IS5 in R: Understanding and Comparing Distributions (Chapter 4)

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Introduction and background

This document is intended to help describe how to undertake analyses introduced as examples in the Fifth Edition of *Intro Stats* (2018) by De Veaux, Velleman, and Bock. This file as well as the associated Quarto reproducible analysis source file used to create it can be found at http://nhorton.people.amherst.edu/is5.

This work leverages initiatives undertaken by Project MOSAIC (http://www.mosaic-web.org), an NSF-funded effort to improve the teaching of statistics, calculus, science and computing in the undergraduate curriculum. In particular, we utilize the `mosaic` package, which was written to simplify the use of R for introductory statistics courses. A short summary of the R needed to teach introductory statistics can be found in the mosaic package vignettes (https://cran.r-project.org/web/packages/mosaic). A paper describing the mosaic approach was published in the *R Journal*: https://journal.r-project.org/archive/2017/RJ-2017-024.

We begin by loading packages that will be required for our analyses.

```
library(mosaic)
library(tidyverse)
```

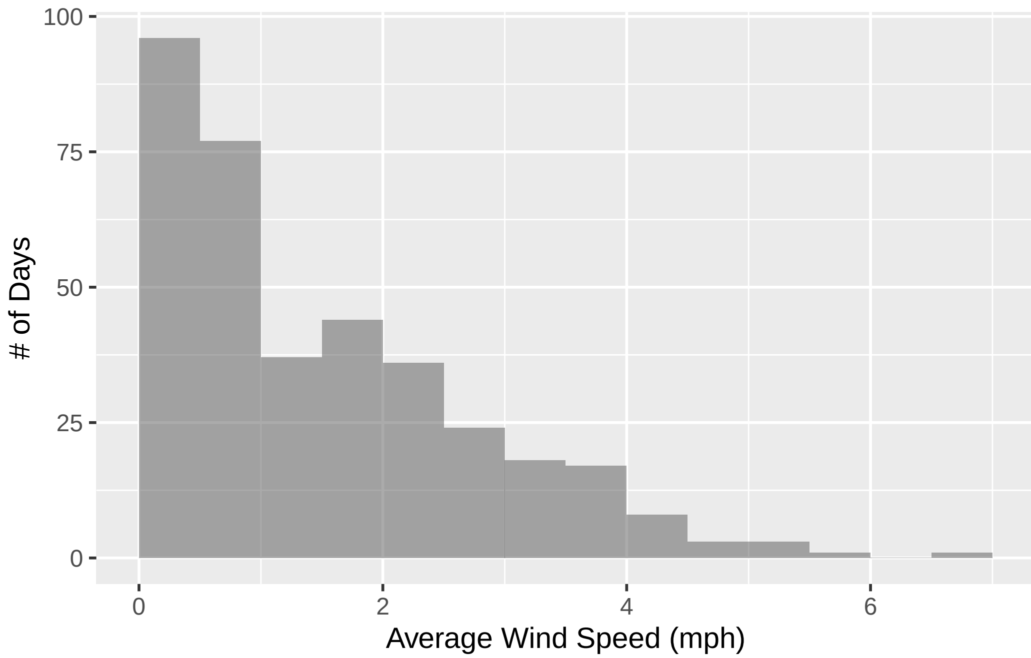
Chapter 4: Understanding and Comparing Distributions

```
library(mosaic)
library(readr)
library(janitor)
HopkinsForest <-
  read_csv("http://nhorton.people.amherst.edu/is5/data/Hopkins_Forest.csv") |>
  janitor::clean_names()
names(HopkinsForest)
```

```
 [1] "date"                 "year"                 "month"
 [4] "day"                  "day_of_year"          "avg_temp_c"
 [7] "max_temp_c"           "min_temp_c"           "avg_temp_f"
[10] "max_temp_f"           "min_temp_f"           "avg_rel_hum_percent"
[13] "max_rel_hum_percent" "min_rel_hum_percent" "avg_sol_rad_w_m_2"
[16] "max_sol_rad_w_m_2"    "min_sol_rad_w_m_2"    "total_sol_rad_w_m_2"
[19] "avg_wind_mph"         "max_wind_mph"         "min_wind_mph"
[22] "avg_barom_mb"         "max_barom_mb"         "min_barom_mb"
[25] "precip_in"            "deep_well_ft"         "shallow_well_ft"
[28] "x80_cm_soil_c"        "x10_cm_soil_c"
```

By default, `read_csv()` prints the variable names. We suppressed these using the `message = FALSE` code chunk option to save space and improve readability. Here we use the `clean_names()` function from the `janitor` package to sanitize the names of the columns (which would otherwise contain special characters or whitespace). You can use the `names()` function to check the cleaned names.

```
# Figure 4.1, page 96
gf_histogram(~ avg_wind_mph,
  data = HopkinsForest,
  xlab = "Average Wind Speed (mph)",
  ylab = "# of Days",
  binwidth = 0.5,
  center = 0.25
)
```




```
df_stats(~ avg_wind_mph, data = HopkinsForest)  # an alternative version of "favstats()"
```

```
      response min   Q1 median   Q3  max     mean       sd   n missing
1 avg_wind_mph   0 0.46   1.12 2.28 6.73 1.507808 1.260161 365       0
```

