Data Cleaning

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Data

- We will be using multiple data sets in this lecture:
  - Salary, Monument, Circulator, and Restaurant from OpenBaltimore: `https://data.baltimorecity.gov/browse?limitTo=datasets`
  - Gap Minder - very interesting way of viewing longitudinal data
    - Data is here - `http://www.gapminder.org/data/`
  - `http://spreadsheets.google.com/pub?key=rMsQHawTObBb6_U2ESjKXYw&output=xls`

Data Cleaning

In general, data cleaning is a process of investigating your data for inaccuracies, or recoding it in a way that makes it more manageable.
MOST IMPORTANT RULE - LOOK AT YOUR DATA!
Again - `table`, `summarize`, `is.na`, `any`, `all` are useful.

Dealing with Missing Data

Missing data types

One of the most important aspects of data cleaning is missing values.
Types of "missing" data:

- `NA` - general missing data
- `NaN` - stands for "**N**ot **a** **N**umber", happens when you do 0/0.
- `Inf` and `-Inf` - Infinity, happens when you take a positive number (or negative number) by 0.

Finding Missing data

Each missing data type has a function that returns `TRUE` if the data is missing:

- `NA` - `is.na`
- `NaN` - `is.nan`
- `Inf` and `-Inf` - `is.infinite`
- `is.finite` returns `FALSE` for all missing data and `TRUE` for non-missing
- `complete.cases` on a `data.frame`/`matrix` returns `TRUE` if all values in that row of the object are not missing.

Missing Data with Logicals

One important aspect (esp with subsetting) is that logical operations return `NA` for `NA` values. Think about it, the data could be > 2 or not we don't know, so `R` says there is no `TRUE` or `FALSE`, so that is missing:

```
x = c(0, NA, 2, 3, 4)
x > 2
```

```
[1] FALSE    NA FALSE  TRUE  TRUE
```

Missing Data with Logicals

What to do? What if we want if `x > 2` and `x` isn't `NA`?
Don't do `x != NA`, do `x > 2` and `x` is NOT `NA`:

```
x != NA
```

```
[1] NA NA NA NA NA
```

```
x > 2 & !is.na(x)
```

```
[1] FALSE FALSE FALSE  TRUE  TRUE
```

Missing Data with Logicals

What about seeing if a value is equal to multiple values? You can do `(x == 1 | x == 2) & !is.na(x)`, but that is not efficient. Introduce the `%in%` operator:

```
(x == 0 | x == 2) # has NA
```

```
[1]  TRUE    NA  TRUE FALSE FALSE
```

```
(x == 0 | x == 2) & !is.na(x) # No NA
```

```
[1]  TRUE FALSE  TRUE FALSE FALSE
```

```
x %in% c(0, 2) # NEVER has NA and returns logical
```

```
[1]  TRUE FALSE  TRUE FALSE FALSE
```

Missing Data with Operations

Similarly with logicals, operations/arithmetic with `NA` will result in `NA`s:

```
x + 2
```

```
[1]  2 NA  4  5  6
```

```
x * 2
```

```
[1]  0 NA  4  6  8
```

Tables and Tabulations

Creating One-way Tables

Here we will use `table` to make tabulations of the data. Look at `?table` to see options for missing data.

```
table(x)
```

```
x
0 2 3 4
1 1 1 1
```

```
table(x, useNA = "ifany")
```

```
x
   0    2    3    4 <NA>
   1    1    1    1    1
```

Creating One-way Tables

You can set `useNA = "always"` to have it always have a column for `NA`

```
table(c(0, 1, 2, 3, 2, 3, 3, 2,2, 3),
        useNA = "always")
```

```
   0    1    2    3 <NA>
   1    1    4    4    0
```

Creating Two-way Tables

A two-way table. If you pass in 2 vectors, `table` creates a 2-dimensional table.

```
tab <- table(c(0, 1, 2, 3, 2, 3, 3, 2,2, 3),
             c(0, 1, 2, 3, 2, 3, 3, 4, 4, 3),
              useNA = "always")
```

