Data and Information Resources, Role of Hypothesis, Exploration and Distributions

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Data Analytics

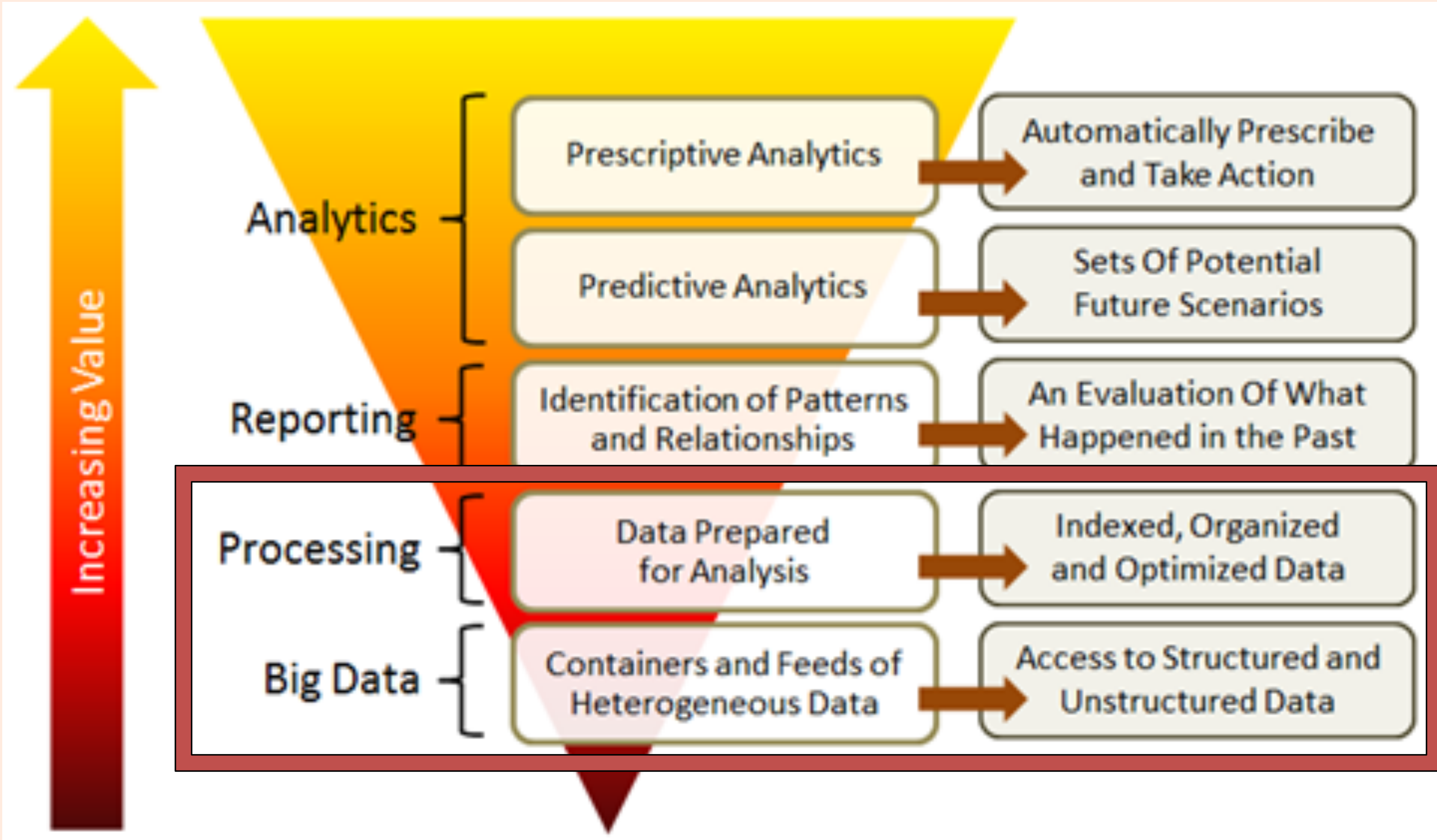
ITWS-4600/ITWS-6600/MATP-4450/CSCI-4960 MGMT-4962/6962 BCBP 4960

Group 1 Module 3(a), ~ Feb 01st , 2021

Contents

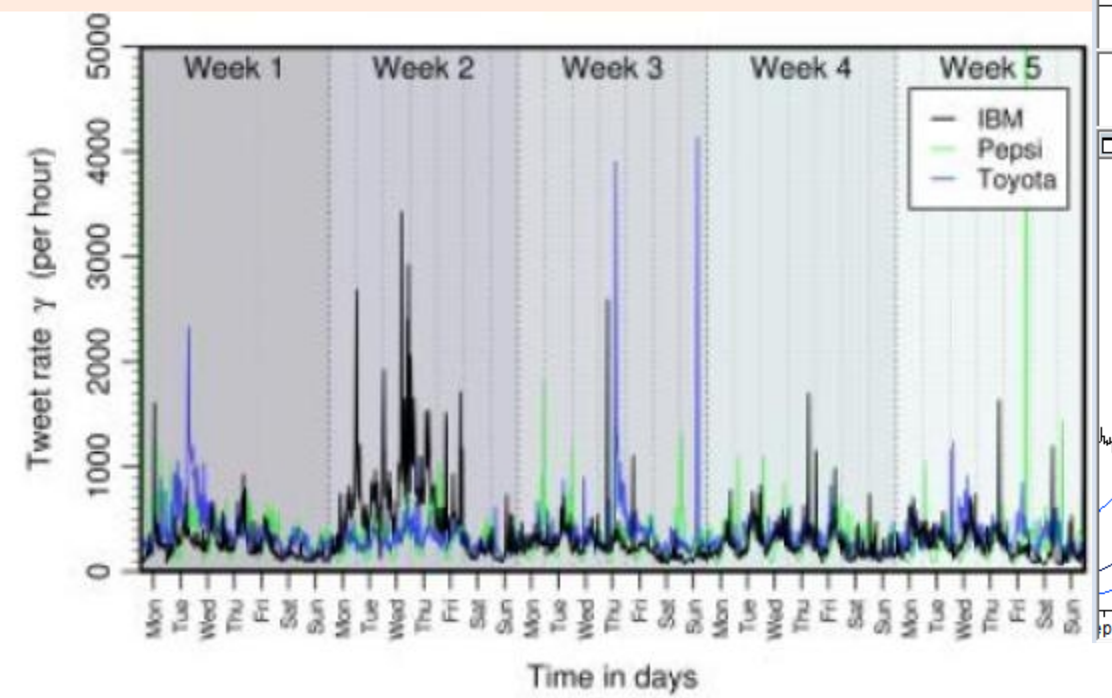
- Data sources
  - Cyber
  - Human
- “Munging”
- Exploring
  - Distributions…
  - Summaries
  - Visualization
- Testing and evaluating the results (beginning)

Lower layers in the Analytics Stack

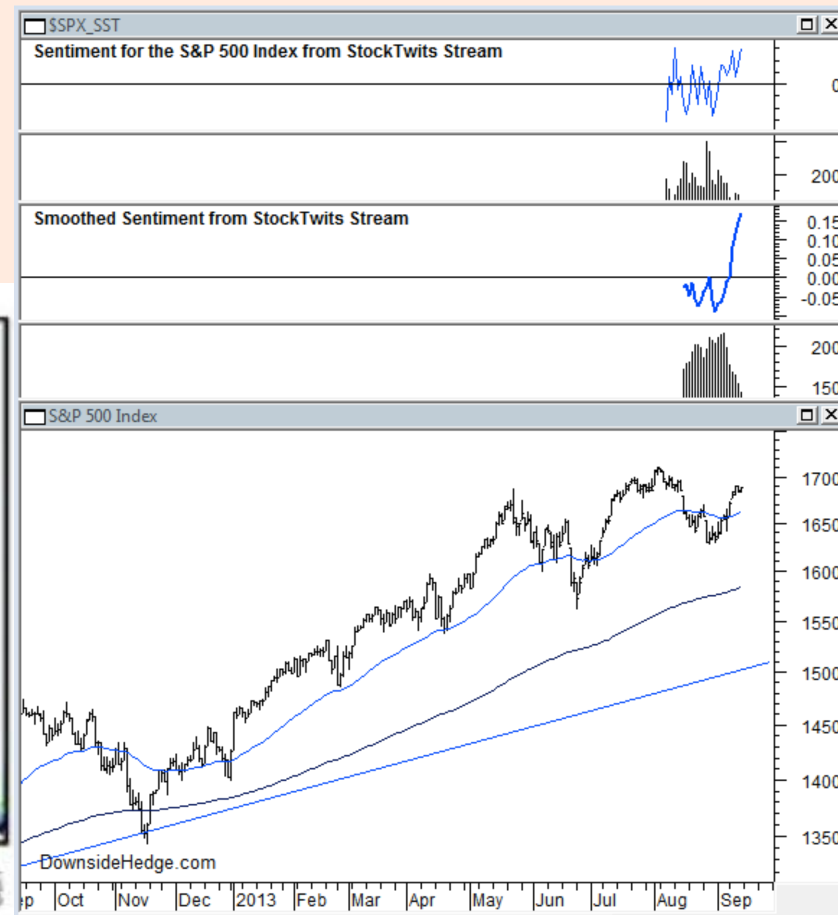


"Cyber Data"
…

"Human Data" …



Week 1
Week 2
Week 3
Week 4
Week 5
IBM
Pepsi
Toyota
Tweet rate γ (per hour)
Time in days



$SPX_SST
Sentiment for the S&P 500 Index from StockTwits Stream
Smoothed Sentiment from StockTwits Stream
S&P 500 Index
DownsideHedge.com

Statistics Review – Probability

You have learned this in your Statistics class.

Probability …

- Before dive into the Naïve Bayes lecture in upcoming classes, lets go over some definitions in probability.
- Probability is the measure of the likelihood that an event will occur.
- In other words, probability is a measurement of how likely an event occurs.
- *Probability of event **A***:

$$P(A) = \frac{Number\ of\ ways\ for\ A}{Total\ number\ of\ possible\ outcomes}$$

