Lab 1

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11:59PM February 1

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 TO-DO'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)
pi
```

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

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

```
sum(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
```

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

```
prod(2^(-(0:386)))
```

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

Is this answer *exactly* correct?

no

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

```
sum(log10(2^(-(0:386))))
```

```
## [1] -22484.231406
```

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

```
c(Inf, seq(20,-20, by=-2))
```

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

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

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

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

Comment on the appropriateness of the non-numeric values NAN and -Inf.

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

```
x > 0 & is.finite(x)
```

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

```
## starting httpd help server ... done
```

```r
which(is.infinite(x) | is.nan(x))
```

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

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

```r
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.

```r
y=x
y[is.infinite(x)]=NA
which.min(y)
```

```
## [1] 51
```

```r
which.max(y)
```

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

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

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

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

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

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

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

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

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

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

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

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

```
y=x[is.finite(x)]
```

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

```
sum((seq(0,1-1e-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.

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

```
## [1] 0.46
```

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

```
mean(sample(c(0,1), size=500, replace=TRUE, prob = c(.1, .9)))
```

```
## [1] 0.878
```

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

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

```
## [1] 0.897
```

- 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.

```
vec = sample(c(rep(0, 1250), rep(1, 625), rep(2, 625)))
vec
```

```
##    [1] 2 2 2 0 0 1 0 1 0 0 2 0 1 0 0 1 0 2 0 1 2 0 2 0 1 1 0 0 1 2 0 0 0 2 0 0 2
##   [38] 0 0 0 1 1 1 0 2 0 1 0 0 2 1 0 0 1 1 2 0 0 2 1 0 0 2 0 0 1 1 0 0 1 1 2 0 0
##   [75] 2 2 1 1 2 0 2 2 1 1 1 0 2 0 0 2 1 1 2 0 1 1 1 0 1 0 2 1 2 0 1 0 1 0 0 1 2
##  [112] 2 1 2 2 2 2 0 0 2 0 2 1 1 0 0 0 0 0 0 0 0 0 0 2 2 1 0 0 2 0 1 2 0 1 1 0 1 2
##  [149] 0 1 2 0 2 0 1 2 0 0 0 1 1 1 2 0 1 0 0 2 0 2 0 0 1 1 1 2 0 0 0 1 0 2 0 1 0
##  [186] 0 2 2 2 0 0 1 2 1 0 2 0 2 0 0 0 2 2 0 2 2 2 1 1 0 1 1 0 0 0 0 0 1 0 0 0 0
##  [223] 0 0 0 1 0 0 0 2 1 0 1 1 1 0 0 0 0 0 1 2 0 0 0 1 2 1 0 2 1 0 0 0 2 0 1 2 1
##  [260] 0 0 1 2 0 1 0 2 1 1 1 0 2 2 0 2 0 1 0 1 0 0 0 2 0 0 0 2 1 2 0 2 1 1 2 1 1
##  [297] 2 0 0 1 1 1 0 0 2 1 2 0 1 0 2 2 1 1 0 0 0 0 2 0 2 0 1 0 0 2 0 0 0 0 1 0 1
##  [334] 1 2 1 1 1 2 0 0 1 1 2 0 0 0 2 1 1 0 1 2 1 1 0 2 1 1 1 0 2 2 0 0 2 2 0 0 2
##  [371] 1 1 0 0 0 1 0 1 1 1 2 1 0 0 1 0 0 0 0 0 0 1 2 0 0 2 2 2 0 0 2 0 1 0 2 0 1
##  [408] 0 0 0 1 0 0 2 1 1 1 0 2 0 2 0 0 0 2 1 0 0 0 0 0 0 1 0 0 0 0 0 0 2 2 0 0 0 0
##  [445] 0 1 0 1 2 0 0 0 1 1 0 0 0 0 2 2 0 0 1 0 2 0 0 0 2 1 0 2 1 1 2 0 2 0 0 2 1
##  [482] 0 2 0 0 1 0 0 0 1 0 0 1 0 0 1 0 2 1 1 0 0 0 2 2 0 2 0 1 0 2 0 2 1 0 1 1 0
##  [519] 0 2 1 1 2 1 2 0 1 0 0 0 2 0 0 2 0 0 2 0 2 0 0 0 1 2 0 2 1 2 0 0 2 0 2 0 1
##  [556] 1 0 1 2 2 0 0 2 0 2 0 1 2 2 1 1 0 0 0 2 1 0 0 1 0 0 2 0 2 2 0 0 0 0 1 1 1
##  [593] 1 2 0 0 1 2 2 0 1 1 2 2 2 2 2 1 0 1 0 0 0 1 1 0 0 0 1 0 2 2 1 2 2 2 2 0 1
##  [630] 0 1 2 0 0 1 1 0 0 1 0 0 1 1 0 1 2 2 0 1 2 0 0 1 2 2 2 0 1 1 2 0 2 0 1 2 0
##  [667] 0 0 0 2 2 2 1 0 1 0 2 2 1 0 2 0 0 1 2 0 2 0 2 0 0 0 0 0 1 2 1 0 0 0 0 0 0
##  [704] 1 0 0 1 0 0 1 0 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 2 0 0 2 0 0 1 1 0 0 2 0 0 2
##  [741] 1 0 1 0 0 1 0 1 0 1 2 2 1 2 1 0 2 2 0 0 0 2 1 1 2 2 2 0 0 2 0 0 2 2 2 1 0
##  [778] 2 0 0 0 0 0 1 0 0 0 0 0 1 2 1 2 1 2 2 2 2 1 0 0 2 2 0 0 2 1 1 0 0 2 1 2 0 0 0 0
##  [815] 0 0 1 0 0 0 0 0 0 0 0 2 2 2 0 0 1 0 0 2 2 2 0 0 0 0 1 1 1 0 0 0 2 0 0 0 1 2
##  [852] 0 0 1 2 0 1 0 0 0 0 0 0 0 0 2 0 0 1 2 0 0 0 2 2 0 1 0 0 0 1 0 2 2 1 1 1 0 1
##  [889] 0 1 1 2 2 0 0 2 1 2 1 0 1 0 2 0 0 0 2 0 0 0 2 2 0 1 0 0 0 0 2 2 2 0 0 0 1 1
##  [926] 1 1 2 0 2 0 0 1 1 2 1 0 2 1 1 0 0 0 0 0 2 1 1 0 2 1 2 1 1 0 1 0 0 0 0 1 0
##  [963] 0 1 0 0 2 2 2 0 1 2 0 2 1 1 0 2 2 1 0 0 1 2 0 2 2 2 0 0 0 1 0 0 0 2 2 2 0
## [1000] 0 0 2 2 1 2 0 2 2 0 2 1 2 1 0 0 2 0 1 1 0 1 0 2 0 1 2 1 0 1 0 0 2 1 0 2 0
## [1037] 1 2 2 2 0 0 0 0 2 0 0 0 0 2 0 1 0 0 0 2 1 0 1 1 2 0 2 0 1 0 1 1 0 2 0 2 0
## [1074] 0 0 0 2 2 2 0 0 1 0 0 0 1 0 1 2 2 1 0 2 0 2 0 0 0 0 1 0 0 1 2 2 1 0 0 2 1
## [1111] 2 2 0 2 1 0 1 0 0 1 0 0 2 2 2 0 0 1 0 2 2 2 1 2 0 0 0 0 0 2 0 0 0 0 2 1 1
## [1148] 0 2 0 2 0 2 1 2 0 1 0 0 0 2 0 1 0 2 1 0 0 1 2 0 0 1 0 1 2 1 0 0 1 0 1 2 1
## [1185] 1 0 0 1 0 2 1 1 1 2 0 0 0 0 1 2 0 0 0 1 0 2 0 0 1 0 2 0 0 0 0 1 1 2 0 1 0
## [1222] 2 0 0 1 0 1 0 1 1 0 0 1 0 1 1 2 1 0 2 0 1 0 0 2 0 0 0 0 0 2 0 2 0 1 2 0 1
## [1259] 0 0 2 1 0 0 0 0 0 1 2 1 0 2 0 0 0 0 0 2 1 0 1 0 0 0 2 0 0 0 0 2 1 0 1 0 0
## [1296] 0 0 1 1 0 1 0 0 1 2 2 2 0 0 0 1 0 1 0 0 1 1 0 0 1 0 0 1 0 2 1 2 1 1 2 0 0
## [1333] 0 0 0 1 1 0 2 1 1 1 0 1 0 2 0 0 0 0 0 1 0 0 0 0 0 0 1 2 2 0 1 2 0 2 0 1 2
## [1370] 2 0 0 1 1 2 1 1 0 2 1 0 0 1 0 0 0 1 1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 2 0 1 2
## [1407] 1 0 1 1 0 1 0 0 0 0 0 0 2 0 0 1 0 0 0 2 0 0 2 1 0 0 1 2 0 1 1 0 1 2 0 2 0
## [1444] 0 0 2 2 0 0 2 0 1 1 2 0 2 0 2 0 0 0 1 0 0 0 0 0 0 0 1 1 1 0 0 0 2 2 0 0 0 1
## [1481] 1 2 0 1 1 1 2 0 0 1 0 2 2 0 0 0 0 2 0 0 0 2 0 2 1 2 0 0 0 0 0 0 0 2 1 0 0 0
## [1518] 0 0 2 1 0 2 2 1 2 2 1 2 0 1 2 0 2 1 1 1 2 0 0 1 1 0 0 0 0 0 0 0 1 2 2 0 2
## [1555] 1 1 0 0 2 0 0 0 0 0 0 0 0 0 2 2 0 0 2 2 0 0 0 0 2 0 0 0 0 0 1 2 0 0 2 1 1 2
## [1592] 1 1 0 2 0 0 0 0 0 1 0 0 0 0 1 2 0 0 1 0 1 1 2 1 2 2 0 0 0 0 0 2 1 1 2 2 0 1
## [1629] 0 0 2 1 0 1 1 1 1 1 2 0 2 0 0 2 1 0 0 0 2 0 0 0 0 0 0 1 0 1 1 0 0 0 1 0 1
## [1666] 1 2 0 0 1 2 1 2 0 1 1 2 2 1 1 2 0 2 1 2 0 0 2 0 0 0 1 1 0 0 2 0 0 0 0 0 0
## [1703] 0 1 1 0 2 0 0 0 1 1 1 2 2 2 1 0 1 1 0 1 1 0 1 0 0 0 1 1 0 2 0 1 2 2 2 1 2
## [1740] 0 2 0 2 0 2 0 2 2 1 2 2 0 0 1 1 0 0 0 0 2 0 2 1 0 0 1 1 0 1 0 0 0 1 0 1 1
## [1777] 2 2 0 1 0 0 0 2 2 0 2 1 1 1 0 1 1 1 0 2 1 1 2 0 0 0 0 0 1 2 1 2 0 0 2 2 2
## [1814] 0 0 0 1 0 1 1 0 1 2 2 2 0 2 0 1 2 0 2 0 0 0 1 0 0 2 0 0 0 2 0 2 0 0 0 1 1
## [1851] 2 1 0 1 0 0 0 0 1 0 1 2 1 2 0 2 0 1 1 2 0 2 1 0 2 0 0 1 2 2 0 0 0 2 2 0 0
## [1888] 2 0 0 0 0 0 1 0 2 1 2 0 1 0 0 1 0 1 0 1 2 0 2 0 2 1 0 1 2 1 0 1 0 0 2 2 0 1
## [1925] 1 1 0 1 2 0 2 2 0 2 2 0 2 2 0 0 2 2 0 1 0 2 0 0 0 0 0 1 1 0 0 0 0 0 0 1 2 2
## [1962] 2 0 0 0 0 0 2 0 0 2 2 0 1 2 1 0 0 0 1 2 0 0 0 0 0 2 1 2 1 1 0 0 2 1 0 0 0 1 0
```

