Chapter 4_The tidyverse

Chapter 4: The tidyverse

Up to now we have been manipulating vectors by reordering and subsetting them through indexing. However, once we start more advanced analyses, the preferred unit for data storage is not the vector but the data frame. In this chapter we learn to work directly with data frames, which greatly facilitate the organization of information. We will be using data frames for the majority of this book. We will focus on a specific data format referred to as tidy and on specific collection of packages that are particularly helpful for working with tidy data referred to as the tidyverse.

We can load all the tidyverse packages at once by installing and loading the tidyverse package:

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --

## v ggplot2 3.3.5     v purrr   0.3.4
## v tibble  3.1.4     v dplyr   1.0.7
## v tidyr   1.1.3     v stringr 1.4.0
## v readr   2.0.1     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

We will learn how to implement the tidyverse approach throughout the book, but before delving into the details, in this chapter we introduce some of the most widely used tidyverse functionality, starting with the dplyr package for manipulating data frames and the purrr package for working with functions. Note that the tidyverse also includes a graphing package, ggplot2, which we introduce later in Chapter 7 in the Data Visualization part of the book; the readr package discussed in Chapter 5; and many others. In this chapter, we first introduce the concept of tidy data and then demonstrate how we use the tidyverse to work with data frames in this format.

4.1 Tidy data

We say that a data table is in tidy format if each row represents one observation and columns represent the different variables available for each of these observations. The murders dataset is an example of a tidy data frame.

Each row represent a state with each of the five columns providing a different variable related to these states: name, abbreviation, region, population, and total murders.

To see how the same information can be provided in different formats, consider the following example:

This tidy dataset provides fertility rates for two countries across the years. This is a tidy dataset because each row presents one observation with the three variables being country, year, and fertility rate. However, this dataset originally came in another format and was reshaped for the dslabs package. Originally, the data was in the following format:

The same information is provided, but there are two important differences in the format: 1) each row includes several observations and 2) one of the variables, year, is stored in the header. For the tidyverse packages to be optimally used, data need to be reshaped into tidy format, which you will learn to do in the Data Wrangling part of the book. Until then, we will use example datasets that are already in tidy format.

Although not immediately obvious, as you go through the book you will start to appreciate the advantages of working in a framework in which functions use tidy formats for both inputs and outputs. You will see how this permits the data analyst to focus on more important aspects of the analysis rather than the format of the data.

4.2 Exercises

Q1. Examine the built-in dataset co2. Which of the following is true:

a. co2 is tidy data: it has one year for each row.
b. co2 is not tidy: we need at least one column with a character vector.
c. co2 is not tidy: it is a matrix instead of a data frame.
d. co2 is not tidy: to be tidy we would have to wrangle it to have three columns (year, month and value), then each co2 observation would have a row.

```r
data("co2")
co2
```

```
##         Jan    Feb    Mar    Apr    May    Jun    Jul    Aug    Sep    Oct
## 1959 315.42 316.31 316.50 317.56 318.13 318.00 316.39 314.65 313.68 313.18
## 1960 316.27 316.81 317.42 318.87 319.87 319.43 318.01 315.74 314.00 313.68
## 1961 316.73 317.54 318.38 319.31 320.42 319.61 318.42 316.63 314.83 315.16
## 1962 317.78 318.40 319.53 320.42 320.85 320.45 319.45 317.25 316.11 315.27
## 1963 318.58 318.92 319.70 321.22 322.08 321.31 319.58 317.61 316.05 315.83
## 1964 319.41 320.07 320.74 321.40 322.06 321.73 320.27 318.54 316.54 316.71
## 1965 319.27 320.28 320.73 321.97 322.00 321.71 321.05 318.71 317.66 317.14
## 1966 320.46 321.43 322.23 323.54 323.91 323.59 322.24 320.20 318.48 317.94
## 1967 322.17 322.34 322.88 324.25 324.83 323.93 322.38 320.76 319.10 319.24
## 1968 322.40 322.99 323.73 324.86 325.40 325.20 323.98 321.95 320.18 320.09
## 1969 323.83 324.26 325.47 326.50 327.21 326.54 325.72 323.50 322.22 321.62
## 1970 324.89 325.82 326.77 327.97 327.91 327.50 326.18 324.53 322.93 322.90
## 1971 326.01 326.51 327.01 327.62 328.76 328.40 327.20 325.27 323.20 323.40
## 1972 326.60 327.47 327.58 329.56 329.90 328.92 327.88 326.16 324.68 325.04
## 1973 328.37 329.40 330.14 331.33 332.31 331.90 330.70 329.15 327.35 327.02
## 1974 329.18 330.55 331.32 332.48 332.92 332.08 331.01 329.23 327.27 327.21
## 1975 330.23 331.25 331.87 333.14 333.80 333.43 331.73 329.90 328.40 328.17
## 1976 331.58 332.39 333.33 334.41 334.71 334.17 332.89 330.77 329.14 328.78
## 1977 332.75 333.24 334.53 335.90 336.57 336.10 334.76 332.59 331.42 330.98
## 1978 334.80 335.22 336.47 337.59 337.84 337.72 336.37 334.51 332.60 332.38
## 1979 336.05 336.59 337.79 338.71 339.30 339.12 337.56 335.92 333.75 333.70
## 1980 337.84 338.19 339.91 340.60 341.29 341.00 339.39 337.43 335.72 335.84
## 1981 339.06 340.30 341.21 342.33 342.74 342.08 340.32 338.26 336.52 336.68
## 1982 340.57 341.44 342.53 343.39 343.96 343.18 341.88 339.65 337.81 337.69
## 1983 341.20 342.35 342.93 344.77 345.58 345.14 343.81 342.21 339.69 339.82
## 1984 343.52 344.33 345.11 346.88 347.25 346.62 345.22 343.11 340.90 341.18
```

```
## 1985 344.79 345.82 347.25 348.17 348.74 348.07 346.38 344.51 342.92 342.62
## 1986 346.11 346.78 347.68 349.37 350.03 349.37 347.76 345.73 344.68 343.99
## 1987 347.84 348.29 349.23 350.80 351.66 351.07 349.33 347.92 346.27 346.18
## 1988 350.25 351.54 352.05 353.41 354.04 353.62 352.22 350.27 348.55 348.72
## 1989 352.60 352.92 353.53 355.26 355.52 354.97 353.75 351.52 349.64 349.83
## 1990 353.50 354.55 355.23 356.04 357.00 356.07 354.67 352.76 350.82 351.04
## 1991 354.59 355.63 357.03 358.48 359.22 358.12 356.06 353.92 352.05 352.11
## 1992 355.88 356.63 357.72 359.07 359.58 359.17 356.94 354.92 352.94 353.23
## 1993 356.63 357.10 358.32 359.41 360.23 359.55 357.53 355.48 353.67 353.95
## 1994 358.34 358.89 359.95 361.25 361.67 360.94 359.55 357.49 355.84 356.00
## 1995 359.98 361.03 361.66 363.48 363.82 363.30 361.94 359.50 358.11 357.80
## 1996 362.09 363.29 364.06 364.76 365.45 365.01 363.70 361.54 359.51 359.65
## 1997 363.23 364.06 364.61 366.40 366.84 365.68 364.52 362.57 360.24 360.83
##         Nov    Dec
## 1959 314.66 315.43
## 1960 314.84 316.03
## 1961 315.94 316.85
## 1962 316.53 317.53
## 1963 316.91 318.20
## 1964 317.53 318.55
## 1965 318.70 319.25
## 1966 319.63 320.87
## 1967 320.56 321.80
## 1968 321.16 322.74
## 1969 322.69 323.95
## 1970 323.85 324.96
## 1971 324.63 325.85
## 1972 326.34 327.39
## 1973 327.99 328.48
## 1974 328.29 329.41
## 1975 329.32 330.59
## 1976 330.14 331.52
## 1977 332.24 333.68
## 1978 333.75 334.78
## 1979 335.12 336.56
## 1980 336.93 338.04
## 1981 338.19 339.44
## 1982 339.09 340.32
## 1983 340.98 342.82
## 1984 342.80 344.04
## 1985 344.06 345.38
## 1986 345.48 346.72
## 1987 347.64 348.78
## 1988 349.91 351.18
## 1989 351.14 352.37
## 1990 352.69 354.07
## 1991 353.64 354.89
## 1992 354.09 355.33
## 1993 355.30 356.78
## 1994 357.59 359.05
## 1995 359.61 360.74
## 1996 360.80 362.38
## 1997 362.49 364.34
```

<Solution & Answer> "co2" is not tidy because one of the variables, month, is sored in the header. To be a tidy format, each row presents one observation with the three variables being year, month, and value. Therefore, the correct explanation is "d"

Q2. Examine the built-in dataset ChickWeight. Which of the following is true:

a. ChickWeight is not tidy: each chick has more than one row.
b. ChickWeight is tidy: each observation (a weight) is represented by one row. The chick from which this measurement came is one of the variables.
c. ChickWeight is not tidy: we are missing the year column.
d. ChickWeight is tidy: it is stored in a data frame.

```
data("ChickWeight")
ChickWeight
```

```
##     weight Time Chick Diet
## 1       42    0     1    1
## 2       51    2     1    1
## 3       59    4     1    1
## 4       64    6     1    1
## 5       76    8     1    1
## 6       93   10     1    1
## 7      106   12     1    1
## 8      125   14     1    1
## 9      149   16     1    1
## 10     171   18     1    1
## 11     199   20     1    1
## 12     205   21     1    1
## 13      40    0     2    1
## 14      49    2     2    1
## 15      58    4     2    1
## 16      72    6     2    1
## 17      84    8     2    1
## 18     103   10     2    1
## 19     122   12     2    1
## 20     138   14     2    1
## 21     162   16     2    1
## 22     187   18     2    1
## 23     209   20     2    1
## 24     215   21     2    1
## 25      43    0     3    1
## 26      39    2     3    1
## 27      55    4     3    1
## 28      67    6     3    1
## 29      84    8     3    1
## 30      99   10     3    1
## 31     115   12     3    1
## 32     138   14     3    1
## 33     163   16     3    1
## 34     187   18     3    1
## 35     198   20     3    1
## 36     202   21     3    1
## 37      42    0     4    1
## 38      49    2     4    1
```

```
## 39    56   4    4   1
## 40    67   6    4   1
## 41    74   8    4   1
## 42    87  10    4   1
## 43   102  12    4   1
## 44   108  14    4   1
## 45   136  16    4   1
## 46   154  18    4   1
## 47   160  20    4   1
## 48   157  21    4   1
## 49    41   0    5   1
## 50    42   2    5   1
## 51    48   4    5   1
## 52    60   6    5   1
## 53    79   8    5   1
## 54   106  10    5   1
## 55   141  12    5   1
## 56   164  14    5   1
## 57   197  16    5   1
## 58   199  18    5   1
## 59   220  20    5   1
## 60   223  21    5   1
## 61    41   0    6   1
## 62    49   2    6   1
## 63    59   4    6   1
## 64    74   6    6   1
## 65    97   8    6   1
## 66   124  10    6   1
## 67   141  12    6   1
## 68   148  14    6   1
## 69   155  16    6   1
## 70   160  18    6   1
## 71   160  20    6   1
## 72   157  21    6   1
## 73    41   0    7   1
## 74    49   2    7   1
## 75    57   4    7   1
## 76    71   6    7   1
## 77    89   8    7   1
## 78   112  10    7   1
## 79   146  12    7   1
## 80   174  14    7   1
## 81   218  16    7   1
## 82   250  18    7   1
## 83   288  20    7   1
## 84   305  21    7   1
## 85    42   0    8   1
## 86    50   2    8   1
## 87    61   4    8   1
## 88    71   6    8   1
## 89    84   8    8   1
## 90    93  10    8   1
## 91   110  12    8   1
## 92   116  14    8   1
```

```
## 93      126  16     8     1
## 94      134  18     8     1
## 95      125  20     8     1
## 96       42   0     9     1
## 97       51   2     9     1
## 98       59   4     9     1
## 99       68   6     9     1
## 100      85   8     9     1
## 101      96  10     9     1
## 102      90  12     9     1
## 103      92  14     9     1
## 104      93  16     9     1
## 105     100  18     9     1
## 106     100  20     9     1
## 107      98  21     9     1
## 108      41   0    10     1
## 109      44   2    10     1
## 110      52   4    10     1
## 111      63   6    10     1
## 112      74   8    10     1
## 113      81  10    10     1
## 114      89  12    10     1
## 115      96  14    10     1
## 116     101  16    10     1
## 117     112  18    10     1
## 118     120  20    10     1
## 119     124  21    10     1
## 120      43   0    11     1
## 121      51   2    11     1
## 122      63   4    11     1
## 123      84   6    11     1
## 124     112   8    11     1
## 125     139  10    11     1
## 126     168  12    11     1
## 127     177  14    11     1
## 128     182  16    11     1
## 129     184  18    11     1
## 130     181  20    11     1
## 131     175  21    11     1
## 132      41   0    12     1
## 133      49   2    12     1
## 134      56   4    12     1
## 135      62   6    12     1
## 136      72   8    12     1
## 137      88  10    12     1
## 138     119  12    12     1
## 139     135  14    12     1
## 140     162  16    12     1
## 141     185  18    12     1
## 142     195  20    12     1
## 143     205  21    12     1
## 144      41   0    13     1
## 145      48   2    13     1
## 146      53   4    13     1
```

```
## 147     60    6     13     1
## 148     65    8     13     1
## 149     67   10     13     1
## 150     71   12     13     1
## 151     70   14     13     1
## 152     71   16     13     1
## 153     81   18     13     1
## 154     91   20     13     1
## 155     96   21     13     1
## 156     41    0     14     1
## 157     49    2     14     1
## 158     62    4     14     1
## 159     79    6     14     1
## 160    101    8     14     1
## 161    128   10     14     1
## 162    164   12     14     1
## 163    192   14     14     1
## 164    227   16     14     1
## 165    248   18     14     1
## 166    259   20     14     1
## 167    266   21     14     1
## 168     41    0     15     1
## 169     49    2     15     1
## 170     56    4     15     1
## 171     64    6     15     1
## 172     68    8     15     1
## 173     68   10     15     1
## 174     67   12     15     1
## 175     68   14     15     1
## 176     41    0     16     1
## 177     45    2     16     1
## 178     49    4     16     1
## 179     51    6     16     1
## 180     57    8     16     1
## 181     51   10     16     1
## 182     54   12     16     1
## 183     42    0     17     1
## 184     51    2     17     1
## 185     61    4     17     1
## 186     72    6     17     1
## 187     83    8     17     1
## 188     89   10     17     1
## 189     98   12     17     1
## 190    103   14     17     1
## 191    113   16     17     1
## 192    123   18     17     1
## 193    133   20     17     1
## 194    142   21     17     1
## 195     39    0     18     1
## 196     35    2     18     1
## 197     43    0     19     1
## 198     48    2     19     1
## 199     55    4     19     1
## 200     62    6     19     1
```

```
## 201    65   8   19   1
## 202    71  10   19   1
## 203    82  12   19   1
## 204    88  14   19   1
## 205   106  16   19   1
## 206   120  18   19   1
## 207   144  20   19   1
## 208   157  21   19   1
## 209    41   0   20   1
## 210    47   2   20   1
## 211    54   4   20   1
## 212    58   6   20   1
## 213    65   8   20   1
## 214    73  10   20   1
## 215    77  12   20   1
## 216    89  14   20   1
## 217    98  16   20   1
## 218   107  18   20   1
## 219   115  20   20   1
## 220   117  21   20   1
## 221    40   0   21   2
## 222    50   2   21   2
## 223    62   4   21   2
## 224    86   6   21   2
## 225   125   8   21   2
## 226   163  10   21   2
## 227   217  12   21   2
## 228   240  14   21   2
## 229   275  16   21   2
## 230   307  18   21   2
## 231   318  20   21   2
## 232   331  21   21   2
## 233    41   0   22   2
## 234    55   2   22   2
## 235    64   4   22   2
## 236    77   6   22   2
## 237    90   8   22   2
## 238    95  10   22   2
## 239   108  12   22   2
## 240   111  14   22   2
## 241   131  16   22   2
## 242   148  18   22   2
## 243   164  20   22   2
## 244   167  21   22   2
## 245    43   0   23   2
## 246    52   2   23   2
## 247    61   4   23   2
## 248    73   6   23   2
## 249    90   8   23   2
## 250   103  10   23   2
## 251   127  12   23   2
## 252   135  14   23   2
## 253   145  16   23   2
## 254   163  18   23   2
```

```
## 255    170   20    23     2
## 256    175   21    23     2
## 257     42    0    24     2
## 258     52    2    24     2
## 259     58    4    24     2
## 260     74    6    24     2
## 261     66    8    24     2
## 262     68   10    24     2
## 263     70   12    24     2
## 264     71   14    24     2
## 265     72   16    24     2
## 266     72   18    24     2
## 267     76   20    24     2
## 268     74   21    24     2
## 269     40    0    25     2
## 270     49    2    25     2
## 271     62    4    25     2
## 272     78    6    25     2
## 273    102    8    25     2
## 274    124   10    25     2
## 275    146   12    25     2
## 276    164   14    25     2
## 277    197   16    25     2
## 278    231   18    25     2
## 279    259   20    25     2
## 280    265   21    25     2
## 281     42    0    26     2
## 282     48    2    26     2
## 283     57    4    26     2
## 284     74    6    26     2
## 285     93    8    26     2
## 286    114   10    26     2
## 287    136   12    26     2
## 288    147   14    26     2
## 289    169   16    26     2
## 290    205   18    26     2
## 291    236   20    26     2
## 292    251   21    26     2
## 293     39    0    27     2
## 294     46    2    27     2
## 295     58    4    27     2
## 296     73    6    27     2
## 297     87    8    27     2
## 298    100   10    27     2
## 299    115   12    27     2
## 300    123   14    27     2
## 301    144   16    27     2
## 302    163   18    27     2
## 303    185   20    27     2
## 304    192   21    27     2
## 305     39    0    28     2
## 306     46    2    28     2
## 307     58    4    28     2
## 308     73    6    28     2
```