Reference: https://en.wikipedia.org/wiki/Probability

Probability …

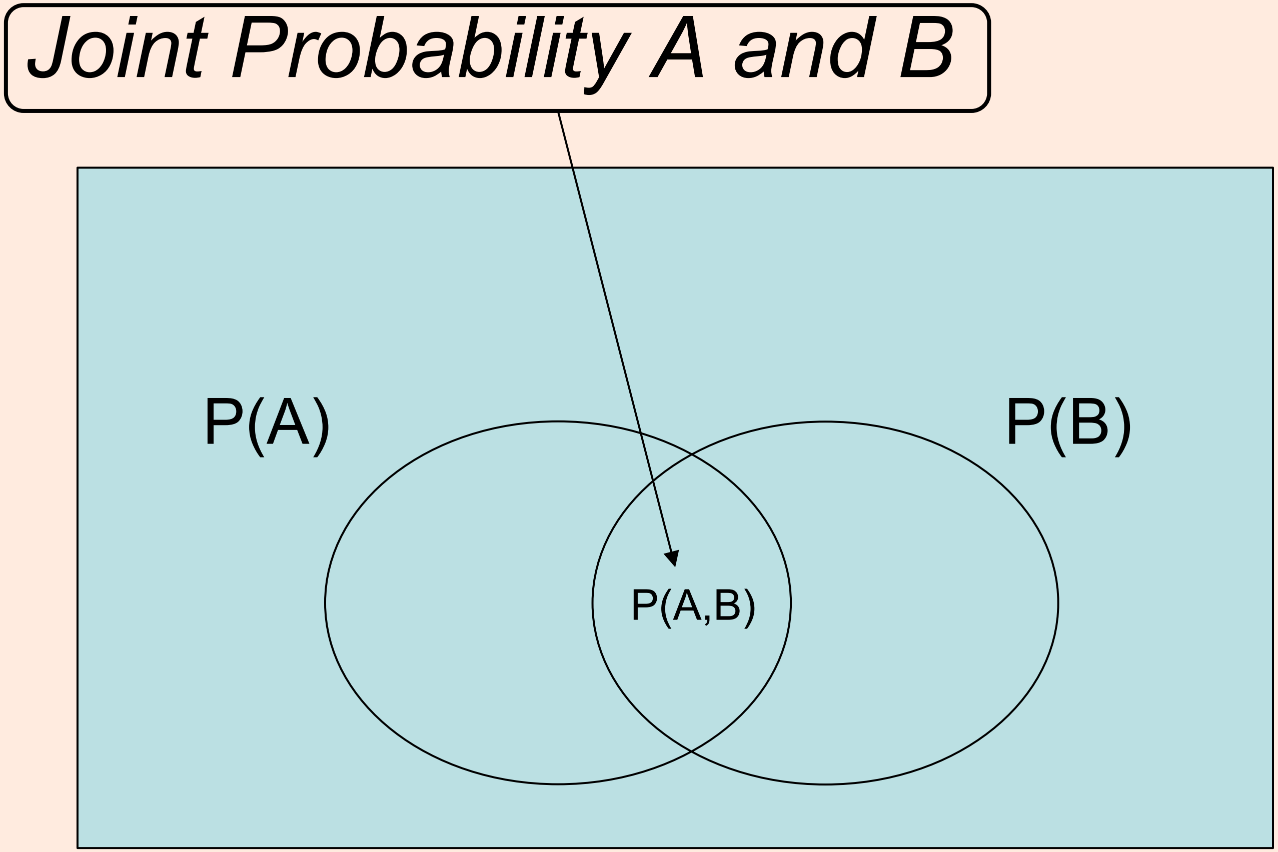
- Before we do a deep dive, You should know/understand the two probability concepts:

  1) Joint Probability
  2) Conditional Probability

Reference: https://en.wikipedia.org/wiki/Probability

Probability …

Joint Probability: ***specifies the probability of event A and event B occurring together***.



https://en.wikipedia.org/wiki/Joint_probability_distribution

Probability …

<u>Joint Probability</u>: ***specifies the probability of event A and event B occurring together***.

If the two events are independent,

What is the probability of getting two 6’s when you roll two dice?

The probability of rolling(getting) two 6’s:

$$P(A,B) = P(A) * P(B) = \frac{1}{6} * \frac{1}{6} = \frac{1}{36}$$

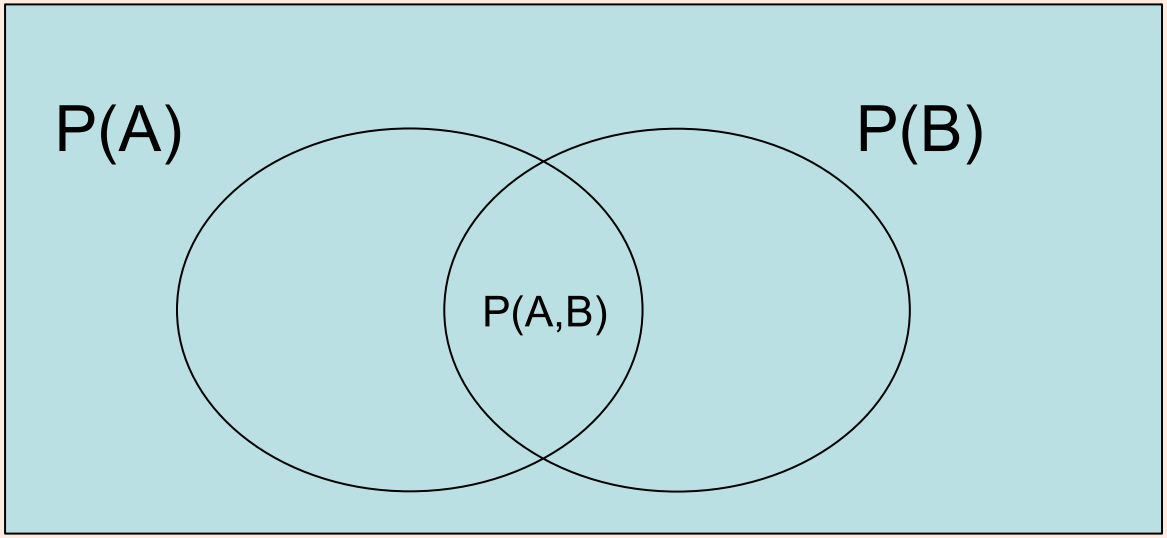
https://en.wikipedia.org/wiki/Joint_probability_distribution

Image/Photo Credit: https://pngtree.com/freepng/two-dice_1504759.html

Probability …

<u>**Conditional Probability**</u>: ***probability of event A occurring, given that event B occurred***.

$$P(A|B) = \frac{P(A,B)}{P(B)} =$$ Probability of A, given B ; P(B)>0



https://en.wikipedia.org/wiki/Conditional_probability

Bayes Theorem…

- The relationship between conditional probabilities, P(B|A) and P(A|B) can be expressed using the Bayes Theorem.

$$P(B|A) = \frac{P(A|B) * P(B)}{P(A)}$$

Reference: https://en.wikipedia.org/wiki/Bayes%27_theorem

EPI data set from previous lecture…

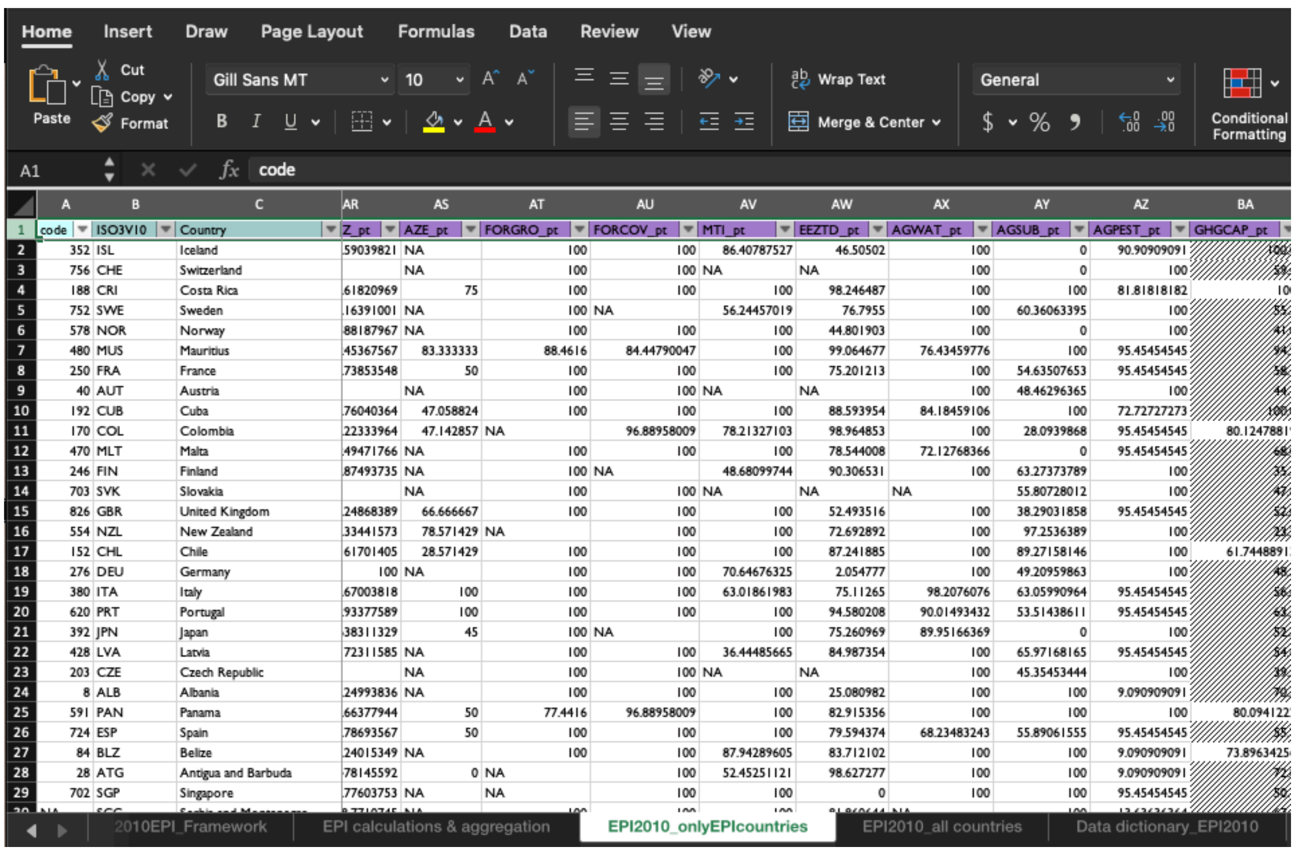
Index of /html/DA/EPI

Name	Last modified	Size	Description
Parent Directory		-	
2010EPI_data.csv	05-Feb-2016 00:28	10M	
2010EPI_data.xls	05-Feb-2016 00:35	11M	
2016 EPI Wastewater Data Appendix.xls	19-Jan-2018 16:01	907K	
2016EPI_Backcasted_Scores.xls	19-Jan-2018 16:01	1.3M	
2016EPI_Full_Report_opt.pdf	19-Jan-2018 16:02	15M	
2016EPI_Raw_Data.xls	19-Jan-2018 16:02	1.5M	
2016_epi_framework_indicator_scores_friendly.xls	19-Jan-2018 16:02	740K	
2016epi_weightings_0.xls	19-Jan-2018 16:02	660K	
EPI_data.csv	05-Feb-2016 00:28	232K	
EPI_data.xls	05-Feb-2016 00:36	11M	
Fisheries_Penalties.xls	19-Jan-2018 16:02	120K	
OnlyEPI_data.csv	05-Feb-2016 00:29	10M	
OnlyEPI_data.xls	05-Feb-2016 00:37	11M	
filters_materiality_for_2016epi.xls	19-Jan-2018 16:02	64K	

