

IS5 in R: Multiple Regression (Chapter 9)

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December 13, 2020

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 R Markdown 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>.

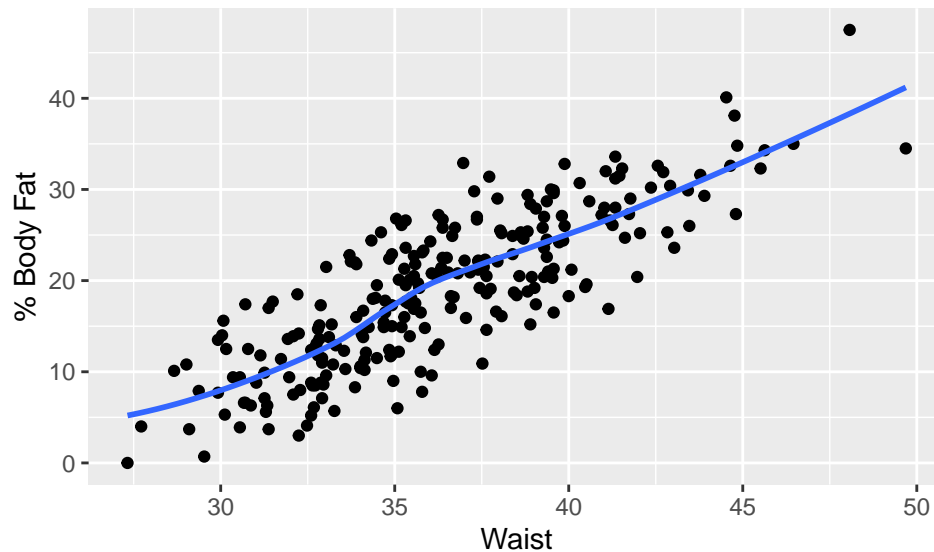
Chapter 9: Multiple Regression

```
library(mosaic)
library(readr)
library(janitor)
library(broom) # We'll use this for augment() later
BodyFat <- read_csv("http://nhorton.people.amherst.edu/is5/data/Bodyfat.csv") %>%
  janitor::clean_names()
```

By default, `read_csv()` prints the variable names. These messages have been suppressed 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).

```
# Figure 9.1, page 276
gf_point(pct_bf ~ waist, data = BodyFat) %>%
  gf_labs(x = "Waist", y = "% Body Fat") %>%
  gf_smooth()
```

```
## `geom_smooth()` using method = 'loess'
```



We've added `gf_smooth()` to demonstrate how to add a smoother.

Section 9.1: What is Multiple Regression?

```
# Table 9.1, page 277
multiplereg <- lm(pct_bf ~ waist + height, data = BodyFat)
summary(multiplereg)

##
## Call:
## lm(formula = pct_bf ~ waist + height, data = BodyFat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.1692  -3.4133  -0.0977   3.0995   9.9082
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -3.10088    7.68611  -0.403   0.687
## waist         1.77309    0.07158  24.770 < 2e-16 ***
## height       -0.60154    0.10994  -5.472 1.09e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.46 on 247 degrees of freedom
## Multiple R-squared:  0.7132, Adjusted R-squared:  0.7109
## F-statistic: 307.1 on 2 and 247 DF, p-value: < 2.2e-16
```

The `summary()` function provides the multiple R-squared along with the regression coefficients.

```
RealEstate <- read_csv("http://nhorton.people.amherst.edu/is5/data/Real_Estate.csv") %>%
  janitor::clean_names()
realestatelm <- lm(price ~ living_area + bedrooms, data = RealEstate)
summary(realestatelm)
```