```
## [1999] 0 0 1 2 2 0 0 0 0 2 2 0 2 1 0 1 1 0 0 1 0 0 0 2 2 2 0 1 2 1 2 1 0 0 0 0 0
## [2036] 2 0 0 0 2 0 2 0 0 0 0 1 0 2 0 2 0 0 1 0 0 1 2 0 1 1 0 1 0 0 2 0 2 1 2 0 2
## [2073] 1 0 1 0 0 2 1 0 0 1 1 2 1 0 0 0 0 0 0 0 1 0 0 1 2 1 2 0 1 2 1 0 0 2 1 0 0
## [2110] 2 2 0 0 0 0 0 2 2 2 0 0 1 0 0 2 0 2 1 0 0 1 0 1 1 0 2 0 0 1 2 2 2 1 0 2 2
## [2147] 0 2 0 1 1 0 1 0 2 0 0 0 0 0 0 1 1 2 1 1 2 0 0 0 0 0 2 2 0 1 1 2 0 2 0 2 0
## [2184] 0 0 0 0 2 0 1 1 0 0 1 0 0 0 0 0 2 2 1 0 2 0 0 1 1 2 2 2 0 0 0 0 2 0 0 1 1
## [2221] 1 0 0 0 0 0 1 0 2 0 2 0 0 0 0 0 0 1 2 0 0 2 2 0 0 0 0 0 0 0 0 2 2 0 1 0 2 0 1 0
## [2258] 1 0 2 2 2 0 1 1 0 2 1 2 1 0 2 0 0 2 0 2 1 2 0 2 0 0 1 2 0 1 0 0 2 0 0 2 2
## [2295] 2 0 2 0 1 0 0 1 0 0 0 0 0 0 0 2 1 2 0 0 1 0 0 0 2 2 2 0 1 1 1 1 1 0 0 0 0 0
## [2332] 0 0 0 1 0 2 1 0 1 0 0 2 0 2 0 1 0 0 2 0 0 2 0 0 0 2 0 2 0 0 2 0 2 2 2 2 0
## [2369] 0 2 2 0 1 0 1 2 0 0 2 0 0 1 0 1 2 2 0 2 2 1 0 2 0 1 2 0 2 2 0 2 0 1 2 0 0
## [2406] 2 1 0 0 2 1 0 0 0 1 2 1 1 0 0 0 0 0 2 2 1 1 0 1 1 2 0 1 2 0 2 1 2 1 0 0 0
## [2443] 2 2 2 1 2 0 0 0 0 0 0 0 2 1 1 0 0 1 2 0 2 1 0 0 1 0 0 0 0 1 1 1 0 0 2 2 0 0
## [2480] 2 2 0 0 1 0 1 0 0 0 0 0 0 2 2 0 0 0 2 0 0 1
```

```
R = matrix(vec, nrow=50, ncol=50)
R
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
##  [1,]    2    1    2    2    0    1    1    0    2     0     0     2     1
##  [2,]    2    0    1    0    2    0    1    1    0     0     0     0     1
##  [3,]    2    0    2    2    2    0    0    2    1     1     0     2     2
##  [4,]    0    1    0    0    0    0    0    1    0     1     2     0     2
##  [5,]    0    1    1    1    2    2    2    1    2     0     2     1     2
##  [6,]    1    2    0    2    2    0    1    0    0     0     0     1     2
##  [7,]    0    0    1    0    2    1    2    2    1     0     2     0     2
##  [8,]    1    0    0    0    1    2    0    1    0     0     0     1     1
##  [9,]    0    2    0    0    1    1    1    1    0     2     1     2     0
## [10,]    0    1    1    1    0    0    0    1    0     2     0     2     1
## [11,]    2    0    2    1    1    0    2    0    1     0     2     0     0
## [12,]    0    0    2    1    1    1    2    2    0     0     0     0     0
## [13,]    1    2    1    2    0    2    1    2    0     1     2     2     0
## [14,]    0    0    2    0    0    0    1    0    2     0     1     0     1
## [15,]    0    0    2    1    0    1    0    0    1     2     0     2     1
## [16,]    1    1    2    0    0    0    0    2    1     0     1     0     0
## [17,]    0    1    2    0    0    2    0    2    1     0     1     1     0
## [18,]    2    0    0    2    1    1    0    0    0     0     0     2     0
## [19,]    0    0    0    0    0    1    2    0    2     2     0     2     1
## [20,]    1    1    2    2    0    1    0    2    0     1     2     1     0
## [21,]    2    1    0    0    0    0    2    1    2     0     1     1     2
## [22,]    0    2    2    0    0    2    0    1    0     2     1     0     2
## [23,]    2    0    1    1    0    2    1    0    0     1     2     0     1
## [24,]    0    0    1    1    0    0    0    0    0     1     1     0     2
## [25,]    1    2    0    1    0    2    0    0    2     2     2     2     2
## [26,]    1    2    0    2    1    0    2    1    1     0     0     1     2
## [27,]    0    1    0    0    0    1    0    0    0     2     1     0     2
## [28,]    0    1    0    0    0    0    0    1    0     0     0     0     0
## [29,]    1    2    0    0    0    1    0    1    0     0     0     1     1
## [30,]    2    0    0    1    2    0    0    1    0     2     0     0     0
## [31,]    0    2    0    0    1    0    1    2    0     1     2     0     1
## [32,]    0    2    0    2    0    0    0    1    0     0     0     2     2
## [33,]    0    1    0    0    1    2    1    0    1     2     0     0     0
## [34,]    2    1    2    1    1    0    1    0    0     0     2     2     0
## [35,]    0    1    2    0    1    0    2    1    0     0     0     2     1
```

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

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

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

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

```
## [48,]     0
## [49,]     0
## [50,]     1
```

```
table(c(R))
```

```
##
##    0    1    2
## 1250  625  625
```

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

```
R[runif(2500)<.3]=NA
R
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
##  [1,]    2   NA    2    2    0    1    1    0    2     0     0     2     1
##  [2,]    2    0    1    0    2    0   NA    1    0    NA     0     0     1
##  [3,]   NA    0    2    2    2    0    0   NA    1     1    NA     2    NA
##  [4,]    0    1    0    0    0    0    0    1    0     1     2    NA     2
##  [5,]   NA    1    1    1    2   NA   NA    1    2     0    NA     1     2
##  [6,]    1   NA   NA    2   NA    0    1   NA   NA    NA    NA     1     2
##  [7,]    0    0    1    0    2    1    2   NA    1    NA     2     0     2
##  [8,]   NA    0    0    0   NA    2   NA    1    0    NA     0     1     1
##  [9,]    0    2   NA   NA    1    1    1    1   NA     2     1     2    NA
## [10,]   NA    1   NA    1   NA   NA    0   NA    0     2     0    NA     1
## [11,]    2    0    2   NA    1   NA    2   NA    1     0     2    NA     0
## [12,]    0    0    2   NA   NA    1    2   NA    0     0     0     0    NA
## [13,]    1    2    1   NA   NA    2   NA    2    0    NA     2     2     0
## [14,]    0   NA    2    0   NA    0    1    0    2     0    NA    NA     1
## [15,]    0    0    2    1   NA    1    0    0    1     2    NA     2    NA
## [16,]   NA    1    2    0    0   NA    0    2   NA     0     1     0     0
## [17,]   NA    1    2    0   NA    2    0    2   NA    NA     1     1    NA
## [18,]    2   NA   NA    2    1    1   NA   NA   NA     0     0     2    NA
## [19,]   NA   NA    0    0    0   NA    2   NA    2     2     0     2     1
## [20,]   NA    1   NA   NA   NA    1    0    2    0     1    NA     1    NA
## [21,]   NA    1    0    0    0   NA    2    1    2    NA     1     1    NA
## [22,]    0    2    2    0   NA   NA   NA    1    0     2    NA     0     2
## [23,]    2    0    1    1   NA    2    1    0    0     1     2     0    NA
## [24,]    0    0    1    1    0    0    0    0    0     1     1     0     2
## [25,]    1    2    0    1    0    2    0   NA    2     2     2     2     2
## [26,]   NA   NA    0   NA   NA    0    2    1    1    NA     0     1     2
## [27,]   NA    1    0    0    0    1   NA    0    0    NA     1     0     2
## [28,]    0    1    0    0    0    0   NA    1   NA     0    NA    NA     0
## [29,]    1    2   NA    0   NA    1    0    1    0     0    NA    NA     1
## [30,]    2    0   NA    1    2   NA    0    1    0     2     0     0     0
## [31,]    0    2    0    0    1    0    1    2    0     1    NA     0     1
## [32,]    0    2    0    2    0   NA    0    1    0     0     0    NA     2
## [33,]    0    1   NA   NA   NA    2    1    0    1     2     0     0     0
## [34,]    2    1   NA    1   NA    0    1   NA    0     0     2    NA     0
## [35,]    0    1    2    0    1    0    2    1   NA     0     0     2     1
## [36,]   NA   NA   NA    0    0    0    1   NA    0     1    NA     0     1
```

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

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

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

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

```
## [49,]     0
## [50,]     1
```

- 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),]
```

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

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

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

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

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

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

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

```
##  [1] 0.90640641031 0.80950789391 0.86556706800 0.81110710565 0.76706848591
##  [6] 0.86576807934 0.80224045248 0.78000215471 0.80481505498 0.88475742377
## [11] 0.90004668413 0.84723257155 0.80752760964 0.79831171061 0.81833347095
## [16] 0.79282496717 0.84492824744 0.87380361840 0.90718713932 0.84515425473
## [21] 0.74935870018 0.93641704218 0.80250768410 0.85174074953 0.81064348338
## [26] 0.82196730598 0.87581131218 0.88917961857 0.76200076200 0.85588532090
## [31] 0.80622577483 0.85011121368 0.75833704583 0.78030184399 0.88021291446
## [36] 0.69006555934 0.87521588477 0.89348717267 0.92547622274 0.85723303999
## [41] 0.79831171061 0.77185887896 0.83145829832 0.80988516377 0.90517714369
## [46] 0.78288136126 0.85749292571 0.82085126024 0.77681933283 0.83333333333
```

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

```
##  [1] 0.86370672384 0.76997217018 0.86828094908 0.83205029434 0.80229555709
##  [6] 0.81110710565 0.77459666924 0.76928561439 0.81019149367 0.82108110085
## [11] 0.85208592300 0.86540923480 0.81015381648 0.91335896499 0.55065942873
## [16] 0.85391256383 0.86384984757 0.83190353531 0.85588532090 0.88021291446
## [21] 0.87926630988 0.89056355656 0.88687914726 0.78000215471 0.79311553891
## [26] 0.73009111283 0.83219007599 0.79042848102 0.79755169718 0.80277297192
## [31] 0.88227495199 0.88288571145 0.86556706800 0.78030184399 0.81809201053
## [36] 0.79716245540 0.86036613430 0.80722543520 0.81649658093 0.84437134187
## [41] 0.89459504822 0.78857386432 0.85682148078 0.81477944636 0.85835983666
## [46] 0.89984254133 0.80662322409 0.96076892283 0.78857386432 0.75643884756
```

- 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.

```r
apply(R, MARGIN = 2, function(x){sum(x==1|x==2, na.rm = TRUE)})
```

```
##  [1] 16 24 23 18 14 23 22 22 16 20 17 20 24 18 10 25 14 19 16 22 19 12 20 19 14
## [26] 15 17 18 13 15 17 17 18 19 27 15 17 12 15 14 17 18 24 13 10 22 17 15 18 13
```

- 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`.