Apache/2.2.14 (Ubuntu) Server at aquarius.tw.rpi.edu Port 443

https://aquarius.tw.rpi.edu/html/DA/EPI/

2010EPI_data.xls



	A	B	C	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA
1	code	ISO3V10	Country	Z_pt	AZE_pt	FORGRO_pt	FORCOV_pt	MTI_pt	EEZTD_pt	AGWAT_pt	AGSUB_pt	AGPEST_pt	GHGCAP_pt
2	352	ISL	Iceland	.59039821	NA	100	100	86.40787527	46.50502	100	0	90.90909091	100
3	756	CHE	Switzerland		NA	100	100	NA	NA	100	0	100	59
4	188	CRI	Costa Rica	.61820969	75	100	100	100	98.246487	100	100	81.81818182	10
5	752	SWE	Sweden	.16391001	NA	100	NA	56.24457019	76.7955	100	60.36063395	100	55
6	578	NOR	Norway	.88187967	NA	100	100	100	44.801903	100	0	100	41
7	480	MUS	Mauritius	.45367567	83.333333	88.4616	84.44790047	100	99.064677	76.43459776	100	95.45454545	94
8	250	FRA	France	.73853548	50	100	100	100	75.201213	100	54.63507653	95.45454545	58
9	40	AUT	Austria		NA	100	100	NA	NA	100	48.46296365	100	44
10	192	CUB	Cuba	.76040364	47.058824	100	100	100	88.593954	84.18459106	100	72.72727273	100
11	170	COL	Colombia	.22333964	47.142857	NA	96.88958009	78.21327103	98.964853	100	28.0939868	95.45454545	80.1247881
12	470	MLT	Malta	.49471766	NA	100	100	100	78.544008	72.12768366	0	95.45454545	68
13	246	FIN	Finland	.87493735	NA	100	NA	48.68099744	90.306531	100	63.27373789	100	35
14	703	SVK	Slovakia		NA	100	100	NA	NA	NA	55.80728012	100	47
15	826	GBR	United Kingdom	.24868389	66.666667	100	100	100	52.493516	100	38.29031858	95.45454545	52
16	554	NZL	New Zealand	.33441573	78.571429	NA	100	100	72.692892	100	97.2536389	100	23
17	152	CHL	Chile	61701405	28.571429	100	100	100	87.241885	100	89.27158146	100	61.744889
18	276	DEU	Germany	100	NA	100	100	70.64676325	2.054777	100	49.20959863	100	48
19	380	ITA	Italy	.67003818	100	100	100	63.01861983	75.11265	98.2076076	63.05990964	95.45454545	56
20	620	PRT	Portugal	.93377589	100	100	100	100	94.580208	90.01493432	53.51438611	95.45454545	63
21	392	JPN	Japan	.38311329	45	100	NA	100	75.260969	89.95166369	0	100	52
22	428	LVA	Latvia	72311585	NA	100	100	36.44485665	84.987354	100	65.97168165	95.45454545	54
23	203	CZE	Czech Republic		NA	100	100	NA	NA	100	45.35453444	100	39
24	8	ALB	Albania	.24993836	NA	100	100	100	25.080982	100	100	9.090909091	70
25	591	PAN	Panama	.66377944	50	77.4416	96.88958009	100	82.915356	100	100	100	80.094122
26	724	ESP	Spain	.78693567	50	100	100	100	79.594374	68.23483243	55.89061555	95.45454545	55
27	84	BLZ	Belize	.24015349	NA	100	100	87.94289605	83.712102	100	100	9.090909091	73.8963425
28	28	ATG	Antigua and Barbuda	78145592	0	NA	100	52.45251121	98.627277	100	100	9.090909091	72
29	702	SGP	Singapore	.77603753	NA	NA	100	100	0	100	100	95.45454545	50

2010EPI dataset in R

Before:

	Note..Values.in.cells.with.cross.hatching.are.based.on.imputed.data	X	X.1	X.2	X.3
1	code	ISO3V10	Country	EPI_regions	GEO_subreg
2	352	ISL	Iceland	Europe	Western Eur
3	756	CHE	Switzerland	Europe	Western Eur
4	188	CRI	Costa Rica	Latin America and Caribbean	Meso Ameri

We want this: Change the first row to be the header:

	code	ISO3V10	Country	EPI_regions	GEO_subregion
2	352	ISL	Iceland	Europe	Western Europe
3	756	CHE	Switzerland	Europe	Western Europe
4	188	CRI	Costa Rica	Latin America and Caribbean	Meso America

How to change the first row to be the header in 2010EPI ?

How to change the first row to be the header in R?

names(data_2010EPI) <- as.matrix(data_2010EPI[1,])

data_2010EPI <- data_2010EPI[-1,]

data_2010EPI[] <- lapply(data_2010EPI, function(x) type.convert(as.character(x)))

data_2010EPI

View(data_2010EPI)


```r
# How to change the first row to be the header in R?
names(data_2010EPI) <- as.matrix(data_2010EPI[1, ])
data_2010EPI <- data_2010EPI[-1, ]
data_2010EPI[] <- lapply(data_2010EPI, function(x) type.convert(as.character(x)))
data_2010EPI
View(data_2010EPI)
```

Data Prepared for Analysis = Munging

- Missing values, null values, etc.
- E.g. in the EPI_data – they use "--"
  - Most data applications provide built ins for these higher-order functions – in R "NA" is used and functions such as is.na(var), etc. provide powerful filtering options (we'll cover these on next class)
- Of course, different variables often are missing "different" values
- In R – higher-order functions such as: Reduce, Filter, Map, Find, Position and Negate will become your enemies and then your friends: http://www.johnmyleswhite.com/notebook/2010/09/23/higher-order-functions-in-r/

Explore the “Missing values” -- NA

ISL	Iceland	.59039821	NA	100
CHE	Switzerland		NA	100
CRI	Costa Rica	.61820969	75	100
SWE	Sweden	.16391001	NA	100
NOR	Norway	88187967	NA	100
MUS	Mauritius	.45367567	83.333333	88.4616
FRA	France	.73853548	50	100
AUT	Austria		NA	100
CUB	Cuba	.76040364	47.058824	100
COL	Colombia	.22333964	47.142857	NA
MLT	Malta	.49471766	NA	100
FIN	Finland	.87493735	NA	100
SVK	Slovakia		NA	100
GBR	United Kingdom	.24868389	66.666667	100
NZL	New Zealand	.33441573	78.571429	NA
CHL	Chile	61701405	28.571429	100
DEU	Germany	100	NA	100
ITA	Italy	.67003818	100	100
PRT	Portugal	.93377589	100	100
JPN	Japan	.38311329	45	100
LVA	Latvia	72311585	NA	100
CZE	Czech Republic		NA	100
ALB	Albania	.24993836	NA	100
PAN	Panama	.66377944	50	77.4416

Getting started – summarize data

- Summary statistic
  - Ranges, “hinges”
  - Tukey’s five numbers
- Look for a distribution match
- Tests…for…
  - Normality – shapiro-wilks

  and a p-value – what is the null hypothesis here?

```
> shapiro.test(EPI_data$EPI)
   Shapiro-Wilk normality test
data:  EPI_data$EPI
p-value = 0.1188
```

Accept or Reject?

- **Reject the null hypothesis if the p-value is less than the level of significance.**

- **You will fail to reject the null hypothesis if the p-value is greater than or equal to the level of significance.**

- **Typical significance 0.05 (!)**

Another variable in EPI

```
> shapiro.test(EPI_data$DALY)

        Shapiro-Wilk normality test

data:  EPI_data$DALY
W = 0.9365, p-value = 1.891e-07
```

Read: [1] https://en.wikipedia.org/wiki/Shapiro%E2%80%93Wilk_test
[2] http://www.sthda.com/english/wiki/normality-test-in-r
[3] https://www.dummies.com/programming/r/how-to-test-data-normality-in-a-formal-way-in-r/
[4] https://emilkirkegaard.dk/en/?p=4452

Distribution tests

most distributions have tests

- Wilcoxon (Mann-Whitney)
  - Comparing populations

  Two data samples are independent if they come from distinct populations and the samples do not affect each other. Using the Mann-Whitney-Wilcoxon Test, we can decide whether the population distributions are identical without assuming them to follow the normal distribution. http://www.r-tutor.com/elementary-statistics/non-parametric-methods/mann-whitney-wilcoxon-test
- Kolmogorov-Smirnov (KS)
- It got out of control when people realized they can name the test after themselves, v. someone else…

Getting started – look at the data

- Visually
  - What is the improvement in the understanding of the data as compared to the situation without visualization?
  - Which visualization techniques are suitable for one's data?
    - Scatter plot diagrams
    - Box plots (min, 1st quartile, median, 3rd quartile, max)
    - Stem and leaf plots
    - Frequency plots
    - Group Frequency Distributions plot
    - Cumulative Frequency plots
    - Distribution plots

Why visualization?

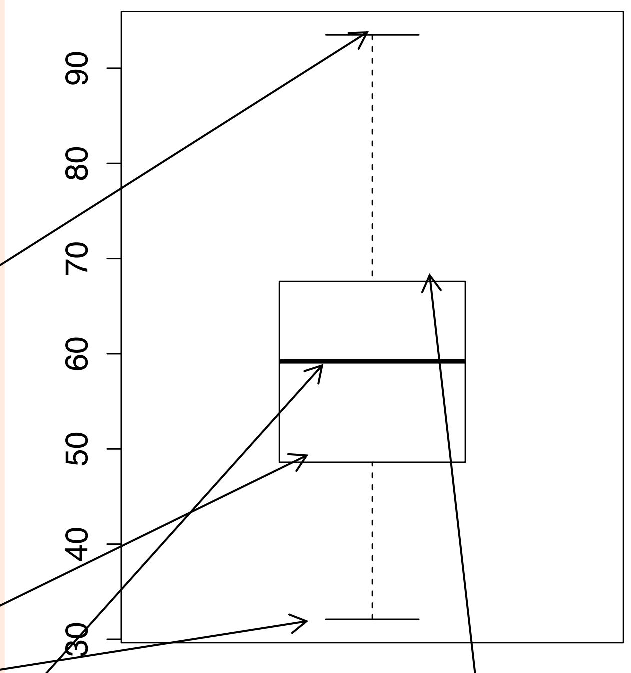
- Reducing amount of data, quantization
- Patterns
- Features
- Events
- Trends
- Irregularities
- Leading to presentation of data, i.e. information products
- *Exit points for analysis*

Exploring the distribution

> summary(EPI)   # stats

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
32.10	48.60	59.20	58.37	67.60	93.50	68

> boxplot(EPI)



> fivenum(EPI,na.rm=TRUE)

