STAT 33B Lab 1

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R Markdown Documents

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can choose to knit your document to an HTML, Word, or PDF file.

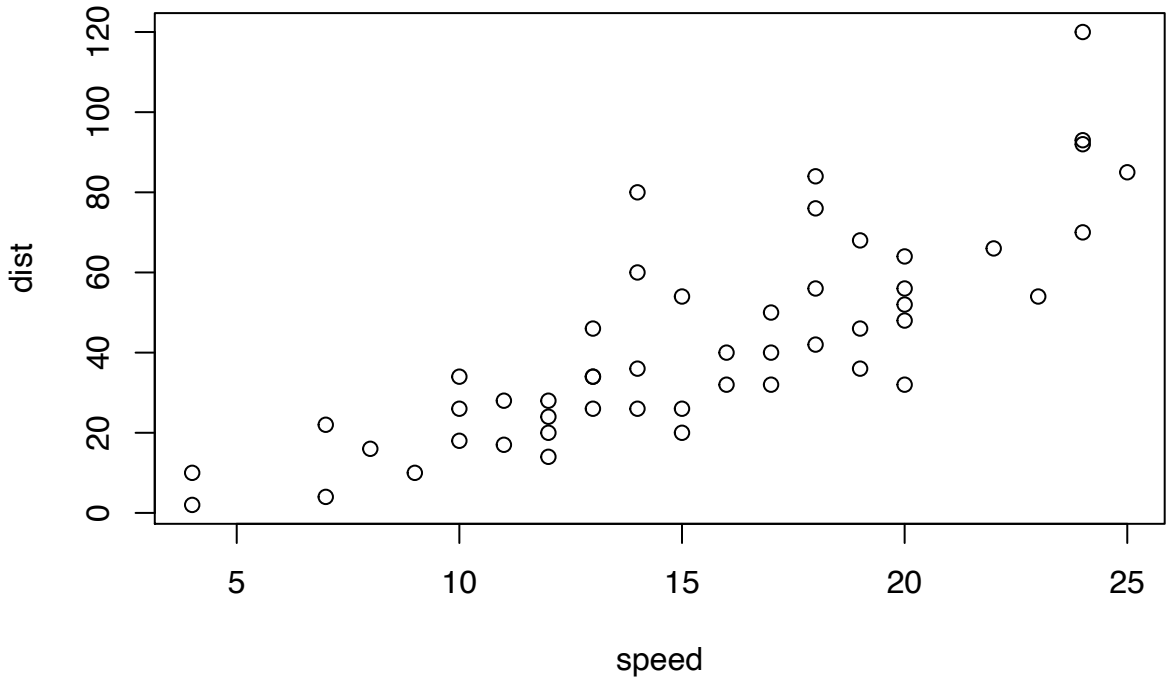
In order to knit to PDF, if you do not already have LaTex on your computer, you'll need to install the `tinytex` package in R. You can do this in R with the command `install.packages("tinytex")`. If you need help with this, come to office hours.

You can embed an R code chunk in the document like this:

```
summary(cars)
```

```
##      speed           dist       
##  Min.   : 4.0   Min.   :  2.00  
##  1st Qu.:12.0   1st Qu.: 26.00  
##  Median :15.0   Median : 36.00  
##  Mean   :15.4   Mean   : 42.98  
##  3rd Qu.:19.0   3rd Qu.: 56.00  
##  Max.   :25.0   Max.   :120.00
```

You can also embed plots, for example:



Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.

Submission Instructions

Edit this file, knit to PDF, and:

- Submit the Rmd file on bCourses.
- Submit the PDF file on Gradescope.

If you think you'll need help with submission, please ask in office hours *before* the assignment is due.

Answer all questions with complete sentences, and put code in code chunks. You can make as many new code chunks as you like. Please do not delete the exercises already in this notebook, because it may interfere with our grading tools.

As you work, you may find it helpful to be able to run your code. You can run a single line of code by pressing Ctrl + Enter. You can run an entire code chunk by clicking on the green arrow in the upper right corner of the code chunk.

Knit the document from time to time to make sure that your code runs without errors from top to bottom in a fresh R environment.

The code below controls the number of significant digits shown for the return values in your knitted document.

```
options(digits = 3)
```

Exercise 1

Create a vector `y` with the values `3 5 9 17 33`. Use sequence generating functions such as `:` and vectorized math rather than `c()`.

```
s = seq(1, 5, 1)
y = 2^s+1
y
```

```
## [1]  3  5  9 17 33
```