Section 4.1: Displays for Comparing Groups

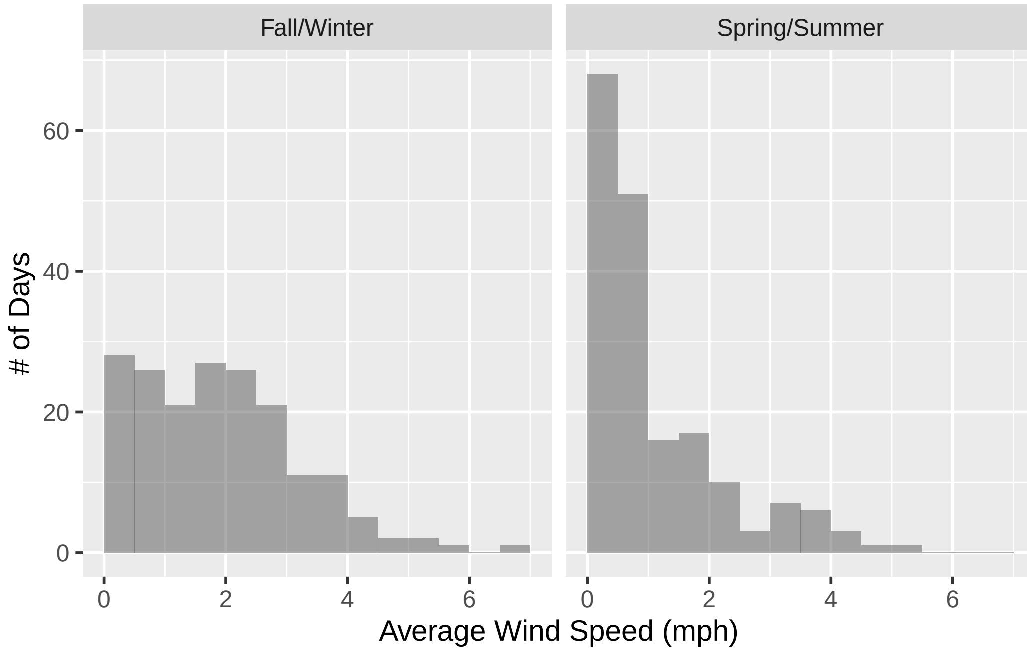
Histograms

We began by creating a new month to categorize the dates.

```
HopkinsForest <- HopkinsForest |>
  mutate(catmonth = ifelse(
    month <= 9 & month >= 4,
    "Spring/Summer",
    "Fall/Winter")
  )
```

```
# Figure 4.2, page 96
gf_histogram(~ avg_wind_mph,
  data = HopkinsForest, binwidth = 0.5, center = 0.25,
  xlab = "Average Wind Speed (mph)", ylab = "# of Days"
```

```
) |>
  gf_facet_wrap(~ catmonth)
```




```
df_stats(avg_wind_mph ~ catmonth, data = HopkinsForest)
```

```
      response      catmonth  min   Q1 median     Q3  max     mean       sd   n
1 avg_wind_mph   Fall/Winter 0.02 0.84   1.72 2.6575 6.73 1.904176 1.287233 182
2 avg_wind_mph Spring/Summer 0.00 0.35   0.71 1.6150 5.47 1.113607 1.102176 183
  missing
1       0
2       0
```

Example 4.1: Comparing Groups with Stem-And-Leaf

We begin by reading in the data.

```
# Figure 4.1, page 97
NestEgg <- read_csv("http://nhorton.people.amherst.edu/is5/data/Nest_Egg_Index.csv") |>
  janitor::clean_names()
with(NestEgg, stem(nest_egg_index)) # or stem(NestEgg$nest_egg_index)
```

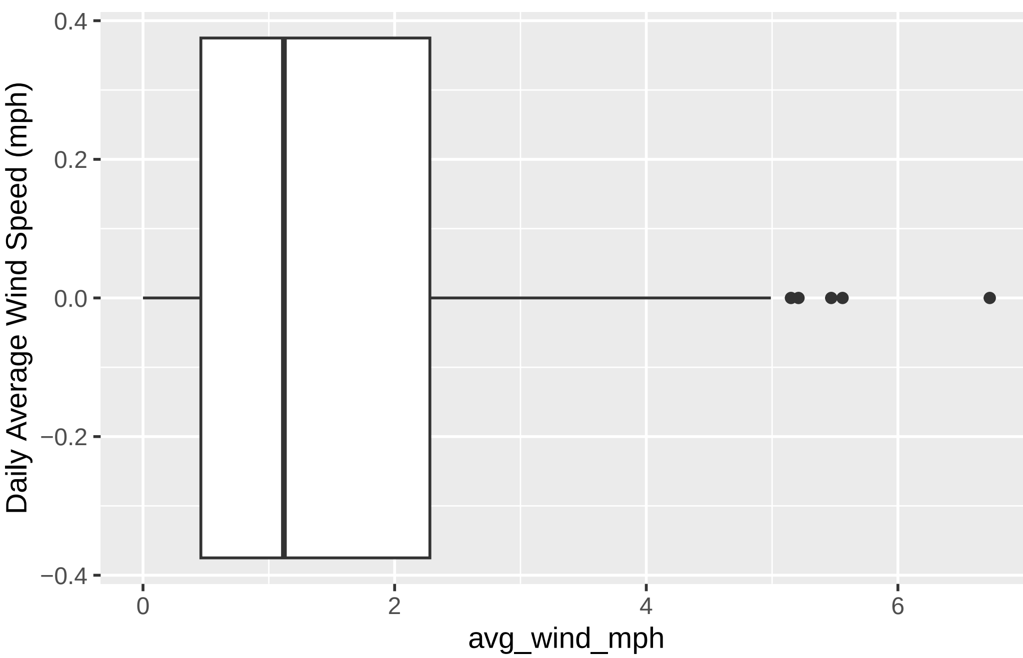
```
  The decimal point is 1 digit(s) to the right of the |

   8 | 57789
   9 | 0123344
   9 | 667777888899
  10 | 0012233333344
  10 | 5566779
  11 | 122444
```

