Introduction to R and RStudio

The goal of this lab is to introduce you to R and RStudio, which you'll be using throughout the course both to learn the statistical concepts discussed in the texbook and also to analyze real data and come to informed conclusions. To straighten out which is which: R is the name of the programming language itself and RStudio is a convenient interface.

As the labs progress, you are encouraged to explore beyond what the labs dictate; a willingness to experiment will make you a much better programmer. Before we get to that stage, however, you need to build some basic fluency in R. Today we begin with the fundamental building blocks of R and RStudio: the interface, reading in data, and basic commands.

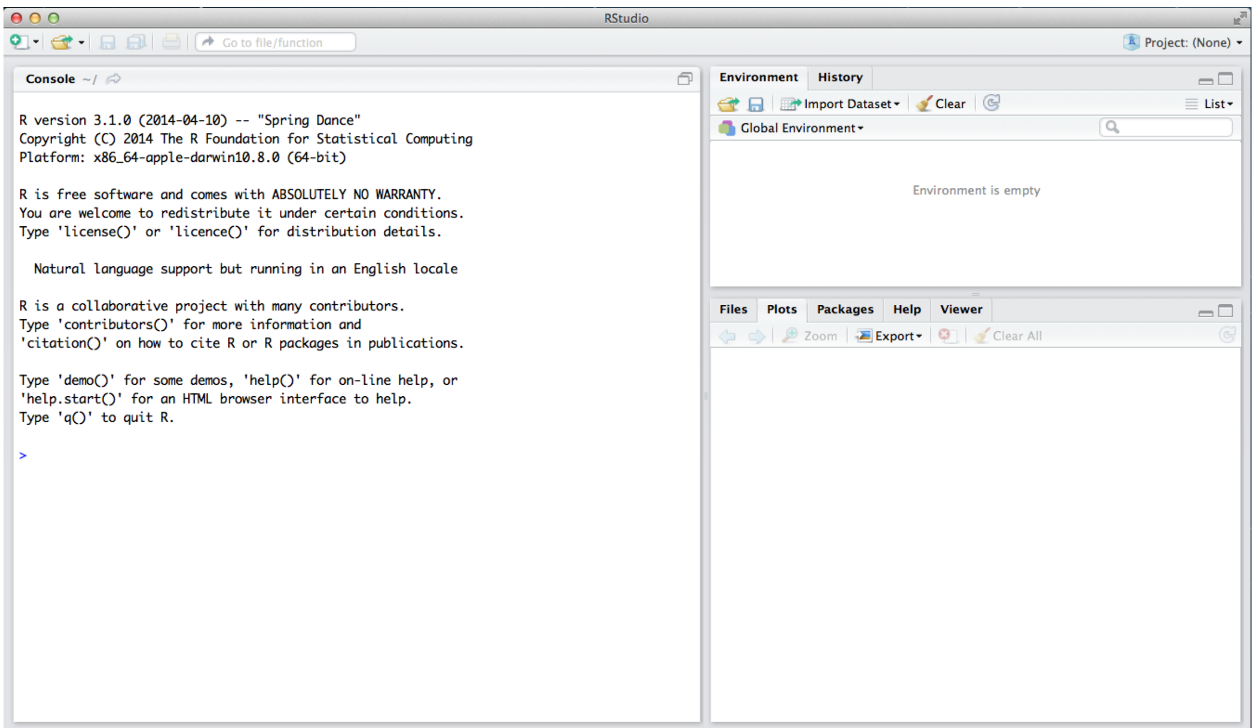


Figure 1: rinterface

The panel in the upper right contains your *workspace* as well as a history of the commands that you've previously entered. Any plots that you generate will show up in the panel in the lower right corner.

The panel on the left is where the action happens. It's called the *console*. Everytime you launch RStudio, it will have the same text at the top of the console telling you the version of R that you're running. Below that information is the *prompt*. As its name suggests, this prompt is really a request, a request for a command. Initially, interacting with R is all about typing commands and interpreting the output. These commands and their syntax have evolved over decades (literally) and now provide what many users feel is a fairly natural way to access data and organize, describe, and invoke statistical computations.

To get you started, enter the following command at the R prompt (i.e. right after `>` on the console). You can either type it in manually or copy and paste it from this document.

```r
source("more/arbuthnot.R")
```

This command instructs R to access the OpenIntro website and fetch some data: the Arbuthnot baptism counts for boys and girls. You should see that the workspace area in the upper righthand corner of the RStudio window now lists a data set called `arbuthnot` that has 82 observations on 3 variables. As you interact with R, you will create a series of objects. Sometimes you load them as we have done here, and sometimes you create them yourself as the byproduct of a computation or some analysis you have performed. Note that because you are accessing data from the web, this command (and the entire assignment) will work in a computer lab, in the library, or in your dorm room; anywhere you have access to the Internet.