Exercise 2

Begin by loading the Best in Show "Dogs" data set (posted on bCourses; see lecture 2 for details). You'll need to edit the path to match where you downloaded the file on your computer.

```
dogs = readRDS("/Users/andre/Desktop/33b/dogs_full.rds")
dogs
```

```
##                              breed        group datadog popularity_all
## 1                     Border Collie      herding    3.64             45
## 2                    Border Terrier      terrier    3.61             80
## 3                          Brittany     sporting    3.54             30
## 4                     Cairn Terrier      terrier    3.53             59
## 5             Welsh Springer Spaniel     sporting    3.34            130
## 6             English Cocker Spaniel     sporting    3.33             63
## 7                     Cocker Spaniel     sporting    3.30             27
## 8                           Papillon          toy    3.26             38
## 9             Australian Cattle Dog      herding    3.25             60
## 10                Shetland Sheepdog      herding    3.22             20
## 11                   Siberian Husky      working    3.22             16
## 12                       Lhasa Apso non-sporting    3.21             62
## 13                    Affenpinscher          toy    3.20            139
## 14                        Dachshund        hound    3.19              9
## 15               Miniature Schnauzer      terrier    3.19             12
## 16                        Chihuahua          toy    3.15             14
## 17              Australian Terrier      terrier    3.11            121
## 18                         Whippet        hound    3.11             57
## 19          English Springer Spaniel     sporting    3.09             29
## 20       West Highland White Terrier      terrier    3.08             35
## 21              Bedlington Terrier      terrier    3.07            134
## 22                          Poodle non-sporting    3.04              8
## 23                    Bichon Frise non-sporting    3.03             39
## 24       German Shorthaired Pointer     sporting    3.03             15
## 25                          Pointer     sporting    3.03            115
## 26                 Tibetan Spaniel non-sporting    3.02            114
## 27              Labrador Retriever     sporting    2.97              1
## 28                          Maltese          toy    2.93             23
## 29                       Pomeranian          toy    2.93             17
## 30                         Shih Tzu          toy    2.93             11
## 31              Australian Shepherd      herding    2.91             24
## 32                Yorkshire Terrier          toy    2.85              5
## 33                     Irish Setter     sporting    2.84             70
## 34                   Pharaoh Hound        hound    2.81            151
## 35                Brussels Griffon          toy    2.80             77
## 36                Golden Retriever     sporting    2.80              4
## 37                         Samoyed      working    2.80             69
## 38                          Beagle        hound    2.79              3
## 39          Chesapeake Bay Retriever     sporting    2.78             46
## 40                   Tibetan Terrier non-sporting    2.75             86
## 41                     Gordon Setter     sporting    2.73             94
## 42                   English Setter     sporting    2.72             87
## 43                              Pug          toy    2.72             26
## 44                          Briard      herding    2.71            125
## 45                  Norfolk Terrier      terrier    2.71            120
## 46             Flat-Coated Retriever     sporting    2.70             90
```

```
## 47                    Boston Terrier non-sporting    2.61            22
## 48                 Doberman Pinscher      working    2.59            13
## 49               English Toy Spaniel          toy    2.59           129
## 50                  Belgian Tervuren      herding    2.57           108
## 51       Cavalier King Charles Spaniel          toy    2.57            21
## 52                          Dalmatian non-sporting    2.57            73
## 53                      Basset Hound        hound    2.54            41
## 54                           Basenji        hound    2.51            93
## 55                Italian Greyhound          toy    2.49            65
## 56          Staffordshire Bull Terrier      terrier    2.48            76
## 57                Bouvier des Flandres      herding    2.47            83
## 58                Pembroke Welsh Corgi      herding    2.45            25
## 59                     Clumber Spaniel     sporting    2.44           133
## 60              Dandie Dinmont Terrier      terrier    2.42           160
## 61                              Saluki        hound    2.41           117
## 62                    Giant Schnauzer      working    2.38            95
## 63                          Greyhound        hound    2.29           140
## 64                    Scottish Terrier      terrier    2.27            54
## 65                          Rottweiler      working    2.24            10
## 66                  Kerry Blue Terrier      terrier    2.13           124
## 67                       Afghan Hound        hound    2.08            88
## 68                       Newfoundland      working    2.07            43
## 69                    German Shepherd      herding    2.06             2
## 70                          Pekingese          toy    2.05            64
## 71                Old English Sheepdog      herding    2.04            84
## 72                               Akita      working    1.95            47
## 73                Rhodesian Ridgeback        hound    1.91            44
## 74                     French Bulldog non-sporting    1.90            18
## 75                             Borzoi        hound    1.89           102
## 76                Bernese Mountain Dog      working    1.85            34
## 77                        Bull Terrier      terrier    1.85            51
## 78                               Boxer      working    1.83             7
## 79                    Alaskan Malamute      working    1.82            58
## 80                           Chow Chow non-sporting    1.76            68
## 81                         Bloodhound        hound    1.66            48
## 82                      Irish Wolfhound        hound    1.66            79
## 83                          Bullmastiff      working    1.64            40
## 84                             Mastiff      working    1.57            28
## 85                          Great Dane      working    1.53            19
## 86                        Saint Bernard      working    1.42            49
## 87                              Bulldog non-sporting    0.99             6
## 88                     Airedale Terrier      terrier      NA            55
## 89          American English Coonhound        hound      NA            33
## 90                American Eskimo Dog non-sporting      NA           116
## 91                  American Foxhound        hound      NA           173
## 92       American Staffordshire Terrier      terrier      NA            72
## 93               American Water Spaniel     sporting      NA           157
## 94              Anatolian Shepherd Dog      working      NA           111
## 95                      Bearded Collie      herding      NA           112
## 96                           Beauceron      herding      NA           144
## 97                    Belgian Malinois      herding      NA            74
## 98                    Belgian Sheepdog      herding      NA           118
## 99              Black and Tan Coonhound        hound      NA           109
## 100               Black Russian Terrier      working      NA           128
```