Finding Row or Column Totals

`margin.table` finds the marginal sums of the table. `margin` is 1 for rows, 2 for columns in general in `R`. Here is the column sums of the table:

```
margin.table(tab, 2)
```

```
  0   1   2   3   4 <NA>
  1   1   2   4   2    0
```

Proportion Tables

`prop.table` finds the marginal proportions of the table. Think of it dividing the table by it's respective marginal totals. If `margin` not set, divides by overall total.

```
prop.table(tab)
```

```
          0   1   2   3   4 <NA>
  0     0.1 0.0 0.0 0.0 0.0  0.0
  1     0.0 0.1 0.0 0.0 0.0  0.0
  2     0.0 0.0 0.2 0.0 0.2  0.0
  3     0.0 0.0 0.0 0.4 0.0  0.0
  <NA> 0.0 0.0 0.0 0.0 0.0  0.0
```

```
prop.table(tab,1)
```

```
          0   1   2   3   4 <NA>
  0     1.0 0.0 0.0 0.0 0.0  0.0
```

Download Salary FY2014 Data

From https://data.baltimorecity.gov/City-Government/Baltimore-City-Employee-Salaries-FY2014/2j28-xzd7
http://www.aejaffe.com/summerR_2016/data/Baltimore_City_Employee_Salaries_FY2014.csv
Read the CSV into R Sal:

```
Sal = read.csv("http://www.aejaffe.com/summerR_2016/data/Ba
                  as.is = TRUE)
```

Checking for logical conditions

- any() - checks if there are any TRUEs
- all() - checks if ALL are true

```
head(Sal,2)
```

```
                Name                          JobTitle AgencyID
1  Aaron,Keontae E                AIDE BLUE CHIP   W02200
2 Aaron,Patricia G Facilities/Office Services II   A03031
                Agency   HireDate AnnualSalary  GrossPay
1      Youth Summer   06/10/2013    $11310.00   $873.63
2 OED-Employment Dev  10/24/1979    $53428.00 $52868.38
```

```
any(is.na(Sal$Name)) # are there any NAs?
```

```
[1] FALSE
```

Recoding Variables

Example of Recoding: base R

For example, let's say gender was coded as Male, M, m, Female, F, f. Using Excel to find all of these would be a matter of filtering and changing all by hand or using if statements.
In R, you can simply do something like:

```
data$gender[data$gender %in%
    c("Male", "M", "m")] <- "Male"
```

Example of Cleaning: more complicated

Sometimes though, it's not so simple. That's where functions that find patterns come in very useful.

```
table(gender)
```

```
gender
     F FeMAle FEMALE     Fm      M     Ma   mAle   Male    M
    75     82     74     89     89     79     87     89
   Man  Woman
    73     80
```

String functions

Pasting strings with paste and paste0

Paste can be very useful for joining vectors together:

```
paste("Visit", 1:5, sep = "_")
```

```
[1] "Visit_1" "Visit_2" "Visit_3" "Visit_4" "Visit_5"
```

```
paste("Visit", 1:5, sep = "_", collapse = " ")
```

```
[1] "Visit_1 Visit_2 Visit_3 Visit_4 Visit_5"
```

```
paste("To", "is going be the ", "we go to the store!", sep
```

```
[1] "Today is going be the day we go to the store!"
```

```
# and paste0 can be even simpler see ?paste0
paste0("Visit",1:5)
```

```
[1] "Visit1" "Visit2" "Visit3" "Visit4" "Visit5"
```

Paste Depicting How Collapse Works

```
paste(1:5)
```

```
[1] "1" "2" "3" "4" "5"
```

```
paste(1:5, collapse = " ")
```

```
[1] "1 2 3 4 5"
```

Useful String Functions

Useful String functions

- `toupper()`, `tolower()` - uppercase or lowercase your data:
- `str_trim()` (in the `stringr` package) or `trimws` in base
  - will trim whitespace
- `nchar` - get the number of characters in a string
- `paste()` - paste strings together with a space
- `paste0` - paste strings together with no space as default

