SML 201 – Week 4

John D. Storey

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R Packages

Install These Packages

Run this code in RStudio and let us know if you experience any errors.

```
pkgs <- c("dplyr", "babynames", "readr", "tidyr", "reshape2",
          "hexbin", "ggplot2", "ggthemes", "broom",
          "devtools", "RColorBrewer", "rvest", "xtable")
install.packages(pkgs)
```

Manipulating Data Frames

`dplyr` Package

`dplyr` is a package with the following description:

> A fast, consistent tool for working with data frame like objects, both in memory and out of memory.

This package offers a "grammar" for manipulating data frames.

Everything that `dplyr` does can also be done using basic R commands – however, it tends to be much faster and easier to use `dplyr`.

Grammar of `dplyr`

Verbs:

- `filter`: extract a subset of rows from a data frame based on logical conditions
- `arrange`: reorder rows of a data frame
- `rename`: rename variables in a data frame
- `select`: return a subset of the columns of a data frame, using a flexible notation

Partially based on *R Programming for Data Science*

Grammar of `dplyr`

Verbs (continued):

- `mutate`: add new variables/columns or transform existing variables
- `distinct`: returns only the unique values in a table
- `summarize`: generate summary statistics of different variables in the data frame, possibly within strata
- `group_by`: breaks down a dataset into specified groups of rows

Partially based on *R Programming for Data Science*

Example: Baby Names

```
> library("dplyr", verbose=FALSE)
> library("babynames")
> ls()
character(0)
> babynames <- babynames::babynames
> ls()
[1] "babynames"
```

babynames Object

```
> class(babynames)
[1] "tbl_df"     "tbl"        "data.frame"
> dim(babynames)
[1] 1825433       5
```

```
> babynames
Source: local data frame [1,825,433 x 5]

    year   sex      name     n       prop
   (dbl) (chr)     (chr) (int)      (dbl)
1   1880     F      Mary  7065 0.07238359
2   1880     F      Anna  2604 0.02667896
3   1880     F      Emma  2003 0.02052149
4   1880     F Elizabeth  1939 0.01986579
5   1880     F    Minnie  1746 0.01788843
6   1880     F  Margaret  1578 0.01616720
7   1880     F       Ida  1472 0.01508119
8   1880     F     Alice  1414 0.01448696
9   1880     F    Bertha  1320 0.01352390
10  1880     F     Sarah  1288 0.01319605
..   ...   ...       ...   ...         ...
```

Peek at the Data

```
> set.seed(201)
> sample_n(babynames, 10)
Source: local data frame [10 x 5]

    year   sex    name     n         prop
   (dbl) (chr)   (chr) (int)        (dbl)
1   1991     M  Esaias     5 2.359700e-06
```

```
2   1933     F   Maida    33 3.155410e-05
3   1967     M   Alvis    33 1.853916e-05
4   1905     M Gaylord    11 7.679151e-05
5   1993     F Kyleigh   157 7.965969e-05
6   1927     M   Della     8 6.886519e-06
7   1908     F Luberta    12 3.384753e-05
8   1968     F  Andrea  7086 4.145300e-03
9   1921     F Ardelle    50 3.907288e-05
10  1955     M  Dainel     7 3.351657e-06
> # try also sample_frac(babynames, 6e-6)
```

%>% Operator

Originally from R package `magrittr`. Provides a mechanism for chaining commands with a forward-pipe operator, %>%.

```
> x <- 1:10
>
> x %>% log(base=10) %>% sum
[1] 6.559763
>
> sum(log(x,base=10))
[1] 6.559763
```

```
> babynames %>% sample_n(5)
Source: local data frame [5 x 5]

   year   sex    name     n         prop
  (dbl) (chr)   (chr) (int)        (dbl)
1  1979     M   Sunil    42 2.344364e-05
2  1996     F  Kelina     5 2.608857e-06
3  1991     F  Gimena     7 3.443326e-06
4  1979     M Neilson     9 5.023636e-06
5  1984     F Romelia     5 2.774045e-06
```

