Lab 1

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You should have RStudio installed to edit this file. You will write code in places marked "TO-DO" to complete the problems. Some of this will be a pure programming assignment. The tools for the solutions to these problems can be found in the class practice lectures. I want you to use the methods I taught you, not for you to google and come up with whatever works. You won't learn that way.

To "hand in" the homework, you should compile or publish this file into a PDF that includes output of your code. Once it's done, push by the deadline to your repository in a directory called "labs".

- Print out the numerical constant pi with ten digits after the decimal point using the internal constant `pi`.

```
options(digits=11)
pi
```

```
## [1] 3.1415926536
```

- Sum up the first 103 terms of the series 1 + 1/2 + 1/4 + 1/8 + ...

```
sum(1/(2^(0:102)))
```

```
## [1] 2
```

- Find the product of the first 37 terms in the sequence 1/3, 1/6, 1/9 ...

```
prod((1/seq(from=3,by=3,length.out=37)))
```

```
## [1] 1.613528728e-61
```

- Find the product of the first 387 terms of `1 * 1/2 * 1/4 * 1/8 *` ...

```
prod(1/(2^(0:386)))
```

```
## [1] 0
```

Is this answer *exactly* correct?

No, it's not exactly correct because the number should be positive, not zero, the issue is that we experienced numerical underflow.

- Figure out a means to express the answer more exactly. Not compute exactly, but express more exactly.

```
-log(2)*sum(0:386)
```

```
## [1] -51771.856063
```

- Create the sequence `x = [Inf, 20, 18, ..., -20]`.

```
x<-c(Inf,seq(from=20, by=-2, to=-20))
x
```

```
##  [1] Inf  20  18  16  14  12  10   8   6   4   2   0  -2  -4  -6  -8 -10 -12 -14
```

```
## [20] -16 -18 -20
```

Create the sequence `x = [log_3(Inf), log_3(100), log_3(98), ... log_3(-20)]`.

```
x<-c(Inf, seq(from=100,to=-20,by=-2))
x = log(x, base=3)
```

```
## Warning: NaNs produced
```

```
x
```

```
##  [1]           Inf 4.19180654858 4.17341725189 4.15464876786 4.13548512895
##  [6] 4.11590933734 4.09590327429 4.07544759936 4.05452163807 4.03310325630
## [11] 4.01116871959 3.98869253500 3.96564727304 3.94200336639 3.91772888179
## [16] 3.89278926071 3.86714702345 3.84076143031 3.81358809222 3.78557852143
## [21] 3.75667961083 3.72683302786 3.69597450568 3.66403300988 3.63092975357
## [26] 3.59657702662 3.56087679501 3.52371901429 3.48497958377 3.44451784579
## [31] 3.40217350273 3.35776278143 3.31107361282 3.26185950714 3.20983167673
## [36] 3.15464876786 3.09590327429 3.03310325630 2.96564727304 2.89278926071
## [41] 2.81358809222 2.72683302786 2.63092975357 2.52371901429 2.40217350273
## [46] 2.26185950714 2.09590327429 1.89278926071 1.63092975357 1.26185950714
## [51] 0.63092975357          -Inf           NaN           NaN           NaN
## [56]           NaN           NaN           NaN           NaN           NaN
## [61]           NaN           NaN
```

Comment on the appropriateness of the non-numeric values.

Firstly, log is undefined for negative values so those values resulted in the Nan's. Secondly, it makes sense that the first value is infinity because log of infinity should be infinity since log is a slowly, but strictly, increasing function to infinity. Lastly, log of zero is negative infinity.

- Create a vector of booleans where the entry is true if `x[i]` is positive and finite.

```
y=!is.nan(x) & is.finite(x) & x>0
```

- Locate the indices of the non-real numbers in this vector. Hint: use the `which` function. Don't hesitate to use the documentation via `?which`.

```
which(y==FALSE)
```

```
##  [1]  1 52 53 54 55 56 57 58 59 60 61 62
```

- Locate the indices of the infinite quantities in this vector.

```
which(is.infinite(x))
```

```
## [1]  1 52
```

- Locate the indices of the min and max in this vector. Hint: use the `which.min` and `which.max` functions.

```
which.min(x)
```

```
## [1] 52
```

```
which.max(x)
```

```
## [1] 1
```

- Count the number of unique values in `x`.

```
length(unique(x))
```

```
## [1] 53
```

- Cast `x` to a factor. Do the number of levels make sense?

```
as.factor(x)
```

```
##  [1] Inf               4.19180654857877  4.1734172518943   4.15464876785729
##  [5] 4.13548512895119  4.11590933734319  4.09590327428938  4.07544759935851
##  [9] 4.05452163806914  4.03310325630434  4.01116871959141  3.98869253500376
## [13] 3.96564727304425  3.94200336638929  3.91772888178973  3.89278926071437
## [17] 3.86714702345081  3.84076143030548  3.81358809221559  3.78557852142874
## [21] 3.75667961082847  3.72683302786084  3.69597450568212  3.66403300987579
## [25] 3.63092975357146  3.59657702661571  3.56087679500731  3.52371901428583
## [29] 3.48497958377173  3.44451784578705  3.40217350273288  3.3577627814323
## [33] 3.31107361281783  3.26185950714291  3.20983167673402  3.15464876785729
## [37] 3.09590327428938  3.03310325630434  2.96564727304425  2.89278926071437
## [41] 2.8135880922156   2.72683302786084  2.63092975357146  2.52371901428583
## [45] 2.40217350273288  2.26185950714291  2.09590327428938  1.89278926071437
## [49] 1.63092975357146  1.26185950714291  0.630929753571457 -Inf
## [53] NaN               NaN               NaN               NaN
## [57] NaN               NaN               NaN               NaN
## [61] NaN               NaN
## 53 Levels: -Inf 0.630929753571457 1.26185950714291 ... NaN
```

- Cast `x` to integers. What do we learn about R's infinity representation in the integer data type?

```
as.integer(x)
```

```
## Warning: NAs introduced by coercion to integer range
```

```
##  [1] NA  4  4  4  4  4  4  4  4  4  4  3  3  3  3  3  3  3  3  3  3  3  3  3
## [26]  3  3  3  3  3  3  3  3  3  3  3  3  2  2  2  2  2  2  2  2  2  1  1  1
## [51]  0 NA NA NA NA NA NA NA NA NA NA NA
```

- Use `x` to create a new vector `y` containing only the real numbers in x.

```
y=x[(!is.nan(x) & is.finite(x) & x>0)]
y
```

```
##  [1] 4.19180654858 4.17341725189 4.15464876786 4.13548512895 4.11590933734
##  [6] 4.09590327429 4.07544759936 4.05452163807 4.03310325630 4.01116871959
## [11] 3.98869253500 3.96564727304 3.94200336639 3.91772888179 3.89278926071
## [16] 3.86714702345 3.84076143031 3.81358809222 3.78557852143 3.75667961083
## [21] 3.72683302786 3.69597450568 3.66403300988 3.63092975357 3.59657702662
## [26] 3.56087679501 3.52371901429 3.48497958377 3.44451784579 3.40217350273
## [31] 3.35776278143 3.31107361282 3.26185950714 3.20983167673 3.15464876786
## [36] 3.09590327429 3.03310325630 2.96564727304 2.89278926071 2.81358809222
## [41] 2.72683302786 2.63092975357 2.52371901429 2.40217350273 2.26185950714
## [46] 2.09590327429 1.89278926071 1.63092975357 1.26185950714 0.63092975357
```

- Use the left rectangle method to numerically integrate x^2 from 0 to 1 with rectangle width size 1e-6.

```
sum(seq(from=0, to=1-1e-6, by=1e-6)^2) * 1e-6
```

```
## [1] 0.33333283333
```

- Calculate the average of 100 realizations of standard Bernoullis in one line using the `sample` function.

```
sample(c(0,1), size=100, replace=TRUE)
```

```
##   [1] 1 1 0 0 0 0 1 1 1 0 0 1 1 1 1 0 1 0 1 0 1 0 0 1 1 0 0 1 1 1 1 0 0 0 0 1 0
##  [38] 1 0 1 0 0 0 0 1 1 1 1 1 0 1 1 1 1 1 0 1 0 0 0 1 0 0 1 0 1 1 0 1 1 0 1 1 0
##  [75] 1 0 0 0 1 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 1 1 1 0 1
```

- Calculate the average of 500 realizations of Bernoullis with p = 0.9 in one line using the `sample` and `mean` functions.

```
mean(sample(c(0,1), size=500, replace=TRUE, prob=c(0.1,0.9)))
```

```
## [1] 0.88
```

- Calculate the average of 1000 realizations of Bernoullis with p = 0.9 in one line using `rbinom`.

```
mean(rbinom(n=1000,size=1, prob=0.9))
```

```
## [1] 0.915
```

- In class we considered a variable `x_3` which measured "criminality". We imagined L = 4 levels "none", "infraction", "misdimeanor" and "felony". Create a variable `x_3` here with 100 random elements (equally probable). Create it as a nominal (i.e. unordered) factor.

```
x_3 = as.factor(sample(c("none", "infraction", "misdimeanor", "felony"), size=100, replace=TRUE))
```

- Use `x_3` to create `x_3_bin`, a binary feature where 0 is no crime and 1 is any crime.

```
x_3_bin = (x_3!="none")
x_3_bin
```

```
##   [1]  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE FALSE  TRUE  TRUE
##  [13]  TRUE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE
##  [25] FALSE  TRUE FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [37]  TRUE FALSE FALSE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE
##  [49]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE FALSE
##  [61] FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [73] FALSE FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE  TRUE FALSE  TRUE  TRUE
##  [85] FALSE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE FALSE FALSE  TRUE  TRUE  TRUE
##  [97]  TRUE  TRUE  TRUE  TRUE
```

- Use `x_3` to create `x_3_ord`, an ordered factor variable. Ensure the proper ordinal ordering.

```
factor(x_3, levels = c("none", "infraction", "misdimeanor", "felony"), ordered = TRUE)
```

```
##   [1] felony      infraction  none        felony      infraction  misdimeanor
##   [7] infraction  none        misdimeanor none        felony      felony
##  [13] misdimeanor none        felony      misdimeanor misdimeanor felony
##  [19] misdimeanor infraction  infraction  infraction  none        infraction
##  [25] none        infraction  none        none        felony      misdimeanor
##  [31] felony      infraction  felony      infraction  felony      infraction
##  [37] infraction  none        none        infraction  felony      misdimeanor
##  [43] infraction  none        infraction  infraction  felony      infraction
##  [49] felony      felony      infraction  infraction  infraction  infraction
##  [55] misdimeanor misdimeanor none        infraction  felony      none
##  [61] none        misdimeanor felony      none        felony      infraction
##  [67] misdimeanor misdimeanor felony      infraction  misdimeanor misdimeanor
##  [73] none        none        none        misdimeanor none        none
##  [79] none        felony      infraction  none        felony      infraction
##  [85] none        misdimeanor infraction  misdimeanor felony      none
##  [91] infraction  none        none        felony      infraction  infraction
##  [97] felony      infraction  infraction  felony
## Levels: none < infraction < misdimeanor < felony
```

- Convert this variable into three binary variables without any information loss and put them into a data matrix. (leave out none)

```r
M = matrix(nrow = length(x_3), ncol=3)
M[ ,1]= as.numeric(x_3 == "infraction")
M[ ,2]= as.numeric(x_3 == "misdimeanor")
M[ ,3] = as.numeric(x_3 == "felony")
colnames(M) = c("has_inf","has_fel", "has_misdim")
M
```

```
##        has_inf has_fel has_misdim
##   [1,]       0       0          1
##   [2,]       1       0          0
##   [3,]       0       0          0
##   [4,]       0       0          1
##   [5,]       1       0          0
##   [6,]       0       1          0
##   [7,]       1       0          0
##   [8,]       0       0          0
##   [9,]       0       1          0
##  [10,]       0       0          0
##  [11,]       0       0          1
##  [12,]       0       0          1
##  [13,]       0       1          0
##  [14,]       0       0          0
##  [15,]       0       0          1
##  [16,]       0       1          0
##  [17,]       0       1          0
##  [18,]       0       0          1
##  [19,]       0       1          0
##  [20,]       1       0          0
##  [21,]       1       0          0
##  [22,]       1       0          0
##  [23,]       0       0          0
##  [24,]       1       0          0
##  [25,]       0       0          0
##  [26,]       1       0          0
##  [27,]       0       0          0
##  [28,]       0       0          0
##  [29,]       0       0          1
##  [30,]       0       1          0
##  [31,]       0       0          1
##  [32,]       1       0          0
##  [33,]       0       0          1
##  [34,]       1       0          0
##  [35,]       0       0          1
##  [36,]       1       0          0
##  [37,]       1       0          0
##  [38,]       0       0          0
##  [39,]       0       0          0
##  [40,]       1       0          0
##  [41,]       0       0          1
##  [42,]       0       1          0
##  [43,]       1       0          0
##  [44,]       0       0          0
##  [45,]       1       0          0
##  [46,]       1       0          0
```

```
##  [47,]       0       0          1
##  [48,]       1       0          0
##  [49,]       0       0          1
##  [50,]       0       0          1
##  [51,]       1       0          0
##  [52,]       1       0          0
##  [53,]       1       0          0
##  [54,]       1       0          0
##  [55,]       0       1          0
##  [56,]       0       1          0
##  [57,]       0       0          0
##  [58,]       1       0          0
##  [59,]       0       0          1
##  [60,]       0       0          0
##  [61,]       0       0          0
##  [62,]       0       1          0
##  [63,]       0       0          1
##  [64,]       0       0          0
##  [65,]       0       0          1
##  [66,]       1       0          0
##  [67,]       0       1          0
##  [68,]       0       1          0
##  [69,]       0       0          1
##  [70,]       1       0          0
##  [71,]       0       1          0
##  [72,]       0       1          0
##  [73,]       0       0          0
##  [74,]       0       0          0
##  [75,]       0       0          0
##  [76,]       0       1          0
##  [77,]       0       0          0
##  [78,]       0       0          0
##  [79,]       0       0          0
##  [80,]       0       0          1
##  [81,]       1       0          0
##  [82,]       0       0          0
##  [83,]       0       0          1
##  [84,]       1       0          0
##  [85,]       0       0          0
##  [86,]       0       1          0
##  [87,]       1       0          0
##  [88,]       0       1          0
##  [89,]       0       0          1
##  [90,]       0       0          0
##  [91,]       1       0          0
##  [92,]       0       0          0
##  [93,]       0       0          0
##  [94,]       0       0          1
##  [95,]       1       0          0
##  [96,]       1       0          0
##  [97,]       0       0          1
##  [98,]       1       0          0
##  [99,]       1       0          0
## [100,]       0       0          1
```

- What should the sum of each row be (in English)?