Boxplots

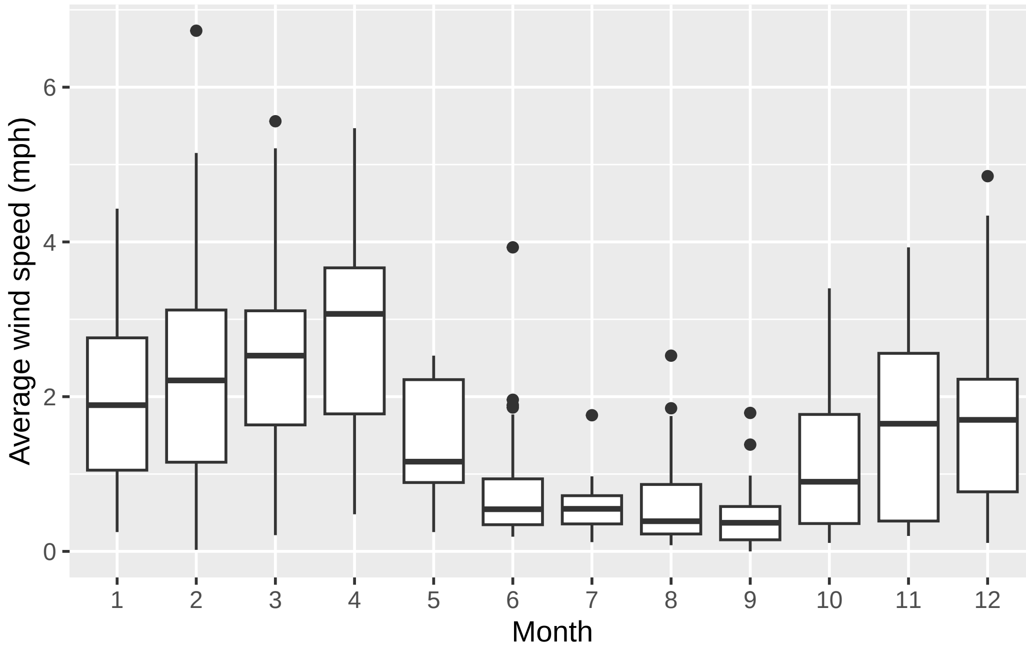
As noted in the book, boxplots are most useful to compare distributions. Below, we have replicated the single boxplot from page 98.

```
# Step 4 on page 98
gf_boxplot(~ avg_wind_mph, data = HopkinsForest) |> # or gf_boxplot(X ~ 1)
  gf_labs(y = "Daily Average Wind Speed (mph)")
```



The use of single boxplots isn't recommended. Instead, one can make comparisons more easily by placing boxplots side by side with the following code:

```
# Figure 4.3, page 99
gf_boxplot(avg_wind_mph ~ as.factor(month), data = HopkinsForest) |>
  gf_labs(x = "Month", y = "Average wind speed (mph)")
```



We use the `as.factor()` function to convert a variable into a factor.

We also use `gf_labs()` to clean up the code for the first line and improve readability.

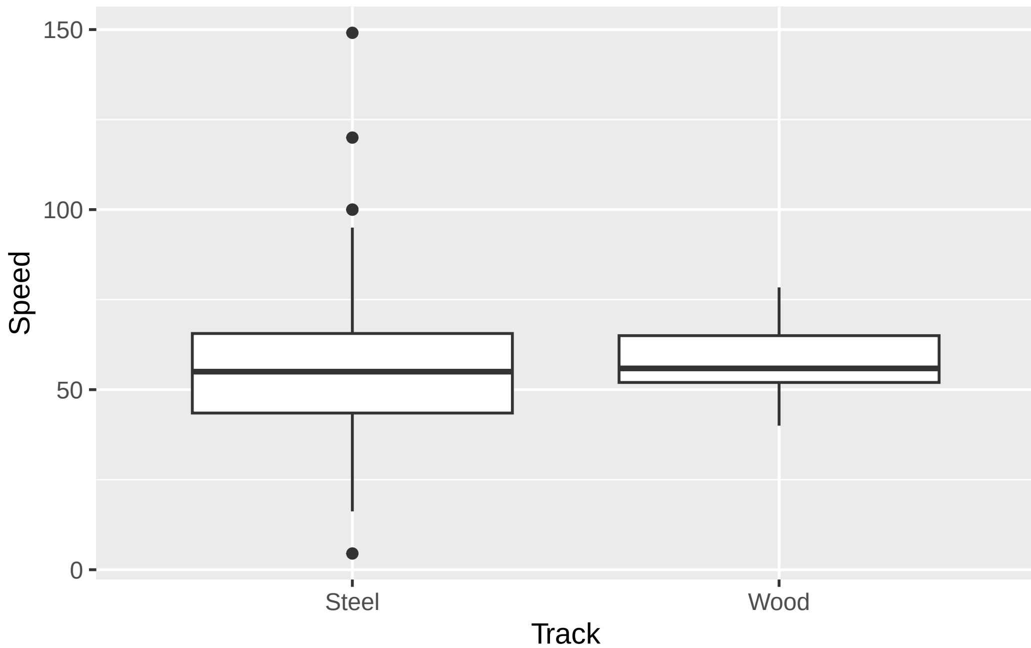
Here we use the mosaic modeling language to specify the variables. The ~ symbol is used to separate the response variable from the explanatory variable.