Example 9.1: Modeling Home Prices

```
##
## Call:
## lm(formula = price ~ living_area + bedrooms, data = RealEstate)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -433211 -198136  -63249   137183 1054177
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 308100.44   41147.84    7.488 1.69e-13 ***
## living_area   135.09     11.48   11.771 < 2e-16 ***
## bedrooms    -43346.81   12844.14   -3.375 0.000771 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 266900 on 891 degrees of freedom
## Multiple R-squared:  0.1463, Adjusted R-squared:  0.1444
## F-statistic: 76.34 on 2 and 891 DF,  p-value: < 2.2e-16

# Predicted Values
realestatefn <- makeFun(realestatelm) # Making a function to find predicted values
# Predicted price for a home with 2800 sq ft living area and 5 bedrooms
realestatefn(living_area = 2800, bedrooms = 5)

##           1
## 469614.9

# Predicted price for a home with 2801 sq ft living area and 5 bedrooms
realestatefn(living_area = 2801, bedrooms = 5)

##           1
## 469750

# If we subtract predicted values one value apart, we get the slope
realestatefn(living_area = 2801, bedrooms = 5) - realestatefn(living_area = 2800, bedrooms = 5)

##           1
## 135.0887
```

Section 9.2: Interpreting Multiple Regression Coefficients

```
# Figure 9.2, page 279
gf_point(pct_bf ~ height, data = BodyFat) %>%
  gf_smooth() %>% # Added a smoother to assess linearity
  gf_labs(x = "Height (in)", y = "% Body Fat")

## `geom_smooth()` using method = 'loess'
```