The sum of each row should be either 0 - if it's a "none" - or a 1 since it'll be one of the three categories left.

Verify that.

```
table(rowSums(M))
```

```
##
##  0  1
## 26 74
```

- How should the column sum look (in English)?

Since this is a uniform distribution, the columns sums should be somewhere around the expectation value.

Verify that.

```
colSums(M)
```

```
##    has_inf    has_fel has_misdim
##         32         18         24
```

- Generate a matrix with 100 rows where the first column is realization from a normal with mean 17 and variance 38, the second column is uniform between -10 and 10, the third column is poisson with mean 6, the fourth column in exponential with lambda of 9, the fifth column is binomial with n = 20 and p = 0.12 and the sixth column is a binary variable with exactly 24% 1's dispersed randomly. Name the rows the entries of the `fake_first_names` vector.

```
n=100
M = matrix(nrow = n, ncol=6)
M[, 1] = rnorm(n = n, mean = 17, sd = sqrt(38))
M[, 2] = runif(n = n, min = -10, max = 10)
M[, 3] = rpois(n, lambda = 6)
M[, 4] = rexp(n, rate = 9)
M[, 5] = rbinom(n, size = 20, prob = 0.12)
M[, 6] = sample(c(rep(1, n * .24), rep(0, n * .76)))

fake_first_names = c(
  "Sophia", "Emma", "Olivia", "Ava", "Mia", "Isabella", "Riley",
  "Aria", "Zoe", "Charlotte", "Lily", "Layla", "Amelia", "Emily",
  "Madelyn", "Aubrey", "Adalyn", "Madison", "Chloe", "Harper",
  "Abigail", "Aaliyah", "Avery", "Evelyn", "Kaylee", "Ella", "Ellie",
  "Scarlett", "Arianna", "Hailey", "Nora", "Addison", "Brooklyn",
  "Hannah", "Mila", "Leah", "Elizabeth", "Sarah", "Eliana", "Mackenzie",
  "Peyton", "Maria", "Grace", "Adeline", "Elena", "Anna", "Victoria",
  "Camilla", "Lillian", "Natalie", "Jackson", "Aiden", "Lucas",
  "Liam", "Noah", "Ethan", "Mason", "Caden", "Oliver", "Elijah",
  "Grayson", "Jacob", "Michael", "Benjamin", "Carter", "James",
  "Jayden", "Logan", "Alexander", "Caleb", "Ryan", "Luke", "Daniel",
  "Jack", "William", "Owen", "Gabriel", "Matthew", "Connor", "Jayce",
  "Isaac", "Sebastian", "Henry", "Muhammad", "Cameron", "Wyatt",
  "Dylan", "Nathan", "Nicholas", "Julian", "Eli", "Levi", "Isaiah",
  "Landon", "David", "Christian", "Andrew", "Brayden", "John",
  "Lincoln"
)
rownames(M) = fake_first_names
M
```

```
##                   [,1]            [,2] [,3]             [,4] [,5] [,6]
```

```
## Sophia    13.7733518698 -3.019495215267    6 0.00102990453605    1    0
## Emma      25.9273756407  5.238953656517    5 0.04590156224246    1    0
## Olivia     9.3813172270  0.032697012648    4 0.03299709023797    1    0
## Ava       26.8762592502  7.859894791618    5 0.01055423216894    2    0
## Mia       13.3852716671  5.733684389852    3 0.06278648672418    2    1
## Isabella  16.2066362049 -0.716323587112    6 0.06667271059834    5    1
## Riley      5.0119868679 -0.275440048426    5 0.00365708390665    1    0
## Aria       6.1512366791  1.941614779644    6 0.18378741760956    2    0
## Zoe       21.8230441927 -3.487926530652    9 0.04656012744332    1    0
## Charlotte 16.1302483695  0.245467694476    4 0.01950741045904    1    1
## Lily      18.5901614146  9.032875332050    4 0.04863951593224    1    0
## Layla     11.8841893347  7.932106107473    5 0.02060723758989    3    0
## Amelia    20.4688790519  8.872203952633   14 0.06136175731404    2    0
## Emily     19.6757187231  8.942109621130    6 0.09002247731666    6    0
## Madelyn   19.7561954686  4.926254292950    6 0.13129594812497    2    0
## Aubrey     7.4956664279  1.633846419863    2 0.16503275081410    2    1
## Adalyn    33.0777121180  2.395492224023    2 0.15968247233060    3    1
## Madison   18.4061481006  9.968550303020    7 0.07878585705610    5    0
## Chloe     19.7013718016  1.071700998582    6 0.01076410100278    5    0
## Harper    18.0501717781 -2.842340995558    9 0.14282454601540    1    0
## Abigail   18.4696250754 -9.183977204375    5 0.03196048015347    5    0
## Aaliyah   20.5571560976 -0.602212212980    5 0.31135022390009    8    1
## Avery     22.9491223305 -5.460317311808    6 0.02258656251555    4    0
## Evelyn    13.3555741570 -6.143842590973    3 0.06739528440974    5    0
## Kaylee    11.0593603419 -5.640570521355    3 0.01593084405694    1    0
## Ella      22.0968914046 -9.676501038484    5 0.03151767499124    3    0
## Ellie     26.0117857516 -1.422029961832    8 0.09517165604098    3    0
## Scarlett  21.2852139333  2.613247046247    5 0.27168676518716    3    0
## Arianna   16.9552987786  5.398988910019    3 0.12837186745005    5    1
## Hailey    20.1629157539  2.041287985630    5 0.24816252434675    5    0
## Nora      14.2653704435  9.196344995871    6 0.01381570855213    2    0
## Addison   13.0191684878 -9.054537615739    7 0.04357048299991    1    0
## Brooklyn  12.7921060565 -2.113867504522    4 0.02847914996685    2    0
## Hannah    17.0698831306  0.861195456237    7 0.16659555190034    2    1
## Mila      14.0934040355 -8.094856562093    5 0.16310311407231    2    1
## Leah      18.1069236252 -3.750693826005    8 0.19933194666167    1    0
## Elizabeth 16.3218734670 -8.104541120119    3 0.37840735248182    2    0
## Sarah     26.4555922606 -6.754725766368    6 0.08086855305513    4    1
## Eliana    15.1055763347  2.112463391386    4 0.08235902932483    2    0
## Mackenzie 19.0044027879  7.726108147763    6 0.18900711005655    4    0
## Peyton    10.4177938988  1.151086306199    7 0.03664382471229    4    0
## Maria     19.4128411458  9.292313689366    4 0.02328118780214    3    0
## Grace     18.2098598606  7.745852163061    8 0.08309397711469    4    0
## Adeline   10.8673719829  3.356788447127    2 0.13412904625085    2    0
## Elena     29.4959579807 -9.992113127373    1 0.02046427815442    4    0
## Anna      23.8329323316  1.692834552377    4 0.04443006424440    3    0
## Victoria  15.8915612680  1.141447951086    3 0.07159669464454    3    0
## Camilla   18.3603709020 -3.873172206804    4 0.22031036266744    4    1
## Lillian   14.9760101038 -0.768632413819    7 0.10131531891257    4    0
## Natalie   19.2227696436  2.174542476423    0 0.21390506707026    1    0
## Jackson   25.3677374094  9.933876111172    7 0.18395390919407    3    0
## Aiden     21.1657740517 -5.402871482074    6 0.10679667782466    1    0
## Lucas     20.1050255578  1.484918072820    7 0.01390375983384    2    1
## Liam      15.9185249781  0.800901716575    5 0.01307888054806    5    0
```

```
## Noah      12.9418298662 -9.400038192980    4 0.00416810065508    3    0
## Ethan      8.8849156101  2.501891213469    6 0.07198064318962    3    0
## Mason     19.9486591940  3.714092425071    6 0.01356596582466    2    0
## Caden     17.6427943475  0.961359217763    4 0.00617793264488    4    1
## Oliver    25.8432381000  2.006597351283    9 0.16338688920050    1    1
## Elijah    15.5128413337  2.851617950946    8 0.21794151720796    0    0
## Grayson   25.5821098762 -0.159254772589    6 0.00128008828211    1    0
## Jacob     17.7024320794 -3.345780675299    6 0.19890597875045    3    1
## Michael    3.2313409115 -8.172285351902    4 0.25476603864020    5    0
## Benjamin  18.6901382274  0.114256436937   10 0.12455710054219    1    0
## Carter     9.6702159937 -9.439952443354    6 0.19346079995129    3    0
## James     23.5214808416 -3.808358479291    5 0.32507198254682    2    0
## Jayden    21.2073529136  6.881910609081    6 0.13412290407499    0    0
## Logan      3.5635061566 -8.787432820536    8 0.05820497047777    0    0
## Alexander  9.4097749642  1.895772172138    6 0.05445662834164    2    0
## Caleb     18.0469314515  8.648275048472    4 0.10231645829095    0    0
## Ryan       9.7692352490  4.817872145213    5 0.06898554316204    0    0
## Luke      11.2615676149  0.454300963320   10 0.23283332427373    1    0
## Daniel     9.3210286511  4.912082161754    4 0.06840297388327    3    0
## Jack      13.4778643696 -4.777302257717   10 0.05336736169495    2    0
## William   16.1437614944 -0.598088242114    1 0.10294270752980    0    1
## Owen      20.0434139772  4.521135147661    5 0.19336178917261    2    1
## Gabriel   23.3779021760 -3.087518708780    5 0.05335325080281    0    0
## Matthew   16.6085163440 -5.988349905238    7 0.00209721136424    2    0
## Connor    18.0184961849 -2.103809718974    3 0.14081013843778    2    0
## Jayce      9.9469508467  2.079782397486    8 0.00094923598909    0    1
## Isaac      9.9189201865  5.844696993008    6 0.01279705043675    4    0
## Sebastian 22.3779960500  6.647885418497    4 0.09856027012431    2    1
## Henry     27.6170500174 -5.921466336586   10 0.20654811529240    2    1
## Muhammad  17.0981978470  5.518027148210    5 0.07952200620900    1    0
## Cameron   15.6667913136 -1.070513194427   12 0.13124445038898    2    0
## Wyatt     17.4401574020  9.664447964169    5 0.28923946431369    1    0
## Dylan     15.7890333533  2.648317143321    5 0.05097077621354    2    0
## Nathan    11.2096849542  4.954625535756    8 0.04377691753002    1    0
## Nicholas  21.0780748236 -5.274515454657    4 0.00600045458931    1    1
## Julian    11.7110356234 -8.419428924099    5 0.26563519962387    3    0
## Eli       16.3231158875  1.415422484279    3 0.01453185798198    3    0
## Levi      10.2192801043  9.452937995084    5 0.01285217257050    1    0
## Isaiah    14.0096477032  4.130030251108    8 0.05748212456496    0    0
## Landon    14.0632645297 -8.666919227690   10 0.20572079427435    3    1
## David     13.8179854652 -7.234794814140    4 0.04614934909882    3    0
## Christian 26.8730617380 -5.978430509567    6 0.19122955015858    6    0
## Andrew    16.0146998271  6.235474981368    8 0.08932743479755    3    1
## Brayden   18.9753558195 -2.080069067888    8 0.08445614237212    4    0
## John      20.7790641013  3.593741897494    6 0.12294393994689    1    0
## Lincoln   11.8308243180  3.082293369807    5 0.07207187720471    3    1
```

- Create a data frame of the same data as above except make the binary variable a factor "DOMESTIC" vs "FOREIGN" for 0 and 1 respectively. Use RStudio's `View` function to ensure this worked as desired.

```
my_data = data.frame(M)
my_data$X6 = factor(my_data$X6, levels = c(0,1), labels = c("DOMESTIC", "FOREIGN"))
View(my_data, "This is My Data")
```

- Print out a table of the binary variable. Then print out the proportions of "DOMESTIC" vs "FOREIGN".

```
table(my_data$X6)
```

```
##
## DOMESTIC  FOREIGN
##       76       24
```

```
table(my_data$X6) / n
```

```
##
## DOMESTIC  FOREIGN
##     0.76     0.24
```

Print out a summary of the whole dataframe.

```
summary(my_data)
```

```
##        X1                    X2                    X3
##  Min.   : 3.2313409   Min.   :-9.99211313   Min.   : 0.00
##  1st Qu.:13.2714727   1st Qu.:-3.76510999   1st Qu.: 4.00
##  Median :17.0840405   Median : 1.10657447   Median : 5.00
##  Mean   :16.9633626   Mean   : 0.43405197   Mean   : 5.66
##  3rd Qu.:20.2394066   3rd Qu.: 4.84142465   3rd Qu.: 7.00
##  Max.   :33.0777121   Max.   : 9.96855030   Max.   :14.00
##        X4                      X5              X6
##  Min.   :0.00094923599   Min.   :0.00   DOMESTIC:76
##  1st Qu.:0.03184977886   1st Qu.:1.00   FOREIGN :24
##  Median :0.07542886713   Median :2.00
##  Mean   :0.10141573103   Mean   :2.42
##  3rd Qu.:0.16317405785   3rd Qu.:3.00
##  Max.   :0.37840735248   Max.   :8.00
```