As a general form, `GOAL(Y ~ X)` carries out a specific goal for Y as a function of X.

Example 4.2: Comparing Groups with Boxplots

We begin by reading in the data.

```
# Example 4.2, page 99
Coasters <- read_csv("http://nhorton.people.amherst.edu/is5/data/Coasters_2015.csv")
gf_boxplot(Speed ~ Track, data = Coasters)
```



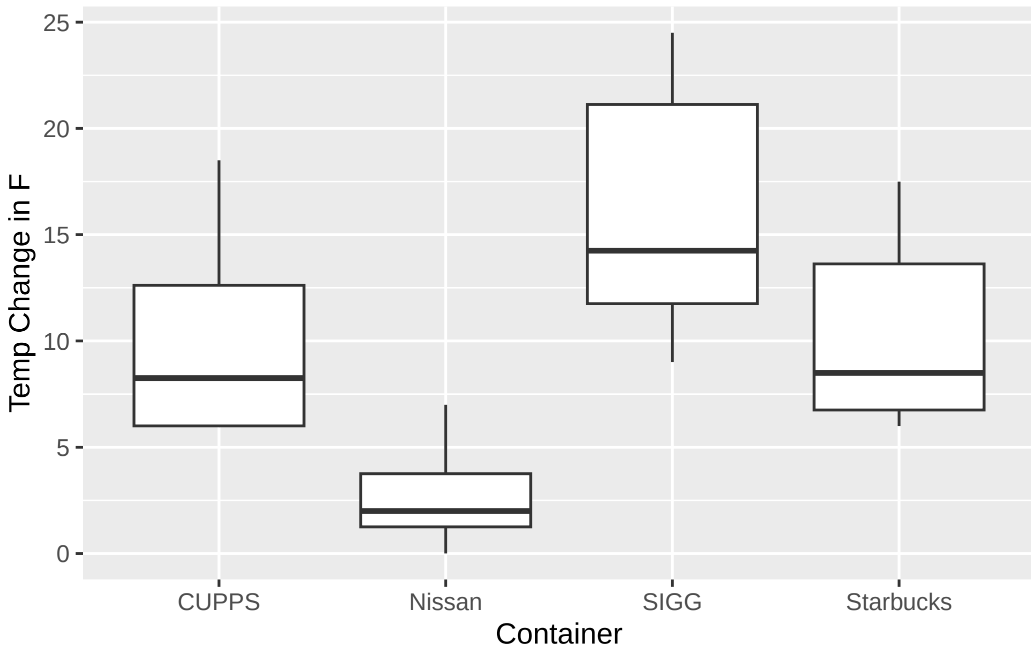
Step-By-Step Example: Comparing Groups

We begin by reading in the data.

```
Cups <- read_csv("http://nhorton.people.amherst.edu/is5/data/Cups.csv")
df_stats(Difference ~ Container, data = Cups)
```

```
    response Container min    Q1 median     Q3  max    mean       sd n missing
1 Difference     CUPPS   6  6.00   8.25 12.625 18.5 10.1875 5.202592 8       0
2 Difference    Nissan   0  1.25   2.00  3.750  7.0  2.7500 2.507133 8       0
3 Difference      SIGG   9 11.75  14.25 21.125 24.5 16.0625 5.900590 8       0
4 Difference Starbucks   6  6.75   8.50 13.625 17.5 10.2500 4.551295 8       0
```

```
# Mechanics, page 101
gf_boxplot(Difference ~ Container, data = Cups, ylab = "Temp Change in F")
```



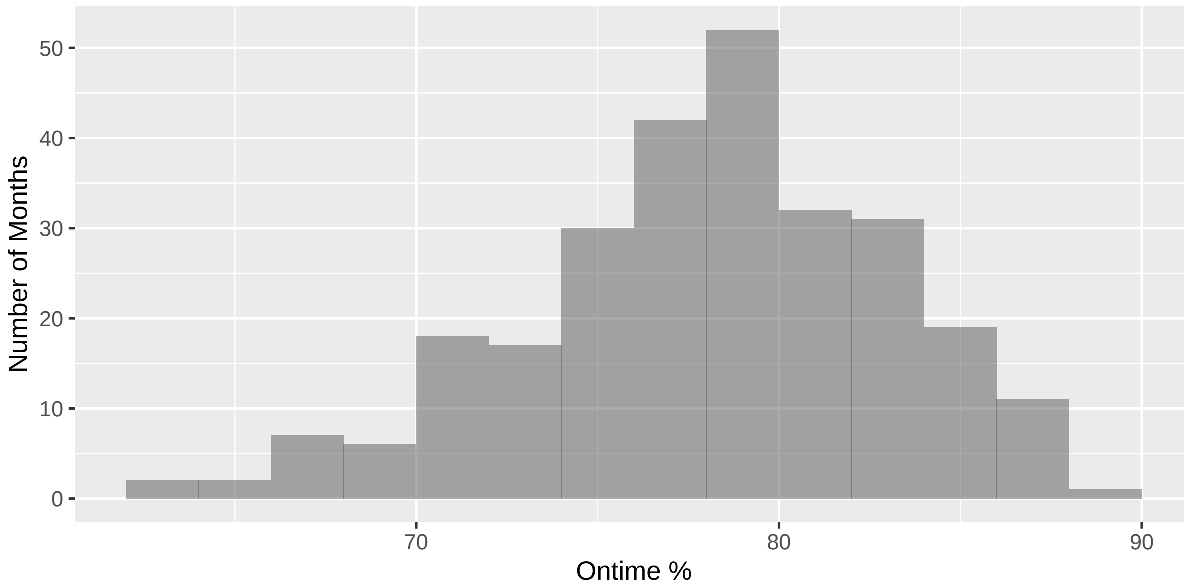
Just Checking

We begin by reading in the data.