The `stringr` package

Like `dplyr`, the `stringr` package:

- Makes some things more intuitive
- Is different than base R
- Is used on forums for answers
- Has a standard format for most functions
  - the first argument is a string like first argument is a `data.frame` in `dplyr`

Splitting/Find/Replace and Regular Expressions

- R can do much more than find exact matches for a whole string
- Like Perl and other languages, it can use regular expressions.
- What are regular expressions?
  - Ways to search for specific strings
  - Can be very complicated or simple
  - Highly Useful - think "Find" on steroids

A bit on Regular Expressions

- `http://www.regular-expressions.info/reference.html`
- They can use to match a large number of strings in one statement
- `.` matches any single character
- `*` means repeat as many (even if 0) more times the last character
- `?` makes the last thing optional
- `^` matches start of vector `^a` - starts with "a"
- `$` matches end of vector `b$` - ends with "b"

Splitting Strings

Substringing

Very similar:
Base R

- `substr(x, start, stop)` - substrings from position start to position stop
- `strsplit(x, split)` - splits strings up - returns list!

`stringr`

- `str_sub(x, start, end)` - substrings from position start to position end
- `str_split(string, pattern)` - splits strings up - returns list!

Splitting String: base R

In base R, `strsplit` splits a vector on a string into a list

```
x <- c("I really", "like writing", "R code programs")
y <- strsplit(x, split = " ") # returns a list
y
```

```
[[1]]
[1] "I"      "really"

[[2]]
[1] "like"    "writing"

[[3]]
[1] "R"        "code"     "programs"
```

Splitting String: stringr

`stringr::str_split` do the same thing:

```
library(stringr)
y2 <- str_split(x, " ") # returns a list
y2
```

```
[[1]]
[1] "I"       "really"

[[2]]
[1] "like"    "writing"

[[3]]
[1] "R"         "code"      "programs"
```

Using a fixed expression

One example case is when you want to split on a period ".". In regular expressions . means **ANY** character, so

```
str_split("I.like.strings", ".")
```

```
[[1]]
 [1] "" "" "" "" "" "" "" "" "" "" "" "" "" "" ""
```

```
str_split("I.like.strings", fixed("."))
```

```
[[1]]
[1] "I"       "like"    "strings"
```

Let's extract from y

```
suppressPackageStartupMessages(library(dplyr)) # must be l
y[[2]]
```

```
[1] "like"    "writing"
```

```
sapply(y, dplyr::first) # on the fly
```

```
[1] "I"    "like" "R"
```

```
sapply(y, nth, 2) # on the fly
```

```
[1] "really"  "writing" "code"
```

```
sapply(y, last) # on the fly
```

```
[1] "really"   "writing"  "programs"
```

'Find' functions: base R

`grep`: `grep`, `grepl`, `regexpr` and `gregexpr` search for matches to argument pattern within each element of a character vector: they differ in the format of and amount of detail in the results.
`grep(pattern, x, fixed=FALSE)`, where:

- pattern = character string containing a regular expression to be matched in the given character vector.
- x = a character vector where matches are sought, or an object which can be coerced by as.character to a character vector.
- If fixed=TRUE, it will do exact matching for the phrase anywhere in the vector (regular find)

'Find' functions: `stringr`

`str_detect`, `str_subset`, `str_replace`, and `str_replace_all` search for matches to argument pattern within each element of a character vector: they differ in the format of and amount of detail in the results.

