

Research and Working with Data in R

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Computational Methods in Statistics and Data Science (Stats 406)

Final Paper

- Goal: perform your own investigation using computational techniques.

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Total length: 10 - 15 pages

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- No code in paper

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Opportunity for one-on-one meetings following return of first draft.

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Second round of one-on-one meetings prior to final due date.

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- Are bicycle sharing rental station locations related to the income of a neighborhood?
 - Data: Bike share locations in Brooklyn, NY.
 - Methods: Spatial point process model of locations with parameter that controls dispersion of locations, test statistics that attended to spread and distance of locations, confidence intervals by test inversion.

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 - Methods: Multiplicative model of mass with bootstrapped confidence intervals, nearest-neighbor hypothesis test of shape-mass relationship.

Starter Projects

Three projects that include a **data set** and a **related paper** that you can use to jumpstart your project.

- School Shootings
- Bumblebee Migration and Climate Change
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You still need to **develop your own research question**.

Rubric (1/2)

Out of 80 total points:

- Intro (10): Clear research question, one or more citations to motivate research, summary of subsequent sections of paper.
- Data (10): Data source cited, several plots showing key relationships, discussion of missing data (including if there is none).
- Methods (12): Description of least three class methods, clear explanation of model and assumptions, explain techniques and algorithms to someone without STATS406 background, citation for each method (class notes and textbooks acceptable).

Rubric (2/2)

- Simulations (14): Connect relevant operating characteristics to methods, Monte Carlo investigation of operating characteristics, interpretation of results (including selection of statistics).
- Analysis (14): Apply each method to data, interpret results of tests/estimators/prediction with emphasis on research question.
- Discussion (10): Summarize research question and main findings, connect different methods into cohesive whole, present shortcomings of methods/data, offer suggestions for future research.
- Overall/Formatting/Labels/Supp. Materials (10): Include code and data in supplemental material, citation in understandable format and bibliography included, proper labels/captions for tables and graphs, no R code in paper body.

Mini Research Project

Migration patterns

The Midwest is booming, but not where you might think. Kansas City, Minneapolis, Indianapolis, Columbus, Grand Rapids, and Des Moines are the fastest-growing cities in the Midwest. . . . The coasts' loss ended up, to some extent, as Indianapolis, Minneapolis, Des Moines, and Columbus' gains, reflecting a growing flight from what are increasingly gated cities, affordable only to the affluent, the subsidized (students), and those older residents who bought when the buying was good. High housing costs – sometimes three times higher adjusted for income compared to the rising Midwest cities – make attaining homeownership all but impossible. Joel Kotkin, The Daily Beast, 2018-04-27

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How do people choose where they move? What factors are important? Can we model the growth of towns and cities?

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At time $t = 0$, each city has population $p_i = 1$. Then at each time period, a person elects to move to a city with probability

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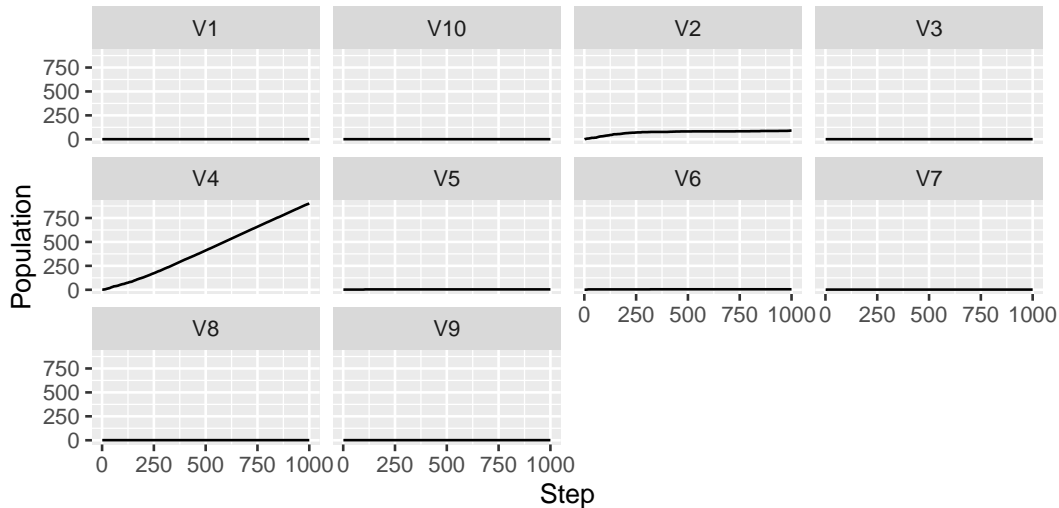
$$P(C(t) = i) = \frac{p_i(t-1)^2}{\sum_{j=1}^k p_j(t-1)^2}$$