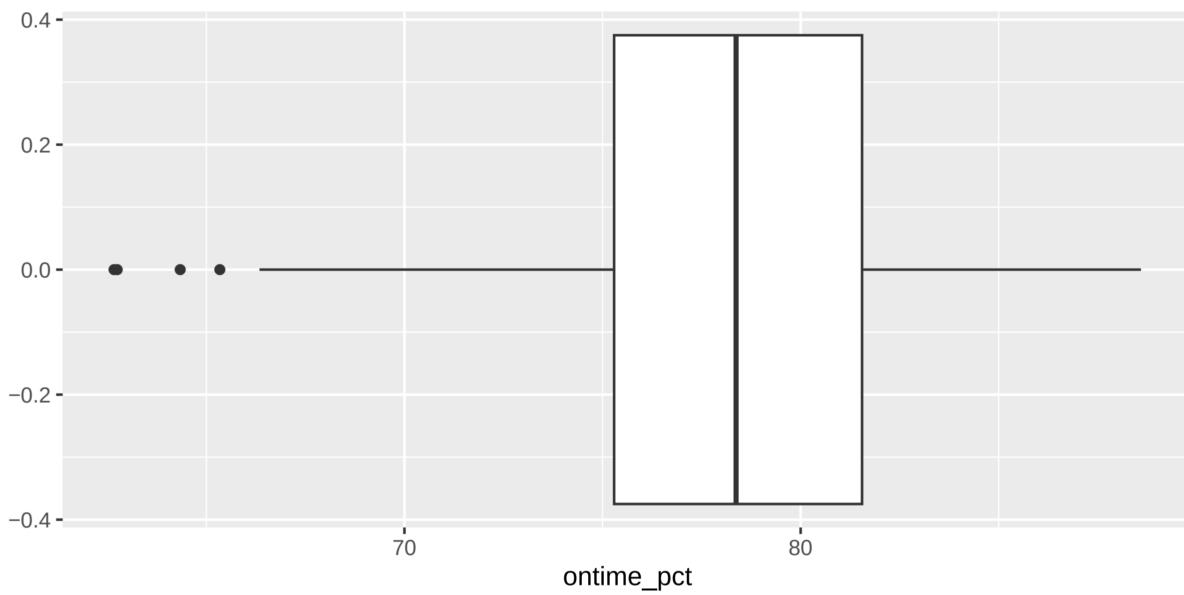
```
Flights <-
  read_csv("http://nhorton.people.amherst.edu/is5/data/Flights_on_time_2016.csv") |>
  janitor::clean_names()
# Let's improve the ordering of the months (by default they are alphabetical!)
Flights <- Flights |>
  mutate(month = forcats::fct_relevel(
    month,
    "January", "February", "March", "April",
    "May", "June", "July", "August",
    "September", "October", "November", "December"
    )
  )
```

Here we use the `fct_relevel()` function from the `forcats` package to reorder the months in the dataset (the default is that the months are ordered alphabetically, which isn't very helpful). This function is a very useful idiom to remember when you want to reorder factor levels.

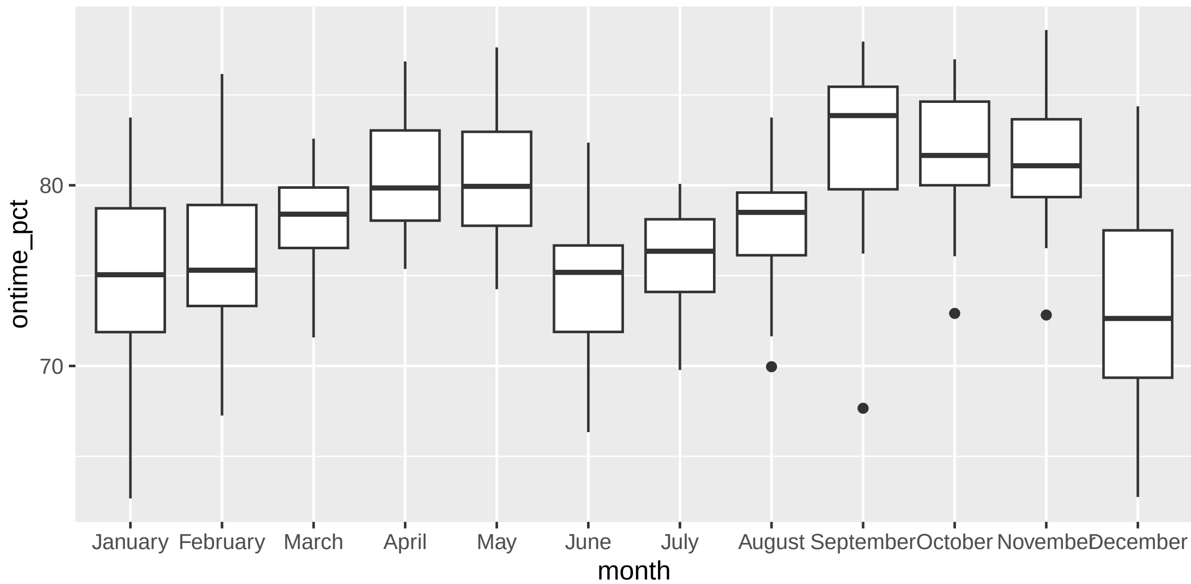
```
# Bureau of Transportation Statistics, page 101
gf_histogram(~ ontime_pct, data = Flights, binwidth = 2, center = 1) |>
  gf_labs(x = "Ontime %", y = "Number of Months")
```




```
gf_boxplot(~ ontime_pct, data = Flights)
```