[1] 32.1 48.6 59.2 67.6 93.5

Tukey: min, lower hinge, median, upper hinge, max

Stem and leaf plot

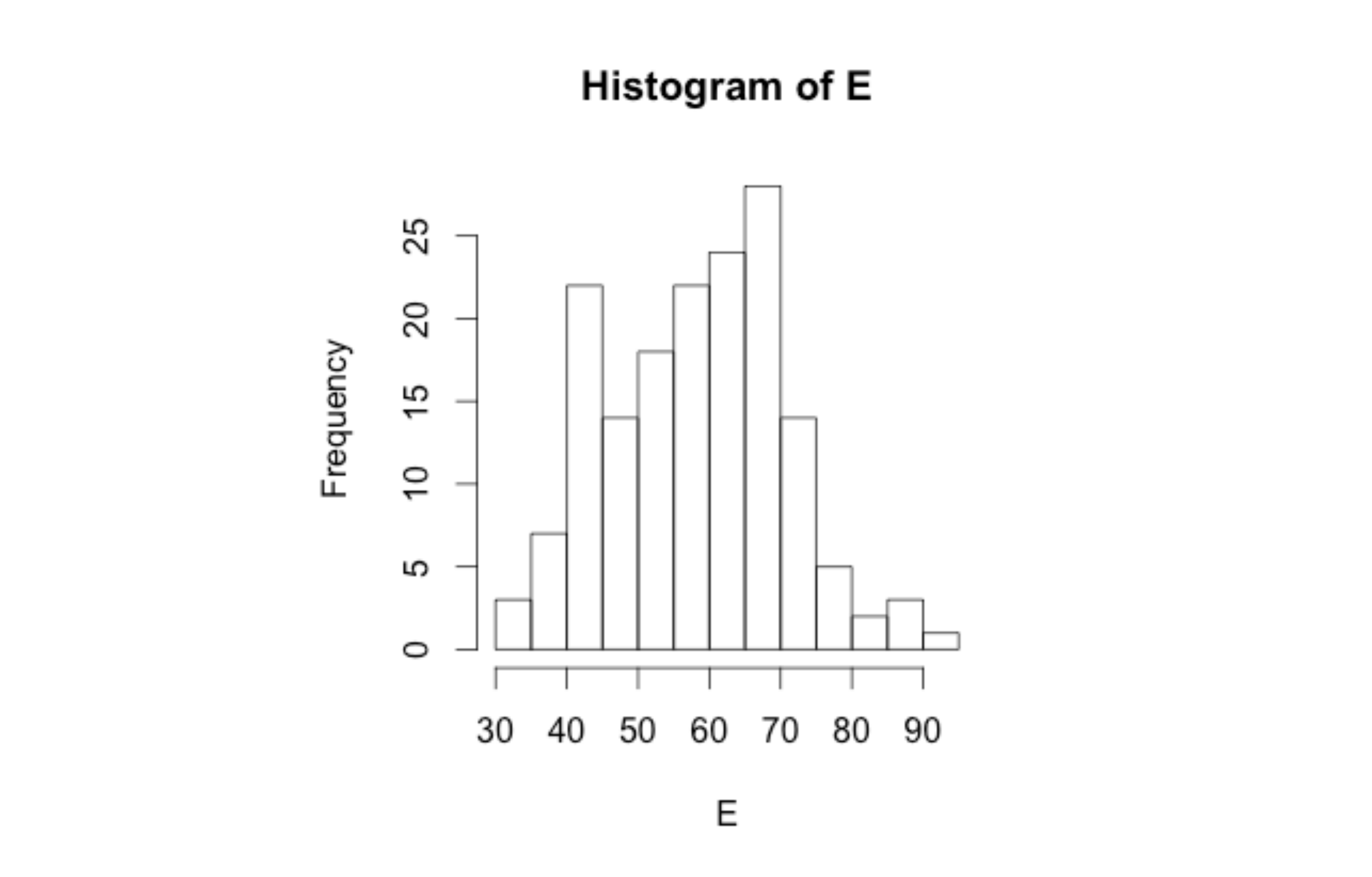
> stem(EPI)   # like-a histogram

The decimal point is 1 digit(s) to the right of the | - but the scale of the stem is 10… watch carefully..

```
3 | 234
3 | 66889
4 | 00011112222223344444
4 | 5555677788888999
5 | 0000111111111244444
5 | 55666677778888999999
6 | 000001111111222333344444
6 | 5555666666677778888889999999
7 | 000111233333334
7 | 5567888
8 | 11
8 | 669
9 | 4
```

Grouped Frequency Distribution aka binning

> hist(EPI)   #defaults



Distributions

- Shape
- Character
- Parameter(s)

- Which one fits?

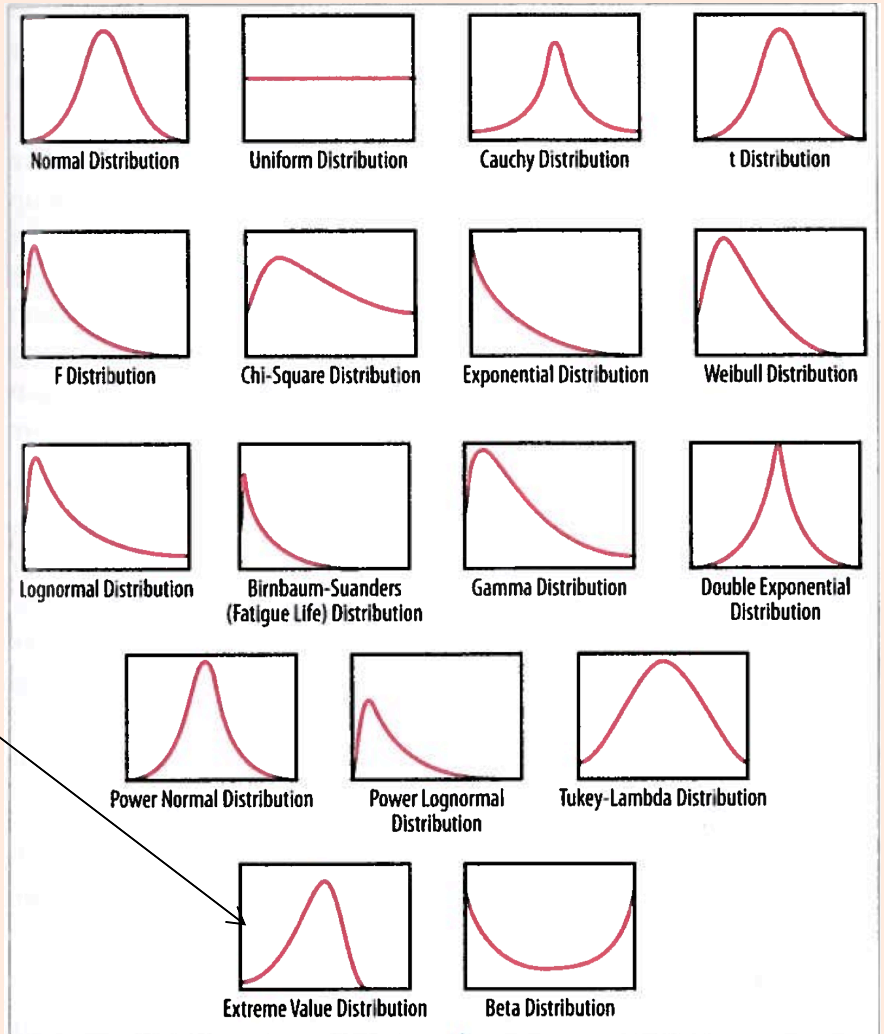
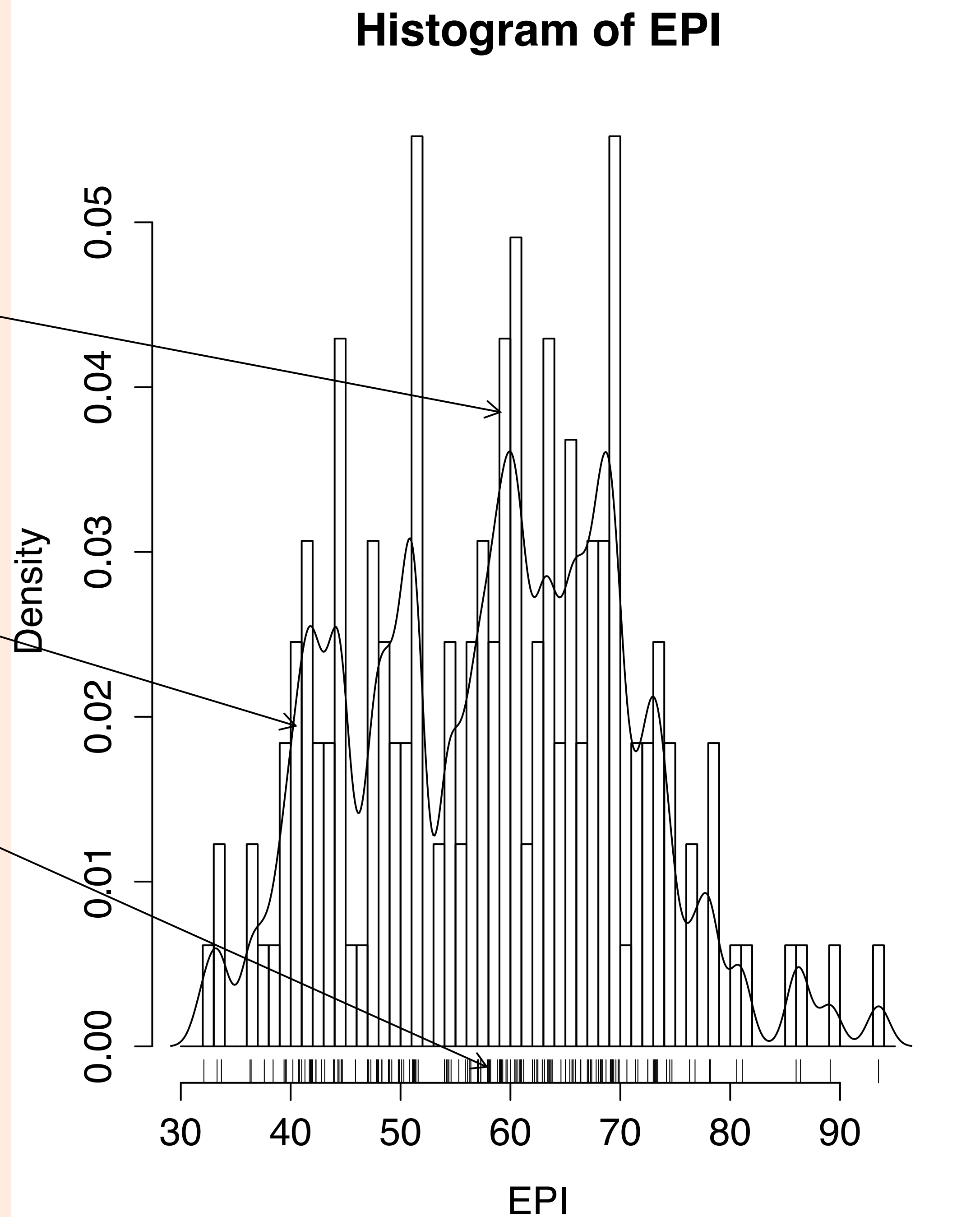


Figure 2-1. A bunch of continuous density functions (aka probability distributions)

> hist(EPI, seq(30., 95., 1.0), prob=TRUE)

> lines (density(EPI,na.rm=TRUE,bw=1.))

> rug(EPI)