filter()

```
> filter(babynames, year==1880, sex=="F")
Source: local data frame [942 x 5]

    year   sex      name     n       prop
   (dbl) (chr)     (chr) (int)      (dbl)
```

```
1   1880     F      Mary  7065 0.07238359
2   1880     F      Anna  2604 0.02667896
3   1880     F      Emma  2003 0.02052149
4   1880     F Elizabeth  1939 0.01986579
5   1880     F    Minnie  1746 0.01788843
6   1880     F  Margaret  1578 0.01616720
7   1880     F       Ida  1472 0.01508119
8   1880     F     Alice  1414 0.01448696
9   1880     F    Bertha  1320 0.01352390
10  1880     F     Sarah  1288 0.01319605
..   ...   ...       ...   ...        ...
> # same as filter(babynames, year==1880 & sex=="F")
```

```
> filter(babynames, year==1880, sex=="F", n > 5000)
Source: local data frame [1 x 5]

   year   sex  name     n       prop
  (dbl) (chr) (chr) (int)      (dbl)
1  1880     F  Mary  7065 0.07238359
```

arrange()

```
> arrange(babynames, name, year, sex)
Source: local data frame [1,825,433 x 5]

    year   sex  name     n         prop
   (dbl) (chr) (chr) (int)        (dbl)
1   2007     M Aaban     5 2.260251e-06
2   2009     M Aaban     6 2.834029e-06
3   2010     M Aaban     9 4.390297e-06
4   2011     M Aaban    11 5.429927e-06
5   2012     M Aaban    11 5.440091e-06
6   2013     M Aaban    14 6.961721e-06
7   2014     M Aaban    16 7.882569e-06
8   2011     F Aabha     7 3.622491e-06
9   2012     F Aabha     5 2.587144e-06
10  2014     F Aabha     9 4.642684e-06
..   ...   ...   ...   ...          ...
```

arrange()

```
> arrange(babynames, desc(name), desc(year), sex)
Source: local data frame [1,825,433 x 5]

    year   sex      name     n         prop
   (dbl) (chr)     (chr) (int)        (dbl)
1   2010     M     Zzyzx     5 2.439054e-06
2   2014     M     Zyyon     6 2.955964e-06
3   2010     F   Zyyanna     6 3.067323e-06
4   2009     M    Zyvion     5 2.361691e-06
5   2010     M Zytavious     6 2.926865e-06
6   2009     M Zytavious     7 3.306368e-06
7   2007     M Zytavious     6 2.712301e-06
8   2006     M Zytavious     7 3.196664e-06
9   2005     M Zytavious     5 2.352830e-06
10  2004     M Zytavious     6 2.841628e-06
..   ...   ...       ...   ...          ...
```

rename()

```
> rename(babynames, number=n)
Source: local data frame [1,825,433 x 5]

    year   sex      name number       prop
   (dbl) (chr)     (chr)  (int)      (dbl)
1   1880     F      Mary   7065 0.07238359
2   1880     F      Anna   2604 0.02667896
3   1880     F      Emma   2003 0.02052149
4   1880     F Elizabeth   1939 0.01986579
5   1880     F    Minnie   1746 0.01788843
6   1880     F  Margaret   1578 0.01616720
7   1880     F       Ida   1472 0.01508119
8   1880     F     Alice   1414 0.01448696
9   1880     F    Bertha   1320 0.01352390
10  1880     F     Sarah   1288 0.01319605
..   ...   ...       ...    ...        ...
```

select()

```
> select(babynames, sex, name, n)
Source: local data frame [1,825,433 x 3]

     sex      name     n
   (chr)     (chr) (int)
1      F      Mary  7065
2      F      Anna  2604
3      F      Emma  2003
4      F Elizabeth  1939
5      F    Minnie  1746
6      F  Margaret  1578
7      F       Ida  1472
8      F     Alice  1414
9      F    Bertha  1320
10     F     Sarah  1288
..   ...       ...   ...
> # same as select(babynames, sex:n)
```

Renaming with `select()`

```
> select(babynames, sex, name, number=n)
Source: local data frame [1,825,433 x 3]

     sex      name number
   (chr)     (chr)  (int)
1      F      Mary   7065
2      F      Anna   2604
3      F      Emma   2003
4      F Elizabeth   1939
5      F    Minnie   1746
6      F  Margaret   1578
7      F       Ida   1472
8      F     Alice   1414
9      F    Bertha   1320
10     F     Sarah   1288
..   ...       ...    ...
```

