{2}(y_i + y_{i+1})$.
  - `diff()`, `head()`, and `tail()` can be used to write a function to compute the area easily.

```
area.R <- function(x, y) {
  sum(diff(x) * (head(y, -1) + tail(y, -1))/2)
  }
area.R(graunt$x, graunt$lx.17th)/100
```

```
## [1] 18.17
```

Comparison with US 1993 life table

The shaded area between the survival functions of Graunt's and US 1993 represents the difference of life expectancies.

1. Draw Graunt's first with axes, lower and upper limits

```r
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v=c(0, 76), lty = 2)
abline(v = c(0, 76), lty = 2)
```
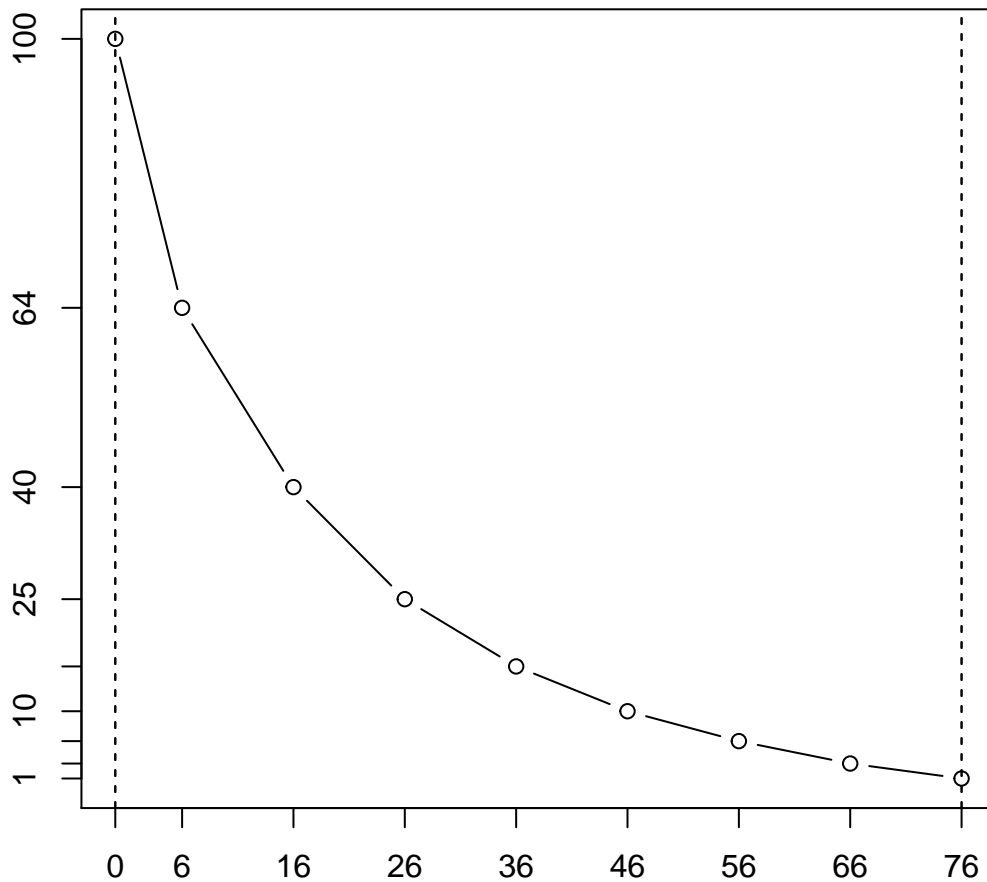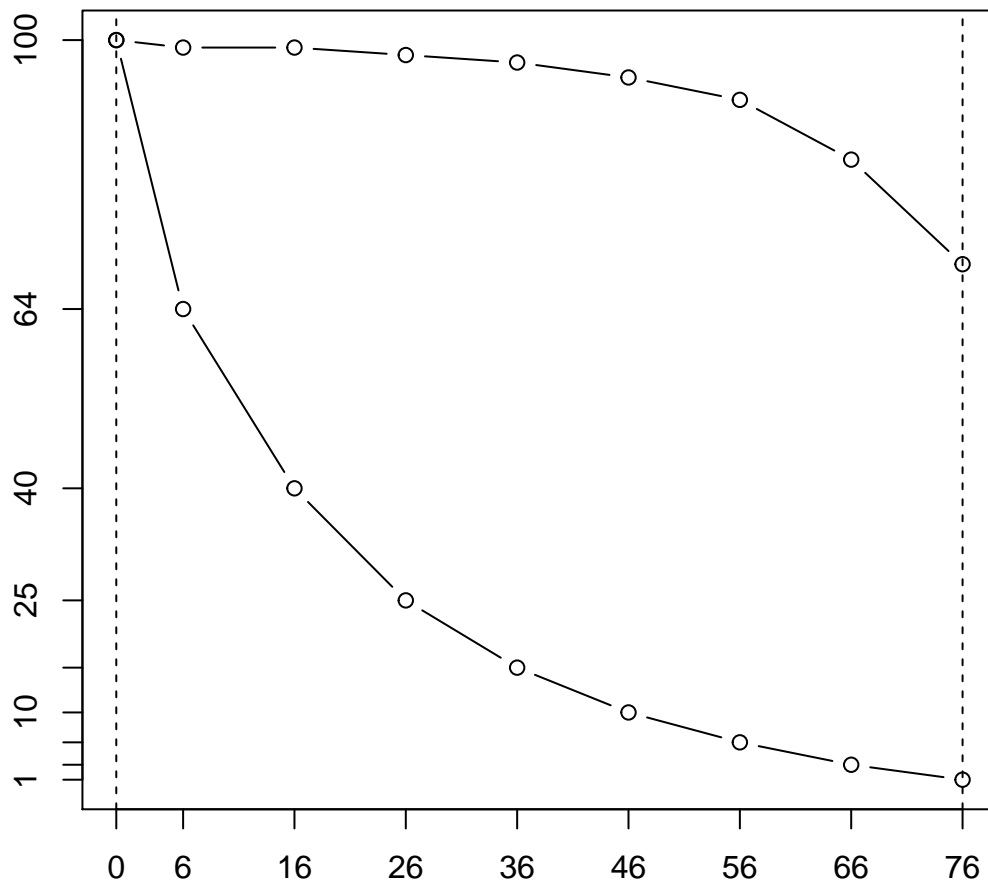

2. Add US 1993 survival function

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
```
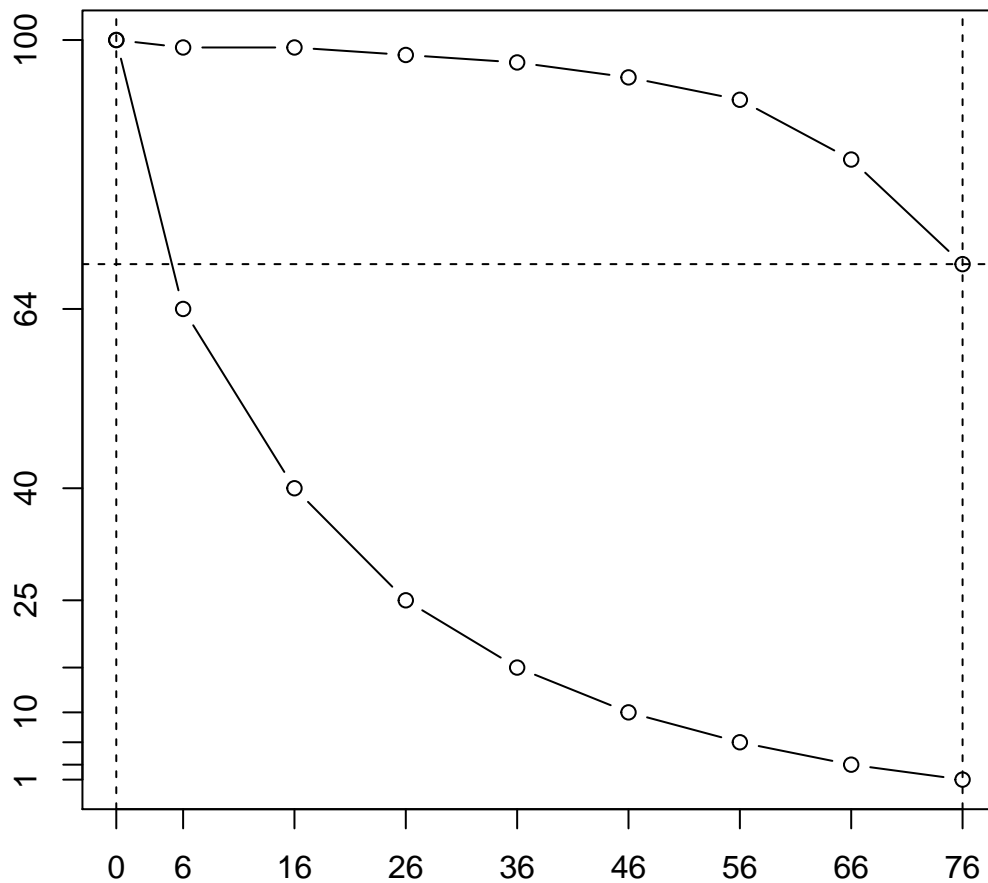

3. Actually, US 1993 life table is truncated at the age 76. Specify that point.

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
abline(h = 70, lty = 2)
```

4. Using `las = 1` to specify 70%.

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
abline(h = 70, lty = 2)
axis(side = 2, at = 70, labels = 70, las = 1)
```

```
us.graunt.x <- c(us.93$x, rev(graunt$x))
us.graunt.y <- c(us.93$lx.93, rev(graunt$lx.17th))
```

Setting coordinates for `polygon()`
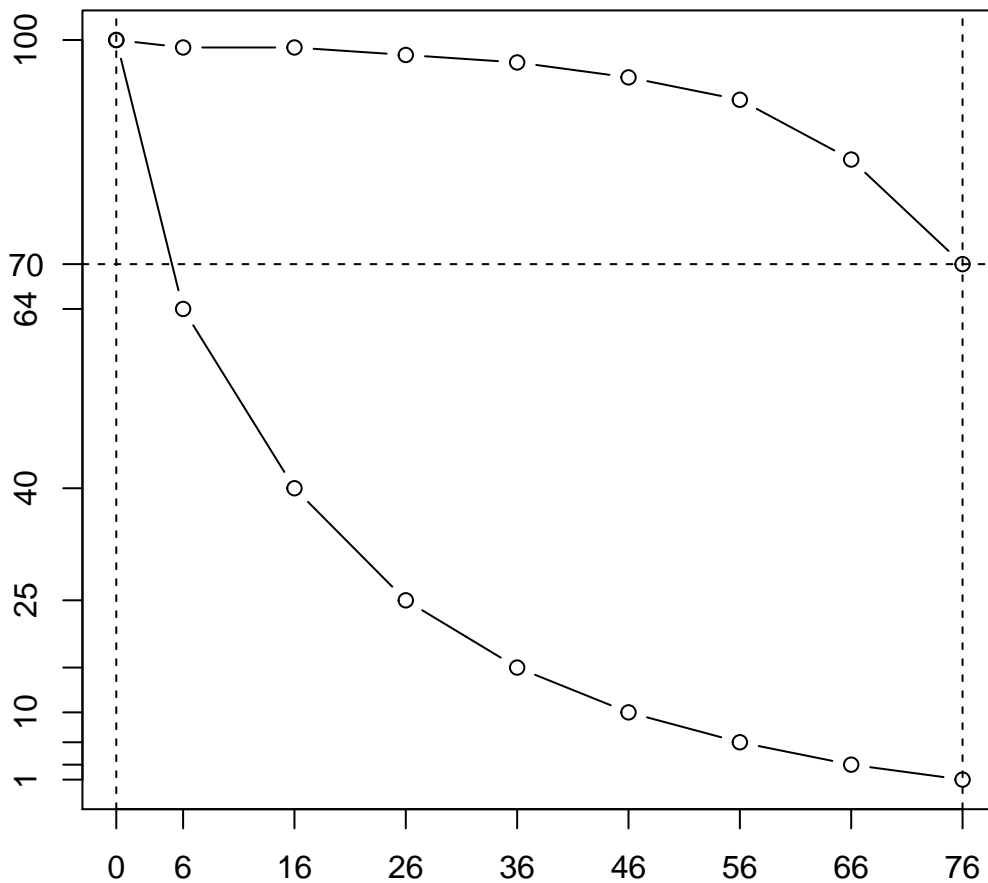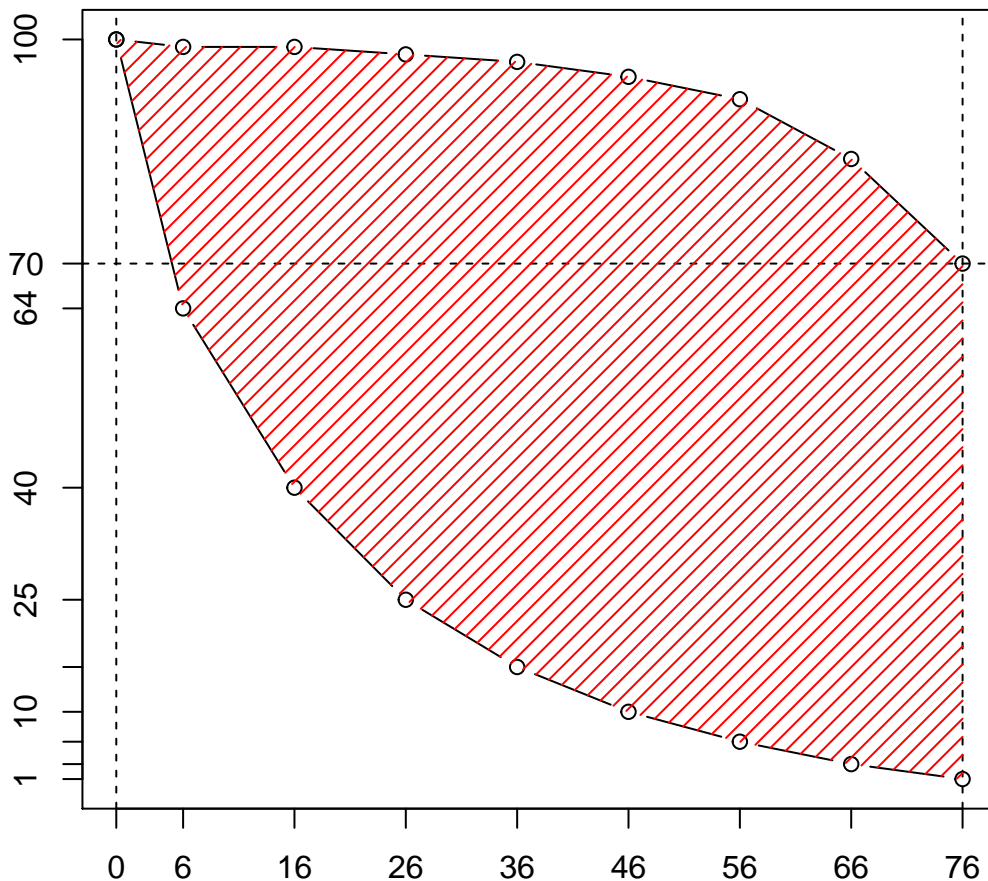
5. Shading

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
```

```
abline(h = 70, lty = 2)
axis(side = 2, at = 70, labels = 70, las = 1)
polygon(us.graunt.x, us.graunt.y, density = 15, col = "red", border = NA)
```


6. Grids

```
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
abline(h = 70, lty = 2)
axis(side = 2, at = 70, labels = 70, las = 1)
polygon(us.graunt.x, us.graunt.y, density = 15, col = "red", border = NA)
abline(v = graunt$x, lty = 2)
```

7. Title, x-axis and y-axis labels

```r
par(family = "Helvetica")
plot(graunt, ann = FALSE, xaxt = "n", yaxt = "n", type = "b")
axis(side = 1, at = graunt$x, labels = graunt$x)
axis(side = 2, at = graunt$lx, labels = graunt$lx.17th)
abline(v = c(0, 76), lty = 2)
lines(us.93$x, us.93$lx.93, type = "b")
abline(h = 70, lty = 2)
axis(side = 2, at = 70, labels = 70, las = 1)
polygon(us.graunt.x, us.graunt.y, density = 15, col = "red", border = NA)
abline(v = graunt$x, lty = 2)
main.title.g.us <- "Survival Function of Graunt and US 1993"
title(main = main.title.g.us, xlab = x.lab, ylab = y.lab)
```
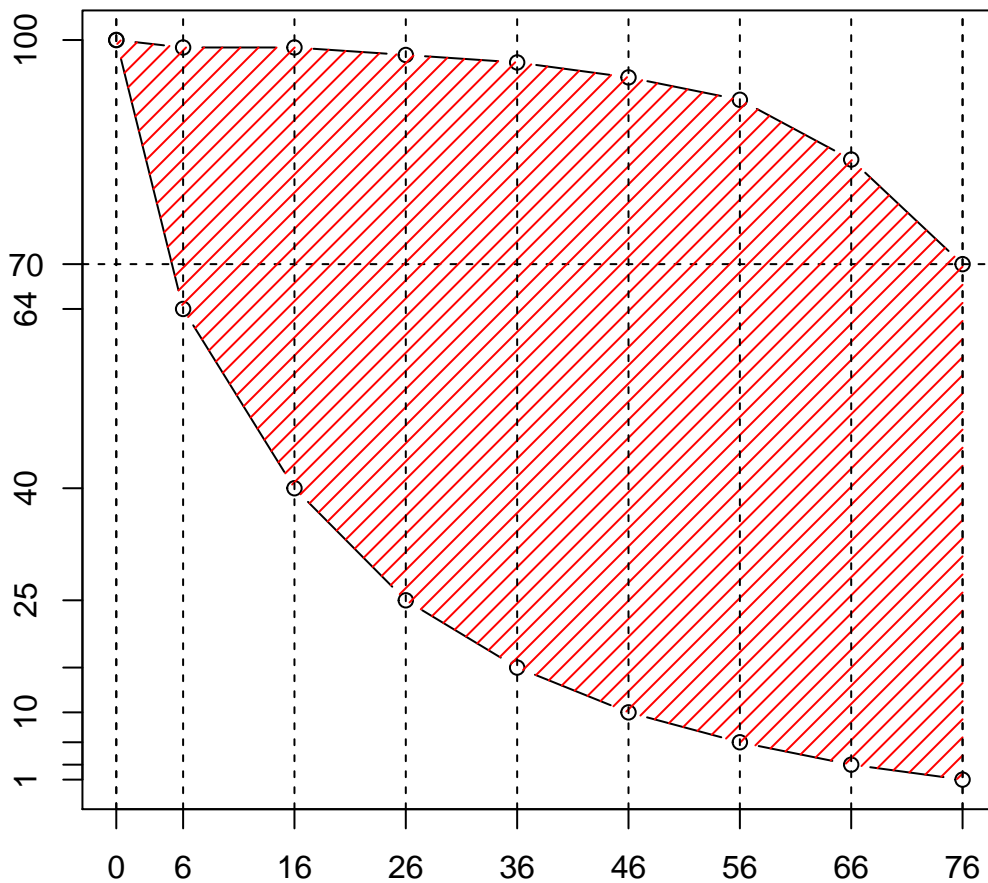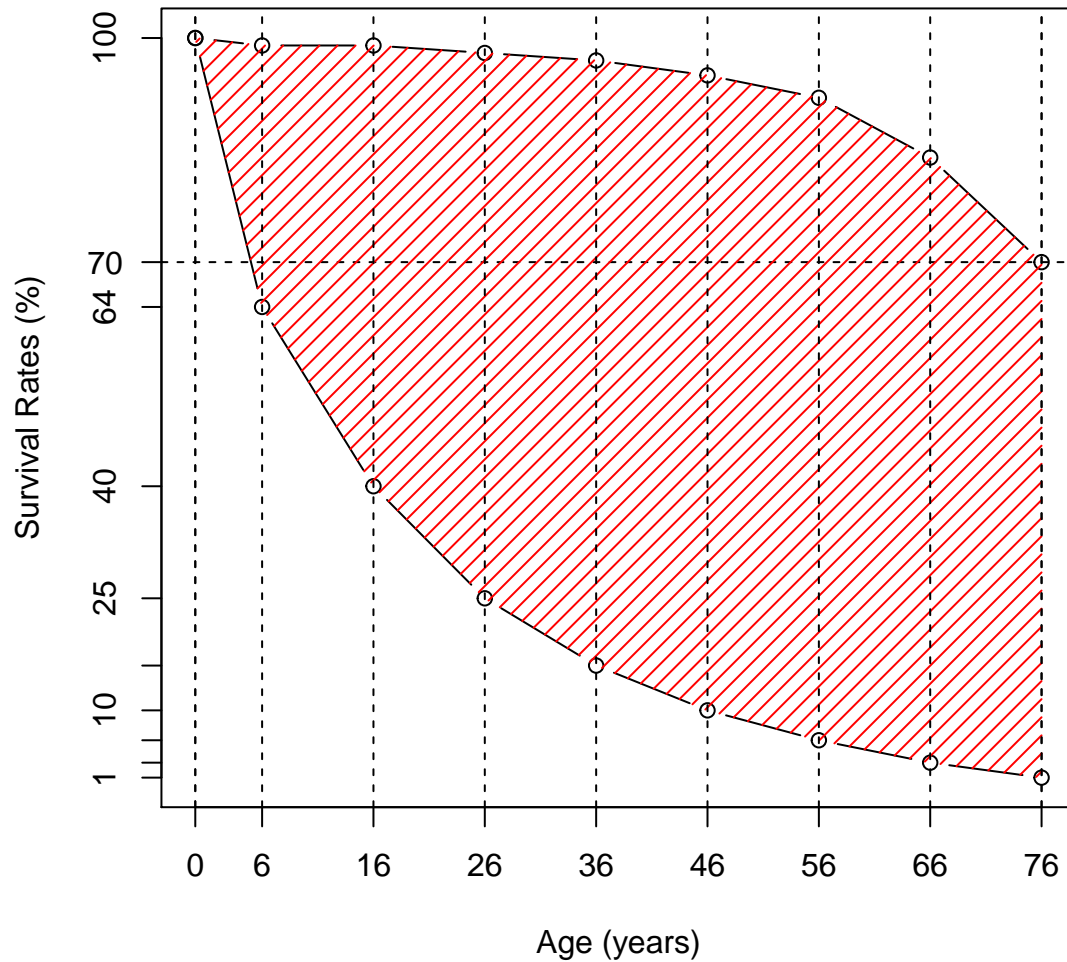
Survival Function of Graunt and US 1993