```
## 309     92   8    28     2
## 310    114  10    28     2
## 311    145  12    28     2
## 312    156  14    28     2
## 313    184  16    28     2
## 314    207  18    28     2
## 315    212  20    28     2
## 316    233  21    28     2
## 317     39   0    29     2
## 318     48   2    29     2
## 319     59   4    29     2
## 320     74   6    29     2
## 321     87   8    29     2
## 322    106  10    29     2
## 323    134  12    29     2
## 324    150  14    29     2
## 325    187  16    29     2
## 326    230  18    29     2
## 327    279  20    29     2
## 328    309  21    29     2
## 329     42   0    30     2
## 330     48   2    30     2
## 331     59   4    30     2
## 332     72   6    30     2
## 333     85   8    30     2
## 334     98  10    30     2
## 335    115  12    30     2
## 336    122  14    30     2
## 337    143  16    30     2
## 338    151  18    30     2
## 339    157  20    30     2
## 340    150  21    30     2
## 341     42   0    31     3
## 342     53   2    31     3
## 343     62   4    31     3
## 344     73   6    31     3
## 345     85   8    31     3
## 346    102  10    31     3
## 347    123  12    31     3
## 348    138  14    31     3
## 349    170  16    31     3
## 350    204  18    31     3
## 351    235  20    31     3
## 352    256  21    31     3
## 353     41   0    32     3
## 354     49   2    32     3
## 355     65   4    32     3
## 356     82   6    32     3
## 357    107   8    32     3
## 358    129  10    32     3
## 359    159  12    32     3
## 360    179  14    32     3
## 361    221  16    32     3
## 362    263  18    32     3
```

```
## 363    291  20   32    3
## 364    305  21   32    3
## 365     39   0   33    3
## 366     50   2   33    3
## 367     63   4   33    3
## 368     77   6   33    3
## 369     96   8   33    3
## 370    111  10   33    3
## 371    137  12   33    3
## 372    144  14   33    3
## 373    151  16   33    3
## 374    146  18   33    3
## 375    156  20   33    3
## 376    147  21   33    3
## 377     41   0   34    3
## 378     49   2   34    3
## 379     63   4   34    3
## 380     85   6   34    3
## 381    107   8   34    3
## 382    134  10   34    3
## 383    164  12   34    3
## 384    186  14   34    3
## 385    235  16   34    3
## 386    294  18   34    3
## 387    327  20   34    3
## 388    341  21   34    3
## 389     41   0   35    3
## 390     53   2   35    3
## 391     64   4   35    3
## 392     87   6   35    3
## 393    123   8   35    3
## 394    158  10   35    3
## 395    201  12   35    3
## 396    238  14   35    3
## 397    287  16   35    3
## 398    332  18   35    3
## 399    361  20   35    3
## 400    373  21   35    3
## 401     39   0   36    3
## 402     48   2   36    3
## 403     61   4   36    3
## 404     76   6   36    3
## 405     98   8   36    3
## 406    116  10   36    3
## 407    145  12   36    3
## 408    166  14   36    3
## 409    198  16   36    3
## 410    227  18   36    3
## 411    225  20   36    3
## 412    220  21   36    3
## 413     41   0   37    3
## 414     48   2   37    3
## 415     56   4   37    3
## 416     68   6   37    3
```

```
## 417     80   8    37    3
## 418     83  10    37    3
## 419    103  12    37    3
## 420    112  14    37    3
## 421    135  16    37    3
## 422    157  18    37    3
## 423    169  20    37    3
## 424    178  21    37    3
## 425     41   0    38    3
## 426     49   2    38    3
## 427     61   4    38    3
## 428     74   6    38    3
## 429     98   8    38    3
## 430    109  10    38    3
## 431    128  12    38    3
## 432    154  14    38    3
## 433    192  16    38    3
## 434    232  18    38    3
## 435    280  20    38    3
## 436    290  21    38    3
## 437     42   0    39    3
## 438     50   2    39    3
## 439     61   4    39    3
## 440     78   6    39    3
## 441     89   8    39    3
## 442    109  10    39    3
## 443    130  12    39    3
## 444    146  14    39    3
## 445    170  16    39    3
## 446    214  18    39    3
## 447    250  20    39    3
## 448    272  21    39    3
## 449     41   0    40    3
## 450     55   2    40    3
## 451     66   4    40    3
## 452     79   6    40    3
## 453    101   8    40    3
## 454    120  10    40    3
## 455    154  12    40    3
## 456    182  14    40    3
## 457    215  16    40    3
## 458    262  18    40    3
## 459    295  20    40    3
## 460    321  21    40    3
## 461     42   0    41    4
## 462     51   2    41    4
## 463     66   4    41    4
## 464     85   6    41    4
## 465    103   8    41    4
## 466    124  10    41    4
## 467    155  12    41    4
## 468    153  14    41    4
## 469    175  16    41    4
## 470    184  18    41    4
```

```
## 471      199   20     41     4
## 472      204   21     41     4
## 473       42    0     42     4
## 474       49    2     42     4
## 475       63    4     42     4
## 476       84    6     42     4
## 477      103    8     42     4
## 478      126   10     42     4
## 479      160   12     42     4
## 480      174   14     42     4
## 481      204   16     42     4
## 482      234   18     42     4
## 483      269   20     42     4
## 484      281   21     42     4
## 485       42    0     43     4
## 486       55    2     43     4
## 487       69    4     43     4
## 488       96    6     43     4
## 489      131    8     43     4
## 490      157   10     43     4
## 491      184   12     43     4
## 492      188   14     43     4
## 493      197   16     43     4
## 494      198   18     43     4
## 495      199   20     43     4
## 496      200   21     43     4
## 497       42    0     44     4
## 498       51    2     44     4
## 499       65    4     44     4
## 500       86    6     44     4
## 501      103    8     44     4
## 502      118   10     44     4
## 503      127   12     44     4
## 504      138   14     44     4
## 505      145   16     44     4
## 506      146   18     44     4
## 507       41    0     45     4
## 508       50    2     45     4
## 509       61    4     45     4
## 510       78    6     45     4
## 511       98    8     45     4
## 512      117   10     45     4
## 513      135   12     45     4
## 514      141   14     45     4
## 515      147   16     45     4
## 516      174   18     45     4
## 517      197   20     45     4
## 518      196   21     45     4
## 519       40    0     46     4
## 520       52    2     46     4
## 521       62    4     46     4
## 522       82    6     46     4
## 523      101    8     46     4
## 524      120   10     46     4
```

```
## 525     144    12     46      4
## 526     156    14     46      4
## 527     173    16     46      4
## 528     210    18     46      4
## 529     231    20     46      4
## 530     238    21     46      4
## 531      41     0     47      4
## 532      53     2     47      4
## 533      66     4     47      4
## 534      79     6     47      4
## 535     100     8     47      4
## 536     123    10     47      4
## 537     148    12     47      4
## 538     157    14     47      4
## 539     168    16     47      4
## 540     185    18     47      4
## 541     210    20     47      4
## 542     205    21     47      4
## 543      39     0     48      4
## 544      50     2     48      4
## 545      62     4     48      4
## 546      80     6     48      4
## 547     104     8     48      4
## 548     125    10     48      4
## 549     154    12     48      4
## 550     170    14     48      4
## 551     222    16     48      4
## 552     261    18     48      4
## 553     303    20     48      4
## 554     322    21     48      4
## 555      40     0     49      4
## 556      53     2     49      4
## 557      64     4     49      4
## 558      85     6     49      4
## 559     108     8     49      4
## 560     128    10     49      4
## 561     152    12     49      4
## 562     166    14     49      4
## 563     184    16     49      4
## 564     203    18     49      4
## 565     233    20     49      4
## 566     237    21     49      4
## 567      41     0     50      4
## 568      54     2     50      4
## 569      67     4     50      4
## 570      84     6     50      4
## 571     105     8     50      4
## 572     122    10     50      4
## 573     155    12     50      4
## 574     175    14     50      4
## 575     205    16     50      4
## 576     234    18     50      4
## 577     264    20     50      4
## 578     264    21     50      4
```