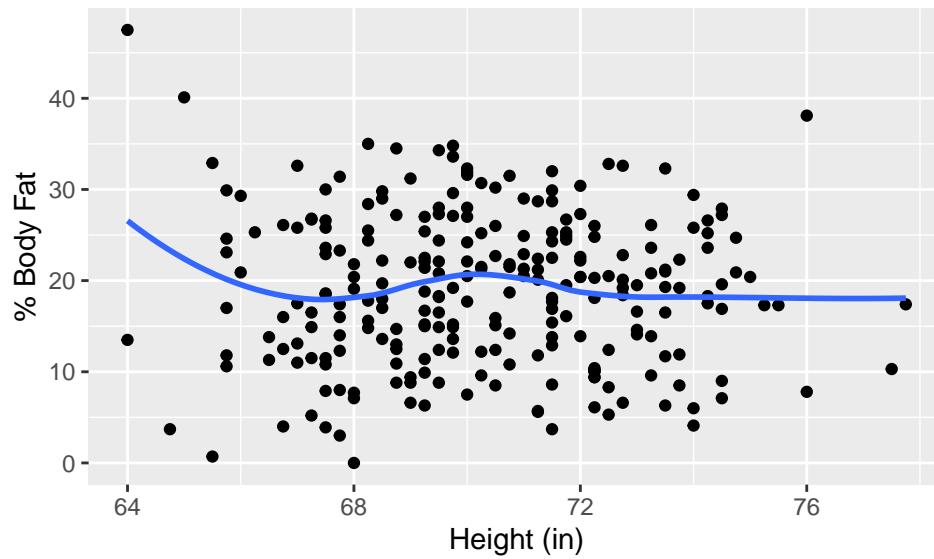
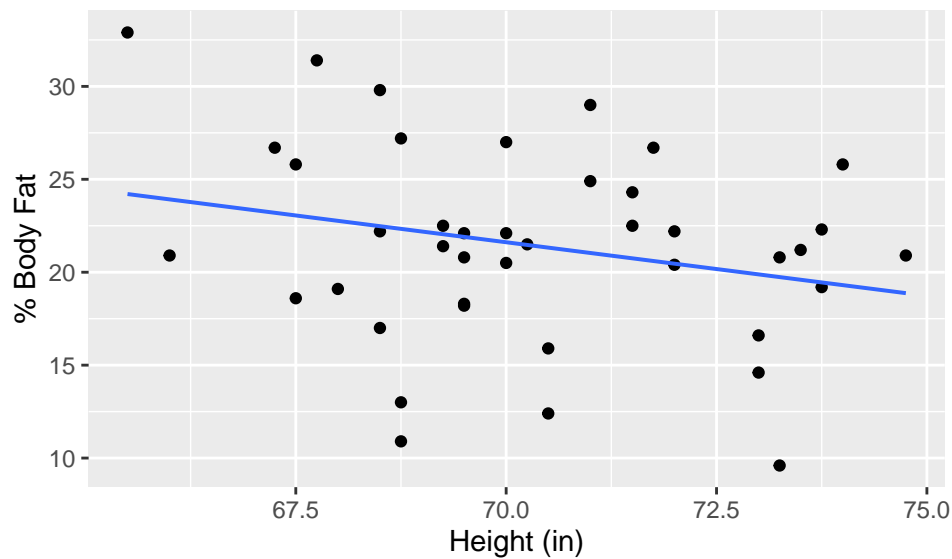
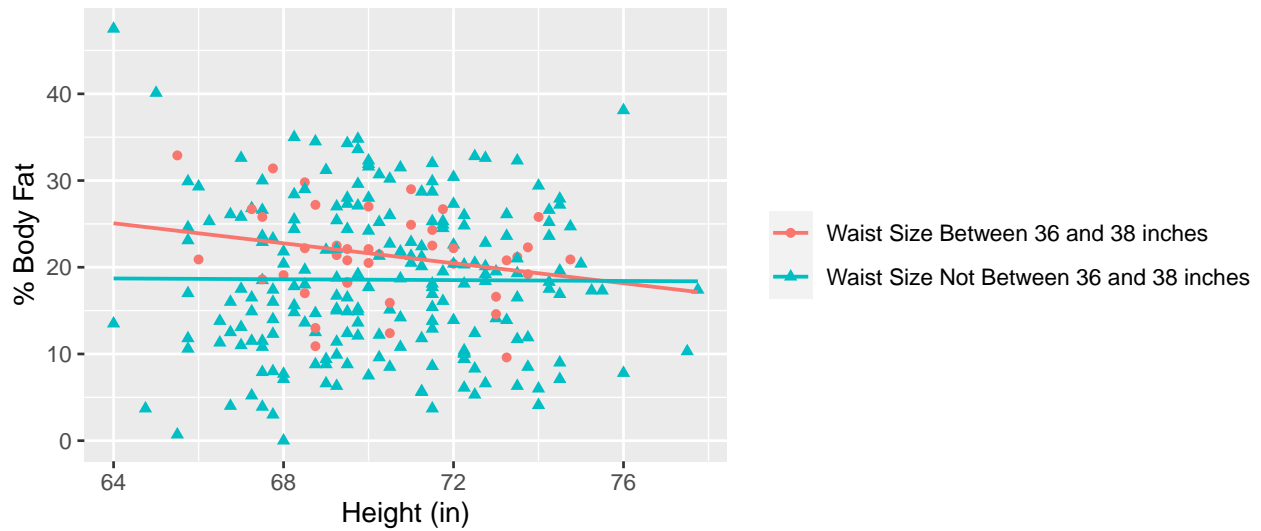


Figure 9.3

```
BodyFat %>%
  filter(waist >= 36 & waist <= 38) %>% # Just plotting waist sizes between 36 and 38 inches
  gf_point(pct_bf ~ height) %>%
  gf_labs(x = "Height (in)", y = "% Body Fat") %>%
  gf_lm()
```