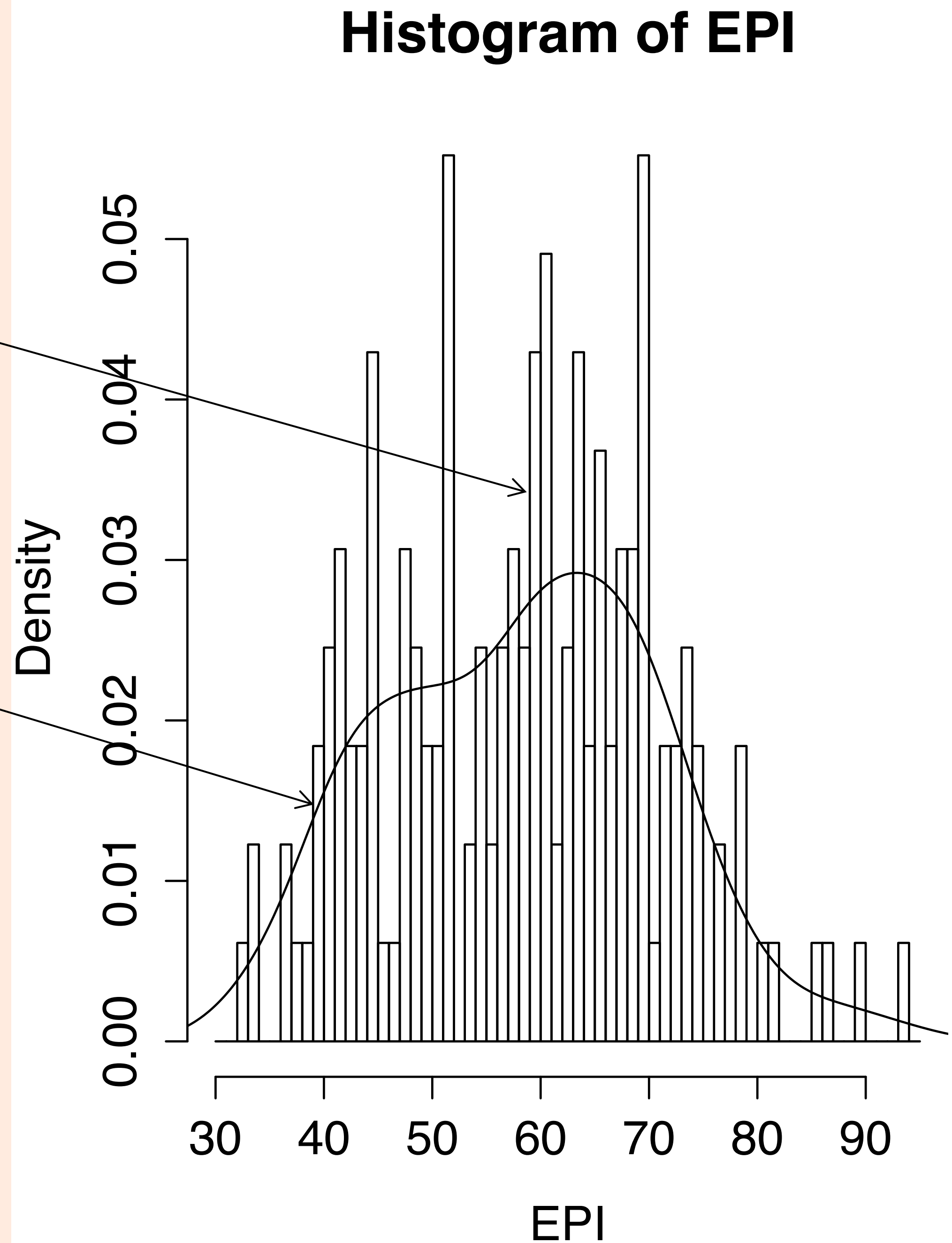


What is a rug plot ?

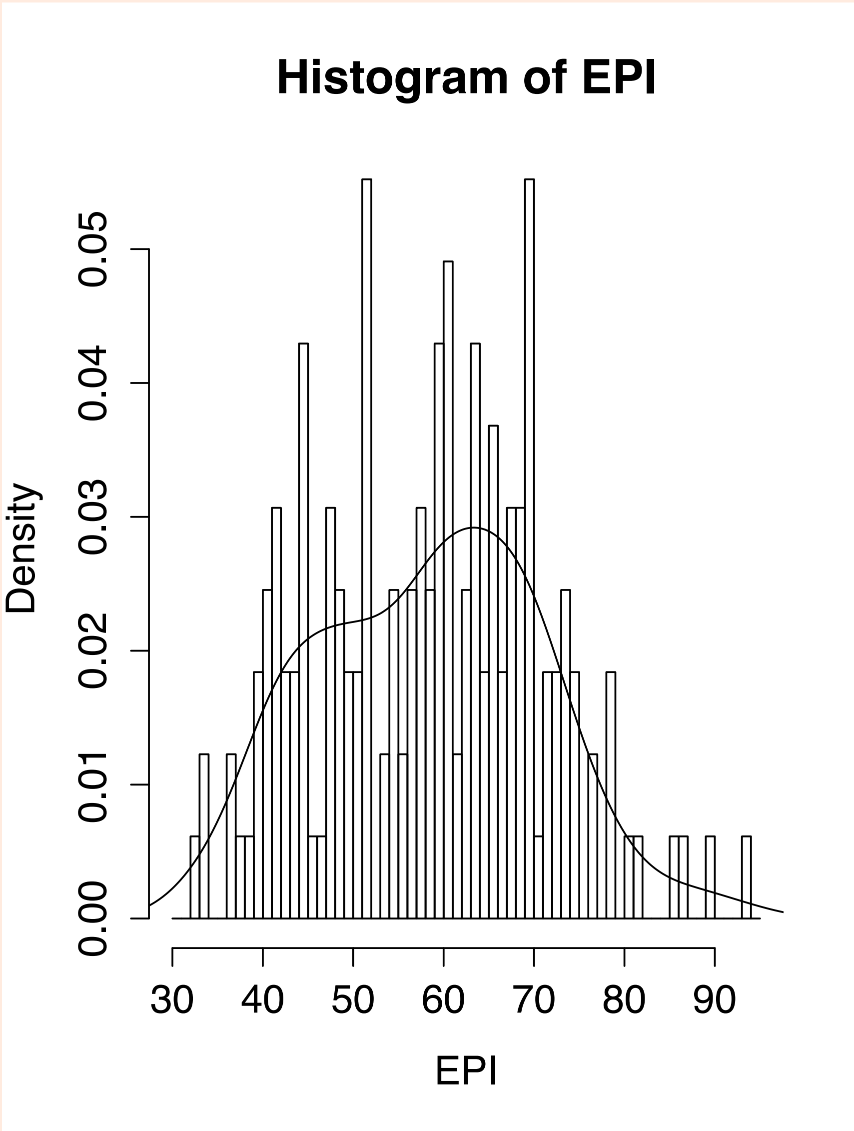
https://en.wikipedia.org/wiki/Rug_plot

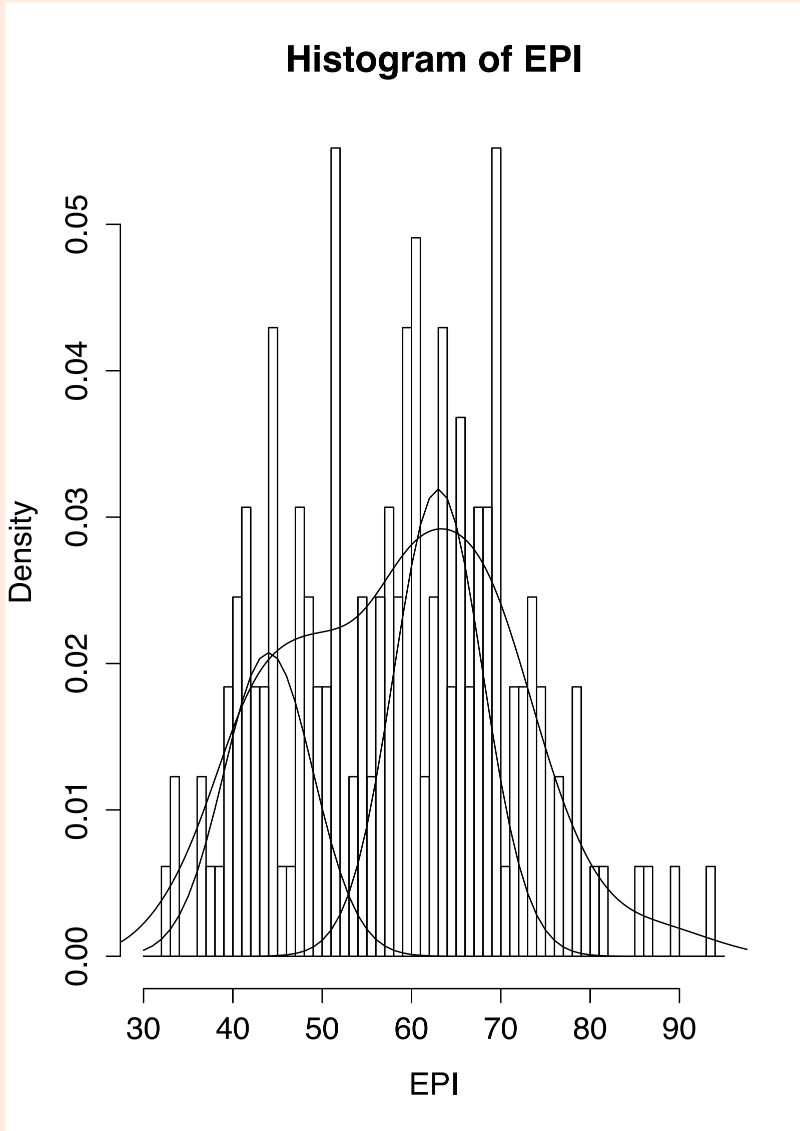
```
> hist(EPI, seq(30., 95., 1.0), prob=TRUE)
```

```
> lines (density(EPI,na.rm=TRUE,bw="SJ"))
```

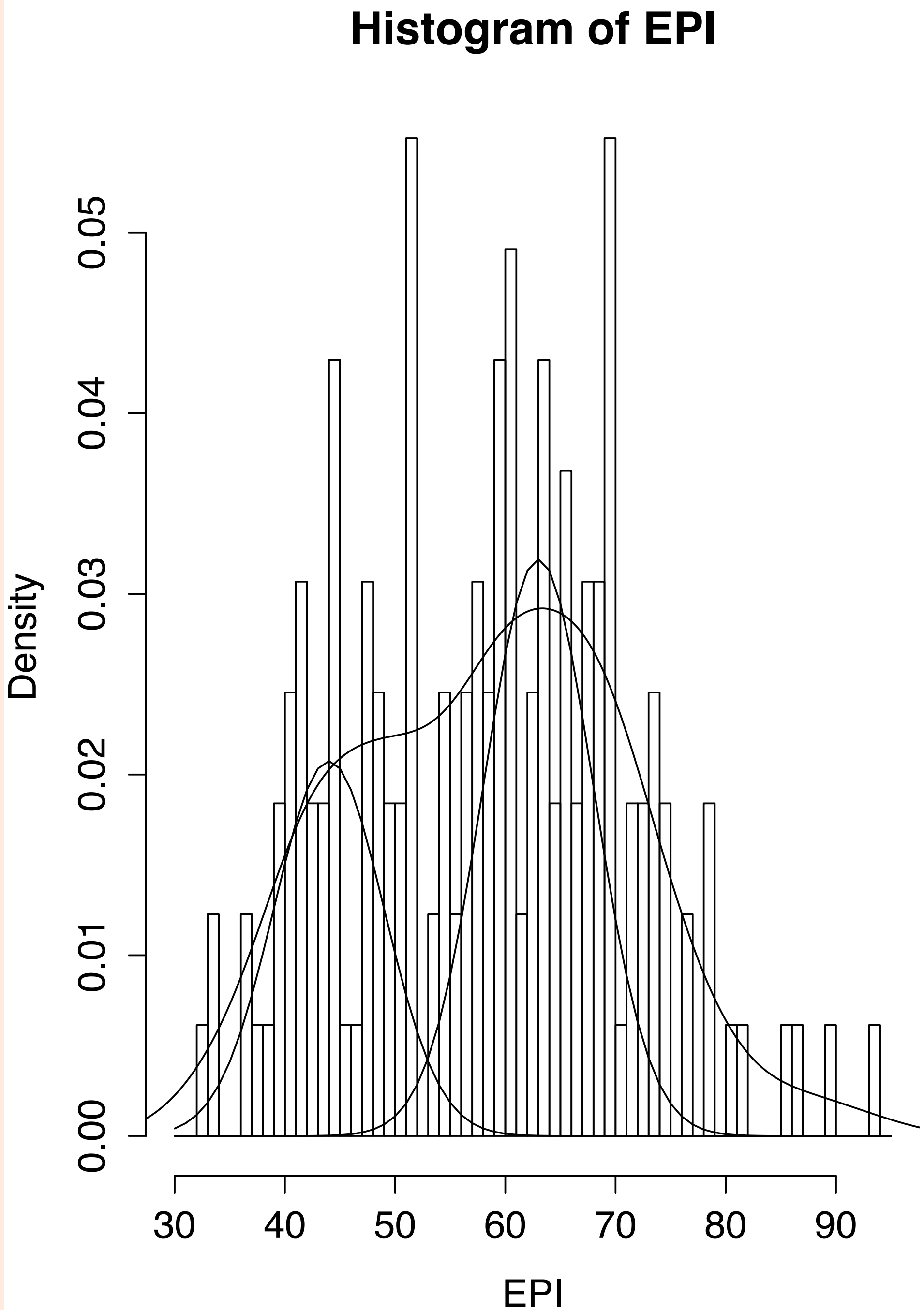


Why are histograms so unsatisfying?