The Data: Dr. Arbuthnot's Baptism Records

The Arbuthnot data set refers to Dr. John Arbuthnot, an 18th century physician, writer, and mathematician. He was interested in the ratio of newborn boys to newborn girls, so he gathered the baptism records for children born in London for every year from 1629 to 1710. We can take a look at the data by typing its name into the console.

```r
arbuthnot
```

```
##    year boys girls
## 1  1629 5218  4683
## 2  1630 4858  4457
## 3  1631 4422  4102
## 4  1632 4994  4590
## 5  1633 5158  4839
## 6  1634 5035  4820
## 7  1635 5106  4928
## 8  1636 4917  4605
## 9  1637 4703  4457
## 10 1638 5359  4952
## 11 1639 5366  4784
## 12 1640 5518  5332
## 13 1641 5470  5200
## 14 1642 5460  4910
## 15 1643 4793  4617
## 16 1644 4107  3997
## 17 1645 4047  3919
## 18 1646 3768  3395
## 19 1647 3796  3536
## 20 1648 3363  3181
## 21 1649 3079  2746
## 22 1650 2890  2722
## 23 1651 3231  2840
## 24 1652 3220  2908
## 25 1653 3196  2959
## 26 1654 3441  3179
## 27 1655 3655  3349
## 28 1656 3668  3382
## 29 1657 3396  3289
## 30 1658 3157  3013
## 31 1659 3209  2781
## 32 1660 3724  3247
```

```
## 33 1661 4748  4107
## 34 1662 5216  4803
## 35 1663 5411  4881
## 36 1664 6041  5681
## 37 1665 5114  4858
## 38 1666 4678  4319
## 39 1667 5616  5322
## 40 1668 6073  5560
## 41 1669 6506  5829
## 42 1670 6278  5719
## 43 1671 6449  6061
## 44 1672 6443  6120
## 45 1673 6073  5822
## 46 1674 6113  5738
## 47 1675 6058  5717
## 48 1676 6552  5847
## 49 1677 6423  6203
## 50 1678 6568  6033
## 51 1679 6247  6041
## 52 1680 6548  6299
## 53 1681 6822  6533
## 54 1682 6909  6744
## 55 1683 7577  7158
## 56 1684 7575  7127
## 57 1685 7484  7246
## 58 1686 7575  7119
## 59 1687 7737  7214
## 60 1688 7487  7101
## 61 1689 7604  7167
## 62 1690 7909  7302
## 63 1691 7662  7392
## 64 1692 7602  7316
## 65 1693 7676  7483
## 66 1694 6985  6647
## 67 1695 7263  6713
## 68 1696 7632  7229
## 69 1697 8062  7767
## 70 1698 8426  7626
## 71 1699 7911  7452
## 72 1700 7578  7061
## 73 1701 8102  7514
## 74 1702 8031  7656
## 75 1703 7765  7683
## 76 1704 6113  5738
## 77 1705 8366  7779
## 78 1706 7952  7417
## 79 1707 8379  7687
## 80 1708 8239  7623
## 81 1709 7840  7380
## 82 1710 7640  7288
```

What you should see are four columns of numbers, each row representing a different year: the first entry in each row is simply the row number (an index we can use to access the data from individual years if we want), the second is the year, and the third and fourth are the numbers of boys and girls baptized that year, respectively. Use the scrollbar on the right side of the console window to examine the complete data set.

Note that the row numbers in the first column are not part of Arbuthnot's data. R adds them as part of its printout to help you make visual comparisons. You can think of them as the index that you see on the left side of a spreadsheet. In fact, the comparison to a spreadsheet will generally be helpful. R has stored Arbuthnot's data in a kind of spreadsheet or table called a *data frame*.

You can see the dimensions of this data frame by typing:

```
dim(arbuthnot)
```

```
## [1] 82  3
```

This command should output `[1] 82 3`, indicating that there are 82 rows and 3 columns (we'll get to what the `[1]` means in a bit), just as it says next to the object in your workspace. You can see the names of these columns (or variables) by typing:

```
names(arbuthnot)
```

```
## [1] "year"  "boys"  "girls"
```

You should see that the data frame contains the columns `year`, `boys`, and `girls`. At this point, you might notice that many of the commands in R look a lot like functions from math class; that is, invoking R commands means supplying a function with some number of arguments. The `dim` and `names` commands, for example, each took a single argument, the name of a data frame.

One advantage of RStudio is that it comes with a built-in data viewer. Click on the name `arbuthnot` in the *Environment* pane (upper right window) that lists the objects in your workspace. This will bring up an alternative display of the data set in the *Data Viewer* (upper left window). You can close the data viewer by clicking on the x in the upper lefthand corner.

Some Exploration

Let's start to examine the data a little more closely. We can access the data in a single column of a data frame separately using a command like

```
arbuthnot$boys
```

```
##  [1] 5218 4858 4422 4994 5158 5035 5106 4917 4703 5359 5366 5518 5470 5460 4793
## [16] 4107 4047 3768 3796 3363 3079 2890 3231 3220 3196 3441 3655 3668 3396 3157
## [31] 3209 3724 4748 5216 5411 6041 5114 4678 5616 6073 6506 6278 6449 6443 6073
## [46] 6113 6058 6552 6423 6568 6247 6548 6822 6909 7577 7575 7484 7575 7737 7487
## [61] 7604 7909 7662 7602 7676 6985 7263 7632 8062 8426 7911 7578 8102 8031 7765
## [76] 6113 8366 7952 8379 8239 7840 7640
```

This command will only show the number of boys baptized each year.