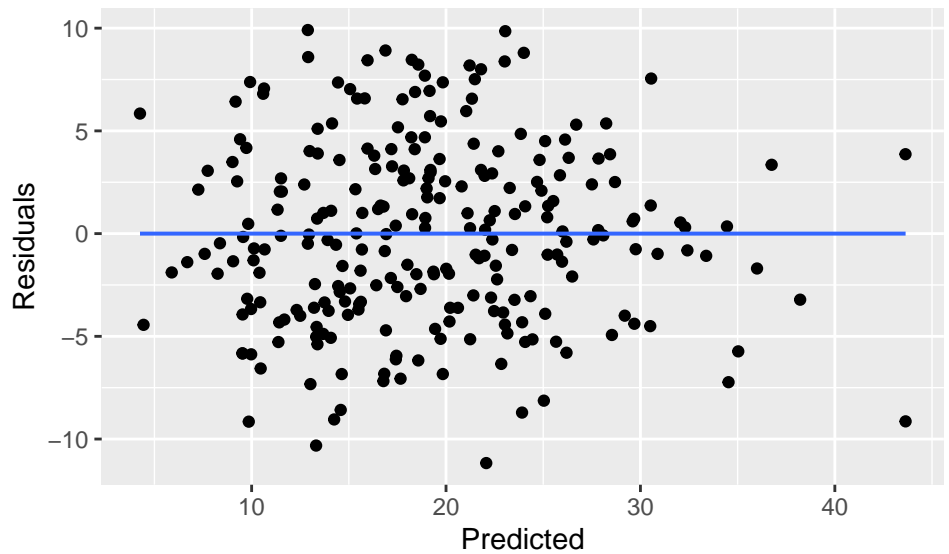
```
# Plotting all points
BodyFat %>%
  mutate(pointtype = ifelse(waist >= 36 & waist <= 38, "Waist Size Between 36 and 38 inches",
    "Waist Size Not Between 36 and 38 inches"
  )) %>% # Subsetting
  gf_point(pct_bf ~ height, shape = ~pointtype, color = ~pointtype) %>%
  gf_labs(x = "Height (in)", y = "% Body Fat", shape = "", color = "") %>%
  gf_lm()
```



Section 9.3: The Multiple Regression Model—Assumptions and Conditions

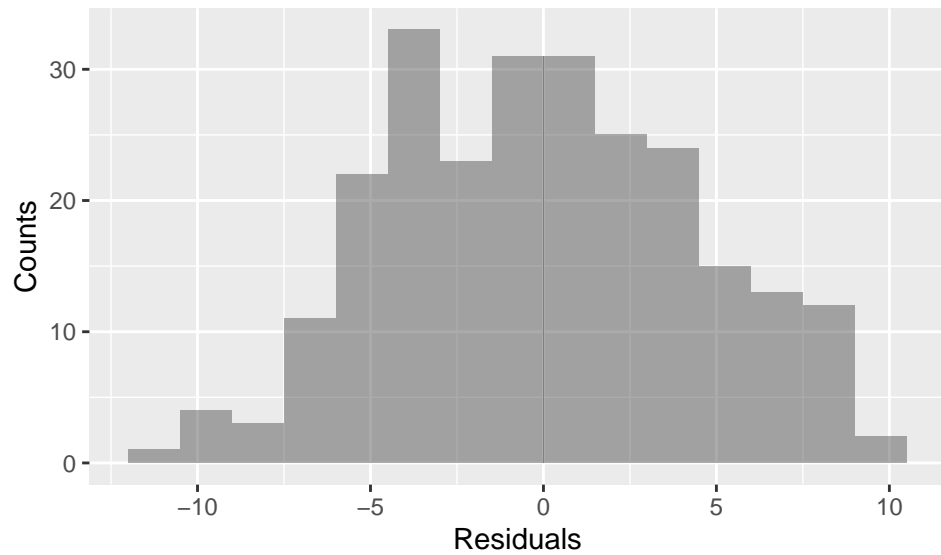
Linearity Assumption

```
bodyfatlm <- lm(pct_bf ~ waist + height, data = BodyFat)
# Figure 9.4, page 282
gf_point(resid(bodyfatlm) ~ fitted(bodyfatlm)) %>%
  gf_lm() %>%
  gf_labs(x = "Predicted", y = "Residuals")
```