- Let `n = 50`. Create a n x n matrix `R` of exactly 50% entries 0's, 25% 1's 25% 2's. These values should be in random locations.

```
n = 50
R = matrix(sample(c(rep(0,n^2*0.5), rep(1, n^2*0.25), rep(2, n^2*.25))), nrow = n, ncol = n)
R
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
##  [1,]    0    2    2    0    0    1    2    0    1     1     0     0     0
##  [2,]    0    0    0    0    2    0    0    0    1     0     1     1     2
##  [3,]    2    2    1    0    1    2    1    1    0     2     0     0     0
##  [4,]    0    2    1    0    2    0    1    0    0     1     0     1     1
##  [5,]    0    0    0    0    0    0    1    0    0     0     2     1     0
##  [6,]    0    2    1    2    2    1    0    0    0     0     0     0     0
##  [7,]    1    2    0    2    0    0    0    0    0     0     0     0     1
##  [8,]    1    2    1    1    0    0    0    1    1     1     1     0     1
##  [9,]    0    0    0    0    1    1    1    0    0     0     1     1     1
## [10,]    0    0    2    1    0    1    0    0    2     0     1     2     2
## [11,]    1    2    1    0    1    1    0    0    0     0     0     1     0
## [12,]    1    1    2    0    2    2    2    1    1     2     2     1     2
## [13,]    1    2    2    1    2    1    1    2    0     2     1     1     0
## [14,]    2    2    0    2    2    1    0    2    2     2     2     2     0
## [15,]    1    2    0    0    2    0    2    0    1     0     1     0     0
## [16,]    2    2    0    1    0    0    0    1    0     0     0     0     0
## [17,]    1    2    2    2    2    0    0    2    1     0     2     0     0
## [18,]    0    0    0    1    0    2    0    0    0     0     0     2     0
```

```
## [19,]    0    2    1    1    0    2    2    2    0    1    0    1    1
## [20,]    1    0    1    0    0    0    0    1    2    1    0    2    0
## [21,]    2    0    2    2    2    0    1    0    2    1    0    1    0
## [22,]    0    0    2    0    0    2    0    1    0    1    0    1    0
## [23,]    0    1    1    1    0    2    2    1    1    2    0    1    0
## [24,]    0    1    0    2    1    0    0    1    0    2    1    2    2
## [25,]    0    0    0    0    0    0    2    0    0    2    0    0    2
## [26,]    0    2    2    0    0    2    1    2    0    0    0    2    2
## [27,]    1    0    2    2    2    2    0    0    0    0    0    0    0
## [28,]    1    2    2    0    0    2    1    1    1    2    0    1    0
## [29,]    1    2    0    2    0    1    0    0    1    1    0    1    0
## [30,]    0    2    2    1    1    0    0    1    0    0    1    0    0
## [31,]    2    2    0    0    2    0    0    0    0    1    0    0    1
## [32,]    0    0    2    1    1    2    0    1    1    2    0    0    1
## [33,]    0    2    1    0    0    2    0    1    0    1    0    2    1
## [34,]    2    0    2    0    1    2    0    0    0    1    2    2    2
## [35,]    2    0    0    0    0    1    0    2    0    2    2    0    0
## [36,]    1    0    0    1    1    1    0    0    2    0    0    0    1
## [37,]    1    0    2    1    1    0    1    2    0    0    0    0    2
## [38,]    0    2    2    1    2    2    0    2    1    2    1    1    2
## [39,]    0    1    0    2    0    0    2    0    0    0    0    0    0
## [40,]    2    0    0    2    0    2    0    2    0    2    0    0    2
## [41,]    1    0    0    0    2    0    0    2    0    0    1    0    2
## [42,]    2    0    0    1    0    0    1    2    0    0    2    0    0
## [43,]    0    0    0    2    0    1    1    0    0    2    1    1    2
## [44,]    1    0    0    0    0    1    1    1    0    0    0    0    0
## [45,]    2    0    1    0    0    0    2    1    0    1    0    0    0
## [46,]    0    0    0    2    2    1    2    2    0    0    0    0    1
## [47,]    1    0    1    0    0    0    0    2    0    1    2    0    2
## [48,]    0    0    2    1    0    0    2    1    2    0    2    0    1
## [49,]    2    0    0    0    0    0    1    0    2    2    1    0    1
## [50,]    1    1    0    2    0    0    0    1    1    0    0    0    1
##       [,14] [,15] [,16] [,17] [,18] [,19] [,20] [,21] [,22] [,23] [,24] [,25]
##  [1,]    2     2     0     2     1     0     2     0     2     1     2     1
##  [2,]    0     0     2     1     2     1     0     0     0     2     2     0
##  [3,]    0     0     0     2     0     0     2     0     2     2     0     0
##  [4,]    2     1     2     0     0     1     0     0     2     0     2     2
##  [5,]    2     2     0     2     0     2     0     0     0     2     1     2
##  [6,]    0     2     2     0     1     2     0     1     0     1     0     0
##  [7,]    0     0     2     0     1     1     0     2     1     0     0     0
##  [8,]    2     0     1     0     1     0     1     1     2     1     2     0
##  [9,]    0     1     0     0     0     0     0     0     1     2     0     0
## [10,]    1     0     0     0     0     1     0     2     2     0     2     0
## [11,]    0     2     0     2     2     0     2     2     0     0     2     1
## [12,]    0     0     2     0     2     2     0     0     0     0     0     0
## [13,]    0     2     2     0     2     1     2     0     0     2     1     2
## [14,]    0     1     0     0     2     0     2     2     0     1     2     1
## [15,]    0     0     1     0     2     1     2     0     2     2     0     1
## [16,]    1     1     2     2     2     1     1     0     2     0     1     0
## [17,]    0     1     0     1     2     2     0     2     0     1     0     0
## [18,]    1     1     2     0     1     0     0     2     0     0     0     0
## [19,]    1     0     0     1     2     0     1     1     0     1     0     0
## [20,]    1     2     0     0     0     1     0     0     0     0     0     0
## [21,]    0     0     2     0     2     2     2     0     1     1     1     2
```

```
## [22,]    2    1    2    0    2    0    0    1    0    2    1    0
## [23,]    2    2    2    0    0    0    0    0    2    2    1    1
## [24,]    0    1    0    2    0    0    0    0    1    0    0    2
## [25,]    1    1    1    0    0    0    0    1    0    0    0    0
## [26,]    0    0    0    1    0    0    0    2    1    0    1    0
## [27,]    1    1    2    0    0    0    2    0    2    2    0    2
## [28,]    0    0    0    1    1    1    0    2    1    1    0    2
## [29,]    0    0    2    0    0    1    1    2    2    1    1    2
## [30,]    0    0    0    0    0    0    1    2    0    2    0    2
## [31,]    0    0    0    0    2    1    0    2    2    2    2    0
## [32,]    2    0    0    0    1    0    0    0    2    0    0    0
## [33,]    0    1    2    2    2    0    0    0    0    2    2    1
## [34,]    0    0    0    0    0    2    0    0    1    0    1    2
## [35,]    1    0    2    1    0    2    1    0    1    2    1    1
## [36,]    2    1    0    1    0    2    0    0    2    1    0    0
## [37,]    1    2    0    1    2    0    0    2    2    1    1    0
## [38,]    2    2    0    0    1    2    2    2    2    0    0    2
## [39,]    1    0    2    1    2    0    0    1    0    2    2    0
## [40,]    1    0    0    0    0    0    0    0    0    0    1    1
## [41,]    0    2    2    1    0    1    0    2    1    2    0    2
## [42,]    1    0    0    0    0    0    1    0    0    2    1    0
## [43,]    0    2    0    1    1    2    0    0    0    1    0    2
## [44,]    0    1    0    2    0    2    1    1    0    0    0    0
## [45,]    2    1    2    0    2    0    0    1    1    0    0    0
## [46,]    0    0    0    0    2    0    0    1    2    0    1    2
## [47,]    0    1    0    1    0    2    0    0    2    2    0    0
## [48,]    2    0    0    1    2    1    0    2    1    2    0    2
## [49,]    0    1    0    2    0    1    0    1    0    0    0    0
## [50,]    0    0    2    0    0    1    2    1    1    0    0    0
##        [,26] [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37]
##  [1,]    1    2    2    0    1    0    2    1    1    0    0    1
##  [2,]    0    0    0    1    0    1    0    1    0    2    2    0
##  [3,]    1    2    0    2    1    0    0    1    2    2    1    0
##  [4,]    0    0    0    2    1    0    2    0    1    2    0    0
##  [5,]    2    0    1    2    1    0    0    2    0    0    1    0
##  [6,]    2    0    0    0    1    0    0    2    1    0    1    2
##  [7,]    1    0    2    0    0    0    0    1    2    2    0    1
##  [8,]    1    0    1    2    1    0    0    0    2    0    1    0
##  [9,]    1    0    1    0    0    2    1    0    0    2    1    0
## [10,]    0    0    0    0    0    0    2    1    1    1    0    2
## [11,]    1    1    1    0    1    0    0    1    2    0    2    1
## [12,]    0    0    0    0    0    1    0    0    0    2    1    2
## [13,]    2    1    2    2    2    0    1    0    0    2    0    0
## [14,]    0    1    0    1    0    2    2    0    0    0    1    2
## [15,]    0    2    0    0    1    1    0    1    0    0    0    0
## [16,]    2    1    1    2    0    0    0    1    0    0    0    2
## [17,]    1    1    2    1    1    1    0    1    0    1    2    2
## [18,]    0    2    2    0    1    0    2    0    0    0    2    0
## [19,]    2    2    1    2    1    1    1    2    2    2    0    1
## [20,]    0    1    0    1    1    2    0    0    2    0    2    1
## [21,]    0    2    1    0    0    1    2    0    1    2    0    0
## [22,]    1    0    0    0    0    2    1    1    0    0    1    0
## [23,]    0    2    2    0    0    1    2    0    1    0    2    1
## [24,]    1    1    0    0    0    1    2    0    2    2    1    0
```

```
## [25,]    0    0    2    0    2    0    1    0    1    1    0    0
## [26,]    0    0    2    0    2    2    0    1    0    1    2    2
## [27,]    0    0    2    0    2    0    0    2    2    1    0    1
## [28,]    0    0    1    0    2    0    0    0    2    0    1    0
## [29,]    2    0    0    0    1    2    1    2    2    2    0    0
## [30,]    0    2    1    1    0    0    0    2    2    2    0    0
## [31,]    0    1    2    1    0    1    0    2    0    2    2    0
## [32,]    0    0    0    0    0    0    2    2    0    0    2    0
## [33,]    0    1    0    0    0    2    0    0    0    1    0    0
## [34,]    0    0    0    0    0    1    0    0    0    2    1    0
## [35,]    1    1    1    1    2    1    2    1    0    1    0    0
## [36,]    0    1    0    2    0    0    1    0    2    0    2    2
## [37,]    1    1    2    2    0    0    0    1    1    2    2    0
## [38,]    0    0    2    1    2    2    0    1    0    0    0    1
## [39,]    0    0    0    1    0    2    2    0    0    1    1    1
## [40,]    1    0    0    1    2    1    1    0    2    2    0    0
## [41,]    0    0    0    2    0    0    0    1    0    1    0    2
## [42,]    0    1    0    0    0    0    0    1    0    2    1    1
## [43,]    2    1    2    2    1    1    0    0    0    2    1    0
## [44,]    0    0    2    1    0    0    0    0    2    0    0    1
## [45,]    0    2    0    1    0    0    2    0    0    1    2    1
## [46,]    0    2    0    0    0    2    1    2    0    0    0    0
## [47,]    0    1    2    1    0    0    0    0    0    0    1    2
## [48,]    2    1    0    0    2    0    2    0    2    0    1    1
## [49,]    0    0    2    1    1    1    1    1    1    1    2    1
## [50,]    1    1    1    0    2    0    0    2    0    2    2    0
##        [,38] [,39] [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49]
##  [1,]    0    2    0    2    1    2    1    1    0    0    2    0
##  [2,]    2    0    1    0    0    2    2    0    0    1    0    2
##  [3,]    1    0    0    2    1    2    2    0    1    2    2    0
##  [4,]    1    0    0    0    2    0    2    0    0    2    0    1
##  [5,]    2    0    0    1    2    1    2    0    2    0    0    0
##  [6,]    1    0    0    2    0    1    0    0    0    0    2    0
##  [7,]    0    2    1    0    2    0    0    2    2    2    1    1
##  [8,]    2    2    2    0    1    0    0    0    2    2    0    0
##  [9,]    1    1    1    1    2    1    1    1    1    2    1    0
## [10,]    1    1    0    0    2    2    1    0    1    2    2    2
## [11,]    2    0    1    0    0    2    2    0    2    0    1    1
## [12,]    2    1    2    0    0    2    2    2    0    0    0    0
## [13,]    1    0    2    0    2    0    1    1    1    0    1    0
## [14,]    0    0    1    2    1    2    1    0    0    1    0    1
## [15,]    2    0    0    0    1    0    0    2    1    1    2    2
## [16,]    0    0    0    0    1    0    0    0    0    1    0    0
## [17,]    0    0    0    0    0    0    0    1    0    1    2    0
## [18,]    1    2    1    0    1    0    2    0    1    0    0    2
## [19,]    0    0    0    1    1    2    0    0    0    0    0    0
## [20,]    1    2    1    2    0    0    0    0    0    0    0    0
## [21,]    1    1    0    0    2    0    0    0    1    0    0    0
## [22,]    0    1    2    0    0    1    0    2    0    1    0    1
## [23,]    2    2    2    1    0    1    2    0    0    1    0    1
## [24,]    0    1    0    0    1    0    2    1    0    0    0    0
## [25,]    0    2    0    1    0    0    0    0    0    1    0    0
## [26,]    0    0    1    0    0    0    0    0    0    0    1    0
## [27,]    1    0    1    2    1    0    0    0    2    2    0    0
```

```
## [28,]    0    1    1    0    1    0    2    0    1    2    1    1
## [29,]    1    1    0    0    1    1    2    2    1    1    1    0
## [30,]    0    0    0    0    0    0    0    0    2    1    2    2
## [31,]    0    2    1    0    2    0    2    2    0    2    0    0
## [32,]    0    1    0    2    0    2    1    0    2    0    0    1
## [33,]    2    1    2    0    0    1    0    0    2    0    2    1
## [34,]    1    0    0    0    1    1    2    0    2    0    1    0
## [35,]    1    0    1    2    1    0    0    1    0    0    2    0
## [36,]    1    1    0    0    2    1    2    0    1    0    2    1
## [37,]    0    0    0    0    2    0    0    0    2    0    0    1
## [38,]    0    1    1    1    1    2    2    2    2    0    0    1
## [39,]    1    0    1    0    0    1    0    0    1    1    0    0
## [40,]    1    1    0    0    1    2    0    0    0    0    0    0
## [41,]    2    2    1    0    0    1    2    0    0    1    1    1
## [42,]    2    0    1    2    0    0    0    0    2    0    0    1
## [43,]    2    0    0    0    2    0    0    2    0    0    0    1
## [44,]    0    1    0    0    2    0    0    0    0    0    2    1
## [45,]    1    0    1    0    2    0    0    2    0    0    0    2
## [46,]    0    1    1    2    2    0    2    0    2    0    0    0
## [47,]    0    2    0    2    1    1    1    1    0    2    0    1
## [48,]    0    1    1    2    1    1    1    0    2    2    0    2
## [49,]    0    0    2    0    2    0    2    0    0    1    0    0
## [50,]    2    0    0    1    2    2    0    0    2    0    0    1
##       [,50]
##  [1,]     1
##  [2,]     0
##  [3,]     0
##  [4,]     0
##  [5,]     0
##  [6,]     0
##  [7,]     0
##  [8,]     0
##  [9,]     1
## [10,]     2
## [11,]     0
## [12,]     0
## [13,]     1
## [14,]     0
## [15,]     2
## [16,]     2
## [17,]     0
## [18,]     0
## [19,]     0
## [20,]     2
## [21,]     2
## [22,]     2
## [23,]     2
## [24,]     0
## [25,]     0
## [26,]     2
## [27,]     1
## [28,]     0
## [29,]     0
## [30,]     1
```

```
## [31,]     0
## [32,]     0
## [33,]     0
## [34,]     1
## [35,]     0
## [36,]     0
## [37,]     1
## [38,]     0
## [39,]     2
## [40,]     2
## [41,]     2
## [42,]     0
## [43,]     1
## [44,]     0
## [45,]     1
## [46,]     0
## [47,]     1
## [48,]     1
## [49,]     2
## [50,]     1
```