Then the appropriate city's population is updated, and the process continues.

R implementation

```
> run_pop_process <- function(cities, steps, start = 1) {  
+   pops <- matrix(1, nrow = steps, ncol = cities)  
+   for (i in 2:steps) {  
+     prev <- pops[i - 1, ]  
+     ps <- prev^2 / sum(prev^2)  
+     which_city <- sample(1:cities, size = 1, prob = ps)  
+     prev[which_city] <- prev[which_city] + 1  
+     pops[i, ] <- prev  
+   }  
+   return(pops)  
+ }  
  
> pops <- run_pop_process(10, 1000)
```

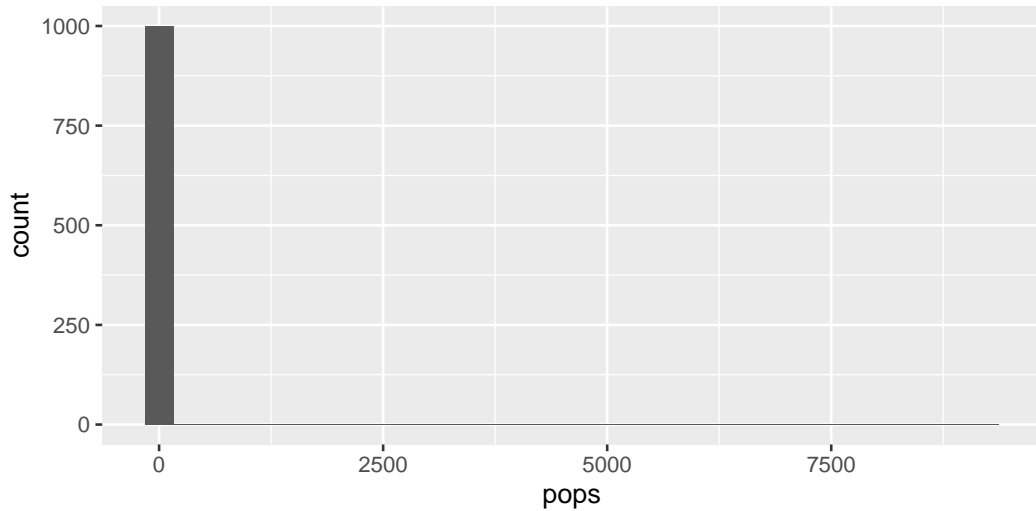
Plotting size v. time



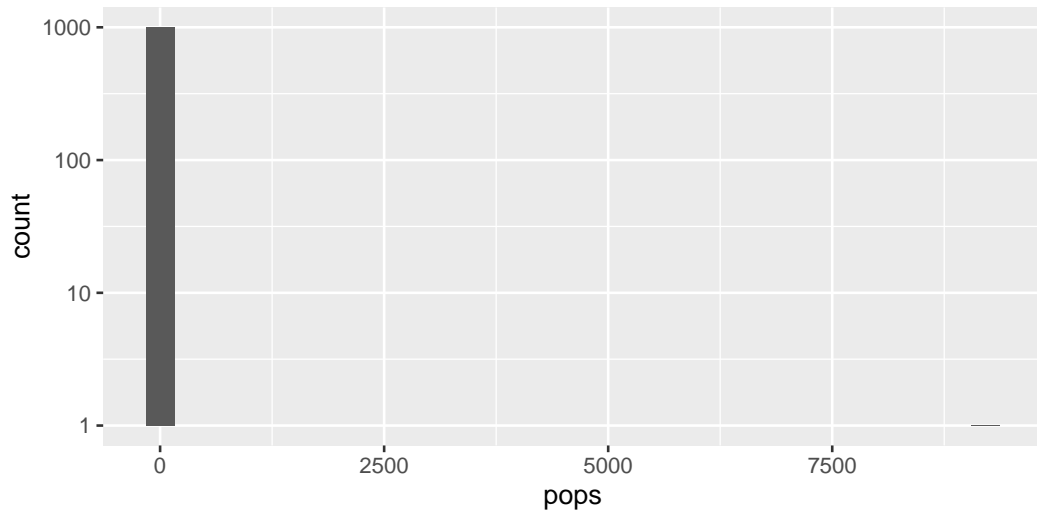
Much larger number of cites

```
> # just get the final value  
> big_pops <- run_pop_process(1000, 10000)[10000, ]  
> range(big_pops)  
  
[1]      1 9207
```

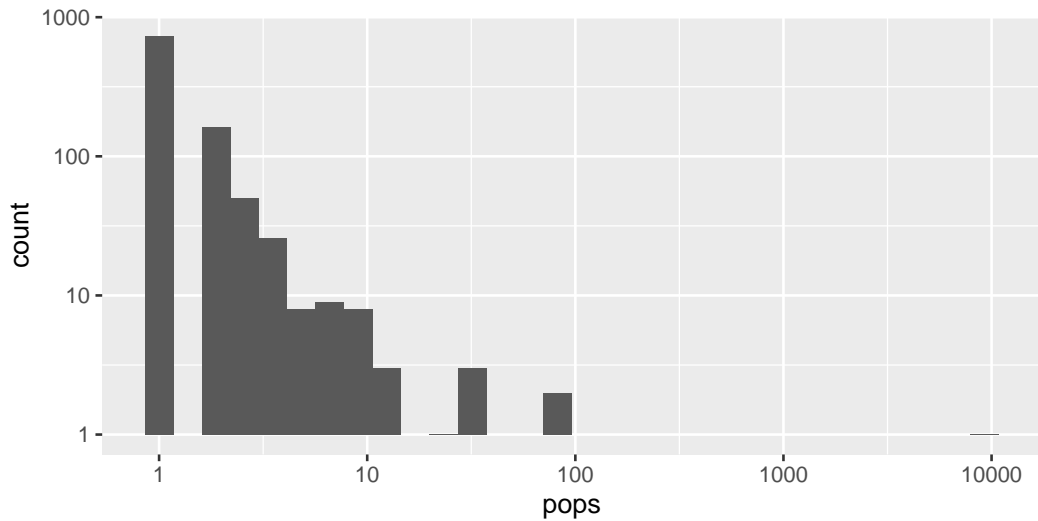
Histogram



Histogram: log y-axis



Histogram: log on both



Power law distributions

A **power law distribution** is defined such that

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In other words, the density or mass function is **linear on the log-log scale**.

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Perhaps, if cities grow like our simple simulation, a power law distribution would be a good model?

Why study power law distributions?

According to M. E. J. Newman

Power-law distributions occur in an extraordinarily diverse range of phenomena. In addition to city populations, the sizes of earthquakes, moon craters, solar flares, computer files and wars, the frequency of use of words in any human language, the frequency of occurrence of personal names in most cultures, the numbers of papers scientists write, the number of citations received by papers, the number of hits on web pages, the sales of books, music recordings and almost every other branded commodity, the numbers of species in biological taxa, people's annual incomes and a host of other variables all follow power-law distributions (Newman, 2005).

The Pareto Distribution

An example of a power law distribution is the **Pareto distribution**:

$$F_X(x) = 1 - \left(\frac{\beta}{x}\right)^r, \quad x \geq \beta > 0, r > 0$$

To simplify matters, we will assume that $\beta = 1$ (could revisit this assumption later).

