## Lab 1

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## 11:59PM February 18, 2021

You should have RStudio installed to edit this file. You will write code in places marked "TO-DO" to complete the problems. Most of this will be a pure programming assignment but there are some questions that instead ask you to "write a few sentences". This is a W class! The tools for the solutions to these problems can be found in the class practice lectures. I prefer you to use the methods I taught you. If you google and find esoteric code you don't understand, this doesn't do you too much good.

To "hand in" the homework, you should first download this file. The best way to do this is by cloning the class repository then copying this file from the folder of that clone into the folder that is your personal class repository. Then do the assignment by filling in the TODO's. After you're done, compile this file into a PDF (use the "knit to PDF" button on the submenu above). This PDF will include output of your code. Then push the PDF and this Rmd file by the deadline to your github repository in a directory called "labs".

## **Basic R Skills**

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

```
options(digits=11)
x <- pi
x
## [1] 3.1415926536</pre>
```

• 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/(3*(1:37)))
## [1] 1.613528728e-61
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?

#TO-DO

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

```
sum(log(1/(2^{(0:386))}))
## [1] -51771.856063
-\log(2)*sum(0:386)
## [1] -51771.856063
    Create the sequence x = [Inf, 20, 18, \ldots, -20].
x \leftarrow c(Inf, seq(from=20, to=-20, by=-2))
Х
##
   [1] Inf 20
                18
                      16 14 12 10
                                         8
                                             6
                                                 4
                                                      2
                                                          0 -2 -4
                                                                         -8 -10 -
                                                                     -6
12 -14
## [20] -16 -18 -20
Create the sequence x = [log_3(Inf), log_3(100), log_3(98), ... log_3(-20)].
x \leftarrow c(Inf, seq(from=100, to=-20, by=-2))
x \leftarrow log(x, base=3)
## Warning: NaNs produced
log(100, 3)
## [1] 4.1918065486
```

Comment on the appropriateness of the non-numeric values.

NAN occurs because you cannot take the log of a negative number. -Inf occurs when you take the log of 0.

• 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
У
                          TRUE
                                                 TRUE
                                                       TRUE
   [1] FALSE
              TRUE
                    TRUE
                                TRUE
                                     TRUE
                                           TRUE
                                                             TRUE
                                                                   TRUE
TRUE
        TRUE
              TRUE
                    TRUE
                          TRUE
                               TRUE
                                     TRUE
                                           TRUE
                                                 TRUE
                                                       TRUE
                                                             TRUE
                                                                   TRUE
## [13]
TRUE
## [25]
        TRUE
              TRUE
                   TRUE
                          TRUE
                               TRUE
                                     TRUE
                                           TRUE
                                                 TRUE
                                                       TRUE
                                                            TRUE
                                                                   TRUE
TRUE
        TRUE TRUE
                   TRUE
                         TRUE
                               TRUE
                                     TRUE
                                           TRUE
                                                 TRUE
                                                       TRUE
                                                             TRUE
## [37]
TRUE
## [49] TRUE TRUE TRUE FALSE FALSE FALSE FALSE FALSE FALSE
```

```
FALSE ## [61] FALSE FALSE
```

• 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
which(!y)
## [1] 1 52 53 54 55 56 57 58 59 60 61 62
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
                         1.26185950714291 0.630929753571457 -Inf
## [49] 1.63092975357146
## [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?

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

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

## [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.

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

```
## [1] 0.52
```

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

```
sum(sample(c(0,1), size=500, replace=TRUE, prob=c(0.1, 0.9)))/500
## [1] 0.91
```

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

```
?rbinom
rbinom(n=1000, size=1, p=0.9)
 1 1 0
 ##
1 1 1
 ##
0 1 1
1 1 1
1 1 1
1 1 1
1 1 1
1 0 1
1 1 1
1 1 1
1 1 1
1 1 1
## [482] 0 1 1 1 1 1 1 0 0 1 0 0 0 1 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 0
## [519] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1
1 1 1
1 1 0
## [593] 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 0 1
1 0 1
```

```
1 1 1
100
1 1 1
1 1 1
1 1 1
1 1 1
1 0 1
## [1000] 1
```

• 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))
x_3
     [1] infraction none
                                misdimeanor infraction misdimeanor
infraction
                    misdimeanor none
##
    [7] felony
                                            none
                                                        misdimeanor
misdimeanor
## [13] infraction infraction infraction felony
                                                        felony
                                                                    none
## [19] infraction misdimeanor infraction
                                            felony
                                                        misdimeanor
infraction
## [25] infraction felony
                                            none
                                                        felony
                                none
misdimeanor
## [31] misdimeanor felony
                                infraction infraction misdimeanor none
                    felony
                                                        infraction
## [37] felony
                                felony
                                            none
infraction
## [43] infraction felony
                                misdimeanor infraction felony
                                                                    none
## [49] infraction misdimeanor felony
                                            infraction none
misdimeanor
## [55] infraction felony
                                infraction none
                                                        misdimeanor felony
## [61] misdimeanor misdimeanor none
                                            infraction
                                                       misdimeanor none
                    infraction none
                                                        misdimeanor
## [67] none
                                            none
infraction
## [73] none
                    infraction misdimeanor none
                                                        misdimeanor
misdimeanor
## [79] misdimeanor none
                                misdimeanor misdimeanor infraction
misdimeanor
```

```
## [85] none none none misdimeanor
infraction
## [91] none infraction felony misdimeanor misdimeanor
misdimeanor
## [97] infraction infraction felony felony
## Levels: felony infraction misdimeanor none
```

• 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 FALSE TRUE TRUE TRUE TRUE TRUE FALSE FALSE
                                                             TRUE
TRUE
## [13]
        TRUE TRUE TRUE TRUE
                              TRUE FALSE
                                        TRUE TRUE
                                                   TRUE
                                                        TRUE
                                                              TRUE
TRUE
## [25]
        TRUE TRUE FALSE FALSE
                              TRUE
                                  TRUE
                                       TRUE TRUE
                                                    TRUE
                                                         TRUE
                                                              TRUE
FALSE
        TRUE TRUE TRUE FALSE TRUE
                                  TRUE TRUE TRUE
                                                   TRUE TRUE
## [37]
                                                              TRUE
FALSE
        TRUE TRUE TRUE FALSE TRUE TRUE TRUE TRUE FALSE
## [49]
                                                              TRUE
TRUE
        TRUE TRUE FALSE TRUE TRUE FALSE FALSE TRUE FALSE FALSE
## [61]
                                                              TRUE
TRUE
## [73] FALSE TRUE TRUE FALSE
                              TRUE TRUE TRUE FALSE
                                                  TRUE
                                                              TRUE
TRUE
## [85] FALSE FALSE FALSE TRUE TRUE FALSE TRUE TRUE 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.

```
x 3 ord = factor(x 3, levels = c("none", "infraction", "misdimeanor",
"felony"), order=TRUE)
x_3_ord
    [1] infraction none
                                misdimeanor infraction misdimeanor
infraction
     [7] felony
                    misdimeanor none
                                                        misdimeanor
##
                                            none
misdimeanor
## [13] infraction infraction infraction
                                            felony
                                                        felony
                                                                    none
                                                        misdimeanor
## [19] infraction misdimeanor infraction
                                            felony
infraction
## [25] infraction felony
                                                        felony
                                none
                                            none
misdimeanor
## [31] misdimeanor felony
                                infraction
                                            infraction misdimeanor none
## [37] felony
                                                        infraction
                    felony
                                felony
                                            none
infraction
## [43] infraction felony
                                misdimeanor infraction
                                                        felony
                                                                    none
## [49] infraction misdimeanor felony
                                            infraction
                                                        none
misdimeanor
```

```
## [55] infraction felony
                                infraction
                                           none
                                                       misdimeanor felony
## [61] misdimeanor misdimeanor none
                                           infraction misdimeanor none
## [67] none
                    infraction none
                                                       misdimeanor
                                           none
infraction
                    infraction misdimeanor none
## [73] none
                                                       misdimeanor
misdimeanor
                                misdimeanor misdimeanor infraction
## [79] misdimeanor none
misdimeanor
## [85] none
                                                       misdimeanor
                    none
                                none
                                           none
infraction
## [91] none
                    infraction
                               felony
                                           misdimeanor misdimeanor
misdimeanor
## [97] infraction infraction felony
                                           felonv
## Levels: none < infraction < misdimeanor < felony
```

 Convert this variable into three binary variables without any information loss and put them into a data matrix.

```
x 3 infraction = as.integer(x 3 == "infraction")
x_3_misdimeanor = as.integer(x_3 == "misdimeanor")
x_3_felony = as.integer(x_3 == "felony")
X = cbind(x_3_infraction, x_3_misdimeanor, x_3_felony)
head(X)
##
        x_3_infraction x_3_misdimeanor x_3_felony
## [1,]
                      1
                                                   0
## [2,]
                      0
                                       0
                                                   0
## [3,]
                      0
                                       1
                                                   0
                      1
## [4,]
                                                   0
## [5,]
                      0
                                        1
                                                   0
                      1
                                                   0
## [6,]
p_{\text{level\_names}} = \text{levels}(x_3)[-1]
X = matrix(NA, nrow = length(x_3), ncol = length(p_level_names))
colnames(X) = p_level_names
for (j in 1 : length(p level names)){
  X[, j] = as.integer(x_3 == p_level_names[j])
head(X)
##
        infraction misdimeanor none
## [1,]
                  1
                               0
## [2,]
                  0
                               0
                                    1
## [3,]
                  0
                               1
                                    0
## [4,]
                  1
                               0
                                    0
## [5,]
                  0
                               1
                                    0
## [6,]
```

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

#TO-DO

Verify that.

```
# The sum of each row should be either 0 or 1. Due to the fact that these
events appear to be mutually exclusive.

table(rowSums(X))
##
## 0 1
## 18 82
```

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

#TO-DO

Verify that.

```
colSums(X)
## infraction misdimeanor none
## 29 29 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.