- Randomly punch holes (i.e. `NA`) values in this matrix so that an each entry is missing with probability 30%.

```
for(i in 1:n) {
  for(j in 1:n) {
    if(runif(1)>0.7) {
      R[i,j] = NA
    }
  }
}

#mean(is.na(R)) to check
```

- Sort the rows in matrix `R` by the largest row sum to lowest. Be careful about the NA's!

```
R = R[order(rowSums(R,na.rm = TRUE), decreasing = TRUE), ]
R
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
##  [1,]    0   NA    2    1   NA    2   NA    2   NA     2     1     1     2
##  [2,]   NA   NA    2    1    2    1   NA    2   NA     2     1    NA     0
##  [3,]    1    2    1    1   NA    0   NA    1    1     1     1     0     1
##  [4,]    0    0    2    1    0    0    2   NA   NA    NA     2     0     1
##  [5,]   NA    2    0    2    2   NA   NA    2   NA     2     2     2     0
##  [6,]   NA   NA    2    1    0   NA    0    0    2     0     1     2     2
##  [7,]    2    2   NA    0    1   NA    1    1    0    NA     0     0     0
##  [8,]   NA    2    1    0    2    0    1   NA   NA    NA     0     1     1
##  [9,]    2    0    0    0    0    1    0    2    0    NA     2     0     0
## [10,]    1    0   NA   NA   NA   NA   NA   NA    0     0     1     0     2
## [11,]    0    2   NA    0    0    1   NA    0    1     1    NA     0     0
## [12,]    1    2    0   NA    2    0    2    0    1     0     1     0    NA
## [13,]    0    2    2    0    0    2    1    2    0    NA    NA     2     2
## [14,]   NA    2    0    0    2    0    0    0   NA     1     0    NA     1
## [15,]   NA    2    2   NA    2    0    0    2    1     0     2    NA    NA
## [16,]   NA    0   NA    2    2    0    1    0   NA     1     0     1     0
```

```
## [17,]    0    0    0    2    2    1    2    2    0     0     0    NA    NA
## [18,]    0    0    0    0    2   NA    0   NA    1     0     1     1     2
## [19,]   NA    1   NA    0    2    2    2   NA    1     2     2     1     2
## [20,]    0    1    1   NA    0    2    2    1   NA     2     0     1     0
## [21,]    2    0    1    0    0    0    2   NA    0    NA     0     0     0
## [22,]    0    0    2    0    0    2   NA    1    0    NA     0    NA    NA
## [23,]   NA    0    2    1   NA    2   NA   NA   NA     2     0    NA    NA
## [24,]   NA    2    1   NA   NA   NA    0   NA   NA    NA     0     2     1
## [25,]   NA   NA   NA    1    1    0    1   NA   NA     0     0     0    NA
## [26,]    2    0    0    0    0    0   NA   NA    2     2    NA     0     1
## [27,]    1    2    0    2   NA    0    0   NA    0     0     0     0     1
## [28,]   NA    0   NA   NA    1    1    1    0    0     0     1     1     1
## [29,]    2    2    0    1    0   NA    0    1    0    NA     0     0     0
## [30,]    1   NA    0   NA    1   NA    0    0    2    NA     0     0     1
## [31,]    2    0    0    2    0   NA   NA    2    0     2     0     0    NA
## [32,]    0    0    0    2    0    1    1    0    0    NA     1    NA     2
## [33,]   NA    0    0   NA   NA   NA    1    0    0     0     2    NA     0
## [34,]    0    2    1    2   NA   NA    0    0    0     0     0     0     0
## [35,]   NA   NA   NA    2    2    2    0    0    0     0     0     0    NA
## [36,]    1    2    0    2    0    1    0    0   NA     1    NA     1    NA
## [37,]   NA    2   NA    1    1    0    0    1    0    NA     1    NA     0
## [38,]    2    0    2    0   NA    2    0    0    0     1     2     2     2
## [39,]    1   NA   NA    0    1   NA    0    0    0     0     0     1     0
## [40,]    0   NA   NA    1    0    2    2   NA   NA     1    NA     1    NA
## [41,]    1   NA    1    0    0   NA    0    2    0     1    NA    NA     2
## [42,]    1    2   NA    0   NA    2   NA    1    1     2     0     1     0
## [43,]    0    1    0    2    1   NA    0    1    0    NA     1     2    NA
## [44,]    0    1    0    2    0    0    2    0   NA     0     0     0     0
## [45,]    1   NA    0   NA   NA    0    0    1   NA     0    NA     0     1
## [46,]   NA    0   NA    1    0    2   NA   NA    0     0    NA     2     0
## [47,]   NA    0    1    0    0    0    0   NA    2     1    NA     2     0
## [48,]    2    0    0   NA    0    0    1   NA    0     0    NA    NA     0
## [49,]    1   NA   NA    0    0   NA    1    1   NA     0     0     0     0
## [50,]   NA   NA    0   NA    0    0    2    0    0    NA     0     0     2
##       [,14] [,15] [,16] [,17] [,18] [,19] [,20] [,21] [,22] [,23] [,24] [,25]
##  [1,]     2     2     0     0    NA     2    NA    NA     2     0     0     2
##  [2,]     0     2     2     0     2     1     2    NA    NA    NA     1     2
##  [3,]     2     0     1     0     1    NA     1     1     2     1     2     0
##  [4,]     2     0    NA    NA     2    NA    NA    NA     1     2    NA     2
##  [5,]    NA     1     0    NA     2     0     2    NA    NA     1     2     1
##  [6,]    NA    NA     0     0     0     1     0     2     2     0    NA    NA
##  [7,]    NA     0     0    NA     0     0     2     0     2     2     0    NA
##  [8,]    NA     1     2     0     0    NA    NA    NA     2    NA     2     2
##  [9,]     1    NA     2    NA    NA     2     1    NA     1    NA     1    NA
## [10,]    NA     2     2     1     0     1    NA     2     1     2    NA    NA
## [11,]     2    NA     0     2     1     0     2     0    NA     1     2    NA
## [12,]     0     0     1     0     2     1     2    NA     2     2    NA    NA
## [13,]    NA     0     0     1     0     0     0     2     1     0    NA    NA
## [14,]     0     0     0     0     2    NA     0     2    NA     2     2     0
## [15,]     0     1    NA     1     2     2     0     2     0     1     0     0
## [16,]     0     0     2     0    NA     2     2    NA    NA     1     1     2
## [17,]    NA    NA     0     0    NA    NA     0     1    NA    NA     1     2
## [18,]     0    NA    NA     1     2     1     0    NA    NA     2    NA    NA
## [19,]    NA    NA     2    NA     2    NA     0     0     0    NA     0     0
```

```
## [20,]    NA    NA    NA    NA     0    NA     0    NA    NA     2     1    NA
## [21,]     2     1    NA     0     2    NA     0     1    NA    NA    NA     0
## [22,]     2     1     2     0     2    NA     0    NA    NA    NA     1     0
## [23,]     2     0     0     0     1     0    NA     0     2     0     0    NA
## [24,]     0     1     2     2     2     0     0     0     0     2     2     1
## [25,]     1     2    NA     1     2     0     0     2     2    NA     1     0
## [26,]     0     1    NA     2    NA     1     0    NA     0     0     0     0
## [27,]     0     0    NA     0     1     1     0     2    NA    NA     0    NA
## [28,]     0    NA     0     0     0    NA     0     0     1     2     0     0
## [29,]     1     1     2     2     2     1     1     0     2     0     1     0
## [30,]     2    NA    NA    NA     0     2     0     0     2     1    NA     0
## [31,]    NA     0    NA     0    NA    NA     0     0     0    NA     1     1
## [32,]     0     2     0     1     1    NA     0     0     0     1    NA     2
## [33,]     2    NA    NA    NA     0     2     0     0    NA    NA    NA    NA
## [34,]     0     2     2     0     1    NA     0     1     0     1    NA    NA
## [35,]    NA     1     2     0     0     0     2    NA    NA    NA     0    NA
## [36,]     0    NA    NA     0    NA    NA    NA     2    NA     1     1     2
## [37,]     0     0     0    NA    NA     0     1     2    NA     2    NA     2
## [38,]     0    NA     0     0    NA    NA     0    NA     1     0     1     2
## [39,]    NA     2     0     2     2     0     2    NA     0     0    NA     1
## [40,]     1     0     0    NA    NA     0     1     1    NA     1     0    NA
## [41,]     0    NA     0    NA     0     2     0    NA     2     2     0     0
## [42,]    NA     0     0    NA     1     1     0     2    NA     1     0    NA
## [43,]     0    NA    NA     2     0    NA     0    NA    NA     0     0     2
## [44,]     1     0    NA     1     2     0     0    NA    NA     2     2     0
## [45,]     0     0     2     0    NA     1     2    NA    NA     0     0     0
## [46,]     1     1    NA     0     1     0     0     2    NA     0    NA     0
## [47,]    NA    NA    NA     0     0    NA    NA     0     0     0    NA     0
## [48,]     1     0     0     0     0     0     1    NA     0    NA    NA     0
## [49,]     0     1    NA     2     0    NA     1     1    NA     0    NA    NA
## [50,]     1    NA    NA    NA    NA    NA     0     1     0     0    NA     0
##       [,26] [,27] [,28] [,29] [,30] [,31] [,32] [,33] [,34] [,35] [,36] [,37]
##  [1,]     0    NA    NA     1     2     2     0     1     0     0     0     1
##  [2,]     2     1     2     2     2     0    NA     0     0     2     0    NA
##  [3,]     1     0     1     2     1     0     0     0     2     0     1     0
##  [4,]     2    NA    NA    NA     2     0     2     0     2    NA     1     1
##  [5,]    NA    NA     0     1     0     2     2     0     0    NA     1    NA
##  [6,]     0     0     0    NA     0    NA     2     1     1    NA     0     2
##  [7,]     1     2     0     2     1    NA     0     1    NA    NA     1     0
##  [8,]     0     0     0     2    NA    NA     2    NA     1     2    NA     0
##  [9,]     1     1     1     1     2     1     2     1     0     1     0     0
## [10,]     0     0     0    NA     0     0     0     1    NA     1     0     2
## [11,]    NA     2     2    NA     1     0    NA    NA     1     0     0     1
## [12,]    NA     2     0     0     1     1     0     1    NA    NA     0     0
## [13,]    NA    NA     2     0     2     2    NA    NA     0    NA     2     2
## [14,]     0     1     2     1     0     1     0     2     0    NA     2     0
## [15,]    NA    NA     2     1     1    NA     0     1     0    NA    NA     2
## [16,]     0     2    NA     0    NA     1     2     0    NA    NA    NA     0
## [17,]    NA     2     0     0    NA     2    NA     2     0     0     0     0
## [18,]     0     0     0    NA    NA     1    NA    NA     0     2     2    NA
## [19,]    NA     0     0    NA    NA     1    NA    NA     0    NA     1    NA
## [20,]     0     2    NA    NA     0     1    NA    NA     1     0    NA     1
## [21,]     0     2    NA     1    NA     0     2    NA    NA     1     2     1
## [22,]    NA     0     0     0    NA     2     1     1     0     0    NA     0
```

```
## [23,]     0     0     0    NA    NA     0     2     2     0    NA     2    NA
## [24,]     0    NA     0     0     0    NA     0     0     0     1    NA     0
## [25,]    NA     1    NA     2     0     0     0     1     1    NA     2     0
## [26,]     0     0     2     1     1     1    NA     1     1     1     2     1
## [27,]     1     0     2     0     0     0     0    NA     2     2     0     1
## [28,]     1     0     1     0     0     2     1     0    NA     2     1     0
## [29,]    NA    NA     1    NA    NA     0    NA     1     0    NA    NA     2
## [30,]     0     1    NA     2     0     0    NA     0     2     0    NA    NA
## [31,]    NA     0     0     1     2     1     1    NA     2     2    NA    NA
## [32,]     2    NA    NA    NA     1    NA     0     0    NA     2     1     0
## [33,]     2    NA    NA     2     1     0     0     2    NA     0     1    NA
## [34,]     2    NA     0     0     1     0    NA     2    NA    NA     1     2
## [35,]     0     0     2     0     2     0     0     2    NA     1     0     1
## [36,]    NA     0     0     0     1     2     1     2    NA    NA     0     0
## [37,]    NA     2     1     1    NA     0     0     2     2    NA    NA     0
## [38,]    NA    NA     0    NA    NA     1     0     0     0    NA     1    NA
## [39,]     1     1     1     0     1    NA    NA     1     2     0    NA     1
## [40,]     2    NA    NA     2    NA    NA    NA     2     2     2     0    NA
## [41,]    NA     1    NA    NA    NA    NA     0     0     0     0     1     2
## [42,]     0     0    NA     0    NA    NA    NA    NA     2     0     1    NA
## [43,]     1     1    NA     0     0     1     2     0    NA     2     1    NA
## [44,]    NA    NA    NA     1    NA     2    NA    NA     0    NA    NA     1
## [45,]     1    NA     1     0    NA     0     0     2     0    NA    NA    NA
## [46,]     0     2    NA    NA     1     0    NA     0     0     0    NA     0
## [47,]     0     1     0     1     1     2     0     0    NA    NA    NA    NA
## [48,]    NA     1    NA     0     0    NA     0     1    NA     2    NA     1
## [49,]    NA     0     2     1     0    NA    NA    NA     2     0     0     1
## [50,]     0    NA     2     0     2     0    NA     0    NA     1     0     0
##       [,38] [,39] [,40] [,41] [,42] [,43] [,44] [,45] [,46] [,47] [,48] [,49]
##  [1,]     0     1     1     1     1     2    NA     2     2    NA     0     1
##  [2,]     1    NA    NA     0     2     0    NA    NA     1    NA    NA    NA
##  [3,]     2    NA     2     0     1     0     0     0     2     2     0     0
##  [4,]     0    NA     1    NA     1     1     1    NA     2     2    NA     2
##  [5,]     0     0     1     2     1     2     1    NA     0     1     0    NA
##  [6,]     1     1    NA     0    NA     2     1     0     1     2     2     2
##  [7,]     1    NA    NA     2     1     2    NA    NA     1     2     2     0
##  [8,]     1    NA     0    NA     2     0     2     0     0     2     0     1
##  [9,]     1     0    NA     2     1     0     0    NA    NA    NA     2     0
## [10,]     2     2     1     0     0     1     2     0     0     1     1     1
## [11,]     0     2     0     2     1    NA     1    NA    NA    NA     2     0
## [12,]     2    NA     0    NA    NA     0    NA     2    NA     1     2    NA
## [13,]     0     0     1    NA     0     0    NA     0    NA     0     1     0
## [14,]    NA     2    NA     0    NA     0     2     2     0     2     0     0
## [15,]     0     0    NA     0     0     0    NA     1    NA    NA     2     0
## [16,]     1     1     0    NA     2     0     0     0     1     0     0    NA
## [17,]    NA     1     1     2     2    NA     2     0     2     0     0     0
## [18,]     2     0     1     0    NA     2     2     0    NA     1     0     2
## [19,]    NA     1     2    NA     0     2     2    NA     0     0    NA     0
## [20,]     2     2    NA     1     0     1     2     0    NA     1     0     1
## [21,]     1    NA    NA    NA     2     0     0     2    NA     0    NA     2
## [22,]     0     1     2     0     0     1    NA     2     0     1    NA     1
## [23,]    NA     1     0     2     0     2     1     0     2     0     0     1
## [24,]     2    NA     2    NA     0    NA     0    NA     2     0     2    NA
## [25,]    NA     0    NA    NA     2     0     0     0     2     0     0     1
```

```
## [26,]    NA     0     2     0    NA    NA    NA     0     0     1    NA     0
## [27,]    NA     2    NA    NA    NA     0     0     2    NA     2     1     1
## [28,]     1     1     1    NA    NA     1     1     1     1    NA     1     0
## [29,]     0     0     0    NA    NA    NA     0    NA    NA     1     0    NA
## [30,]     1     1    NA     0     2    NA     2     0     1     0     2    NA
## [31,]     1     1    NA    NA     1     2    NA     0    NA     0     0    NA
## [32,]     2     0     0     0    NA     0    NA     2     0    NA     0     1
## [33,]     2    NA     0     1     2     1     2     0     2     0     0     0
## [34,]    NA     0     0     2     0     1     0     0     0     0     2     0
## [35,]    NA    NA     1    NA    NA     0     0     0     2     2     0    NA
## [36,]     1    NA     0     0    NA    NA    NA     2    NA     1     1     0
## [37,]     0    NA    NA     0     0    NA     0     0     2     1    NA    NA
## [38,]     1     0     0     0     1    NA     2     0    NA     0     1    NA
## [39,]    NA     0     1     0    NA    NA     2    NA    NA    NA     1    NA
## [40,]     0     0    NA     1    NA     2    NA     0     0     0    NA    NA
## [41,]    NA     2     0     2    NA    NA     1     1    NA    NA    NA     1
## [42,]     0     1     1    NA    NA     0    NA     0     1    NA     1     1
## [43,]    NA    NA     0     0     1     0    NA     1     0     0     0    NA
## [44,]    NA     0     1     0     0    NA     0     0     1     1    NA     0
## [45,]     2    NA     0     1    NA     2     0     0     2    NA     0     1
## [46,]     1    NA    NA     0     1     0     2     0     1     0     0     2
## [47,]     1     2     1     2     0     0     0     0    NA    NA     0     0
## [48,]     2     0     1     2     0     0    NA    NA     2     0     0     1
## [49,]    NA     1    NA     0    NA     0    NA    NA     0     0     2    NA
## [50,]     0    NA    NA     1     0     0     0     0    NA     1     0     0
##       [,50]
##  [1,]     0
##  [2,]     1
##  [3,]    NA
##  [4,]     1
##  [5,]     0
##  [6,]     2
##  [7,]     0
##  [8,]     0
##  [9,]    NA
## [10,]     2
## [11,]     1
## [12,]    NA
## [13,]     2
## [14,]     0
## [15,]     0
## [16,]     2
## [17,]     0
## [18,]    NA
## [19,]     0
## [20,]    NA
## [21,]     1
## [22,]     2
## [23,]     0
## [24,]     0
## [25,]     1
## [26,]     2
## [27,]     0
## [28,]     1
```

```
## [29,]     2
## [30,]     0
## [31,]     2
## [32,]     1
## [33,]    NA
## [34,]    NA
## [35,]     1
## [36,]     0
## [37,]     1
## [38,]     1
## [39,]     0
## [40,]     0
## [41,]    NA
## [42,]     0
## [43,]     0
## [44,]     2
## [45,]     1
## [46,]     0
## [47,]     2
## [48,]     0
## [49,]     0
## [50,]     0
```