`mutate()`

```
> mutate(babynames, total_by_year=round(n/prop))
Source: local data frame [1,825,433 x 6]
```

```
    year   sex      name     n       prop total_by_year
   (dbl) (chr)     (chr) (int)      (dbl)         (dbl)
1   1880     F      Mary  7065 0.07238359         97605
2   1880     F      Anna  2604 0.02667896         97605
3   1880     F      Emma  2003 0.02052149         97605
4   1880     F Elizabeth  1939 0.01986579         97605
5   1880     F    Minnie  1746 0.01788843         97605
6   1880     F  Margaret  1578 0.01616720         97605
7   1880     F       Ida  1472 0.01508119         97605
8   1880     F     Alice  1414 0.01448696         97605
9   1880     F    Bertha  1320 0.01352390         97605
10  1880     F     Sarah  1288 0.01319605         97605
..   ...   ...       ...   ...        ...           ...
> # see also transmutate
```

No. Individuals by Year and Sex

Let's put a few things together now adding the function `distinct()`...

```
> babynames %>% mutate(total_by_year=round(n/prop)) %>%
+   select(sex, year, total_by_year) %>% distinct()
Source: local data frame [270 x 3]

     sex  year total_by_year
   (chr) (dbl)         (dbl)
1      F  1880         97605
2      M  1880        118400
3      F  1881         98856
4      M  1881        108284
5      F  1882        115698
6      M  1882        122033
7      F  1883        120064
8      M  1883        112480
9      F  1884        137588
10     M  1884        122741
..   ...   ...           ...
```

summarize()

```
> summarize(babynames, mean_n = mean(n), median_n = median(n),
+           number_sex = n_distinct(sex),
+           distinct_names = n_distinct(name))
```

```
Source: local data frame [1 x 4]

    mean_n median_n number_sex distinct_names
     (dbl)    (int)      (int)          (int)
1 184.6879       12          2          93889
```

group_by()

```
> babynames %>% group_by(year, sex)
Source: local data frame [1,825,433 x 5]
Groups: year, sex [270]

    year   sex      name     n       prop
   (dbl) (chr)     (chr) (int)      (dbl)
1   1880     F      Mary  7065 0.07238359
2   1880     F      Anna  2604 0.02667896
3   1880     F      Emma  2003 0.02052149
4   1880     F Elizabeth  1939 0.01986579
5   1880     F    Minnie  1746 0.01788843
6   1880     F  Margaret  1578 0.01616720
7   1880     F       Ida  1472 0.01508119
8   1880     F     Alice  1414 0.01448696
9   1880     F    Bertha  1320 0.01352390
10  1880     F     Sarah  1288 0.01319605
..   ...   ...       ...   ...         ...
```

No. Individuals by Year and Sex

```
> babynames %>% group_by(year, sex) %>%
+   summarize(total_by_year=sum(n))
Source: local data frame [270 x 3]
Groups: year [?]

    year   sex total_by_year
   (dbl) (chr)         (int)
1   1880     F         90993
2   1880     M        110491
3   1881     F         91954
4   1881     M        100745
5   1882     F        107850
6   1882     M        113688
7   1883     F        112321
```

```
8   1883     M        104629
9   1884     F        129022
10  1884     M        114445
..   ...    ...           ...
```

Compare to earlier slide. Why the difference?

How Many Distinct Names?

```
> babynames %>% group_by(sex) %>%
+   summarize(mean_n = mean(n),
+             distinct_names_sex = n_distinct(name))
Source: local data frame [2 x 3]

    sex   mean_n distinct_names_sex
  (chr)    (dbl)              (int)
1     F 154.4542              64911
2     M 228.6588              39199
```

Most Popular Names

```
> top_names <- babynames %>% group_by(year, sex) %>%
+   summarize(top_name = name[which.max(n)])
>
> head(top_names)
Source: local data frame [6 x 3]
Groups: year [3]

   year   sex top_name
  (dbl) (chr)    (chr)
1  1880     F     Mary
2  1880     M     John
3  1881     F     Mary
4  1881     M     John
5  1882     F     Mary
6  1882     M     John
```

Most Popular Names

Recent Years

```
> tail(top_names, n=10)
Source: local data frame [10 x 3]
Groups: year [5]

    year   sex top_name
   (dbl) (chr)    (chr)
1   2010     F Isabella
2   2010     M    Jacob
3   2011     F   Sophia
4   2011     M    Jacob
5   2012     F   Sophia
6   2012     M    Jacob
7   2013     F   Sophia
8   2013     M     Noah
9   2014     F     Emma
10  2014     M     Noah
```