Age (years)

```r
dev.copy(device = png, file = "../pics/graunt_us93.png")
```

```
## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database
```

```
## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_us93.png"): font
## family not found in Windows font database
```

```
## png
##   3
```

Life expectancy   The area under the US 1993 survival function is

```
area.R(us.93$x, us.93$lx.93)/100
```

```
## [1] 70.92
```

The area of shaded region is

```
area.R(us.93$x, us.93$lx.93)/100 - area.R(graunt$x, graunt$lx.17th)/100
```

```
## [1] 52.75
```

Comparison with Halley's life table

```
age <- 0:84
lx <- c(1238, 1000, 855, 798, 760, 732, 710, 692, 680, 670, 661, 653, 646, 640, 634, 628, 622, 616, 610
length(lx)
```

Halley's life table

```
## [1] 85
```

```
halley <- data.frame(age, lx)
halley$px <- round(halley$lx/1238*100, digits = 1)
head(halley)
```

```
##   age   lx    px
## 1   0 1238 100.0
## 2   1 1000  80.8
## 3   2  855  69.1
## 4   3  798  64.5
## 5   4  760  61.4
## 6   5  732  59.1
```

```
tail(halley)
```

```
##    age lx  px
## 80  79 50 4.0
## 81  80 41 3.3
## 82  81 34 2.7
## 83  82 28 2.3
## 84  83 23 1.9
## 85  84 20 1.6
```
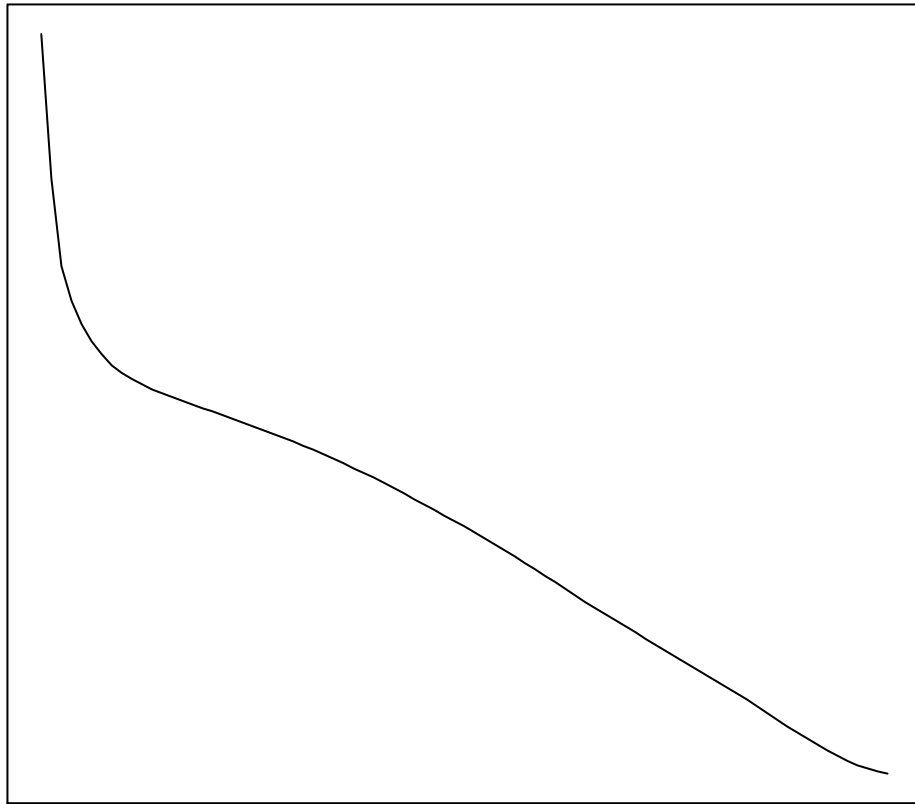
R base graphics

To make the comparison easy, plot the points at the same age group of Graunt's, 0, 6, 16, 26, 36, 46, 56, 66, 76. Step by step approach
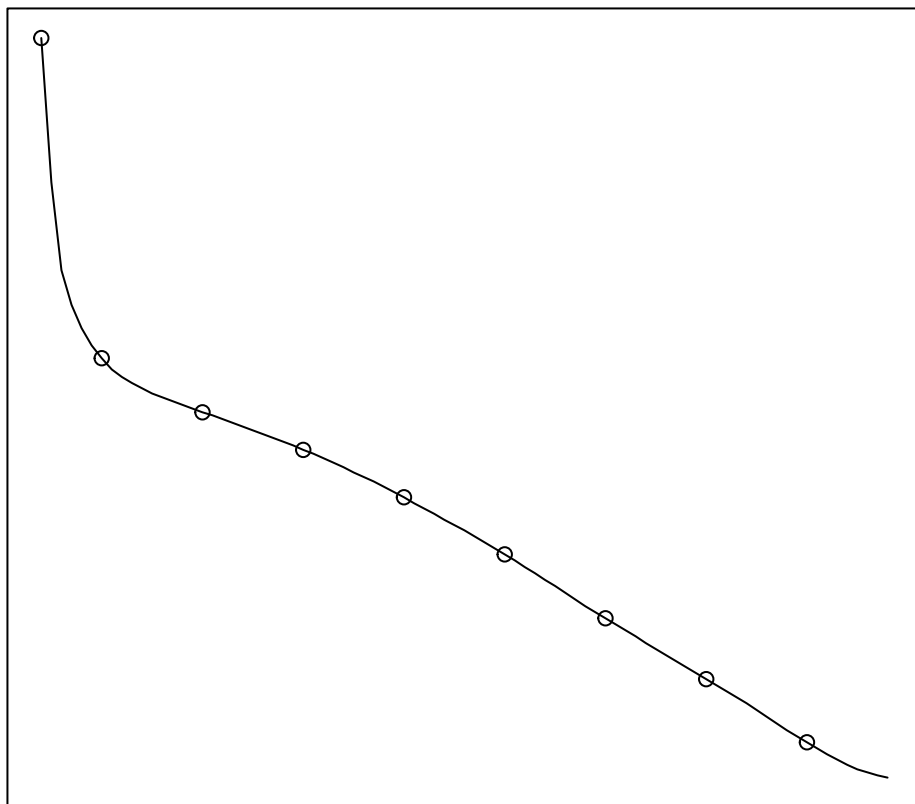
  1. Halley's survival function first

```
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
```

2. Mark the points at 0, 6, 16, 26, 36, 46, 56, 66, 76 on Halley's survival function.

```
age.graunt <- age %in% graunt$x
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px[age.graunt] ~ age[age.graunt], data = halley)
```

```
halley.graunt <- subset(halley, age.graunt)
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
```
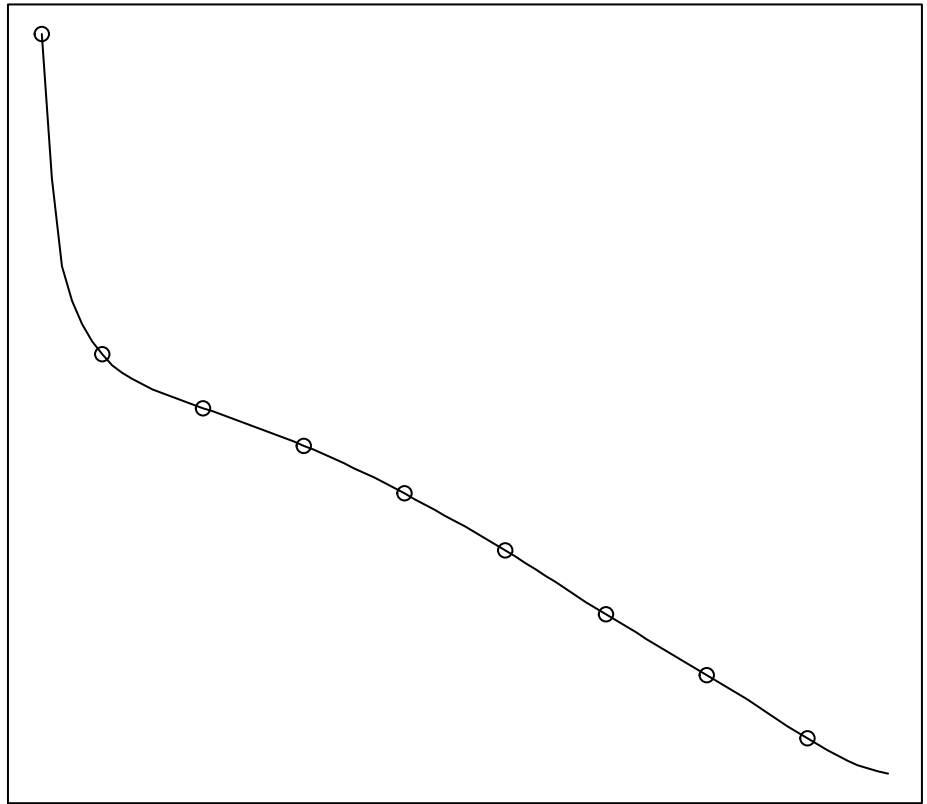
Using subset()

3. Add Graunt's survival function

```r
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
```
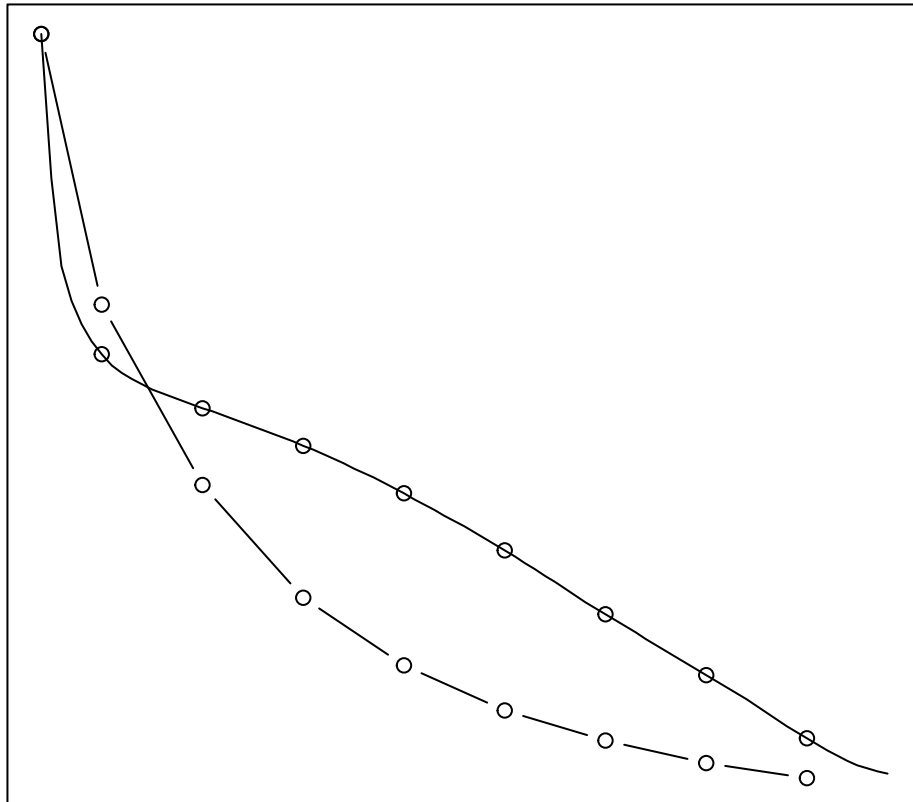
4. x-axis label and y-axis label with `las = 1`

```
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
```

5. Vertical dotted lines at the ages 0, 76, and 84

```r
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
abline(v = c(0, 76, 84), lty = 2)
```

6. Specify the developers at proper coordinates with `text()`

```r
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
abline(v = c(0, 76, 84), lty = 2)
text(x = c(16, 36), y = c(20, 50), label = c("Graunt", "Halley"))
```
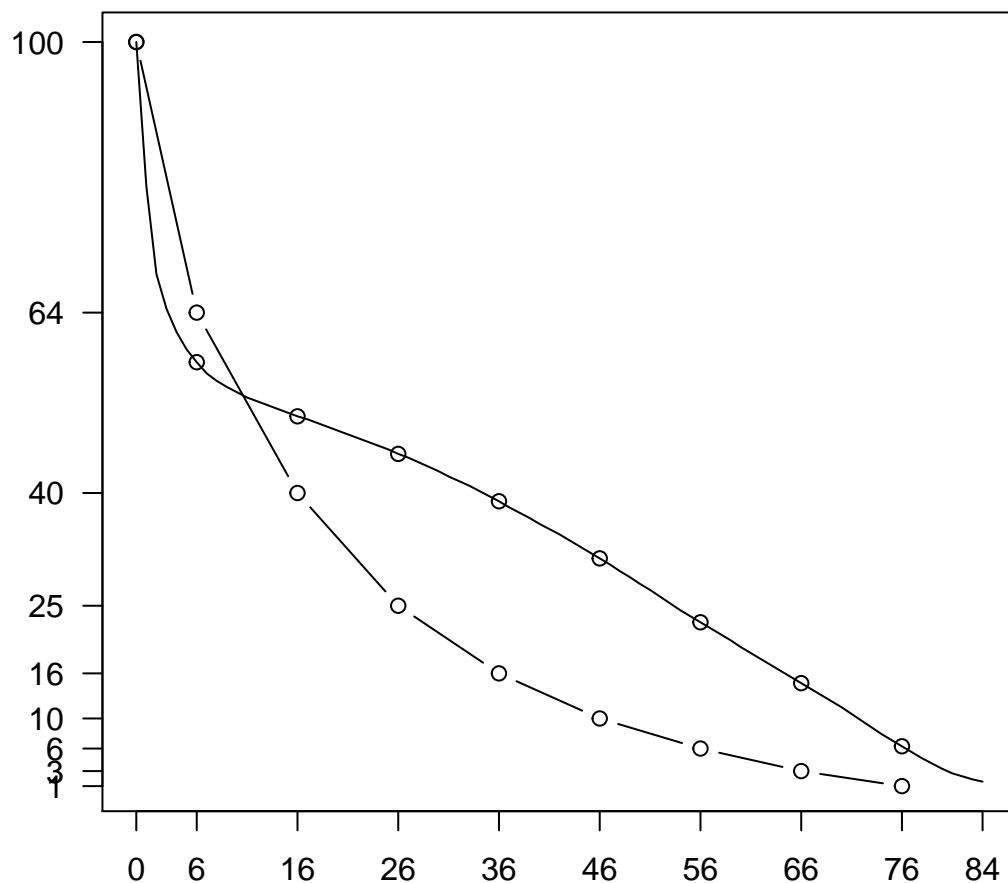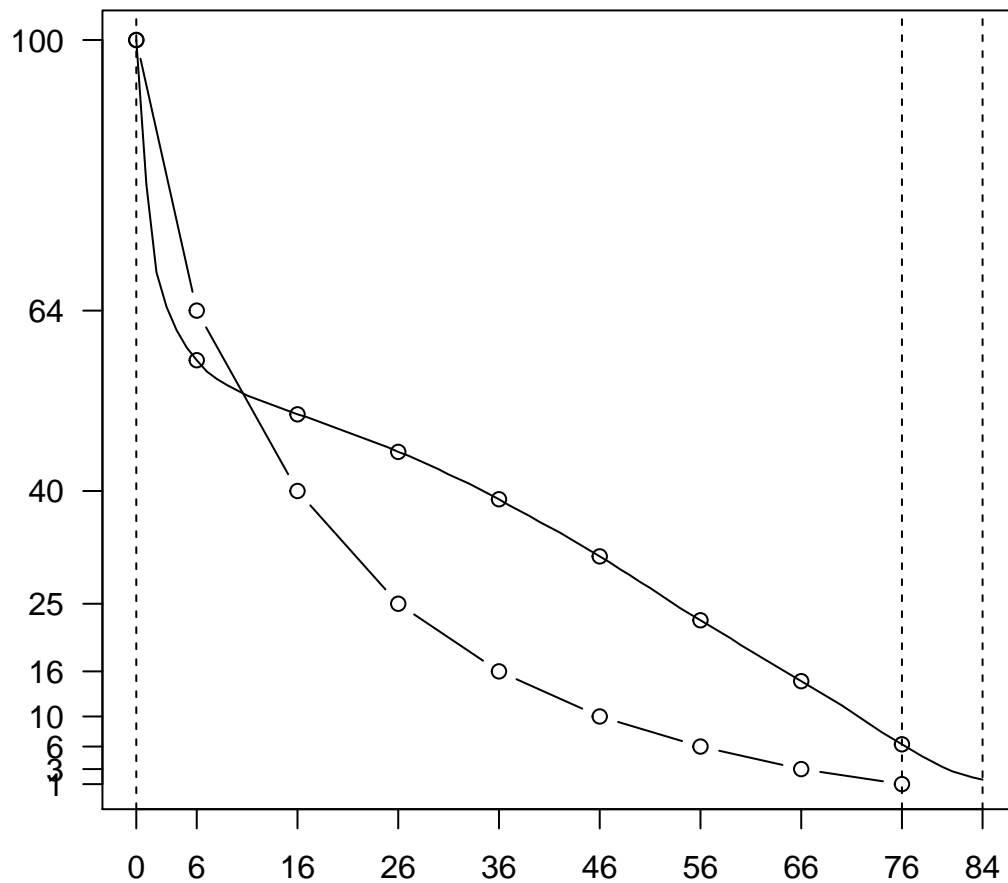
7. Main title, x-axis label, and y-axis label

```
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
abline(v = c(0, 76, 84), lty = 2)
text(x = c(16, 36), y = c(20, 50), label = c("Graunt", "Halley"))
main.title.2 <- "Survival Function of Graunt and Halley"
title(main = main.title.2, xlab = x.lab, ylab = y.lab)
```
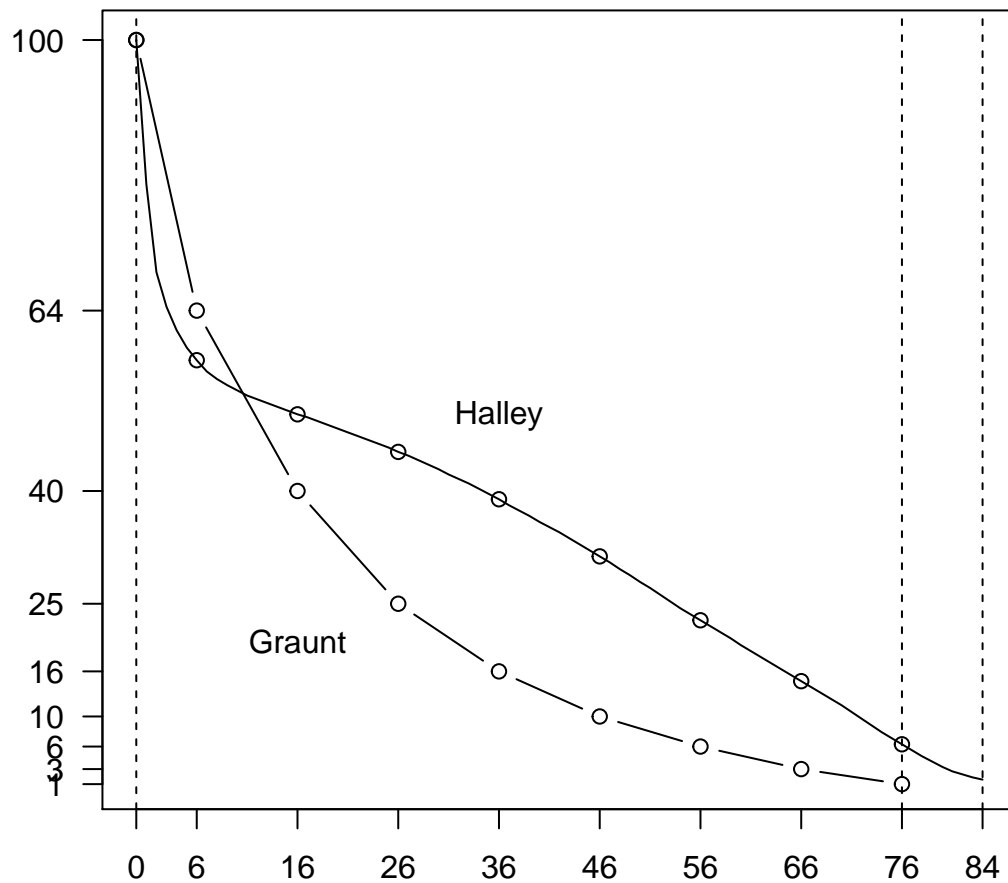
Survival Function of Graunt and Halley

Polygon

Setting the coordinates for `polygon()`. The intersection is found at `x = 10.8, y = 52.8` with `locator(1)` and couple of trial and errors.