```
## 101                  Bluetick Coonhound        hound      NA            136
## 102                      Boykin Spaniel     sporting      NA            138
## 103                         Canaan Dog      herding      NA            168
## 104                         Cane Corso      working      NA             67
## 105                 Cardigan Welsh Corgi      herding      NA             81
## 106                       Cesky Terrier      terrier      NA            106
## 107                    Chinese Crested          toy      NA             61
## 108                  Chinese Shar Pei non-sporting      NA             50
## 109                               Collie      herding      NA             36
## 110              Curly Coated Retriever     sporting      NA            154
## 111                   English Foxhound        hound      NA            171
## 112            Entlebucher Mountain Dog      herding      NA            146
## 113                       Field Spaniel     sporting      NA            141
## 114                    Finnish Lapphund      herding      NA            104
## 115                       Finnish Spitz non-sporting      NA            167
## 116                    German Pinscher      working      NA            137
## 117           German Wirehaired Pointer     sporting      NA             75
## 118               Glen of Imaal Terrier      terrier      NA            158
## 119                    Great Pyrenees      working      NA             71
## 120          Greater Swiss Mountain Dog      working      NA             82
## 121                             Harrier        hound      NA            172
## 122                            Havanese          toy      NA             31
## 123                         Ibizan Hound        hound      NA            149
## 124                  Icelandic Sheepdog      herding      NA            143
## 125          Irish Red and White Setter     sporting      NA            147
## 126                       Irish Terrier      terrier      NA            132
## 127                  Irish Water Spaniel     sporting      NA            150
## 128                        Japanese Chin          toy      NA             78
## 129                             Keeshond non-sporting      NA             98
## 130                             Komondor      working      NA            166
## 131                               Kuvasz      working      NA            148
## 132                    Lakeland Terrier      terrier      NA            135
## 133                          Leonberger      working      NA            103
## 134                             Löwchen non-sporting      NA            152
## 135                  Manchester Terrier      terrier      NA            119
## 136               Miniature Bull Terrier      terrier      NA            127
## 137                  Miniature Pinscher          toy      NA             42
## 138                  Neapolitan Mastiff      working      NA            110
## 139                    Norwegian Buhund      herding      NA            165
## 140                  Norwegian Elkhound        hound      NA             96
## 141                 Norwegian Lundehund non-sporting      NA            170
## 142                     Norwich Terrier      terrier      NA             89
## 143 Nova Scotia Duck Tolling Retriever     sporting      NA            107
## 144                           Otterhound        hound      NA            169
## 145               Parson Russell Terrier      terrier      NA             97
## 146       Petit Basset Griffon Vendeen        hound      NA            131
## 147                               Plott        hound      NA            145
## 148             Polish Lowland Sheepdog      herding      NA            159
## 149                Portuguese Water Dog      working      NA             56
## 150                                Puli      herding      NA            156
## 151                  Pyrenean Shepherd      herding      NA            162
## 152                  Redbone Coonhound        hound      NA            126
## 153                          Schipperke non-sporting      NA            105
## 154                  Scottish Deerhound        hound      NA            142
```

```
## 155                   Sealyham Terrier      terrier      NA            163
## 156                         Shiba Inu non-sporting      NA             53
## 157                      Silky Terrier          toy      NA             85
## 158                       Skye Terrier      terrier      NA            164
## 159                 Smooth Fox Terrier      terrier      NA            113
## 160        Soft-Coated Wheaten Terrier      terrier      NA             52
## 161                   Spinone Italiano     sporting      NA            123
## 162                 Standard Schnauzer      working      NA             91
## 163                     Sussex Spaniel     sporting      NA            161
## 164                   Swedish Vallhund      herding      NA            153
## 165                    Tibetan Mastiff      working      NA            122
## 166                    Toy Fox Terrier          toy      NA            101
## 167                             Vizsla     sporting      NA             37
## 168                          Weimaraner     sporting      NA             32
## 169                      Welsh Terrier      terrier      NA             99
## 170                   Wire Fox Terrier      terrier      NA            100
## 171        Wirehaired Pointing Griffon     sporting      NA             92
## 172                      Xoloitzcuintli non-sporting      NA            155
##     popularity lifetime_cost intelligence_rank longevity ailments price
## 1           39         20143                 1     12.52        2   623
## 2           61         22638                30     14.00        0   833
## 3           30         22589                19     12.92        0   618
## 4           48         21992                35     13.84        2   435
## 5           81         20224                31     12.49        1   750
## 6           51         18993                18     11.66        0   800
## 7           27         24330                20     12.50        2   465
## 8           33         21001                 8     13.00        5   740
## 9           49         20395                10     11.67        1   530
## 10          20         21006                 6     12.53        5   465
## 11          16         22049                45     12.58        0   650
## 12          50         22031                68     13.92        1   350
## 13          84         18333                37     11.42        0   510
## 14           9         20113                49     12.63        2   423
## 15          12         20087                12     11.81        2   715
## 16          14         26250                67     16.50        1   588
## 17          77         17892                34     11.05        0   640
## 18          46         20976                51     12.87        0   915
## 19          29         21946                13     12.54        4   615
## 20          32         20490                47     12.80        3   538
## 21          83         22107                40     13.51        2  1058
## 22           8         21237                 2     11.95        2   900
## 23          34         19735                45     12.21        0   693
## 24          15         25842                17     11.46        1   545
## 25          74         24445                43     12.42        1   294
## 26          73         25549                46     14.42        0  1050
## 27           1         21299                 7     12.04        3   810
## 28          23         19084                59     12.25        1   650
## 29          17         15792                23      9.67        1   670
## 30          11         21152                70     13.20        1   583
## 31          24         21458                42     12.28        2   565
## 32           5         20701                27     12.60        4  1057
## 33          56         20323                35     11.63        2   525
## 34          86         21047                37     11.83        0   913
## 35          59         19551                59     12.00        0   833
```