<Solution & Answer> As mentioned in Q1 solution, a key feature of tidy is that each observation is represented by one row. The "ChickWeight" dataset satisfies this condtion. Also the chick is one of the variables in the table, as each of one appears with number and is included in the column "Chick". Therefore, the correct answer is "b".

Q3. Examine the built-in dataset BOD. Which of the following is true:

a. BOD is not tidy: it only has six rows.
b. BOD is not tidy: the first column is just an index.
c. BOD is tidy: each row is an observation with two values (time and demand)
d. BOD is tidy: all small datasets are tidy by definition.

```
data("BOD")
BOD
```

```
##   Time demand
## 1    1    8.3
## 2    2   10.3
## 3    3   19.0
## 4    4   16.0
## 5    5   15.6
## 6    7   19.8
```

<Solution & Answer> "c" exactly explain the dataset BOD. Each row is an observation with time and demand. Therefore the answer is "c".

Q4. Which of the following built-in datasets is tidy (you can pick more than one):

a. BJsales
b. EuStockMarkets
c. DNase
d. Formaldehyde
e. Orange
f. UCBAdmissions

```
# a
data("BJsales")
BJsales
```

```
## Time Series:
## Start = 1
## End = 150
## Frequency = 1
##   [1] 200.1 199.5 199.4 198.9 199.0 200.2 198.6 200.0 200.3 201.2 201.6 201.5
##  [13] 201.5 203.5 204.9 207.1 210.5 210.5 209.8 208.8 209.5 213.2 213.7 215.1
##  [25] 218.7 219.8 220.5 223.8 222.8 223.8 221.7 222.3 220.8 219.4 220.1 220.6
##  [37] 218.9 217.8 217.7 215.0 215.3 215.9 216.7 216.7 217.7 218.7 222.9 224.9
##  [49] 222.2 220.7 220.0 218.7 217.0 215.9 215.8 214.1 212.3 213.9 214.6 213.6
##  [61] 212.1 211.4 213.1 212.9 213.3 211.5 212.3 213.0 211.0 210.7 210.1 211.4
##  [73] 210.0 209.7 208.8 208.8 208.8 210.6 211.9 212.8 212.5 214.8 215.3 217.5
##  [85] 218.8 220.7 222.2 226.7 228.4 233.2 235.7 237.1 240.6 243.8 245.3 246.0
##  [97] 246.3 247.7 247.6 247.8 249.4 249.0 249.9 250.5 251.5 249.0 247.6 248.8
## [109] 250.4 250.7 253.0 253.7 255.0 256.2 256.0 257.4 260.4 260.0 261.3 260.4
```

```
## [121] 261.6 260.8 259.8 259.0 258.9 257.4 257.7 257.9 257.4 257.3 257.6 258.9
## [133] 257.8 257.7 257.2 257.5 256.8 257.5 257.0 257.6 257.3 257.5 259.6 261.1
## [145] 262.9 263.3 262.8 261.8 262.2 262.7
```

```r
# b
data("EuStockMarkets")
EuStockMarkets
```

```
## Time Series:
## Start = c(1991, 130)
## End = c(1998, 169)
## Frequency = 260
##               DAX    SMI    CAC   FTSE
## 1991.496 1628.75 1678.1 1772.8 2443.6
## 1991.500 1613.63 1688.5 1750.5 2460.2
## 1991.504 1606.51 1678.6 1718.0 2448.2
## 1991.508 1621.04 1684.1 1708.1 2470.4
## 1991.512 1618.16 1686.6 1723.1 2484.7
## 1991.515 1610.61 1671.6 1714.3 2466.8
## 1991.519 1630.75 1682.9 1734.5 2487.9
## 1991.523 1640.17 1703.6 1757.4 2508.4
## 1991.527 1635.47 1697.5 1754.0 2510.5
## 1991.531 1645.89 1716.3 1754.3 2497.4
## 1991.535 1647.84 1723.8 1759.8 2532.5
## 1991.538 1638.35 1730.5 1755.5 2556.8
## 1991.542 1629.93 1727.4 1758.1 2561.0
## 1991.546 1621.49 1733.3 1757.5 2547.3
## 1991.550 1624.74 1734.0 1763.5 2541.5
## 1991.554 1627.63 1728.3 1762.8 2558.5
## 1991.558 1631.99 1737.1 1768.9 2587.9
## 1991.562 1621.18 1723.1 1778.1 2580.5
## 1991.565 1613.42 1723.6 1780.1 2579.6
## 1991.569 1604.95 1719.0 1767.7 2589.3
## 1991.573 1605.75 1721.2 1757.9 2595.0
## 1991.577 1616.67 1725.3 1756.6 2595.6
## 1991.581 1619.29 1727.2 1754.7 2588.8
## 1991.585 1620.49 1727.2 1766.8 2591.7
## 1991.588 1619.67 1731.6 1766.5 2601.7
## 1991.592 1623.07 1724.1 1762.2 2585.4
## 1991.596 1613.98 1716.9 1759.5 2573.3
## 1991.600 1631.87 1723.4 1782.4 2597.4
## 1991.604 1630.37 1723.0 1789.5 2600.6
## 1991.608 1633.47 1728.4 1783.5 2570.6
## 1991.612 1626.55 1722.1 1780.4 2569.4
## 1991.615 1650.43 1724.5 1808.8 2584.9
## 1991.619 1650.06 1733.6 1820.3 2608.8
## 1991.623 1654.11 1739.0 1820.3 2617.2
## 1991.627 1653.60 1726.2 1820.3 2621.0
## 1991.631 1501.82 1587.4 1687.5 2540.5
## 1991.635 1524.28 1630.6 1725.6 2554.5
## 1991.638 1603.65 1685.5 1792.9 2601.9
## 1991.642 1622.49 1701.3 1819.1 2623.0
## 1991.646 1636.68 1718.0 1833.5 2640.7
## 1991.650 1652.10 1726.2 1853.4 2640.7
```

```
## 1991.654 1645.81 1716.6 1849.7 2619.8
## 1991.658 1650.36 1725.8 1851.8 2624.2
## 1991.662 1651.55 1737.4 1857.7 2638.2
## 1991.665 1649.88 1736.6 1864.3 2645.7
## 1991.669 1653.52 1732.4 1863.5 2679.6
## 1991.673 1657.51 1731.2 1873.2 2669.0
## 1991.677 1649.55 1726.9 1860.8 2664.6
## 1991.681 1649.09 1727.8 1868.7 2663.3
## 1991.685 1646.41 1720.2 1860.4 2667.4
## 1991.688 1638.65 1715.4 1855.9 2653.2
## 1991.692 1625.80 1708.7 1840.5 2630.8
## 1991.696 1628.64 1713.0 1842.6 2626.6
## 1991.700 1632.22 1713.5 1861.2 2641.9
## 1991.704 1633.65 1718.0 1876.2 2625.8
## 1991.708 1631.17 1701.7 1878.3 2606.0
## 1991.712 1635.80 1701.7 1878.4 2594.4
## 1991.715 1621.27 1684.9 1869.4 2583.6
## 1991.719 1624.70 1687.2 1880.4 2588.7
## 1991.723 1616.13 1690.6 1885.5 2600.3
## 1991.727 1618.12 1684.3 1888.4 2579.5
## 1991.731 1627.80 1679.9 1885.2 2576.6
## 1991.735 1625.79 1672.9 1877.9 2597.8
## 1991.738 1614.80 1663.1 1876.5 2595.6
## 1991.742 1612.80 1669.3 1883.8 2599.0
## 1991.746 1605.47 1664.7 1880.6 2621.7
## 1991.750 1609.32 1672.3 1887.4 2645.6
## 1991.754 1607.48 1687.7 1878.3 2644.2
## 1991.758 1607.48 1686.8 1867.1 2625.6
## 1991.762 1604.89 1686.6 1851.9 2624.6
## 1991.765 1589.12 1675.8 1843.6 2596.2
## 1991.769 1582.27 1677.4 1848.1 2599.5
## 1991.773 1567.99 1673.2 1843.4 2584.1
## 1991.777 1568.16 1665.0 1843.6 2570.8
## 1991.781 1569.71 1671.3 1833.8 2555.0
## 1991.785 1571.74 1672.4 1833.4 2574.5
## 1991.788 1585.41 1676.2 1856.9 2576.7
## 1991.792 1570.01 1692.6 1863.4 2579.0
## 1991.796 1561.89 1696.5 1855.5 2588.7
## 1991.800 1565.18 1716.1 1864.2 2601.1
## 1991.804 1570.34 1713.3 1846.0 2575.7
## 1991.808 1577.00 1705.1 1836.8 2559.5
## 1991.812 1590.29 1711.3 1830.4 2561.1
## 1991.815 1572.72 1709.8 1831.6 2528.3
## 1991.819 1572.07 1688.6 1834.8 2514.7
## 1991.823 1579.19 1698.9 1852.1 2558.5
## 1991.827 1588.73 1700.0 1849.8 2553.3
## 1991.831 1586.01 1693.0 1861.8 2577.1
## 1991.835 1579.77 1683.9 1856.7 2566.0
## 1991.838 1572.58 1679.2 1856.7 2549.5
## 1991.842 1568.09 1673.9 1841.5 2527.8
## 1991.846 1578.21 1683.9 1846.9 2540.9
## 1991.850 1573.94 1688.4 1836.1 2534.2
## 1991.854 1582.06 1693.9 1838.6 2538.0
## 1991.858 1610.18 1720.9 1857.6 2559.0
```

```
## 1991.862 1605.16 1717.9 1857.6 2554.9
## 1991.865 1623.84 1733.6 1858.4 2575.5
## 1991.869 1615.26 1729.7 1846.8 2546.5
## 1991.873 1627.08 1735.6 1868.5 2561.6
## 1991.877 1626.97 1734.1 1863.2 2546.6
## 1991.881 1605.70 1699.3 1808.3 2502.9
## 1991.885 1589.70 1678.6 1765.1 2463.1
## 1991.888 1589.70 1675.5 1763.5 2472.6
## 1991.892 1603.26 1670.1 1766.0 2463.5
## 1991.896 1599.75 1652.2 1741.3 2446.3
## 1991.900 1590.86 1635.0 1743.3 2456.2
## 1991.904 1603.50 1654.9 1769.0 2471.5
## 1991.908 1589.86 1642.0 1757.9 2447.5
## 1991.912 1587.92 1638.7 1754.9 2428.6
## 1991.915 1571.06 1622.6 1739.7 2420.2
## 1991.919 1549.81 1596.1 1708.8 2414.9
## 1991.923 1549.36 1612.4 1722.2 2420.2
## 1991.927 1554.65 1625.0 1713.9 2423.8
## 1991.931 1557.52 1610.5 1703.2 2407.0
## 1991.935 1555.31 1606.6 1685.7 2388.7
## 1991.938 1559.76 1610.7 1663.4 2409.6
## 1991.942 1548.44 1603.1 1636.9 2392.0
## 1991.946 1543.99 1591.5 1645.6 2380.2
## 1991.950 1550.21 1605.2 1671.6 2423.3
## 1991.954 1557.03 1621.4 1688.3 2451.6
## 1991.958 1551.78 1622.5 1696.8 2440.8
## 1991.962 1562.89 1626.6 1711.7 2432.9
## 1991.965 1570.28 1627.4 1706.2 2413.6
## 1991.969 1559.26 1614.9 1684.2 2391.6
## 1991.973 1545.87 1602.3 1648.5 2358.1
## 1991.977 1542.77 1598.3 1633.6 2345.4
## 1991.981 1542.77 1627.0 1699.1 2384.4
## 1991.985 1542.77 1627.0 1699.1 2384.4
## 1991.988 1542.77 1627.0 1722.5 2384.4
## 1991.992 1564.27 1655.7 1720.7 2418.7
## 1991.996 1577.26 1670.1 1741.9 2420.0
## 1992.000 1577.26 1670.1 1765.7 2493.1
## 1992.004 1577.26 1670.1 1765.7 2493.1
## 1992.008 1598.19 1670.1 1749.9 2492.8
## 1992.012 1604.05 1704.0 1770.3 2504.1
## 1992.015 1604.69 1711.8 1787.6 2493.2
## 1992.019 1593.65 1700.5 1778.7 2482.9
## 1992.023 1581.68 1690.3 1785.6 2467.1
## 1992.027 1599.14 1715.4 1833.9 2497.9
## 1992.031 1613.82 1723.5 1837.4 2477.9
## 1992.035 1620.45 1719.4 1824.3 2490.1
## 1992.038 1629.51 1734.4 1843.8 2516.3
## 1992.042 1663.70 1772.8 1873.6 2537.1
## 1992.046 1664.09 1760.3 1860.2 2541.6
## 1992.050 1669.29 1747.2 1860.2 2536.7
## 1992.054 1685.14 1750.2 1865.9 2544.9
## 1992.058 1687.07 1755.3 1867.9 2543.4
## 1992.062 1680.13 1754.6 1841.3 2522.0
## 1992.065 1671.84 1751.2 1838.7 2525.3
```