- Upper region

```
poly.1.x <- c(graunt$x[1:2], 10.8, halley$age[11:1])
poly.1.y <- c(graunt$lx.17th[1:2], 52.8, halley$px[11:1])
poly.upper <- data.frame(x = poly.1.x, y = poly.1.y)
```

- Lower region

```
poly.2.x <- c(10.8, halley$age[12:85], graunt$x[9:3])
poly.2.y <- c(52.8, halley$px[12:85], graunt$lx.17th[9:3])
poly.lower <- data.frame(x = poly.2.x, y = poly.2.y)
```
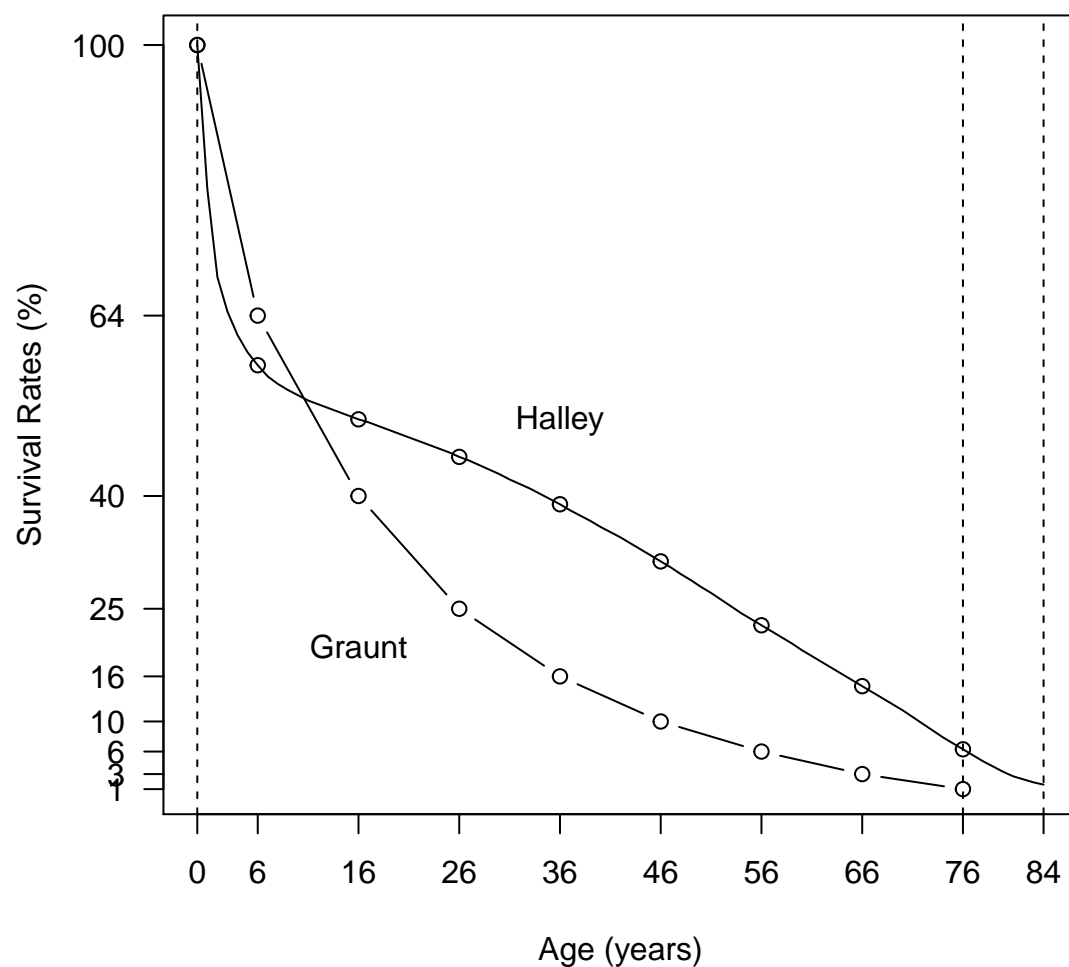
8. Shading upper region first

```
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
abline(v=c(0, 76, 84), lty = 2)
text(x = c(16, 36), y = c(20, 50), label = c("Graunt", "Halley"))
title(main = main.title.2, xlab = x.lab, ylab = y.lab)
polygon(poly.1.x, poly.1.y, angle = 45, density = 15, col = "blue")
```


Survival Function of Graunt and Halley
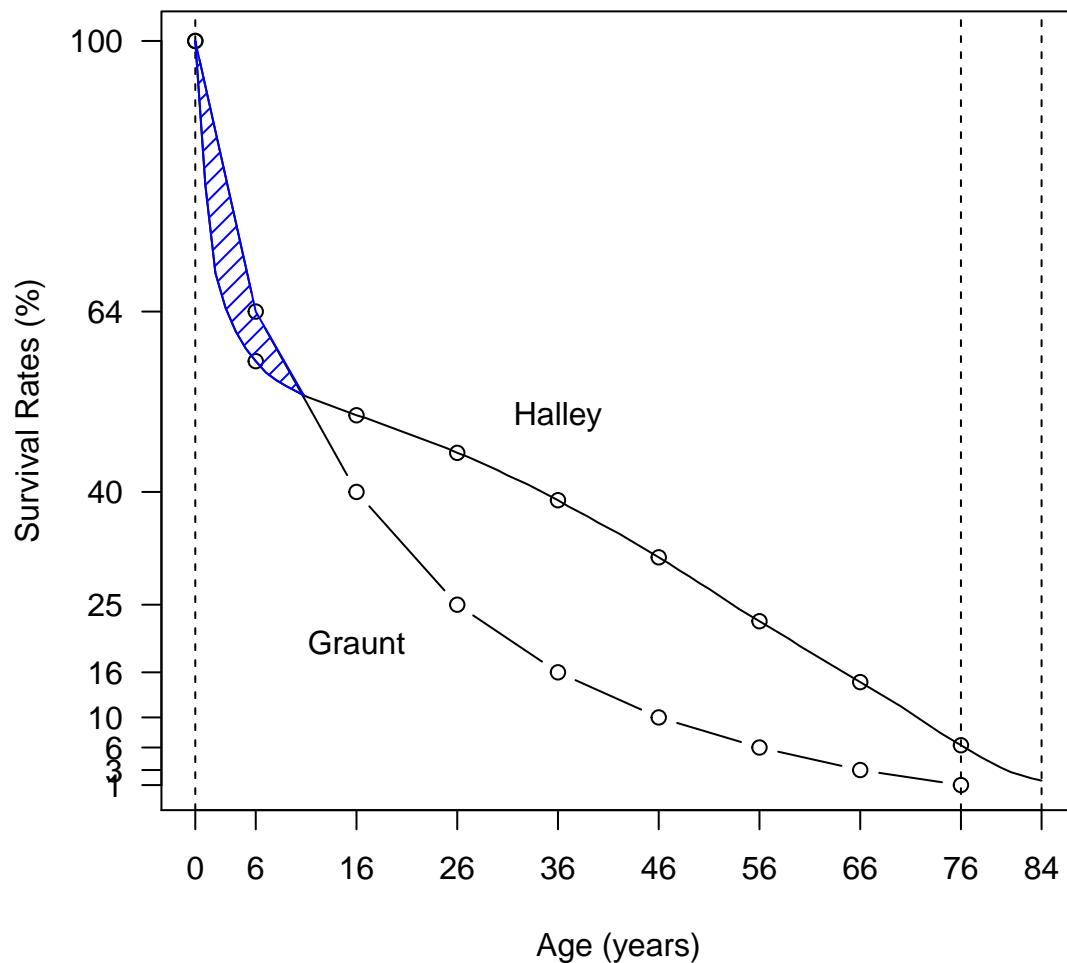
9. Shading lower region next

```
par(family = "Helvetica")
plot(px ~ age, data = halley, ann = FALSE, xaxt = "n", yaxt = "n", type = "l")
points(px ~ age, data = halley.graunt)
lines(lx.17th ~ x, data = graunt, type = "b")
axis(side = 1, at = c(graunt$x, 84), labels = c(graunt$x, 84))
axis(side = 2, at = graunt$lx.17th, labels = graunt$lx.17th, las = 1)
abline(v=c(0, 76, 84), lty = 2)
text(x = c(16, 36), y = c(20, 50), label = c("Graunt", "Halley"))
title(main = main.title.2, xlab = x.lab, ylab = y.lab)
polygon(poly.1.x, poly.1.y, angle = 45, density = 15, col = "blue")
polygon(poly.2.x, poly.2.y, angle = 45, density = 15, col = "red")
```
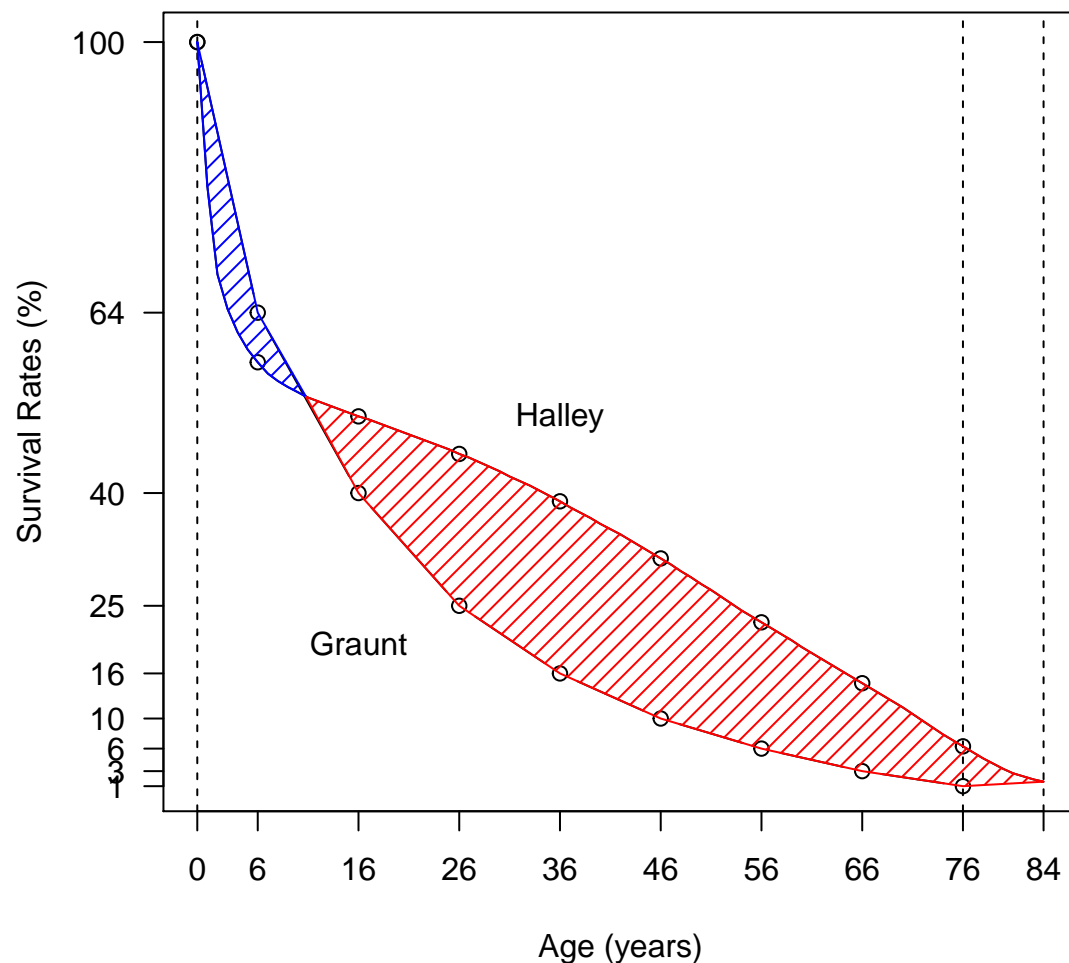
Survival Function of Graunt and Halley


```
dev.copy(device = png, file = "../pics/graunt_halley.png")
```

```
## Warning in dev.copy(device = png, file = "../pics/graunt_halley.png"): font
```

```
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_halley.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_halley.png"): font
## family not found in Windows font database

## Warning in dev.copy(device = png, file = "../pics/graunt_halley.png"): font
## family not found in Windows font database

## png
##   4
```

Life expectancy   Compute the difference of life expectancies

```
(life.exp.halley <- area.R(halley$age, halley$px)/100)
```

```
## [1] 27.872
```

```
(life.exp.graunt <- area.R(graunt$x, graunt$lx.17th)/100)
```

```
## [1] 18.17
```

ggplot

```
library(ggplot2)
```

Data Reshape

Attach **reshape2** package to change wide format to long format

```
library(reshape2)
```

How `melt()` works

```
graunt.us.melt <- melt(graunt.us, id.vars = "x", measure.vars = c("lx.17th", "lx.93"), value.name = "lx
graunt.us.melt
```

```
##     x   times  lx
## 1   0 lx.17th 100
## 2   6 lx.17th  64
## 3  16 lx.17th  40
## 4  26 lx.17th  25
## 5  36 lx.17th  16
## 6  46 lx.17th  10
## 7  56 lx.17th   6
```

```
## 8   66 lx.17th    3
## 9   76 lx.17th    1
## 10  0    lx.93 100
## 11  6    lx.93  99
## 12 16    lx.93  99
## 13 26    lx.93  98
## 14 36    lx.93  97
## 15 46    lx.93  95
## 16 56    lx.93  92
## 17 66    lx.93  84
## 18 76    lx.93  70
```

```
str(graunt.us.melt)
```

```
## 'data.frame':    18 obs. of  3 variables:
##  $ x    : num  0 6 16 26 36 46 56 66 76 0 ...
##  $ times: Factor w/ 2 levels "lx.17th","lx.93": 1 1 1 1 1 1 1 1 1 2 ...
##  $ lx   : num  100 64 40 25 16 10 6 3 1 100 ...
```

- Change factor levels of `times`

```
levels(graunt.us.melt$times) <- c("17th", "1993")
str(graunt.us.melt)
```

```
## 'data.frame':    18 obs. of  3 variables:
##  $ x    : num  0 6 16 26 36 46 56 66 76 0 ...
##  $ times: Factor w/ 2 levels "17th","1993": 1 1 1 1 1 1 1 1 1 2 ...
##  $ lx   : num  100 64 40 25 16 10 6 3 1 100 ...
```

- Fonts for pdf output

```
theme.pdf <- theme(axis.title.x = element_text(family = "Helvetica"),
               axis.title.y = element_text(family = "Helvetica"),
               axis.text.x = element_text(family = "Helvetica"),
               axis.text.y = element_text(family = "Helvetica"),
               plot.title = element_text(family = "Helvetica"),
               legend.title = element_text(family = "Helvetica"),
               legend.text = element_text(family = "Helvetica"))
```