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

```
## $`1`
##  [1]  2  2 NA  0 NA  1  0 NA  0 NA  2  0  1  0  0 NA NA  2 NA NA NA  0  2  0  1
## [26] NA NA  0  1  2  0  0  0  2  0 NA  2  0  0  0  1  1  1 NA NA  0 NA  0 NA  2
##
## $`2`
##  [1] NA  0  0  1  1 NA  0  0  2  1  0  0  2 NA  0  1  1 NA NA  1  1  2  0  0  2
## [26] NA  1  1  2  0  2  2  1  1  1 NA NA NA  0  2  1  1  2  0  1 NA NA NA NA NA
##
## $`3`
##  [1]  2  1  2  0  1 NA  1  0 NA NA  2  2  1  2  2  2  2 NA  0 NA  0  2  1  1  0
## [26]  0  0  0 NA NA  0  0 NA NA  2 NA NA  0  2  0 NA  2  0  1  1  0  1  2  0  1
```

```
##
## $`4`
##  [1]  2  0  2  0  1  2  0  0 NA  1 NA NA NA  0  1  0  0  2  0 NA  0  0  1  1  1
## [26] NA  0  0  0  1  0  2 NA  1  0  0  2  2  2  0  0 NA  2  1  0 NA  0 NA  0 NA
##
## $`5`
##  [1]  0  2  2  0  2 NA  2 NA  1 NA  1 NA NA NA NA  0 NA  1  0 NA  0 NA NA  0  0
## [26] NA  0  0 NA  2  1  0 NA NA  1  0  0  0  0 NA  1 NA  0 NA  0  1 NA  1 NA  2
##
## $`6`
##  [1]  1  0  0  0 NA  0  1  2  1 NA NA  1  2  0  1 NA  2  1 NA  1 NA NA  2  0  2
## [26]  0  1  0  1 NA  0 NA  2  0  0  0  2 NA  2  0  2  1  1  2  1  1 NA  0  0 NA
##
## $`7`
##  [1]  1 NA  0  0 NA  1  2 NA  1  0  2  2 NA  1  0  0  0 NA  2  0  2 NA  1  0  0
## [26]  2 NA NA  0  0  1  0  1  1  2  1  1  1 NA NA NA  1 NA  2  0 NA  0 NA  1  1
##
## $`8`
##  [1]  0  1 NA  1  1 NA NA  1  1 NA NA NA  2  0  0  2  2 NA NA  2  1  1  0  0 NA
## [26]  1  0  1  1  1  2  1  0 NA  1 NA  0  0 NA  0  0  1  2 NA NA NA  2  2  0 NA
##
## $`9`
##  [1]  2  0  1  0  2 NA  1  0 NA  0  1  0  0  2  1 NA NA NA  2  0  2  0  0  0  2
## [26]  1  0 NA  0  0  0  0  1  0 NA  0 NA  0  2  2  0 NA  0  0  0  1  0  1 NA  0
##
## $`10`
##  [1]  0 NA  1  1  0 NA NA NA  2  2  0  0 NA  0  2  0 NA  0  2  1 NA  2  1  1  2
## [26] NA NA  0  0  2  1  0  2  0  0  1  0  0 NA  1  0  0  1  0 NA  1 NA  2  1 NA
##
## $`11`
##  [1]  0  0 NA  2 NA NA  2  0  1  0  2  0  2 NA NA  1  1  0  0 NA  1 NA  2  1  2
## [26]  0  1 NA NA  0 NA  0  0  2  0 NA  2  0  2  0  0  0  1 NA NA NA  1 NA  0  0
##
## $`12`
##  [1]  2  0  2 NA  1  1  0  1  2 NA NA  0  2 NA  2  0  1  2  2  1  1  0  0  0  2
## [26]  1  0 NA NA  0  0 NA  0 NA  2  0  0  0  0 NA NA NA  1  2  0  0  1 NA  2  0
##
## $`13`
##  [1]  1  1 NA  2  2  2  2  1 NA  1  0 NA  0  1 NA  0 NA NA  1 NA NA  2 NA  2  2
## [26]  2  2  0  1  0  1  2  0  0  1  1  0  0  1  0  0 NA  1 NA  1 NA NA  0 NA  2
##
## $`14`
##  [1]  0 NA  1  2 NA  2  0 NA  1  2  0 NA  0 NA NA  0 NA  0 NA  2  2  2  1  0  1
## [26]  0  2 NA  1  0  2 NA  0 NA  2 NA  2  0  2  0 NA  0  0 NA  1  2 NA  0  0 NA
##
## $`15`
##  [1]  0 NA NA  1 NA  0  1 NA NA NA NA NA  0 NA  1 NA NA  0  0  0  1  0 NA  0  0
## [26]  0  2 NA  0 NA  0  0 NA NA  0  0 NA  0  0 NA  1 NA  1  0  0  1  0  1  0  1
##
## $`16`
##  [1]  2  2  1  2  1 NA  2  2 NA NA NA  2  1 NA  2  2  2 NA NA  2  0  0  2  2 NA
## [26] NA  0  2  0 NA NA  0  1  0 NA  0 NA NA NA  1  2  1  2  2  2 NA  0 NA  2  2
##
## $`17`
```

```
##  [1]  0  0  2  1  1 NA  0  2  1  2  0 NA  0  0  0 NA NA  0 NA  0 NA  0  0 NA  2
## [26]  2  2 NA NA NA  0  0  2 NA  2  0  0  0 NA  1 NA  1  0 NA NA NA NA NA NA  1
##
## $`18`
##  [1] NA NA  0  1  2  0  1  0 NA  0 NA  0  0 NA  2  0  0 NA  2 NA  0  0 NA  2  0
## [26] NA NA  0  0 NA  0 NA  2  1  1  1  0  1  0  1 NA  2  2 NA  2  1  2  1  0  1
##
## $`19`
##  [1]  0 NA  0  0 NA  2  0  0  0  2  2  0 NA  0 NA  0  0 NA  2  2  0  0  0  1 NA
## [26]  1 NA NA  0 NA NA NA  1  1  2 NA NA  2 NA  1  0  0  0  0  0  2  1  1  0  2
##
## $`20`
##  [1] NA  2  1  1 NA  1  0 NA  0 NA NA  0  0  1  0  0  2  2  2  0  1  2 NA  2  1
## [26]  1  0 NA  2 NA  0  0  1  2  0  2  2  2  0 NA NA  1 NA NA  0 NA  2  2  0  0
##
## $`21`
##  [1] NA  2 NA  1  2  0 NA NA NA  2 NA NA  1 NA  0  2  0  1 NA  0  1 NA  2  0  1
## [26]  2  1  0 NA  0  0  2  1  0 NA NA  1  2  2 NA  0  0  0  0  2 NA  0  0  0  2
##
## $`22`
##  [1]  0 NA  0  0 NA  2  1  0  1 NA NA  0  2  0 NA NA  1 NA NA  2  0 NA  0  0 NA
## [26]  0 NA  2  2  0  0 NA NA NA  0 NA  0 NA  2  2 NA  0 NA NA  2 NA  0  0 NA  1
##
## $`23`
##  [1] NA  0  1  2  2  1  0 NA NA  1  2  2  0  2  1  0 NA  0 NA  1  0  0 NA NA  2
## [26]  0  0  1 NA  2  2  2 NA  2  0 NA NA NA NA  2  0  0 NA  0  2  1  1  0 NA  0
##
## $`24`
##  [1]  2  0 NA NA NA NA  1  0  0  0  2  0  1  0  2  1 NA NA  1 NA  0  0  1  0  1
## [26]  2 NA NA  0  1  0  1  2 NA NA  0 NA NA  0  2  1  1  1 NA  0  0 NA  0  1  2
##
## $`25`
##  [1] NA  0  0  1  0  2  0  0 NA NA  2 NA  0  0 NA  1  1  2  0  1  0  2  0 NA  1
## [26]  0 NA NA NA NA  0  0  1  0  1 NA  2 NA NA  2 NA  1 NA  0 NA  0 NA  0 NA  0
##
## $`26`
##  [1] NA  0  2  0  1 NA  0  1 NA NA NA  1 NA  0  0  0  0  1  2  1  0  2  0  0  0
## [26]  0  0  2  1  0  1 NA  0  0  2  0  0  0 NA NA  1  0  1 NA NA  0 NA NA  1  0
##
## $`27`
##  [1]  1  0 NA NA  2  2  2  0  0  0  1 NA  1  0  0  1 NA NA NA NA  0  0 NA NA  2
## [26]  1  2 NA  1  2  0 NA NA  0  0 NA  1 NA  2 NA  1 NA  0  1  0  2 NA  0  0 NA
##
## $`28`
##  [1] NA  1  0  0  0  0 NA NA  1 NA  2  0  1  2  0  2 NA  1  2  2  0  0  1  1  2
## [26] NA  1  0 NA  1 NA  0  1  0  0 NA  1  1 NA NA NA  0  0 NA NA  2  0  0 NA NA
##
## $`29`
##  [1] NA NA  2  0  1 NA NA NA  1  1  0 NA  0  0  0  0  0 NA NA  0  0 NA  0  0 NA
## [26] NA  0  0  2  1 NA NA  1  2  0  1  1  0 NA NA  0  2  0 NA  0  2  2 NA  0 NA
##
## $`30`
##  [1] NA  1  1  2  0  2  0  2  0 NA  0  1  0 NA  0  0 NA NA  1 NA  1  0  0  0  2
## [26] NA  0  0  0 NA  1 NA  0 NA NA  1  2  0  0  1  0 NA  2  0  0 NA NA  2  0  0
```

```
##
## $`31`
##  [1]  0 NA NA  2  1  2 NA  0  0 NA  0  0  2  1 NA NA  0 NA  0  2  1  0  2  2 NA
## [26]  2 NA NA  2  0 NA  2  0 NA NA  1  1  2  0 NA  1 NA  0  0  0  0 NA  0 NA  1
##
## $`32`
##  [1]  2 NA  0  2  1  1  0  0  2  0  0  0 NA  0  0  0  0  2 NA  0  0  2  2 NA NA
## [26]  0 NA  2 NA  0  0  0  0  1  2  0  0  2  1 NA  2 NA  1  0  2  0  0  0 NA  1
##
## $`33`
##  [1]  0 NA  0 NA  1 NA  0  0  1  0  1 NA  2  1  2 NA  0  0  0  0 NA  2  1 NA  2
## [26]  2  0 NA NA  0  2 NA  0 NA  1 NA  1 NA  2  0  2  0 NA  2  1  0  0  0  2  0
##
## $`34`
##  [1]  0 NA  0  0  0  1 NA  1  1 NA NA NA  1  0  1  1  2  0 NA  1  2  1  2 NA  1
## [26] NA NA  2 NA  1 NA NA  2  1  2  0  0  2  0 NA  0  1 NA NA  0 NA  0 NA  0 NA
##
## $`35`
##  [1] NA NA NA  1  1  0  2 NA  0  0  1  1  1  2 NA  2  1 NA NA  1 NA NA NA  0  1
## [26]  0  0  0  1  1  0  2  0  1  2  2  2  1  2 NA  2  0  2  0  2 NA  2  2  1  2
##
## $`36`
##  [1]  2  0  0  1  1  0  0  0  0  2 NA NA NA  0  0  1  1 NA NA  0  0 NA  1 NA  1
## [26]  1 NA  2 NA NA  0 NA NA  2  2 NA  2 NA NA NA  0 NA NA  1  0 NA  1 NA NA  0
##
## $`37`
##  [1]  0  0 NA NA  1 NA NA  2 NA  0  2  2 NA NA NA NA  1  0  1  1  0  1  2 NA NA
## [26]  0  2  0  1  2 NA NA  0 NA NA  1  0  0  2  0 NA NA  2  0  2 NA  0 NA NA  1
##
## $`38`
##  [1] NA  1 NA  1  0  0  0  0 NA  0  1 NA NA NA  0  2  0 NA  1  2 NA  2  1  0 NA
## [26]  0  0 NA NA  2  0  0  0 NA NA  0 NA NA  0  0  0 NA NA  0  2  1  2 NA NA  0
##
## $`39`
##  [1]  0  1  0  1  0  1  2  0  2 NA  2  1  0  1  2  1  0  1  0  0 NA  2  0 NA NA
## [26]  1 NA NA NA NA NA  2 NA NA  2  0 NA NA  0  0 NA NA  0 NA  0 NA  0  0  0  0
##
## $`40`
##  [1] NA  1 NA  0  0  0  0 NA NA  2 NA  2  0  0 NA NA  2 NA  0 NA  2 NA  1  2  1
## [26] NA NA NA  1  2 NA  0 NA  0 NA NA NA  1  1  0  0  2 NA  0 NA NA  1 NA  0  0
##
## $`41`
##  [1] NA  2  2 NA  0  0  0 NA  2  0  2  1 NA  1 NA  0  0 NA  0  0  0  2  2  2  0
## [26]  1  2  1  2  1 NA  0  0  0 NA NA  0 NA  0  2 NA NA  0  0  0  0  1  0  2 NA
##
## $`42`
##  [1]  2  0  0 NA  0  0  1  2 NA  1 NA  0  1  0  0 NA  0  2  1  2  0 NA  1  0 NA
## [26]  0  0  2  1  0  0  1 NA  2  1 NA  0 NA NA  0 NA NA  1  0 NA  1  2  1 NA NA
##
## $`43`
##  [1]  1  2  1 NA  0  2  1  0 NA  2  2  0 NA  0  0  0  2  2 NA  0  0  1  0  0  2
## [26]  0  2  1  0  0  1  0  1  1 NA NA NA  0  1  2  2  2  1 NA  2  2 NA NA NA  1
##
## $`44`
```

```
##  [1] NA  0 NA  0  2  0  0  0  0  0  0  1 NA  2  1  1 NA  0  0  0  0  0  2  2 NA
## [26] NA NA  2 NA  2 NA NA  0  0  0  0  0  2 NA  1  1 NA  0  1  0  0  0 NA NA NA
##
## $`45`
##  [1] NA NA  0 NA  0 NA  1  1  2 NA  2 NA  0 NA  0 NA NA  0 NA NA NA  0  0  0  0
## [26] NA NA  2 NA NA NA  0  0 NA NA  1  2  0  0  2  2  0  0  0  0  0  0  0  2 NA
##
## $`46`
##  [1] NA  1  0  2  0  1  0  1  0 NA  2  2  0  1  1  0  2 NA  2 NA  0  2  0 NA  2
## [26] NA  2  1 NA  0  2  0  0  1  2 NA  1  0 NA NA  0  0  2  2  2  0  2  0 NA  0
##
## $`47`
##  [1]  0 NA  0 NA  0  0  0  0  2  1  2  0 NA  1  0  0  0  2  2  2  0  1  1 NA  1
## [26]  1  0 NA  0  0  0  0  0 NA  1 NA  2 NA  0  1  0  0  2  0 NA  0  1  0 NA  2
##
## $`48`
##  [1] NA NA  2 NA  0  0 NA NA  2  0  0  2  0  2 NA NA NA NA NA NA  2  0  1  0 NA
## [26]  2  0 NA NA NA  0  1 NA  1 NA  2  0  2 NA NA  0  2 NA NA NA NA  2  2  0  2
##
## $`49`
##  [1]  0 NA  2 NA  0  2 NA  0  0  2  1  0 NA  0  1 NA  1  1 NA  0  0 NA  0  2 NA
## [26]  1  1 NA  1  1 NA  0 NA NA  0 NA  1  2  1  0  0  0  2 NA  2  1 NA  0  0  0
##
## $`50`
##  [1]  0  0  0  2 NA NA  0  0 NA  2  0 NA  1 NA  0  1  0 NA  0  0  1 NA  1  0  0
## [26]  2 NA NA  0  2  2  0  0  1  0  1  0  0  0  0  0 NA NA  0  0  0  2  0  0  1
```