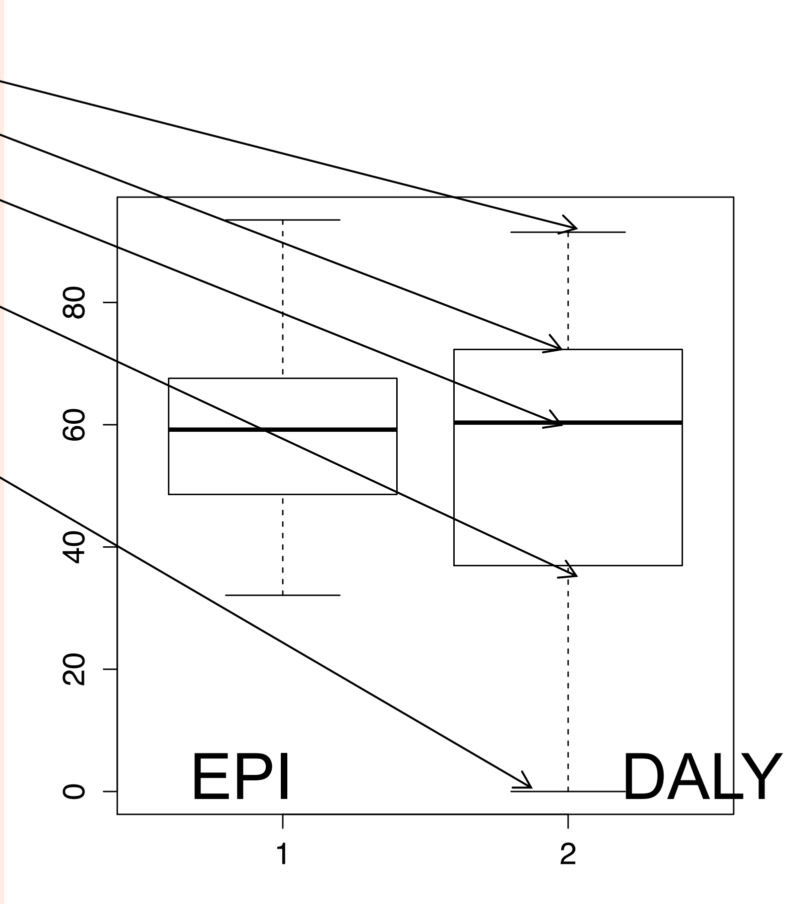


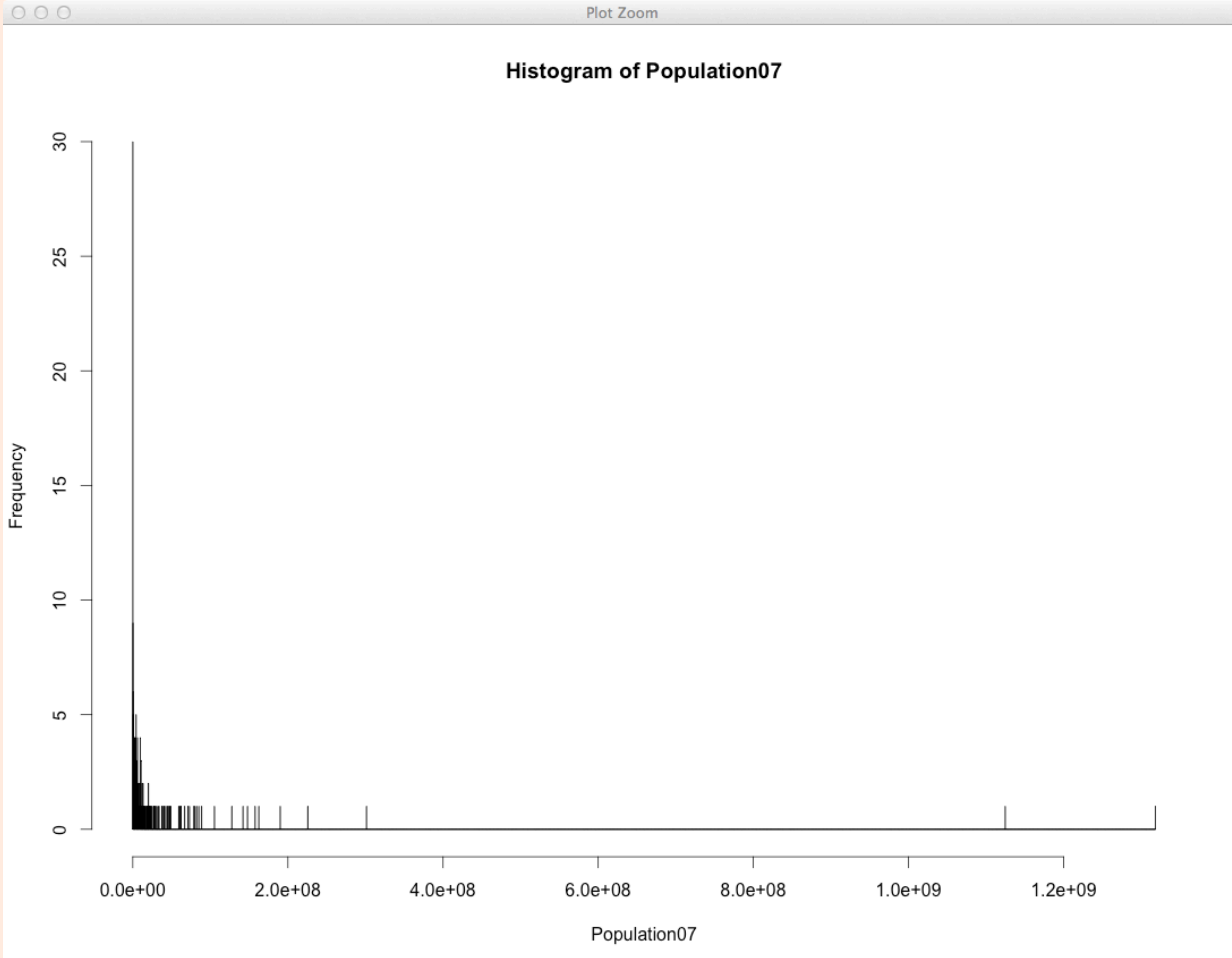
```
> xn<-seq(30,95,1)
> qn<-
dnorm(xn,mean=63,
sd=5,log=FALSE)
> lines(xn,qn)
> lines(xn,.4*qn)
> ln<-dnorm(xn,mean=44,
sd=5,log=FALSE)
> lines(xn,.26*ln)
```