Plot

Points and Lines   Step by step approach to understand the grammar of ggplot

- We set `ggplot()` to accept varying `data.frame()` and `aes()`in `geom_polygon`

```
g1 <- ggplot() +
  geom_point(data = graunt.us.melt, aes(x = x, y = lx, colour = times)) +
  theme.pdf
g1
```
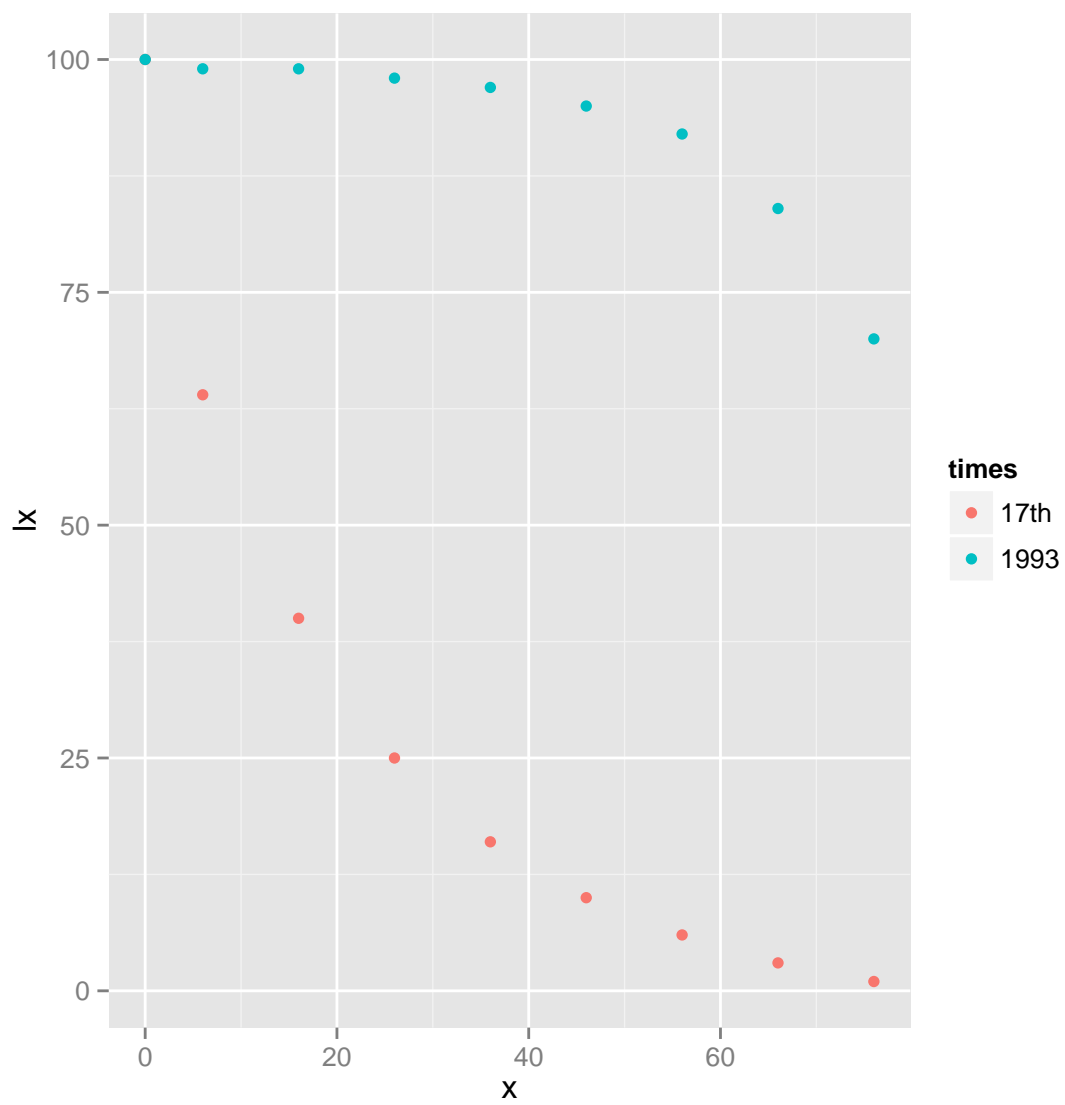
```
g2 <- g1 +
  geom_line(data = graunt.us.melt, aes(x = x, y = lx, colour = times))
g2
```
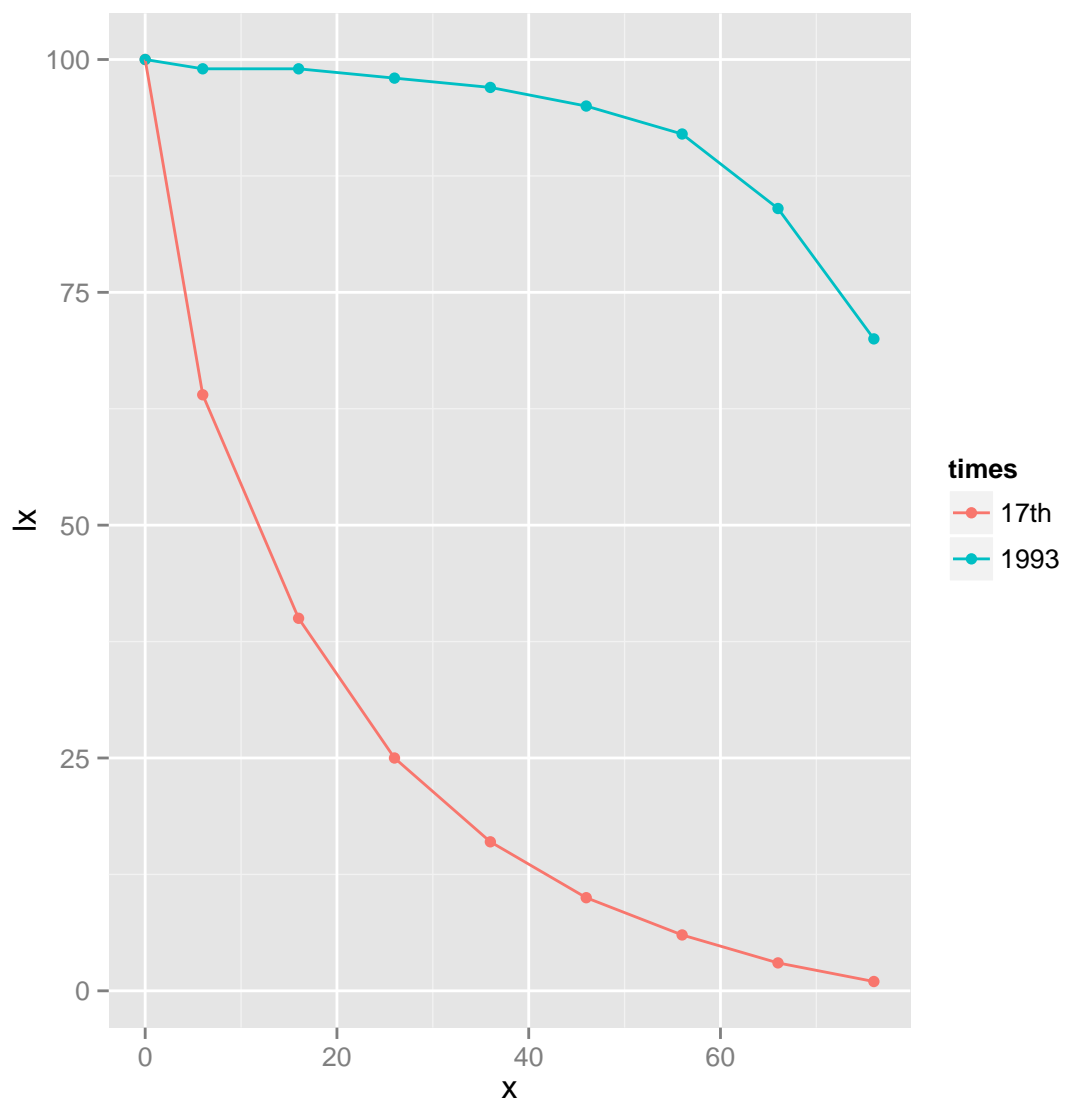
```
g3 <- g2 +
  theme_bw()
g3
```
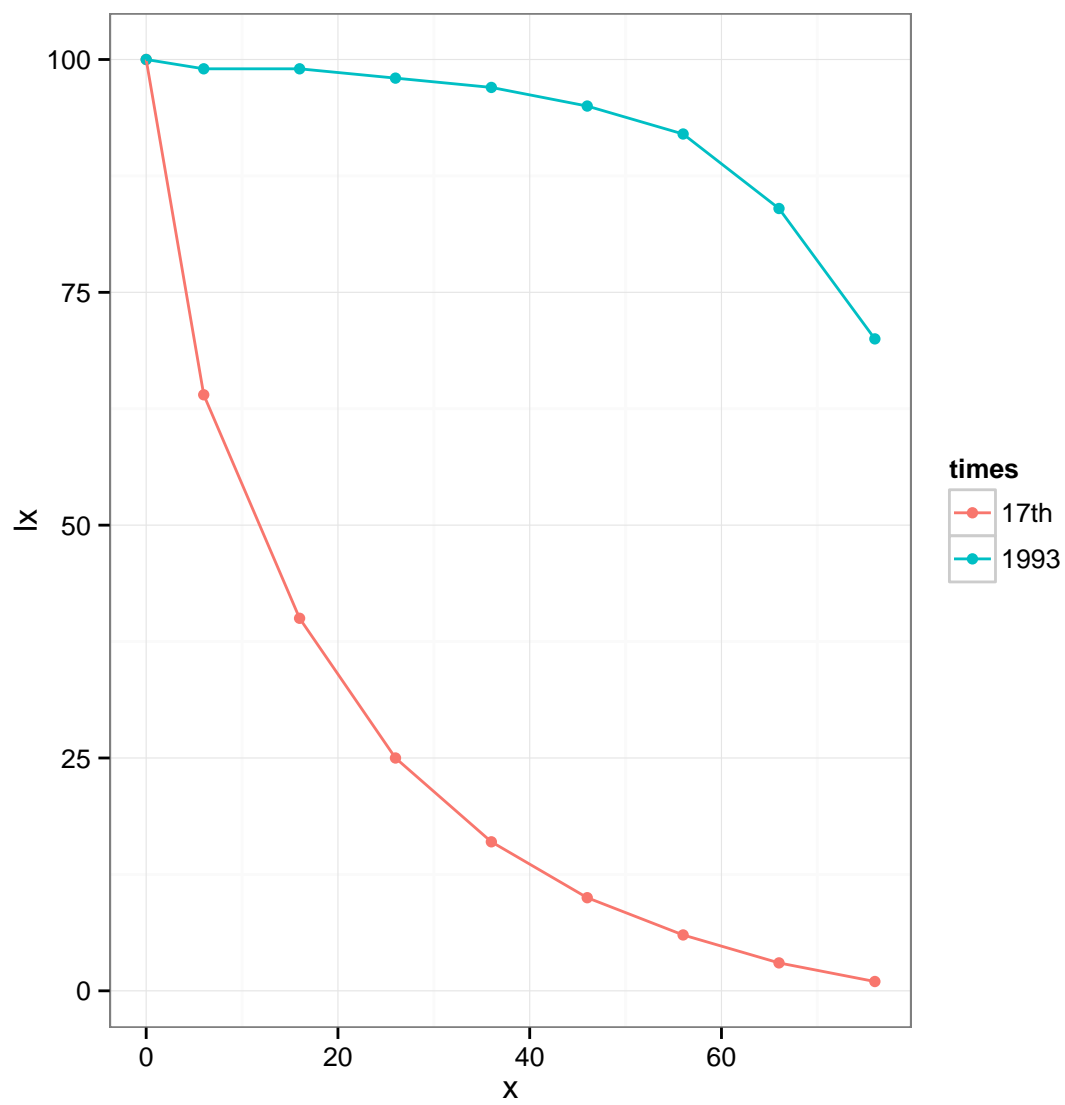
```
g3 <- g3 +
  theme.pdf
g3
```
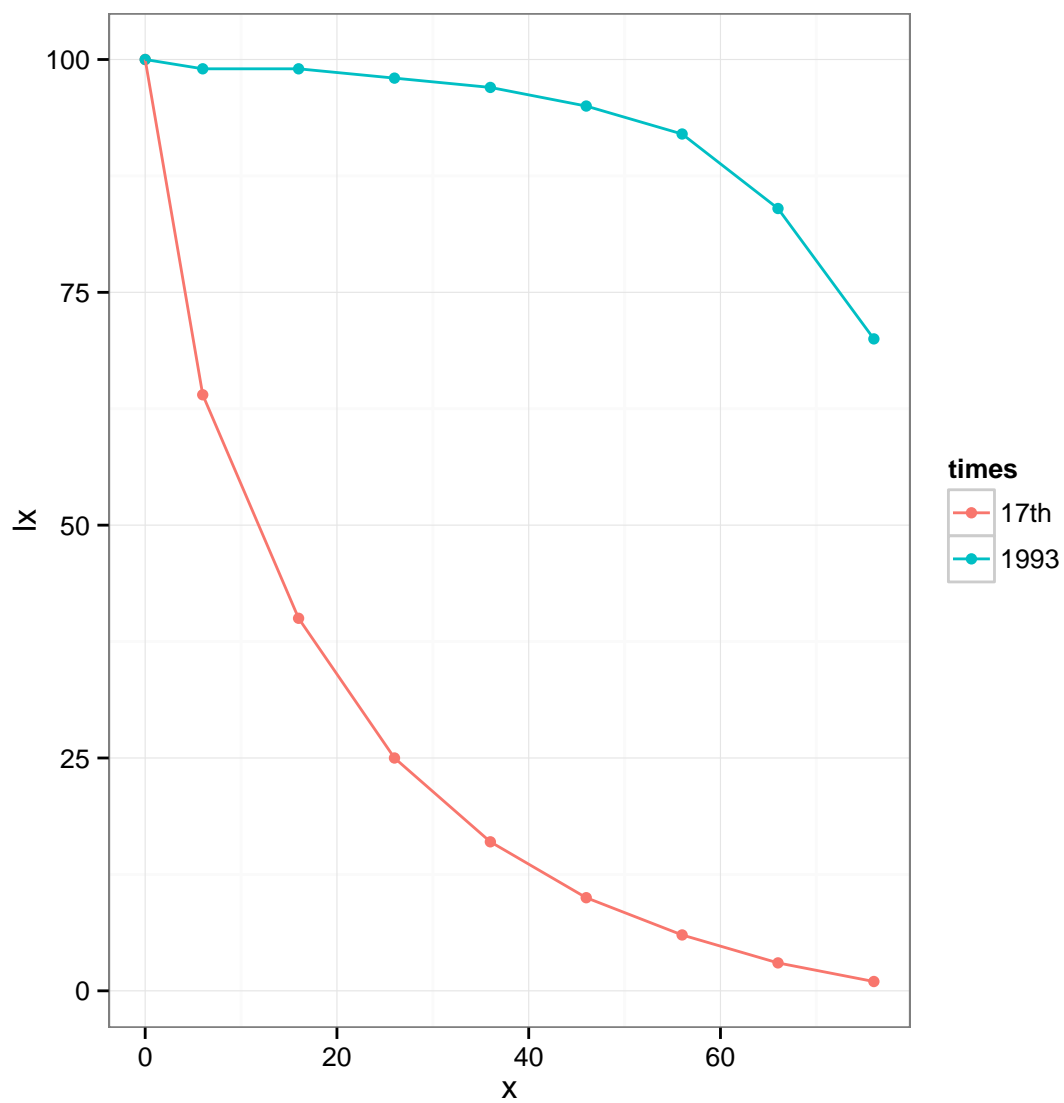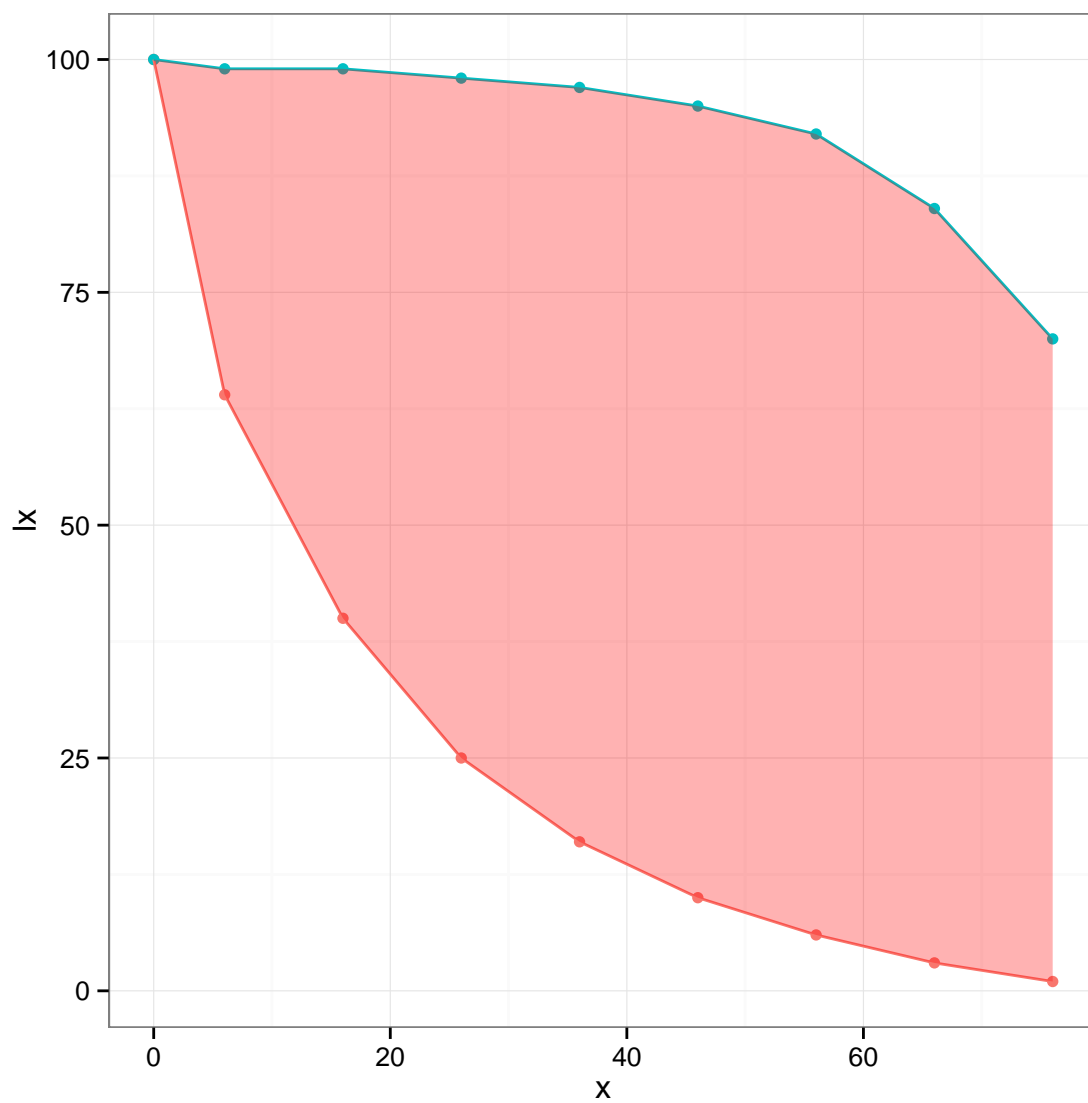
Polygon Reuse `us.graunt.x` and `us.graunt.y` for `polygon()`. Note how to remove default legends.

```
par(family = "Helvetica")
p3 <- g3 +
  geom_polygon(data = data.frame(x = us.graunt.x, y = us.graunt.y), aes(x = x, y = y), alpha = 0.3, fil
p3
```
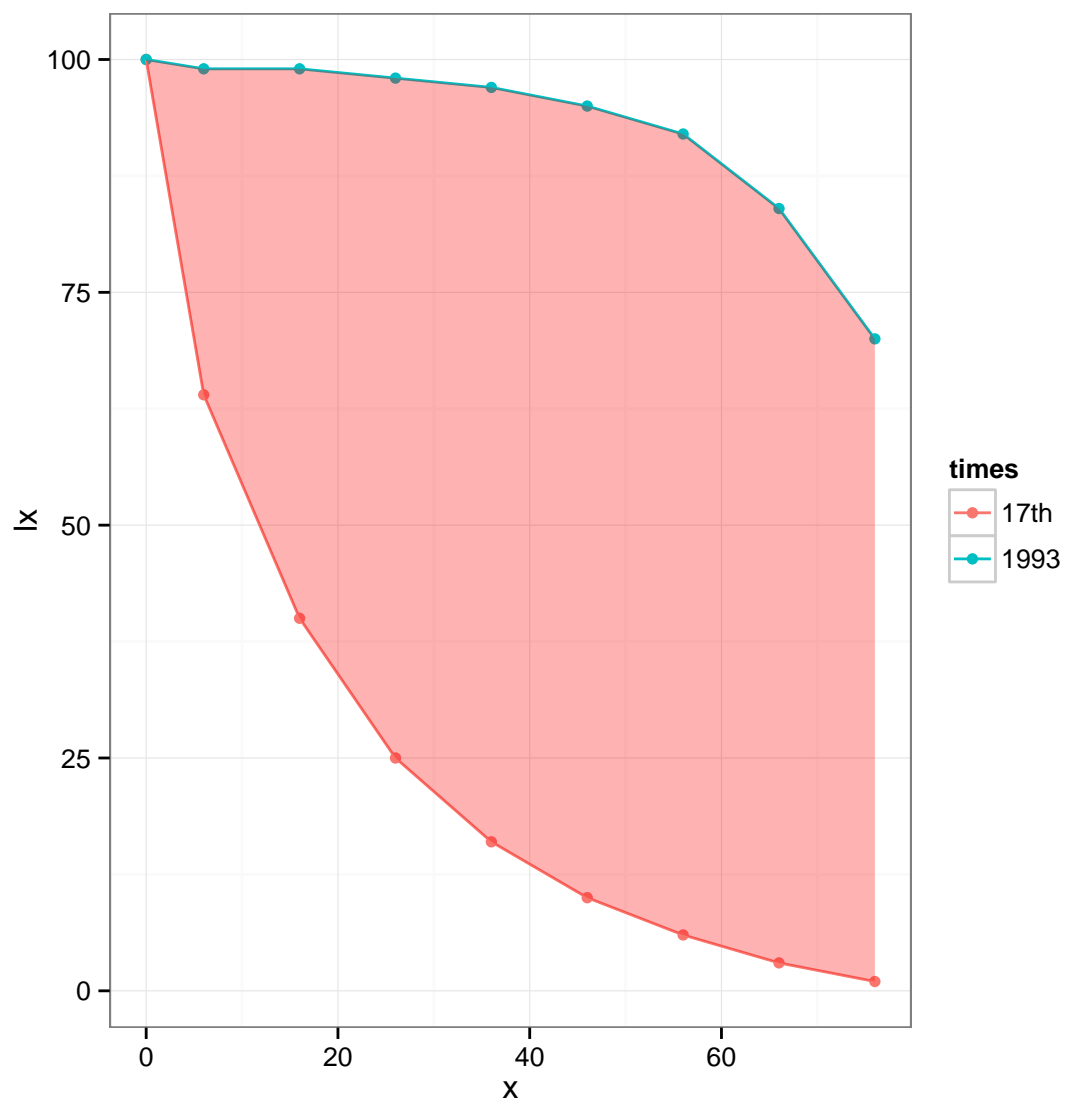
```
p4 <- p3 +
  guides(colour = "none")
p4
```

Change default annotations

Points and Lines

1. Change the x-axis and y-axis labels

```
(g4 <- g3 +
   xlab(x.lab) +
   ylab(y.lab))
```

2. Main title

```
(g4 <- g3 +
    xlab(x.lab) +
    ylab(y.lab) +
    ggtitle(main.title.g.us))
```

Survival Function of Graunt and US 1993
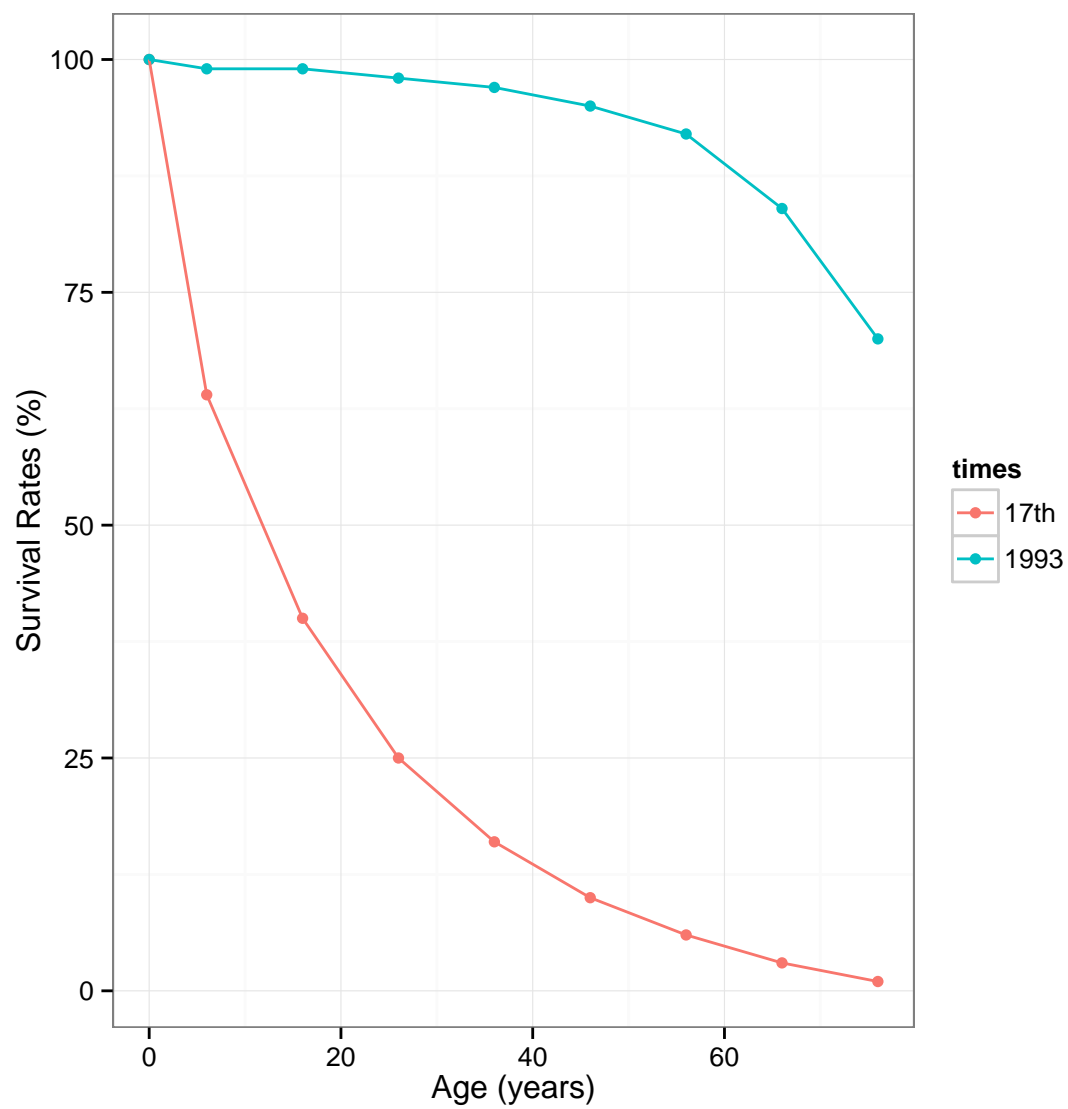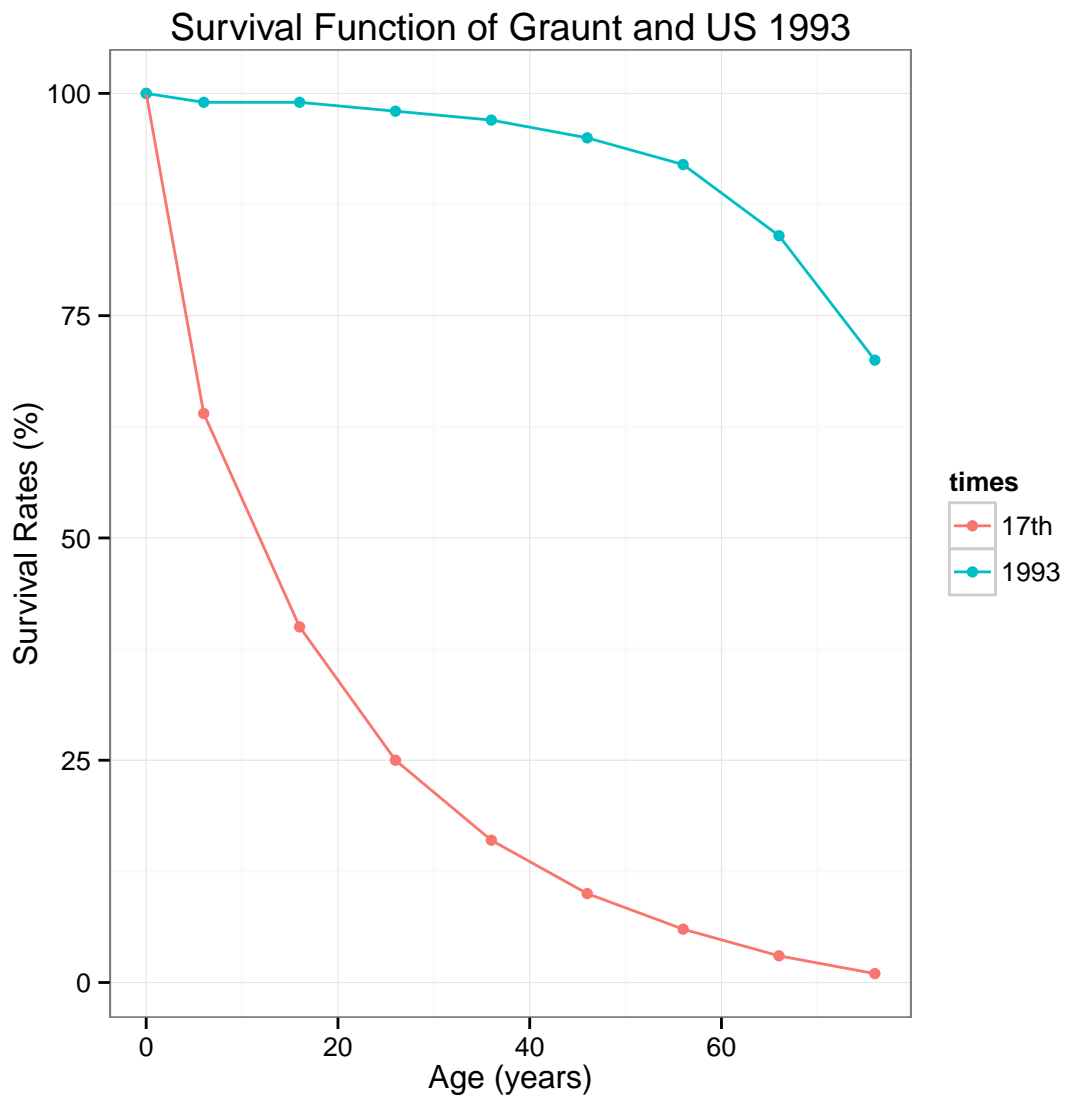
3. Change legend title

```
(g4 <- g3 +
    xlab(x.lab) +
    ylab(y.lab) +
    ggtitle(main.title.g.us) +
    labs(colour = "Era"))
```