1. What command would you use to extract just the counts of girls baptized? Try it!

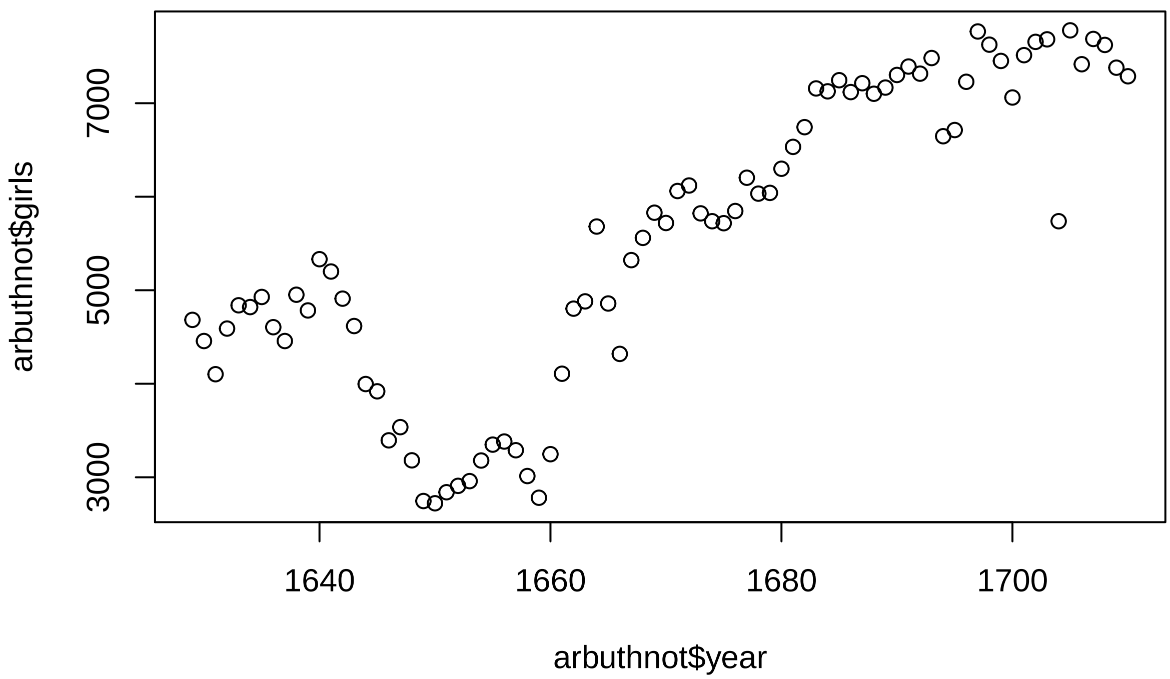
```
arbuthnot$girls
```

```
##  [1] 4683 4457 4102 4590 4839 4820 4928 4605 4457 4952 4784 5332 5200 4910 4617
## [16] 3997 3919 3395 3536 3181 2746 2722 2840 2908 2959 3179 3349 3382 3289 3013
## [31] 2781 3247 4107 4803 4881 5681 4858 4319 5322 5560 5829 5719 6061 6120 5822
## [46] 5738 5717 5847 6203 6033 6041 6299 6533 6744 7158 7127 7246 7119 7214 7101
## [61] 7167 7302 7392 7316 7483 6647 6713 7229 7767 7626 7452 7061 7514 7656 7683
## [76] 5738 7779 7417 7687 7623 7380 7288
```

Notice that the way R has printed these data is different. When we looked at the complete data frame, we saw 82 rows, one on each line of the display. These data are no longer structured in a table with other variables, so they are displayed one right after another. Objects that print out in this way are called *vectors*; they represent a set of numbers. R has added numbers in [brackets] along the left side of the printout to indicate locations within the vector. For example, `5218` follows `[1]`, indicating that `5218` is the first entry in the vector. And if `[43]` starts a line, then that would mean the first number on that line would represent the 43rd entry in the vector.