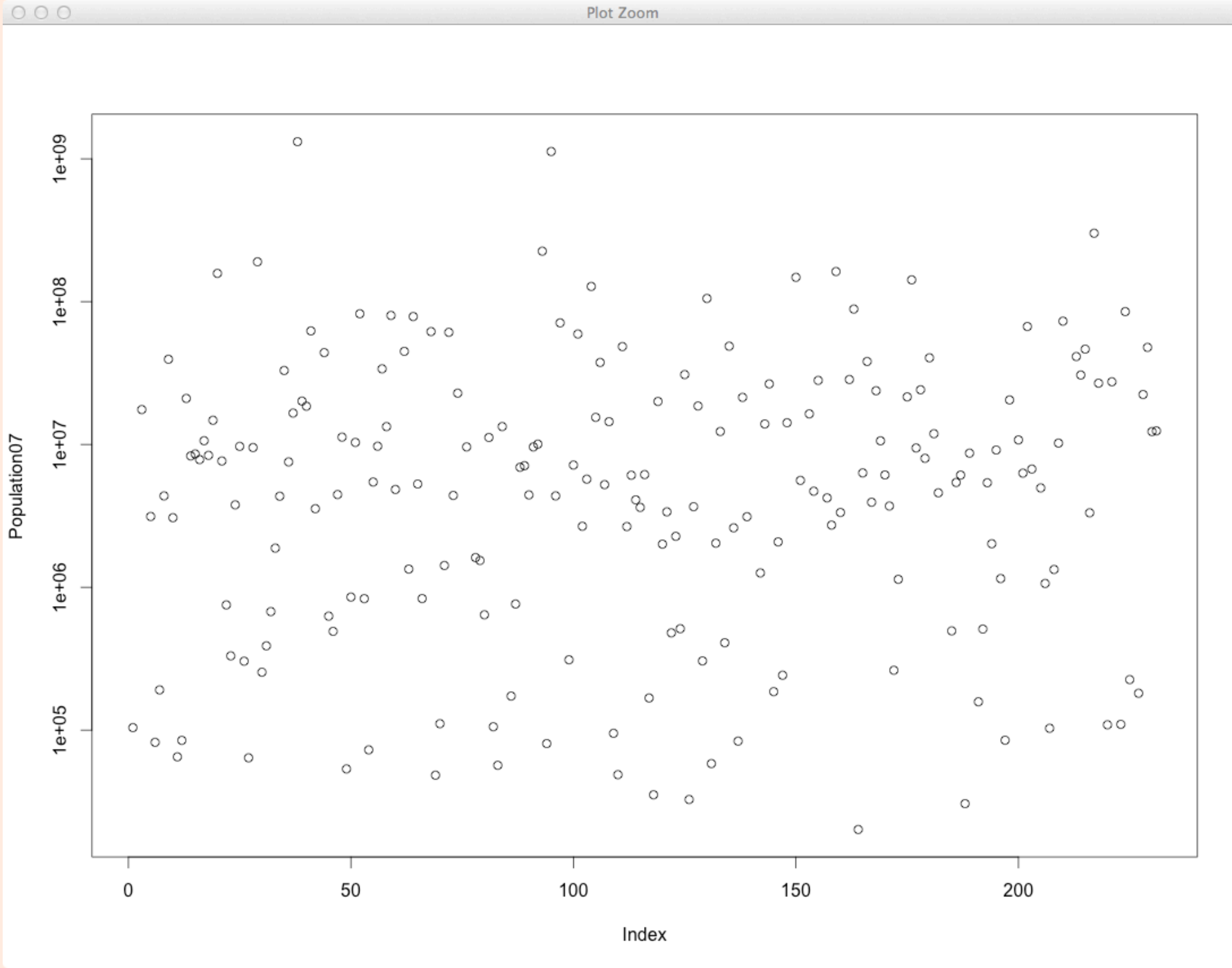


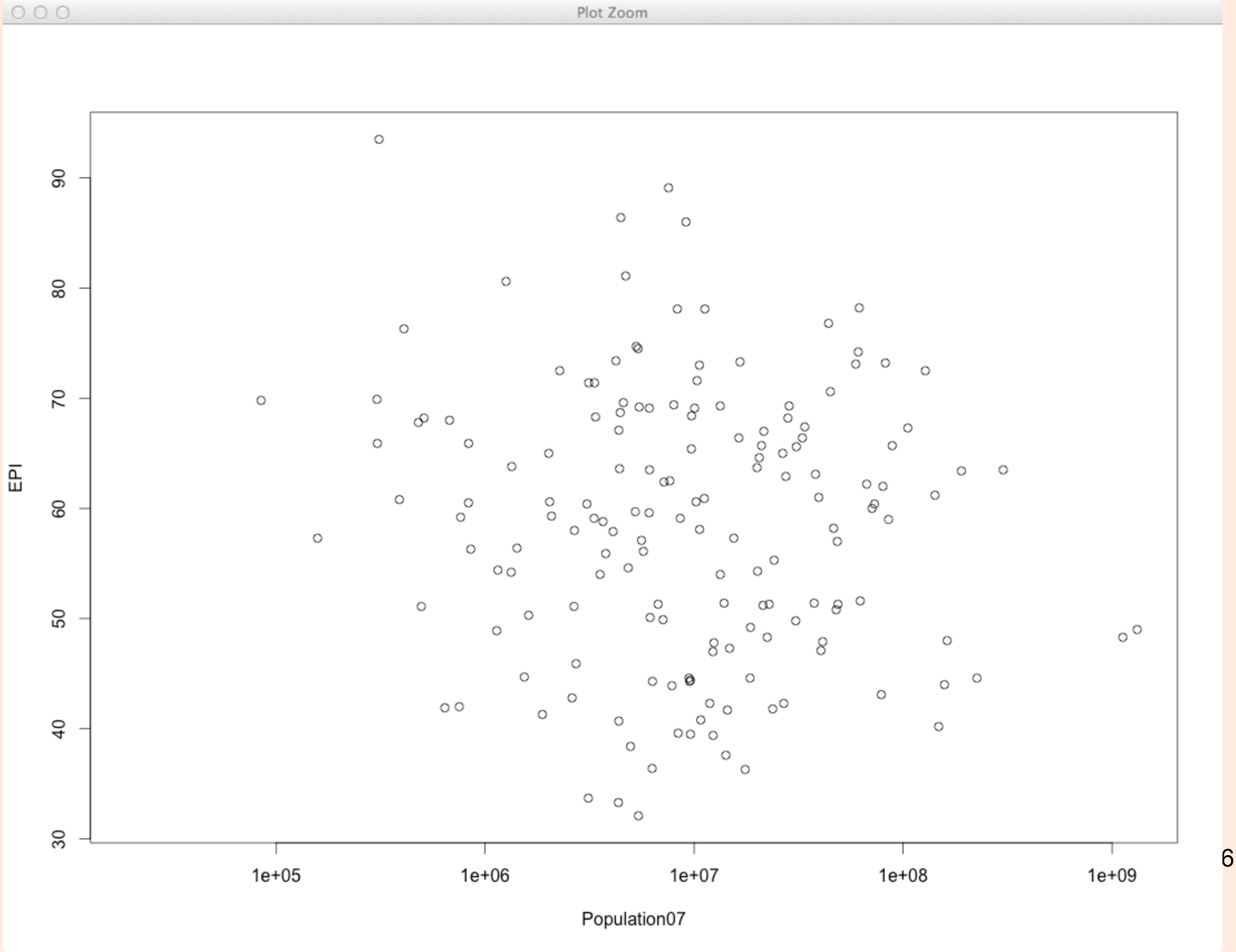
Exploring the distribution

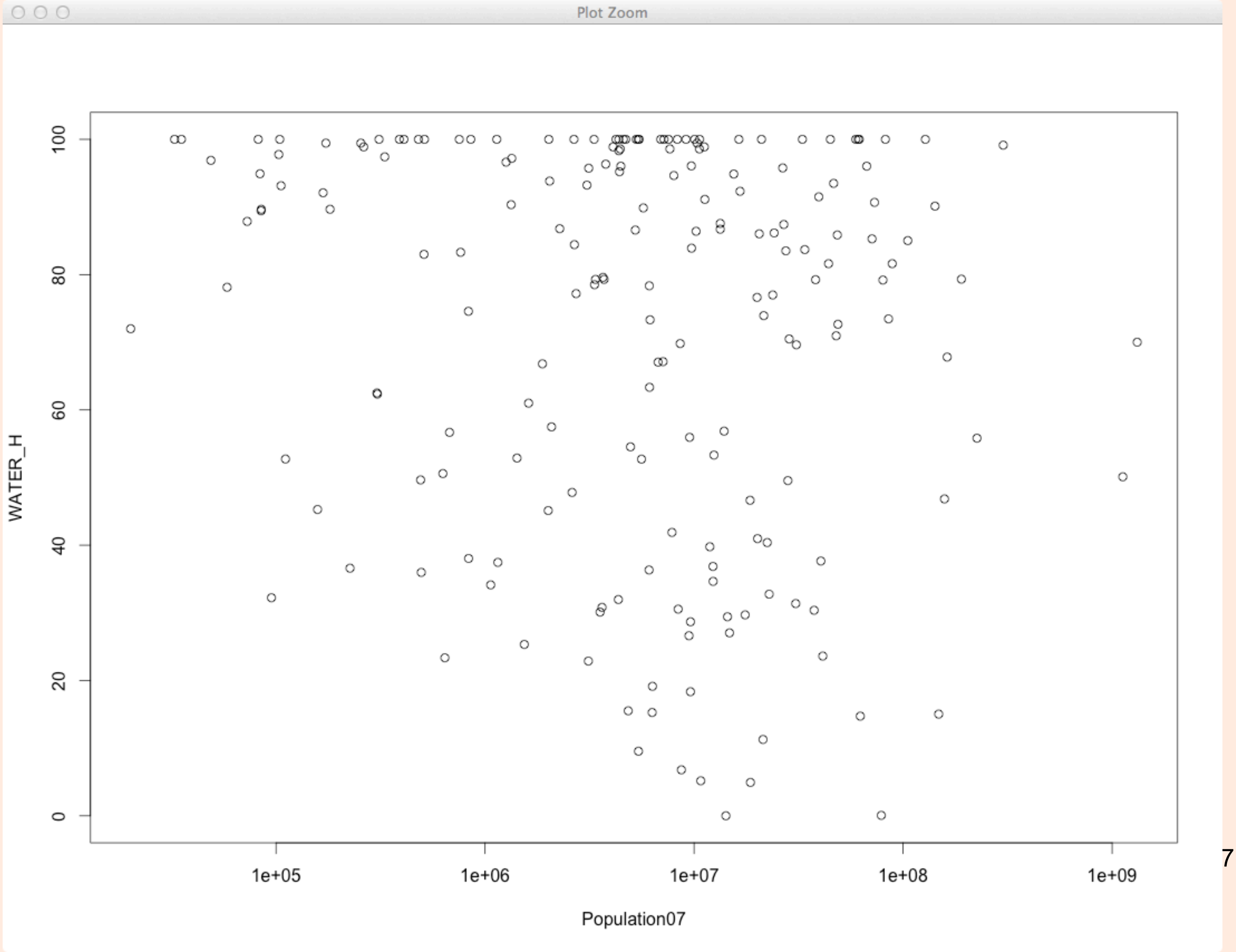
```
> summary(DALY)   # stats
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
   0.00   37.19   60.35   53.94   71.97   91.50      39

> fivenum(DALY,na.rm=TRUE)
[1]  0.000 36.955 60.350 72.320 91.500
```




Plot Zoom
Histogram of Population07
Frequency
0
5
10
15
20
25
30
0.0e+00
2.0e+08
4.0e+08
6.0e+08
8.0e+08
1.0e+09
1.2e+09
Population07