Most Popular Female Names

1990s

```
> top_names %>% filter(year >= 1990 & year < 2000, sex=="F")
Source: local data frame [10 x 3]
Groups: year [10]

    year   sex top_name
   (dbl) (chr)    (chr)
1   1990     F  Jessica
2   1991     F   Ashley
3   1992     F   Ashley
4   1993     F  Jessica
5   1994     F  Jessica
6   1995     F  Jessica
7   1996     F    Emily
8   1997     F    Emily
9   1998     F    Emily
10  1999     F    Emily
```

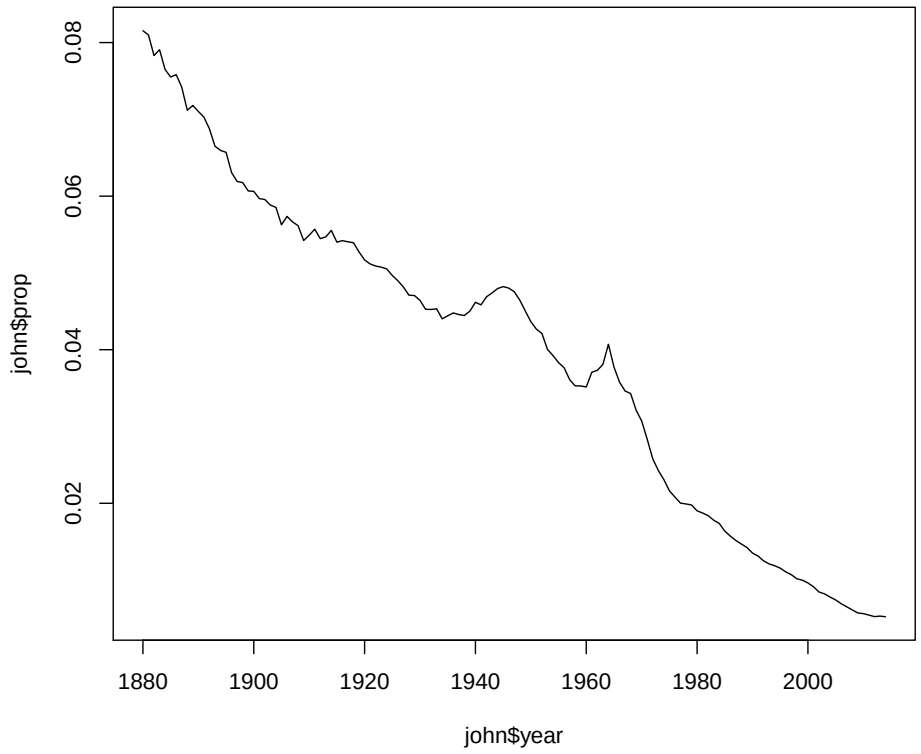
Most Popular Male Names

1990s

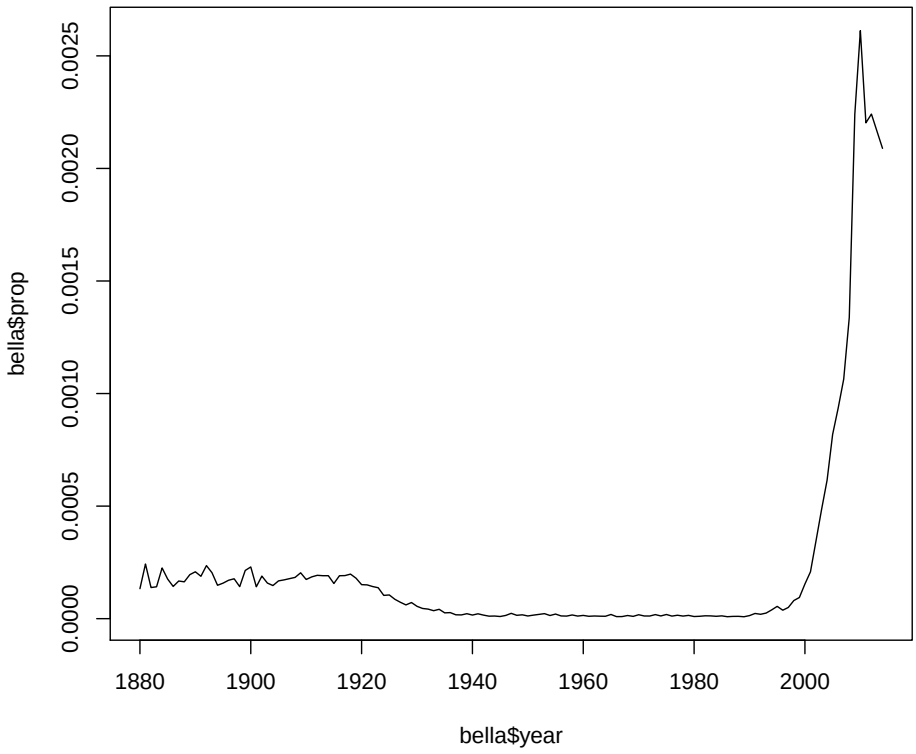
```
> top_names %>% filter(year >= 1990 & year < 2000, sex=="M")
Source: local data frame [10 x 3]
Groups: year [10]

    year   sex top_name
   (dbl) (chr)    (chr)
1   1990     M  Michael
2   1991     M  Michael
3   1992     M  Michael
4   1993     M  Michael
5   1994     M  Michael
6   1995     M  Michael
7   1996     M  Michael
8   1997     M  Michael
9   1998     M  Michael
10  1999     M    Jacob
```

```
> # Analyzing the name 'John'
> john <- babynames %>% filter(sex=="M", name=="John")
> plot(john$year, john$prop, type="l")
```




```
> # Analyzing the name 'Bella'
> bella <- babynames %>% filter(sex=="F", name=="Bella")
> plot(bella$year, bella$prop, type="l")
```