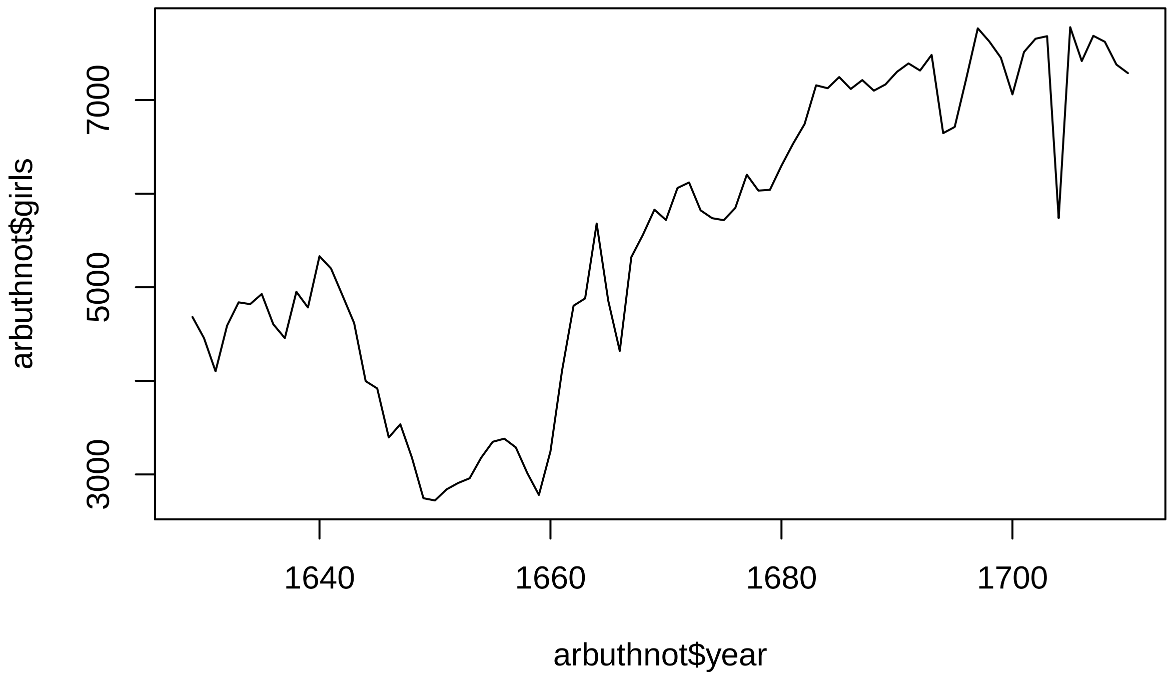
R has some powerful functions for making graphics. We can create a simple plot of the number of girls baptized per year with the command

```
plot(x = arbuthnot$year, y = arbuthnot$girls)
```



By default, R creates a scatterplot with each x,y pair indicated by an open circle. The plot itself should appear under the *Plots* tab of the lower right panel of RStudio. Notice that the command above again looks like a function, this time with two arguments separated by a comma. The first argument in the plot function specifies the variable for the x-axis and the second for the y-axis. If we wanted to connect the data points with lines, we could add a third argument, the letter `l` for **l**ine.

```
plot(x = arbuthnot$year, y = arbuthnot$girls, type = "l")
```



You might wonder how you are supposed to know that it was possible to add that third argument. Thankfully, R documents all of its functions extensively. To read what a function does and learn the arguments that are available to you, just type in a question mark followed by the name of the function that you're interested in. Try the following.

```
?plot
```

Notice that the help file replaces the plot in the lower right panel. You can toggle between plots and help files using the tabs at the top of that panel.

2. Is there an apparent trend in the number of girls baptized over the years?
   How would you describe it?

It is increasing for the most part year-over-year. There is some issue between 1640 and 1665, where in the number of boys and girls drops dramatically, but other than that there appears to be a linear relationship to the number of births as a function of time.

Now, suppose we want to plot the total number of baptisms. To compute this, we could use the fact that R is really just a big calculator. We can type in mathematical expressions like

```
5218 + 4683
```

```
## [1] 9901
```

to see the total number of baptisms in 1629. We could repeat this once for each year, but there is a faster way. If we add the vector for baptisms for boys and girls, R will compute all sums simultaneously.

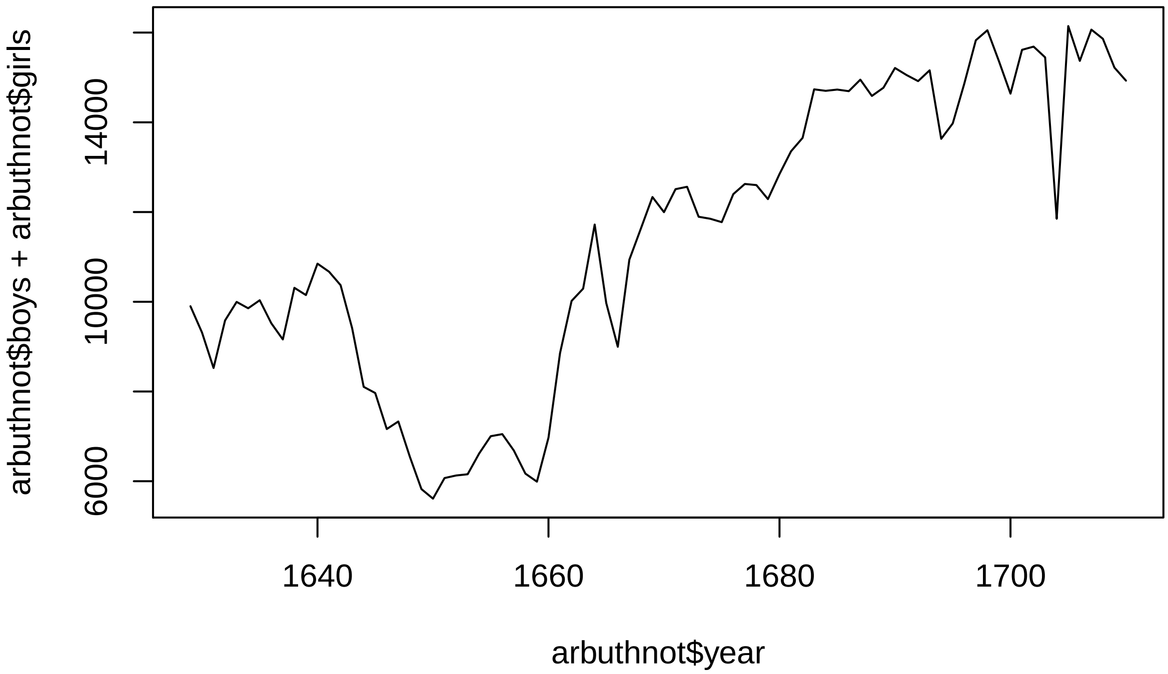
```
arbuthnot$boys + arbuthnot$girls
```

```
##  [1]  9901  9315  8524  9584  9997  9855 10034  9522  9160 10311 10150 10850
## [13] 10670 10370  9410  8104  7966  7163  7332  6544  5825  5612  6071  6128
```

```
## [25]  6155  6620  7004  7050  6685  6170  5990  6971  8855 10019 10292 11722
## [37]  9972  8997 10938 11633 12335 11997 12510 12563 11895 11851 11775 12399
## [49] 12626 12601 12288 12847 13355 13653 14735 14702 14730 14694 14951 14588
## [61] 14771 15211 15054 14918 15159 13632 13976 14861 15829 16052 15363 14639
## [73] 15616 15687 15448 11851 16145 15369 16066 15862 15220 14928
```