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

```
lapply(1:50, function(n){
  column=R[ , n]
  list(
    min = min(column, na.rm = TRUE),
    max = max(column, na.rm = TRUE),
    pct_missing = mean(is.na(column)),
    first_NA = which(is.na(column))[1]
  )
})
```

```
## [[1]]
## [[1]]$min
## [1] 0
##
## [[1]]$max
## [1] 2
##
## [[1]]$pct_missing
## [1] 0.32
##
## [[1]]$first_NA
```

```
## [1] 3
##
##
## [[2]]
## [[2]]$min
## [1] 0
##
## [[2]]$max
## [1] 2
##
## [[2]]$pct_missing
## [1] 0.28
##
## [[2]]$first_NA
## [1] 1
##
##
## [[3]]
## [[3]]$min
## [1] 0
##
## [[3]]$max
## [1] 2
##
## [[3]]$pct_missing
## [1] 0.24
##
## [[3]]$first_NA
## [1] 6
##
##
## [[4]]
## [[4]]$min
## [1] 0
##
## [[4]]$max
## [1] 2
##
## [[4]]$pct_missing
## [1] 0.22
##
## [[4]]$first_NA
## [1] 9
##
##
## [[5]]
## [[5]]$min
## [1] 0
##
## [[5]]$max
## [1] 2
##
## [[5]]$pct_missing
## [1] 0.4
```

```
##
## [[5]]$first_NA
## [1] 6
##
##
## [[6]]
## [[6]]$min
## [1] 0
##
## [[6]]$max
## [1] 2
##
## [[6]]$pct_missing
## [1] 0.24
##
## [[6]]$first_NA
## [1] 5
##
##
## [[7]]
## [[7]]$min
## [1] 0
##
## [[7]]$max
## [1] 2
##
## [[7]]$pct_missing
## [1] 0.28
##
## [[7]]$first_NA
## [1] 2
##
##
## [[8]]
## [[8]]$min
## [1] 0
##
## [[8]]$max
## [1] 2
##
## [[8]]$pct_missing
## [1] 0.32
##
## [[8]]$first_NA
## [1] 3
##
##
## [[9]]
## [[9]]$min
## [1] 0
##
## [[9]]$max
## [1] 2
##
```

```
## [[9]]$pct_missing
## [1] 0.2
##
## [[9]]$first_NA
## [1] 6
##
##
## [[10]]
## [[10]]$min
## [1] 0
##
## [[10]]$max
## [1] 2
##
## [[10]]$pct_missing
## [1] 0.26
##
## [[10]]$first_NA
## [1] 2
##
##
## [[11]]
## [[11]]$min
## [1] 0
##
## [[11]]$max
## [1] 2
##
## [[11]]$pct_missing
## [1] 0.3
##
## [[11]]$first_NA
## [1] 3
##
##
## [[12]]
## [[12]]$min
## [1] 0
##
## [[12]]$max
## [1] 2
##
## [[12]]$pct_missing
## [1] 0.24
##
## [[12]]$first_NA
## [1] 4
##
##
## [[13]]
## [[13]]$min
## [1] 0
##
## [[13]]$max
```

```
## [1] 2
##
## [[13]]$pct_missing
## [1] 0.28
##
## [[13]]$first_NA
## [1] 3
##
##
## [[14]]
## [[14]]$min
## [1] 0
##
## [[14]]$max
## [1] 2
##
## [[14]]$pct_missing
## [1] 0.32
##
## [[14]]$first_NA
## [1] 2
##
##
## [[15]]
## [[15]]$min
## [1] 0
##
## [[15]]$max
## [1] 2
##
## [[15]]$pct_missing
## [1] 0.38
##
## [[15]]$first_NA
## [1] 2
##
##
## [[16]]
## [[16]]$min
## [1] 0
##
## [[16]]$max
## [1] 2
##
## [[16]]$pct_missing
## [1] 0.34
##
## [[16]]$first_NA
## [1] 6
##
##
## [[17]]
## [[17]]$min
## [1] 0
```

```
##
## [[17]]$max
## [1] 2
##
## [[17]]$pct_missing
## [1] 0.38
##
## [[17]]$first_NA
## [1] 6
##
##
## [[18]]
## [[18]]$min
## [1] 0
##
## [[18]]$max
## [1] 2
##
## [[18]]$pct_missing
## [1] 0.28
##
## [[18]]$first_NA
## [1] 1
##
##
## [[19]]
## [[19]]$min
## [1] 0
##
## [[19]]$max
## [1] 2
##
## [[19]]$pct_missing
## [1] 0.28
##
## [[19]]$first_NA
## [1] 2
##
##
## [[20]]
## [[20]]$min
## [1] 0
##
## [[20]]$max
## [1] 2
##
## [[20]]$pct_missing
## [1] 0.26
##
## [[20]]$first_NA
## [1] 1
##
##
## [[21]]
```

```
## [[21]]$min
## [1] 0
##
## [[21]]$max
## [1] 2
##
## [[21]]$pct_missing
## [1] 0.3
##
## [[21]]$first_NA
## [1] 1
##
##
## [[22]]
## [[22]]$min
## [1] 0
##
## [[22]]$max
## [1] 2
##
## [[22]]$pct_missing
## [1] 0.42
##
## [[22]]$first_NA
## [1] 2
##
##
## [[23]]
## [[23]]$min
## [1] 0
##
## [[23]]$max
## [1] 2
##
## [[23]]$pct_missing
## [1] 0.3
##
## [[23]]$first_NA
## [1] 1
##
##
## [[24]]
## [[24]]$min
## [1] 0
##
## [[24]]$max
## [1] 2
##
## [[24]]$pct_missing
## [1] 0.3
##
## [[24]]$first_NA
## [1] 3
##
```

```
##
## [[25]]
## [[25]]$min
## [1] 0
##
## [[25]]$max
## [1] 2
##
## [[25]]$pct_missing
## [1] 0.36
##
## [[25]]$first_NA
## [1] 1
##
##
## [[26]]
## [[26]]$min
## [1] 0
##
## [[26]]$max
## [1] 2
##
## [[26]]$pct_missing
## [1] 0.26
##
## [[26]]$first_NA
## [1] 1
##
##
## [[27]]
## [[27]]$min
## [1] 0
##
## [[27]]$max
## [1] 2
##
## [[27]]$pct_missing
## [1] 0.36
##
## [[27]]$first_NA
## [1] 3
##
##
## [[28]]
## [[28]]$min
## [1] 0
##
## [[28]]$max
## [1] 2
##
## [[28]]$pct_missing
## [1] 0.32
##
## [[28]]$first_NA
```

```
## [1] 1
##
##
## [[29]]
## [[29]]$min
## [1] 0
##
## [[29]]$max
## [1] 2
##
## [[29]]$pct_missing
## [1] 0.36
##
## [[29]]$first_NA
## [1] 1
##
##
## [[30]]
## [[30]]$min
## [1] 0
##
## [[30]]$max
## [1] 2
##
## [[30]]$pct_missing
## [1] 0.28
##
## [[30]]$first_NA
## [1] 1
##
##
## [[31]]
## [[31]]$min
## [1] 0
##
## [[31]]$max
## [1] 2
##
## [[31]]$pct_missing
## [1] 0.34
##
## [[31]]$first_NA
## [1] 2
##
##
## [[32]]
## [[32]]$min
## [1] 0
##
## [[32]]$max
## [1] 2
##
## [[32]]$pct_missing
## [1] 0.2
```

```
##
## [[32]]$first_NA
## [1] 2
##
##
## [[33]]
## [[33]]$min
## [1] 0
##
## [[33]]$max
## [1] 2
##
## [[33]]$pct_missing
## [1] 0.28
##
## [[33]]$first_NA
## [1] 2
##
##
## [[34]]
## [[34]]$min
## [1] 0
##
## [[34]]$max
## [1] 2
##
## [[34]]$pct_missing
## [1] 0.36
##
## [[34]]$first_NA
## [1] 2
##
##
## [[35]]
## [[35]]$min
## [1] 0
##
## [[35]]$max
## [1] 2
##
## [[35]]$pct_missing
## [1] 0.24
##
## [[35]]$first_NA
## [1] 1
##
##
## [[36]]
## [[36]]$min
## [1] 0
##
## [[36]]$max
## [1] 2
##
```

```
## [[36]]$pct_missing
## [1] 0.42
##
## [[36]]$first_NA
## [1] 11
##
##
## [[37]]
## [[37]]$min
## [1] 0
##
## [[37]]$max
## [1] 2
##
## [[37]]$pct_missing
## [1] 0.4
##
## [[37]]$first_NA
## [1] 3
##
##
## [[38]]
## [[38]]$min
## [1] 0
##
## [[38]]$max
## [1] 2
##
## [[38]]$pct_missing
## [1] 0.38
##
## [[38]]$first_NA
## [1] 1
##
##
## [[39]]
## [[39]]$min
## [1] 0
##
## [[39]]$max
## [1] 2
##
## [[39]]$pct_missing
## [1] 0.34
##
## [[39]]$first_NA
## [1] 10
##
##
## [[40]]
## [[40]]$min
## [1] 0
##
## [[40]]$max
```

```
## [1] 2
##
## [[40]]$pct_missing
## [1] 0.44
##
## [[40]]$first_NA
## [1] 1
##
##
## [[41]]
## [[41]]$min
## [1] 0
##
## [[41]]$max
## [1] 2
##
## [[41]]$pct_missing
## [1] 0.26
##
## [[41]]$first_NA
## [1] 1
##
##
## [[42]]
## [[42]]$min
## [1] 0
##
## [[42]]$max
## [1] 2
##
## [[42]]$pct_missing
## [1] 0.3
##
## [[42]]$first_NA
## [1] 4
##
##
## [[43]]
## [[43]]$min
## [1] 0
##
## [[43]]$max
## [1] 2
##
## [[43]]$pct_missing
## [1] 0.22
##
## [[43]]$first_NA
## [1] 4
##
##
## [[44]]
## [[44]]$min
## [1] 0
```

```
##
## [[44]]$max
## [1] 2
##
## [[44]]$pct_missing
## [1] 0.3
##
## [[44]]$first_NA
## [1] 1
##
##
## [[45]]
## [[45]]$min
## [1] 0
##
## [[45]]$max
## [1] 2
##
## [[45]]$pct_missing
## [1] 0.4
##
## [[45]]$first_NA
## [1] 1
##
##
## [[46]]
## [[46]]$min
## [1] 0
##
## [[46]]$max
## [1] 2
##
## [[46]]$pct_missing
## [1] 0.22
##
## [[46]]$first_NA
## [1] 1
##
##
## [[47]]
## [[47]]$min
## [1] 0
##
## [[47]]$max
## [1] 2
##
## [[47]]$pct_missing
## [1] 0.2
##
## [[47]]$first_NA
## [1] 2
##
##
## [[48]]
```

```
## [[48]]$min
## [1] 0
##
## [[48]]$max
## [1] 2
##
## [[48]]$pct_missing
## [1] 0.46
##
## [[48]]$first_NA
## [1] 1
##
##
## [[49]]
## [[49]]$min
## [1] 0
##
## [[49]]$max
## [1] 2
##
## [[49]]$pct_missing
## [1] 0.3
##
## [[49]]$first_NA
## [1] 2
##
##
## [[50]]
## [[50]]$min
## [1] 0
##
## [[50]]$max
## [1] 2
##
## [[50]]$pct_missing
## [1] 0.22
##
## [[50]]$first_NA
## [1] 5
```

```
result_list <- lapply(R, function(col) list(min = min(col, na.rm = TRUE), max = max(col, na.rm = TRUE),
```

```
## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf
```

```
## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf
```

```
## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf
```

```
## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf
```

```
## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf
```

```
## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf
```

```
## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf
```

```
## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf
```

```
## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

## Warning in min(col, na.rm = TRUE): no non-missing arguments to min; returning
## Inf

## Warning in max(col, na.rm = TRUE): no non-missing arguments to max; returning
## -Inf

## Warning in min(which(!complete.cases(col))): no non-missing arguments to min;
## returning Inf

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```

- 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(1984)
v = rnorm(1000, mean = -10, sd = sqrt(100))
v
```

```
##    [1]  -5.907967837848 -13.230249711542  -3.641476728099 -28.461287840183
##    [5]  -0.463526345932   1.884898434527  -4.575455508365 -18.327254297791
##    [9] -15.262078844968   4.159827577661  -7.179889961089  -7.120662839077
##   [13]  -1.629517497472   0.239344591583  -9.822549038531   7.239940163302
##   [17]  -8.792581946274 -27.755604888401  -8.738544713872 -27.137578805260
##   [21]   2.419565681512  -5.702593853895 -16.486159297728  -0.966060191427
##   [25] -10.132181397739  -7.524822819274  -9.082818499712  -1.777153515054
##   [29] -15.863086046754   0.079884895602 -21.075868894090 -24.704241772855
```

```
##   [33]  -3.941626535813  -0.437010718166  -7.023340366897 -18.540283563095
##   [37]  15.043537483732 -12.885110625623 -13.414171677182  -7.566944854592
##   [41]  -9.505236602083  -1.990133477413 -11.096117546406 -23.391921634916
##   [45]   2.413408685243   1.844163655127 -14.567750979295   1.488720466005
##   [49] -16.665213892812   1.086566888100   2.433551595888 -16.300208079582
##   [53] -19.742576234419 -21.768072753930 -13.802778431831 -25.658038024179
##   [57] -16.482595589272 -18.241688010551 -16.894619981025 -10.165760888876
##   [61] -17.373002462482  -3.464473713071   6.659049799653 -13.321305243734
##   [65]   6.165060618426 -12.827467143342 -15.400284670377 -16.295196830202
##   [69]  -8.858491637950  -1.004302660494 -15.083693956850 -20.749370120806
##   [73]  -7.001793876345 -15.521919477345 -14.212968950599 -12.698072164255
##   [77]  -5.049670733834 -13.885928724155 -17.649676612805 -14.862037282777
##   [81]  -8.049045745867  -4.382631482206 -14.567309558063 -24.493760197247
##   [85]  -8.410937198140   1.713361217610 -14.720721343185 -18.831191856760
##   [89]  12.241012961202 -11.088447670934 -10.780651567418 -15.831032592703
##   [93] -28.406454759483   1.695408930296   2.435150380876  -2.631564364475
##   [97] -14.358805528767 -17.592505011760   4.049569284674 -23.172188266200
##  [101]  -7.879751588063 -21.319399604980  -5.253177064529 -17.270474137982
##  [105]  13.227819475928 -16.292793210798 -21.821565209665 -10.108592633176
##  [109] -15.445859335521 -11.220809642277 -22.579709047418  -4.192769747001
##  [113] -13.520318820538  -6.113335687084 -11.557133250441 -18.800990882444
##  [117] -25.304083452334 -13.589279914083   2.429299728249   0.570734650090
##  [121] -11.000496522589 -23.389355173269  -0.483385834283 -18.244146028459
##  [125] -10.164068610706  -0.440215338231  -1.615417652724 -16.582196348099
##  [129] -12.942885941587 -12.285283135299 -17.394519397224 -21.285678626194
##  [133] -10.143975759934  -0.393138709567  -8.959825919445   9.287073372188
##  [137] -11.980988389462 -27.661027280500 -19.093465856646  -1.123038674641
##  [141]  -3.112646264292 -26.673999255343 -19.344306610818  -8.777229397747
##  [145] -15.051440042064  -4.423859629458 -11.564024080641  -5.163291482224
##  [149] -36.418631696018   6.854775777339 -15.990068769031  -0.910574549707
##  [153]  -1.688020714881  -1.476077303500 -20.906549236909 -14.191691955532
##  [157] -16.896340546112  -1.401676233388  -7.201499375011 -19.259043541469
##  [161] -10.997795405381 -10.713773019271  -7.464686074121 -12.212801514453
##  [165] -12.388043119996 -13.064274160836 -12.874575170328 -31.105916505358
##  [169] -14.203826790807  -9.539991533779 -10.894715446609 -10.820980389922
##  [173]  -7.304629514025 -35.769294802098   0.752112928745   3.726943647744
##  [177] -21.881178852076   9.188975131770 -16.657397669512 -10.813516107026
##  [181]  -8.103999052844 -20.800994917407  -4.210874478890  -2.117733035486
##  [185] -18.909043715714  -8.615838471917 -21.923244363360 -10.936292659635
##  [189]  -4.603019466692  -3.172761926535 -11.732138682117 -17.490394782113
##  [193] -23.732475277553   1.426375676840   1.008098510431  -7.064687878542
##  [197]   4.748953178030 -13.019355856452  -1.285150417710  -1.963289931885
##  [201] -12.481528001114  -8.656481870154 -16.870429133637 -16.927508118387
##  [205] -12.848990628530  -7.195425835717 -17.449784307604 -21.399208107464
##  [209] -21.100783063785 -19.499084208761  -8.042964192706 -11.296324270516
##  [213]  10.463493457482 -22.947859415248 -19.316140097778  -1.226497233014
##  [217] -10.506181574521 -20.733794220824  -8.699243250622 -12.071578583631
##  [221] -10.032840378538 -18.552060616865 -16.269728934031 -20.409276351113
##  [225]   0.303448901382 -14.281653835455  17.323465736565 -20.921447288450
##  [229]  -3.515407274625 -20.409512570056 -15.280293165995 -12.720127823532
##  [233] -15.827845910575 -18.264471427469  -0.657805250830 -18.662170035406
##  [237]  -8.798509639946 -36.117488827543 -21.476608683333 -16.469819284430
##  [241] -14.175947498281   4.355943448218  -1.416029803095 -11.075370039267
##  [245]  -2.665790934636  -0.535948556907 -17.881662275682   7.820248935160
```

```