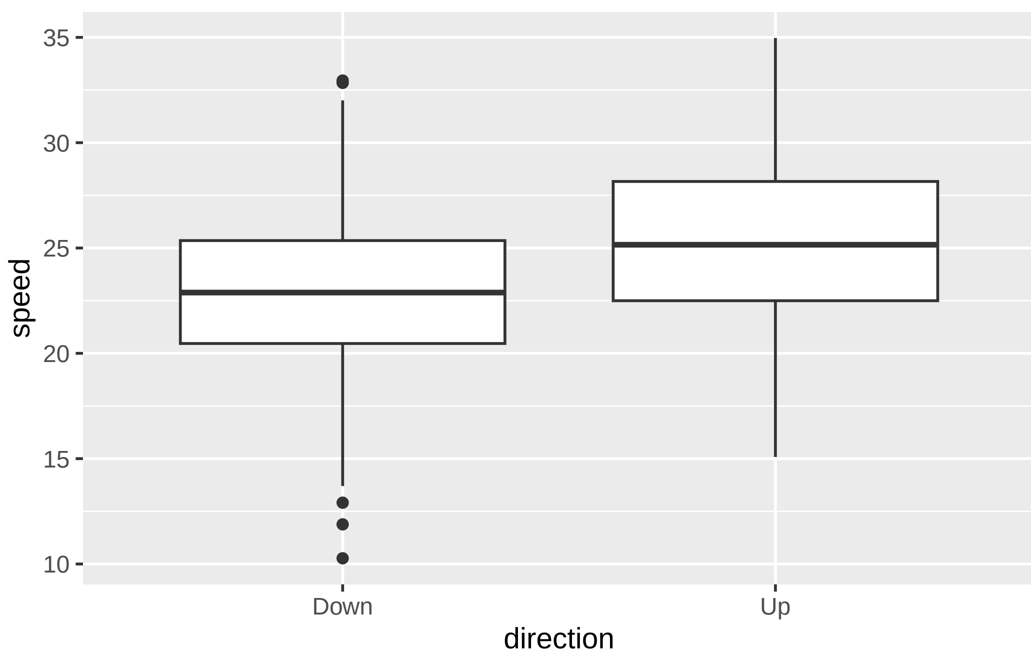

```
gf_boxplot(ontime_pct ~ month, data = Flights)   # now they are in order!
```



Random Matters

We begin by reading in the data.

```
# Figure 4.4, page 102
CarSpeeds <- read_csv("http://nhorton.people.amherst.edu/is5/data/Car_speeds.csv")
gf_boxplot(speed ~ direction, data = CarSpeeds)
```



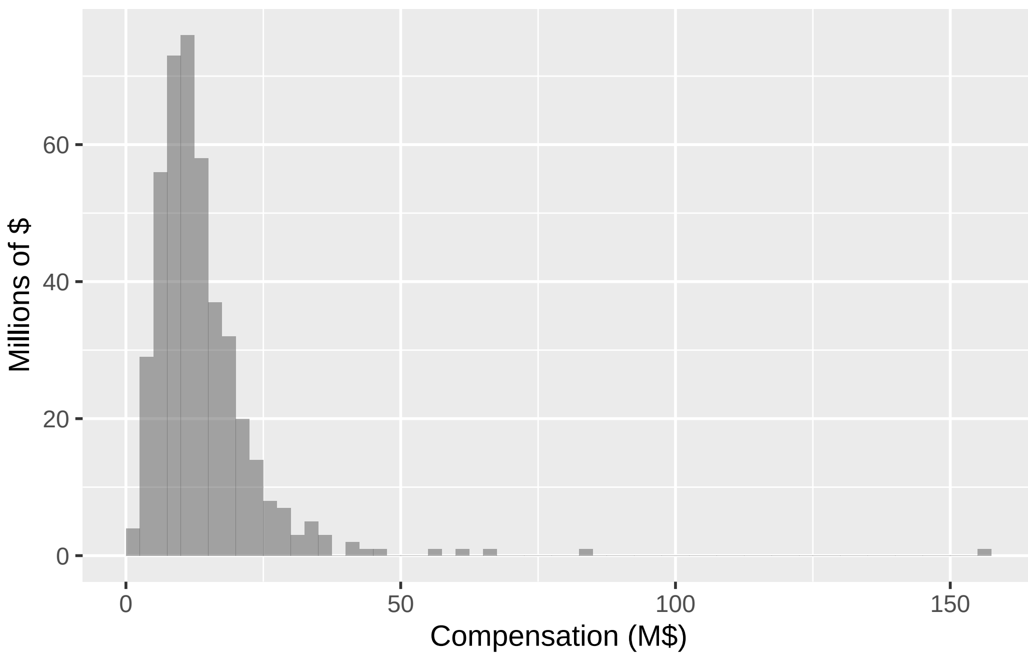
Section 4.3: Re-Expressing Data: A First Look