```
"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(X)= fake_first_names
Χ
                        [,1]
                                                                [,4] [,5] [,6]
##
                                         [,2] [,3]
## Sophia
              24.8188165537
                              9.125269912183
                                                  9 0.1587412576615
                                                                         2
                                                                              0
## Emma
              20.4783669392
                              9.071766566485
                                                  7 0.0602435882514
                                                                         1
                                                                              1
## Olivia
                              2.044677576050
                                                  8 0.0032740980079
                                                                         2
              10.3955264915
                                                                              0
              17.0358899194 -9.387335558422
                                                 12 0.0870577835742
                                                                         3
                                                                              0
## Ava
## Mia
              18.4665636575
                             7.249305052683
                                                  8 0.1052566152019
                                                                         3
                                                                              0
## Isabella
             26.0294001579
                              7.102146213874
                                                  8 0.2192423294367
                                                                         1
                                                                              0
              19.0145055935 -5.004552206956
                                                  7 0.0255512944423
                                                                         1
## Riley
                                                                              0
## Aria
              18.9829945699 -5.670656017028
                                                  3 0.0445471205749
                                                                         0
                                                                              0
                                                  4 0.0492995754402
## Zoe
              13.3179331057
                              9.207044662908
                                                                         4
                                                                              0
                                                                         2
## Charlotte 21.2586733803 -6.720953411423
                                                 10 0.0893347485971
                                                                              0
                              0.582132521085
                                                  3 0.0438075131840
                                                                         2
## Lily
              17.3233172665
                                                                              0
## Layla
               5.3769232856 -3.938631322235
                                                  9 0.0797862479830
                                                                         6
                                                                              1
## Amelia
              17.8422487543
                              0.549068548717
                                                  6 0.1560836368044
                                                                         3
                                                                              0
## Emily
              22.5090258305 -9.544669818133
                                                  9 0.1932706553396
                                                                         1
                                                                              0
                              9.147345959209
## Madelyn
              15.8065435665
                                                  9 0.2159838074104
                                                                         6
                                                                              0
## Aubrey
              20.8890191842
                              5.368922925554
                                                  7 0.1491265917771
                                                                         4
                                                                              0
                                                  5 0.0094077724756
## Adalyn
              18.9774337504
                              2.257681987248
                                                                         1
                                                                              0
                                                                         5
## Madison
              29.8288592111
                              3.216581572779
                                                  7 0.0321831762170
                                                                              1
              18.0531887943
                                                  6 0.0264292595805
                                                                         3
## Chloe
                              8.626204123721
                                                                              0
                                                                         5
## Harper
              18.6489127493 9.850096073933
                                                 10 0.1410369370086
                                                                              0
## Abigail
               8.2384307083 9.529256550595
                                                 10 0.0460556852114
                                                                         2
                                                                              0
## Aaliyah
              13.6041307153
                              0.332923405804
                                                  4 0.1143838922868
                                                                         4
                                                                              0
## Avery
              17.0627948130 -2.354035731405
                                                  2 0.2200271067013
                                                                         1
                                                                              0
## Evelyn
               6.0862449807 -1.414458742365
                                                  3 0.9202939646012
                                                                         2
                                                                              0
                                                                         3
## Kaylee
              16.4990128941
                             8.124920721166
                                                  8 0.0740213712884
                                                                              0
## Ella
              10.3102766911 -1.312565291300
                                                  7 0.2103748704317
                                                                         3
                                                                              0
                                                                         3
## Ellie
              14.0493368028
                              6.770187513903
                                                  6 0.0665895250431
                                                                              0
## Scarlett
             16.6990505630
                              0.039154277183
                                                  6 0.0060785560765
                                                                         3
                                                                              0
## Arianna
              12.1886451100 -9.728737720288
                                                  8 0.0061196078991
                                                                         2
                                                                              1
## Hailey
              17.6079640679 -2.004134599119
                                                  7 0.0514373065800
                                                                         2
                                                                              0
## Nora
              15.4907875525 -7.908802591264
                                                  4 0.1660171478066
                                                                         1
                                                                              0
              15.3981545913
## Addison
                              6.302860588767
                                                  2 0.2781647300829
                                                                         2
                                                                              0
## Brooklyn
              21.9605915199 -4.177221646532
                                                  6 0.0528851905320
                                                                         7
                                                                              0
## Hannah
               4.0427277219 -3.918234785087
                                                  2 0.0720552192587
                                                                         3
                                                                              0
## Mila
              19.0340054117
                             7.628355547786
                                                  4 0.2067624876803
                                                                         2
                                                                              0
                                                  6 0.0199597800618
                                                                         2
                                                                              0
## Leah
              25.2192335856
                              5.464610056952
                                                                         2
                                                                              0
## Elizabeth 20.1207638699
                              0.163831887767
                                                  7 0.0430961765983
## Sarah
          7.2350093642 -7.847764990292
                                                  8 0.0250318194222
                                                                         0
                                                                              0
```

```
## Eliana
              17.1539488716 -4.225652767345
                                                 4 0.0542586704509
                                                                       5
                                                                             1
## Mackenzie 26.6191491883 -1.164651857689
                                                                       4
                                                                             1
                                                 8 0.0427597975876
                                                                       2
## Peyton
              17.7257751404
                             2.691387189552
                                                 6 0.3157995285073
                                                                            0
## Maria
              20.4263094093
                             2.852347488515
                                                 6 0.1996985586888
                                                                       0
                                                                            1
## Grace
              10.1386324265 -3.852952290326
                                                 5 0.5598845332209
                                                                       4
                                                                             1
                                                                       5
## Adeline
              18.3736175005 -0.760810528882
                                                   0.0861538963139
                                                                             1
## Elena
                             0.826004995033
                                                                       1
              21.5271475790
                                                 6 0.0569612405573
                                                                             0
## Anna
              18.0329357352
                             3.672986626625
                                                   0.1011249145653
                                                                       1
                                                                            0
                                                                       3
## Victoria
             16.8957560672 -4.784092213959
                                                   0.0053005873103
                                                                             1
                                                                       2
## Camilla
              14.4630668445 -6.221029893495
                                                   0.1957675576531
                                                                             0
## Lillian
              7.3323418166 -6.464284337126
                                                11 0.0377370483802
                                                                       3
                                                                             1
## Natalie
              12.0097071958
                             5.799827864394
                                                 4 0.0025403125595
                                                                       3
                                                                            0
## Jackson
             16.7743459165 -1.563992514275
                                                 4 0.0336976001143
                                                                       6
                                                                             0
## Aiden
               7.9114210738 -8.219139031135
                                                 6 0.0781679976064
                                                                       1
                                                                             1
              9.0356868971 -6.682232180610
                                                                       4
## Lucas
                                                 8 0.0190018870100
                                                                            0
## Liam
              9.9052044557 -6.973871323280
                                                 4 0.0508371119231
                                                                       2
                                                                             0
## Noah
              30.3934039340
                             5.841336250305
                                                   0.0501520832897
                                                                       3
                                                                             1
                                                                       3
## Ethan
             29.6491031320
                             7.816690425389
                                                 5 0.1776602499921
                                                                            0
             17.7741358407
                             4.083695667796
                                                12 0.1274857251212
                                                                       3
                                                                            0
## Mason
             13.2109744050
                             3.461955948733
                                                 9 0.0025016970728
                                                                       4
                                                                            0
## Caden
                             3.458972177468
                                                                       4
                                                                             0
## Oliver
              8.6585657710
                                                 5 0.0226663815168
                                                                       2
## Elijah
             20.8940682065 -8.561988943256
                                                 4 0.1138987566115
                                                                             0
## Grayson
             15.3926436127
                             6.660069464706
                                                 7 0.1707437686115
                                                                       0
                                                                            0
  Jacob
              15.9419799822
                             3.607416460291
                                                   0.2968146024753
                                                                       3
##
                                                                             0
                                                                       2
## Michael
              21.0324688561
                             3.250835807994
                                                 4 0.0777024127463
                                                                            0
   Benjamin
             24.7336527710 -1.733850291930
                                                   0.1165293956957
                                                                       7
                                                                             1
  Carter
             20.9529828044 -5.881391819566
                                                11 0.1294196595359
                                                                       6
                                                                             0
                                                                       2
##
   James
               8.1754502408 -2.601587376557
                                                 3 0.0627735613638
                                                                             0
                                                                       3
##
   Jayden
             20.1167458640 -0.051560751162
                                                 3 0.0834983808666
                                                                             0
              19.6200395997 -7.763788672164
                                                 9 0.1582192171332
## Logan
                                                                       0
                                                                             0
  Alexander 22.8723534206
                             4.898372339085
                                                 4 0.1020269875573
                                                                       1
                                                                             0
               7.0363537875 -7.092755031772
                                                                       2
## Caleb
                                                 8 0.3986787274627
                                                                             0
## Ryan
              10.8077626236 -3.957749395631
                                                 5 0.0646797569676
                                                                       0
                                                                             1
                                                                       9
## Luke
              22.9336090938
                             8.879725565203
                                                 4 0.1612990086642
                                                                            0
              16.4475104801
## Daniel
                             4.236748460680
                                                   0.0179267019288
                                                                       0
                                                                             1
##
                                                                       2
  Jack
             12.4193912178 -2.978362310678
                                                 7 0.0334979790424
                                                                             0
## William
              21.7597536904
                             8.518663188443
                                                   0.0057624380122
                                                                       3
                                                                            1
              12.7441840106 -5.865928838030
                                                   0.0416244914652
                                                                       4
                                                                             0
## Owen
## Gabriel
             12.6902912892
                             6.000011260621
                                                   0.0667182567736
                                                                       1
                                                                            0
                                                                       2
##
  Matthew
              22.7064883483 -0.784321972169
                                                   0.0969088271007
                                                                             0
## Connor
             16.5579158202
                             7.310636928305
                                                10 0.0275189429004
                                                                       2
                                                                            0
   Jayce
               9.3437497119
                             2.835752279498
                                                 2 0.1036041280962
                                                                       2
                                                                             1
##
  Isaac
             14.4475985107 -1.807989492081
                                                 6 0.0409382751418
                                                                       3
                                                                             0
                                                                       2
   Sebastian 26.0028823200
                             8.720412328839
                                                   0.0526693580776
                                                                            0
                                                                       5
              19.7633459146 -1.778851281852
                                                 5 0.0185522190813
                                                                             0
  Henry
## Muhammad
             17.4753564759
                             7.431445899419
                                                 6 0.2173893822057
                                                                       1
                                                                            1
## Cameron
             17.2356717234 -7.115557421930
                                                 8 0.0594253901185
                                                                       2
                                                                            0
                                                                       4
                                                                            0
## Wyatt
             21.0591997759
                             2.385433777235
                                                 6 0.0233073925806
## Dylan
              16.3648325832
                             7.441194783896
                                                11 0.0623564463005
                                                                       1
                                                                            0
## Nathan
             16.3347652063 4.280693884939
                                                 7 0.0566640083885
                                                                       2
                                                                            0
```