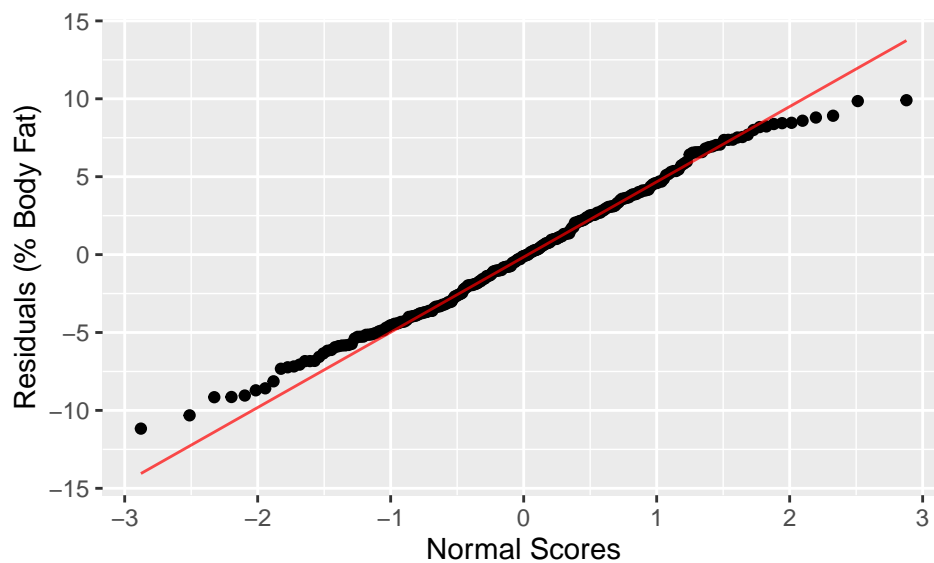
Equal Variance Assumption

```
# Figure 9.5
gf_histogram(~ resid(bodyfatlm), binwidth = 1.5, center = 0.75) %>%
  gf_labs(x = "Residuals", y = "Counts")
```

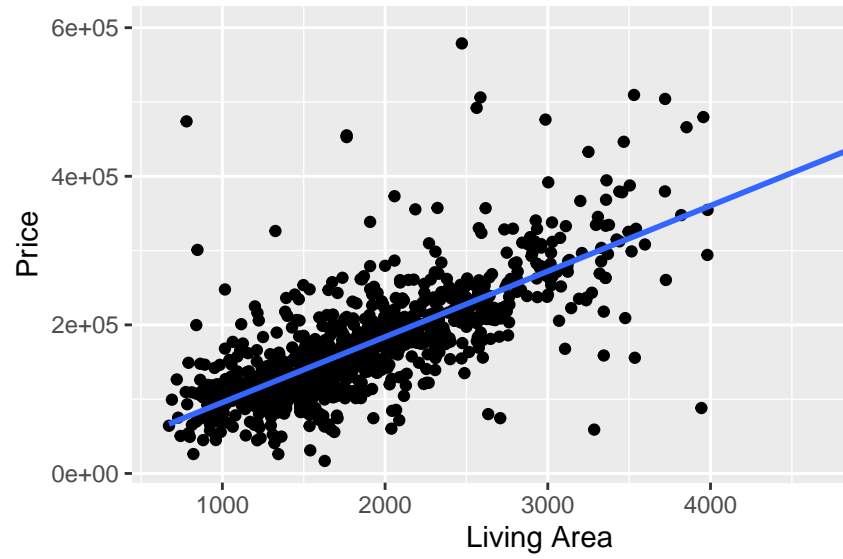


Check the Residuals

```
gf_qq(~ resid(bodyfat1m)) %>%
  gf_qqline(linetype = "solid", color = "red") %>%
  gf_labs(x = "Normal Scores", y = "Residuals (% Body Fat)")
```