##  [249] -22.436815366911 -24.258688546876  16.130540363414 -14.136750884748
##  [253]  -2.715420499469   0.496226416136  -0.808340055030 -16.315756160382
##  [257] -12.673371205995  -9.937855279209 -14.273729499485  -5.073282031037
##  [261] -11.522713054223   0.876445073960 -10.519955278107  -6.731176388956
##  [265] -10.769451555755  -4.637561693192   0.028611698593  -2.694812662126
##  [269] -15.739656750104 -20.506762485241  -7.351332141586 -36.452300687178
##  [273] -13.837302669591 -27.947268623835   0.108822407068  -5.739633467294
##  [277]  -3.871617773590   1.885998355699 -16.522282041095 -21.775160138229
##  [281]  -0.060037225553 -18.912748287671   2.765917537768 -20.981307373965
##  [285] -16.680454737034 -13.273650030875 -23.393934493673 -25.793503654633
##  [289]  -0.190753384703  -5.154931274367 -19.460353814415 -11.785024137145
##  [293] -20.979996826494 -20.838989883113  -3.165014417318 -14.839167888403
##  [297] -11.317729496136  -5.332116376795 -12.188243769223 -13.967688057996
##  [301]  -9.295509521372 -15.052289167383  -9.360786531757  -4.192678742600
##  [305]  -8.348648468926 -31.301770697135 -29.329902619032   5.544880344353
##  [309]  -9.871539886944  -3.905640963104  -7.287178884539 -21.995362586758
##  [313]  -0.080470852660 -16.666840477431  -4.669569201240   0.370911173633
##  [317] -10.653258367436   4.671293101751 -12.353629140039  13.553788203311
##  [321]   3.806083401774 -13.585889447945   3.222199058553   2.508451264930
##  [325] -19.950984243812 -21.378209578435 -13.850683195657  -3.631332870780
##  [329] -17.035650587295 -18.230616826056  -7.533150641651 -11.823589111847
##  [333] -13.243559595414 -11.320464629371 -14.143129106299 -10.195474234454
##  [337]  -6.511340343784  -8.912760383219  -0.414650025364 -10.501162155552
##  [341] -23.652234829064  -5.959653434834 -17.352375249251 -24.111516551579
##  [345]  -2.424698423065   1.975708313105 -21.362344389827 -25.516506747560
##  [349] -11.377548628837 -15.390354626410 -31.137015785045  -1.160938203500
##  [353] -19.377985710845 -18.287923989528 -13.705556890629 -11.375601091558
##  [357]   4.875659387303   2.864997746061 -32.012858809437  -2.638440038843
##  [361]  -8.478000242231  -5.405785712991 -16.892520789861  -6.936036269504
##  [365]  -7.447241593357  -9.721933037352 -11.885865658399 -16.537068104134
##  [369] -17.627134733980  -3.062658730968  -6.002217115931 -12.023507306357
##  [373] -12.327543803221   6.119626314299  -4.983114962191 -14.399007658295
##  [377]  -4.013288360791  -1.883170272478 -15.102679547797 -11.050272170434
##  [381] -14.363243147620  -4.464214043029  -2.629156535275  14.502319261124
##  [385] -31.321871328736  -3.539593168041 -20.894417832653  -9.450165991637
##  [389]  -1.225885888899  -7.415846090362  -1.649700469415   4.350227400892
##  [393]  -5.010632080886 -23.800476936127  -6.817542711522 -31.502239765334
##  [397] -11.047175613040  -6.622695881386  11.237629339891 -18.703758956861
##  [401]  -2.205454783091 -21.321996562884 -25.855691241136  -7.921666743598
##  [405]  -9.143811026381  -8.218372648966  -8.584126343044  14.681311922425
##  [409] -14.993470906826   6.616838199881 -27.343482016719 -21.682895202473
##  [413] -10.565585010288  -5.685463546366  -2.770541513744  -8.350238346628
##  [417] -11.826576647438 -18.722973104199  -7.933471222281 -14.927235102510
##  [421] -18.270578602393  -5.215961524815 -15.571616732356 -15.596811966398
##  [425]  -6.194221617798 -10.070238604443   2.315382744595  -8.067810855508
##  [429] -14.267075260544  -6.526527147017 -11.047580651524  -3.137368110646
##  [433] -18.245750888746 -30.552057037150 -23.814183527912  -8.582758008547
##  [437]   4.356459050377  -4.446465740489   5.819946746543  -6.129245841334
##  [441]   5.407106555049 -10.660886944598 -17.114772583616  -4.021091979941
##  [445] -13.869595237718  -4.830242261184  -7.895332493730 -10.872138296623
##  [449] -10.026750600324  -3.994633739237  -7.696606542032 -15.440426028858
##  [453]  -3.079332558114   6.259108187631 -19.114264576306   3.627537230302
##  [457]  -7.127879370304   3.524074837024 -12.540985685399   4.208205881425
##  [461] -28.781815973298 -12.671541013176  -5.332865574341 -17.230031395726
```

```
##  [465] -24.680622731835 -14.578427505458   8.718366880519 -10.153025011819
##  [469] -29.964890731059 -19.235425621797 -11.828824474634 -15.474793038822
##  [473]  -9.158717453615 -29.208401503265 -21.952455298257 -13.826007452325
##  [477] -17.019785250090 -10.129245105693   1.733863802217 -14.617985522934
##  [481]   0.235367029154   6.450253937556 -13.014461819738   1.448217192583
##  [485]  -3.192832405117 -13.134230654378 -15.597797706019 -12.829081378583
##  [489]  -6.266122903782 -11.875599885965 -14.232942706784  -1.292969758640
##  [493] -24.294342296176  -7.076236318416 -10.358180764982   0.139955520932
##  [497] -14.379240242927   0.322065338253   5.711308388404  12.256920288776
##  [501] -14.555500962659 -19.493648190935 -11.719753718798  -2.162891902173
##  [505]   3.976371252068 -26.579439344259 -15.331719279167 -11.990722368401
##  [509] -10.949414902123  -9.725280111563 -18.462022709099 -14.468065135914
##  [513] -11.920356634368 -21.084374805564   1.060806517513  -5.479358644945
##  [517] -12.353273309171 -22.338954349380 -25.119591964887 -34.624231785273
##  [521]  -6.569891829041   2.050389156138  -6.800072080707  -5.293094198328
##  [525]   4.383736120283 -11.270635721473 -10.545392846413 -17.473493128655
##  [529]   1.015595896583 -14.091697948425 -16.760754276234  -6.734904221588
##  [533] -15.490309351448 -17.228813280232  -0.079881218364  -8.923050153828
##  [537] -13.091375380636 -14.199899562882 -36.249558330412 -10.395774633912
##  [541] -13.470102605547 -24.291421578637 -17.094404273500  -8.263239754959
##  [545]  11.234068036702   2.610133414323 -19.046521659644   1.832498929591
##  [549] -10.921069394892   0.034455297857  -1.398068451037  -1.813306366622
##  [553] -24.221095233032 -17.644869052896  -4.644207116310 -10.034738354643
##  [557]   7.086038673258  -4.081394812980  -6.519796607461 -18.082339206840
##  [561] -14.545156559797  -6.070639784849 -34.983499401790  -8.776979782170
##  [565]  -7.965457546340 -32.361264555459 -15.150271005176 -19.148165100135
##  [569]  -5.779021112018  -5.931963334840  -6.365195393789   8.273378322711
##  [573]  -4.546625860587 -14.816368355185 -25.905741019258 -22.965478299249
##  [577]  18.075192110328  -5.920883762827 -15.894704145439 -11.200164333395
##  [581]  -1.405939184275 -13.697798386752 -13.119126033441 -11.379516451225
##  [585] -37.074451556222 -15.496907641250 -19.618370148513 -16.792911439902
##  [589]  -4.866461852037 -24.853940997907 -29.725135036892  -7.654416730168
##  [593] -16.295932239993  20.151469209636 -13.322685042422   6.940742013021
##  [597] -25.663733794587  -6.757755029319 -18.516812361399 -23.623185620267
##  [601]  -6.383344922303  -7.390285924840 -16.285803434962 -28.088962329960
##  [605] -10.495421649439  -5.502488207977 -15.033282742532  -8.910278058209
##  [609]   0.512003394753 -16.818292548619  -3.691836865301 -12.030644366977
##  [613] -18.418463286127  -3.801052817304  13.089558143522  -4.668255127423
##  [617] -18.844273991635  -6.470488648822  -8.467944989510  -3.664951564133
##  [621] -18.220547763016   0.357650322319 -26.434044453216  10.407809854215
##  [625] -10.788900099189 -23.033313441574 -15.033017754166  -2.880816350591
##  [629] -15.171146029940 -12.282494835785 -28.808009935254 -12.395999748514
##  [633]  -9.224246164120 -20.917442488056 -24.847987655300 -23.309909298221
##  [637] -20.636053579667   1.016725286760 -11.294704311803 -12.297229114023
##  [641]  -1.522031002062 -27.635161919387  -9.518945542057 -12.934459282048
##  [645]   0.505594760025 -12.193711036033  -8.280145619826 -21.808004721312
##  [649] -24.605469088986 -20.909805074367 -20.138092598866   3.246804042723
##  [653] -14.438000510211   1.217300386578 -30.664473120921   1.355879211553
##  [657] -28.664927449892 -22.500020744172 -20.361828823428 -10.095650478695
##  [661] -12.988514056496  -0.353703243674  -8.070403580153   3.251492573138
##  [665] -19.534374398250   7.014937713478 -11.524073469346 -24.799447757933
##  [669]  -8.527391442382 -26.791814522303 -13.303570721329  -7.059140197667
##  [673] -11.811353827334 -10.952040013190  10.270309057244  -3.283895463910
##  [677]  -6.670895772173  -8.271726884733  -1.625013805320  -3.083814034457
```

```
##  [681]  -7.689302588421  -7.667548822962  -6.939165371016  -5.646697276032
##  [685] -22.264596145893 -18.435448077518 -18.648650770261 -20.241192118467
##  [689] -21.027317571116  -2.736500183287 -12.850014512323 -24.077704497454
##  [693] -23.600655806012  -1.378681680281   1.925360185559   6.037197863199
##  [697] -12.131744796222 -20.632275908633  -9.320793585273 -13.211972497069
##  [701]  -1.381834095610 -23.306193759365 -10.037345196936 -23.852224526905
##  [705] -12.810797570694  -7.704551155983 -17.643989538282  -7.912312788601
##  [709]  10.130711932976  -5.182476894938   3.990215952453   1.257358979452
##  [713]  -7.744757196009  -7.453386074161  -6.912886264416  -1.747859909154
##  [717] -15.387032084497 -18.856485158014 -14.284205646933 -17.630527150499
##  [721]  -5.973156455445 -19.293096170008 -21.561668320724 -16.469840463653
##  [725]  -2.645310225514 -11.630181068026 -13.269773029785 -22.066786820106
##  [729] -23.535718246327 -22.921831868020 -22.460731450019  -9.194097583731
##  [733] -24.961788728513  -9.160624244011   8.767533033464 -15.289125031823
##  [737] -17.833353647457 -10.189036160689 -23.011310935238 -13.742595430912
##  [741] -14.596774871344 -12.498919911353 -11.795642145879 -21.971668253703
##  [745] -10.755296998140 -22.692931568827 -24.491900663328   1.358602220525
##  [749] -11.886169259088  -9.840675198682 -13.002490755053  10.196817306848
##  [753] -16.770163023441  10.520596183913 -32.888934358354  -3.836071446515
##  [757]  -2.825594924180   5.222152700027 -30.476401194871 -17.761650209474
##  [761]   1.163287296688 -13.245602348485  -6.816767463464  -4.053374520024
##  [765] -20.841630693010  -8.454074401458 -22.592800248113 -17.868129362409
##  [769]  -4.870512278589 -11.646716408076  -1.882013894074  -5.216040446776
##  [773] -24.724692654231  -8.081347295116   0.075142601202  -2.595774573009
##  [777]  -3.956522552684   2.836004511918 -15.427987440477 -16.728096137994
##  [781] -16.235706216531 -13.400996555262 -17.027197218526  -5.626307081955
##  [785] -21.279992876218   6.175452799584  -2.034637399608  -0.987570319110
##  [789] -30.721000707981   2.411869495672  -3.255317539253 -12.735896100006
##  [793] -13.574793779872 -20.136239520409 -16.115411018193   2.383242199250
##  [797]  -8.668264007508 -19.835627640429 -31.042141504609 -23.373248228689
##  [801] -18.674176331499 -11.818848083992 -12.138470145355   0.965961017079
##  [805]  -6.103533758463 -21.382939602587 -17.105425766300 -17.865370376538
##  [809] -11.214421288463  -5.486979570914  -2.890127739091 -27.683528121239
##  [813] -20.300215423144 -17.682174924247 -23.603745463959  -3.118999025381
##  [817]   6.992072305571  -9.220136340306 -12.662861162528   4.504170047680
##  [821]  -6.591060975043  -6.766576256497 -23.246911356221   1.195313668134
##  [825] -13.267236620648   3.805167481101   1.866820447964 -17.146761752978
##  [829] -14.716643083454 -20.587686508747  -5.862627404996  -3.357646076817
##  [833] -13.253337044886 -10.657245124878 -17.430851815142 -18.857815794514
##  [837]  -1.570414913321 -22.983821329745  -1.828951836073  -7.409274592819
##  [841] -22.243251475791  -8.385006744564 -18.546972774969 -13.640683500843
##  [845] -12.208594516976 -13.786681397402 -14.797433816646  -3.692713570951
##  [849]  -5.757700853492  -7.624217656462 -17.866840232006 -32.338761142262
##  [853]  -1.699971459628   4.274093673272 -12.943019145814  -5.346004927162
##  [857]   0.576473737031 -11.926587523145  -8.020020948113  -3.804940400593
##  [861]   7.418474128932  -6.881962690596   1.462574291375 -26.377141719257
##  [865]  -9.439039554436 -31.432286114822   9.296192256955  -7.278129105980
##  [869] -17.108840045471  -4.173688842575  16.832244966630 -14.170754881253
##  [873] -13.076863414513 -14.471540416624 -16.397904276812  -0.594558700914
##  [877]   0.655111536204  -4.124118076765 -23.993803075941 -11.934902243331
##  [881] -24.043704609620   4.929232838767  -4.974201447739  -4.396818561231
##  [885]   2.583795483214  -5.854809802245  -8.515997485576  -0.632613656023
##  [889]  -1.810246577249  -0.840016362101 -21.542492459438   1.406589479366
##  [893] -15.062480221766  -5.288125629505   4.518471778389  -1.627866678623
```

```
##  [897]   7.824685988660  -3.379611518472   4.328321561186  -6.991724341270
##  [901]  15.604521456049 -15.998362421540   6.759240162884 -11.091065339937
##  [905] -14.503382238486  -8.062595302692  -4.680961288146 -19.648129307928
##  [909]  -5.133941747158 -27.271084932827  -8.189517366368 -13.783325527097
##  [913]   0.775835008295 -24.924236717901   4.823427817493  -8.277910139633
##  [917] -18.432308414271 -15.496054534321 -10.492922671606 -26.661529285528
##  [921]  -6.371823984003 -11.551026691417   0.166512808679  -1.478373083754
##  [925] -19.195115577427  -2.508490616413 -21.266954368021  -7.326771716285
##  [929] -15.546732144415 -13.253557701186  -9.019487664448  -2.261330442106
##  [933]  -0.256667769085  -1.810942994580 -18.229719923919  15.067205185317
##  [937] -14.137841420159   4.916043498359  -8.536090458718 -20.557742188117
##  [941] -12.616347254563 -21.263577347676 -26.561000566661 -16.434811095816
##  [945] -12.116937160783 -17.708349873144  -9.529553483022  -3.519242270986
##  [949]  -2.785983145909  -9.652226706081   4.256032373663 -10.079037741626
##  [953] -20.881090388130  -9.520827512512  -2.909114042759  -3.545075397819
##  [957]  -8.112496881723 -25.065071197945 -11.227639418990  -3.084041925953
##  [961]  -4.089651133319 -21.802231017585 -26.619907286451  -4.541318223911
##  [965]   6.946753383932 -12.107801572086 -11.513590454149 -28.367633799160
##  [969]  -5.819835243973 -22.120006238393  -8.064739337816  -6.853646958583
##  [973] -30.536354845714  -4.741093905914  -4.138380817021 -27.545721102617
##  [977]  12.581803528468   0.408654403883 -11.179603552132 -19.761283307194
##  [981]  -4.459718417565   8.332551147257  -8.560509630305  -0.972337434717
##  [985]   5.609664333370  -2.752444433041  -4.046963301637 -31.109777308833
##  [989] -23.120062908659 -24.351341934072  -1.765302502889  -0.217312241380
##  [993]  -4.577909083109   3.489837076073  -7.861940827184 -11.654735703889
##  [997] -32.307206322589 -10.891012634756  -8.758025142259 -20.952176209139
```