Additional Examples

You should study additional tutorials of `dplyr` that utilize other data sets:

- Read the `dplyr` introductory vignette
- Read the examples given in *R Programming for Data Science*, the "Managing Data Frames with the `dplyr` Package" chapter

Additional `dplyr` Features

- We've only scratched the surface – many interesting demos of `dplyr` can be found online
- `dplyr` can work with other data frame backends such as SQL databases
- There is an SQL interface for relational databases via the `DBI` package
- `dplyr` can be integrated with the `data.table` package for large fast tables
- There is a healthy rivalry between `dplyr` and `data.table`

Getting Data In and Out of R

Some Functions for Data In/Out

- We have already used the `load()` function to load `.Rdata` files; the `save()` function saves R objects to `.RData` files
- The function `read.table()` is a standard function for reading in data from a **text** file
- Similarly `write.table()` is a standard function for writing data to a **text** file
- Study the help files:

```
> ?read.table
> ?write.table
```

Key Arguments

For `read.table`:

- `file` – the name of a file, or a connection
- `header` – logical indicating if the file has a header line
- `sep` – character string indicating how the values are separated
- `colClasses` – character vector indicating the class of each column
- `nrows` – maximum number of rows to be read in
- `skip` – number of lines to skip from beginning of file
- `stringsAsFactors` – a logical indicating if character strings should be coerced to factors

There are similar arguments for `write.table`.

CSV Files

- A CSV file is a "comma separated value" file, meaning the entries are separated by commas
- The functions `read.csv()` and `write.csv()` are specialized versions of `read.table()` and `write.table()` where essentially it sets `sep=","`
- Many data sets are distributed as `.csv` files, so these are worth knowing about
- Read the help files, `?read.csv` and `?write.csv`

`airquality` Data: Out

Let's write the `airquality` data frame to a tab-delimited text file (aka TSV) and a CSV file.

```
> data("airquality", package="datasets")
> head(airquality, n=8)
  Ozone Solar.R Wind Temp Month Day
1    41     190  7.4   67     5   1
2    36     118  8.0   72     5   2
3    12     149 12.6   74     5   3
4    18     313 11.5   62     5   4
5    NA      NA 14.3   56     5   5
6    28      NA 14.9   66     5   6
7    23     299  8.6   65     5   7
8    19      99 13.8   59     5   8
>
> write.table(airquality, file="../data/airquality.txt",
+             sep="\t", row.names=FALSE)
> write.csv(airquality, file="../data/airquality.csv",
+           row.names=FALSE)
```

`airquality` Data: In

We will read in the two files we wrote in the previous slide. We first look at the top couple lines of each file using `readLines` to understand what is in the files.

```
> readLines(con="../data/airquality.txt", n=2)
[1] "\"Ozone\"\t\"Solar.R\"\t\"Wind\"\t\"Temp\"\t\"Month\"\t\"Day\""
[2] "41\t190\t7.4\t67\t5\t1"
> aq1 <- read.table(file="../data/airquality.txt", header=TRUE,
+                   sep="\t")
>
> readLines(con="../data/airquality.csv", n=2)
[1] "\"Ozone\",\"Solar.R\",\"Wind\",\"Temp\",\"Month\",\"Day\""
[2] "41,190,7.4,67,5,1"
> aq2 <- read.csv(file="../data/airquality.csv", header=TRUE)
>
> dim(aq1) == dim(aq2)
[1] TRUE TRUE
> sum(aq1 != aq2, na.rm=TRUE)
[1] 0
```

`readr` Package

There are a number of R packages that provide more sophisticated tools for getting data in and out of R, especially as data sets have become larger and larger.