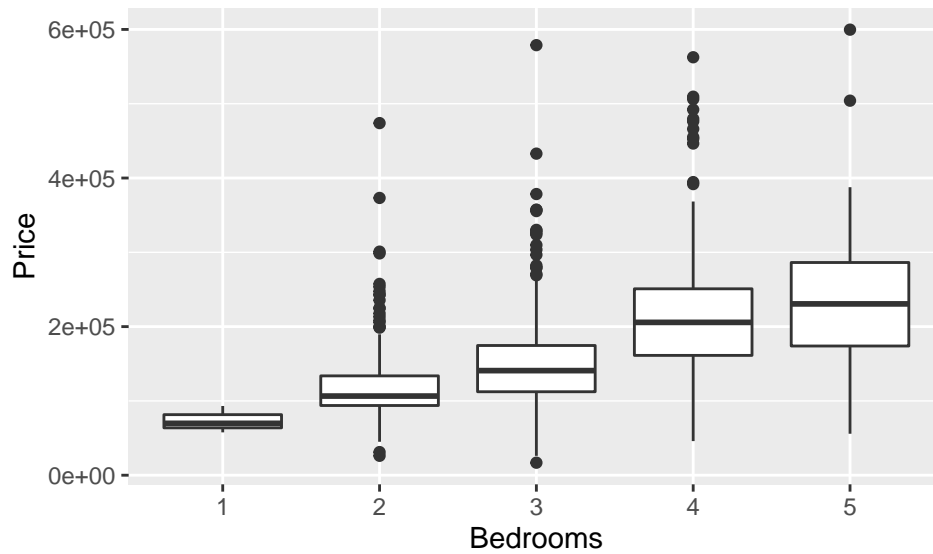


```
HousingPrices <- read_csv("http://nhorton.people.amherst.edu/is5/data/Housing_prices.csv") %>%
  janitor::clean_names()
gf_point(price ~ living_area, data = HousingPrices) %>%
  gf_smooth() %>%
  gf_labs(x = "Living Area", y = "Price")
```



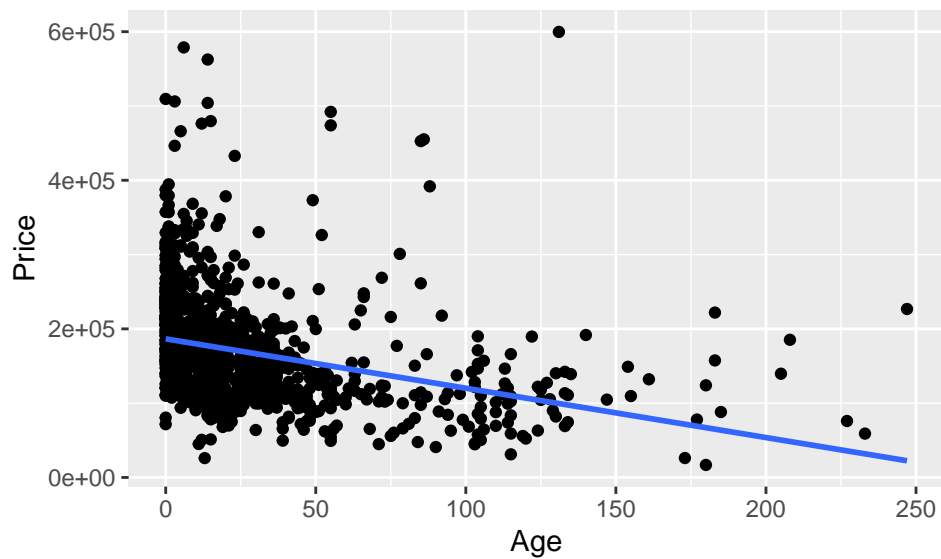
Step-By-Step Example: Multiple Regression

```
gf_boxplot(price ~ as.factor(bedrooms), data = HousingPrices) %>%
  gf_labs(x = "Bedrooms", y = "Price")
```