```
## 36          4         21447           4    12.04        4   958
## 37         55         25352          33    12.44        1  1162
## 38          3         19468          73    12.30        1   288
## 39         40         16697          27     9.48        1   522
## 40         64         20336          62    12.31        0  1140
## 41         69         19605          34    11.10        1   700
## 42         65         20312          37    11.57        2   615
## 43         26         18527          57    11.00        1   469
## 44         79         19673          30    11.17        1   650
## 45         76         24308          56    13.07        0  2083
## 46         67         16000          18     9.02        0   600
## 47         22         17741          54    10.92        1   690
## 48         13         18397           5    10.33        4   790
## 49         80         17521          45    10.10        0   925
## 50         72         19132          14    10.60        2  1070
## 51         21         18639          44    11.29        2  1017
## 52         57         19886          39    11.27        2   695
## 53         36         18328          71    11.43        2   490
## 54         68         22096          79    13.58        3   940
## 55         53         16463          60    10.02        0   800
## 56         58         21650          49    12.05        1  1145
## 57         62         18959          29    10.34        1  1335
## 58         25         23978          11    12.25        9   587
## 59         82         18084          37    10.00        0  1033
## 60         87         21633          62    12.17        0   925
## 61         75         24866          43    12.00        0  1525
## 62         70         26686          28    10.00        1   810
## 63         85         15819          46     9.36        1  1175
## 64         45         17525          65    10.69        1   829
## 65         10         18886           9     9.11        3  1118
## 66         78         17240          35     9.40        1  1200
## 67         66         24077          80    11.92        0   890
## 68         37         19351          34     9.32        2  1178
## 69          2         17416           3     9.73        8   820
## 70         52         20565          74    11.56        1   885
## 71         63         22611          63    11.19        1   832
## 72         41         20994          54    10.16        1  1202
## 73         38         16530          52     9.10        2   995
## 74         18         17266          58     9.00        0  1900
## 75         71         16176          76     9.08        0   675
## 76         31         16099          22     7.56        4  1320
## 77         44         18490          66    10.21        2  1085
## 78          7         15746          48     8.81        4   700
## 79         47         21986          50    10.67        2  1210
## 80         54         15898          77     9.01        2   515
## 81         42         13824          75     6.75        2   608
## 82         60         18435          41     6.94        3  1333
## 83         35         13936          69     7.57        2   980
## 84         28         13581          72     6.50        2   900
## 85         19         14662          48     6.96        4  1040
## 86         43         20022          65     7.78        3   875
## 87          6         13479          78     6.29        5  2680
## 88         NA            NA          29    11.45        1   733
## 89         NA            NA          NA    11.50       NA   283
```

```
## 90          NA           NA                NA        NA        0   560
## 91          NA           NA                46        NA       NA   757
## 92          NA           NA                34        NA        1  1043
## 93          NA           NA                44        NA        0   730
## 94          NA           NA                NA     10.75       NA    NA
## 95          NA           NA                34     12.77        0    NA
## 96          NA           NA                NA        NA       NA   967
## 97          NA           NA                22        NA        0  1080
## 98          NA           NA                15        NA        4    NA
## 99          NA           NA                44        NA        0   325
## 100         NA           NA                NA        NA        0  2833
## 101         NA           NA                NA        NA        0   370
## 102         NA           NA                NA        NA       NA   531
## 103         NA           NA                NA     14.67        0    NA
## 104         NA           NA                NA        NA       NA  1070
## 105         NA           NA                26     12.70        0   828
## 106         NA           NA                NA      8.42       NA    NA
## 107         NA           NA                61     10.08       NA   538
## 108         NA           NA                51        NA        4   840
## 109         NA           NA                16        NA        2   650
## 110         NA           NA                41     10.75        0    NA
## 111         NA           NA                46        NA        0    NA
## 112         NA           NA                NA        NA       NA  1167
## 113         NA           NA                34      9.90        0    NA
## 114         NA           NA                NA      7.33       NA    NA
## 115         NA           NA                43     11.17        0    NA
## 116         NA           NA                NA     11.42       NA  1500
## 117         NA           NA                44     10.00        1   655
## 118         NA           NA                NA     10.42       NA    NA
## 119         NA           NA                64     10.00        1   503
## 120         NA           NA                NA      6.80        1  1605
## 121         NA           NA                NA        NA        0    NA
## 122         NA           NA                NA     10.25        0   830
## 123         NA           NA                53        NA        0  1500
## 124         NA           NA                NA        NA       NA    NA
## 125         NA           NA                NA     11.57       NA  1000
## 126         NA           NA                53        NA        0   588
## 127         NA           NA                24      9.33        1    NA
## 128         NA           NA                62      9.25        0   513
## 129         NA           NA                16     12.17        1   610
## 130         NA           NA                NA      9.17        1   656
## 131         NA           NA                42        NA        1    NA
## 132         NA           NA                62        NA        0  1093
## 133         NA        15141                NA      6.98       NA  1480
## 134         NA           NA                NA     10.00        0    NA
## 135         NA           NA                32      9.32        0   720
## 136         NA           NA                NA      6.60        0  1740
## 137         NA           NA                37        NA        0   535
## 138         NA           NA                NA        NA        1  1760
## 139         NA           NA                NA     12.67       NA    NA
## 140         NA           NA                36        NA        1   448
## 141         NA           NA                NA        NA       NA    NA
## 142         NA           NA                38        NA        0  1245
## 143         NA        12653                NA      6.50        1  1500
```