- `str_detect` - returns `TRUE` if `pattern` is found
- `str_subset` - returns only the strings which pattern were detected
  - convenient wrapper around `x[str_detect(x, pattern)]`
- `str_extract` - returns only strings which pattern were detected, but ONLY the pattern
- `str_replace` - replaces `pattern` with `replacement` the first time
- `str_replace_all` - replaces `pattern` with `replacement` as many times matched

'Find' functions: stringr compared to base R

Base R does not use these functions. Here is a "translator" of the `stringr` function to base R functions

- `str_detect` - similar to `grepl` (return logical)
- `grep(value = FALSE)` is similar to `which(str_detect())`
- `str_subset` - similar to `grep(value = TRUE)` - return value of matched
- `str_replace` - similar to `sub` - replace one time
- `str_replace_all` - similar to `gsub` - replace many times

Let's look at modifier for `stringr`

`?modifiers`

- `fixed` - match everything exactly
- `regexp` - default - uses **reg**ular **exp**ressions
- `ignore_case` is an option to not have to use `tolower`

Important Comparisons

Base R:

- Argument order is `(pattern, x)`
- Uses option `(fixed = TRUE)`

`stringr`

- Argument order is `(string, pattern)` aka `(x, pattern)`
- Uses function `fixed(pattern)`

'Find' functions: Finding Indices

These are the indices where the pattern match occurs:

```
grep("Rawlings",Sal$Name)
```

```
[1] 13832 13833 13834 13835
```

```
which(grepl("Rawlings", Sal$Name))
```

```
[1] 13832 13833 13834 13835
```

```
which(str_detect(Sal$Name, "Rawlings"))
```

```
[1] 13832 13833 13834 13835
```

'Find' functions: Finding Logicals

These are the indices where the pattern match occurs:

```
head(grepl("Rawlings",Sal$Name))
```

```
[1] FALSE FALSE FALSE FALSE FALSE FALSE
```

```
head(str_detect(Sal$Name, "Rawlings"))
```

```
[1] FALSE FALSE FALSE FALSE FALSE FALSE
```

'Find' functions: finding values, base R

```
grep("Rawlings",Sal$Name,value=TRUE)
```

```
[1] "Rawlings,Kellye A"                "Rawlings,MarqWell D"
[3] "Rawlings,Paula M"                 "Rawlings-Blake,Stephanie
```

```
Sal[grep("Rawlings",Sal$Name),]
```

```
                              Name                JobTitle Agenc
13832            Rawlings,Kellye A EMERGENCY DISPATCHER   A40
13833          Rawlings,MarqWell D       AIDE BLUE CHIP   W02
13834            Rawlings,Paula M       COMMUNITY AIDE   A04
13835 Rawlings-Blake,Stephanie C                MAYOR   A01
                       Agency   HireDate AnnualSalary   GrossP
13832 M-R Info Technology  01/06/2003    $47980.00  $68426.
13833       Youth Summer   06/15/2012    $11310.00    $507.
13834      R&P-Recreation  12/10/2007    $19802.00   $8195.
13835       Mayors Office  12/07/1995   $163365.00 $161219.
```

'Find' functions: finding values, stringr and dplyr

```
str_subset(Sal$Name, "Rawlings")
```

```
[1] "Rawlings,Kellye A"          "Rawlings,MarqWell D"
[3] "Rawlings,Paula M"           "Rawlings-Blake,Stephanie
```

```
Sal %>% filter(str_detect(Name, "Rawlings"))
```

	Name	JobTitle	AgencyID
1	Rawlings,Kellye A	EMERGENCY DISPATCHER	A40302
2	Rawlings,MarqWell D	AIDE BLUE CHIP	W02384
3	Rawlings,Paula M	COMMUNITY AIDE	A04015
4	Rawlings-Blake,Stephanie C	MAYOR	A01001

	Agency	HireDate	AnnualSalary	GrossPay
1	M-R Info Technology	01/06/2003	$47980.00	$68426.73
2	Youth Summer	06/15/2012	$11310.00	$507.50
3	R&P-Recreation	12/10/2007	$19802.00	$8195.79
4	Mayors Office	12/07/1995	$163365.00	$161219.24

Showing differnce in `str_extract`

`str_extract` extracts just the matched string

```
ss = str_extract(Sal$Name, "Rawling")
head(ss)
```

```
[1] NA NA NA NA NA NA
```

```
ss[ !is.na(ss)]
```

```
[1] "Rawling" "Rawling" "Rawling" "Rawling"
```