Survival Function of Graunt and US 1993
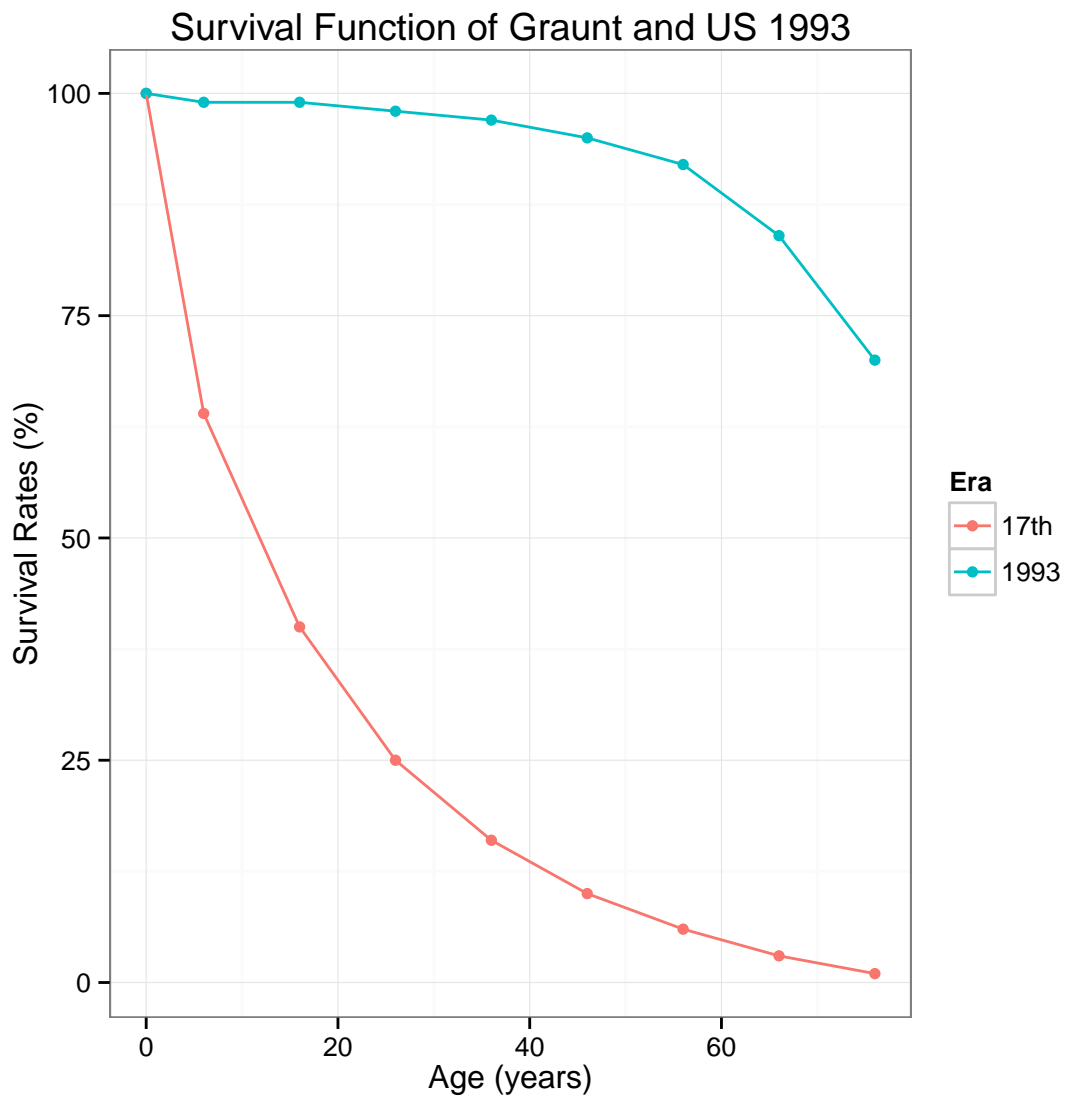
4. Change legends.

```
(g4 <- g3 +
   xlab(x.lab) +
   ylab(y.lab) +
   ggtitle(main.title.g.us) +
   labs(colour = "Era") +
   scale_colour_discrete(labels = c("Graunt Era", "US 1993")))
```

Survival Function of Graunt and US 1993
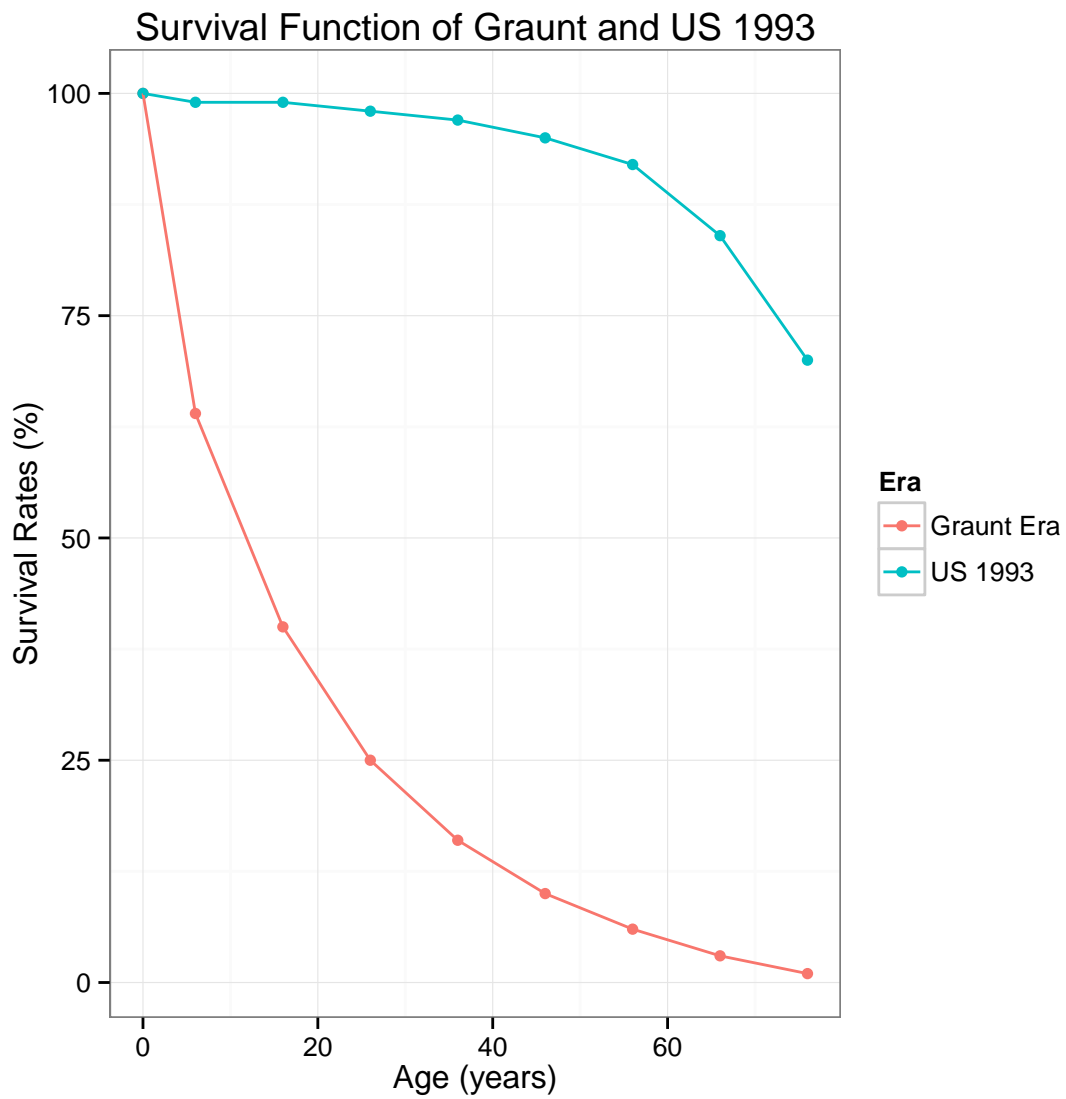
5. Place legends inside the plot

```
(g5 <- g4 +
   theme(legend.position = c(0.8, 0.5)))
```

Survival Function of Graunt and US 1993
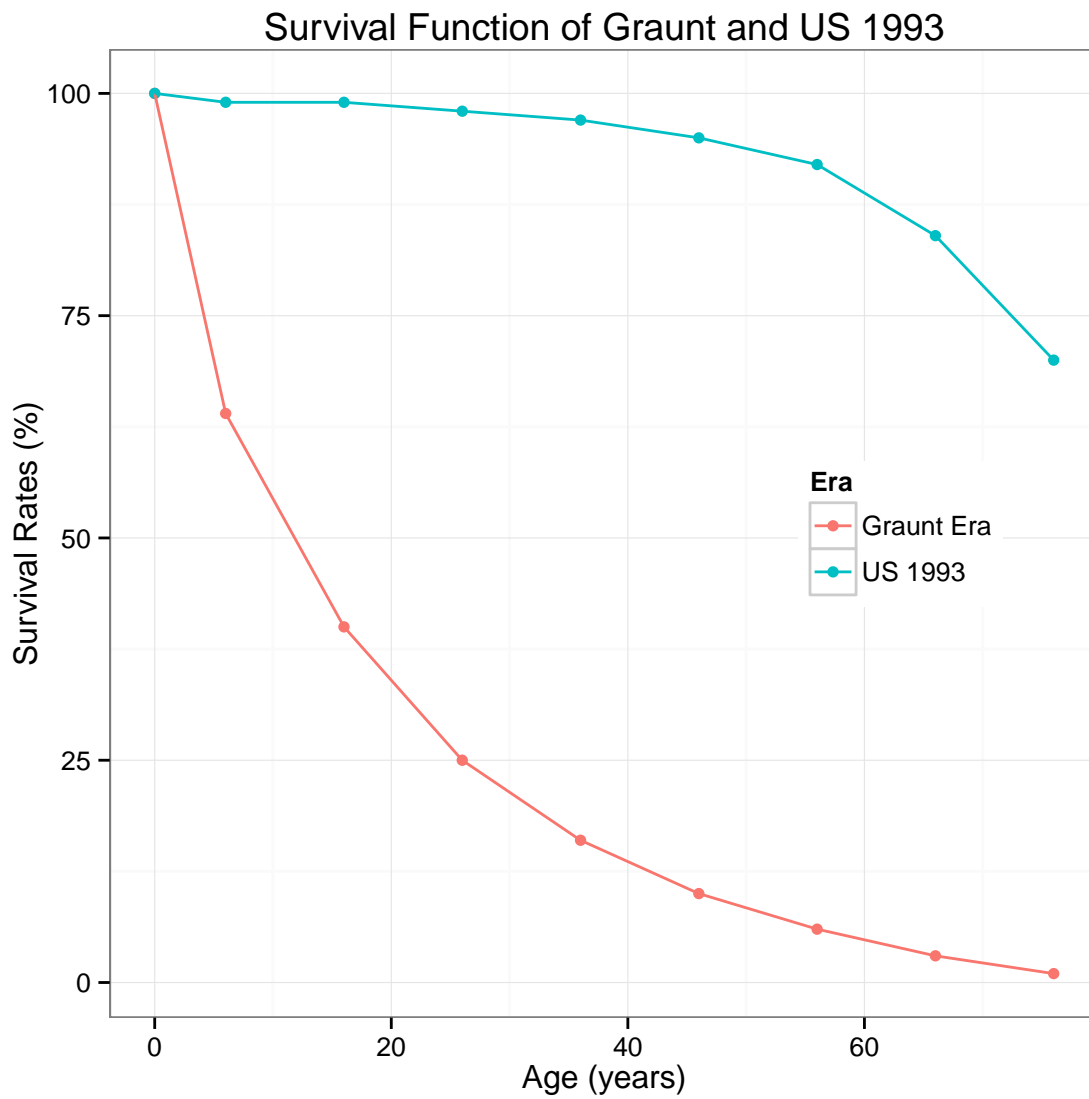
6. Change x-axis and y-axis tick marks

```
(g6 <- g5 +
    scale_x_continuous(breaks = graunt$x) + scale_y_continuous(breaks = graunt$lx.17th))
```

Survival Function of Graunt and US 1993
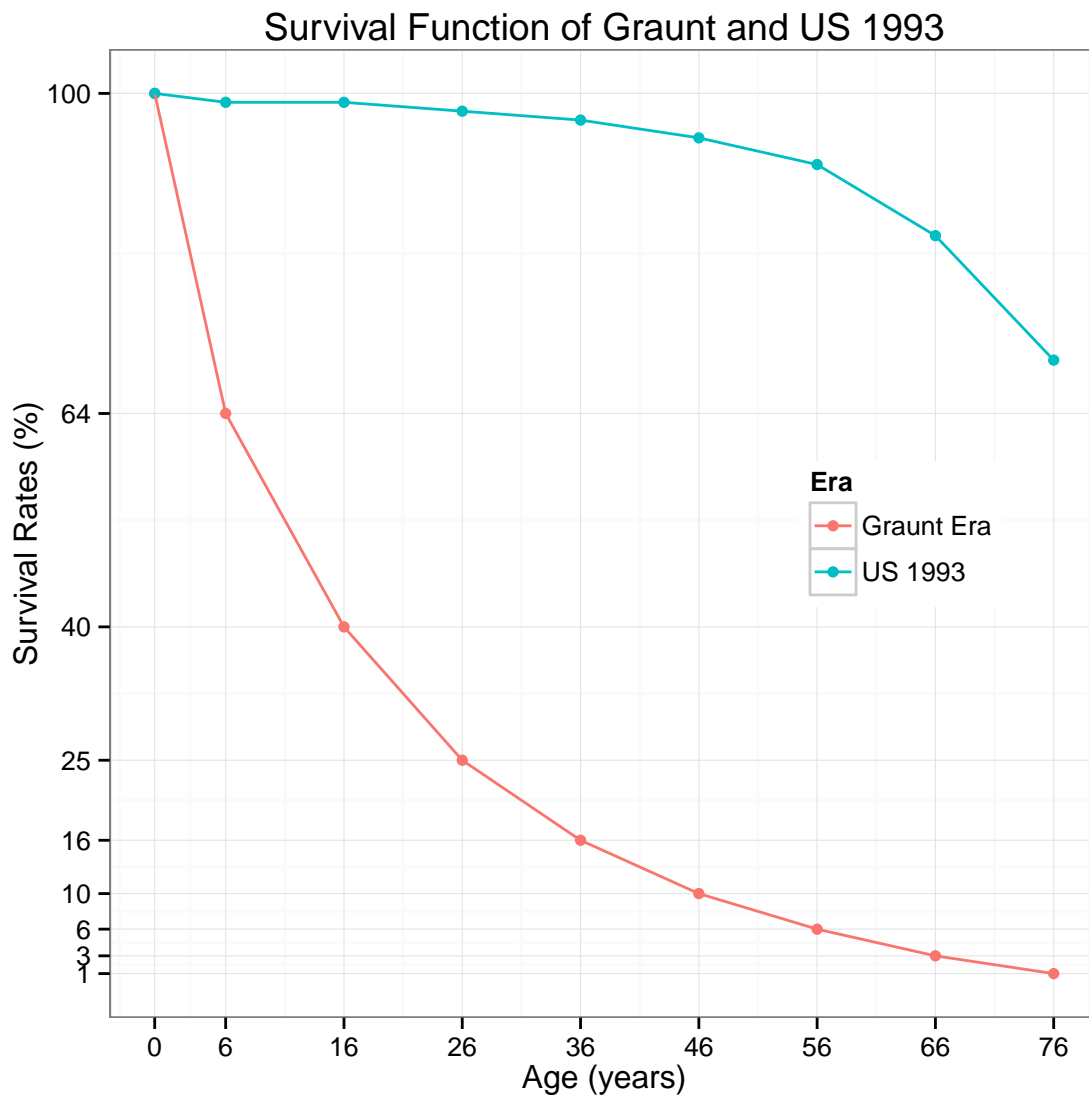

```r
ggsave("../pics/graunt_us_plot.png", g6)
```

```
## Saving 6 x 6 in image
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

Polygon Add information to the plot drawn with `polygon()`

1. Start with `p4`

```
p4
```

2. Main title, x-axis and y-axis labels

```
(p5 <- p4 +
   xlab(x.lab) +
   ylab(y.lab) +
   ggtitle(main.title.g.us))
```

Survival Function of Graunt and US 1993

3. `"Graunt Era"`, `"US 1993"`, `"Difference of Life Expectancies"` at proper positions

```
(p6 <- p5 +
  annotate("text", x = c(20, 40, 70), y = c(20, 60, 90), label = c("Graunt Era", "Difference of\nLife B
```

Survival Function of Graunt and US 1993

4. x-axis and y-axis tick marks

```r
(p7 <- p6 +
    scale_x_continuous(breaks = graunt$x) + scale_y_continuous(breaks = graunt$lx.17th))
```

Survival Function of Graunt and US 1993