```
## 144         NA            NA                46     10.80        1    NA
## 145         NA            NA                NA        NA        0   528
## 146         NA            NA                62     12.70        0   400
## 147         NA            NA                NA        NA        0    NA
## 148         NA            NA                NA     10.80       NA    NA
## 149         NA            NA                NA     11.42        0    NA
## 150         NA            NA                27        NA        0   913
## 151         NA            NA                NA        NA       NA    NA
## 152         NA            NA                NA        NA        0   425
## 153         NA            NA                15     13.00        4   658
## 154         NA            NA                47      8.70        2    NA
## 155         NA            NA                56     12.25        1    NA
## 156         NA            NA                NA      7.00        1   890
## 157         NA            NA                37     14.25        0   448
## 158         NA            NA                55     11.00        0   550
## 159         NA            NA                40     13.17        0   575
## 160         NA            NA                40     12.16        0   832
## 161         NA            NA                NA      9.00       NA  1725
## 162         NA            NA                18        NA        1   855
## 163         NA            NA                NA     11.17        0    NA
## 164         NA         22839                NA     14.17       NA   772
## 165         NA         23747                NA     11.92       NA  3460
## 166         NA            NA                NA        NA       NA   460
## 167         NA            NA                25     12.50        0   935
## 168         NA            NA                21        NA        1   562
## 169         NA            NA                53        NA        0   843
## 170         NA            NA                51     13.17        0   668
## 171         NA            NA                46      8.80        0   755
## 172         NA            NA                NA        NA       NA   717
##     food_cost grooming   kids megarank_kids megarank   size weight height
## 1         324   weekly    low             1       29 medium     NA  20.00
## 2         324   weekly   high             2        1  small   13.5     NA
## 3         466   weekly medium             3       11 medium   35.0  19.00
## 4         324   weekly   high             4        2  small   14.0  10.00
## 5         324   weekly   high             5        4 medium     NA  18.00
## 6         324   weekly   high             6        5 medium   30.0  16.00
## 7         674   weekly   high             7        6  small   25.0  14.50
## 8         324   weekly medium             8       22  small     NA   9.50
## 9         466   weekly    low             9       52 medium     NA  18.50
## 10        405    daily   high            11        8  small   22.0  14.50
## 11        466  monthly   high            10        3 medium   47.5  21.75
## 12        324   weekly   high            12        7  small   15.0  10.50
## 13        324   weekly medium            13       26  small     NA  10.25
## 14        324   weekly    low            14       54  small   24.0     NA
## 15        405   weekly medium            14       27  small   15.5  13.00
## 16        324   weekly    low            16       55  small    5.5   5.00
## 17        324   weekly medium            17       30  small     NA  10.50
## 18        324   weekly medium            17       30 medium     NA  20.00
## 19        466   weekly   high            19        9 medium   45.0  19.50
## 20        324   weekly   high            20       10  small     NA  10.50
## 21        324   weekly medium            21       35  small   20.0     NA
## 22        466   weekly medium            22       39 medium     NA  16.00
## 23        324    daily   high            25       16  small     NA  10.50
## 24        971   weekly   high            23       12  large   62.5  24.00
```

```
## 25        710   weekly   high          24       13  large   59.5  25.50
## 26        466   weekly   high          26       14  small   12.0  10.00
## 27        466   weekly   high          27       15 medium   67.5  23.00
## 28        270    daily    low          29       65  small    5.0   9.00
## 29        324   weekly medium          28       45  small    5.0     NA
## 30        324    daily   high          29       19  small   12.5   9.75
## 31        466   weekly medium          31       46 medium     NA  20.50
## 32        324    daily    low          32       69  small    5.5     NA
## 33        466   weekly   high          33       17  large   65.0  26.00
## 34        466   weekly medium          34       47 medium     NA  23.00
## 35        324   weekly    low          36       66  small    9.0     NA
## 36        466   weekly   high          37       20 medium   60.0  22.75
## 37        710   weekly   high          35       18 medium     NA  21.25
## 38        324    daily   high          38       28  small     NA  14.00
## 39        466   weekly   high          39       21  large   67.5  23.50
## 40        324   weekly medium          40       51  small   24.0  15.50
## 41        466   weekly   high          41       23  large   62.5  25.00
## 42        466   weekly   high          43       25  large     NA  24.50
## 43        405   weekly   high          42       24 medium   16.0  16.00
## 44        466    daily   high          44       33  large     NA  24.50
## 45        466   weekly medium          45       53  small   12.0   9.50
## 46        466    daily   high          46       34 medium     NA  23.25
## 47        324   weekly   high          47       32 medium     NA     NA
## 48        466   weekly medium          49       57  large     NA  26.00
## 49        405   weekly medium          48       56  small   11.0  10.00
## 50        466   weekly   high          52       38  large     NA  24.00
## 51        324   weekly   high          50       35  small   15.5  12.50
## 52        466   weekly   high          50       35 medium     NA  21.00
## 53        324   weekly   high          53       39  small     NA  14.00
## 54        324   weekly medium          54       59 medium   23.0  16.50
## 55        324   weekly    low          55       77  small     NA  14.00
## 56        466   weekly   high          56       41 medium   31.0  15.00
## 57        466   weekly   high          57       42  large     NA  25.50
## 58        674   weekly   high          58       43  small   26.0  11.00
## 59        466   weekly   high          59       44 medium   70.0  18.50
## 60        466    daily   high          60       49  small   21.0   9.00
## 61        710    daily   high          61       50 medium     NA  23.00
## 62       1349    daily medium          62       67  large   77.5  25.50
## 63        324   weekly   high          63       48  large   65.0     NA
## 64        324    daily medium          64       71  small   20.0  10.00
## 65        710   weekly medium          65       68  large     NA  24.50
## 66        466    daily medium          66       76 medium   36.5  18.50
## 67        710    daily   high          67       60  large   55.0  26.00
## 68        710   weekly   high          68       58  large  125.0  27.00
## 69        466   weekly medium          69       74  large     NA  24.00
## 70        466    daily medium          70       78  small   13.0     NA
## 71        710    daily   high          71       61 medium     NA  22.00
## 72        710   weekly    low          72       86  large     NA  26.00
## 73        466   weekly medium          73       79  large   77.5  25.50
## 74        466   weekly   high          74       62 medium   27.0     NA
## 75        466    daily medium          75       82  large   82.5  28.00
## 76        710   weekly   high          76       63  large     NA  25.25
## 77        466   weekly medium          77       80 medium   60.0  21.50
## 78        466   weekly   high          78       64 medium     NA  23.25
```