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## 1992.069 1669.52 1752.5 1849.9 2510.4
## 1992.073 1686.71 1769.4 1869.3 2539.9
## 1992.077 1685.51 1767.6 1890.6 2552.0
## 1992.081 1671.01 1750.0 1879.6 2546.5
## 1992.085 1683.06 1747.1 1873.9 2550.8
## 1992.088 1685.70 1753.5 1875.3 2571.2
## 1992.092 1685.66 1752.8 1857.0 2560.2
## 1992.096 1678.77 1752.9 1856.5 2556.8
## 1992.100 1685.85 1764.7 1865.8 2547.1
## 1992.104 1683.71 1776.8 1860.6 2534.3
## 1992.108 1686.59 1779.3 1861.6 2517.2
## 1992.112 1683.73 1785.1 1865.6 2538.4
## 1992.115 1679.14 1798.2 1864.1 2537.1
## 1992.119 1685.03 1794.1 1861.6 2523.7
## 1992.123 1680.81 1795.2 1876.5 2522.6
## 1992.127 1676.17 1780.4 1865.1 2513.9
## 1992.131 1688.46 1789.5 1882.1 2541.0
## 1992.135 1696.55 1794.2 1912.2 2555.9
## 1992.138 1690.24 1784.4 1915.4 2536.7
## 1992.142 1711.35 1800.1 1951.2 2543.4
## 1992.146 1711.29 1804.0 1962.4 2542.3
## 1992.150 1729.86 1816.2 1976.5 2559.7
## 1992.154 1716.63 1810.5 1953.5 2546.8
## 1992.158 1743.36 1821.9 1981.3 2565.0
## 1992.162 1745.17 1828.2 1985.1 2562.0
## 1992.165 1746.76 1840.6 1983.4 2562.1
## 1992.169 1749.29 1841.1 1979.7 2554.3
## 1992.173 1763.86 1846.3 1983.8 2565.4
## 1992.177 1762.27 1850.0 1988.1 2558.4
## 1992.181 1762.29 1839.0 1973.0 2538.3
## 1992.185 1746.77 1820.2 1966.9 2533.1
## 1992.188 1753.50 1815.2 1976.3 2550.7
## 1992.192 1753.21 1820.6 1993.9 2574.8
## 1992.196 1739.88 1807.1 1968.0 2522.4
## 1992.200 1723.92 1791.4 1941.8 2493.3
## 1992.204 1734.42 1806.2 1947.1 2476.0
## 1992.208 1723.13 1798.7 1929.2 2470.7
## 1992.212 1732.92 1818.2 1943.6 2491.2
## 1992.215 1729.89 1820.5 1928.2 2464.7
## 1992.219 1725.74 1833.3 1922.0 2467.6
## 1992.223 1730.90 1837.1 1919.1 2456.6
## 1992.227 1714.17 1818.2 1884.6 2441.0
## 1992.231 1716.20 1824.1 1896.3 2458.7
## 1992.235 1719.06 1830.1 1928.3 2464.9
## 1992.238 1718.21 1835.6 1934.8 2472.2
## 1992.242 1698.84 1828.7 1923.5 2447.9
## 1992.246 1714.76 1839.2 1943.8 2452.9
## 1992.250 1718.35 1837.2 1942.4 2440.1
## 1992.254 1706.69 1826.7 1928.1 2408.6
## 1992.258 1723.37 1838.0 1942.0 2405.4
## 1992.262 1716.18 1829.1 1942.7 2382.7
## 1992.265 1738.78 1843.1 1974.8 2400.9
## 1992.269 1737.41 1850.5 1975.4 2404.2
## 1992.273 1714.77 1827.1 1907.5 2393.2
```

```
## 1992.277 1724.24 1829.1 1943.6 2436.4
## 1992.281 1733.77 1848.0 1974.1 2572.6
## 1992.285 1729.96 1840.5 1963.3 2591.0
## 1992.288 1734.46 1853.8 1972.3 2600.5
## 1992.292 1744.35 1874.1 1990.7 2640.2
## 1992.296 1746.88 1871.3 1978.2 2638.6
## 1992.300 1746.88 1871.3 1978.2 2638.6
## 1992.304 1746.88 1871.3 1978.2 2638.6
## 1992.308 1747.47 1860.5 1980.4 2625.8
## 1992.312 1753.10 1874.7 1983.7 2607.8
## 1992.315 1745.17 1880.1 1978.1 2609.8
## 1992.319 1745.72 1874.7 1984.9 2643.0
## 1992.323 1742.92 1875.6 1995.7 2658.2
## 1992.327 1731.68 1859.5 2006.6 2651.0
## 1992.331 1731.18 1874.2 2036.7 2664.9
## 1992.335 1728.09 1880.1 2031.1 2654.1
## 1992.338 1728.09 1880.1 2031.1 2659.8
## 1992.342 1731.29 1907.7 2041.6 2659.8
## 1992.346 1733.82 1920.5 2046.9 2662.2
## 1992.350 1745.78 1937.3 2047.2 2698.7
## 1992.354 1752.57 1936.8 2063.4 2701.9
## 1992.358 1748.13 1949.1 2063.4 2725.7
## 1992.362 1750.70 1963.7 2077.5 2737.8
## 1992.365 1747.91 1950.8 2063.6 2722.4
## 1992.369 1745.79 1953.5 2053.2 2720.5
## 1992.373 1735.34 1945.0 2017.0 2694.7
## 1992.377 1719.92 1921.1 2024.0 2682.6
## 1992.381 1763.59 1939.1 2051.6 2703.6
## 1992.385 1766.76 1928.0 2023.1 2700.6
## 1992.388 1785.40 1933.4 2030.8 2711.9
## 1992.392 1783.56 1925.7 2016.8 2702.0
## 1992.396 1804.42 1931.7 2045.1 2715.0
## 1992.400 1812.33 1928.7 2046.3 2715.0
## 1992.404 1799.51 1924.5 2029.6 2704.6
## 1992.408 1792.80 1914.2 2014.1 2698.6
## 1992.412 1792.80 1914.2 2014.1 2694.2
## 1992.415 1806.36 1920.6 2033.3 2707.6
## 1992.419 1798.23 1923.3 2017.4 2697.6
## 1992.423 1800.62 1930.4 2024.9 2705.9
## 1992.427 1786.19 1915.2 1992.6 2680.9
## 1992.431 1791.35 1916.9 1994.9 2681.9
## 1992.435 1789.05 1913.8 1981.6 2668.5
## 1992.438 1789.05 1913.8 1981.6 2645.8
## 1992.442 1784.71 1899.7 1962.2 2635.4
## 1992.446 1789.45 1888.0 1953.7 2636.1
## 1992.450 1779.74 1868.8 1928.8 2614.1
## 1992.454 1786.97 1879.9 1928.3 2603.7
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## 1998.181 4695.78 7118.6 3397.0 5764.8
## 1998.185 4693.86 7153.1 3421.9 5767.3
## 1998.188 4781.62 7273.0 3446.7 5820.6
## 1998.192 4759.62 7259.5 3414.9 5807.7
## 1998.196 4690.52 7130.5 3381.3 5733.1
## 1998.200 4676.42 7077.3 3395.8 5695.6
## 1998.204 4762.71 7197.2 3483.2 5782.9
## 1998.208 4828.89 7187.5 3525.9 5818.9
## 1998.212 4852.22 7246.5 3521.5 5828.5
## 1998.215 4862.41 7276.7 3539.4 5829.8
## 1998.219 4838.67 7267.9 3526.6 5794.8
## 1998.223 4872.24 7328.0 3540.2 5782.3
## 1998.227 4905.59 7261.2 3598.3 5785.1
## 1998.231 4945.91 7236.5 3661.3 5834.9
## 1998.235 4908.55 7132.4 3652.5 5903.6
## 1998.238 4949.91 7143.8 3688.7 5997.9
## 1998.242 5045.16 7300.5 3688.9 5956.3
## 1998.246 5014.13 7341.0 3680.1 5947.0
## 1998.250 5064.35 7407.4 3738.5 5983.7
## 1998.254 5114.13 7472.1 3818.7 5967.8
## 1998.258 5029.00 7415.9 3783.8 5905.6
## 1998.262 5066.90 7530.3 3810.2 5939.3
## 1998.265 5069.89 7536.3 3800.2 5911.9
## 1998.269 5097.25 7585.5 3875.3 5932.2
## 1998.273 5135.35 7615.5 3883.3 6017.6
## 1998.277 5179.04 7638.8 3935.9 6052.8
## 1998.281 5254.32 7725.9 3932.0 6064.2
## 1998.285 5345.89 7827.7 3986.8 6105.8
## 1998.288 5309.67 7744.3 3903.3 6094.0
## 1998.292 5267.35 7588.1 3873.9 6055.2
## 1998.296 5312.25 7624.1 3894.5 6105.5
```

```
## 1998.300 5312.25 7624.1 3894.5 6105.5
## 1998.304 5312.25 7624.1 3894.5 6105.5
## 1998.308 5367.98 7662.9 3867.7 6104.1
## 1998.312 5359.24 7616.3 3884.6 6074.1
## 1998.315 5292.97 7500.1 3845.9 6002.0
## 1998.319 5326.63 7453.7 3861.6 5922.2
## 1998.323 5407.93 7500.1 3885.7 5954.1
## 1998.327 5373.80 7369.1 3860.4 5955.0
## 1998.331 5312.28 7308.9 3835.1 5931.1
## 1998.335 5262.57 7265.5 3822.1 5898.1
## 1998.338 5144.42 7232.3 3788.7 5863.9
## 1998.342 5002.71 7053.5 3689.4 5722.4
## 1998.346 5110.88 7180.1 3777.2 5806.6
## 1998.350 5083.80 7241.8 3726.2 5833.1
## 1998.354 5241.23 7401.4 3867.9 5928.3
## 1998.358 5241.23 7401.4 3867.9 6011.3
## 1998.362 5337.75 7640.8 3979.3 6011.3
## 1998.365 5226.20 7596.2 3945.5 5986.5
## 1998.369 5264.62 7610.8 3947.5 5992.4
## 1998.373 5164.89 7536.0 3912.8 5938.0
## 1998.377 5270.61 7587.1 3912.8 5969.8
## 1998.381 5348.75 7677.5 4007.3 6028.3
## 1998.385 5307.82 7627.3 3986.1 5956.7
## 1998.388 5371.99 7582.8 4018.5 5972.9
## 1998.392 5374.11 7550.6 4012.0 5948.5
## 1998.396 5414.31 7519.4 3990.2 5917.8
## 1998.400 5343.66 7371.4 3945.3 5826.2
## 1998.404 5441.00 7483.2 3980.8 5877.8
## 1998.408 5514.51 7495.8 4047.9 5907.4
## 1998.412 5514.51 7495.8 4047.9 5935.6
## 1998.415 5530.19 7542.7 4049.8 5955.6
## 1998.419 5592.46 7657.1 4108.7 5955.6
## 1998.423 5639.89 7731.9 4115.9 5970.7
## 1998.427 5466.88 7633.5 4017.4 5870.2
## 1998.431 5507.36 7605.0 4014.9 5862.3
## 1998.435 5556.99 7656.1 4041.2 5870.7
## 1998.438 5556.99 7656.1 4041.2 5837.9
## 1998.442 5583.83 7657.5 4087.0 5842.3
## 1998.446 5640.42 7676.3 4149.4 5898.4
## 1998.450 5605.38 7592.9 4119.0 5860.8
## 1998.454 5724.75 7699.5 4185.1 5947.3
## 1998.458 5787.05 7743.4 4204.6 6037.8
## 1998.462 5773.77 7716.8 4201.9 6019.8
## 1998.465 5799.22 7652.6 4208.6 5987.4
## 1998.469 5799.22 7498.4 4141.6 5852.5
## 1998.473 5631.34 7417.4 4050.8 5769.8
## 1998.477 5581.24 7342.7 4005.3 5715.7
## 1998.481 5621.71 7388.7 4013.3 5729.7
## 1998.485 5742.83 7562.7 4092.9 5832.7
## 1998.488 5689.89 7488.0 4052.3 5812.1
## 1998.492 5644.22 7518.6 4027.3 5748.1
## 1998.496 5648.11 7511.8 4018.6 5712.4
## 1998.500 5748.34 7624.8 4065.0 5772.0
## 1998.504 5784.40 7667.9 4126.3 5804.9
```