- We will now learn the `apply` function. This is a handy function that saves writing for loops which should be eschewed in R. Use the apply function to compute a vector whose entries are the standard deviation of each row. Use the apply function to compute a vector whose entries are the standard deviation of each column. Be careful about the NA's! This should be one line.

```
apply(R, 1, sd, na.rm = TRUE)
```

```
##  [1] 0.85682148078 0.84611411223 0.76739096221 0.83371203516 0.87785814380
##  [6] 0.88169305646 0.85512059455 0.88687914726 0.78933142388 0.82285973943
## [11] 0.83333333333 0.86675285070 0.92836515545 0.91598274560 0.87831006565
## [16] 0.85424219618 0.91697374054 0.86936369051 0.90755490962 0.79311553891
## [21] 0.86936369051 0.83827364428 0.90632696717 0.91025898983 0.80622577483
## [26] 0.80229046222 0.84166062230 0.62273981569 0.81683957468 0.85208592300
## [31] 0.85723303999 0.80891195385 0.90640641031 0.84252688501 0.89348717267
## [36] 0.79176634141 0.83029750053 0.82182530102 0.75996059566 0.84806357230
## [41] 0.84497248158 0.72821908125 0.77024496813 0.80752760964 0.77907115956
## [46] 0.77254475393 0.78000215471 0.73678839761 0.72289739601 0.69695032136
```

```
apply(R, 2, sd, na.rm = TRUE)
```

```
##  [1] 0.80759998882 0.95711753129 0.84890218555 0.84412712744 0.88013003579
##  [6] 0.89066116505 0.82802958970 0.83313723183 0.70458139176 0.84091786587
## [11] 0.77418277839 0.79979754523 0.84172562293 0.84890218555 0.79042848102
## [16] 0.96511740887 0.80071289558 0.90045033778 0.80455691406 0.82325018299
## [21] 0.88991798666 0.90267093385 0.84806793314 0.79247977485 0.92728015446
## [26] 0.79311553891 0.83313723183 0.88006238638 0.79601107633 0.78363384079
## [31] 0.81982893820 0.89577863049 0.81110710565 0.88593112011 0.88473646963
## [36] 0.76986467779 0.77868427899 0.79082034964 0.78078528960 0.71905872816
## [41] 0.88593112011 0.80833723835 0.86705137903 0.90008912215 0.82974571505
## [46] 0.86602540378 0.79471941424 0.85334935882 0.72529333388 0.82814879686
```

- Use the `apply` function to compute a vector whose entries are the count of entries that are 1 or 2 in each column. This should be one line.

```
apply(R>0, 2, na.rm=TRUE, sum)
```

```
##  [1] 19 20 17 22 18 18 19 19 11 18 18 19 20 17 18 14 14 23 17 16 18 17 23 18 15
## [26] 14 19 17 20 21 20 13 23 16 17 20 19 24 19 19 16 19 17 19 12 21 20 18 18 21
```