Re-Expressing to Improve Symmetry

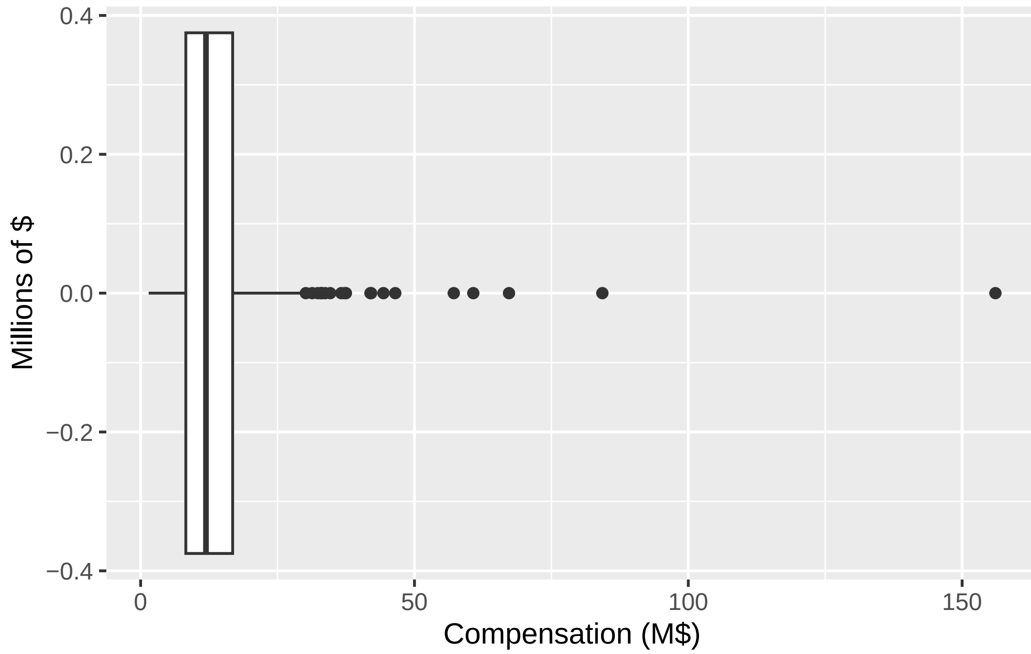
We begin by reading in the data.

```
CEOComp <-
  read_csv("http://nhorton.people.amherst.edu/is5/data/CEO_Compensation_2014.csv") |>
  janitor::clean_names()
```

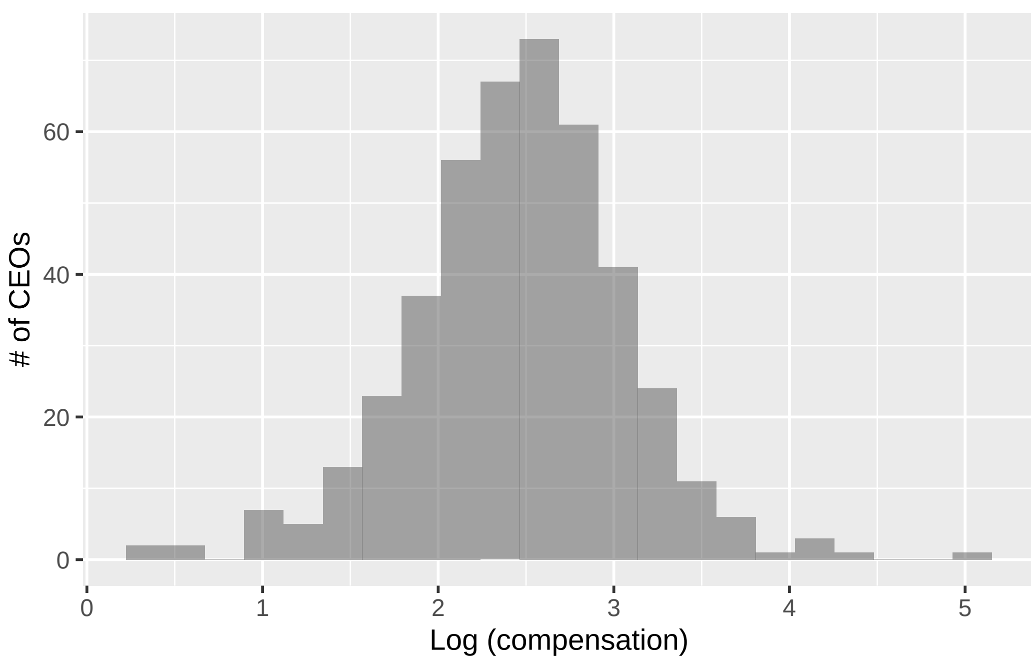
```
# Figure 4.6, page 105
gf_histogram(~ ceo_compensation_m, data = CEOComp, binwidth = 2.5, center = 2.5 / 2) |>
  gf_labs(x = "Compensation (M$)", y = "Millions of $")
```




```
gf_boxplot(~ ceo_compensation_m, data = CEOComp) |>
  gf_labs(x = "Compensation (M$)", y = "Millions of $")
```




```
# Figure 4.7, page 106
gf_histogram(~ log(ceo_compensation_m), data = CEOComp, binwidth = 0.224, center = 0.112) |>
  gf_labs(x = "Log (compensation)", y = "# of CEOs")
```