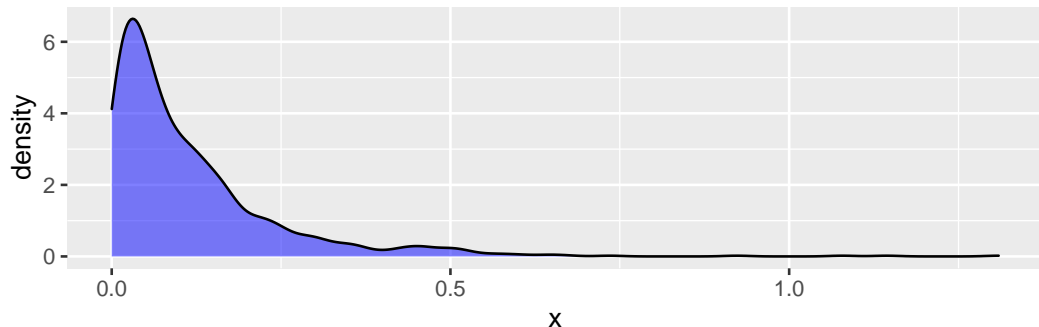
We can generate from a Pareto distribution using a mixture distribution of the form (random parameters):

$$L \sim \text{Gamma}(r, 1), \quad X \sim 1 + \text{Exponential}(L)$$

```
> rpareto <- function(n, r) {  
+   ls <- rgamma(n, r, 1)  
+   rexp(n, ls)  
+ }
```

Example estimated density when $r = 10$

```
> ggplot(data.frame(x = rpareto(1000, 10)), aes(x = x)) +  
+   geom_density(fill = "blue", alpha = 0.5)
```



Newman suggests the **maximum likelihood estimator**:

$$\hat{r}_{MLE} = 1 + n \left[\sum_{i=1}^n \log(X_i) \right]^{-1}$$

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Another option would be to use a method of moments estimator:

$$E(X) = \frac{r}{r-1} \Rightarrow r_{MoM} = \frac{\bar{X}}{\bar{X}-1}$$

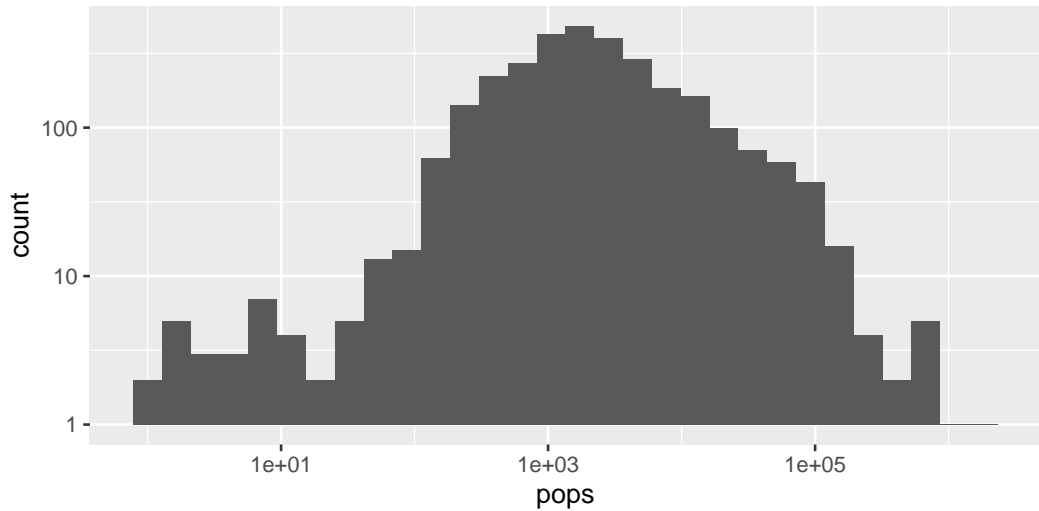
(Wikipedia, “Pareto Distribution”, 2018)