```
## Nicholas
             19.2804049042
                             0.075596682727
                                                8 0.2518919726967
                                                                      2
                                                                           1
             21.9098811596
## Julian
                                                                      3
                                                                            0
                             2.004571580328
                                                5 0.3116668390356
                                                                      2
## Eli
              2.4305753450 -2.015974260867
                                                4 0.0434806525397
                                                                            0
                                                7 0.1240640444013
                                                                      4
                                                                           1
## Levi
             10.8306731256
                             7.521508047357
                             3.911067624576
## Isaiah
             10.5398127717
                                                6 0.0405466910969
                                                                      1
                                                                            1
                                                9 0.1876239406059
## Landon
             18.1636568093
                             2.733903387561
                                                                      1
                                                                           0
## David
             16.9697711456
                             2.588588474318
                                                7 0.0656975601903
                                                                           0
                                                                      2
## Christian 16.7587209624
                             0.817433088087
                                                9 0.0850282351750
                                                                           1
## Andrew
                                                                      3
             22.0496103202 -4.646312841214
                                               11 0.0449011596955
                                                                            0
                                                                      2
## Brayden
             18.1741344776
                             7.441352303140
                                                5 0.0875738516110
                                                                           1
## John
             28.1813685320
                             5.178652005270
                                                4 0.1533884150447
                                                                      3
                                                                           0
## Lincoln
             12.4275615480 -2.145625231788
                                                2 0.2907056238437
                                                                      1
                                                                            0
#TO-DO
```

• 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.

```
df = data.frame(X)
df$X6= factor(df$X6,levels=c(0,1),labels=c("DOMESTIC","FOREIGN"))
df
##
                        X1
                                        X2 X3
                                                            X4 X5
                                                                        X6
## Sophia
                                             9 0.1587412576615
             24.8188165537
                            9.125269912183
                                                                2 DOMESTIC
             20.4783669392
                            9.071766566485
                                              0.0602435882514
                                                                   FOREIGN
## Emma
## Olivia
             10.3955264915
                            2.044677576050
                                             8 0.0032740980079
                                                                2 DOMESTIC
## Ava
             17.0358899194 -9.387335558422 12 0.0870577835742
                                                                3 DOMESTIC
## Mia
             18.4665636575
                            7.249305052683
                                             8 0.1052566152019
                                                                3 DOMESTIC
## Isabella
             26.0294001579
                            7.102146213874
                                             8 0.2192423294367
                                                                1 DOMESTIC
## Riley
             19.0145055935 -5.004552206956
                                             7 0.0255512944423
                                                                1 DOMESTIC
## Aria
             18.9829945699 -5.670656017028
                                             3 0.0445471205749
                                                                0 DOMESTIC
## Zoe
             13.3179331057
                            9.207044662908
                                             4 0.0492995754402
                                                                4 DOMESTIC
## Charlotte 21.2586733803 -6.720953411423 10 0.0893347485971
                                                                2 DOMESTIC
## Lily
                                             3 0.0438075131840
                                                                2 DOMESTIC
             17.3233172665
                            0.582132521085
## Layla
              5.3769232856 -3.938631322235
                                             9 0.0797862479830
                                                                   FOREIGN
## Amelia
             17.8422487543
                            0.549068548717
                                             6 0.1560836368044
                                                                3 DOMESTIC
## Emily
             22.5090258305 -9.544669818133
                                             9 0.1932706553396
                                                                1 DOMESTIC
                            9.147345959209
## Madelyn
                                             9 0.2159838074104
             15.8065435665
                                                                6 DOMESTIC
## Aubrey
             20.8890191842
                            5.368922925554
                                             7 0.1491265917771
                                                                4 DOMESTIC
## Adalyn
             18.9774337504
                            2.257681987248
                                             5 0.0094077724756
                                                                1 DOMESTIC
## Madison
                                             7 0.0321831762170
             29.8288592111
                            3.216581572779
                                                                   FOREIGN
## Chloe
             18.0531887943
                            8.626204123721
                                             6 0.0264292595805
                                                                3 DOMESTIC
## Harper
                            9.850096073933 10 0.1410369370086
                                                                5 DOMESTIC
             18.6489127493
## Abigail
              8.2384307083
                            9.529256550595 10 0.0460556852114
                                                                2 DOMESTIC
## Aaliyah
                            0.332923405804
                                             4 0.1143838922868
                                                                4 DOMESTIC
             13.6041307153
## Avery
             17.0627948130 -2.354035731405
                                             2 0.2200271067013
                                                                1 DOMESTIC
## Evelyn
                                             3 0.9202939646012
                                                                2 DOMESTIC
              6.0862449807 -1.414458742365
## Kaylee
             16.4990128941
                            8.124920721166
                                             8 0.0740213712884
                                                                3 DOMESTIC
## Ella
             10.3102766911 -1.312565291300
                                             7 0.2103748704317
                                                                3 DOMESTIC
                           6.770187513903
## Ellie
             14.0493368028
                                             6 0.0665895250431
                                                                3 DOMESTIC
```