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

```
set.seed(1984)
v = rnorm(1000, mean = -10, sd = sqrt(100))
v
```

```
##    [1]  -5.907967837848 -13.230249711542  -3.641476728099 -28.461287840183
##    [5]  -0.463526345932   1.884898434527  -4.575455508365 -18.327254297791
##    [9] -15.262078844968   4.159827577661  -7.179889961089  -7.120662839077
##   [13]  -1.629517497472   0.239344591583  -9.822549038531   7.239940163302
##   [17]  -8.792581946274 -27.755604888401  -8.738544713872 -27.137578805260
##   [21]   2.419565681512  -5.702593853895 -16.486159297728  -0.966060191427
##   [25] -10.132181397739  -7.524822819274  -9.082818499712  -1.777153515054
##   [29] -15.863086046754   0.079884895602 -21.075868894090 -24.704241772855
##   [33]  -3.941626535813  -0.437010718166  -7.023340366897 -18.540283563095
##   [37]  15.043537483732 -12.885110625623 -13.414171677182  -7.566944854592
##   [41]  -9.505236602083  -1.990133477413 -11.096117546406 -23.391921634916
##   [45]   2.413408685243   1.844163655127 -14.567750979295   1.488720466005
##   [49] -16.665213892812   1.086566888100   2.433551595888 -16.300208079582
##   [53] -19.742576234419 -21.768072753930 -13.802778431831 -25.658038024179
##   [57] -16.482595589272 -18.241688010551 -16.894619981025 -10.165760888876
##   [61] -17.373002462482  -3.464473713071   6.659049799653 -13.321305243734
##   [65]   6.165060618426 -12.827467143342 -15.400284670377 -16.295196830202
##   [69]  -8.858491637950  -1.004302660494 -15.083693956850 -20.749370120806
##   [73]  -7.001793876345 -15.521919477345 -14.212968950599 -12.698072164255
##   [77]  -5.049670733834 -13.885928724155 -17.649676612805 -14.862037282777
```

```
##   [81]  -8.049045745867  -4.382631482206 -14.567309558063 -24.493760197247
##   [85]  -8.410937198140   1.713361217610 -14.720721343185 -18.831191856760
##   [89]  12.241012961202 -11.088447670934 -10.780651567418 -15.831032592703
##   [93] -28.406454759483   1.695408930296   2.435150380876  -2.631564364475
##   [97] -14.358805528767 -17.592505011760   4.049569284674 -23.172188266200
##  [101]  -7.879751588063 -21.319399604980  -5.253177064529 -17.270474137982
##  [105]  13.227819475928 -16.292793210798 -21.821565209665 -10.108592633176
##  [109] -15.445859335521 -11.220809642277 -22.579709047418  -4.192769747001
##  [113] -13.520318820538  -6.113335687084 -11.557133250441 -18.800990882444
##  [117] -25.304083452334 -13.589279914083   2.429299728249   0.570734650090
##  [121] -11.000496522589 -23.389355173269  -0.483385834283 -18.244146028459
##  [125] -10.164068610706  -0.440215338231  -1.615417652724 -16.582196348099
##  [129] -12.942885941587 -12.285283135299 -17.394519397224 -21.285678626194
##  [133] -10.143975759934  -0.393138709567  -8.959825919445   9.287073372188
##  [137] -11.980988389462 -27.661027280500 -19.093465856646  -1.123038674641
##  [141]  -3.112646264292 -26.673999255343 -19.344306610818  -8.777229397747
##  [145] -15.051440042064  -4.423859629458 -11.564024080641  -5.163291482224
##  [149] -36.418631696018   6.854775777339 -15.990068769031  -0.910574549707
##  [153]  -1.688020714881  -1.476077303500 -20.906549236909 -14.191691955532
##  [157] -16.896340546112  -1.401676233388  -7.201499375011 -19.259043541469
##  [161] -10.997795405381 -10.713773019271  -7.464686074121 -12.212801514453
##  [165] -12.388043119996 -13.064274160836 -12.874575170328 -31.105916505358
##  [169] -14.203826790807  -9.539991533779 -10.894715446609 -10.820980389922
##  [173]  -7.304629514025 -35.769294802098   0.752112928745   3.726943647744
##  [177] -21.881178852076   9.188975131770 -16.657397669512 -10.813516107026
##  [181]  -8.103999052844 -20.800994917407  -4.210874478890  -2.117733035486
##  [185] -18.909043715714  -8.615838471917 -21.923244363360 -10.936292659635
##  [189]  -4.603019466692  -3.172761926535 -11.732138682117 -17.490394782113
##  [193] -23.732475277553   1.426375676840   1.008098510431  -7.064687878542
##  [197]   4.748953178030 -13.019355856452  -1.285150417710  -1.963289931885
##  [201] -12.481528001114  -8.656481870154 -16.870429133637 -16.927508118387
##  [205] -12.848990628530  -7.195425835717 -17.449784307604 -21.399208107464
##  [209] -21.100783063785 -19.499084208761  -8.042964192706 -11.296324270516
##  [213]  10.463493457482 -22.947859415248 -19.316140097778  -1.226497233014
##  [217] -10.506181574521 -20.733794220824  -8.699243250622 -12.071578583631
##  [221] -10.032840378538 -18.552060616865 -16.269728934031 -20.409276351113
##  [225]   0.303448901382 -14.281653835455  17.323465736565 -20.921447288450
##  [229]  -3.515407274625 -20.409512570056 -15.280293165995 -12.720127823532
##  [233] -15.827845910575 -18.264471427469  -0.657805250830 -18.662170035406
##  [237]  -8.798509639946 -36.117488827543 -21.476608683333 -16.469819284430
##  [241] -14.175947498281   4.355943448218  -1.416029803095 -11.075370039267
##  [245]  -2.665790934636  -0.535948556907 -17.881662275682   7.820248935160
##  [249] -22.436815366911 -24.258688546876  16.130540363414 -14.136750884748
##  [253]  -2.715420499469   0.496226416136  -0.808340055030 -16.315756160382
##  [257] -12.673371205995  -9.937855279209 -14.273729499485  -5.073282031037
##  [261] -11.522713054223   0.876445073960 -10.519955278107  -6.731176388956
##  [265] -10.769451555755  -4.637561693192   0.028611698593  -2.694812662126
##  [269] -15.739656750104 -20.506762485241  -7.351332141586 -36.452300687178
##  [273] -13.837302669591 -27.947268623835   0.108822407068  -5.739633467294
##  [277]  -3.871617773590   1.885998355699 -16.522282041095 -21.775160138229
##  [281]  -0.060037225553 -18.912748287671   2.765917537768 -20.981307373965
##  [285] -16.680454737034 -13.273650030875 -23.393934493673 -25.793503654633
##  [289]  -0.190753384703  -5.154931274367 -19.460353814415 -11.785024137145
##  [293] -20.979996826494 -20.838989883113  -3.165014417318 -14.839167888403
```

```
##  [297] -11.317729496136  -5.332116376795 -12.188243769223 -13.967688057996
##  [301]  -9.295509521372 -15.052289167383  -9.360786531757  -4.192678742600
##  [305]  -8.348648468926 -31.301770697135 -29.329902619032   5.544880344353
##  [309]  -9.871539886944  -3.905640963104  -7.287178884539 -21.995362586758
##  [313]  -0.080470852660 -16.666840477431  -4.669569201240   0.370911173633
##  [317] -10.653258367436   4.671293101751 -12.353629140039  13.553788203311
##  [321]   3.806083401774 -13.585889447945   3.222199058553   2.508451264930
##  [325] -19.950984243812 -21.378209578435 -13.850683195657  -3.631332870780
##  [329] -17.035650587295 -18.230616826056  -7.533150641651 -11.823589111847
##  [333] -13.243559595414 -11.320464629371 -14.143129106299 -10.195474234454
##  [337]  -6.511340343784  -8.912760383219  -0.414650025364 -10.501162155552
##  [341] -23.652234829064  -5.959653434834 -17.352375249251 -24.111516551579
##  [345]  -2.424698423065   1.975708313105 -21.362344389827 -25.516506747560
##  [349] -11.377548628837 -15.390354626410 -31.137015785045  -1.160938203500
##  [353] -19.377985710845 -18.287923989528 -13.705556890629 -11.375601091558
##  [357]   4.875659387303   2.864997746061 -32.012858809437  -2.638440038843
##  [361]  -8.478000242231  -5.405785712991 -16.892520789861  -6.936036269504
##  [365]  -7.447241593357  -9.721933037352 -11.885865658399 -16.537068104134
##  [369] -17.627134733980  -3.062658730968  -6.002217115931 -12.023507306357
##  [373] -12.327543803221   6.119626314299  -4.983114962191 -14.399007658295
##  [377]  -4.013288360791  -1.883170272478 -15.102679547797 -11.050272170434
##  [381] -14.363243147620  -4.464214043029  -2.629156535275  14.502319261124
##  [385] -31.321871328736  -3.539593168041 -20.894417832653  -9.450165991637
##  [389]  -1.225885888899  -7.415846090362  -1.649700469415   4.350227400892
##  [393]  -5.010632080886 -23.800476936127  -6.817542711522 -31.502239765334
##  [397] -11.047175613040  -6.622695881386  11.237629339891 -18.703758956861
##  [401]  -2.205454783091 -21.321996562884 -25.855691241136  -7.921666743598
##  [405]  -9.143811026381  -8.218372648966  -8.584126343044  14.681311922425
##  [409] -14.993470906826   6.616838199881 -27.343482016719 -21.682895202473
##  [413] -10.565585010288  -5.685463546366  -2.770541513744  -8.350238346628
##  [417] -11.826576647438 -18.722973104199  -7.933471222281 -14.927235102510
##  [421] -18.270578602393  -5.215961524815 -15.571616732356 -15.596811966398
##  [425]  -6.194221617798 -10.070238604443   2.315382744595  -8.067810855508
##  [429] -14.267075260544  -6.526527147017 -11.047580651524  -3.137368110646
##  [433] -18.245750888746 -30.552057037150 -23.814183527912  -8.582758008547
##  [437]   4.356459050377  -4.446465740489   5.819946746543  -6.129245841334
##  [441]   5.407106555049 -10.660886944598 -17.114772583616  -4.021091979941
##  [445] -13.869595237718  -4.830242261184  -7.895332493730 -10.872138296623
##  [449] -10.026750600324  -3.994633739237  -7.696606542032 -15.440426028858
##  [453]  -3.079332558114   6.259108187631 -19.114264576306   3.627537230302
##  [457]  -7.127879370304   3.524074837024 -12.540985685399   4.208205881425
##  [461] -28.781815973298 -12.671541013176  -5.332865574341 -17.230031395726
##  [465] -24.680622731835 -14.578427505458   8.718366880519 -10.153025011819
##  [469] -29.964890731059 -19.235425621797 -11.828824474634 -15.474793038822
##  [473]  -9.158717453615 -29.208401503265 -21.952455298257 -13.826007452325
##  [477] -17.019785250090 -10.129245105693   1.733863802217 -14.617985522934
##  [481]   0.235367029154   6.450253937556 -13.014461819738   1.448217192583
##  [485]  -3.192832405117 -13.134230654378 -15.597797706019 -12.829081378583
##  [489]  -6.266122903782 -11.875599885965 -14.232942706784  -1.292969758640
##  [493] -24.294342296176  -7.076236318416 -10.358180764982   0.139955520932
##  [497] -14.379240242927   0.322065338253   5.711308388404  12.256920288776
##  [501] -14.555500962659 -19.493648190935 -11.719753718798  -2.162891902173
##  [505]   3.976371252068 -26.579439344259 -15.331719279167 -11.990722368401
##  [509] -10.949414902123  -9.725280111563 -18.462022709099 -14.468065135914
```