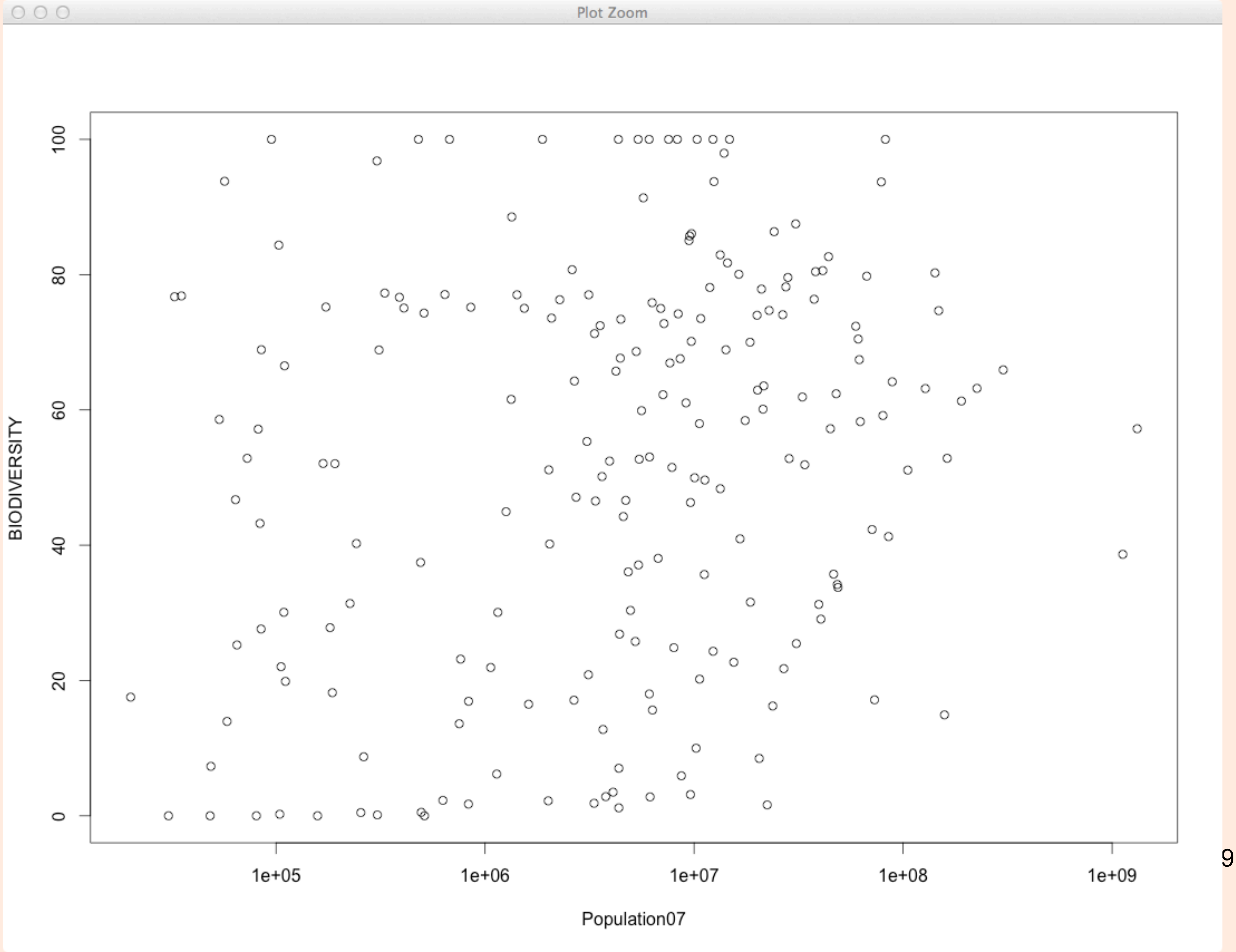

Plot Zoom
1e+05
1e+06
1e+07
1e+08
1e+09
Population07
0
50
100
150
200
Index

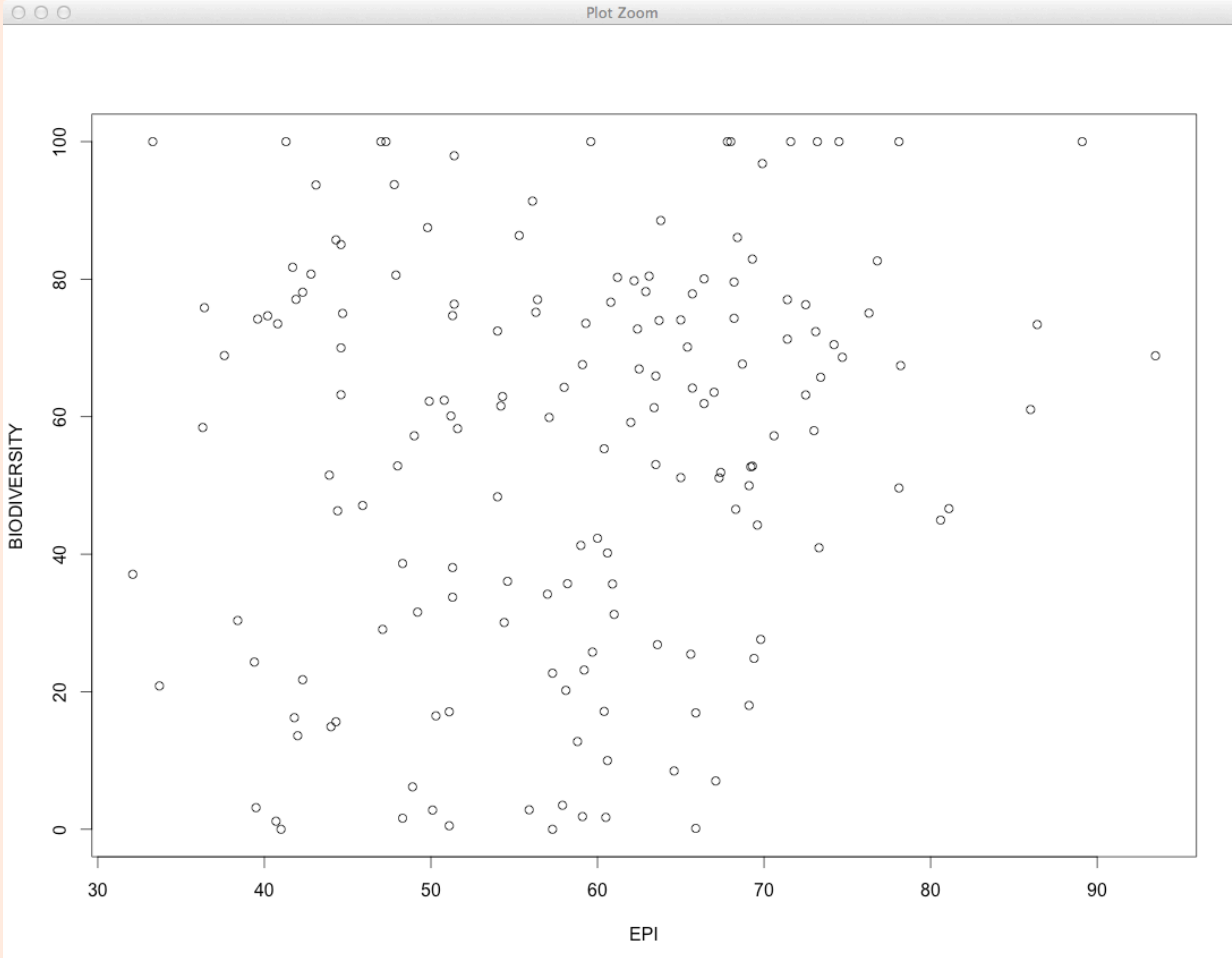

Plot Zoom
EPI
90
80
70
60
50
40
30
1e+05
1e+06
1e+07
1e+08
1e+09
Population07


Plot Zoom
WATER_H
0
20
40
60
80
100
1e+05
1e+06
1e+07
1e+08
1e+09
Population07

More munging

- Bad values, outliers, corrupted entries, thresholds …
- Noise reduction – low-pass filtering, binning
- Modal filtering
- REMEMBER: when you munge you MUST record what you did (and why) and save copies of pre- and post- operations…


Plot Zoom
BIODIVERSITY
0
20
40
60
80
100
1e+05
1e+06
1e+07
1e+08
1e+09
Population07



Plot Zoom
BIODIVERSITY
0
20
40
60
80
100
30
40
50
60
70
80
90
EPI

Populations within populations

- In the EPI example:
  - Geographic regions (GEO_subregion)
  - EPI_regions
  - Eco-regions
  - Primary industry(ies)
  - Climate region

- What would you do to start exploring?

Environmental Performance Index (EPI)
https://sedac.ciesin.columbia.edu/data/collection/epi

EPI	ENVHEALTH	ECOSYSTEM	DALY	AIR_H	WATER_H	AIR_E	WATER_E	BIODIVERSITY	FORESTRY	FISHERIES	AGRICULTURE	CLIMATE	DALY
NA	NA	NA	NA	NA	100.00	33.13	NA	0.23	100.00	92.86	40.00	NA	NA
NA	11.55	NA	0.00	35.49	10.72	72.03	57.43	3.11	22.63	NA	39.59	NA	0.000
36.3	18.29	54.40	0.00	43.47	29.70	40.13	64.76	58.43	94.79	86.74	54.55	53.85	0.000
NA	NA	NA	NA	NA	NA	86.54	NA	0.26	100.00	NA	40.00	NA	NA
71.4	69.93	72.92	65.50	52.97	95.73	49.16	91.24	77.02	100.00	62.54	54.55	68.97	65.50
NA	90.21	NA	84.77	91.28	100.00	52.41	NA	57.16	100.00	NA	40.00	NA	84.77
NA	NA	NA	NA	79.04	NA	18.19	NA	52.05	100.00	68.27	40.00	NA	NA
40.7	81.29	0.06	89.10	48.63	98.32	34.00	5.27	1.17	100.00	50.00	39.09	20.58	89.09
61.0	74.49	47.60	71.63	63.21	91.50	48.24	72.91	31.25	82.81	48.08	95.45	49.58	71.63
60.4	71.63	49.26	62.31	68.66	93.23	61.96	50.52	55.34	63.02	NA	92.84	49.85	62.31
NA	NA	NA	NA	NA	NA	46.47	NA	25.25	95.02	94.36	40.00	NA	NA
69.8	83.21	56.38	73.01	97.37	89.44	36.03	70.87	27.61	100.00	75.54	54.55	61.88	73.01
65.7	91.73	39.58	84.77	97.37	100.00	29.46	57.95	77.86	96.89	96.53	97.19	27.64	84.77
78.1	89.47	66.80	86.86	84.15	100.00	39.83	97.55	100.00	100.00	NA	84.54	50.07	86.86
59.1	62.72	55.43	57.61	65.86	69.81	54.33	51.40	67.57	100.00	NA	44.13	58.09	57.60
43.9	22.56	65.25	4.09	40.17	41.89	51.96	69.90	51.50	0.00	NA	100.00	78.02	4.089
58.1	89.05	27.09	80.96	94.30	100.00	21.44	56.53	20.20	100.00	48.74	70.00	36.65	80.95
39.6	22.94	56.24	16.40	28.43	30.55	50.30	68.62	74.20	22.24	91.50	99.80	54.71	16.39
47.3	12.24	82.33	4.94	12.04	27.04	58.68	59.90	100.00	79.12	NA	81.00	76.31	4.939
44.0	32.33	55.57	39.85	2.78	46.84	42.98	79.96	14.92	87.64	26.02	54.55	70.72	39.85
62.5	73.21	51.85	65.50	63.26	98.58	41.33	68.68	66.94	100.00	93.20	95.44	39.92	65.50

Or, a twist – n=1 but many attributes?

EPI	ENVHEALTH	ECOSYSTEM	DALY	AIR_H	WATER_H	AIR_E	WATER_E	BIODIVERSITY	FORESTRY	FISHERIES	AGRICULTURE	CLIMATE	DALY
NA	NA	NA	NA	NA	100.00	33.13	NA	0.23	100.00	92.86	40.00	NA	NA
NA	11.55	NA	0.00	35.49	10.72	72.03	57.43	3.11	22.63	NA	39.59	NA	0.000
36.3	18.29	54.40	0.00	43.47	29.70	40.13	64.76	58.43	94.79	86.74	54.55	53.85	0.000
NA	NA	NA	NA	NA	NA	86.54	NA	0.26	100.00	NA	40.00	NA	NA
71.4	69.93	72.92	65.50	52.97	95.73	49.16	91.24	77.02	100.00	62.54	54.55	68.97	65.50
NA	90.21	NA	84.77	91.28	100.00	52.41	NA	57.16	100.00	NA	40.00	NA	84.77
NA	NA	NA	NA	79.04	NA	18.19	NA	52.05	100.00	68.27	40.00	NA	NA
40.7	81.29	0.06	89.10	48.63	98.32	34.00	5.27	1.17	100.00	50.00	39.09	20.58	89.09
61.0	74.49	47.60	71.63	63.21	91.50	48.24	72.91	31.25	82.81	48.08	95.45	49.58	71.63
60.4	71.63	49.26	62.31	68.66	93.23	61.96	50.52	55.34	63.02	NA	92.84	49.85	62.31
NA	NA	NA	NA	NA	NA	46.47	NA	25.25	95.02	94.36	40.00	NA	NA
69.8	83.21	56.38	73.01	97.37	89.44	36.03	70.87	27.61	100.00	75.54	54.55	61.88	73.01
65.7	91.73	39.58	84.77	97.37	100.00	29.46	57.95	77.86	96.89	96.53	97.19	27.64	84.77
78.1	89.47	66.80	86.86	84.15	100.00	39.83	97.55	100.00	100.00	NA	84.54	50.07	86.86
59.1	62.72	55.43	57.61	65.86	69.81	54.33	51.40	67.57	100.00	NA	44.13	58.09	57.60
43.9	22.56	65.25	4.09	40.17	41.89	51.96	69.90	51.50	0.00	NA	100.00	78.02	4.089
58.1	89.05	27.09	80.96	94.30	100.00	21.44	56.53	20.20	100.00	48.74	70.00	36.65	80.95
39.6	22.94	56.24	16.40	28.43	30.55	50.30	68.62	74.20	22.24	91.50	99.80	54.71	16.39
47.3	12.24	82.33	4.94	12.04	27.04	58.68	59.90	100.00	79.12	NA	81.00	76.31	4.939
44.0	32.33	55.57	39.85	2.78	46.84	42.98	79.96	14.92	87.64	26.02	54.55	70.72	39.85
62.5	73.21	51.85	65.50	63.26	98.58	41.33	68.68	66.94	100.00	93.20	95.44	39.92	65.50

The item of interest in relation to its attributes

Summary: exploration

- Going from preliminary to initial analysis…

- Determining if there is one or more common distributions involved – i.e. parametric statistics (assumes or asserts a probability distribution)
- Fitting that distribution -> provides a model!
- Or NOT
  - A hybrid model or
  - Non-parametric (statistics) approaches are needed – more on this to come

Summary

- Cyber and Human data; quality, uncertainty and bias – you will often spend a lot of time with the data
- Distributions – the common and not-so common ones and how cyber and human data can have distinct distributions
- How simple statistical distributions can mislead us
- Populations and samples and how inferential statistics will lead us to model choices (no we have not actually done that yet in detail)
- Munging toward exploratory analysis
- Toward models!

Reminder: finish Lab 0

- Reminder to finish the last week intro to Lab (Lab 0)
- R! (how is your learning/coding in R going?) keep learning/coding…
- Create the Github repository for this class if you have not created so far and share the Data Analytics Class Github repo URL with the TA (please email TA your Github repo URL)