```
ggsave("../pics/graunt_us_poly.png", p7)
```
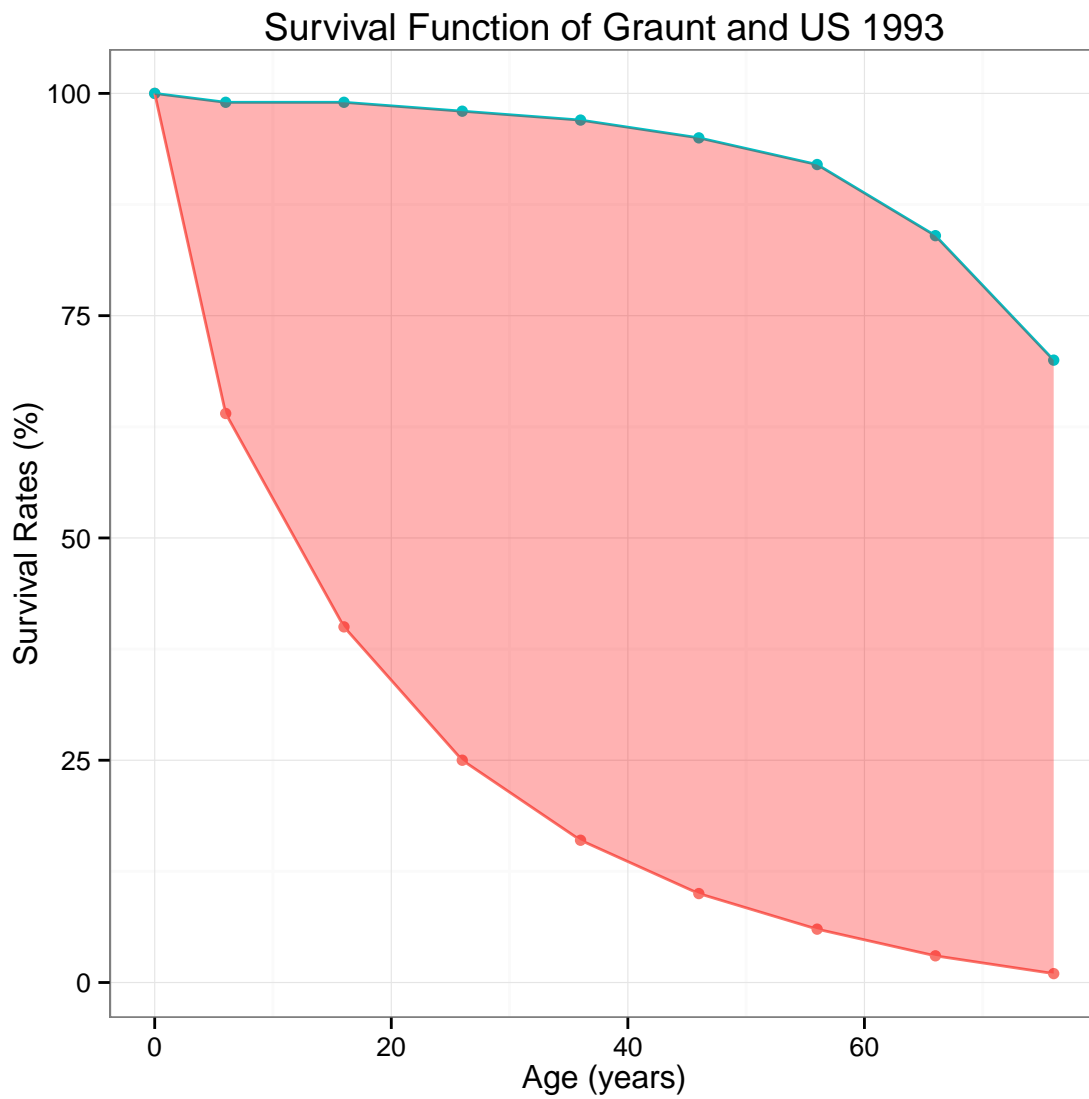
```
## Saving 6 x 6 in image
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```
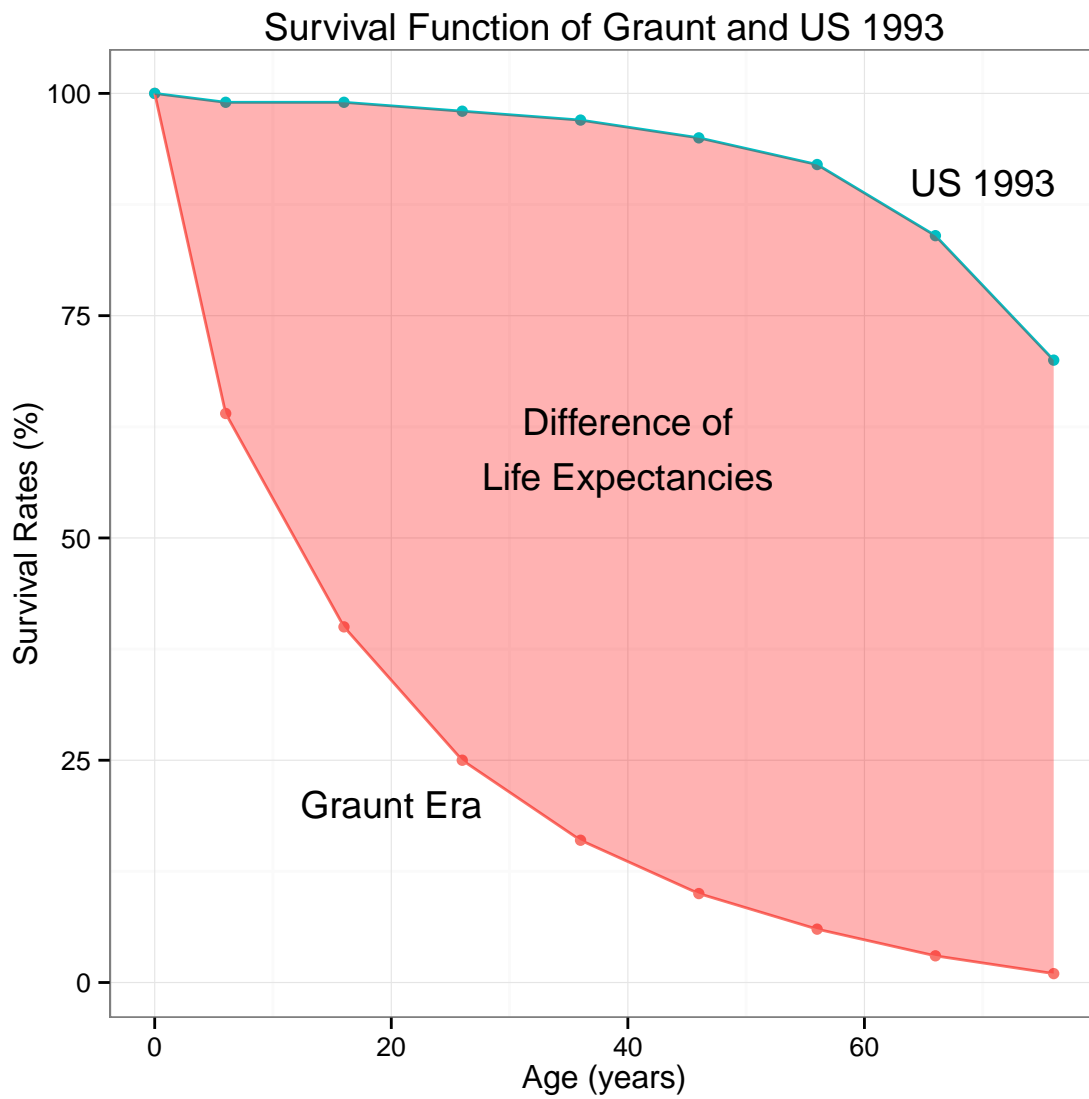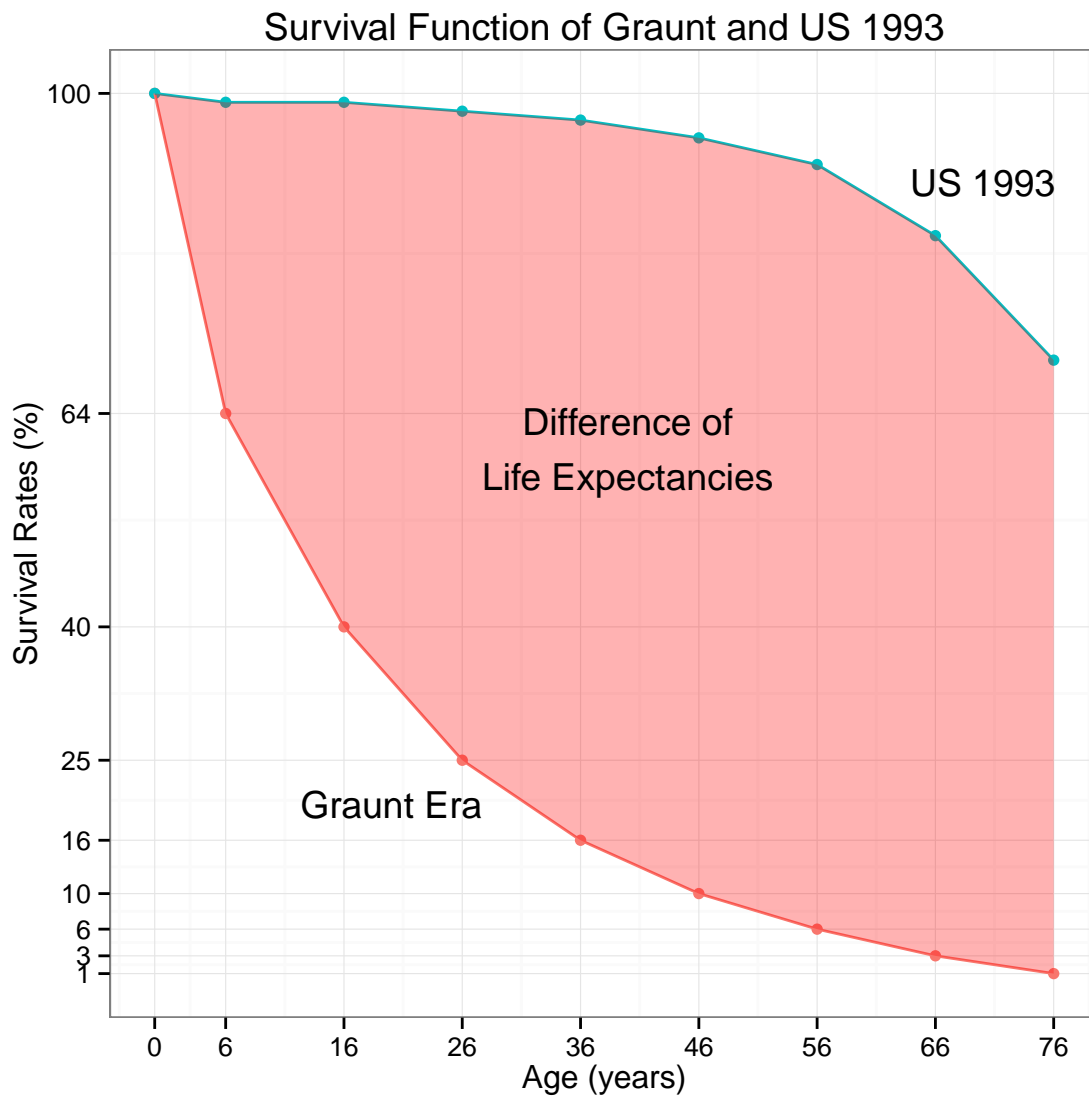
```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database


## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database


## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database


## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database


## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database


## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database


## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database


## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database


## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

Graunt and Halley

Data Reshaping   Since the observed ages are different, we need to final structure of the data frame to be melted. So, create copies of `graunt` and `halley` and extract parts of what we need and give feasible names.

```
graunt.2 <- graunt
names(graunt.2) <- c("x", "Graunt")
halley.2 <- halley[-2]
names(halley.2) <- c("x", "Halley")
graunt.halley.melt <- melt(list(graunt.2, halley.2), id.vars = "x", value.name = "lx", variable.name =
str(graunt.halley.melt)
```

```
## 'data.frame':    94 obs. of  4 variables:
##  $ x  : num  0 6 16 26 36 46 56 66 76 0 ...
##  $ Who: Factor w/ 2 levels "Graunt","Halley": 1 1 1 1 1 1 1 1 1 2 ...
##  $ lx : num  100 64 40 25 16 10 6 3 1 100 ...
##  $ L1 : int  1 1 1 1 1 1 1 1 1 2 ...
```

```
graunt.halley.melt <- graunt.halley.melt[-4]
graunt.halley.melt.g <- subset(graunt.halley.melt, graunt.halley.melt$x %in% graunt$x)
head(graunt.halley.melt.g, n = 20)
```

```
##      x    Who     lx
## 1    0 Graunt 100.0
## 2    6 Graunt  64.0
## 3   16 Graunt  40.0
## 4   26 Graunt  25.0
## 5   36 Graunt  16.0
## 6   46 Graunt  10.0
## 7   56 Graunt   6.0
## 8   66 Graunt   3.0
## 9   76 Graunt   1.0
## 10   0 Halley 100.0
## 16   6 Halley  57.4
## 26  16 Halley  50.2
## 36  26 Halley  45.2
## 46  36 Halley  38.9
## 56  46 Halley  31.3
## 66  56 Halley  22.8
## 76  66 Halley  14.7
## 86  76 Halley   6.3
```

```
gh1 <- ggplot() +
  geom_line(data = graunt.halley.melt, aes(x = x, y = lx, colour = Who)) +
  theme.pdf
gh1
```
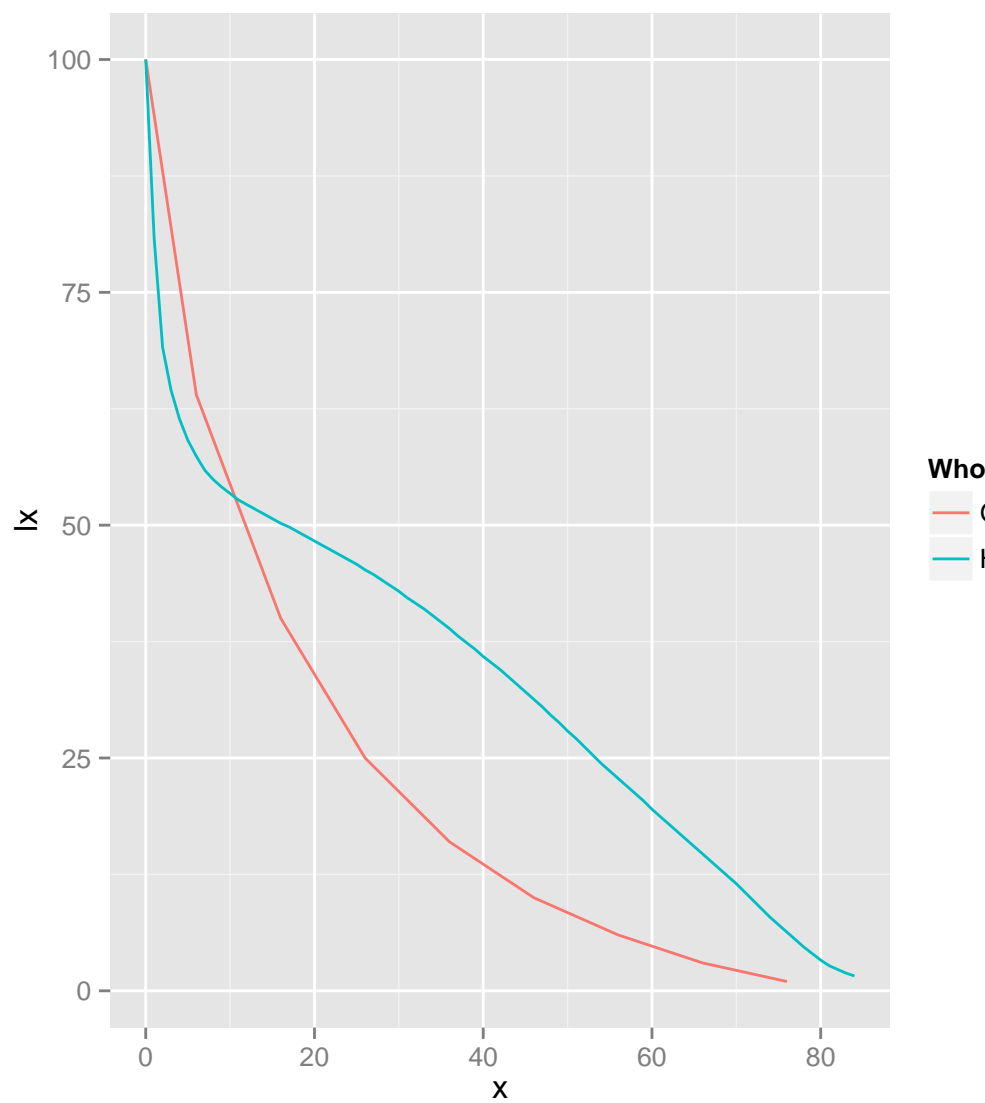
Survival Function, Step by Step

```
gh2 <- gh1 +
  geom_point(data = graunt.halley.melt.g, aes(x = x, y = lx, colour = Who))
gh2
```
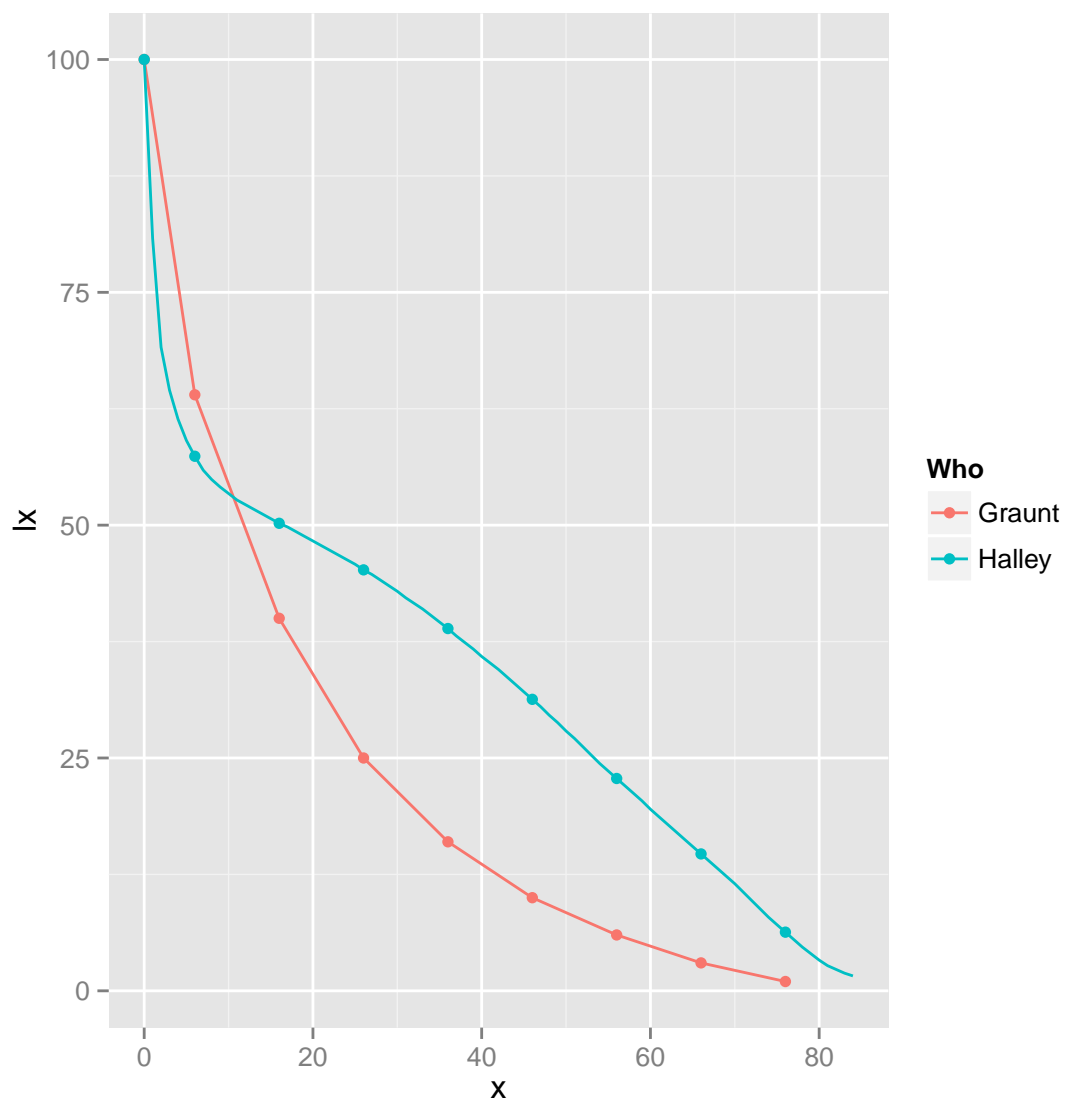
```
gh3 <- gh2 +
  theme_bw() +
  theme.pdf +
  xlab(x.lab) +
    ylab(y.lab) +
  ggtitle(main.title.2)
gh3
```

Survival Function of Graunt and Halley
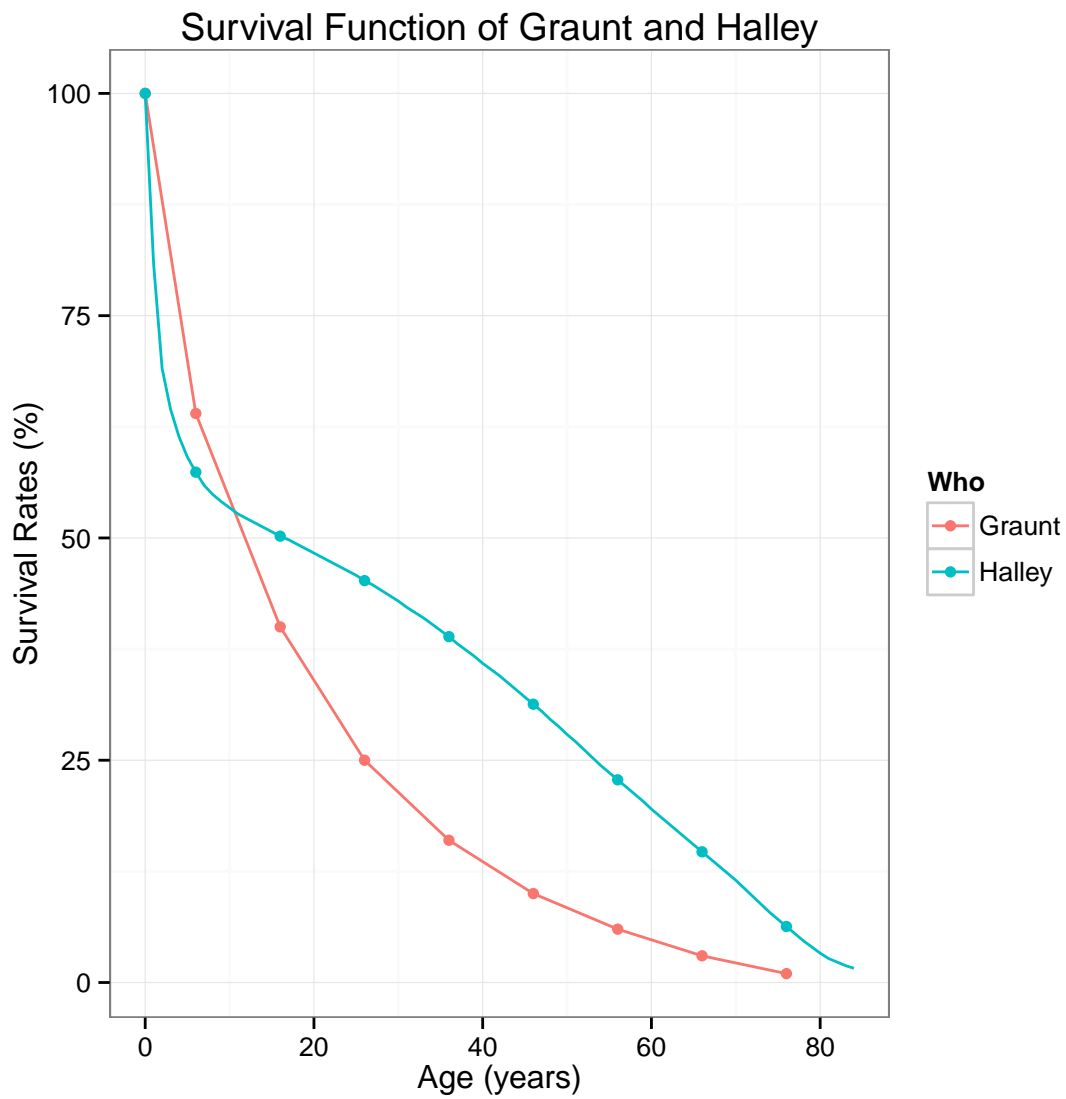