```
## Scarlett
             16.6990505630
                             0.039154277183
                                              6 0.0060785560765
                                                                  3 DOMESTIC
## Arianna
                                                                  2
             12.1886451100 -9.728737720288
                                              8 0.0061196078991
                                                                     FOREIGN
## Hailey
             17.6079640679 -2.004134599119
                                              7 0.0514373065800
                                                                  2 DOMESTIC
             15.4907875525 -7.908802591264
## Nora
                                              4 0.1660171478066
                                                                  1 DOMESTIC
## Addison
             15.3981545913
                             6.302860588767
                                              2 0.2781647300829
                                                                  2 DOMESTIC
## Brooklyn
             21.9605915199 -4.177221646532
                                              6 0.0528851905320
                                                                  7 DOMESTIC
## Hannah
              4.0427277219 -3.918234785087
                                              2 0.0720552192587
                                                                   DOMESTIC
## Mila
             19.0340054117
                             7.628355547786
                                                0.2067624876803
                                                                   DOMESTIC
## Leah
             25.2192335856
                             5.464610056952
                                              6 0.0199597800618
                                                                  2 DOMESTIC
## Elizabeth 20.1207638699
                             0.163831887767
                                                0.0430961765983
                                                                  2 DOMESTIC
                                              8 0.0250318194222
## Sarah
              7.2350093642 -7.847764990292
                                                                  0
                                                                   DOMESTIC
## Eliana
             17.1539488716
                            -4.225652767345
                                              4 0.0542586704509
                                                                     FOREIGN
  Mackenzie 26.6191491883 -1.164651857689
                                              8 0.0427597975876
                                                                  4
                                                                     FOREIGN
## Peyton
             17.7257751404
                             2.691387189552
                                              6 0.3157995285073
                                                                  2 DOMESTIC
## Maria
             20.4263094093
                             2.852347488515
                                              6 0.1996985586888
                                                                  a
                                                                     FOREIGN
## Grace
             10.1386324265 -3.852952290326
                                               0.5598845332209
                                                                     FOREIGN
## Adeline
             18.3736175005
                            -0.760810528882
                                               0.0861538963139
                                                                     FOREIGN
## Elena
             21.5271475790
                             0.826004995033
                                                                  1 DOMESTIC
                                              6 0.0569612405573
## Anna
             18.0329357352
                             3.672986626625
                                              4 0.1011249145653
                                                                  1
                                                                   DOMESTIC
             16.8957560672 -4.784092213959
                                               0.0053005873103
                                                                  3
                                                                     FOREIGN
## Victoria
             14.4630668445 -6.221029893495
                                               0.1957675576531
                                                                  2 DOMESTIC
## Camilla
## Lillian
              7.3323418166 -6.464284337126 11 0.0377370483802
                                                                  3
                                                                     FOREIGN
## Natalie
                             5.799827864394
             12.0097071958
                                              4 0.0025403125595
                                                                  3 DOMESTIC
##
  Jackson
             16.7743459165 -1.563992514275
                                              4 0.0336976001143
                                                                   DOMESTIC
## Aiden
              7.9114210738 -8.219139031135
                                              6 0.0781679976064
                                                                  1
                                                                     FOREIGN
## Lucas
              9.0356868971
                            -6.682232180610
                                              8 0.0190018870100
                                                                  4 DOMESTIC
                                                                  2 DOMESTIC
## Liam
              9.9052044557 -6.973871323280
                                              4 0.0508371119231
## Noah
             30.3934039340
                             5.841336250305
                                              6
                                               0.0501520832897
                                                                  3
                                                                     FOREIGN
                                                                  3 DOMESTIC
## Ethan
             29.6491031320
                             7.816690425389
                                              5
                                               0.1776602499921
## Mason
             17.7741358407
                             4.083695667796 12 0.1274857251212
                                                                  3 DOMESTIC
## Caden
             13.2109744050
                             3.461955948733
                                                0.0025016970728
                                                                  4 DOMESTIC
                                                                  4 DOMESTIC
## Oliver
                             3.458972177468
                                              5 0.0226663815168
              8.6585657710
## Elijah
             20.8940682065 -8.561988943256
                                              4 0.1138987566115
                                                                  2 DOMESTIC
## Grayson
             15.3926436127
                             6.660069464706
                                              7 0.1707437686115
                                                                   DOMESTIC
##
  Jacob
             15.9419799822
                             3.607416460291
                                                0.2968146024753
                                                                   DOMESTIC
## Michael
             21.0324688561
                             3.250835807994
                                              4 0.0777024127463
                                                                  2 DOMESTIC
                                                                  7
##
  Benjamin
             24.7336527710 -1.733850291930
                                              7 0.1165293956957
                                                                     FOREIGN
## Carter
             20.9529828044 -5.881391819566 11 0.1294196595359
                                                                  6 DOMESTIC
##
  James
              8.1754502408 -2.601587376557
                                              3 0.0627735613638
                                                                  2 DOMESTIC
  Jayden
             20.1167458640 -0.051560751162
                                              3 0.0834983808666
                                                                   DOMESTIC
##
## Logan
             19.6200395997 -7.763788672164
                                              9 0.1582192171332
                                                                   DOMESTIC
## Alexander 22.8723534206
                             4.898372339085
                                              4 0.1020269875573
                                                                  1 DOMESTIC
## Caleb
              7.0363537875 -7.092755031772
                                              8 0.3986787274627
                                                                  2 DOMESTIC
## Ryan
             10.8077626236
                           -3.957749395631
                                               0.0646797569676
                                                                     FOREIGN
                             8.879725565203
                                                                  9
## Luke
             22.9336090938
                                              4 0.1612990086642
                                                                    DOMESTIC
## Daniel
             16.4475104801
                             4.236748460680
                                              9 0.0179267019288
                                                                  0
                                                                     FOREIGN
## Jack
             12.4193912178 -2.978362310678
                                              7 0.0334979790424
                                                                  2 DOMESTIC
## William
             21.7597536904
                             8.518663188443
                                              5 0.0057624380122
                                                                  3
                                                                     FOREIGN
## Owen
             12.7441840106
                           -5.865928838030
                                              7 0.0416244914652
                                                                   DOMESTIC
                                                                  1 DOMESTIC
## Gabriel
             12.6902912892
                            6.000011260621
                                              1 0.0667182567736
```

```
## Matthew
             22.7064883483 -0.784321972169 4 0.0969088271007
                                                                 2 DOMESTIC
                                                                2 DOMESTIC
## Connor
             16.5579158202
                            7.310636928305 10 0.0275189429004
## Jayce
              9.3437497119
                            2.835752279498
                                             2 0.1036041280962
                                                                2
                                                                   FOREIGN
## Isaac
             14.4475985107 -1.807989492081
                                             6 0.0409382751418
                                                                3 DOMESTIC
                                                                2 DOMESTIC
## Sebastian 26.0028823200
                            8.720412328839
                                             6 0.0526693580776
## Henry
             19.7633459146 -1.778851281852
                                             5 0.0185522190813
                                                                 5 DOMESTIC
## Muhammad
             17.4753564759
                            7.431445899419
                                             6 0.2173893822057
                                                                1
                                                                    FOREIGN
## Cameron
             17.2356717234 -7.115557421930
                                             8 0.0594253901185
                                                                 2 DOMESTIC
## Wyatt
             21.0591997759
                            2.385433777235
                                             6 0.0233073925806
                                                                4 DOMESTIC
## Dylan
             16.3648325832
                            7.441194783896 11 0.0623564463005
                                                                 1 DOMESTIC
## Nathan
             16.3347652063
                            4.280693884939
                                             7 0.0566640083885
                                                                 2 DOMESTIC
## Nicholas
             19.2804049042
                            0.075596682727
                                             8 0.2518919726967
                                                                   FOREIGN
## Julian
             21.9098811596
                            2.004571580328
                                             5 0.3116668390356
                                                                3 DOMESTIC
## Eli
              2.4305753450 -2.015974260867
                                             4 0.0434806525397
                                                                2 DOMESTIC
             10.8306731256
                            7.521508047357
                                             7 0.1240640444013
                                                                4
                                                                    FOREIGN
## Levi
## Isaiah
             10.5398127717
                            3.911067624576
                                             6 0.0405466910969
                                                                1
                                                                   FOREIGN
## Landon
             18.1636568093
                            2.733903387561
                                             9 0.1876239406059
                                                                1 DOMESTIC
## David
                                                                 4 DOMESTIC
             16.9697711456
                            2.588588474318
                                             7 0.0656975601903
## Christian 16.7587209624
                            0.817433088087
                                             9 0.0850282351750
                                                                2
                                                                   FOREIGN
## Andrew
             22.0496103202 -4.646312841214 11 0.0449011596955
                                                                 3 DOMESTIC
## Brayden
             18.1741344776
                            7.441352303140
                                             5 0.0875738516110
                                                                2 FOREIGN
## John
             28.1813685320
                            5.178652005270
                                             4 0.1533884150447
                                                                 3 DOMESTIC
## Lincoln
             12.4275615480 -2.145625231788
                                             2 0.2907056238437
                                                                1 DOMESTIC
```

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

```
table(df$X6)
##
## DOMESTIC FOREIGN
## 76 24
table(df$X6)/k
##
## DOMESTIC FOREIGN
## 0.76 0.24
```

Print out a summary of the whole dataframe.

```
summary(df)
##
                                 X2
                                                         X3
          X1
##
            : 2.4305753
                                  :-9.72873772
                                                          : 1.00
    Min.
                          Min.
                                                  Min.
    1st Qu.:12.7307108
                          1st Qu.:-3.92333392
                                                  1st Qu.: 4.00
##
    Median :17.1948103
                                                  Median: 6.00
##
                          Median: 0.82171904
##
    Mean
            :16.8149175
                          Mean
                                  : 0.88360575
                                                  Mean
                                                          : 6.28
    3rd Qu.:20.5810300
##
                          3rd Qu.: 5.81020496
                                                  3rd Qu.: 8.00
            :30.3934039
                                  : 9.85009607
                                                          :12.00
##
    Max.
                          Max.
                                                  Max.
##
          X4
                                   X5
                                                    X6
                                             DOMESTIC:76
##
    Min.
          :0.0025016971
                            Min.
                                    :0.00
```