- Use the `split` function to create a list whose keys are the column number and values are the vector of the columns. Look at the last example in the documentation `?split`.

```
split(R, col(R))
```

```
## $`1`
##  [1]  0 NA  1  0 NA NA  2 NA  2  1  0  1  0 NA NA NA  0  0 NA  0  2  0 NA NA NA
## [26]  2  1 NA  2  1  2  0 NA  0 NA  1 NA  2  1  0  1  1  0  0  1 NA NA  2  1 NA
##
## $`2`
##  [1] NA NA  2  0  2 NA  2  2  0  0  2  2  2  2  2  0  0  0  1  1  0  0  0  2 NA
## [26]  0  2  0  2 NA  0  0  0  2 NA  2  2  0 NA NA NA  2  1  1 NA  0  0  0 NA NA
##
## $`3`
##  [1]  2  2  1  2  0  2 NA  1  0 NA NA  0  2  0  2 NA  0  0 NA  1  1  2  2  1 NA
## [26]  0  0 NA  0  0  0  0  0  1 NA  0 NA  2 NA NA  1 NA  0  0  0 NA  1  0 NA  0
##
## $`4`
##  [1]  1  1  1  1  2  1  0  0  0 NA  0 NA  0  0 NA  2  2  0  0 NA  0  0  1 NA  1
## [26]  0  2 NA  1 NA  2  2 NA  2  2  2  1  0  0  1  0  0  2  2 NA  1  0 NA  0 NA
##
## $`5`
##  [1] NA  2 NA  0  2  0  1  2  0 NA  0  2  0  2  2  2  2  2  2  0  0  0 NA NA  1
## [26]  0 NA  1  0  1  0  0 NA NA  2  0  1 NA  1  0  0 NA  1  0 NA  0  0  0  0  0
##
## $`6`
##  [1]  2  1  0  0 NA NA NA  0  1 NA  1  0  2  0  0  0  1 NA  2  2  0  2  2 NA  0
## [26]  0  0  1 NA NA NA  1 NA NA  2  1  0  2 NA  2 NA  2 NA  0  0  2  0  0 NA  0
##
## $`7`
##  [1] NA NA NA  2 NA  0  1  1  0 NA NA  2  1  0  0  1  2  0  2  2  2 NA NA  0  1
## [26] NA  0  1  0  0 NA  1  1  0  0  0  0  0  0  2  0 NA  0  2  0 NA  0  1  1  2
##
## $`8`
##  [1]  2  2  1 NA  2  0  1 NA  2 NA  0  0  2  0  2  0  2 NA NA  1 NA  1 NA NA NA
## [26] NA NA  0  1  0  2  0  0  0  0  0  1  0  0 NA  2  1  1  0  1 NA NA NA  1  0
##
## $`9`
##  [1] NA NA  1 NA NA  2  0 NA  0  0  1  1  0 NA  1 NA  0  1  1 NA  0  0 NA NA NA
## [26]  2  0  0  0  2  0  0  0  0  0 NA  0  0  0 NA  0  1  0 NA NA  0  2  0 NA  0
##
## $`10`
##  [1]  2  2  1 NA  2  0 NA NA NA  0  1  0 NA  1  0  1  0  0  2  2 NA NA  2 NA  0
## [26]  2  0  0 NA NA  2 NA  0  0  0  1 NA  1  0  1  1  2 NA  0  0  0  1  0  0 NA
##
## $`11`
##  [1]  1  1  1  2  2  1  0  0  2  1 NA  1 NA  0  2  0  0  1  2  0  0  0  0  0  0
## [26] NA  0  1  0  0  0  1  2  0  0 NA  1  2  0 NA NA  0  1  0 NA NA NA NA  0  0
##
## $`12`
```

```
##  [1]  1 NA  0  0  2  2  0  1  0  0  0  0  2 NA NA  1 NA  1  1  1  0 NA NA  2  0
## [26]  0  0  1  0  0  0 NA NA  0  0  1 NA  2  1  1 NA  1  2  0  0  2  2 NA  0  0
##
## $`13`
##  [1]  2  0  1  1  0  2  0  1  0  2  0 NA  2  1 NA  0 NA  2  2  0  0 NA NA  1 NA
## [26]  1  1  1  0  1 NA  2  0  0 NA NA  0  2  0 NA  2  0 NA  0  1  0  0  0  0  2
##
## $`14`
##  [1]  2  0  2  2 NA NA NA NA  1 NA  2  0 NA  0  0  0 NA  0 NA NA  2  2  2  0  1
## [26]  0  0  0  1  2 NA  0  2  0 NA  0  0  0 NA  1  0 NA  0  1  0  1 NA  1  0  1
##
## $`15`
##  [1]  2  2  0  0  1 NA  0  1 NA  2 NA  0  0  0  1  0 NA NA NA NA  1  1  0  1  2
## [26]  1  0 NA  1 NA  0  2 NA  2  1 NA  0 NA  2  0 NA  0 NA  0  0  1 NA  0  1 NA
##
## $`16`
##  [1]  0  2  1 NA  0  0  0  2  2  2  0  1  0  0 NA  2  0 NA  2 NA NA  2  0  2 NA
## [26] NA NA  0  2 NA NA  0 NA  2  2 NA  0  0  0  0  0  0 NA NA  2 NA NA  0 NA NA
##
## $`17`
##  [1]  0  0  0 NA NA  0 NA  0 NA  1  2  0  1  0  1  0  0  1 NA NA  0  0  0  2  1
## [26]  2  0  0  2 NA  0  1 NA  0  0  0 NA  0  2 NA NA NA  2  1  0  0  0  0  2 NA
##
## $`18`
##  [1] NA  2  1  2  2  0  0  0 NA  0  1  2  0  2  2 NA NA  2  2  0  2  2  1  2  2
## [26] NA  1  0  2  0 NA  1  0  1  0 NA NA NA  2 NA  0  1  0  2 NA  1  0  0  0 NA
##
## $`19`
##  [1]  2  1 NA NA  0  1  0 NA  2  1  0  1  0 NA  2  2 NA  1 NA NA NA NA  0  0  0
## [26]  1  1 NA  1  2 NA NA  2 NA  0 NA  0 NA  0  0  2  1 NA  0  1  0 NA  0 NA NA
##
## $`20`
##  [1] NA  2  1 NA  2  0  2 NA  1 NA  2  2  0  0  0  2  0  0  0  0  0  0 NA  0  0
## [26]  0  0  0  1  0  0  0  0  0  2 NA  1  0  2  1  0  0  0  0  2  0 NA  1  1  0
##
## $`21`
##  [1] NA NA  1 NA NA  2  0 NA NA  2  0 NA  2  2  2 NA  1 NA  0 NA  1 NA  0  0  2
## [26] NA  2  0  0  0  0  0  0  1 NA  2  2 NA NA  1 NA  2 NA NA NA  2  0 NA  1  1
##
## $`22`
##  [1]  2 NA  2  1 NA  2  2  2  1  1 NA  2  1 NA  0 NA NA NA  0 NA NA NA  2  0  2
## [26]  0 NA  1  2  2  0  0 NA  0 NA NA NA  1  0 NA  2 NA NA NA NA NA  0  0 NA  0
##
## $`23`
##  [1]  0 NA  1  2  1  0  2 NA NA  2  1  2  0  2  1  1 NA  2 NA  2 NA NA  0  2 NA
## [26]  0 NA  2  0  1 NA  1 NA  1 NA  1  2  0  0  1  2  1  0  2  0  0  0 NA  0  0
##
## $`24`
##  [1]  0  1  2 NA  2 NA  0  2  1 NA  2 NA NA  2  0  1  1 NA  0  1 NA  1  0  2  1
## [26]  0  0  0  1 NA  1 NA NA NA  0  1 NA  1 NA  0  0  0  0  2  0 NA NA NA NA NA
##
## $`25`
##  [1]  2  2  0  2  1 NA NA  2 NA NA NA NA NA  0  0  2  2 NA  0 NA  0  0 NA  1  0
## [26]  0 NA  0  0  0  1  2 NA NA NA  2  2  2  1 NA  0 NA  2  0  0  0  0  0 NA  0
```

```
##
## $`26`
##  [1]  0  2  1  2 NA  0  1  0  1  0 NA NA NA  0 NA  0 NA  0 NA  0  0 NA  0  0 NA
## [26]  0  1  1 NA  0 NA  2  2  2  0 NA NA NA  1  2 NA  0  1 NA  1  0  0 NA NA  0
##
## $`27`
##  [1] NA  1  0 NA NA  0  2  0  1  0  2  2 NA  1 NA  2  2  0  0  2  2  0  0 NA  1
## [26]  0  0  0 NA  1  0 NA NA NA  0  0  2 NA  1 NA  1  0  1 NA NA  2  1  1  0 NA
##
## $`28`
##  [1] NA  2  1 NA  0  0  0  0  1  0  2  0  2  2  2 NA  0  0  0 NA NA  0  0  0 NA
## [26]  2  2  1  1 NA  0 NA NA  0  2  0  1  0  1 NA NA NA NA NA  1 NA  0 NA  2  2
##
## $`29`
##  [1]  1  2  2 NA  1 NA  2  2  1 NA NA  0  0  1  1  0  0 NA NA NA  1  0 NA  0  2
## [26]  1  0  0 NA  2  1 NA  2  0  0  0  1 NA  0  2 NA  0  0  1  0 NA  1  0  1  0
##
## $`30`
##  [1]  2  2  1  2  0  0  1 NA  2  0  1  1  2  0  1 NA NA NA NA  0 NA NA NA  0  0
## [26]  1  0  0 NA  0  2  1  1  1  2  1 NA NA  1 NA NA NA  0 NA NA  1  1  0  0  2
##
## $`31`
##  [1]  2  0  0  0  2 NA NA NA  1  0  0  1  2  1 NA  1  2  1  1  1  0  2  0 NA  0
## [26]  1  0  2  0  0  1 NA  0  0  0  2  0  1 NA NA NA NA  1  2  0  0  2 NA NA  0
##
## $`32`
##  [1]  0 NA  0  2  2  2  0  2  2  0 NA  0 NA  0  0  2 NA NA NA NA  2  1  2  0  0
## [26] NA  0  1 NA NA  1  0  0 NA  0  1  0  0 NA NA  0 NA  2 NA  0 NA  0  0 NA NA
##
## $`33`
##  [1]  1  0  0  0  0  1  1 NA  1  1 NA  1 NA  2  1  0  2 NA NA NA NA  1  2  0  1
## [26]  1 NA  0  1  0 NA  0  2  2  2  2  2  0  1  2  0 NA  0 NA  2  0  0  1 NA  0
##
## $`34`
##  [1]  0  0  2  2  0  1 NA  1  0 NA  1 NA  0  0  0 NA  0  0  0  1 NA  0  0  0  1
## [26]  1  2 NA  0  2  2 NA NA NA NA NA  2  0  2  2  0  2 NA  0  0  0 NA NA  2 NA
##
## $`35`
##  [1]  0  2  0 NA NA NA NA  2  1  1  0 NA NA NA NA NA  0  2 NA  0  1  0 NA  1 NA
## [26]  1  2  2 NA  0  2  2  0 NA  1 NA NA NA  0  2  0  0  2 NA NA  0 NA  2  0  1
##
## $`36`
##  [1]  0  0  1  1  1  0  1 NA  0  0  0  0  2  2 NA NA  0  2  1 NA  2 NA  2 NA  2
## [26]  2  0  1 NA NA NA  1  1  1  0  0 NA  1 NA  0  1  1  1 NA NA NA NA NA  0  0
##
## $`37`
##  [1]  1 NA  0  1 NA  2  0  0  0  2  1  0  2  0  2  0  0 NA NA  1  1  0 NA  0  0
## [26]  1  1  0  2 NA NA  0 NA  2  1  0  0 NA  1 NA  2 NA NA  1 NA  0 NA  1  1  0
##
## $`38`
##  [1]  0  1  2  0  0  1  1  1  1  2  0  2  0 NA  0  1 NA  2 NA  2  1  0 NA  2 NA
## [26] NA NA  1  0  1  1  2  2 NA NA  1  0  1 NA  0 NA  0 NA NA  2  1  1  2 NA  0
##
## $`39`
```

```
##  [1]  1 NA NA NA  0  1 NA NA  0  2  2 NA  0  2  0  1  1  0  1  2 NA  1  1 NA  0
## [26]  0  2  1  0  1  1  0 NA  0 NA NA NA  0  0  0  2  1 NA  0 NA NA  2  0  1 NA
##
## $`40`
##  [1]  1 NA  2  1  1 NA NA  0 NA  1  0  0  1 NA NA  0  1  1  2 NA NA  2  0  2 NA
## [26]  2 NA  1  0 NA NA  0  0  0  1  0 NA  0  1 NA  0  1  0  1  0 NA  1  1 NA NA
##
## $`41`
##  [1]  1  0  0 NA  2  0  2 NA  2  0  2 NA NA  0  0 NA  2  0 NA  1 NA  0  2 NA NA
## [26]  0 NA NA NA  0 NA  0  1  2 NA  0  0  0  0  1  2 NA  0  0  1  0  2  2  0  1
##
## $`42`
##  [1]  1  2  1  1  1 NA  1  2  1  0  1 NA  0 NA  0  2  2 NA  0  0  2  0  0  0  2
## [26] NA NA NA NA  2  1 NA  2  0 NA NA  0  1 NA NA NA NA  1  0 NA  1  0  0 NA  0
##
## $`43`
##  [1]  2  0  0  1  2  2  2  0  0  1 NA  0  0  0  0  0 NA  2  2  1  0  1  2 NA  0
## [26] NA  0  1 NA NA  2  0  1  1  0 NA NA NA NA  2 NA  0  0 NA  2  0  0  0  0  0
##
## $`44`
##  [1] NA NA  0  1  1  1 NA  2  0  2  1 NA NA  2 NA  0  2  2  2  2  0 NA  1  0  0
## [26] NA  0  1  0  2 NA NA  2  0  0 NA  0  2  2 NA  1 NA NA  0  0  2  0 NA NA  0
##
## $`45`
##  [1]  2 NA  0 NA NA  0 NA  0 NA  0 NA  2  0  2  1  0  0  0 NA  0  2  2  0 NA  0
## [26]  0  2  1 NA  0  0  2  0  0  0  2  0  0 NA  0  1  0  1  0  0  0  0 NA NA  0
##
## $`46`
##  [1]  2  1  2  2  0  1  1  0 NA  0 NA NA NA  0 NA  1  2 NA  0 NA NA  0  2  2  2
## [26]  0 NA  1 NA  1 NA  0  2  0  2 NA  2 NA NA  0 NA  1  0  1  2  1 NA  2  0 NA
##
## $`47`
##  [1] NA NA  2  2  1  2  2  2 NA  1 NA  1  0  2 NA  0  0  1  0  1  0  1  0  0  0
## [26]  1  2 NA  1  0  0 NA  0  0  2  1  1  0 NA  0 NA NA  0  1 NA  0 NA  0  0  1
##
## $`48`
##  [1]  0 NA  0 NA  0  2  2  0  2  1  2  2  1  0  2  0  0  0 NA  0 NA NA  0  2  0
## [26] NA  1  1  0  2  0  0  0  2  0  1 NA  1  1 NA NA  1  0 NA  0  0  0  0  2  0
##
## $`49`
##  [1]  1 NA  0  2 NA  2  0  1  0  1  0 NA  0  0  0 NA  0  2  0  1  2  1  1 NA  1
## [26]  0  1  0 NA NA NA  1  0  0 NA  0 NA NA NA NA  1  1 NA  0  1  2  0  1 NA  0
##
## $`50`
##  [1]  0  1 NA  1  0  2  0  0 NA  2  1 NA  2  0  0  2  0 NA  0 NA  1  2  0  0  1
## [26]  2  0  1  2  0  2  1 NA NA  1  0  1  1  0  0 NA  0  0  2  1  0  2  0  0  0
```