Estimating MSE

```
> r_mle <- function(x) { 1 + 1 / (mean(log(x))) }  
> r_mom <- function(x) { mean(x) / (mean(x) - 1) }  
> samples <- rerun(1000, rpareto(10, r = 10))  
> mean(map_dbl(samples, ~ (r_mle(.x) - 10)^2))  
  
[1] 87.61  
  
> mean(map_dbl(samples, ~ (r_mom(.x) - 10)^2 ))  
  
[1] 102.6
```

```
> # read the data and drop the first (garbage) row
> michigan_complete <- read.csv("sub-est2017_26.csv",
+                               stringsAsFactors = FALSE)[-1, ] %>%
+   mutate(CENSUS2010POP = as.numeric(CENSUS2010POP)) %>%
+   filter(CENSUS2010POP > 0, FUNCSTAT == "A")
>
```


City size distribution



```
> r_mle(na.omit(michigan_complete$CENSUS2010POP))  
[1] 1.131
```

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```

As we saw, the distribution did not look much like our typical Pareto (a mixture of exponentials), and this parameter is **the minimum possible r** .

Further directions

- Investigate fit of Pareto distribution, consider other distributions
- Other data sources, more variables, conditional distributions.
- How robust are the different test statistics to deviations from the assumptions (e.g., $\beta > 1$, data are dependent in some fashion, mixture distributions).
- Further considering why power law distributions are useful (or not! See Clauset et al. (2009)).

Clauset, A.; Shalizi, C. R. & Newman, M. E. J. (2009) "Power-Law Distributions in Empirical Data." *SIAM Review*, 51, 661-703

Newman, M. E. J. (2005) "Power laws, Pareto distributions and Zipf's law." *Contemporary Physics*, 46:5, 323-351

Wikipedia (2018) "Pareto distribution." Retrieved 2018-10-02.
https://en.wikipedia.org/wiki/Pareto_distribution

Working with real data

Generally, we will find two types of data file formats in the wild:

- Proprietary: .xls or .xlsx (Excel), .dta (Stata), .sqlite (SQLite)
- Delimited: tab, comma, other

Support for these varies. For example, support for .xlsx files has been hit or miss in the past.

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The foreign library can read some formats (SPSS, Stata, SAS).

Delimited

A **delimited** data file is a **text file** where the columns are separated by special characters:

```
1, "some text", 8, 2.30
2, "other text" ,, 9.88
3, "text, with comma", 0, -5.23
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Common delimiters include commas and tabs:

```
read.csv
read.table
```

Also the more generic `read.delim`.

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Then load it into a variable using a `read` function.

You may need to convert some columns to different data types (using `as.SOMETHING`)

Saving Data in R

R has its own proprietary format, `.rda`.

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You can save not only single tables, but collections of information, functions, variables.

```
> k <- 100000  
> myrands <- rnorm(k)  
> save(file = "example.rda", k, myrands)
```


Loading saved files

```
> rm(k) ; rm(myrands)
> load("example.rda")
> print(k)

[1] 1e+05
```

Basic Data Cleaning

Real data often has missing values, bad values.

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It is useful to investigate to see if there missing values or things that can't happen.

```
> summary(somedata)
```

	x1	x2
Min.	:-2.587	Length:100
1st Qu.:	-0.621	Class :character
Median :	0.083	Mode :character
Mean :	-0.014	
3rd Qu.:	0.562	
Max.	: 2.958	
NA's	:5	

We could delete things with missing, but it might be better to **impute** a value

```
> somedata$x1[is.na(somedata$x1)] <- mean(somedata$x1, na.rm = TRUE)
> summary(somedata)
```

x1	x2
Min. :-2.5868	Length:100
1st Qu.: -0.5186	Class :character
Median :-0.0136	Mode :character
Mean :-0.0136	
3rd Qu.: 0.5593	
Max. : 2.9579	

Example: Loading data from the National Health And Nutrition Examination Survey

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I downloaded data on **aspirin use** and **blood pressure exams** for survey participants.

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The **National Health And Nutrition Examination Survey (NHANES)** provides survey data on the dietary and health habits of people in the United States.

For many years, **low dose aspirin** was thought to be beneficial for those at risk of **heart disease**.

I downloaded data on **aspirin use** and **blood pressure exams** for survey participants.

Opening data

There are two data files, both in XPT format (a SAS format). `rseek.org` suggested the `haven` package:

```
> library(haven)
> aspirin <- read_xpt("./RXQASA_H.XPT")
> dim(aspirin)
```

```
[1] 3815    8
```

```
> bp <- read_xpt("./BPX_H.XPT")
> dim(bp)
```

```
[1] 9813   23
```

Coding “taking aspirin” variable

```
> ### Questions:
> # RXQ515 - Followed (doctor's) advice, took low-dose aspirin?
> # RXQ520 - Taking low-dose aspirin on your own?
>
> eq1 <- function(x) {
+   tmp <- x == 1
+   tmp[is.na(tmp)] <- FALSE
+   return(tmp)
+ }
> aspirin$taking_aspirin <- eq1(aspirin$RXQ515) | eq1(aspirin$RXQ520)
```

Aggregating multiple blood pressure readings

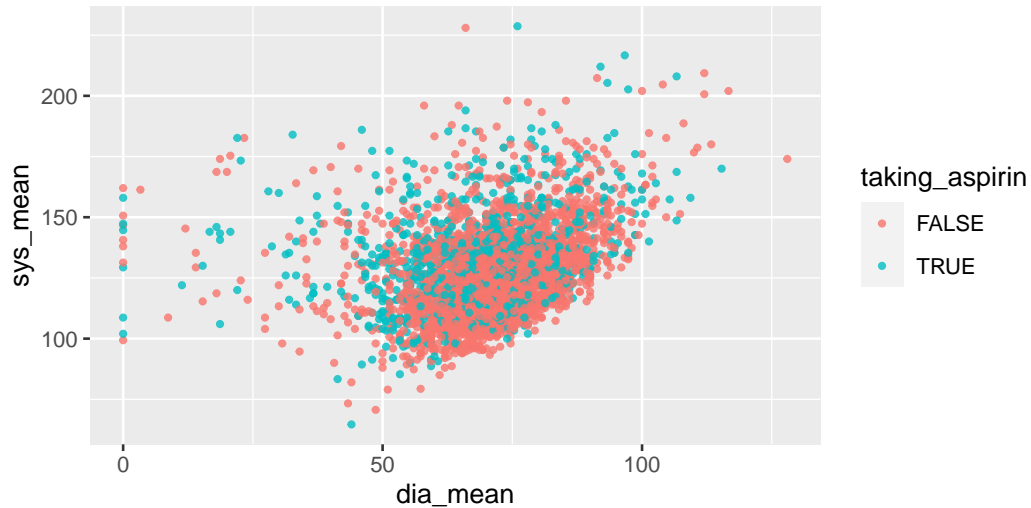
```
> bp$sys_mean <- rowMeans(bp[, c("BPXSY1", "BPXSY2", "BPXSY3", "BPXSY4")],  
> bp$dia_mean <- rowMeans(bp[, c("BPXDI1", "BPXDI2", "BPXDI3", "BPXDI4")],
```

Combining

The dplyr (part of tidyverse) has several methods for **joining tables**:

- `inner_join` matches the tables on a **common key**, discard any entries that do not have a match (multiple matches possible)
- `left_join` keeps everything in the first table, even if no match (NA values for unmatched)
- `full_join` keeps everything in both tables, matching where it can (again, NA for unmatched)

```
> combined <- inner_join(aspirin, bp, "SEQN") # common "sequence number" ID
```



Final Thoughts

- Document, document, document: use scripts/RMarkdown documents to record your changes to data
- Investigate outliers, missing values, strange patterns. Does -9 make sense for count data?
- Use `rseek.org` with your file extension to find packages.
- Open in other software and convert to CSV files.