```
##
    1st Ou.:0.0424759711
                           1st Ou.:2.00
                                           FOREIGN:24
##
   Median :0.0730382953
                           Median :2.00
                                   :2.63
##
   Mean
           :0.1123689329
                           Mean
##
    3rd Qu.:0.1566175319
                           3rd Qu.:3.00
##
   Max.
           :0.9202939646
                           Max. :9.00
```

• 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*0,25))),nrow=n,ncol=
n)
R
##
           [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
##
     [1,]
                      0
                                   0
                                                      0
                                                             0
                                                                   0
                     0
                                                                   0
                                                                           0
                                                                                          0
                                                                                                  0
##
     [2,]
               0
                            0
                                   0
                                         0
                                                0
                                                      0
                                                             0
                                                                                   0
##
     [3,]
               0
                      0
                            0
                                   0
                                         0
                                                0
                                                      0
                                                             0
                                                                   1
                                                                           0
                                                                                   0
                                                                                          0
                                                                                                  0
                                                                                                  2
##
     [4,]
               0
                      0
                            0
                                   0
                                         0
                                                0
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## [36,] ## [37,] ## [38,] ## [40,] ## [41,] ## [42,] ## [43,] ## [44,] ## [45,] ## [46,] ## [47,] ## [48,] ## [49,]	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 1 0	0 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6		0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 2 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0	00000000000000	0000000000000	0 0 0 0 0 0 0 0 0 0 0
## [50,]	0	0	0	0 0	9 0	0	2	0	0	0	0	0
## [,25]	[,14]	[,15]	[,16]	[,17]	[,18]	[,19]	[,20]	[,21]	[,22]	[,23]	[,24]	
## [1,]	0	1	0	0	0	0	0	0	0	0	0	
<b>##</b> [2,]	0	0	0	0	0	0	0	0	0	0	2	
0 ## [3,]	0	0	0	0	0	0	0	0	0	0	0	
0 ## [4,]	0	0	0	0	0	0	0	0	0	0	0	
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## [5,] 0	0	0	0	0	0	0	0	0	2	0	0	
## [6,]	0	0	0	0	0	0	0	0	0	0	0	
<b>##</b> [7,]	0	0	0	0	0	0	1	0	0	0	0	
0 ## [8,]	1	0	0	0	0	0	0	0	0	0	0	
0 ## [9,]	0	0	0	0	0	0	0	0	0	0	0	
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## [11,] 0	0	0	0	0	0	0	0	0	0	0	0	
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0 ## [15,]	0	0	0	0	0	0	0	0	0	0	0	
0 ## [16,]	0	0	0	0	0	0	0	0	0	0	0	
0 ## [17,]	0	0	0	0	0	0	0	0	0	0	0	

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_	[18,]	0	0	0	0	0	0	0	1	0	0	0
0 ## [ 0	[19,]	0	0	0	0	2	1	0	0	0	0	0
	[20,]	0	0	0	0	2	0	0	0	0	0	0
	[21,]	0	0	0	0	0	0	0	0	0	0	0
	[22,]	0	0	1	0	0	0	0	0	0	0	1
0	[23,]	0	0	0	0	0	0	0	0	0	0	0
0	[24,]	0	0	0	0	0	0	0	0	0	0	0
0	[25,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[26,]	0	1	2	0	0	0	0	0	0	0	0
## [ 0	[27,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[28,]	0	0	0	0	0	0	0	0	1	0	0
## [ 0	[29,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[30,]	0	2	0	0	0	0	0	0	0	0	1
## [ 0	[31,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[32,]	0	0	0	0	0	0	0	0	0	2	0
0	[33,]	0	0	0	0	0	0	0	0	0	2	0
## [ 0	[34,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[35,]	0	0	0	0	0	0	0	0	1	0	0
## [ 0	[36,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[37,]	0	0	0	0	0	0	0	0	0	0	0
0	[38,]	0	0	0	0	1	0	0	0	0	0	0
2	[39,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[40,]	0	0	0	0	0	0	0	0	0	0	0
## [ 0	[41,]	0	0	0	0	0	0	0	0	2	0	0
## [	[42,]	0	0	0	0	0	0	0	0	0	0	1

0 ## [43	,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [44	,]	0	0	0	0	0	0	0	1	0	0	0
0 ## [45		0	0	0	0	0	0	0	0	0	0	0
0 ## [46	_	0	0	0	0	0	0	0	0	0	0	0
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## [47 0	_											
## [48 0	_	0	0	0	2	0	0	0	0	0	0	0
## [49 0	,]	0	0	0	0	1	0	2	0	0	0	0
## [50 0	,]	0	0	0	0	0	0	0	0	0	0	0
## [,37]	[.	,26]	[,27]	[,28]	[,29]	[,30]	[,31]	[,32]	[,33]	[,34]	[,35]	[,36]
## [1 0	,]	0	0	0	0	0	0	0	0	0	0	0
## [2	,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [3	,]	0	0	0	0	0	0	0	0	0	1	0
0 ## [4	,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [5	,]	0	0	0	1	0	0	0	0	0	0	0
0 ## [6	,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [7	_	0	0	0	0	0	0	0	0	0	0	0
0 ## [8		0	0	0	0	0	0	0	0	0	0	0
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## [9 0		0	0	0	0	2	0	0	0	0	0	0
## [10 0		0	0	0	2	0	0	0	0	0	0	0
## [11 0	,]	0	0	0	0	0	0	0	0	0	0	0
## [12 0	,]	0	0	0	0	0	0	0	0	0	0	0
## [13 0	,]	0	0	0	0	0	0	2	0	0	0	0
## [14 0	,]	0	0	0	0	0	0	0	0	0	0	0
## [15	,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [16	,]	0	0	0	0	0	0	0	0	0	0	0

-	[17,]	0	0	0	0	0	0	0	0	0	0	0
0 ##   0	[18,]	0	0	0	0	0	0	0	0	0	0	0
	[19,]	0	0	0	0	0	0	0	0	0	0	0
	[20,]	0	0	0	0	0	0	0	0	0	0	0
	[21,]	0	0	0	0	0	1	0	0	0	2	0
	[22,]	0	0	0	0	0	0	0	0	0	0	0
	[23,]	0	0	0	0	0	0	0	0	0	0	0
	[24,]	0	0	0	0	0	2	0	0	0	0	0
	[25,]	0	0	0	0	0	0	0	0	0	0	0
	[26,]	0	0	0	0	0	0	0	0	0	0	0
##   0	[27,]	0	0	0	2	0	0	0	0	0	0	0
##   0	[28,]	0	0	0	0	0	0	0	1	0	0	0
##   0	[29,]	0	0	0	0	0	0	0	0	0	0	0
##   0	[30,]	0	0	0	2	0	0	0	0	0	0	0
0	[31,]	0	0	0	0	0	0	0	0	0	0	0
0	[32,]	0	0	0	0	0	0	0	0	0	0	0
0	[33,]	0	0	0	0	0	0	0	0	0	0	0
0	[34,]	0	0	0	0	0	0	0	0	0	2	0
0	[35,]	0	0	0	0	0	0	1	0	0	0	0
0	[36,]	0	0	0	0	0	0	0	0	0	0	0
0	[37,]	0	0	0	0	0	0	0	0	0	0	0
0	[38,]	0	0	0	0	0	0	0	0	0	2	0
0	[39,]	0	0	0	0	0	0	0	0	0	0	0
0	[40,]	0	0	0	0	0	0	0	0	0	0	0
##	[41,]	0	0	0	1	0	0	0	0	0	0	0

0 ##	[42,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[43,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[44,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[45,]	1	0	0	0	0	0	0	0	0	0	0
	[46,]	0	0	0	0	0	0	0	0	0	0	0
	[47,]	0	0	0	0	0	0	0	0	0	0	0
	[48,]	0	0	0	1	0	0	0	0	0	0	0
	[49,]	0	0	0	0	0	0	0	0	2	0	0
	[50,]	0	0	0	0	0	0	0	0	2	0	0
0 ##		[,38]	[,39]	[,40]	[,41]	[,42]	[,43]	[,44]	[,45]	[,46]	[,47]	[,48]
[,4 ##	.9] [1,]	0	0	0	1	0	0	0	0	0	0	0
0 ##	[2,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[3,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[4,]	0	2	0	0	0	0	0	0	0	0	0
0 ##	[5,]	0	0	0	0	0	0	0	0	0	0	2
0 ## 0	[6,]	0	0	0	0	0	0	0	0	0	0	0
## 0	[7,]	0	0	0	0	0	0	0	0	1	0	0
## 0	[8,]	0	0	1	0	0	0	0	0	0	0	0
## 0	[9,]	0	0	0	0	0	0	0	0	0	0	0
	[10,]	0	0	0	0	0	0	0	0	0	0	0
	[11,]	0	0	0	0	0	0	0	0	0	0	0
	[12,]	0	0	0	0	0	0	0	0	0	0	0
	[13,]	0	0	0	0	0	0	0	0	0	0	0
	[14,]	0	0	0	0	0	0	0	0	0	0	0
	[15,]	0	0	0	0	0	0	0	0	0	0	0

_	6,]	0	0	0	0	0	0	0	0	0	0	0
	7,]	0	0	0	0	0	0	0	0	0	0	0
	8,]	0	0	0	0	0	0	0	0	0	1	0
0 ## [19	9,]	0	0	0	0	0	0	2	1	0	0	0
0 ## [20	0,]	1	0	0	0	0	0	2	0	0	0	0
0 ## [2: 0	1,]	0	0	0	0	0	0	0	0	0	0	0
	2,]	0	0	0	0	1	0	0	0	0	0	0
## [2] 0	3,]	0	0	0	0	0	0	0	0	0	0	0
	4,]	0	0	0	0	0	0	0	0	0	0	0
	5,]	0	0	0	0	0	0	0	0	0	0	0
	6,]	0	0	0	1	2	0	0	0	0	0	0
## [2 <sup>1</sup> ]	7,]	0	0	0	0	0	0	0	0	0	0	0
## [28 0	8,]	0	0	0	0	0	0	0	0	0	0	1
## [2 <sup>9</sup>	9,]	0	0	0	0	0	0	0	0	0	0	0
## [30 0	_	0	0	0	2	0	0	0	0	0	0	0
0	1,]	0	0	0	0	0	0	0	0	0	0	0
## [3] 2		0	0	0	0	0	0	0	0	0	0	0
## [3]		0	0	0	0	0	0	0	0	0	0	0
## [34 0		0	0	0	0	0	0	0	0	0	0	0
## [3] 0		0	0	0	0	0	0	0	0	0	0	1
## [30 0		0	0	0	0	0	0	0	0	0	0	0
## [3] 0 ## [3]		0	0	0	0	0	0	0	0	0	0	0
## [3: 0 ## [3:		0	0	0	0	0	0	0	0	0	0	0
## [3] 0 ## [4]		0	0	0	0	0	0	0	0	0	0	0
11 1 L-4	~, <u>]</u>	5	J	5	J	J	J	5	J	J	5	J

0 ## [41,]	0	0	0	0	0	0	0	0	0	0	2
## [41,] 0	V	V	v	V	v	v	v	v	V	V	2
## [42,]	0	0	0	0	0	0	0	0	0	0	0
0 ## [43,]	0	0	0	0	0	0	0	0	0	0	0
0											
## [44,] 0	0	0	0	0	0	0	0	0	0	1	0
## [45,]	0	2	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
## [46,] 0	0	0	0	0	0	0	0	0	0	0	0
## [47,]	0	0	0	0	0	0	0	0	0	0	0
1 ## [48,]	0	0	0	0	0	2	0	0	0	0	0
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## [49,] 0	0	0	0	0	0	0	1	0	2	0	0
## [50,]	0	0	0	0	0	0	0	0	0	0	0
0 ##	[,50]										
## [1,]	0										
## [2,]	2										
## [3,]	0										
## [4,]	0										
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## [10,]	0										
## [11,]	0										
<b>##</b> [12,]	0										
## [13,]	0										
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## [17,]	0										
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## [22,]	1										
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## [24,]	0										
## [25,]	0										
## [26,]	0										
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## [28,]	V										

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## [29,]
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## [30,]
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## [40,]
## [41,]
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## [42,]
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## [43,]
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## [44,]
## [45,]
               0
## [46,]
## [47,]
              0
## [48,]
               0
## [49,]
               0
## [50,]
              0
```