One of those packages is `readr`. It reads and writes data quickly, provides a useful status bar for large files, and does a good job at determining data types.

`readr` is organized similarly to the base R functions. For example, there are functions `read_table`, `read_csv`, `write_tsv`, and `write_csv`.

Scraping from the Web (Ex. 1)

There are several packages that facilitate "scraping" data from the web, including `rvest` demonstrated here.

```
> library("rvest")
> schedule <- read_html("http://sml201.github.io/schedule/")
> first_table <- html_table(schedule)[[1]]
> names(first_table) <- c("week", "topics", "reading")
> first_table[4,"week"]
[1] 4
> first_table[4,"topics"] %>% strsplit(split="  ")
[[1]]
[1] "Getting data in and out of R"
[2] "Exploring and visualizing data (part 1)"
> first_table[4,"reading"] %>% strsplit(split="  ")
[[1]]
[1] "ADS Ch. 4"           " EDAR, Ch. 3-9"
[3] "EDAS, Ch. 5, 10, 11" "RPDS, Ch. 6, 7"
> grep("EDAR", first_table$reading)
[1]  3  4  5 11
```

Scraping from the Web (Ex. 2)

The `rvest` documentation recommends SelectorGadget, which is "a javascript bookmarklet that allows you to interactively figure out what css selector you need to extract desired components from a page."

```
> usg_url <- "http://princetonusg.com/meet-your-usg-officers/"
> usg <- read_html(usg_url)
> officers <- html_nodes(usg, ".team-member-name") %>%
+             html_text
> head(officers, n=20)
```

```
 [1] "Ella Cheng"         "Aleksandra Czulak"
 [3] "Jeremy Burton"      "Hunter Dong"
 [5] "Sung Won Chang"     "Naimah Hakim"
 [7] "Jacob Cannon"       "Dallas Nan"
 [9] "Brandon McGhee"     "Christopher Hsu"
[11] "Ethan Marcus"       "Lavinia Liang"
[13] "Miranda Rosen"      "Shobhit Kumar"
[15] "Pooja Patel"        "Deana Davoudiasl"
[17] "Kristen Coke"       "Kishan Bhatt"
[19] "Cailin Hong"        "Paul Draper"
```

APIs

API stands for "application programming interface" which is a set of routines, protocols, and tools for building software and applications.

A specific website may provide an API for scraping data from that website.

There are R packages that provide an interface with specific APIs, such as the `twitteR` package.

Exploratory Data Analysis

Numerical Summaries of Data

Data Visualization Basics

Extras

License

https://github.com/SML201/lectures/blob/master/LICENSE.md

Source Code

https://github.com/SML201/lectures/tree/master/week4

Session Information

```
> sessionInfo()
R version 3.2.3 (2015-12-10)
Platform: x86_64-apple-darwin13.4.0 (64-bit)
Running under: OS X 10.11.3 (El Capitan)

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods
[7] base

other attached packages:
[1] babynames_0.2.0 dplyr_0.4.3     rvest_0.3.1
[4] xml2_0.1.2      knitr_1.12.3    magrittr_1.5
[7] devtools_1.10.0

loaded via a namespace (and not attached):
 [1] Rcpp_0.12.3     R6_2.1.2        stringr_1.0.0
 [4] httr_1.1.0      highr_0.5.1     tools_3.2.3
 [7] parallel_3.2.3  DBI_0.3.1       selectr_0.2-3
[10] htmltools_0.3   yaml_2.1.13     lazyeval_0.1.10
[13] digest_0.6.9    assertthat_0.1  formatR_1.2.1
[16] curl_0.9.6      memoise_1.0.0   evaluate_0.8
[19] rmarkdown_0.9.2 stringi_1.0-1   XML_3.98-1.3
```