- In one statement, use the `lapply` function to create a list whose keys are the column number and values are themselves a list with keys: "min" whose value is the minimum of the column, "max" whose value is the maximum of the column, "pct_missing" is the proportion of missingness in the column and "first_NA" whose value is the row number of the first time the NA appears.

```
lapply(split(R, col(R)), function(x){as.list(c(min=min(x,na.rm =TRUE), max = max(x, na.rm=TRUE), pct_mi
```

```
## $`1`
```

```
## $`1`$min
## [1] 0
##
## $`1`$max
## [1] 2
##
## $`1`$pct_missing
## [1] 0.36
##
## $`1`$first_NA
## [1] 1
##
##
## $`2`
## $`2`$min
## [1] 0
##
## $`2`$max
## [1] 2
##
## $`2`$pct_missing
## [1] 0.24
##
## $`2`$first_NA
## [1] 3
##
##
## $`3`
## $`3`$min
## [1] 0
##
## $`3`$max
## [1] 2
##
## $`3`$pct_missing
## [1] 0.28
##
## $`3`$first_NA
## [1] 1
##
##
## $`4`
## $`4`$min
## [1] 0
##
## $`4`$max
## [1] 2
##
## $`4`$pct_missing
## [1] 0.22
##
## $`4`$first_NA
## [1] 1
##
```

```
##
## $`5`
## $`5`$min
## [1] 0
##
## $`5`$max
## [1] 2
##
## $`5`$pct_missing
## [1] 0.22
##
## $`5`$first_NA
## [1] 2
##
##
## $`6`
## $`6`$min
## [1] 0
##
## $`6`$max
## [1] 2
##
## $`6`$pct_missing
## [1] 0.3
##
## $`6`$first_NA
## [1] 1
##
##
## $`7`
## $`7`$min
## [1] 0
##
## $`7`$max
## [1] 2
##
## $`7`$pct_missing
## [1] 0.24
##
## $`7`$first_NA
## [1] 4
##
##
## $`8`
## $`8`$min
## [1] 0
##
## $`8`$max
## [1] 2
##
## $`8`$pct_missing
## [1] 0.3
##
## $`8`$first_NA
```

```
## [1] 1
##
##
## $`9`
## $`9`$min
## [1] 0
##
## $`9`$max
## [1] 2
##
## $`9`$pct_missing
## [1] 0.32
##
## $`9`$first_NA
## [1] 3
##
##
## $`10`
## $`10`$min
## [1] 0
##
## $`10`$max
## [1] 2
##
## $`10`$pct_missing
## [1] 0.28
##
## $`10`$first_NA
## [1] 1
##
##
## $`11`
## $`11`$min
## [1] 0
##
## $`11`$max
## [1] 2
##
## $`11`$pct_missing
## [1] 0.2
##
## $`11`$first_NA
## [1] 1
##
##
## $`12`
## $`12`$min
## [1] 0
##
## $`12`$max
## [1] 2
##
## $`12`$pct_missing
## [1] 0.22
```

```
##
## $`12`$first_NA
## [1] 1
##
##
## $`13`
## $`13`$min
## [1] 0
##
## $`13`$max
## [1] 2
##
## $`13`$pct_missing
## [1] 0.22
##
## $`13`$first_NA
## [1] 1
##
##
## $`14`
## $`14`$min
## [1] 0
##
## $`14`$max
## [1] 2
##
## $`14`$pct_missing
## [1] 0.28
##
## $`14`$first_NA
## [1] 1
##
##
## $`15`
## $`15`$min
## [1] 0
##
## $`15`$max
## [1] 2
##
## $`15`$pct_missing
## [1] 0.32
##
## $`15`$first_NA
## [1] 1
##
##
## $`16`
## $`16`$min
## [1] 0
##
## $`16`$max
## [1] 2
##
```

```
## $`16`$pct_missing
## [1] 0.36
##
## $`16`$first_NA
## [1] 1
##
##
## $`17`
## $`17`$min
## [1] 0
##
## $`17`$max
## [1] 2
##
## $`17`$pct_missing
## [1] 0.26
##
## $`17`$first_NA
## [1] 1
##
##
## $`18`
## $`18`$min
## [1] 0
##
## $`18`$max
## [1] 2
##
## $`18`$pct_missing
## [1] 0.24
##
## $`18`$first_NA
## [1] 2
##
##
## $`19`
## $`19`$min
## [1] 0
##
## $`19`$max
## [1] 2
##
## $`19`$pct_missing
## [1] 0.38
##
## $`19`$first_NA
## [1] 1
##
##
## $`20`
## $`20`$min
## [1] 0
##
## $`20`$max
```

```
## [1] 2
##
## $`20`$pct_missing
## [1] 0.14
##
## $`20`$first_NA
## [1] 2
##
##
## $`21`
## $`21`$min
## [1] 0
##
## $`21`$max
## [1] 2
##
## $`21`$pct_missing
## [1] 0.4
##
## $`21`$first_NA
## [1] 3
##
##
## $`22`
## $`22`$min
## [1] 0
##
## $`22`$max
## [1] 2
##
## $`22`$pct_missing
## [1] 0.44
##
## $`22`$first_NA
## [1] 1
##
##
## $`23`
## $`23`$min
## [1] 0
##
## $`23`$max
## [1] 2
##
## $`23`$pct_missing
## [1] 0.26
##
## $`23`$first_NA
## [1] 1
##
##
## $`24`
## $`24`$min
## [1] 0
```

```
##
## $`24`$max
## [1] 2
##
## $`24`$pct_missing
## [1] 0.36
##
## $`24`$first_NA
## [1] 1
##
##
## $`25`
## $`25`$min
## [1] 0
##
## $`25`$max
## [1] 2
##
## $`25`$pct_missing
## [1] 0.34
##
## $`25`$first_NA
## [1] 1
##
##
## $`26`
## $`26`$min
## [1] 0
##
## $`26`$max
## [1] 2
##
## $`26`$pct_missing
## [1] 0.36
##
## $`26`$first_NA
## [1] 1
##
##
## $`27`
## $`27`$min
## [1] 0
##
## $`27`$max
## [1] 2
##
## $`27`$pct_missing
## [1] 0.3
##
## $`27`$first_NA
## [1] 2
##
##
## $`28`
```

```
## $`28`$min
## [1] 0
##
## $`28`$max
## [1] 2
##
## $`28`$pct_missing
## [1] 0.32
##
## $`28`$first_NA
## [1] 2
##
##
## $`29`
## $`29`$min
## [1] 0
##
## $`29`$max
## [1] 2
##
## $`29`$pct_missing
## [1] 0.26
##
## $`29`$first_NA
## [1] 1
##
##
## $`30`
## $`30`$min
## [1] 0
##
## $`30`$max
## [1] 2
##
## $`30`$pct_missing
## [1] 0.32
##
## $`30`$first_NA
## [1] 1
##
##
## $`31`
## $`31`$min
## [1] 0
##
## $`31`$max
## [1] 2
##
## $`31`$pct_missing
## [1] 0.24
##
## $`31`$first_NA
## [1] 1
##
```

```
##
## $`32`
## $`32`$min
## [1] 0
##
## $`32`$max
## [1] 2
##
## $`32`$pct_missing
## [1] 0.36
##
## $`32`$first_NA
## [1] 1
##
##
## $`33`
## $`33`$min
## [1] 0
##
## $`33`$max
## [1] 2
##
## $`33`$pct_missing
## [1] 0.24
##
## $`33`$first_NA
## [1] 1
##
##
## $`34`
## $`34`$min
## [1] 0
##
## $`34`$max
## [1] 2
##
## $`34`$pct_missing
## [1] 0.3
##
## $`34`$first_NA
## [1] 1
##
##
## $`35`
## $`35`$min
## [1] 0
##
## $`35`$max
## [1] 2
##
## $`35`$pct_missing
## [1] 0.4
##
## $`35`$first_NA
```

```
## [1] 1
##
##
## $`36`
## $`36`$min
## [1] 0
##
## $`36`$max
## [1] 2
##
## $`36`$pct_missing
## [1] 0.32
##
## $`36`$first_NA
## [1] 1
##
##
## $`37`
## $`37`$min
## [1] 0
##
## $`37`$max
## [1] 2
##
## $`37`$pct_missing
## [1] 0.28
##
## $`37`$first_NA
## [1] 1
##
##
## $`38`
## $`38`$min
## [1] 0
##
## $`38`$max
## [1] 2
##
## $`38`$pct_missing
## [1] 0.28
##
## $`38`$first_NA
## [1] 1
##
##
## $`39`
## $`39`$min
## [1] 0
##
## $`39`$max
## [1] 2
##
## $`39`$pct_missing
## [1] 0.32
```

```
##
## $`39`$first_NA
## [1] 1
##
##
## $`40`
## $`40`$min
## [1] 0
##
## $`40`$max
## [1] 2
##
## $`40`$pct_missing
## [1] 0.34
##
## $`40`$first_NA
## [1] 1
##
##
## $`41`
## $`41`$min
## [1] 0
##
## $`41`$max
## [1] 2
##
## $`41`$pct_missing
## [1] 0.3
##
## $`41`$first_NA
## [1] 1
##
##
## $`42`
## $`42`$min
## [1] 0
##
## $`42`$max
## [1] 2
##
## $`42`$pct_missing
## [1] 0.34
##
## $`42`$first_NA
## [1] 1
##
##
## $`43`
## $`43`$min
## [1] 0
##
## $`43`$max
## [1] 2
##
```

```
## $`43`$pct_missing
## [1] 0.24
##
## $`43`$first_NA
## [1] 1
##
##
## $`44`
## $`44`$min
## [1] 0
##
## $`44`$max
## [1] 2
##
## $`44`$pct_missing
## [1] 0.32
##
## $`44`$first_NA
## [1] 3
##
##
## $`45`
## $`45`$min
## [1] 0
##
## $`45`$max
## [1] 2
##
## $`45`$pct_missing
## [1] 0.24
##
## $`45`$first_NA
## [1] 1
##
##
## $`46`
## $`46`$min
## [1] 0
##
## $`46`$max
## [1] 2
##
## $`46`$pct_missing
## [1] 0.34
##
## $`46`$first_NA
## [1] 1
##
##
## $`47`
## $`47`$min
## [1] 0
##
## $`47`$max
```

```
## [1] 2
##
## $`47`$pct_missing
## [1] 0.24
##
## $`47`$first_NA
## [1] 3
##
##
## $`48`
## $`48`$min
## [1] 0
##
## $`48`$max
## [1] 2
##
## $`48`$pct_missing
## [1] 0.2
##
## $`48`$first_NA
## [1] 1
##
##
## $`49`
## $`49`$min
## [1] 0
##
## $`49`$max
## [1] 2
##
## $`49`$pct_missing
## [1] 0.3
##
## $`49`$first_NA
## [1] 1
##
##
## $`50`
## $`50`$min
## [1] 0
##
## $`50`$max
## [1] 2
##
## $`50`$pct_missing
## [1] 0.16
##
## $`50`$first_NA
## [1] 1
```

- Set a seed and then create a vector `v` consisting of a sample of 1,000 iid normal realizations with mean -10 and variance 100.

```
set.seed(5398)
v = rnorm(1000, mean = -10, sd = sqrt(100))
```

```
v
```

```
##    [1] -29.7822658207719   2.9814597328652 -12.9090033408132  -0.3826488408265
##    [5]   7.9167465302294  -1.1357543600378 -15.0566061894899 -18.7153257384681
##    [9]   5.8342740996780  -4.3017536118456 -15.7729147605050  -6.1416187661872
##   [13]  -9.9844920497262 -10.2795288008437 -15.9448512844326  -5.4632452781792
##   [17]  -8.7604338838950  -3.6865933329669  -3.1224045112879   1.1575232103199
##   [21] -14.3331791013150  -2.6249698670441 -18.4884428639831 -12.8815344672985
##   [25]  -7.8047288991171   0.9207236362268  -0.7019817790242 -21.0363988277657
##   [29] -22.8984316915486 -18.5775166048531 -17.6649288576929  -3.2741924186805
##   [33] -20.5849543861565 -36.3419288307443  -7.0616878896370 -10.5163801879698
##   [37] -23.3105420836788  -7.5613331368523 -11.4376604608500 -26.7349302207470
##   [41] -17.8685929742117 -11.8458531408693  -3.8690429350450 -23.9560681507522
##   [45]  -4.8662564953253 -22.8294722117113 -42.2030408030274  -4.1143844137106
##   [49] -10.0872835882376 -28.5217159573076 -17.9064721366590 -10.6746204564481
##   [53]   0.9834390875279  -0.9634731803603 -16.0819642190016 -14.8650220508511
##   [57]  -6.8943083277345 -20.5099797420659 -17.6336051768124 -10.3075291940746
##   [61] -11.2962007915913 -14.4631766389718  -8.9730724329120  -2.6491072799780
##   [65] -28.0726632058488 -17.1778936823319 -25.5208087599486 -12.0412881976528
##   [69] -16.0668976681019 -16.4310487067380 -29.8384355871970 -25.8280633271574
##   [73]  -4.3740275372159 -12.9711155232517  -6.8117290947547 -13.6337014799373
##   [77]  -5.1954023617627 -33.2868551349579 -10.4201514945132  -2.5046003061248
##   [81] -24.5403873598435 -16.8601805882014  -0.4826823346768 -16.2732496258850
##   [85] -30.3519338736599 -12.3202806592143 -18.5579669773299 -21.5015563656374
##   [89] -15.0423778608791 -23.3132182221972  -4.7157161430432  -8.6116762324702
##   [93]  -7.2410466693445 -17.0000584919572 -25.3575724138688  -2.2812716154867
##   [97]   2.3851342254760 -22.1294674581884  -9.5791031511307 -23.4704999364069
##  [101]   1.4689635143831 -10.0500590621611 -21.1560338701086 -25.3672142463078
##  [105]  -0.9089374416604  -6.2693073767866 -21.3197922453424   3.9440626548553
##  [109] -16.5856616551696  -7.8071046934869 -23.5253771031258 -16.5740858250782
##  [113]  -2.3148919376808 -14.3268271046751 -12.3691904551910 -30.1443727379144
##  [117]  -2.5886241449375 -16.5928190139832 -19.1611998420163  24.9302561686436
##  [121] -15.9646290679477  -8.9756922908559 -14.5236091537104 -18.4861454964200
##  [125] -21.3619451836440 -20.6195227648517 -18.9189974201708 -21.8020270796045
##  [129] -12.0724319615708 -33.1986881393447  -2.6984380592249 -17.5825820977453
##  [133]  -6.8576383458428 -16.6711492092643  -3.7040552257482  -3.0132043304876
##  [137]  -9.1652021911706  -7.7318089159668 -26.5253055675957  -0.1078188156573
##  [141]  -9.0110810139958   7.0702237772930  -3.2757920980204 -15.8711467580087
##  [145] -10.8800511972587 -17.1977908729822 -12.0506578310088  -8.5044839819724
##  [149] -19.6297015000689  -4.9190211069931  -3.8476099480735  -2.3337520376981
##  [153]   1.1808317220982 -19.2264073655930 -25.0759516971105  -0.4445600117516
##  [157]  -4.7258180894805 -10.3997249587348 -10.3146147680860 -13.3886169174249
##  [161] -12.8061366670201 -16.4484200869686 -24.7272312491421 -37.2035047597033
##  [165] -10.3849333823071 -16.2073190133240 -28.8327936255725 -15.0978122989144
##  [169]  -6.0546198047483 -19.9540173969804  -0.5794627162851 -27.7322754594344
##  [173]  -9.1075777437758 -15.7747622165763   6.1956823320163  -3.8931898084770
##  [177] -29.8345897256425 -19.3664032422507   0.9029338161718  -7.4178371801863
##  [181]  -7.6590130543803  -5.3765137701292 -22.0619253231623 -11.0510584107088
##  [185]  -0.8488638338803 -18.4411795102756  -2.5996039828382  -2.8471881066800
##  [189]  -8.1227364666852   0.2287741092425  -2.6789221674679 -18.2634534997095
##  [193] -13.4645055515551 -14.4939842862156 -12.7739999271888  -6.8923240361536
##  [197] -26.1747702071147  -3.8349363960691 -14.2778729896523 -30.1316052679497
##  [201]  -0.2279503007000  -7.6619102507695 -31.2277635695432   4.7316026957305
##  [205] -14.0209598550911 -34.4297605783192 -18.2194496534019  -6.6501841023421
```

```
##  [209]  -6.2131679101504 -20.6959161253891  -3.8581632301202   3.5696801339295
##  [213] -23.4911864431869  -4.5070052343965   4.2866372533486  -0.0816249192141
##  [217]  -9.1444890939862   4.6532064345805 -11.3592678718346  -9.9000802373275
##  [221]  -4.5472086555062   2.1440523852695  -6.0126722298847   9.8519492158866
##  [225]  -2.8850877631991 -10.7975421534976  -5.8721845601800  -4.4061371029315
##  [229] -14.5277548076104 -14.9385273091907 -17.3774173792111   8.7918293699665
##  [233] -24.9438437373971  -0.1266023302449   0.1160313684227   2.8187034358325
##  [237] -12.5750321027522 -10.9866378475516  -4.9229877508247  10.1474459481485
##  [241] -21.5463689656814 -17.7137857869781 -10.2460305757040 -11.4269718837984
##  [245] -10.7421614654846 -42.7062417731949 -13.5721720138255  -7.5333766602006
##  [249] -22.8910004241266  -6.8617434608159  -9.5438075769978 -19.6264623746873
##  [253]  -1.0045645666318 -13.5372287101187  -2.1553732334510 -28.0885149581306
##  [257]  -0.5606986233779 -11.1376381318338 -14.3231196974398   1.4158790814220
##  [261]  13.1338697962168 -10.6640732902724 -23.6512654328791 -47.1470929562556
##  [265] -27.8058660021396 -14.9892524958902  -6.9561990660244  -9.1843041316950
##  [269] -17.5646258713005   5.4370010379188 -19.7138689030029 -12.2607566263394
##  [273] -17.9446049984807 -21.6136533280589 -11.3298681040705 -17.2142243398956
##  [277]  -6.1567154119275 -18.1079620993931  -2.5614635134410  -7.8983431065956
##  [281] -11.4367837768950 -11.8510742480066  -2.4288452340346  -3.5404477114938
##  [285]  -6.6645515862473 -14.7170893805954  -6.2689894945611  -0.9187724294763
##  [289] -14.4928054813931  -4.3469577125770 -28.0088937622916   9.9311147261244
##  [293]  -8.8436255111404   2.2038650608333  -4.4096328001437 -28.7010885859517
##  [297]  -0.1396770021818  -1.2513354753501 -17.9935793490911 -18.7722508236268
##  [301]  -8.4267284464773  -9.6303021221580 -29.2868036902303  -9.2123493307903
##  [305] -14.7936744167110  -7.4289578528803  -5.1333363612274 -36.9291106196194
##  [309] -19.9714611630305 -19.2471474970915  -6.7940513495913   3.1444322775978
##  [313]  -3.8041986936339  -4.3974251494384 -19.4712069545793 -18.6715048981782
##  [317]   3.4035024519978  -6.1241747434881 -16.8509173856207  -2.6392387094906
##  [321]   0.1031138753885  -4.4449044999039  -9.6018863021513 -15.9028355568966
##  [325] -21.4066589706686 -12.1932159839468 -11.6600540638390 -21.7719181874243
##  [329] -17.8516746326127   2.0507488275757 -16.1265642644880  -9.6821089784087
##  [333] -11.0705447980230  -0.1787041901108 -19.0612000896578 -13.6892616287542
##  [337]   0.9112803352784 -14.9864240708795  -3.2415347846684 -24.1962552196273
##  [341] -17.2417915507452  -3.1002130874104 -14.4488906109967 -22.0289429345690
##  [345] -29.2038112393708  -9.5660604276085 -19.5097998814136 -13.9354214004502
##  [349]  -4.7539568302774 -17.6861283880388 -18.2250469255219 -30.9124733369231
##  [353]  -2.5510161938078  -3.3189979201107   6.8228190998768   3.2587537603330
##  [357] -12.9915308480444  -4.8744639993778 -11.0103288605587  -0.3939354282557
##  [361] -32.8989365796234   2.0960670999067 -22.6810757103525  -6.5363057287024
##  [365]   1.0899516690261   4.1603913936278  -1.6512516039064 -10.3393065391342
##  [369]   2.0703780010421  -7.6746932261039 -17.0320925017285 -15.5600635841317
##  [373] -15.5561872579613 -12.5146357682634 -20.5829629842064 -19.1684609635610
##  [377]  -4.9370238438346  -8.5923263765926 -11.0613787963048 -19.3613333633141
##  [381]  -7.4595032906716 -16.2056131114186  -5.3743738025553  -1.3264742264285
##  [385] -13.5666905714292 -26.1706267217507 -27.1399777742530 -33.7942440936840
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##  [393]  -7.3419522148013 -25.2086547381410  -8.1437599644474   1.5188178822587
##  [397] -28.9785825309149  -3.3237988965069   0.5909702233452 -17.2976487760606
##  [401] -18.7841174890733  -2.2321048675290 -10.7640045933541  -3.0167199010455
##  [405]  -8.6411238403282  -7.1140493578900   8.0747541572565 -14.9423606051538
##  [409] -13.4240403528157 -10.2281480308548 -21.3002349009147 -25.7811951215746
##  [413]  -0.2148430532901  -3.2442057497400 -20.7134777876378 -15.8146484939610
##  [417]   5.7545539904326 -13.2602444719548 -10.4314931347266   9.9826757151500
##  [421]   7.4878957177974  -7.1677437465988 -10.8395923338411 -14.3830402222939
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##  [425] -16.1376810262733  -1.5848829019650  -6.1361735516083 -21.2882887805662
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##  [433] -17.5012974579704  -9.8458618936271 -15.8021501564605  -5.8069302159666
##  [437] -25.1831320025162 -13.9690696094351 -13.1873403580543  -8.6935363929741
##  [441] -23.0883027584824 -10.1664601822640  -9.2138085996947 -12.8942884428678
##  [445] -12.7387182748970 -18.0216428163698 -12.5774473680659  -5.4950837298359
##  [449]   7.8283388074375  -4.1951094441124  -3.1730501285387  -4.7268660815917
##  [453]   5.4955573196811   1.3989460752930   2.6999669176495  -1.8762085382559
##  [457]  -9.5794836338250  -2.1568184286006  -8.2063284319680 -15.9841500273795
##  [461]  -1.0614878247340  -9.3814681785707 -14.2045103501001 -39.2355402670735
##  [465]  -1.2903636792243  -2.5337704571679 -11.2016017369639  -3.8444047069736
##  [469]  -6.9539825432949 -11.3916732815366 -11.0613468452138   7.2357552396343
##  [473] -16.8158331464859 -10.2989032295491  -7.7089999400388 -19.7903114427632
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##  [481] -17.1632570260131   0.3952020616305 -14.2022904870647 -13.0383518434670
##  [485]  -5.6810626252361 -11.0820607106936   6.7246606445208 -18.6554463309379
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##  [501] -17.5074753111145 -21.7520567933418  -1.1317914758813  -1.7643075181546
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##  [509]  -7.3684614491041  -3.3037509645276  -2.9650861558644 -32.2297018410494
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##  [517] -12.5083030012239 -28.6514591126761  -8.2292192861926   1.5294142416029
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##  [585]   2.6070536270051 -19.5447787978954   0.6818680398736  -7.4627240400697
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##  [593] -12.0932888583684 -20.5284436718545 -18.5654186428046 -26.4726370293446
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##  [613]   0.4783040501755 -10.7501804403093  -3.0688444696507   3.1962715601720
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##  [621]  -9.9644183884449   4.4303577862150  -8.1078819775489 -22.7633176530462
##  [625] -21.4137750531199 -11.0117799311295 -31.5042890637756  -6.4996313838202
##  [629] -26.7876739826136 -35.1501171679018 -11.7165281677738 -13.5080213459635
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##  [725]  11.6323695054908 -23.5683044891743 -15.9258968127672 -42.8718990846987
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##  [809] -15.5052017215028 -12.0494383182705   6.1329698624843  -4.9496630972756
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##  [821] -27.8492527419512 -18.6006360763057  -8.3382237702306  -5.1128132298793
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##  [829] -16.6672517326219 -19.7747928634956  -1.3586282961123 -12.7306261572520
##  [833] -10.1430819591528 -10.3474306368715  -7.3490775616644  -7.3336633796796
##  [837] -16.6601840642203  11.5674059630612 -25.4556369041603   8.2849618609212
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##  [845] -17.8769869805949  -9.9279900978363 -11.6697742413300 -24.3235917999920
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##  [881]  -7.7260129426359 -17.0692042664311  -7.4561620467842   4.8362578083493
##  [885] -23.8802420550328 -14.3209534964755  -3.2832115841624  -9.6981290470649
##  [889]  -8.6115499059928  -5.7143782549343   4.4910148126714  -2.0629458115045
##  [893] -15.0707934873680   9.5283151618154  -4.1325717938521   0.3224077617607
##  [897]  -9.1250624431649 -19.0484386007444   3.9707944967400 -12.0133710540649
##  [901]  -2.0981654964719  -3.7364575111212  23.5455847379828 -22.2188987743021
##  [905] -10.8716776626431  11.8147752914154  -5.4322869681426  12.3151762261903
##  [909]   4.9245062438274  -2.5304950409055  -0.5517332887552  -3.2889887905609
##  [913] -17.6037754472705 -33.0126945394033   6.8240160580478 -11.6986538584789
##  [917] -12.6772122679435   2.2429125664583 -19.0725562976929  -7.7096024233706
##  [921]  -5.6217333183620 -24.9323231942301 -11.6446469932123 -24.6512753525649
##  [925]   0.5842481861386 -13.4205009302451 -21.7729181978689  -5.1148451699076
##  [929]  -8.8003079328662   5.4803844511924   2.5205297794363 -19.0456219380948
##  [933]   2.6916973682081   1.8232606697534  -7.7099148226459  -1.1584138333553
##  [937]  -4.6951893889854 -16.5926765999883 -13.0562517186381   1.9960515907097
##  [941]  -6.9581299296603 -29.0966038870903  -5.0017438359296 -10.9876399571557
##  [945]  -6.7497816256632 -10.0287803386666  -7.7196151960810 -16.9870036999549
##  [949]  -7.5992668253970  -9.2842591264328 -21.0976371803514  -9.4859095609296
##  [953] -22.6108217581237  -1.3371574462754  -1.7489395708026 -19.9264732804183
##  [957]  -6.4546527760737 -17.5417545477495   2.0401440805277 -14.0262298730014
##  [961] -10.3087144116744 -28.6502243468403 -35.1015447715192 -17.4641143939731
##  [965] -33.9483126913246   0.7770238249219  -1.0105886831542  -9.4610170010326
##  [969] -17.5326374095220 -12.7166228671914  -7.4797178473245 -16.8552271858281
##  [973]   5.8470944882455 -18.9828711916282  -8.3479438299252  -8.6343581310342
##  [977] -12.1748612875810  -5.4811973593104  -3.5800953079341  -3.4442930045008
##  [981] -14.4717097154314  -8.3088539973517 -19.7000701940201 -24.6001193338675
##  [985]  -7.5395381639835  -0.7547445297658 -15.0716826384072   1.2462420517380
##  [989]  -8.3975633122461 -11.1215065240539  11.9617345051851 -18.9718156011265
##  [993]   5.4604580130160  -6.5439169358340  -1.2286745401384 -12.9328455817846
##  [997] -12.5044340150724  -7.6832914600289  -9.8255731276054 -27.1630523197220
```