```
## 79        710    daily medium          79       83  large   80.0  24.00
## 80        466    daily medium          80       85 medium     NA  18.50
## 81        710   weekly medium          81       84  large   85.0  25.00
## 82       1217   weekly   high          82       70  large     NA  32.00
## 83        466   weekly   high          83       72  large  115.0  25.50
## 84        701   weekly   high          84       73  large  175.0  30.00
## 85        710   weekly   high          85       75  large     NA  30.00
## 86       1217    daily   high          86       81  large  155.0  26.50
## 87        466   weekly medium          87       87 medium   45.0     NA
## 88         NA     <NA>   <NA>          NA       NA medium     NA  23.00
## 89         NA     <NA>   <NA>          NA       NA  large     NA  24.50
## 90         NA     <NA>   <NA>          NA       NA  small     NA  14.00
## 91         NA     <NA>   <NA>          NA       NA medium     NA  23.00
## 92         NA     <NA>   <NA>          NA       NA medium     NA  18.00
## 93         NA     <NA>   <NA>          NA       NA medium   35.0  16.50
## 94         NA   weekly medium          NA       NA  large  115.0  28.00
## 95         NA    daily   high          NA       NA medium     NA  21.00
## 96         NA     <NA>   <NA>          NA       NA  large     NA  25.75
## 97         NA   weekly   high          NA       NA  large     NA  24.00
## 98         NA     <NA>   <NA>          NA       NA  large     NA  24.00
## 99         NA     <NA>   <NA>          NA       NA  large     NA  25.00
## 100        NA     <NA>   <NA>          NA       NA  large     NA  28.00
## 101        NA     <NA>   <NA>          NA       NA  large   62.5  24.00
## 102        NA     <NA>   <NA>          NA       NA medium     NA  16.00
## 103        NA   weekly   high          NA       NA medium   45.0  21.50
## 104        NA     <NA>   <NA>          NA       NA  large     NA  25.00
## 105        NA     <NA>   <NA>          NA       NA  small   31.5  11.50
## 106        NA   weekly   high          NA       NA  small   19.0  11.50
## 107        NA     <NA>   <NA>          NA       NA  small     NA  12.00
## 108        NA     <NA>   <NA>          NA       NA medium   52.5  19.00
## 109        NA     <NA>   <NA>          NA       NA  large   62.5  24.00
## 110        NA   weekly medium          NA       NA  large     NA  25.00
## 111        NA     <NA>   <NA>          NA       NA  large     NA  24.00
## 112        NA     <NA>   <NA>          NA       NA medium     NA  18.50
## 113        NA    daily medium          NA       NA medium     NA  17.50
## 114        NA    daily   high          NA       NA medium     NA  18.50
## 115        NA   weekly   high          NA       NA medium     NA  17.75
## 116        NA     <NA>   <NA>          NA       NA medium     NA  18.50
## 117        NA     <NA>   <NA>          NA       NA  large     NA  24.00
## 118        NA     <NA>   <NA>          NA       NA  small   35.0  13.25
## 119        NA     <NA>   <NA>          NA       NA  large     NA  28.50
## 120        NA     <NA>   <NA>          NA       NA  large     NA  26.00
## 121        NA     <NA>   <NA>          NA       NA medium     NA  20.00
## 122        NA     <NA>   <NA>          NA       NA  small     NA   9.75
## 123        NA   weekly   high          NA       NA  large     NA  25.00
## 124        NA     <NA>   <NA>          NA       NA medium     NA  17.25
## 125        NA     <NA>   <NA>          NA       NA  large     NA  24.25
## 126        NA   weekly   high          NA       NA medium   26.0  18.00
## 127        NA   weekly   high          NA       NA medium   55.0  22.50
## 128        NA     <NA>   <NA>          NA       NA  small     NA   9.50
## 129        NA     <NA>   <NA>          NA       NA medium     NA  17.50
## 130        NA     <NA>   <NA>          NA       NA  large  100.0  27.50
## 131        NA     <NA>   <NA>          NA       NA  large   92.5  28.00
## 132        NA   weekly   high          NA       NA  small   17.0  14.50
```

```
## 133        NA   weekly   high           NA       NA  large     NA  28.50
## 134        NA     <NA>   <NA>           NA       NA  small     NA  13.00
## 135        NA     <NA>   <NA>           NA       NA  small   17.0     NA
## 136        NA     <NA>   <NA>           NA       NA  small     NA  12.00
## 137        NA     <NA>   <NA>           NA       NA  small     NA  11.25
## 138        NA   weekly   high           NA       NA  large  130.0  27.50
## 139        NA     <NA>   <NA>           NA       NA medium   33.0  17.25
## 140        NA     <NA>   <NA>           NA       NA medium   51.5  20.00
## 141        NA     <NA>   <NA>           NA       NA  small     NA  13.50
## 142        NA   weekly medium           NA       NA  small   12.0  10.00
## 143        NA   weekly   high           NA       NA medium     NA  19.00
## 144        NA   weekly   high           NA       NA  large   97.5  25.50
## 145        NA   weekly medium           NA       NA  small   15.0  13.50
## 146        NA     <NA>   <NA>           NA       NA  small     NA  14.00
## 147        NA     <NA>   <NA>           NA       NA medium   50.0  22.50
## 148        NA   weekly medium           NA       NA medium     NA  18.50
## 149        NA     <NA>   <NA>           NA       NA medium   47.5  20.00
## 150        NA     <NA>   <NA>           NA       NA medium     NA  16.50
## 151        NA     <NA>   <NA>           NA       NA medium     NA  18.00
## 152        NA     <NA>   <NA>           NA       NA  large     NA  24.00
## 153        NA     <NA>   <NA>           NA       NA  small     NA  11.50
## 154        NA     <NA>   <NA>           NA       NA  large   92.5     NA
## 155        NA     <NA>   <NA>           NA       NA  small   24.0  10.50
## 156        NA     <NA>   <NA>           NA       NA  small   20.0  15.00
## 157        NA     <NA>   <NA>           NA       NA  small   10.0   9.50
## 158        NA     <NA>   <NA>           NA       NA  small   40.0   9.75
## 159        NA     <NA>   <NA>           NA       NA  small   17.5  15.00
## 160        NA     <NA>   <NA>           NA       NA medium   35.0  18.00
## 161        NA     <NA>   <NA>           NA       NA  large     NA  24.50
## 162        NA     <NA>   <NA>           NA       NA medium     NA  18.50
## 163        NA   weekly    low           NA       NA  small   40.0  14.00
## 164        NA   weekly   high           NA       NA  small     NA  12.50
## 165        NA   weekly   high           NA       NA  large     NA  25.00
## 166        NA     <NA>   <NA>           NA       NA  small     NA  10.00
## 167        NA     <NA>   <NA>           NA       NA medium     NA  22.50
## 168        NA   weekly   high           NA       NA  large     NA  25.00
## 169        NA   weekly   high           NA       NA  small   20.0  15.00
## 170        NA     <NA>   <NA>           NA       NA  small   17.5  15.00
## 171        NA     <NA>   <NA>           NA       NA medium     NA  22.00
## 172        NA     <NA>   <NA>           NA       NA medium     NA  16.50
```