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

```
n = 100
R = matrix(rnorm(n^2), nrow = n, ncol = n)
for (i in 1 : n){
  for (j in 1 : n){
    if (runif(1) < 0.3){
      R[i,j] = NA
  }
}
R
##
                      [,1]
                                      [,2]
                                                       [,3]
                                                                        [,4]
##
          1.0835926630003 1.314004253229 -0.575114433555 0.0903335498291
     [1,]
##
     [2,] -2.4962696937714 -0.984084423426 -0.632150651064 -0.7146394144521
##
     [3,]
          1.2002367224902
                                        NA -0.653894576970 -0.6416596271874
     [4,] -1.5447166717594 0.613363631609 0.358025423055 0.6007975842126
##
##
     [5,] -0.3363618741184 -0.170933779359 -0.393339340391
                                                            0.1261440055630
##
     [6,]
          1.4615727826931
                           0.520174277380
                                                        NA 0.0645284754135
##
                                        NA 0.080234517006 -0.7662738396198
     [7,]
                        NA
##
     [8,] -0.1543425003881 -0.428272651317 -0.240190629995 0.4526649766466
##
     [9,] -0.7545065657307 -1.419892412247
                                                         NA
                                                                          NA
##
                        NA
                                        NA 0.245339632768 -1.4917334797483
    [10,]
    [11,] -0.2938184979744 -0.162700802188 2.453013524134 1.7405511437202
##
   [12,] 1.4901999514499 -2.164251862141 -0.643657024572 -1.6251062005731
```

```
[13,] 0.1243450404831 -1.296394429723 -0.027542133566
                                                                       NA
   [14,] -0.4142795484569
                                      NA 0.616399044793 0.0020547402141
    [15,] -0.7249516054401 -1.231807885528 0.253558679920 0.2245746808783
##
    [16,] -0.1011434294252 -0.437247022298  0.609000391516  2.3380705439855
##
    [17,]
                       NA
                                      NA 1.433829819154
                                                                      NA
   [18,]
         0.6263818133794
                          1.528299754139 -0.784631692310 0.9717858325529
##
         0.0512620221207 -0.015918805288 -0.682999975693 -1.5194973943860
   [19,]
##
    [20,]
                       NA
                                      NA -0.715994262086 -0.7348964440136
          0.6780591314351
                                         1.319424636344
   [21,]
                                                         0.4593820870744
##
                       NA -1.769110593108 -1.163212290283 -0.9765744737120
    [22,]
    [23,] -0.0426529294205 -1.011564804017
                                          1.723919276320 -2.0626309362233
##
    [24,] 0.6611793515421
                                      NA
                                                      NA
                                                                      NA
                                                      NA
                                                                      NA
    [25,] -0.4322692920496
   [26,] -0.9438794177343 -0.372888668944
                                          0.118211344716
                                                         1.0943087923103
         ##
    [27,]
         0.9931239775192
                                      NA -0.750594591903 0.0994355820550
   [28,]
##
    [29,]
         0.0830458353420
                                                         1.2277324218809
   [30,] -0.6383886653303  0.106150740225 -0.985504706206
                                                         1.1763571673982
    [31,] -0.3361619713725
                         0.282293634627
                                          0.559185990535
                                                          1.4182048041800
         1.2866035262435 -2.048391630622
                                                      NA -0.2872799487379
##
   [32,]
         1.1913665358635
                                      NA -0.098658888683
                                                         0.2481572805275
##
   [33,]
##
                      NA
                                      NA -0.096470653981 -0.8851766260556
   [34,]
                       NA
##
   [35,]
                                      NA
                                                      NA
                                                                      NA
##
                       NA -0.652186136741 -0.554134576657
                                                                       NA
    [36,]
   [37,] -1.3374821363842
                                         1.014359390620
                                                         1.5648468731772
    [38,]
         0.8781133247048
                                      NA
                                          0.925851184020
                                                          0.5850340231345
                                         0.579646551337
   [39,]
                           0.282341020133 -0.013086345597
##
   [40,]
          1.6484117431721
                                                                       NA
                           0.983265460444
                                                      NA -1.3124958812488
##
    [41,]
                       NA
##
   [42,] -0.2024106935939
                          0.549345732504
                                                      NA -2.1530918556740
##
    [43,]
         0.3205643769663 -1.366548010141 -0.329300345305
                                                                       NA
                       ##
   [44,]
##
    [45,] 1.1027529230767
                                      NA -0.186238840510 -0.1183274772490
    [46,] 1.9713836798394
                                      NA -1.706358244027
##
    [47,]
         0.9299615861334
                          0.646468215887 -0.356188844295
                                                         0.4585348253036
    [48,] -1.9185708759409
                                      NA
                                                      NA 0.1748343716236
                           0.540331480219 -1.349568529076 -0.5216265913928
##
   [49,]
                       NA
##
   [50,] -0.3927485331598
                                      NA -0.592916075516 -1.2605485344288
##
                       NA -1.803060082265 -0.879277945744 -0.9838707019013
   [51,]
                                          2.275639562960 -0.6218438280020
##
    [52,]
                       NA
                          1.603377386704
##
                          0.837737869248 -0.497151914378
   [53,]
##
                       NA
                           0.035526013545
                                                      NA
                                                          0.8898269751809
    [54,]
   [55,] 0.0211360524192
                           0.674149350806
                                                          0.8189743854791
##
    [56,] -1.2119891400447
                                      NA
                                                      NA
                                                                       NA
                       NA -2.309480080273
                                          1.288854775426 -1.3864263035856
##
   [57,]
         0.2824680794507
##
   [58,]
                                      NA
                                                      NA
                                                          0.7089975591870
##
    [59,]
                       NA -0.098258054474
                                                      NA
                                                                       NΔ
##
         1.4528873705055 0.366327488717
                                                      NA 0.6011196731667
   [60,]
##
    [61,]
         1.1978146655416 -0.334282600760 -0.098623083129 1.2056156139656
   [62,] 0.4337053949532 -1.465655380691 0.345154015182 1.7764714942142
```

```
[63,] -0.2147106815798 -0.893946026385 0.670219285022 0.6213907015685
                     NA 0.918387088005
                                                  NA
##
   [64,]
   [65,] -0.5172287920297 2.685570236402 0.039388449558 -0.4278300555666
##
   [66,] NA -2.045085809815 -2.275733526888
                        NA 1.028626123871
   [67,] -0.7378150123842
                                                                 NA
   [68,] -0.9572763135799 0.371804153958
##
                                                  NA -0.2650059403585
             NA -0.941802326851 2.229019552384 -0.3361399998328
   [69,]
                                                  NA 0.5508792174829
##
   [70,]
                    NA
                                   NA
   [71,] -1.6280955312273
                                   NA -1.620755651694 0.9340579918886
##
             NA -0.326624985432 -0.324275972016 -0.5164385122766
   [72,]
   [73,] 0.5871787122591
##
                                                  NA -1.8506871667113
                                   NA
##
   [74,] 0.5630896912249
                                                  NA 2.5168093763557
   [75,] 0.4748596588300 0.939384100936
##
                                      1.364440781115
                                                                 NA
##
            NA 1.178594293438 -0.525083961512
                                                                 NA
   [76,]
##
   [77,] 0.0843693471663 -0.011746560985
                                                  NA -0.9845110713071
   [78,] 0.3247910180274
                                   NA -0.730131415174 -0.1707248812674
##
   [79,]
                                                  NA 0.5654001925468
##
                     NA 0.864391421584 2.990829005613
                                                      0.2641195871643
   [80,]
##
   [81,]
                    NA -0.755550218837
                                                  NA
   [82,] 0.2094826726098 NA -0.680889395170 -0.1815224114296
##
  [83,] 1.4454844105028 -0.353248527725 -0.623074325166 -0.9102129449082
                        NA -0.706537484490 2.3839642379569
##
   [84,] -0.0367619844562
   [85,] 0.0967079078226 -0.983192731211 -2.168966320796 -0.7628143545837
              NA 1.385352735571 0.622230486624
##
   [86,]
                    NA -1.290908487129 -1.244594249540 -0.7528373518956
##
  [87,]
   [88,] -0.3060299371511 NA 0.314635652118
  [89,] -0.5399771132941 0.403224603867 NA -0.4553527318424
  [90,] -0.1381158205008 2.127391664069 0.384726533129 1.0915166950165
   [91,] 0.6306378638390 -0.230715597879 -0.580422174701 1.3826059937640
##
           NA -0.351872358047 -0.591489246038 -1.0894622777878
NA 0.136463164238 -1.106693714407 NA
##
  [92,]
                    NA 0.136463164238 -1.106693714407
##
   [93,]
   [94,] -0.3086529005993
                        NA
                                                 NA -1.2220220327457
                    NA -1.040357307551 1.260875482213 -0.1180250179796
   [95,]
   [96,] -0.2806237725337 -0.506550295958 NA -0.4495315299133
                         NA 0.150455203363
NA 0.418342767135
##
   [97,]
         NA
                                                                 NA
   [98,] -0.7999288975141
  [99,] 0.6575475231802 0.723698188585 0.507239608472 0.1717329825639
##
  [100,] -1.2124781509995 -0.261923631015 0.476651374665 0.0399174197886
                         [,6]
                                         [,7]
##
                 [,5]
                                                                [8,]
##
    [1,] -1.4307781529872  0.3274163444336  1.4848617228315
                                                                  NA
    [2,] 0.6633000579074 1.4179354674510
                                                   NA
##
    [3,] -0.5519920594947 -0.8825176388887
                                                    NA 0.592562486164
    [4,] -0.3753301965462 1.5783995631695 1.1539360032983
##
                        NA -0.1590655149255
##
    [5,] 0.7705610358586
        0.4953887208646 -0.8734100677085 -0.7193167558393 -0.468383208416
##
             NA -0.0038489314604 NA
##
    [7,]
                                                                  NA
##
                    NA
                              NA 0.8300691752252
                                                                  NA
    [8,]
                    NA -0.1652761299780
##
    [9,]
                                                   NΑ
        0.7150068043195 -0.4857021261537 1.5412850847069 -0.531865511991
##
   [10,]
        NA -1.7554665970245 0.5684992459729
   [11,]
```

```
NA
    [12,]
                        NA
                                         NA
                                                           NA
##
    [13,]
           1.2941786682357 -0.6521075917131 -0.4097309182423 2.478788335838
##
    [14,] -0.6448800679701 0.5034517050406
                                                           NA -1.313411474310
          1.0480286593073
                            0.3376623214817
                                                           NA -0.601916608703
##
    [16,] -0.3990554143209
                                         NA
                                                           NA -0.660808854435
    [17,]
##
          0.3164017333701 -1.2246224785744 -0.7258696029095
                                                              2.042071595685
    [18,] -0.9868548537907 -1.3874639633349
                                                              0.249216713238
##
    [19,]
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                                         NA 0.0157554207000
                                                               1.309156845652
          1.3687290940711 -0.8723769269450 -0.0097473092453 -0.443154657670
    [20,]
    [21,] -1.0272585403399
                                         NA -1.1397860851322 -0.354588763785
##
          2.1187180157360
                                              2.9846531466519 -0.211696183566
    [22,]
##
    [23,]
           1.7591524849745 -0.4127903069950
                                              1.6520680333371 -1.044281118002
                                                                           NA
##
    [24,]
                        NA
                                         NA
                                                           NA
##
    [25,] -0.1569410489561
                                         NA
                                              1.4623345263534
                                                                           NA
                                         NA
##
    [26,]
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                                                           NA
                                                               1.466182677149
          1.0076888657579
                            0.4411110111624
                                              0.9797406699267
                                                               0.144069654158
    [27,]
##
    [28,]
          0.6177549987514 -0.9272486172107
                                                                            NA
                                         NA -1.7436475194736
                                                                            NA
    [29,] -1.1546797608730
##
    [30,]
          0.1953719379762
                                         NA -1.4220611254008
                                                               0.249334215358
    [31,]
                        NA
                                         NA -1.6144863349158
##
    [32,] -1.3339413928880
                                             0.3530660097787
                                                               0.204530508714
##
                            1.3820695560032
##
         1.7505421092338 -0.1961333745399
                                             0.0741404338925
                                                               0.060583635244
    [33,]
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##
    [34,]
          0.3660058637066
                                                                            NA
##
                        NA
                                         NA
                                                                           NA
    [35,]
    [36,] 1.4480725774998
                           0.5299215226675
                                             1.0199872990085
                                                                            NA
    [37,] -1.1156294193801 -0.7850924453149
                                              0.1054174989591
                                                                            NA
                        NA
                                                               0.745113206248
                                                           NA
##
    [39,] -1.0046094295569
                            0.2726020655129
                                              0.4036941767798
                                                                            NA
                        NA -0.9345668086107
                                                               0.289974476909