What you will see are 82 numbers (in that packed display, because we aren't looking at a data frame here), each one representing the sum we're after. Take a look at a few of them and verify that they are right. Therefore, we can make a plot of the total number of baptisms per year with the command

```r
plot(arbuthnot$year, arbuthnot$boys + arbuthnot$girls, type = "l")
```



This time, note that we left out the names of the first two arguments. We can do this because the help file shows that the default for `plot` is for the first argument to be the x-variable and the second argument to be the y-variable.

Similarly to how we computed the proportion of boys, we can compute the ratio of the number of boys to the number of girls baptized in 1629 with

```r
5218 / 4683
```

```
## [1] 1.114243
```

or we can act on the complete vectors with the expression

```r
arbuthnot$boys / arbuthnot$girls
```

```
##  [1] 1.114243 1.089971 1.078011 1.088017 1.065923 1.044606 1.036120 1.067752
##  [9] 1.055194 1.082189 1.121656 1.034884 1.051923 1.112016 1.038120 1.027521
## [17] 1.032661 1.109867 1.073529 1.057215 1.121267 1.061719 1.137676 1.107290
## [25] 1.080095 1.082416 1.091371 1.084565 1.032533 1.047793 1.153901 1.146905
```

```
## [33] 1.156075 1.085988 1.108584 1.063369 1.052697 1.083121 1.055242 1.092266
## [41] 1.116143 1.097744 1.064016 1.052778 1.043112 1.065354 1.059647 1.120575
## [49] 1.035467 1.088679 1.034100 1.039530 1.044237 1.024466 1.058536 1.062860
## [57] 1.032846 1.064054 1.072498 1.054359 1.060974 1.083128 1.036526 1.039092
## [65] 1.025792 1.050850 1.081931 1.055748 1.037981 1.104904 1.061594 1.073219
## [73] 1.078254 1.048981 1.010673 1.065354 1.075460 1.072132 1.090022 1.080808
## [81] 1.062331 1.048299
```

The proportion of newborns that are boys

```
5218 / (5218 + 4683)
```

```
## [1] 0.5270175
```

or this may also be computed for all years simultaneously:

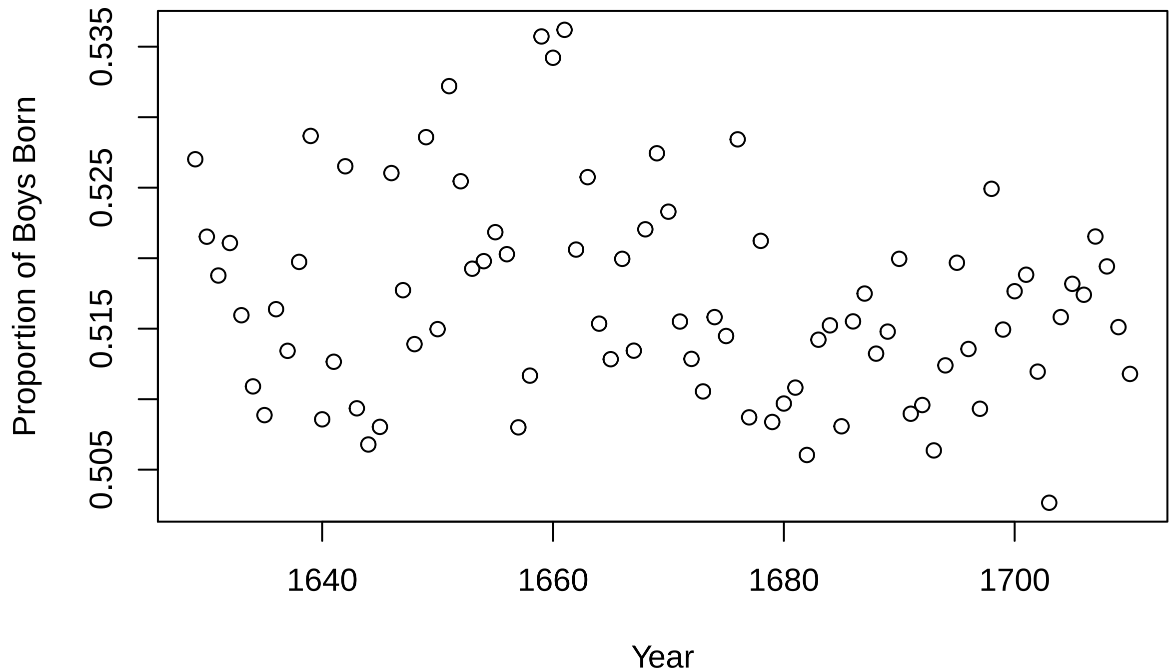
```
arbuthnot$boys / (arbuthnot$boys + arbuthnot$girls)
```

```
##  [1] 0.5270175 0.5215244 0.5187705 0.5210768 0.5159548 0.5109082 0.5088698
##  [8] 0.5163831 0.5134279 0.5197362 0.5286700 0.5085714 0.5126523 0.5265188
## [15] 0.5093518 0.5067868 0.5080341 0.5260366 0.5177305 0.5139059 0.5285837
## [22] 0.5149679 0.5322023 0.5254569 0.5192526 0.5197885 0.5218447 0.5202837
## [29] 0.5080030 0.5116694 0.5357262 0.5342132 0.5361942 0.5206108 0.5257482
## [36] 0.5153557 0.5128359 0.5199511 0.5134394 0.5220493 0.5274422 0.5232975
## [43] 0.5155076 0.5128552 0.5105507 0.5158214 0.5144798 0.5284297 0.5087122
## [50] 0.5212285 0.5083822 0.5096910 0.5108199 0.5060426 0.5142178 0.5152360
## [57] 0.5080788 0.5155165 0.5174905 0.5132301 0.5147925 0.5199527 0.5089677
## [64] 0.5095857 0.5063659 0.5123973 0.5196766 0.5135590 0.5093183 0.5249190
## [71] 0.5149385 0.5176583 0.5188268 0.5119526 0.5026541 0.5158214 0.5181790
## [78] 0.5174052 0.5215362 0.5194175 0.5151117 0.5117899
```

Note that with R as with your calculator, you need to be conscious of the order of operations. Here, we want to divide the number of boys by the total number of newborns, so we have to use parentheses. Without them, R will first do the division, then the addition, giving you something that is not a proportion.

3. Now, make a plot of the proportion of boys over time. What do you see? Tip: If you use the up and down arrow keys, you can scroll through your previous commands, your so-called command history. You can also access it by clicking on the history tab in the upper right panel. This will save you a lot of typing in the future.

```
plot(x=arbuthnot$year, y= (arbuthnot$boys/(arbuthnot$girls + arbuthnot$boys)),
     xlab = "Year", ylab = "Proportion of Boys Born")
```



Finally, in addition to simple mathematical operators like subtraction and division, you can ask R to make comparisons like greater than, `>`, less than, `<`, and equality, `==`. For example, we can ask if boys outnumber girls in each year with the expression

```
arbuthnot$boys > arbuthnot$girls
```

```
##  [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [16] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [31] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [46] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [61] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [76] TRUE TRUE TRUE TRUE TRUE TRUE TRUE
```

This command returns 82 values of either `TRUE` if that year had more boys than girls, or `FALSE` if that year did not (the answer may surprise you). This output shows a different kind of data than we have considered so far. In the `arbuthnot` data frame our values are numerical (the year, the number of boys and girls). Here, we've asked R to create *logical* data, data where the values are either `TRUE` or `FALSE`. In general, data analysis will involve many different kinds of data types, and one reason for using R is that it is able to represent and compute with many of them.

This seems like a fair bit for your first lab, so let's stop here. To exit RStudio you can click the x in the upper right corner of the whole window.
You will be prompted to save your workspace. If you click *save*, RStudio will save the history of your commands and all the objects in your workspace so that the next time you launch RStudio, you will see `arbuthnot` and you will have access to the commands you typed in your previous session. For now, click *save*, then start up RStudio again.

On Your Own

In the previous few pages, you recreated some of the displays and preliminary analysis of Arbuthnot's baptism data. Your assignment involves repeating these steps, but for present day birth records in the United States.

Load up the present day data with the following command.

```r
source("more/present.R")
```

The data are stored in a data frame called `present`.