```
## 1998.508 5886.72 7794.7 4203.8 5858.9
## 1998.512 5870.49 7816.9 4215.7 5877.4
## 1998.515 5933.73 7881.9 4248.2 5884.5
## 1998.519 5841.83 7882.0 4203.5 5832.5
## 1998.523 5910.51 8038.2 4260.7 5919.9
## 1998.527 5905.15 8047.3 4252.1 5960.2
## 1998.531 5961.45 8099.0 4304.4 5988.4
## 1998.535 5942.06 8166.0 4311.1 5990.3
## 1998.538 5975.88 8160.0 4333.1 6003.4
## 1998.542 6018.89 8227.2 4339.9 6009.6
## 1998.546 6000.84 8205.0 4319.2 5969.7
## 1998.550 6001.24 8192.4 4256.4 5927.9
## 1998.554 6023.31 8141.9 4256.4 5958.2
## 1998.558 6101.90 8180.5 4256.4 6100.2
## 1998.562 6106.10 8158.1 4344.3 6151.5
## 1998.565 6108.00 8126.5 4358.1 6116.8
## 1998.569 6162.86 8288.2 4388.5 6174.0
## 1998.573 6186.09 8400.8 4368.9 6179.0
## 1998.577 6184.10 8412.0 4322.1 6132.7
## 1998.581 6081.11 8340.7 4220.1 5989.6
## 1998.585 6043.82 8229.2 4235.9 5976.2
## 1998.588 6040.58 8205.7 4205.4 5892.3
## 1998.592 5854.35 7998.7 4139.5 5836.1
## 1998.596 5867.52 8093.0 4122.4 5835.8
## 1998.600 5828.74 8102.7 4139.2 5844.1
## 1998.604 5906.33 8205.5 4197.6 5910.7
## 1998.608 5861.19 8239.5 4177.3 5837.0
## 1998.612 5774.38 8139.2 4095.0 5809.7
## 1998.615 5718.70 8170.2 4047.9 5736.1
## 1998.619 5614.77 7943.2 3976.4 5632.5
## 1998.623 5528.12 7846.2 3968.6 5594.1
## 1998.627 5598.32 7952.9 4041.9 5680.4
## 1998.631 5460.43 7721.3 3939.5 5587.6
## 1998.635 5285.78 7447.9 3846.0 5432.8
## 1998.638 5386.94 7607.5 3945.7 5462.2
## 1998.642 5355.03 7552.6 3951.7 5399.5
## 1998.646 5473.72 7676.3 3995.0 5455.0
```

```r
# c
data("DNase")
DNase
```

```
##     Run        conc density
## 1     1 0.04882812   0.017
## 2     1 0.04882812   0.018
## 3     1 0.19531250   0.121
## 4     1 0.19531250   0.124
## 5     1 0.39062500   0.206
## 6     1 0.39062500   0.215
## 7     1 0.78125000   0.377
## 8     1 0.78125000   0.374
## 9     1 1.56250000   0.614
## 10    1 1.56250000   0.609
## 11    1 3.12500000   1.019
```

```
## 12    1  3.12500000   1.001
## 13    1  6.25000000   1.334
## 14    1  6.25000000   1.364
## 15    1 12.50000000   1.730
## 16    1 12.50000000   1.710
## 17    2  0.04882812   0.045
## 18    2  0.04882812   0.050
## 19    2  0.19531250   0.137
## 20    2  0.19531250   0.123
## 21    2  0.39062500   0.225
## 22    2  0.39062500   0.207
## 23    2  0.78125000   0.401
## 24    2  0.78125000   0.383
## 25    2  1.56250000   0.672
## 26    2  1.56250000   0.681
## 27    2  3.12500000   1.116
## 28    2  3.12500000   1.078
## 29    2  6.25000000   1.554
## 30    2  6.25000000   1.526
## 31    2 12.50000000   1.932
## 32    2 12.50000000   1.914
## 33    3  0.04882812   0.070
## 34    3  0.04882812   0.068
## 35    3  0.19531250   0.173
## 36    3  0.19531250   0.165
## 37    3  0.39062500   0.277
## 38    3  0.39062500   0.248
## 39    3  0.78125000   0.434
## 40    3  0.78125000   0.426
## 41    3  1.56250000   0.703
## 42    3  1.56250000   0.689
## 43    3  3.12500000   1.067
## 44    3  3.12500000   1.077
## 45    3  6.25000000   1.629
## 46    3  6.25000000   1.479
## 47    3 12.50000000   2.003
## 48    3 12.50000000   1.884
## 49    4  0.04882812   0.011
## 50    4  0.04882812   0.016
## 51    4  0.19531250   0.118
## 52    4  0.19531250   0.108
## 53    4  0.39062500   0.200
## 54    4  0.39062500   0.206
## 55    4  0.78125000   0.364
## 56    4  0.78125000   0.360
## 57    4  1.56250000   0.620
## 58    4  1.56250000   0.640
## 59    4  3.12500000   0.979
## 60    4  3.12500000   0.973
## 61    4  6.25000000   1.424
## 62    4  6.25000000   1.399
## 63    4 12.50000000   1.740
## 64    4 12.50000000   1.732
## 65    5  0.04882812   0.035
```

```
## 66     5  0.04882812   0.035
## 67     5  0.19531250   0.132
## 68     5  0.19531250   0.135
## 69     5  0.39062500   0.224
## 70     5  0.39062500   0.220
## 71     5  0.78125000   0.385
## 72     5  0.78125000   0.390
## 73     5  1.56250000   0.658
## 74     5  1.56250000   0.647
## 75     5  3.12500000   1.060
## 76     5  3.12500000   1.031
## 77     5  6.25000000   1.425
## 78     5  6.25000000   1.409
## 79     5 12.50000000   1.750
## 80     5 12.50000000   1.738
## 81     6  0.04882812   0.086
## 82     6  0.04882812   0.103
## 83     6  0.19531250   0.191
## 84     6  0.19531250   0.189
## 85     6  0.39062500   0.272
## 86     6  0.39062500   0.277
## 87     6  0.78125000   0.440
## 88     6  0.78125000   0.426
## 89     6  1.56250000   0.686
## 90     6  1.56250000   0.676
## 91     6  3.12500000   1.062
## 92     6  3.12500000   1.072
## 93     6  6.25000000   1.424
## 94     6  6.25000000   1.459
## 95     6 12.50000000   1.768
## 96     6 12.50000000   1.806
## 97     7  0.04882812   0.094
## 98     7  0.04882812   0.092
## 99     7  0.19531250   0.182
## 100    7  0.19531250   0.182
## 101    7  0.39062500   0.282
## 102    7  0.39062500   0.273
## 103    7  0.78125000   0.444
## 104    7  0.78125000   0.439
## 105    7  1.56250000   0.686
## 106    7  1.56250000   0.668
## 107    7  3.12500000   1.052
## 108    7  3.12500000   1.035
## 109    7  6.25000000   1.409
## 110    7  6.25000000   1.392
## 111    7 12.50000000   1.759
## 112    7 12.50000000   1.739
## 113    8  0.04882812   0.054
## 114    8  0.04882812   0.054
## 115    8  0.19531250   0.152
## 116    8  0.19531250   0.148
## 117    8  0.39062500   0.226
## 118    8  0.39062500   0.222
## 119    8  0.78125000   0.392
```

```
## 120   8  0.78125000   0.383
## 121   8  1.56250000   0.658
## 122   8  1.56250000   0.644
## 123   8  3.12500000   1.043
## 124   8  3.12500000   1.002
## 125   8  6.25000000   1.466
## 126   8  6.25000000   1.381
## 127   8 12.50000000   1.743
## 128   8 12.50000000   1.724
## 129   9  0.04882812   0.032
## 130   9  0.04882812   0.043
## 131   9  0.19531250   0.142
## 132   9  0.19531250   0.155
## 133   9  0.39062500   0.239
## 134   9  0.39062500   0.242
## 135   9  0.78125000   0.420
## 136   9  0.78125000   0.395
## 137   9  1.56250000   0.624
## 138   9  1.56250000   0.705
## 139   9  3.12500000   1.046
## 140   9  3.12500000   1.026
## 141   9  6.25000000   1.398
## 142   9  6.25000000   1.405
## 143   9 12.50000000   1.693
## 144   9 12.50000000   1.729
## 145  10  0.04882812   0.052
## 146  10  0.04882812   0.094
## 147  10  0.19531250   0.164
## 148  10  0.19531250   0.166
## 149  10  0.39062500   0.259
## 150  10  0.39062500   0.256
## 151  10  0.78125000   0.439
## 152  10  0.78125000   0.439
## 153  10  1.56250000   0.690
## 154  10  1.56250000   0.701
## 155  10  3.12500000   1.042
## 156  10  3.12500000   1.075
## 157  10  6.25000000   1.340
## 158  10  6.25000000   1.406
## 159  10 12.50000000   1.699
## 160  10 12.50000000   1.708
## 161  11  0.04882812   0.047
## 162  11  0.04882812   0.057
## 163  11  0.19531250   0.159
## 164  11  0.19531250   0.155
## 165  11  0.39062500   0.246
## 166  11  0.39062500   0.252
## 167  11  0.78125000   0.427
## 168  11  0.78125000   0.411
## 169  11  1.56250000   0.704
## 170  11  1.56250000   0.684
## 171  11  3.12500000   0.994
## 172  11  3.12500000   0.980
## 173  11  6.25000000   1.421
```

```
## 174  11  6.25000000   1.385
## 175  11 12.50000000   1.715
## 176  11 12.50000000   1.721
```