```
##  [513] -11.920356634368 -21.084374805564   1.060806517513  -5.479358644945
##  [517] -12.353273309171 -22.338954349380 -25.119591964887 -34.624231785273
##  [521]  -6.569891829041   2.050389156138  -6.800072080707  -5.293094198328
##  [525]   4.383736120283 -11.270635721473 -10.545392846413 -17.473493128655
##  [529]   1.015595896583 -14.091697948425 -16.760754276234  -6.734904221588
##  [533] -15.490309351448 -17.228813280232  -0.079881218364  -8.923050153828
##  [537] -13.091375380636 -14.199899562882 -36.249558330412 -10.395774633912
##  [541] -13.470102605547 -24.291421578637 -17.094404273500  -8.263239754959
##  [545]  11.234068036702   2.610133414323 -19.046521659644   1.832498929591
##  [549] -10.921069394892   0.034455297857  -1.398068451037  -1.813306366622
##  [553] -24.221095233032 -17.644869052896  -4.644207116310 -10.034738354643
##  [557]   7.086038673258  -4.081394812980  -6.519796607461 -18.082339206840
##  [561] -14.545156559797  -6.070639784849 -34.983499401790  -8.776979782170
##  [565]  -7.965457546340 -32.361264555459 -15.150271005176 -19.148165100135
##  [569]  -5.779021112018  -5.931963334840  -6.365195393789   8.273378322711
##  [573]  -4.546625860587 -14.816368355185 -25.905741019258 -22.965478299249
##  [577]  18.075192110328  -5.920883762827 -15.894704145439 -11.200164333395
##  [581]  -1.405939184275 -13.697798386752 -13.119126033441 -11.379516451225
##  [585] -37.074451556222 -15.496907641250 -19.618370148513 -16.792911439902
##  [589]  -4.866461852037 -24.853940997907 -29.725135036892  -7.654416730168
##  [593] -16.295932239993  20.151469209636 -13.322685042422   6.940742013021
##  [597] -25.663733794587  -6.757755029319 -18.516812361399 -23.623185620267
##  [601]  -6.383344922303  -7.390285924840 -16.285803434962 -28.088962329960
##  [605] -10.495421649439  -5.502488207977 -15.033282742532  -8.910278058209
##  [609]   0.512003394753 -16.818292548619  -3.691836865301 -12.030644366977
##  [613] -18.418463286127  -3.801052817304  13.089558143522  -4.668255127423
##  [617] -18.844273991635  -6.470488648822  -8.467944989510  -3.664951564133
##  [621] -18.220547763016   0.357650322319 -26.434044453216  10.407809854215
##  [625] -10.788900099189 -23.033313441574 -15.033017754166  -2.880816350591
##  [629] -15.171146029940 -12.282494835785 -28.808009935254 -12.395999748514
##  [633]  -9.224246164120 -20.917442488056 -24.847987655300 -23.309909298221
##  [637] -20.636053579667   1.016725286760 -11.294704311803 -12.297229114023
##  [641]  -1.522031002062 -27.635161919387  -9.518945542057 -12.934459282048
##  [645]   0.505594760025 -12.193711036033  -8.280145619826 -21.808004721312
##  [649] -24.605469088986 -20.909805074367 -20.138092598866   3.246804042723
##  [653] -14.438000510211   1.217300386578 -30.664473120921   1.355879211553
##  [657] -28.664927449892 -22.500020744172 -20.361828823428 -10.095650478695
##  [661] -12.988514056496  -0.353703243674  -8.070403580153   3.251492573138
##  [665] -19.534374398250   7.014937713478 -11.524073469346 -24.799447757933
##  [669]  -8.527391442382 -26.791814522303 -13.303570721329  -7.059140197667
##  [673] -11.811353827334 -10.952040013190  10.270309057244  -3.283895463910
##  [677]  -6.670895772173  -8.271726884733  -1.625013805320  -3.083814034457
##  [681]  -7.689302588421  -7.667548822962  -6.939165371016  -5.646697276032
##  [685] -22.264596145893 -18.435448077518 -18.648650770261 -20.241192118467
##  [689] -21.027317571116  -2.736500183287 -12.850014512323 -24.077704497454
##  [693] -23.600655806012  -1.378681680281   1.925360185559   6.037197863199
##  [697] -12.131744796222 -20.632275908633  -9.320793585273 -13.211972497069
##  [701]  -1.381834095610 -23.306193759365 -10.037345196936 -23.852224526905
##  [705] -12.810797570694  -7.704551155983 -17.643989538282  -7.912312788601
##  [709]  10.130711932976  -5.182476894938   3.990215952453   1.257358979452
##  [713]  -7.744757196009  -7.453386074161  -6.912886264416  -1.747859909154
##  [717] -15.387032084497 -18.856485158014 -14.284205646933 -17.630527150499
##  [721]  -5.973156455445 -19.293096170008 -21.561668320724 -16.469840463653
##  [725]  -2.645310225514 -11.630181068026 -13.269773029785 -22.066786820106
```

```
##  [729] -23.535718246327 -22.921831868020 -22.460731450019  -9.194097583731
##  [733] -24.961788728513  -9.160624244011   8.767533033464 -15.289125031823
##  [737] -17.833353647457 -10.189036160689 -23.011310935238 -13.742595430912
##  [741] -14.596774871344 -12.498919911353 -11.795642145879 -21.971668253703
##  [745] -10.755296998140 -22.692931568827 -24.491900663328   1.358602220525
##  [749] -11.886169259088  -9.840675198682 -13.002490755053  10.196817306848
##  [753] -16.770163023441  10.520596183913 -32.888934358354  -3.836071446515
##  [757]  -2.825594924180   5.222152700027 -30.476401194871 -17.761650209474
##  [761]   1.163287296688 -13.245602348485  -6.816767463464  -4.053374520024
##  [765] -20.841630693010  -8.454074401458 -22.592800248113 -17.868129362409
##  [769]  -4.870512278589 -11.646716408076  -1.882013894074  -5.216040446776
##  [773] -24.724692654231  -8.081347295116   0.075142601202  -2.595774573009
##  [777]  -3.956522552684   2.836004511918 -15.427987440477 -16.728096137994
##  [781] -16.235706216531 -13.400996555262 -17.027197218526  -5.626307081955
##  [785] -21.279992876218   6.175452799584  -2.034637399608  -0.987570319110
##  [789] -30.721000707981   2.411869495672  -3.255317539253 -12.735896100006
##  [793] -13.574793779872 -20.136239520409 -16.115411018193   2.383242199250
##  [797]  -8.668264007508 -19.835627640429 -31.042141504609 -23.373248228689
##  [801] -18.674176331499 -11.818848083992 -12.138470145355   0.965961017079
##  [805]  -6.103533758463 -21.382939602587 -17.105425766300 -17.865370376538
##  [809] -11.214421288463  -5.486979570914  -2.890127739091 -27.683528121239
##  [813] -20.300215423144 -17.682174924247 -23.603745463959  -3.118999025381
##  [817]   6.992072305571  -9.220136340306 -12.662861162528   4.504170047680
##  [821]  -6.591060975043  -6.766576256497 -23.246911356221   1.195313668134
##  [825] -13.267236620648   3.805167481101   1.866820447964 -17.146761752978
##  [829] -14.716643083454 -20.587686508747  -5.862627404996  -3.357646076817
##  [833] -13.253337044886 -10.657245124878 -17.430851815142 -18.857815794514
##  [837]  -1.570414913321 -22.983821329745  -1.828951836073  -7.409274592819
##  [841] -22.243251475791  -8.385006744564 -18.546972774969 -13.640683500843
##  [845] -12.208594516976 -13.786681397402 -14.797433816646  -3.692713570951
##  [849]  -5.757700853492  -7.624217656462 -17.866840232006 -32.338761142262
##  [853]  -1.699971459628   4.274093673272 -12.943019145814  -5.346004927162
##  [857]   0.576473737031 -11.926587523145  -8.020020948113  -3.804940400593
##  [861]   7.418474128932  -6.881962690596   1.462574291375 -26.377141719257
##  [865]  -9.439039554436 -31.432286114822   9.296192256955  -7.278129105980
##  [869] -17.108840045471  -4.173688842575  16.832244966630 -14.170754881253
##  [873] -13.076863414513 -14.471540416624 -16.397904276812  -0.594558700914
##  [877]   0.655111536204  -4.124118076765 -23.993803075941 -11.934902243331
##  [881] -24.043704609620   4.929232838767  -4.974201447739  -4.396818561231
##  [885]   2.583795483214  -5.854809802245  -8.515997485576  -0.632613656023
##  [889]  -1.810246577249  -0.840016362101 -21.542492459438   1.406589479366
##  [893] -15.062480221766  -5.288125629505   4.518471778389  -1.627866678623
##  [897]   7.824685988660  -3.379611518472   4.328321561186  -6.991724341270
##  [901]  15.604521456049 -15.998362421540   6.759240162884 -11.091065339937
##  [905] -14.503382238486  -8.062595302692  -4.680961288146 -19.648129307928
##  [909]  -5.133941747158 -27.271084932827  -8.189517366368 -13.783325527097
##  [913]   0.775835008295 -24.924236717901   4.823427817493  -8.277910139633
##  [917] -18.432308414271 -15.496054534321 -10.492922671606 -26.661529285528
##  [921]  -6.371823984003 -11.551026691417   0.166512808679  -1.478373083754
##  [925] -19.195115577427  -2.508490616413 -21.266954368021  -7.326771716285
##  [929] -15.546732144415 -13.253557701186  -9.019487664448  -2.261330442106
##  [933]  -0.256667769085  -1.810942994580 -18.229719923919  15.067205185317
##  [937] -14.137841420159   4.916043498359  -8.536090458718 -20.557742188117
##  [941] -12.616347254563 -21.263577347676 -26.561000566661 -16.434811095816
```

```
##  [945] -12.116937160783 -17.708349873144  -9.529553483022  -3.519242270986
##  [949]  -2.785983145909  -9.652226706081   4.256032373663 -10.079037741626
##  [953] -20.881090388130  -9.520827512512  -2.909114042759  -3.545075397819
##  [957]  -8.112496881723 -25.065071197945 -11.227639418990  -3.084041925953
##  [961]  -4.089651133319 -21.802231017585 -26.619907286451  -4.541318223911
##  [965]   6.946753383932 -12.107801572086 -11.513590454149 -28.367633799160
##  [969]  -5.819835243973 -22.120006238393  -8.064739337816  -6.853646958583
##  [973] -30.536354845714  -4.741093905914  -4.138380817021 -27.545721102617
##  [977]  12.581803528468   0.408654403883 -11.179603552132 -19.761283307194
##  [981]  -4.459718417565   8.332551147257  -8.560509630305  -0.972337434717
##  [985]   5.609664333370  -2.752444433041  -4.046963301637 -31.109777308833
##  [989] -23.120062908659 -24.351341934072  -1.765302502889  -0.217312241380
##  [993]  -4.577909083109   3.489837076073  -7.861940827184 -11.654735703889
##  [997] -32.307206322589 -10.891012634756  -8.758025142259 -20.952176209139
```