##
    [40,]
                                             2.0866366534865
##
                        NA
    [41,]
                                         NA
                                                                           NA
    [42,] -0.0246896345877
##
                            0.2745645709781
                                              0.2770373878366
                                                              0.258242310842
    [43,] -1.4849305684118
                            1.9047809268529 -0.2623567844719 0.688899372594
##
          0.7392383785238 -0.5862726678076
                                                           NA -1.195092293260
    [44,]
##
    [45,]
                        NA
                                         NA 2.5029586952059 -0.474907296183
                        NA
##
    [46,]
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                                                               0.470725135516
         0.7868907664001
                                         NA -0.6734978240089
                                                                            NA
    [48,] -1.8653940545855 -1.2678042495275 -0.8122943768094 -0.888636639578
##
##
                            0.3153074146350
                                                           NA -0.492091614640
    [49,]
                        NA
                                                           NA -1.561259508672
##
                        NA -0.1374784814985
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         0.0800297130847 -0.8001757464797 -0.0413511878479
##
    [51,]
                                                                            NA
    [52,] -0.5913050434916
                            1.3192068826452 0.3542005472030
                                                                            NA
##
                        NA
                                         NA -1.5062092349310 -0.045932221826
    [53,]
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    [54,] -0.2993396323607 -0.2397539816779
          1.2452936394457 -0.9539609652628
                                                              0.516044635774
    [56,] -0.7630670708040
                            0.7388730873590
                                            1.4273580243098
##
    [57,]
                        NA
                                         NA -0.0453998589566 -0.937462659446
##
                        NA -1.2867204071235
                                            0.4094272744744
    [58,]
    [59,] 0.1630706705515 -1.0075035402212 -0.0157876188114 -0.072904157156
    [60,] -1.3947175547760 -1.9661115056527 1.5055328944932
                                                                            NA
    [61,] 0.6288234339950 -0.8976613998979 1.5520790079246 0.953845632959
```

```
[62,] -1.1900101717940 0.8951562534673 0.5511402398713
                                                                         NA
    [63,] -0.1221070097082
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##
    [64,]
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    [65,] -0.0597487884360
                          0.5013766505171 -2.1335335797178
                                                            0.433675037630
##
##
    [66,]
                       NA
                           0.6509256596892 -1.8720674622450 -0.902356647417
##
    [67,]
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                                        NA
                                                         NA
                                                             0.564852613521
##
                       NA
                          1.7121015007150 -0.2987707705214
                                                             0.010240473557
    [68,]
##
    [69,] -0.4482923904513
                                        NA
                                           1.3086400925207
                                                                         NA
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                                                                         NA
                       NA -0.8452354506553 -0.1152451597785
##
    [71,]
                                                                         NA
##
    [72,]
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                                                                         NA
##
    [73,]
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                           0.1828447087691
                                                         NA -0.319889735843
                          1.2683253717684 0.0270201346631 -0.293484156897
##
         0.1466554906918
    [75,] -0.9775293344304 -1.6727002678260 -1.5174265748805 -0.057066408480
          1.6351060456298 -0.2703265940161
##
    [76,]
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    [77,] -2.8480800086993 0.1035779247185
                                                             0.987968608921
##
    [78,]
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                                                                         NA
          1.6332381185221 -1.6881531487164
                                                         NA
                                                                         NA
                                        NA 1.2184258868422 -0.478665373424
##
    [80,]
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##
          0.4349675237808
                          0.1769816419909
                                            0.2315393999767 -0.240002442805
   [81,]
##
                       NA 0.4017231640750 -1.5163715597468
                                                                         NA
   [82,]
    [83,]
                       NΑ
##
                                  NA
                                                         NA
                                                                         NΑ
    [84,] -0.8373810265163 1.7177241775699
                                                            0.090516188599
##
    [85,] 0.3186708174387 -0.3964094247758
                                                         NA -1.042219445321
##
   [86,]
                       NA -1.6448414374411 0.8046730626649
    [87,] -0.7054969492017 -0.0620671690154
                                                                         NA
                                                         NA -0.166133838850
   [88,] -1.5655235162876
##
    [89,]
                       NA -0.1848420260362
                                                         NA
                                                                         NA
##
                       NA
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    [90,]
##
                                                         NA -0.758560249732
   [91,] -0.1790865582640
                                        NA
##
                       NA
                                        NΑ
                                            0.6723811736680 1.488668810099
    [92,]
    [93,] -0.6060585117723
                           ##
                       NA
                                        NA -0.3485952284689 -1.224293091429
    [94,]
    [95,] -0.8047438808454 -0.8169741976497 0.3522235621736
                                                                         NA
##
    [96,]
                       NA
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                                                                         NA
                          -2.2670488212155 1.8141882347753
    [97,] -2.2154689870338
                                                                         NA
##
    [98,]
                       NA
                           1.3610334850559
                                                         NA -0.805670578859
##
   [99,] -0.8130232957097
                           0.3073340383546 1.5260157384969
                                                                         NA
                       NA 0.4297138293936 -0.3316019841669
##
  [100,]
                                                                         NA
##
                    [,9]
                                                                     [,12]
                               [,10]
                                                    [,11]
##
         1.538799567692
                          0.1155887924022
                                           0.433987977061
     [1,]
##
     [2,]
                      NA
                                       NA
                                           0.334460369117
                                                           1.052519776887
     [3,] 1.268963476486
##
                         0.1501950606233
                                                       NA -0.877837635760
##
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          0.027514099120 -1.1652107324896
##
     [5,]
                                                       NA -0.078897536604
##
     [6,]
         1.934894928883 1.2372479562266
                                                            0.366004368023
##
     [7,] -1.057318806235 -0.4075166583328
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• Sort the rows in matrix R by the largest row sum to lowest. Be careful about the NA's! R[order(rowSums(R,na.rm=TRUE),decreasing=TRUE),]

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                                           0.3199397932774 -1.582499891111
##
    [53,]
          1.335580260723 -0.716269012872
                                                        NA
                                       NA
                                                        NA -1.803556054353
##
    [54,]
         0.020855996956
##
    [55,]
          0.504868784315
                                       NA
                                                        NA
                                                                        NA
##
                       NA 0.927653141610 -0.6153788678587
                                                                        NA
    [56,]
   [57,]
          1.174002193611
                                       NΑ
                                                        NΑ
                                                                        NΑ
##
    [58,]
                       NA -1.099578753323
                                                        NA
                                                                        NA
                       NA -0.068876221138 -2.6908850237742 0.098997259902
  [59,]
```

```
[60,] -0.462873729442
                                             0.6103002299539 -0.892120172600
##
    [61,]
           0.428769921758
                            0.344728622227
                                                          NA -0.636059168345
##
    [62,] -0.809307989762
                                        NA
                                                          NA
                                                               0.071355401110
##
           0.876530772642
                            0.375117023680
                                             0.0160611591205
                                                             -1.484624790072
                                                              2.349560618055
##
    [64,]
           0.349130812808 -0.511575636419
                                                          NA
           1.216771895592 -1.177293349396 -0.0794330668464
##
    [65,]
                                                              0.577591283118
    [66,] -0.052876036276
##
                            1.360981269954 -0.8674535916267 -0.081625216526
##
    [67,] -0.342481674574
                                        NA -1.0017279045704
                                                              1.018585579331
    [68,] -0.878807793481
                                        NA -1.9010209766218 -1.169342210515
##
    [69,] -1.338397286866
                                        NA -1.0495114880866
                                                              0.480369594136
##
    [70,] -1.849917184528 -1.888933124590 -0.7667116236818
                                                              0.534232354191
##
    [71,]
                        NA -0.817316820165
                                           -1.2392387811505
                                                                           NA
##
           0.706374488068
                                        NA -0.8869248877942
                                                              0.975157426250
##
    [73,]
          -0.721824751903 -0.466455494323
                                            1.4439836970907 -0.163644818357
                                        NA -0.3378862965916
                                                             -1.418839223677
##
    [74,] -0.688300342773
           0.707810054973
                                        NA
                                                          NA
                                                                           NA
    [75,]
##
    [76,]
          -0.218232608010
                                        NA
                                           -1.0045092217953
                                                               0.339419899635
                            0.680595344013
                                                          NA
          -0.805087116611
                                                                           NA
##
    [78,]
           1.034851668773
                                                          NA
                                                              -0.110148019754
##
    [79,]
                           1.778195960986
                                                          NA
                                                                           NA
                        NA
##
           0.020645821434
                          -0.798679805303
                                                          NA
                                                                           NA
    [80,]
##
    [81,]
           0.178513761160
                            0.257163384816
                                           -1.8322044755528
                                                                           NA
##
                        NA
    [82,]
                                         NA
                                           -0.4092824266635 -2.033610985193
##
    [83,]
                        NA
                            0.887805534338
                                           -0.5403065609043
                                                               1.583373135437
##
    [84,] -1.731558597828
                                        NA
                                             0.7628072555988
                                                                           NA
    [85,] -0.497974841786 -0.093570496035
                                             1.4026065234494
                                                              0.870065240958
    [86,] -0.032323317347 -1.685056630951
                                                                           NA
##
    [87,]
                        NA -0.296242569679
                                            1.1475889564203
                                                               1.785052291278
    [88,] -0.527834308828 -0.621447508568 -0.0924474626354
##
                                                               1.553208578259
##
    [89,] -0.728224509172 -0.341284929292
                                                                           NA
                                                          NA
##
    [90,]
                        NA -0.032034308204
                                                          NA
                                                              0.246606787184
##
          -0.259171707731
                                        NA -0.4919629174600
    [91,]
                                                               0.095017052268
##
    [92,]
                            0.111157223356 -0.3035302063626 -0.403356726441
##
    [93,]
           0.586539874668
                                            0.0753842138388 -1.158854152698
##
    [94,]
           0.142874581917
                                            0.4502294455375
                                                             -1.149257810463
    [95,] -0.905677327340
                            0.894378024951
                                            0.7482886154085
                                                               0.292835230483
##
    [96,] -0.617321895610 -0.427297965210
                                            1.2551861114017 -1.967579020560
##
    [97,] -0.150370445318 -0.488705320193 -1.1925165936481
                                                               1.026746306530
    [98,] -0.708265137235
                                        NA
                                                          NA -0.515245118780
                                        NA
                                            1.0894623608858 -0.374903673355
    [99,] -2.074366003983
## [100,] -1.413641935122
                                        NA -2.2338906287684 0.048109846171
```