Showing differnce in str_extract and str_extract_all

str_extract_all extracts all the matched strings

```
head(str_extract(Sal$AgencyID, "\\d"))
```

```
[1] "0" "0" "2" "6" "9" "4"
```

```
head(str_extract_all(Sal$AgencyID, "\\d"), 2)
```

```
[[1]]
[1] "0" "2" "2" "0" "0"

[[2]]
[1] "0" "3" "0" "3" "1"
```

Using Regular Expressions

- Look for any name that starts with:
  - Payne at the beginning,
  - Leonard and then an S
  - Spence then capital C

```
head(grep("^Payne.*", x = Sal$Name, value = TRUE), 3)
```

```
[1] "Payne El,Jackie"          "Payne Johnson,Nickole A"
[3] "Payne,Chanel"
```

```
head(grep("Leonard.?S", x = Sal$Name, value = TRUE))
```

```
[1] "Payne,Leonard S"       "Szumlanski,Leonard S"
```

```
head(grep("Spence.*C.*", x = Sal$Name, value = TRUE))
```

```
[1] "Greene,Spencer C"    "Spencer,Charles A"    "Spencer,Ch
[4] "Spencer,Clarence W"  "Spencer,Michael C"
```

Using Regular Expressions: stringr

```
head(str_subset( Sal$Name, "^Payne.*"), 3)
```

```
[1] "Payne El,Jackie"          "Payne Johnson,Nickole A"
[3] "Payne,Chanel"
```

```
head(str_subset( Sal$Name, "Leonard.?S"))
```

```
[1] "Payne,Leonard S"       "Szumlanski,Leonard S"
```

```
head(str_subset( Sal$Name, "Spence.*C.*"))
```

```
[1] "Greene,Spencer C"    "Spencer,Charles A"    "Spencer,Ch
[4] "Spencer,Clarence W"  "Spencer,Michael C"
```

Replace

Let's say we wanted to sort the data set by Annual Salary:

```
class(Sal$AnnualSalary)
```

```
[1] "character"
```

```
sort(c("1", "2", "10")) #  not sort correctly (order simply
```

```
[1] "1"  "10" "2"
```

```
order(c("1", "2", "10"))
```

```
[1] 1 3 2
```

Replace

So we must change the annual pay into a numeric:

```
head(Sal$AnnualSalary, 4)
```

```
[1] "$11310.00" "$53428.00" "$68300.00" "$62000.00"
```

```
head(as.numeric(Sal$AnnualSalary), 4)
```

```
Warning in head(as.numeric(Sal$AnnualSalary), 4): NAs intro
coercion
```

```
[1] NA NA NA NA
```

R didn't like the $ so it thought turned them all to NA.
sub() and gsub() can do the replacing part in base R.

Replacing and subbing

Now we can replace the $ with nothing (used `fixed=TRUE` because $ means ending):

```
Sal$AnnualSalary <- as.numeric(gsub(pattern = "$", replacem
                                    Sal$AnnualSalary, fixed=TRUE)
Sal <- Sal[order(Sal$AnnualSalary, decreasing=TRUE), ]
Sal[1:5, c("Name", "AnnualSalary", "JobTitle")]
```

```
                      Name AnnualSalary                JobTitle
1222  Bernstein,Gregg L         238772       STATE'S ATTORNEY
3175   Charles,Ronnie E         200000    EXECUTIVE LEVEL III
985     Batts,Anthony W         193800    EXECUTIVE LEVEL III
1343      Black,Harry E         190000    EXECUTIVE LEVEL III
16352     Swift,Michael         187200 CONTRACT SERV SPEC II
```

Replacing and subbing: stringr

We can do the same thing (with 2 piping operations!) in dplyr

```
dplyr_sal = Sal
dplyr_sal = dplyr_sal %>% mutate(
  AnnualSalary = AnnualSalary %>%
    str_replace(
      fixed("$"),
      "") %>%
    as.numeric) %>%
  arrange(desc(AnnualSalary))
check_Sal = Sal
rownames(check_Sal) = NULL
all.equal(check_Sal, dplyr_sal)
```

```
[1] TRUE
```