```
gh4 <- gh3 +
  theme(legend.position = c(0.8, 0.8)) +
  annotate("text", x = c(16, 36), y = c(20, 50), label = c("Graunt", "Halley")) +
  scale_x_continuous(breaks = c(graunt$x, 84)) +
  scale_y_continuous(breaks = c(graunt$lx.17th, halley$px[halley$age == 6]))
gh4
```

Survival Function of Graunt and Halley
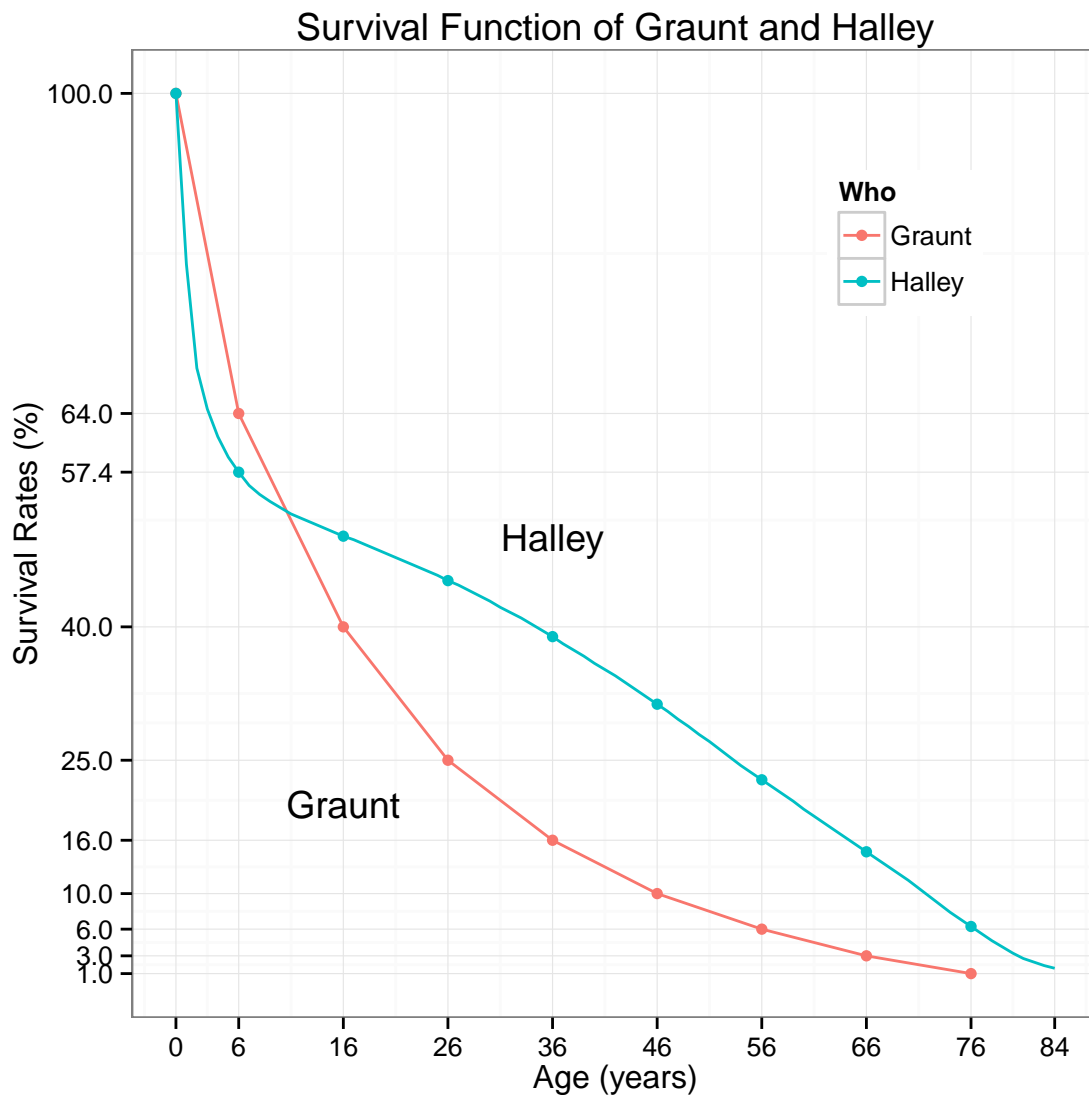
```r
ggsave("../pics/graunt_halley_ggplot.png", gh4)
```

```
## Saving 6 x 6 in image
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```
## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```

```r
ghp4 <- gh4 +
  geom_polygon(data = data.frame(x = poly.1.x, y = poly.1.y), aes(x = x, y = y), alpha = 0.3, fill = "bl
ghp4
```

Survival Function of Graunt and Halley

Polygon

```
ghp5 <- ghp4 +
  geom_polygon(data = data.frame(x = poly.2.x, y = poly.2.y), aes(x = x, y = y), alpha = 0.3, fill = "r
ghp5
```

Survival Function of Graunt and Halley
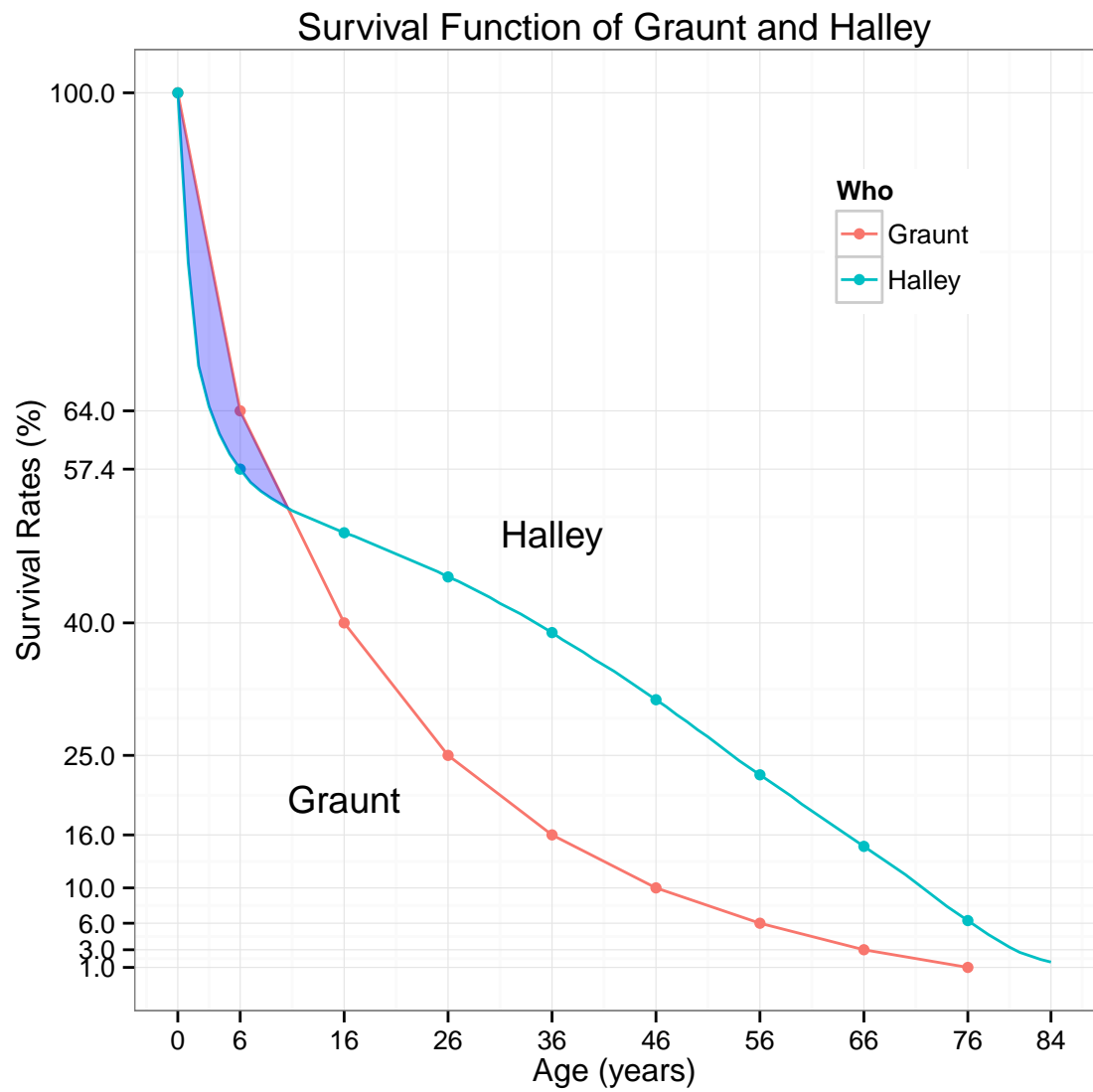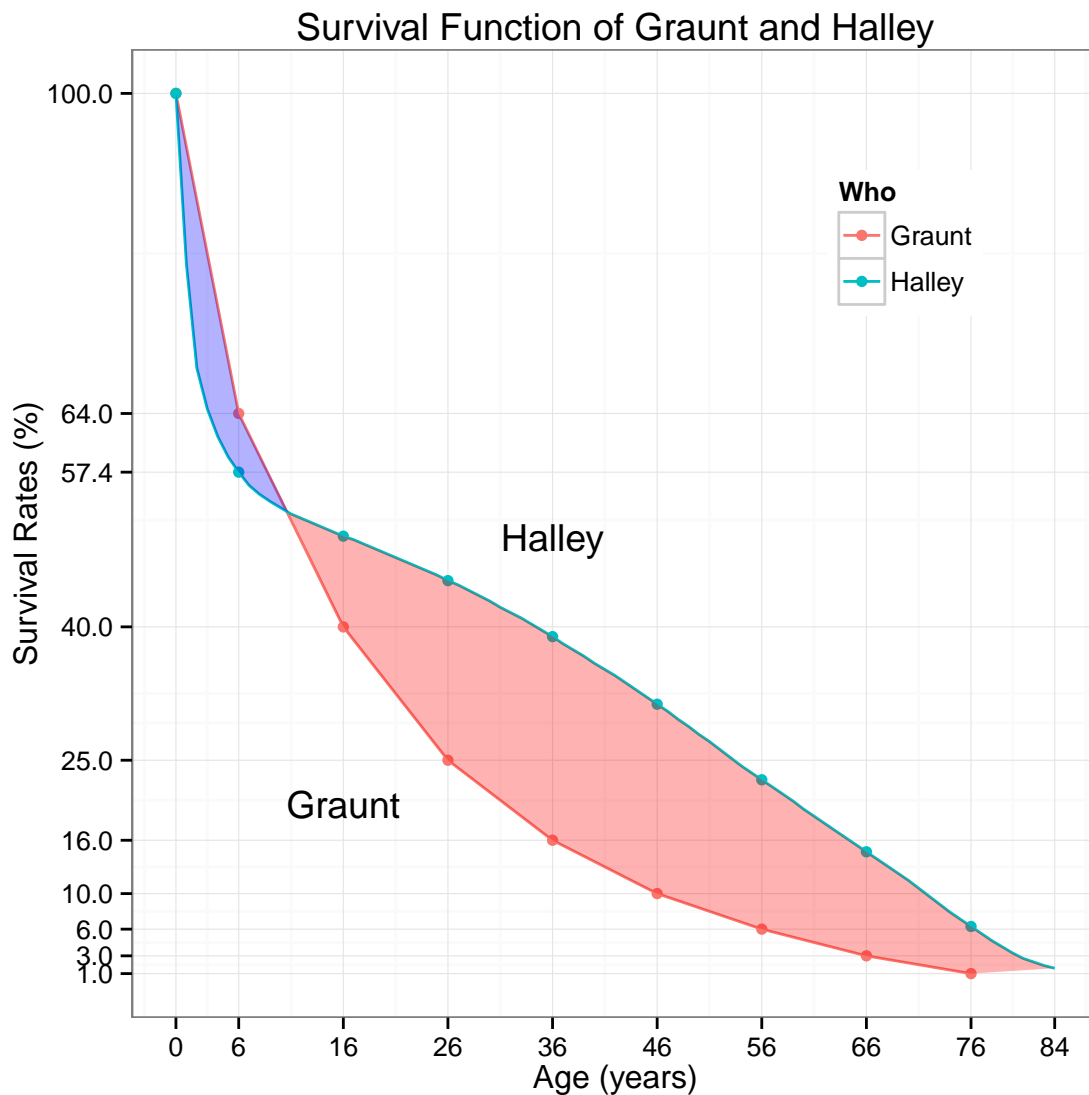
```
ggsave("../pics/graunt_halley_poly_ggplot.png", ghp5)
```

```
## Saving 6 x 6 in image

## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database

## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database

## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database

## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database
```

```
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## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database

## Warning in grid.Call(L_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## font family not found in Windows font database

## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database

## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database

## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database

## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database

## Warning in grid.Call.graphics(L_text, as.graphicsAnnot(x$label), x$x, x
## $y, : font family not found in Windows font database
```
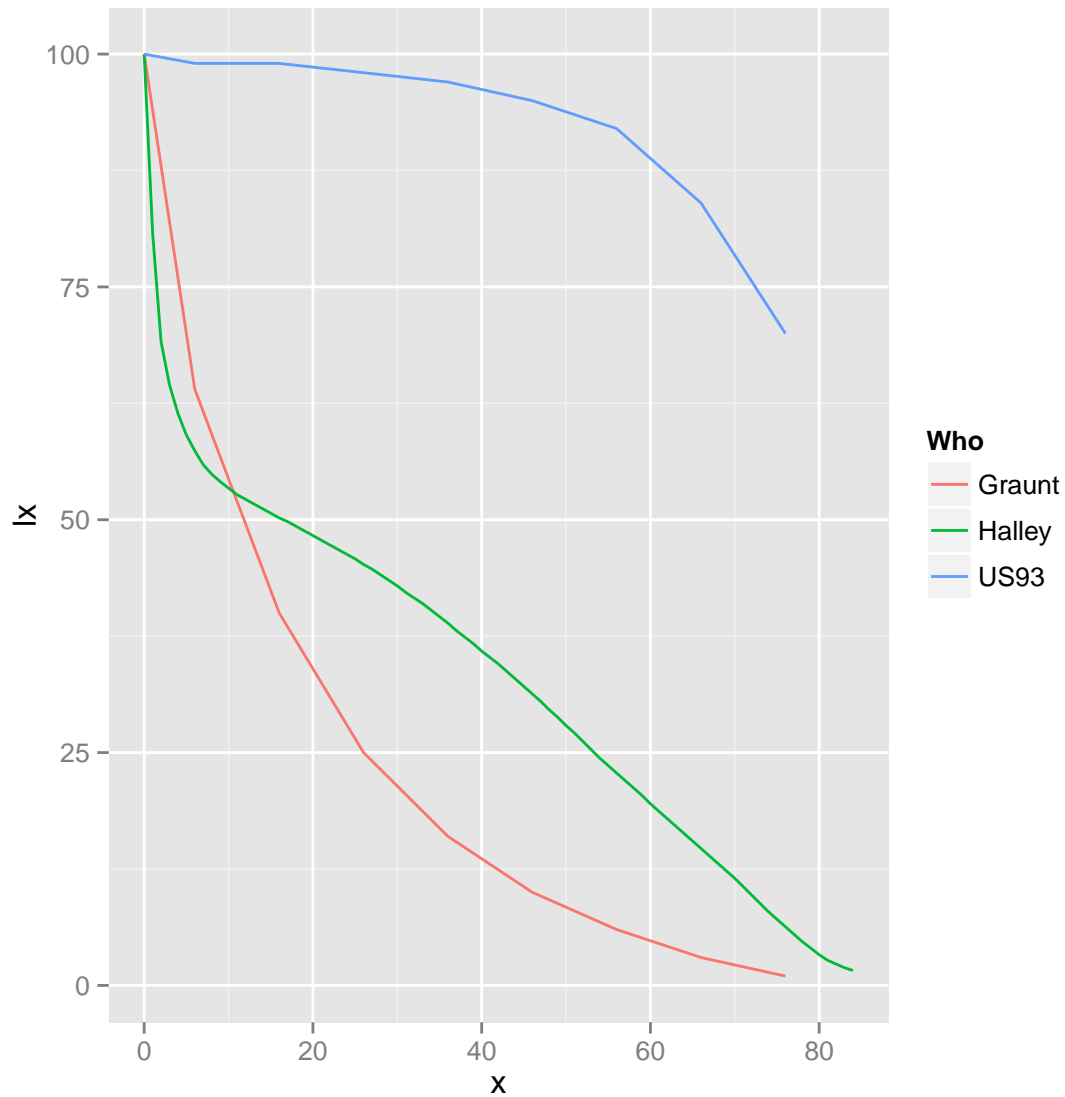
Graunt, Halley, and US93
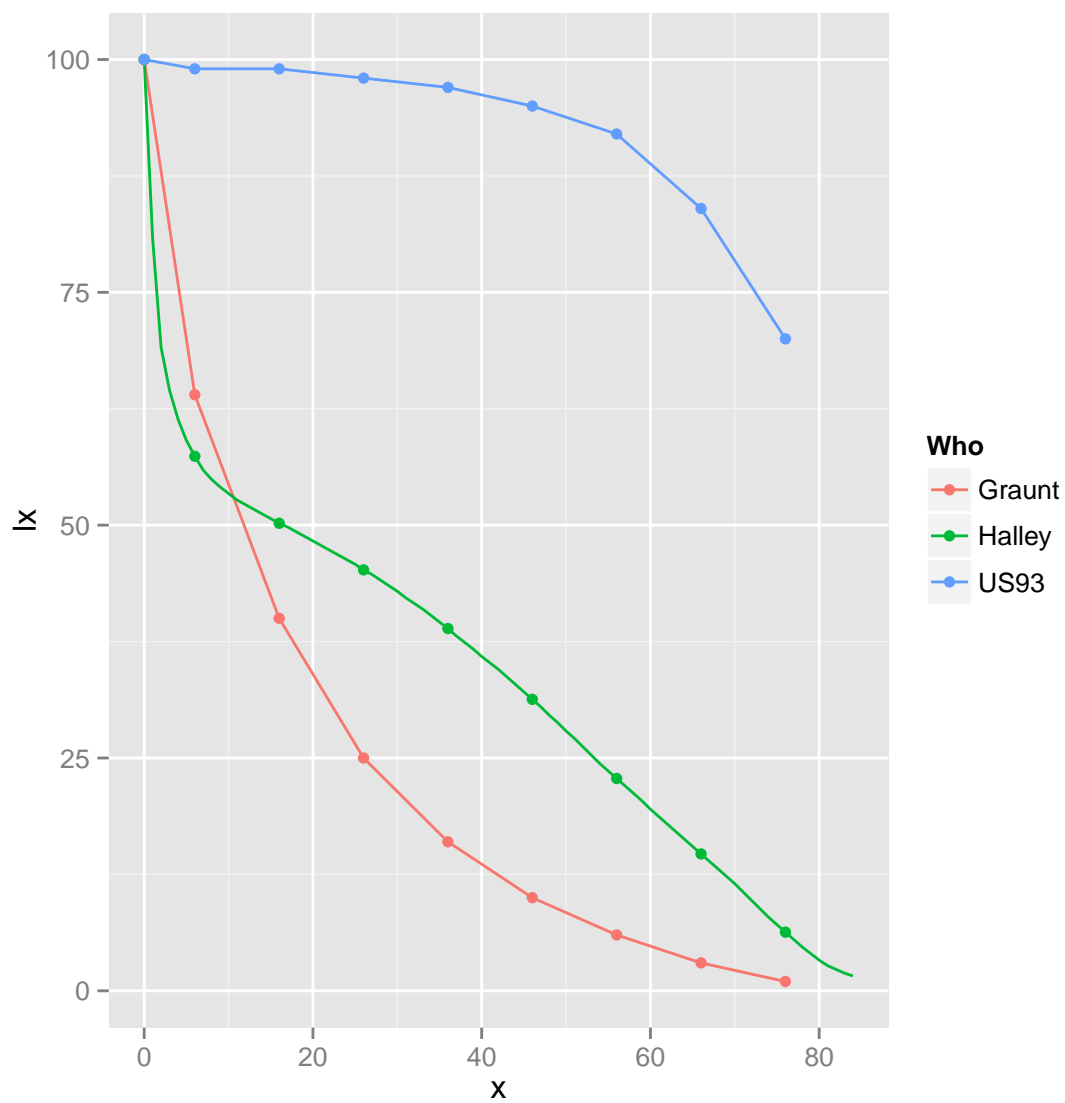
Data Reshape

```
us93.2 <- us.93
names(us93.2) <- c("x", "US93")
ghu.melt <- melt(list(graunt.2, halley.2, us93.2), id.vars = "x", value.name = "lx", variable.name = "W
ghu.melt.g <- ghu.melt[ghu.melt$x %in% graunt$x, ]
main.title.3 <- "Survival Function Plots"
```

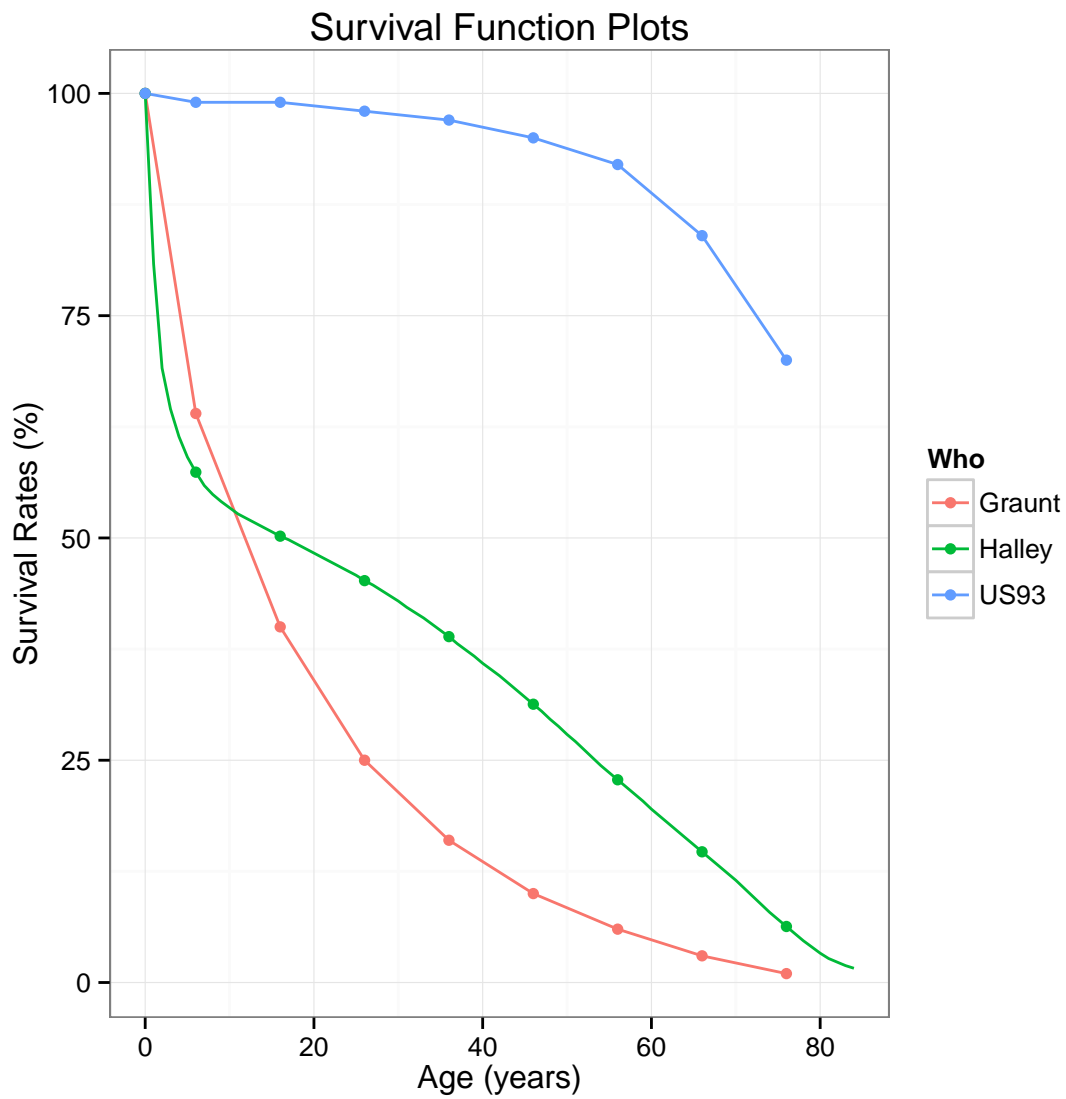### Survival Function Plots with ggplot

```
(ghu1 <- ggplot() +
  geom_line(data = ghu.melt, aes(x = x, y = lx, colour = Who)))
```



```
(ghu2 <- ghu1 +
  geom_point(data = ghu.melt.g, aes(x = x, y = lx, colour = Who)))
```

```
(ghu3 <- ghu2 +
  theme_bw() +
  xlab(x.lab) +
  ylab(y.lab) +
  ggtitle(main.title.3))
```