R provides a special value `NA`, called the missing value, as a placeholder for values that are unknown. The missing value can take the place of any of R's built-in types (integer, numeric, character, and so on).

Missing values are contagious: applying a binary operation to a missing value usually produces another missing value. For instance:

```
5 + NA
```

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

Since we don't know the missing value, we can't possibly know its sum with another number, so the result is again a missing value. An upcoming lecture will provide more details about and examples of missing values.

You can use the `is.na` function to test whether a value is the missing value. Compute the number of missing values in the `longevity` column and assign it to the variable `num_na`.

```
num_na = is.na(dogs$longevity)
num_na = sum(num_na)
num_na
```

```
## [1] 37
```

Check your answer: There are about 30 to 40 missing values in the column.

Exercise 3

The values in the `weight` column are measured in pounds. Convert the entire column into kilograms (at Earth gravity) and assign the new measurements to `weight_kg`.

```
weight_kg = dogs$weight * 0.453592
weight_kg
```

```
##   [1]    NA  6.12 15.88  6.35    NA 13.61 11.34    NA    NA  9.98 21.55  6.80
##  [13]    NA 10.89  7.03  2.49    NA    NA 20.41    NA  9.07    NA    NA 28.35
##  [25] 26.99  5.44 30.62  2.27  2.27  5.67    NA  2.49 29.48    NA  4.08 27.22
##  [37]    NA    NA 30.62 10.89 28.35    NA  7.26    NA  5.44    NA    NA    NA
##  [49]  4.99    NA  7.03    NA    NA 10.43    NA 14.06    NA 11.79 31.75  9.53
##  [61]    NA 35.15 29.48  9.07    NA 16.56 24.95 56.70    NA  5.90    NA    NA
##  [73] 35.15 12.25 37.42    NA 27.22    NA 36.29    NA 38.56    NA 52.16 79.38
##  [85]    NA 70.31 20.41    NA    NA    NA    NA    NA 15.88 52.16    NA    NA
##  [97]    NA    NA    NA    NA 28.35    NA 20.41    NA 14.29  8.62    NA 23.81
## [109] 28.35    NA    NA    NA    NA    NA    NA    NA    NA 15.88    NA    NA
## [121]    NA    NA    NA    NA    NA 11.79 24.95    NA    NA 45.36 41.96  7.71
## [133]    NA    NA  7.71    NA    NA 58.97 14.97 23.36    NA  5.44    NA 44.23
## [145]  6.80    NA 22.68    NA 21.55    NA    NA    NA    NA 41.96 10.89  9.07
## [157]  4.54 18.14  7.94 15.88    NA    NA 18.14    NA    NA    NA    NA    NA
## [169]  9.07  7.94    NA    NA
```

Check your answer: If you did this right, the first few values should roughly be: `NA 6.12 15.88 6.35 NA 13.61`

Exercise 4

The values in the `height` column are measured in inches. Create a logical vector called `smaller_dogs` that has `TRUE` for dogs that are shorter than the median height (ignoring missing values) of the dogs.

Hint: read the documentation for the `median()` to find out how to ignore missing values.

```
m = median(dogs$height, na.rm = TRUE)
smaller_dogs = dogs$height < m
smaller_dogs
```

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

```
## [133] FALSE  TRUE    NA  TRUE  TRUE FALSE  TRUE FALSE  TRUE  TRUE FALSE FALSE
## [145]  TRUE  TRUE FALSE  TRUE FALSE  TRUE  TRUE FALSE  TRUE    NA  TRUE  TRUE
## [157]  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE FALSE  TRUE FALSE FALSE
## [169]  TRUE  TRUE FALSE  TRUE
```

Check your answer: The first few values in the vector should be `FALSE NA FALSE TRUE TRUE TRUE`.