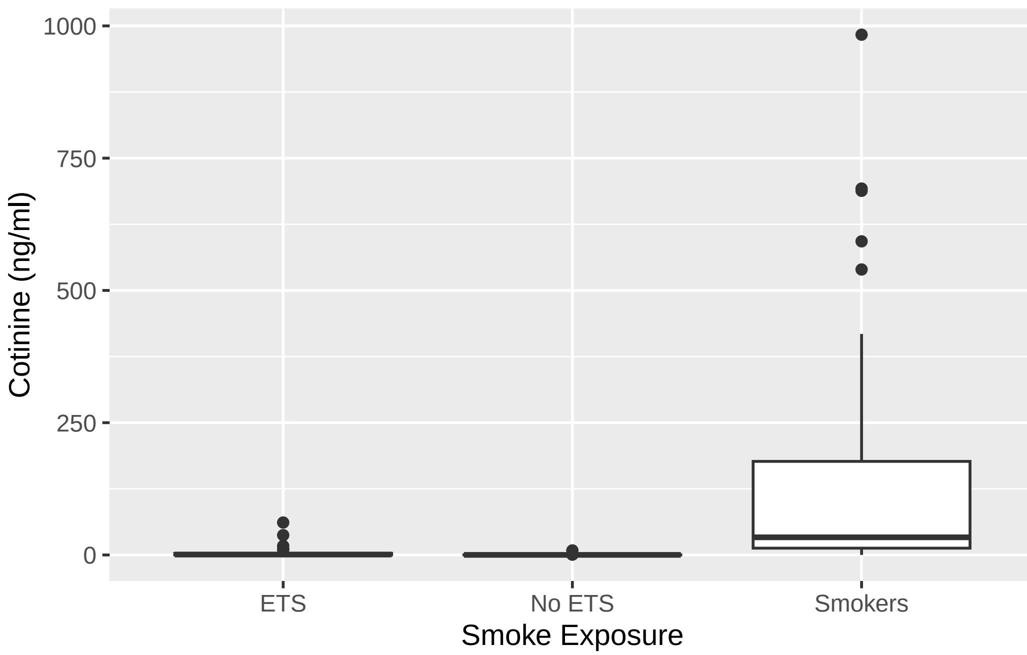
Here we needed to pick magic numbers for the binwidth (e.g., 0.224) and centering of the histogram so that it matched the results from the book.

Re-Expression to Equalize Spread Across Groups

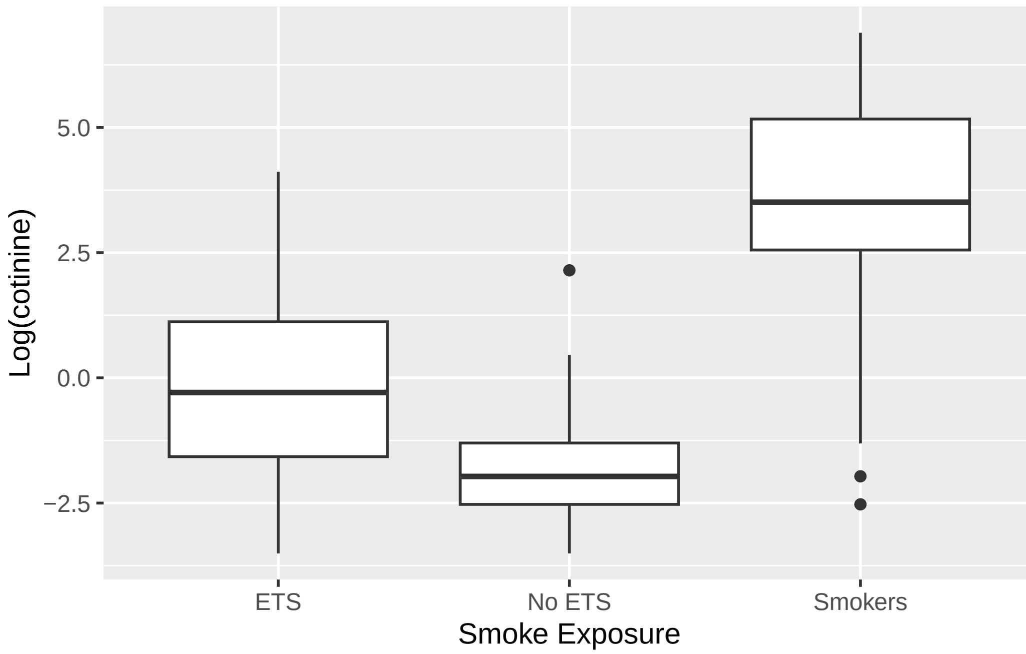
We begin by reading in the data.

```
PassiveSmoke <- read_csv("http://nhorton.people.amherst.edu/is5/data/Passive_smoke.csv")
```

```
# Figure 4.8, page 107
gf_boxplot(cotinine ~ smoke_exposure, data = PassiveSmoke) |>
  gf_labs(x = "Smoke Exposure", y = "Cotinine (ng/ml)")
```




```
# Figure 4.9
gf_boxplot(log(cotinine) ~ smoke_exposure, data = PassiveSmoke) |>
  gf_labs(x = "Smoke Exposure", y = "Log(cotinine)")
```


5.0
2.5
0.0
−2.5
Log(cotinine)
ETS
No ETS
Smokers
Smoke Exposure