- What years are included in this data set? What are the dimensions of the data frame and what are the variable or column names?

```r
summary(present)
```

```
##       year          boys              girls
##  Min.   :1940   Min.   :1211684   Min.   :1148715
##  1st Qu.:1956   1st Qu.:1799857   1st Qu.:1711404
##  Median :1971   Median :1924868   Median :1831679
##  Mean   :1971   Mean   :1885600   Mean   :1793915
##  3rd Qu.:1986   3rd Qu.:2058524   3rd Qu.:1965538
##  Max.   :2002   Max.   :2186274   Max.   :2082052
```

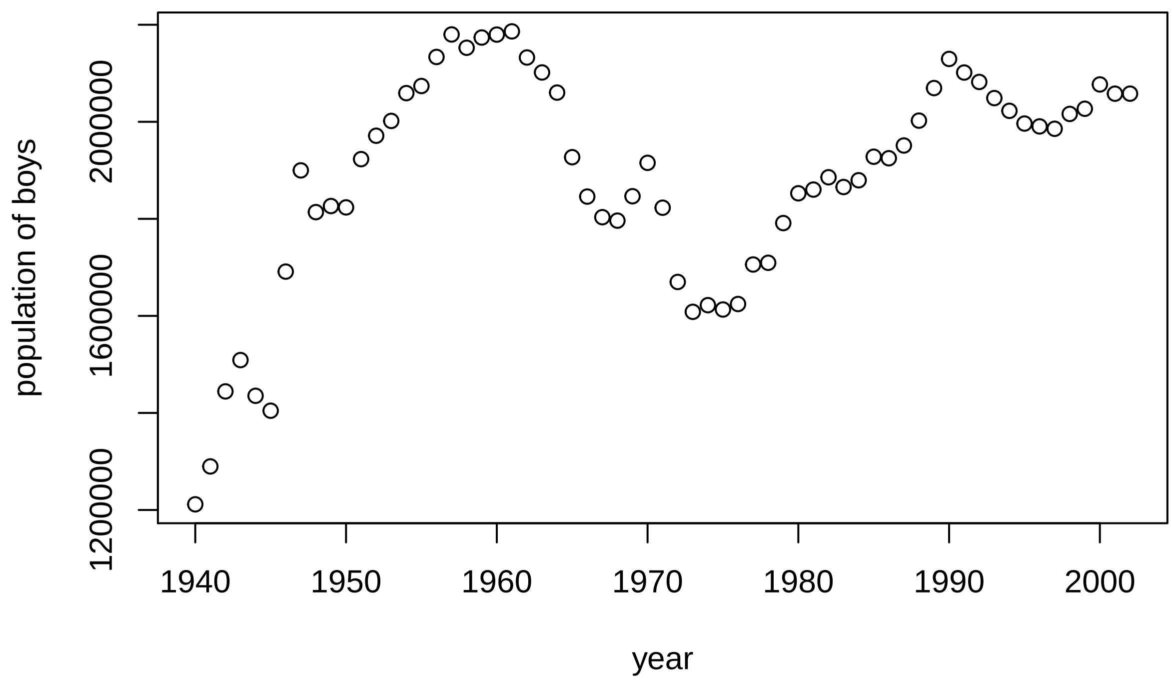
```r
dim(present)
```

```
## [1] 63  3
```

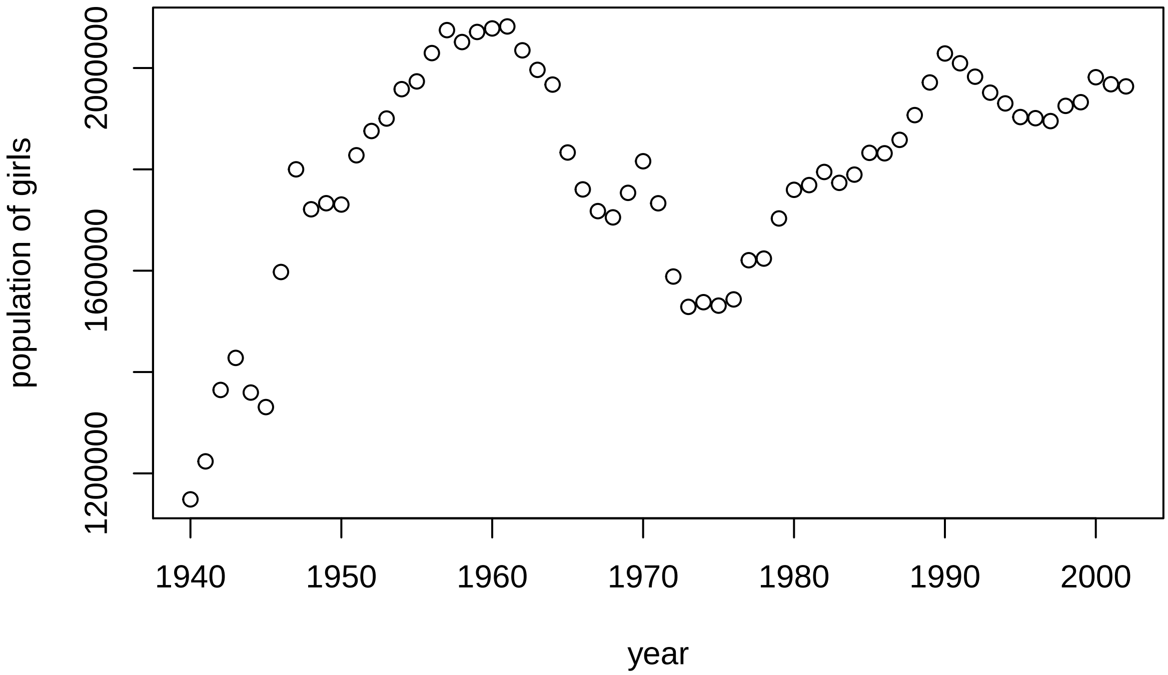
In three columns and 63 rows with have a dataframe of the birth population of boys and girls for a given year from 1940 - 2002. The summary command gives us a nice layout of the numbers.