 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.

```
v <-apply(X=R[,],MARGIN = 2,FUN = sd,na.rm=TRUE)
v</pre>
```

```
## [1] 0.91604471527 1.06790671240 1.02405107372 1.04372083581
1.03760188786
    [6] 1.01666279994 1.13036604954 0.86766463500 1.01992151141
0.93079390276
## [11] 0.97459843951 1.05008693215 0.92310367094 0.93695218828
0.85157007683
## [16] 0.95385701630 0.97596416037 0.91868460371 0.96129631797
1.04705792699
## [21] 1.06123347407 0.96174139738 0.95294394438 0.98632905216
0.87737627369
## [26] 1.08005647863 1.15534644736 1.17255918338 0.82684073205
1.05109331942
## [31] 1.00674713804 0.95026283441 1.01964320953 0.99039341309
1.06222459217
## [36] 1.18435188044 0.78328533818 1.26504455101 1.03419712899
0.98753739318
## [41] 0.83031221033 1.09190196763 0.93795705303 1.00148365242
0.92266550184
## [46] 0.85932420645 1.02169898023 0.93621503629 1.14908550144
0.90015677503
## [51] 1.04399628798 1.08657541516 1.07780823720 0.76075913077
0.98549158910
## [56] 1.05156206452 0.84767558761 0.99040697585 0.98861734819
1.01657010067
## [61] 0.90836591268 0.94843636801 1.04437928490 0.96314701417
0.96196959854
## [66] 0.97904227566 1.13105775182 1.16215815157 0.91157466559
1.01076609753
## [71] 0.99680681730 0.87916390958 1.02580963101 1.04217143936
1.01105538617
## [76] 0.82756026706 0.87911823557 1.18312636317 1.09856249835
0.83372375406
## [81] 1.04380371026 0.98489528258 1.05502087680 1.08419370384
1.02838042797
## [86] 1.01542796654 0.94193808359 1.06902933216 0.99146929591
0.98093645207
## [91] 1.00011487582 0.80177253188 1.05721331565 1.04238843668
0.98279588914
## [96] 0.98008955325 1.06049400756 1.02268097939 0.96411950916
1.04049055563
```

- 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.
- 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.
- 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.

## #TO-DO

• 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(100)
n=1000
v <- dnorm(n, mean = -10, sd = sqrt(100))
v
## [1] 0</pre>
```

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

```
set.seed(890)
n=1000
v <- dnorm(n, mean = -10, sd = sqrt(100))
v
## [1] 0</pre>
```

• Find the average of v and the standard error of v.

```
mean(v)
## [1] 0

stderr <- function(v, na.rm=FALSE) {
    if (na.rm) v <- na.omit(v)
        sqrt(var(v)/length(v))
}

stderr(v)
## [1] NA</pre>
```

• 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?

```
qnorm(0.05,mean=-10,sd=10)
## [1] -26.44853627
```

• 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?