- Repeat this exercise by resetting the seed to ensure you obtain the same results.

```
set.seed(3760)
v
```

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##    [1] -29.7822658207719   2.9814597328652 -12.9090033408132  -0.3826488408265
##    [5]   7.9167465302294  -1.1357543600378 -15.0566061894899 -18.7153257384681
##    [9]   5.8342740996780  -4.3017536118456 -15.7729147605050  -6.1416187661872
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##   [25]  -7.8047288991171   0.9207236362268  -0.7019817790242 -21.0363988277657
##   [29] -22.8984316915486 -18.5775166048531 -17.6649288576929  -3.2741924186805
##   [33] -20.5849543861565 -36.3419288307443  -7.0616878896370 -10.5163801879698
##   [37] -23.3105420836788  -7.5613331368523 -11.4376604608500 -26.7349302207470
##   [41] -17.8685929742117 -11.8458531408693  -3.8690429350450 -23.9560681507522
##   [45]  -4.8662564953253 -22.8294722117113 -42.2030408030274  -4.1143844137106
##   [49] -10.0872835882376 -28.5217159573076 -17.9064721366590 -10.6746204564481
```

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##   [53]   0.9834390875279  -0.9634731803603 -16.0819642190016 -14.8650220508511
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##   [61] -11.2962007915913 -14.4631766389718  -8.9730724329120  -2.6491072799780
##   [65] -28.0726632058488 -17.1778936823319 -25.5208087599486 -12.0412881976528
##   [69] -16.0668976681019 -16.4310487067380 -29.8384355871970 -25.8280633271574
##   [73]  -4.3740275372159 -12.9711155232517  -6.8117290947547 -13.6337014799373
##   [77]  -5.1954023617627 -33.2868551349579 -10.4201514945132  -2.5046003061248
##   [81] -24.5403873598435 -16.8601805882014  -0.4826823346768 -16.2732496258850
##   [85] -30.3519338736599 -12.3202806592143 -18.5579669773299 -21.5015563656374
##   [89] -15.0423778608791 -23.3132182221972  -4.7157161430432  -8.6116762324702
##   [93]  -7.2410466693445 -17.0000584919572 -25.3575724138688  -2.2812716154867
##   [97]   2.3851342254760 -22.1294674581884  -9.5791031511307 -23.4704999364069
##  [101]   1.4689635143831 -10.0500590621611 -21.1560338701086 -25.3672142463078
##  [105]  -0.9089374416604  -6.2693073767866 -21.3197922453424   3.9440626548553
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##  [117]  -2.5886241449375 -16.5928190139832 -19.1611998420163  24.9302561686436
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##  [881]  -7.7260129426359 -17.0692042664311  -7.4561620467842   4.8362578083493
##  [885] -23.8802420550328 -14.3209534964755  -3.2832115841624  -9.6981290470649
##  [889]  -8.6115499059928  -5.7143782549343   4.4910148126714  -2.0629458115045
##  [893] -15.0707934873680   9.5283151618154  -4.1325717938521   0.3224077617607
##  [897]  -9.1250624431649 -19.0484386007444   3.9707944967400 -12.0133710540649
##  [901]  -2.0981654964719  -3.7364575111212  23.5455847379828 -22.2188987743021
##  [905] -10.8716776626431  11.8147752914154  -5.4322869681426  12.3151762261903
##  [909]   4.9245062438274  -2.5304950409055  -0.5517332887552  -3.2889887905609
##  [913] -17.6037754472705 -33.0126945394033   6.8240160580478 -11.6986538584789
```

```
##  [917] -12.6772122679435   2.2429125664583 -19.0725562976929  -7.7096024233706
##  [921]  -5.6217333183620 -24.9323231942301 -11.6446469932123 -24.6512753525649
##  [925]   0.5842481861386 -13.4205009302451 -21.7729181978689  -5.1148451699076
##  [929]  -8.8003079328662   5.4803844511924   2.5205297794363 -19.0456219380948
##  [933]   2.6916973682081   1.8232606697534  -7.7099148226459  -1.1584138333553
##  [937]  -4.6951893889854 -16.5926765999883 -13.0562517186381   1.9960515907097
##  [941]  -6.9581299296603 -29.0966038870903  -5.0017438359296 -10.9876399571557
##  [945]  -6.7497816256632 -10.0287803386666  -7.7196151960810 -16.9870036999549
##  [949]  -7.5992668253970  -9.2842591264328 -21.0976371803514  -9.4859095609296
##  [953] -22.6108217581237  -1.3371574462754  -1.7489395708026 -19.9264732804183
##  [957]  -6.4546527760737 -17.5417545477495   2.0401440805277 -14.0262298730014
##  [961] -10.3087144116744 -28.6502243468403 -35.1015447715192 -17.4641143939731
##  [965] -33.9483126913246   0.7770238249219  -1.0105886831542  -9.4610170010326
##  [969] -17.5326374095220 -12.7166228671914  -7.4797178473245 -16.8552271858281
##  [973]   5.8470944882455 -18.9828711916282  -8.3479438299252  -8.6343581310342
##  [977] -12.1748612875810  -5.4811973593104  -3.5800953079341  -3.4442930045008
##  [981] -14.4717097154314  -8.3088539973517 -19.7000701940201 -24.6001193338675
##  [985]  -7.5395381639835  -0.7547445297658 -15.0716826384072   1.2462420517380
##  [989]  -8.3975633122461 -11.1215065240539  11.9617345051851 -18.9718156011265
##  [993]   5.4604580130160  -6.5439169358340  -1.2286745401384 -12.9328455817846
##  [997] -12.5044340150724  -7.6832914600289  -9.8255731276054 -27.1630523197220
```

- Find the average of `v` and the standard error of `v`.

```
mean(v)
```

```
## [1] -10.918146182
```

```
se = sd(v)/sqrt(length(v))
se
```

```
## [1] 0.32302075758
```

- Find the 5%ile of `v` and use the `qnorm` function to compute what it theoretically should be. Is the estimate about what is expected by theory?

```
#5%tile is
e = quantile(v, 0.05)
e
```

```
##           5%
## -28.316778768
```

```
#theoretically
qnorm(.05, mean(v), sd(v))
```

```
## [1] -27.720018813
```

```
#they are very close but not exactly the same
```

- What is the percentile of `v` that corresponds to the value 0? What should it be theoretically? Is the estimate about what is expected by theory?

```
#theoretically (use the inverse quantile function)
ecdf(v)(0)
```

```
## [1] 0.867
```

```
#estimate
pnorm(0,mean(v), sd(v))
```

```
## [1] 0.85743231682
#these values are very close, but not exactly the same
```