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

```
average = mean(v)
average
```

```
## [1] -10.403337321
```

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

```
## [1] 0.31315004412
```

- 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?

The estimate is pretty close

```
quantile(v, 0.05)
```

```
##           5%
## -26.581462741
```

```
qnorm(0.05, mean = -10, sd = sqrt(100))
```

```
## [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?

```
ecdf(v)(0)*100 #empirical cumulative distribution function
```

```
## [1] 85
```

```r
pnorm(0-(-10)/sd(v))*100 #percentile corresponding to the z score
```

```
## [1] 84.371121231
```

```r
pnorm(0, mean = -10, sd = sqrt(100)) * 100 #theoretical value
```

```
## [1] 84.134474607
```

- Create a function `my_reverse` which takes as required input a vector `v` and returns the vector in reverse where the first entry is the last entry, etc. No function calls are allowed inside your function otherwise that would defeat the purpose of the exercise! (Yes, there is a base R function that does this called `rev`). Use `head` on `v` and `tail` on `my_reverse(v)` to verify it works.

```r
my_reverse = function(v){
  n = length(v)
  reversed = numeric(n)
  for(i in 1:n){
    reversed[n-i+1]=v[i]
  }
  return(reversed)
}
head(v)
```

```
## [1]  -5.90796783785 -13.23024971154  -3.64147672810 -28.46128784018
## [5]  -0.46352634593   1.88489843453
```

```r
tail(my_reverse(v))
```

```
## [1]   1.88489843453  -0.46352634593 -28.46128784018  -3.64147672810
## [5] -13.23024971154  -5.90796783785
```

- Create a function `flip_matrix` which takes as required input a matrix, an argument `dim_to_rev` that returns the matrix with the rows in reverse order or the columns in reverse order depending on the `dim_to_rev` argument. Let the default be the dimension of the matrix that is greater. If the number of rows

```r
flip_matrix = function(matrix, dim_to_rev=NULL){
  if(is.null(dim_to_rev)){
    dim_to_rev=ifelse(nrow(matrix)>=ncol(matrix), 1, 2)
  }
  if(dim_to_rev == 1){
    matrix[nrow(matrix):1, ]
  } else if(dim_to_rev == 2) {
    matrix[ , ncol(matrix):1]
  } else {
    stop("dim_to_rev needs to be 1, 2, or NULL")
  }
}
```

- Create a list named `my_list` with keys "A", "B", ... where the entries are arrays of size 1, 2 x 2, 3 x 3 x 3, etc. Fill the array with the numbers 1, 2, 3, etc. Make 8 entries according to this sequence.

```
my_list = list("A" = array(1,1),
               "B" = array(2, c(2,2)),
               "C" = array(3, c(3,3,3)),
               "D" = array(4, c(4,4,4,4)),
               "E" = array(5, c(5,5,5,5,5)),
               "F" = array(6, c(6,6,6,6,6,6)),
               "G" = array(7, c(7,7,7,7,7,7,7)),
               "H" = array(8, c(8,8,8,8,8,8,8,8)))
?array
```

Run the following code:

```
lapply(my_list, object.size)
```

```
## $A
## 224 bytes
##
## $B
## 248 bytes
##
## $C
## 440 bytes
##
## $D
## 2272 bytes
##
## $E
## 25240 bytes
##
## $F
## 373488 bytes
##
## $G
## 6588584 bytes
##
## $H
## 134217968 bytes
```

Use `?object.size` to read about what these functions do. Then explain the output you see above. For the later arrays, does it make sense given the dimensions of the arrays?

#TO-DO

Packages

Install the package `pacman` using regular base R.

```
#install.packages("pacman")
```

First, install the package `testthat` (a widely accepted testing suite for R) from https://github.com/r-lib/testthat using `pacman`. If you are using Windows, this will be a long install, but you have to go through it for some of the stuff we are doing in class. LINUX (or MAC) is preferred for coding. If you can't get it to work, install this package from CRAN (still using `pacman`), but this is not recommended long term.

```
pacman::p_load(testthat)
```

- Create vector `v` consisting of all numbers from -100 to 100 and test using the second line of code su

```
v = seq(-100, 101)
expect_equal(v, -100 : 101)
```

If there are any errors, the `expect_equal` function will tell you about them. If there are no errors, then it will be silent.

Test the `my_reverse` function using the following code:

```
expect_equal(my_reverse(v), rev(v))
expect_equal(my_reverse(c("A", "B", "C")), c("C", "B", "A"))
```

A little about strings

- Use the `strsplit` function and `sample` to put the sentences in the string `lorem` below in random order. You will also need to manipulate the output of `strsplit` which is a list. You may need to learn basic concepts of regular expressions.

```
lorem = "Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi posuere varius volutpat. Morbi

sample(unlist(strsplit(lorem, "\\. ")))
```

```
##  [1] "Aenean nulla ante, iaculis sed vehicula ac, finibus vel arcu"
##  [2] "Mauris at sodales augue"
##  [3] "Morbi posuere varius volutpat"
##  [4] "Lorem ipsum dolor sit amet, consectetur adipiscing elit"
##  [5] "Cras suscipit id nibh lacinia elementum"
##  [6] "Donec vehicula sagittis nisi non semper"
##  [7] "Morbi faucibus ligula id massa ultricies viverra"
##  [8] "Integer dapibus mi lectus, eu posuere arcu ultricies in"
##  [9] "Curabitur est augue, congue eget quam in, scelerisque semper magna"
## [10] "Donec at tempor erat"
```

You have a set of names divided by gender (M / F) and generation (Boomer / GenX / Millenial):

- M / Boomer "Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie"
- M / GenX "Marc, Jamie, Greg, Darryl, Tim, Dean, Jon, Chris, Troy, Jeff"
- M / Millennial "Zachary, Dylan, Christian, Wesley, Seth, Austin, Gabriel, Evan, Casey, Luis"
- F / Boomer "Gloria, Joan, Dorothy, Shirley, Betty, Dianne, Kay, Marjorie, Lorraine, Mildred"
- F / GenX "Tracy, Dawn, Tina, Tammy, Melinda, Tamara, Tracey, Colleen, Sherri, Heidi"
- F / Millennial "Samantha, Alexis, Brittany, Lauren, Taylor, Bethany, Latoya, Candice, Brittney, Cheyenne"

Create a list-within-a-list that will intelligently store this data.

```
#HINT:
#strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split = ", ")[[1]]
list_within_list=list(
  M=list(
    Boomer=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split = ",
  GenX=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split = ", ")[
  Millennial=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split =
  ),
  F=list(
    Boomer=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split = ",
  GenX=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split = ", ")[
  Millennial=strsplit("Theodore, Bernard, Gene, Herbert, Ray, Tom, Lee, Alfred, Leroy, Eddie", split =
  )
)

list_within_list
```

```
## $M
## $M$Boomer
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
##
## $M$GenX
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
##
## $M$Millennial
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
##
##
## $F
## $F$Boomer
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
##
## $F$GenX
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
##
## $F$Millennial
##  [1] "Theodore" "Bernard"  "Gene"     "Herbert"  "Ray"      "Tom"
##  [7] "Lee"      "Alfred"   "Leroy"    "Eddie"
```

```
list_within_list$M$GenX[3]
```

```
## [1] "Gene"
```

Now cleanup the namespace by deleting all stored objects and functions:

```
rm(list = ls())
```