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.

```
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")
head(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
```

<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

```r
# 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
## 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
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## 1997.973 4061.91 6018.7 2830.3 5045.2
## 1997.977 4029.08 5986.6 2838.3 5121.8
## 1997.981 4150.31 6092.7 2912.2 5203.4
## 1997.985 4154.57 6122.1 2893.3 5190.8
## 1997.988 4162.92 6115.1 2894.5 5168.3
## 1997.992 4055.35 5989.9 2822.9 5020.2
## 1997.996 4125.54 6049.3 2869.7 5018.2
```

```
## 1998.000 4132.79 6044.7 2858.1 5049.8
## 1998.004 4132.79 6046.7 2874.1 5013.9
## 1998.008 4132.79 6046.7 2874.1 5013.9
## 1998.012 4132.79 6046.7 2875.1 5013.9
## 1998.015 4266.02 6190.4 2939.5 5112.4
## 1998.019 4224.30 6267.6 2975.5 5132.3
## 1998.023 4224.30 6265.5 2998.9 5135.5
## 1998.027 4224.30 6265.5 2998.9 5135.5
## 1998.031 4364.32 6265.5 3038.7 5193.5
## 1998.035 4416.95 6397.0 3072.8 5262.5
## 1998.038 4360.05 6375.7 3037.7 5264.4
## 1998.042 4339.98 6390.0 3006.7 5224.1
## 1998.046 4293.64 6330.2 2954.9 5237.1
## 1998.050 4237.75 6251.8 2919.8 5138.3
## 1998.054 4134.64 6062.1 2862.5 5068.8
## 1998.058 4150.01 6169.3 2902.9 5083.9
## 1998.062 4145.41 6149.8 2919.8 5106.9
## 1998.065 4140.22 6148.5 2932.8 5165.8
## 1998.069 4216.24 6274.0 2976.1 5263.1
## 1998.073 4290.05 6340.4 2987.0 5273.6
## 1998.077 4310.83 6397.5 3008.3 5278.2
## 1998.081 4250.47 6391.4 2998.1 5272.3
## 1998.085 4238.77 6356.1 2988.6 5253.1
## 1998.088 4222.16 6391.0 2966.2 5181.4
## 1998.092 4266.34 6411.0 3000.5 5237.2
## 1998.096 4316.05 6424.0 3052.0 5326.3
## 1998.100 4385.29 6508.7 3088.3 5372.6
## 1998.104 4444.53 6530.4 3133.8 5422.4
## 1998.108 4442.53 6582.6 3172.1 5458.5
## 1998.112 4529.88 6688.0 3187.5 5599.0
## 1998.115 4529.18 6720.7 3188.4 5612.8
## 1998.119 4509.25 6708.9 3166.3 5595.8
## 1998.123 4494.72 6772.0 3189.6 5606.4
## 1998.127 4536.91 6857.1 3216.7 5629.7
## 1998.131 4519.56 6828.4 3220.9 5600.9
## 1998.135 4558.62 6860.8 3235.8 5613.3
## 1998.138 4552.46 6931.6 3240.0 5607.9
## 1998.142 4509.37 6856.0 3178.7 5552.5
## 1998.146 4522.42 6898.9 3187.7 5582.3
## 1998.150 4535.56 6905.3 3225.1 5619.9
## 1998.154 4627.42 6990.5 3280.5 5709.5
## 1998.158 4611.66 6966.2 3281.7 5723.4
## 1998.162 4581.08 6953.2 3250.6 5718.5
## 1998.165 4583.03 6986.7 3262.5 5718.5
## 1998.169 4610.66 6986.1 3273.5 5702.8
## 1998.173 4604.55 6945.0 3262.3 5651.0
## 1998.177 4704.58 7065.4 3348.2 5745.1
## 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")
head(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
```

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

```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.

```
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:

```
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.

```
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.

```r
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:

```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
```

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:

```
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:

```
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:

```
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.

```
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) %>% head()
```

```
##        state     rate rank
## 1    Alabama 2.824424   23
## 2     Alaska 2.675186   27
## 3    Arizona 3.629527   10
## 4   Arkansas 3.189390   17
## 5 California 3.374138   14
## 6   Colorado 1.292453   38
```

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
```

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