Exercise 5

The 5% trimmed mean is obtained by taking the mean of the middle 90% of the values (trimming off 10% of the values). Read the documentation for `mean()` and use this function to find the 5% trimmed mean of the `longevity` column. Assign the return value from the call to `mean()` to `longevity_mean5`

```
mean(dogs$longevity, 0.05, TRUE)
```

```
## [1] 11
```

Exercise 6

Create a vector called `weight_rnorm` that is the sum of the `weight` column and random values from a normal distribution with mean 0 and sd 2.

```
# Do not change the set.seed() line!
set.seed(37)
weis = dogs$weight
rans = rnorm(length(weis), 0, 2)
weight_rnorm = weis + rans
weight_rnorm
```

```
##   [1]      NA  14.264  36.158  13.413      NA  29.335  24.616      NA      NA
##  [10]  22.432  46.745  15.077      NA  25.965  16.121   2.165      NA      NA
##  [19]  45.806      NA  19.443      NA      NA  57.731  60.978  11.082  67.666
##  [28]   5.048   0.792  13.426      NA   4.457  66.311      NA   9.620  60.259
##  [37]      NA      NA  67.069  25.798  63.087      NA  13.574      NA   8.098
##  [46]      NA      NA      NA   9.041      NA  16.713      NA      NA  25.955
##  [55]      NA  33.312      NA  24.008  73.048  19.717      NA  76.788  61.627
##  [64]  23.758      NA  38.742  54.896 127.056      NA  11.853      NA      NA
##  [73]  79.766  22.958  82.260      NA  60.319      NA  82.161      NA  83.165
##  [82]      NA 112.845 171.784      NA 152.646  43.685      NA      NA      NA
##  [91]      NA      NA  31.944 116.828      NA      NA      NA      NA      NA
## [100]      NA  65.616      NA  44.442      NA  36.997  17.809      NA  54.903
## [109]  62.121      NA      NA      NA      NA      NA      NA      NA      NA
## [118]  31.826      NA      NA      NA      NA      NA      NA      NA  27.823
## [127]  58.832      NA      NA  99.175  92.275  16.507      NA      NA  16.948
## [136]      NA      NA 127.545  29.618  53.714      NA  10.116      NA  96.321
## [145]  16.542      NA  45.794      NA  48.278      NA      NA      NA      NA
## [154]  93.690  27.829  24.046   9.599  40.796  16.763  36.348      NA      NA
## [163]  41.380      NA      NA      NA      NA      NA  17.469  14.731      NA
## [172]      NA
```

```
# Your code here
```

Check your answer: The first few values of `weight_rnorm` should approximately be `NA 14.26 36.16 13.41 NA 29.33`.

Exercise 7

In this exercise, you'll investigate coercion. Run the following code and inspect the results, then write an explanation as to why each of the returned types makes sense.

```
3L + 3i
smaller_dogs * dogs$height
c(smaller_dogs, dogs$breed)
```

WRITE YOUR EXPLANATION BELOW: 3L + 3i is complex because the sum of an integer and a complex number is a complex number smaller_dogs * dogs height is double because smaller_dogs is of type "logical" where TRUE is same as 1 and FALSE is the same as 0, and dogs height is of type "double". Thus, a logical multipled by double is double. c(smaller_dogs, dogs$breed) is of type "character" because when two different types of data are combined, the result is a "character" type.

Exercise 8

For this exercise, you'll use the R package `lobstr` to inspect R's copy-on-write semantics. Install the `lobstr` package with the code:

```
install.packages("lobstr")
```

For the rest of this exercise, you'll need to work in a regular R console rather than in RStudio (you should have both on your computer if you followed the setup instructions posted to the bCourse). In the R console, load the `lobstr` package with the code:

```
library(lobstr)
```

The function `obj_addr()` in the `lobstr` package prints out the memory address of an R object. Here's some code that I ran in the R console earlier:

```
x = 1:7
obj_addr(x)
# [1] "0x7ffbeeab0c78" This does not cause a copy in memory
x[4] = 1000
obj_addr(x)
# [1] "0x7ffbef5817d8" This does not cause a copy in memory
x[5] = 2000
obj_addr(x)
# [1] "0x7ffbef5817d8" This does not cause a copy in memory
y = x
obj_addr(y)
# [1] "0x7ffbef5817d8" This causes a copy in memory
y[3] = NA
obj_addr(y)
# [1] "0x7ffbef581848" This does not cause a copy in memory
y[1] = 42
obj_addr(y)
# [1] "0x7ffbef581848" This does not cause a copy in memory
y = 1 + y
obj_addr(y)
# [1] "0x7ffbef5818b8" This does not cause a copy in memory
```

Run this code in your R console. You'll see different addresses, but should see the same pattern in when the addresses change.

Edit the code above to replace the memory addresses with the ones you found in your R console. Next to each assignment, add a comment that say whether the expression will cause a copy to be made in memory or not.

Are there any surprises? Can you figure out why?

EXPLAIN: When we assign a variable with the value of another variable in R, the new variable will point to the address of the other variable. Then if we change the value and address of the old variable, the new variable will still be pointed to the same address.

Once you have completed these tasks, check that you have written your name at the top of this document and that the document can be knitted.

Finally, it's good practice to print the output of `sessionInfo()` so that others who want to reproduce your results know what packages and version of R you were using when you first did your analysis.

```
# leave this as-is:
sessionInfo()
```

```
## R version 3.6.2 (2019-12-12)
## Platform: x86_64-apple-darwin15.6.0 (64-bit)
## Running under: macOS Catalina 10.15.3
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] lobstr_1.1.1
##
## loaded via a namespace (and not attached):
##  [1] compiler_3.6.2  magrittr_1.5    tools_3.6.2     htmltools_0.4.0
##  [5] yaml_2.2.0      Rcpp_1.0.3      stringi_1.4.5   rmarkdown_2.1
##  [9] knitr_1.27      stringr_1.4.0   xfun_0.12       digest_0.6.23
## [13] rlang_0.4.4     evaluate_0.14
```