- How do these counts compare to Arbuthnot's? Are they on a similar scale?

```r
plot(present$year, present$boys,xlab= "year", ylab = "population of boys")
```



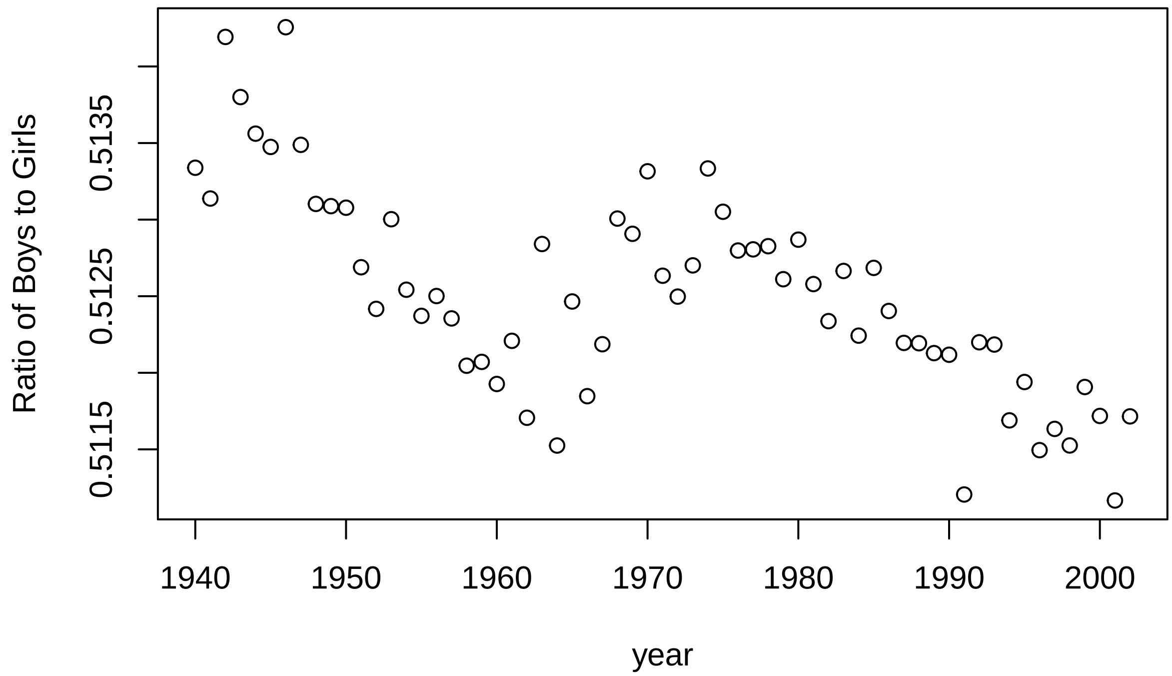
```r
plot(present$year, present$girls,xlab= "year", ylab = "population of girls")
```



These numbers are several orders of magnitude higher than Arbuthnot's sample.It is similar in that it is increasing, but we would need to examine the derivative to understand the relative rates of growth. This population has both a boom and and a dip in the population pattern.

- Make a plot that displays the boy-to-girl ratio for every year in the data set. What do you see? Does Arbuthnot's observation about boys being born in greater proportion than girls hold up in the U.S.? Include the plot in your response.

```r
plot(present$year, (present$boys/(present$boys+present$girls)),
     xlab= "year", ylab = "Ratio of Boys to Girls")
```



It also shows a ratio that is greater than 50% for births of boys, which is inline with Arbuthnot's findings. I am actually a bit shocked by this, I would have expected at least a few years of less boys than girls.

The spread of values for this data does seem to be tighter than Arbuthnot's data. There is a 3% change from max to min birth ratio in Arbuthnot's data and closer to a 1.5% max to min spread in this data. It also apprears to be getting more even, which is strange. Prehaps this is an example of the law of high numbers? The U.S. population is much higher than London 1600s, and as such the ratio is more even? Or prehaps there is a boy bias that has diminished?

- In what year did we see the most total number of births in the U.S.? You can refer to the help files or the R reference card http://cran.r-project.org/doc/contrib/Short-refcard.pdf to find helpful commands.

```
subset(present, boys==max(boys) & year)
```

```
##    year    boys   girls
## 22 1961 2186274 2082052
```

1961 - Right at the tail end of the baby boom.

```
present$total<- present$boys + present$girls
subset(present, total==max(total) & year)
```

```
##    year    boys   girls   total
## 22 1961 2186274 2082052 4268326
```

This is consistent with total maximum birth year (sum of boys and girls).

These data come from a report by the Centers for Disease Control http://www.cdc.gov/nchs/data/nvsr/nvsr53/nvsr53_20.pdf. Check it out if you would like to read more about an analysis of sex ratios at birth in the United States.

That was a short introduction to R and RStudio, but we will provide you with more functions and a more complete sense of the language as the course progresses. Feel free to browse around the websites for R and RStudio if you're interested in learning more, or find more labs for practice at http://openintro.org.