```r
# d
data("Formaldehyde")
Formaldehyde
```

```
##   carb optden
## 1  0.1  0.086
## 2  0.3  0.269
## 3  0.5  0.446
## 4  0.6  0.538
## 5  0.7  0.626
## 6  0.9  0.782
```

```r
# e
data("Orange")
Orange
```

```
##    Tree  age circumference
## 1     1  118            30
## 2     1  484            58
## 3     1  664            87
## 4     1 1004           115
## 5     1 1231           120
## 6     1 1372           142
## 7     1 1582           145
## 8     2  118            33
## 9     2  484            69
## 10    2  664           111
## 11    2 1004           156
## 12    2 1231           172
## 13    2 1372           203
## 14    2 1582           203
## 15    3  118            30
## 16    3  484            51
## 17    3  664            75
## 18    3 1004           108
## 19    3 1231           115
## 20    3 1372           139
## 21    3 1582           140
## 22    4  118            32
## 23    4  484            62
## 24    4  664           112
## 25    4 1004           167
## 26    4 1231           179
## 27    4 1372           209
## 28    4 1582           214
## 29    5  118            30
## 30    5  484            49
## 31    5  664            81
## 32    5 1004           125
```

```
## 33    5 1231           142
## 34    5 1372           174
## 35    5 1582           177
```

```r
# f
data("UCBAdmissions")
UCBAdmissions
```

```
## , , Dept = A
##
##           Gender
## Admit      Male Female
##   Admitted  512     89
##   Rejected  313     19
##
## , , Dept = B
##
##           Gender
## Admit      Male Female
##   Admitted  353     17
##   Rejected  207      8
##
## , , Dept = C
##
##           Gender
## Admit      Male Female
##   Admitted  120    202
##   Rejected  205    391
##
## , , Dept = D
##
##           Gender
## Admit      Male Female
##   Admitted  138    131
##   Rejected  279    244
##
## , , Dept = E
##
##           Gender
## Admit      Male Female
##   Admitted   53     94
##   Rejected  138    299
##
## , , Dept = F
##
##           Gender
## Admit      Male Female
##   Admitted   22     24
##   Rejected  351    317
```

<Solution & Answer> The answer is "c", "d", "e", because each variables of them forms a colummn.

4.3 Manipulating data frames

The dplyr package from the tidyverse introduces functions that perform some of the most common operations when working with data frames and uses names for these functions that are relatively easy to remember. For instance, to change the data table by adding a new column, we use "mutate". To filter the data table to a subset of rows, we use "filter". Finally, to subset the data by selecting specific columns, we use "select".

4.3.1 Adding a column with mutate

We want all the necessary information for our analysis to be included in the data table. So the first task is to add the murder rates to our murders data frame. The function mutate takes the data frame as a first argument and the name and values of the variable as a second argument using the convention name = values. So, to add murder rates, we use:

```
library(dslabs)
data("murders")
murders <- mutate(murders, rate = total/population*100000)
```

Notice that here we used total and population inside the function, which are objects that are not defined in our workspace. But why don't we get an error?

This is one of dplyr's main features. Functions in this package, such as mutate, know to look for variables in the data frame provided in the first argument. In the call to mutate above, total will have the values in murders$total. This approach makes the code much more readable.

We can see that the new column is added:

```
head(murders)
```

```
##        state abb region population total     rate
## 1    Alabama  AL  South    4779736   135 2.824424
## 2     Alaska  AK   West     710231    19 2.675186
## 3    Arizona  AZ   West    6392017   232 3.629527
## 4   Arkansas  AR  South    2915918    93 3.189390
## 5 California  CA   West   37253956  1257 3.374138
## 6   Colorado  CO   West    5029196    65 1.292453
```

Although we have overwritten the original murders object, this does not change the object that loaded with data(murders). If we load the murders data again, the original will overwrite our mutated version.

4.3.2 Subsetting with filter

Now suppose that we want to filter the data table to only show the entries for which the murder rate is lower than 0.71. To do this we use the filter function, which takes the data table as the first argument and then the conditional statement as the second. Like mutate, we can use the unquoted variable names from murders inside the function and it will know we mean the columns and not objects in the workspace.

```
filter(murders, rate<=0.71)
```

```
##           state abb        region population total      rate
## 1        Hawaii  HI          West    1360301     7 0.5145920
## 2          Iowa  IA North Central    3046355    21 0.6893484
## 3 New Hampshire  NH     Northeast    1316470     5 0.3798036
## 4  North Dakota  ND North Central     672591     4 0.5947151
## 5       Vermont  VT     Northeast     625741     2 0.3196211
```

4.3.3 Selecting columns with select

Although our data table only has six columns, some data tables include hundreds. If we want to view just a few, we can use the dplyr select function. In the code below we select three columns, assign this to a new object and then filter the new object:

```
new_table <- select(murders, state, region, rate)
filter(new_table, rate<=0.71)
```

```
##          state        region      rate
## 1       Hawaii          West 0.5145920
## 2         Iowa North Central 0.6893484
## 3 New Hampshire     Northeast 0.3798036
## 4  North Dakota North Central 0.5947151
## 5      Vermont     Northeast 0.3196211
```

In the call to select, the first argument murders is an object, but state, region, and rate are variable names.

4.4 Exercises

Q1. Load the dplyr package and the murders dataset.

```
library(dplyr)
library(dslabs)
data("murders")
```

You can add columns using the dplyr function mutate. This function is aware of the column names and inside the function you can call them unquoted:

```
murders <- mutate(murders, population_in_millions = population / 10^6)
```

We can write population rather than murders$population. The function mutate knows we are grabbing columns from murders.

Use the function mutate to add a murders column named rate with the per 100,000 murder rate as in the example code above. Make sure you redefine murders as done in the example code above (murders <- [your code]) so we can keep using this variable.

```
murders <- mutate(murders, rate = total/population*100000)
head(murders)
```

```
##        state abb region population total population_in_millions     rate
## 1    Alabama  AL  South    4779736   135               4.779736 2.824424
## 2     Alaska  AK   West     710231    19               0.710231 2.675186
## 3    Arizona  AZ   West    6392017   232               6.392017 3.629527
## 4   Arkansas  AR  South    2915918    93               2.915918 3.189390
## 5 California  CA   West   37253956  1257              37.253956 3.374138
## 6   Colorado  CO   West    5029196    65               5.029196 1.292453
```

Q2. If rank(x) gives you the ranks of x from lowest to highest, rank(-x) gives you the ranks from highest to lowest. Use the function mutate to add a column rank containing the rank, from highest to lowest murder rate. Make sure you redefine murders so we can keep using this variable.

```r
murders <- mutate(murders, rank = rank(-rate))
head(murders)
```

```
##        state abb region population total population_in_millions     rate rank
## 1    Alabama  AL  South    4779736   135               4.779736 2.824424   23
## 2     Alaska  AK   West     710231    19               0.710231 2.675186   27
## 3    Arizona  AZ   West    6392017   232               6.392017 3.629527   10
## 4   Arkansas  AR  South    2915918    93               2.915918 3.189390   17
## 5 California  CA   West   37253956  1257              37.253956 3.374138   14
## 6   Colorado  CO   West    5029196    65               5.029196 1.292453   38
```

Q3. With dplyr, we can use select to show only certain columns. For example, with this code we would only show the states and population sizes:

```r
select(murders, state, population) %>% head()
```

```
##        state population
## 1    Alabama    4779736
## 2     Alaska     710231
## 3    Arizona    6392017
## 4   Arkansas    2915918
## 5 California   37253956
## 6   Colorado    5029196
```

Use select to show the state names and abbreviations in murders. Do not redefine murders, just show the results.

```r
select(murders, state, abb)
```

```
##                   state abb
## 1               Alabama  AL
## 2                Alaska  AK
## 3               Arizona  AZ
## 4              Arkansas  AR
## 5            California  CA
## 6              Colorado  CO
## 7           Connecticut  CT
## 8              Delaware  DE
## 9  District of Columbia  DC
## 10              Florida  FL
## 11              Georgia  GA
## 12               Hawaii  HI
## 13                Idaho  ID
## 14             Illinois  IL
## 15              Indiana  IN
## 16                 Iowa  IA
## 17               Kansas  KS
## 18             Kentucky  KY
## 19            Louisiana  LA
## 20                Maine  ME
## 21             Maryland  MD
```

```
## 22        Massachusetts  MA
## 23             Michigan  MI
## 24            Minnesota  MN
## 25          Mississippi  MS
## 26             Missouri  MO
## 27              Montana  MT
## 28             Nebraska  NE
## 29               Nevada  NV
## 30        New Hampshire  NH
## 31           New Jersey  NJ
## 32           New Mexico  NM
## 33             New York  NY
## 34       North Carolina  NC
## 35         North Dakota  ND
## 36                 Ohio  OH
## 37             Oklahoma  OK
## 38               Oregon  OR
## 39         Pennsylvania  PA
## 40         Rhode Island  RI
## 41       South Carolina  SC
## 42         South Dakota  SD
## 43            Tennessee  TN
## 44                Texas  TX
## 45                 Utah  UT
## 46              Vermont  VT
## 47             Virginia  VA
## 48           Washington  WA
## 49        West Virginia  WV
## 50            Wisconsin  WI
## 51              Wyoming  WY
```

Q4. The dplyr function filter is used to choose specific rows of the data frame to keep. Unlike select which is for columns, filter is for rows. For example, you can show just the New York row like this:

```
filter(murders, state=="New York")
```

```
##      state abb    region population total population_in_millions    rate rank
## 1 New York  NY Northeast   19378102   517                19.3781 2.66796   29
```

You can use other logical vectors to filter rows.

Use filter to show the top 5 states with the highest murder rates. After we add murder rate and rank, do not change the murders dataset, just show the result. Remember that you can filter based on the rank column.

```
filter(murders, rank<=5)
```

```
##                  state abb        region population total
## 1 District of Columbia  DC         South     601723    99
## 2            Louisiana  LA         South    4533372   351
## 3             Maryland  MD         South    5773552   293
## 4             Missouri  MO North Central    5988927   321
## 5       South Carolina  SC         South    4625364   207
##   population_in_millions      rate rank
```

```
## 1               0.601723 16.452753    1
## 2               4.533372  7.742581    2
## 3               5.773552  5.074866    4
## 4               5.988927  5.359892    3
## 5               4.625364  4.475323    5
```

Q5. We can remove rows using the != operator. For example, to remove Florida, we would do this:

```
no_florida <- filter(murders, state != "Florida")
```

Create a new data frame called no_south that removes states from the South region. How many states are in this category? You can use the function nrow for this.