Survival Function Plots

```
(ghu4 <- ghu3 +
  theme(legend.position = c(0.2, 0.2)) +
  annotate("text", x = c(36, 36, 70), y = c(25, 50, 90), label = c("Graunt", "Halley", "US93")) +
  scale_x_continuous(breaks = c(graunt$x, 84)) +
  scale_y_continuous(breaks = c(graunt$lx.17th, halley$px[halley$age == 6])))
```

Survival Function Plots
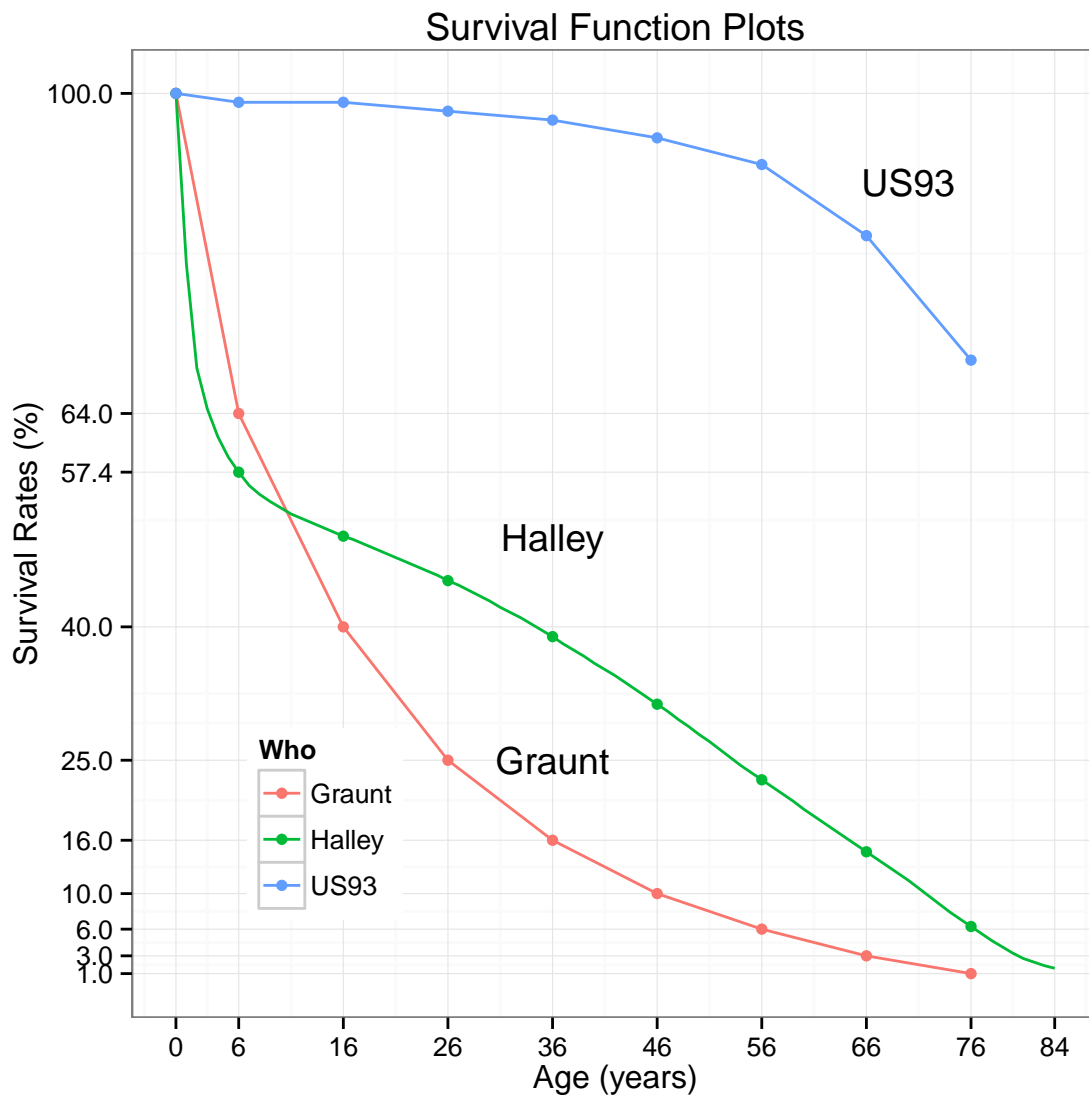
```
ggsave("../pics/graunt_halley_us_ggplot.png", ghu4)
```

```
## Saving 6 x 6 in image
```
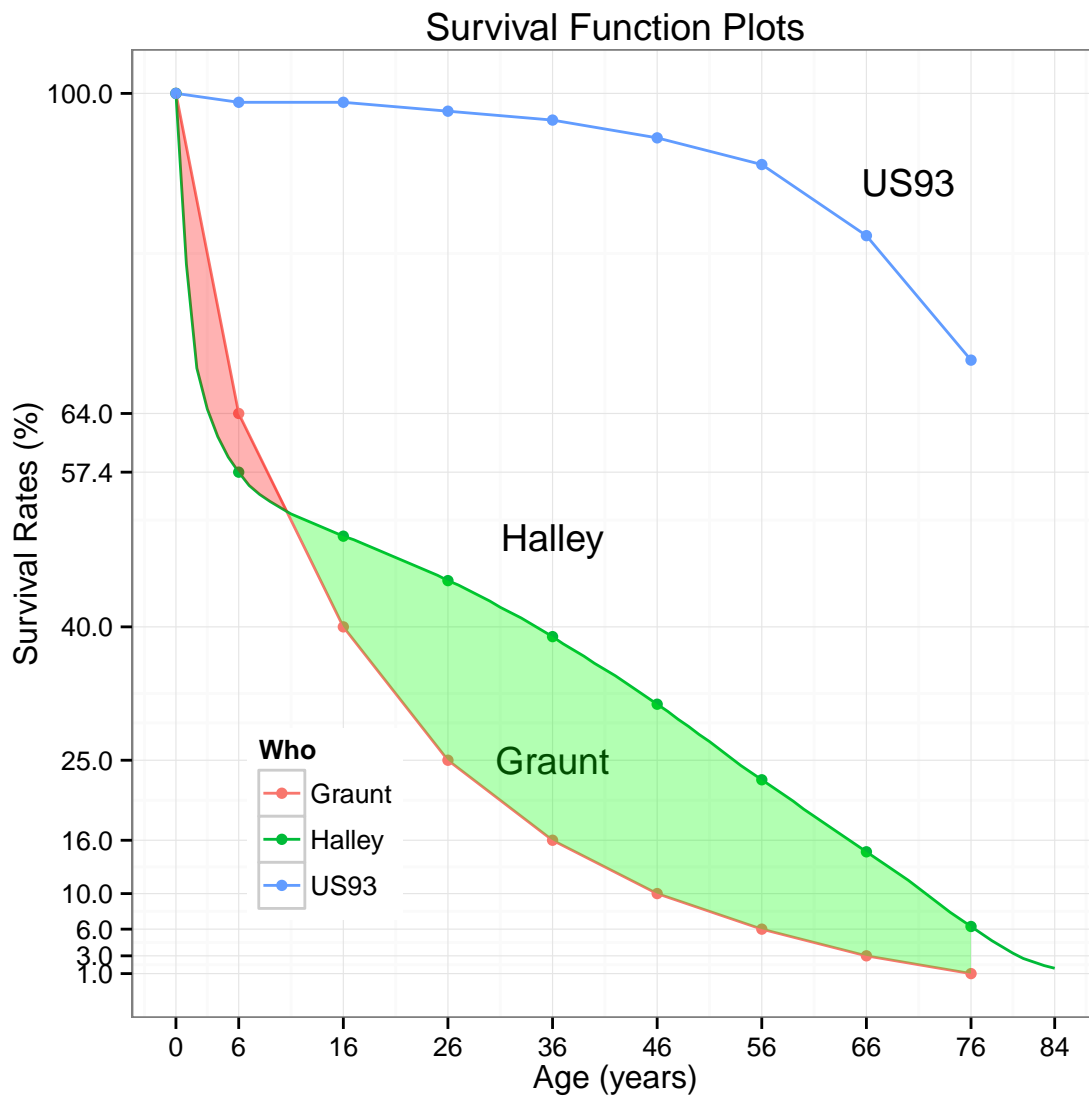
Polygon

Coordinates

In order to make the graphs truncated at the age 76, restrict the age of Halley up to 76.

```
poly.lower.76 <- subset(poly.lower, poly.lower$x <= 76)
poly.3.x <- c(us93.2$x, halley.2$x[85:12], 10.8, graunt.2$x[2:1])
poly.3.y <- c(us93.2$US93, halley.2$Halley[85:12], 52.8, graunt.2$Graunt[2:1])
poly.us <- data.frame(x = poly.3.x, y = poly.3.y)
poly.us.76 <- subset(poly.us, poly.us$x <= 76)
```
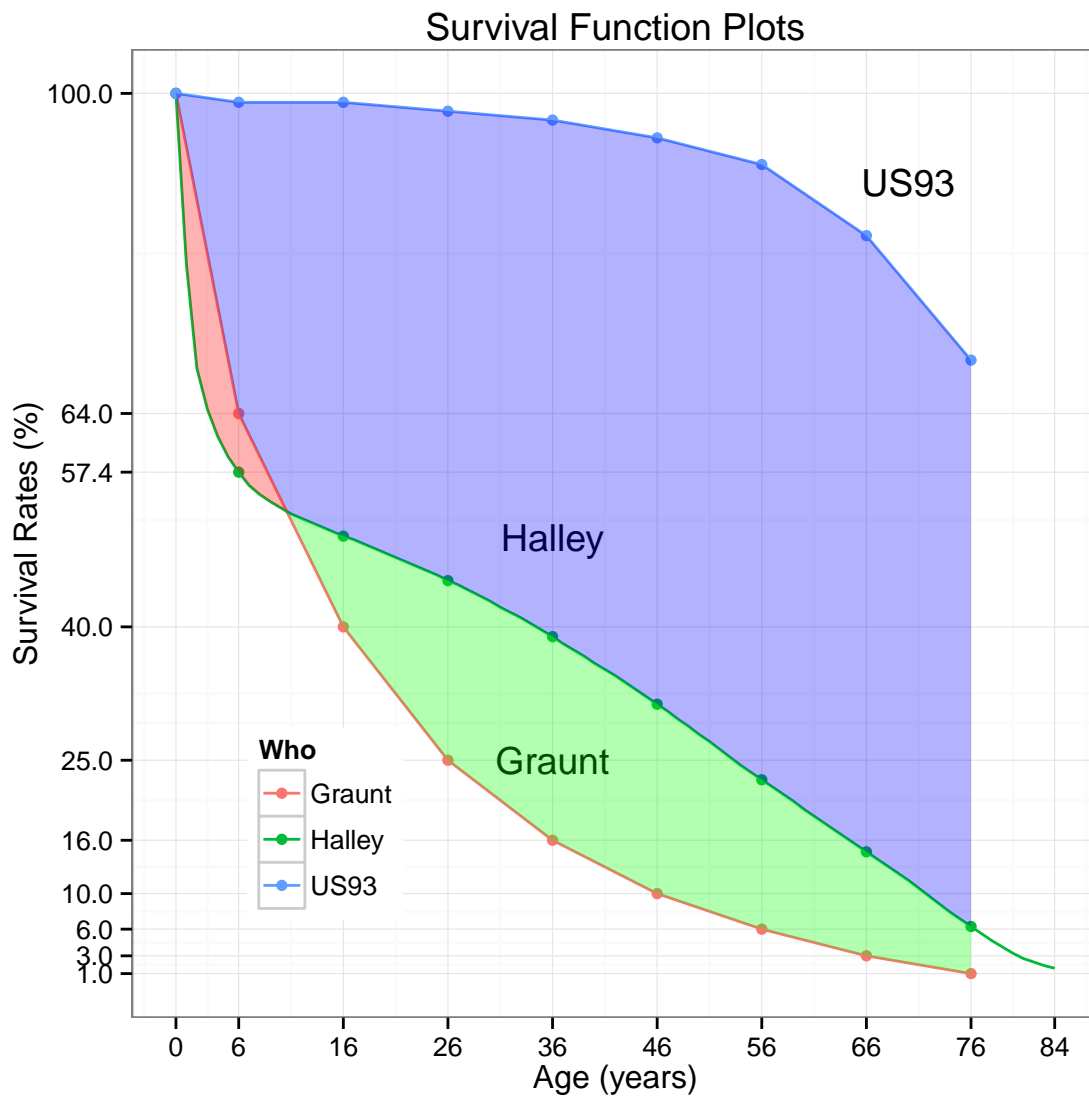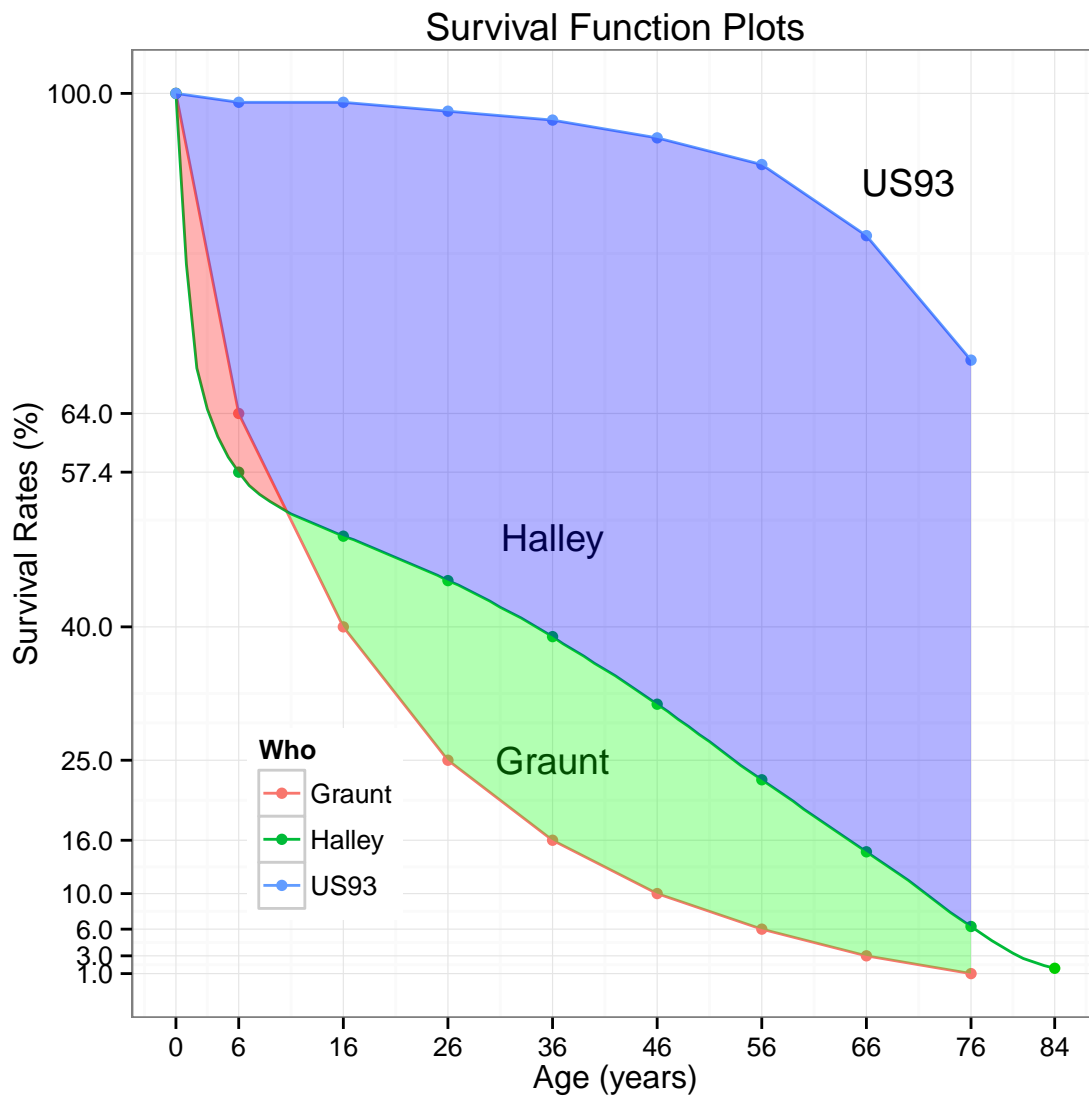
```
(ghup4 <- ghu4 +
  geom_polygon(data = poly.upper, aes(x = x, y = y), alpha = 0.3, fill = "red"))
```
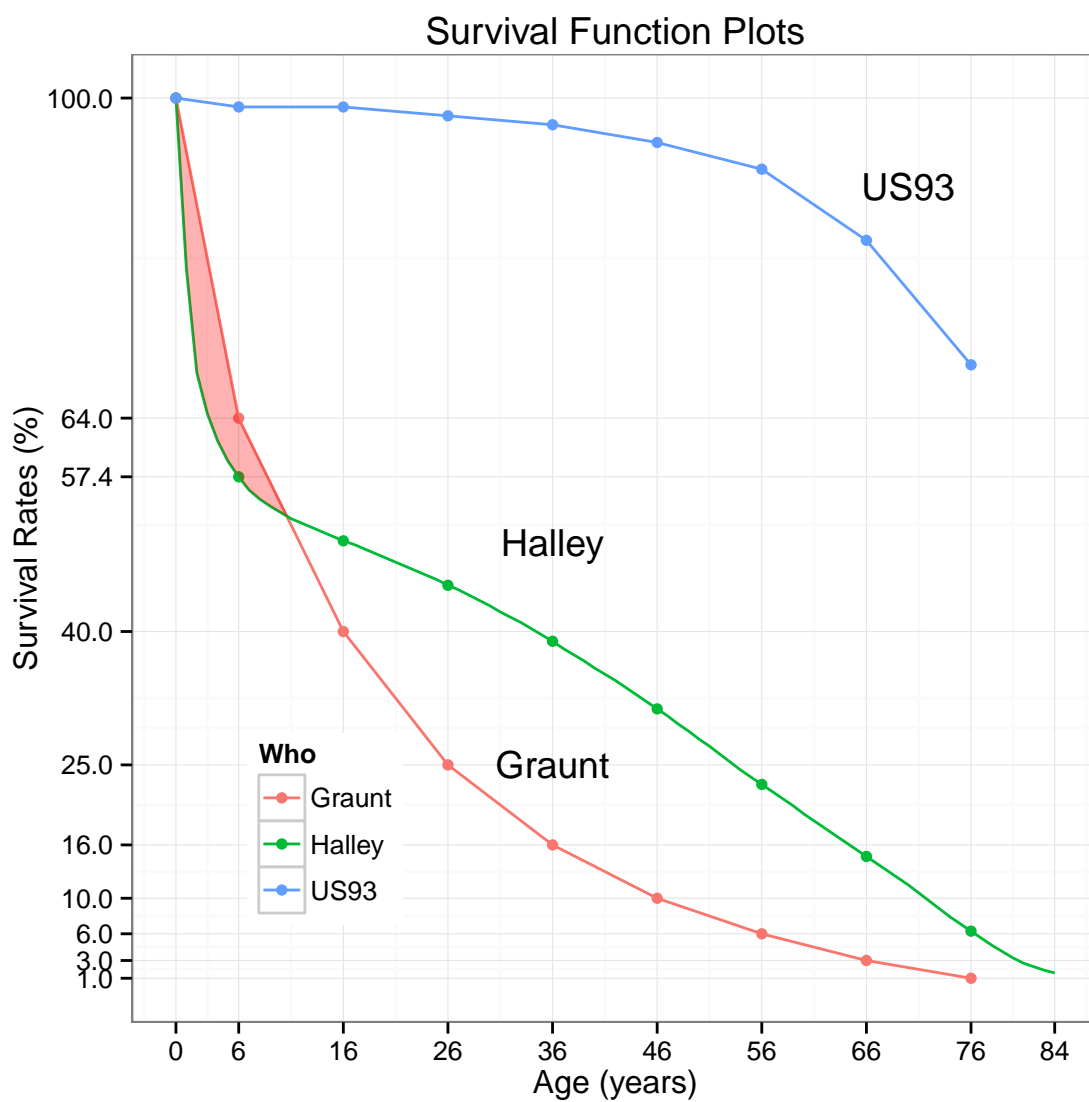


```
(ghup5 <- ghup4 +
  geom_polygon(data = poly.lower.76, aes(x = x, y = y), alpha = 0.3, fill = "green"))
```

Survival Function Plots

```
(ghup6 <- ghup5 +
  geom_polygon(data = poly.us.76, aes(x = x, y = y), alpha = 0.3, fill = "blue"))
```

Survival Function Plots

```
(ghup7 <- ghup6 +
  geom_point(data = data.frame(x = 84, y = halley$px[85]), aes(x = x, y = y),  colour = 3))
```

Survival Function Plots


```r
ggsave("../pics/graunt_halley_us_poly_ggplot.png", ghup7)
```

```
## Saving 6 x 6 in image
```

dump() and source()

- Check out how to save and retrieve. Use `source()` and `load()` for retrieval.

```r
dump("area.R", file = "area.R")
save.image("graunt_halley_160329.rda")
```