

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=rMsQHawT0bBb6_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!

Useful checking functions

- ▶ `is.na` - is TRUE if the data is FALSE otherwise
- ▶ `!` - negation (NOT)
 - ▶ if `is.na(x)` is TRUE, then `!is.na(x)` is FALSE
- ▶ `all` takes in a logical and will be TRUE if ALL are TRUE
 - ▶ `all(!is.na(x))` - are all values of `x` NOT NA
- ▶ `any` will be TRUE if ANY are true
 - ▶ `any(is.na(x))` - do we have any NA's in `x`?
- ▶ `complete.cases` - returns TRUE if EVERY value of a row is NOT NA
 - ▶ very stringent condition
 - ▶ FALSE missing one value (even if not important)

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 $x \neq NA$, 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.

```
(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
```

what to do?

Missing Data with Logicals: %in%

Introduce the %in% operator:

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

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

reads “return TRUE if x is in 0 or 2”. (Like `inlist` in Stata).

Missing Data with Logicals: %in%

NEVER has NA, even if you put it there (BUT DON'T DO THIS):

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

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

```
x %in% c(0, 2) | is.na(x)
```

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

Missing Data with Operations

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

```
x + 2
```

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

```
x * 2
```

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

Tables and Tabulations

Useful checking functions

- ▶ `unique` - gives you the unique values of a variable
- ▶ `table(x)` - will give a one-way table of `x`
 - ▶ `table(x, useNA = "ifany")` - will have row NA
- ▶ `table(x, y)` - will give a cross-tab of `x` and `y`

Creating One-way Tables

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

```
unique(x)
```

```
[1] 0 NA 2 3 4
```

```
table(x)
```

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

```
table(x, useNA = "ifany") # will not
```

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

Creating One-way Tables

`useNA = "ifany"` will not have NA in table heading if no NA:

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

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

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

Tables with Factors

If you use a factor, all levels will be given even if no exist! - (May be wanted or not):

```
fac = factor(c(0, 1, 2, 3, 2, 3, 3, 2,2, 3),  
            levels = 1:4)  
tab = table(fac)  
tab
```

```
fac  
1 2 3 4  
1 4 4 0
```

```
tab[ tab > 0]
```

```
fac  
1 2 3  
1 4 4
```

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 its 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/Baltimore_City_Employee_Salaries_FY2014.csv", 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 loaded  
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`, `grep1`, `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 `grep1` (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 **regular expressions**
- ▶ `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 C"
```

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

			Name	JobTitle	Agency
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	GrossPay	
13832	M-R Info Technology	01/06/2003	\$47980.00	\$68426.00	
13833	Youth Summer	06/15/2012	\$11310.00	\$507.00	
13834	R&P-Recreation	12/10/2007	\$19802.00	\$8195.00	
13835	Mayors Office	12/07/1995	\$163365.00	\$161219.00	

'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 C"
```

```
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 difference 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 difference 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,Clarence W"  
[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,Clarence W"  
[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 introduced by 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$AnnualSalary <- as.numeric(gsub(pattern = "$", replacement = "", x = 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
```