```
no_south <- filter(murders, region != "South")
nrow(no_south)
```

```
## [1] 34
```

Q6. We can also use %in% to filter with dplyr. You can therefore see the data from New York and Texas like this:

```
filter(murders, state %in% c("New York", "Texas"))
```

```
##      state abb    region population total population_in_millions    rate rank
## 1 New York  NY Northeast   19378102   517               19.37810 2.66796   29
## 2    Texas  TX     South   25145561   805               25.14556 3.20136   16
```

Create a new data frame called murders_nw with only the states from the Northeast and the West. How many states are in this category?

```
murders_nw <- filter(murders, region %in% c("Northeast", "West"))
nrow(murders_nw)
```

```
## [1] 22
```

Q7. Suppose you want to live in the Northeast or West and want the murder rate to be less than 1. We want to see the data for the states satisfying these options. Note that you can use logical operators with filter. Here is an example in which we filter to keep only small states in the Northeast region.

```
filter(murders, population < 5000000 & region == "Northeast")
```

```
##           state abb    region population total population_in_millions      rate
## 1   Connecticut  CT Northeast    3574097    97               3.574097 2.7139722
## 2         Maine  ME Northeast    1328361    11               1.328361 0.8280881
## 3 New Hampshire  NH Northeast    1316470     5               1.316470 0.3798036
## 4  Rhode Island  RI Northeast    1052567    16               1.052567 1.5200933
## 5       Vermont  VT Northeast     625741     2               0.625741 0.3196211
##   rank
## 1   25
## 2   44
## 3   50
## 4   35
## 5   51
```

Make sure murders has been defined with rate and rank and still has all states. Create a table called my_states that contains rows for states satisfying both the conditions: it is in the Northeast or West and the murder rate is less than 1. Use select to show only the state name, the rate, and the rank.

```
my_states <- filter(murders, region %in% c("Northeast", "West") & rate <1)
my_states
```

```
##           state abb    region population total population_in_millions      rate
## 1        Hawaii  HI      West    1360301     7               1.360301 0.5145920
## 2         Idaho  ID      West    1567582    12               1.567582 0.7655102
## 3         Maine  ME Northeast    1328361    11               1.328361 0.8280881
## 4 New Hampshire  NH Northeast    1316470     5               1.316470 0.3798036
## 5        Oregon  OR      West    3831074    36               3.831074 0.9396843
## 6          Utah  UT      West    2763885    22               2.763885 0.7959810
## 7       Vermont  VT Northeast     625741     2               0.625741 0.3196211
## 8       Wyoming  WY      West     563626     5               0.563626 0.8871131
##   rank
## 1   49
## 2   46
## 3   44
## 4   50
## 5   42
## 6   45
## 7   51
## 8   43
```

4.5 The pipe: %>%

With dplyr we can perform a series of operations, for example select and then filter, by sending the results of one function to another using what is called the pipe operator: %>%. Some details are included below.

We wrote code above to show three variables (state, region, rate) for states that have murder rates below 0.71. To do this, we defined the intermediate object new_table. In dplyr we can write code that looks more like a description of what we want to do without intermediate objects:

original data → select → filter

For such an operation, we can use the pipe %>%. The code looks like this:

```
murders %>% select(state, region, rate) %>% filter(rate <= 0.71)
```

```
##           state        region      rate
## 1        Hawaii          West 0.5145920
## 2          Iowa North Central 0.6893484
## 3 New Hampshire     Northeast 0.3798036
## 4  North Dakota North Central 0.5947151
## 5       Vermont     Northeast 0.3196211
```

This line of code is equivalent to the two lines of code above. What is going on here?

In general, the pipe sends the result of the left side of the pipe to be the first argument of the function on the right side of the pipe. Here is a very simple example:

```r
16 %>% sqrt()
```

```
## [1] 4
```

We can continue to pipe values along:

```r
16 %>% sqrt() %>% log2()
```

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

The above statement is equivalent to log2(sqrt(16)).

Remember that the pipe sends values to the first argument, so we can define other arguments as if the first argument is already defined:

```r
16 %>% sqrt() %>% log(base = 2)
```

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

Therefore, when using the pipe with data frames and dplyr, we no longer need to specify the required first argument since the dplyr functions we have described all take the data as the first argument. In the code we wrote:

```r
murders %>% select(state, region, rate) %>% filter(rate <= 0.71)
```

```
##           state        region      rate
## 1        Hawaii          West 0.5145920
## 2          Iowa North Central 0.6893484
## 3 New Hampshire     Northeast 0.3798036
## 4  North Dakota North Central 0.5947151
## 5       Vermont     Northeast 0.3196211
```

murders is the first argument of the select function, and the new data frame (formerly new_table) is the first argument of the filter function.

Note that the pipe works well with functions where the first argument is the input data. Functions in tidyverse packages like dplyr have this format and can be used easily with the pipe.

4.6 Exercises

Q1. The pipe %>% can be used to perform operations sequentially without having to define intermediate objects. Start by redefining murder to include rate and rank.

```r
murders <- mutate(murders, rate =  total / population * 100000,
                  rank = rank(-rate))
```

In the solution to the previous exercise, we did the following:

```
my_states <- filter(murders, region %in% c("Northeast", "West") &
                      rate < 1)

select(my_states, state, rate, rank)
```

```
##           state      rate rank
## 1        Hawaii 0.5145920   49
## 2         Idaho 0.7655102   46
## 3         Maine 0.8280881   44
## 4 New Hampshire 0.3798036   50
## 5        Oregon 0.9396843   42
## 6          Utah 0.7959810   45
## 7       Vermont 0.3196211   51
## 8       Wyoming 0.8871131   43
```

The pipe %>% permits us to perform both operations sequentially without having to define an intermediate variable my_states. We therefore could have mutated and selected in the same line like this:

```
mutate(murders, rate =  total / population * 100000,
       rank = rank(-rate)) %>%
  select(state, rate, rank)
```

```
##                   state       rate rank
## 1               Alabama  2.8244238   23
## 2                Alaska  2.6751860   27
## 3               Arizona  3.6295273   10
## 4              Arkansas  3.1893901   17
## 5            California  3.3741383   14
## 6              Colorado  1.2924531   38
## 7           Connecticut  2.7139722   25
## 8              Delaware  4.2319369    6
## 9  District of Columbia 16.4527532    1
## 10              Florida  3.3980688   13
## 11              Georgia  3.7903226    9
## 12               Hawaii  0.5145920   49
## 13                Idaho  0.7655102   46
## 14             Illinois  2.8369608   22
## 15              Indiana  2.1900730   31
## 16                 Iowa  0.6893484   47
## 17               Kansas  2.2081106   30
## 18             Kentucky  2.6732010   28
## 19            Louisiana  7.7425810    2
## 20                Maine  0.8280881   44
## 21             Maryland  5.0748655    4
## 22        Massachusetts  1.8021791   32
## 23             Michigan  4.1786225    7
## 24            Minnesota  0.9992600   40
## 25          Mississippi  4.0440846    8
## 26             Missouri  5.3598917    3
## 27              Montana  1.2128379   39
## 28             Nebraska  1.7521372   33
## 29               Nevada  3.1104763   19
```

```
## 30        New Hampshire  0.3798036   50
## 31           New Jersey  2.7980319   24
## 32           New Mexico  3.2537239   15
## 33             New York  2.6679599   29
## 34       North Carolina  2.9993237   20
## 35         North Dakota  0.5947151   48
## 36                 Ohio  2.6871225   26
## 37             Oklahoma  2.9589340   21
## 38               Oregon  0.9396843   42
## 39         Pennsylvania  3.5977513   11
## 40         Rhode Island  1.5200933   35
## 41       South Carolina  4.4753235    5
## 42         South Dakota  0.9825837   41
## 43            Tennessee  3.4509357   12
## 44                Texas  3.2013603   16
## 45                 Utah  0.7959810   45
## 46              Vermont  0.3196211   51
## 47             Virginia  3.1246001   18
## 48           Washington  1.3829942   37
## 49        West Virginia  1.4571013   36
## 50            Wisconsin  1.7056487   34
## 51              Wyoming  0.8871131   43
```

Notice that select no longer has a data frame as the first argument. The first argument is assumed to be the result of the operation conducted right before the %>%.

Repeat the previous exercise, but now instead of creating a new object, show the result and only include the state, rate, and rank columns. Use a pipe %>% to do this in just one line.

```
murders %>% filter(region %in% c("Northeast", "West") & rate <1) %>% select(state, rate, rank)
```

```
##           state      rate rank
## 1        Hawaii 0.5145920   49
## 2         Idaho 0.7655102   46
## 3         Maine 0.8280881   44
## 4 New Hampshire 0.3798036   50
## 5        Oregon 0.9396843   42
## 6          Utah 0.7959810   45
## 7       Vermont 0.3196211   51
## 8       Wyoming 0.8871131   43
```

Q2. Reset murders to the original table by using data(murders). Use a pipe to create a new data frame called my_states that considers only states in the Northeast or West which have a murder rate lower than 1, and contains only the state, rate and rank columns. The pipe should also have four components separated by three %>%. The code should look something like this:

```
# my_states <- murders %>%
#     mutate SOMETHING %>%
#     filter SOMETHING %>%
#     select SOMETHING
```

```
data("murders")
my_states <- murders %>%
```

```r
  mutate(rate = total/population*100000, rank = rank(-rate)) %>%
  filter(region %in% c("Northeast", "West") & rate<1) %>%
  select(state, rate, rank)
```

```r
my_states
```

```
##           state      rate rank
## 1        Hawaii 0.5145920   49
## 2         Idaho 0.7655102   46
## 3         Maine 0.8280881   44
## 4 New Hampshire 0.3798036   50
## 5        Oregon 0.9396843   42
## 6          Utah 0.7959810   45
## 7       Vermont 0.3196211   51
## 8       Wyoming 0.8871131   43
```