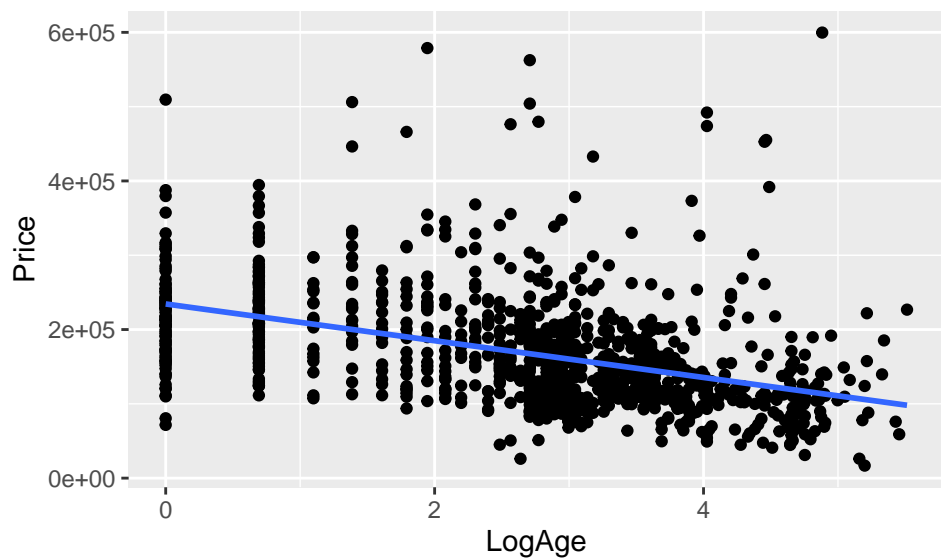
```
gf_point(price ~ age, data = HousingPrices) %>%
  gf_smooth() %>%
  gf_labs(x = "Age", y = "Price")
```

```
## `geom_smooth()` using method = 'gam'
```



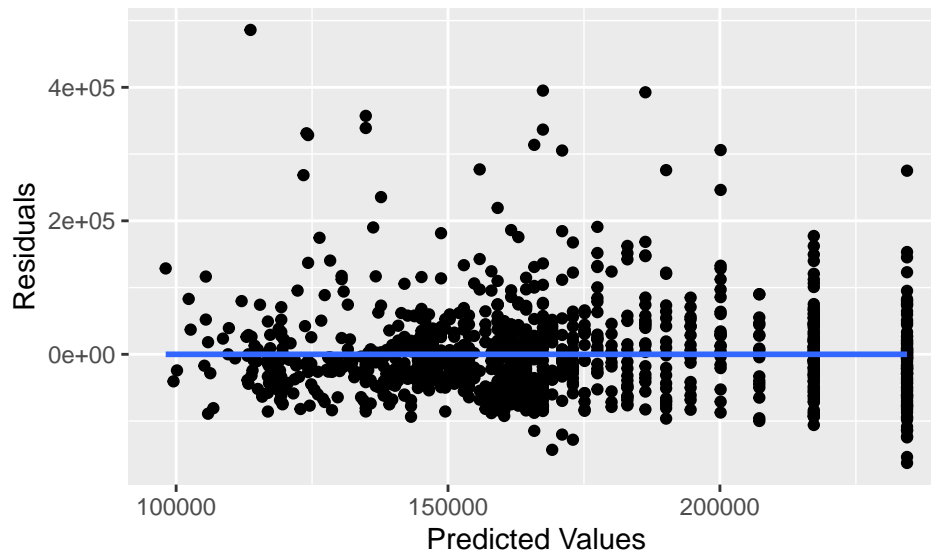
```
gf_point(price ~ log(age + 1), data = HousingPrices) %>%
  gf_smooth() %>%
  gf_labs(x = "LogAge", y = "Price")
```

```
## `geom_smooth()` using method = 'gam'
```



```
housinglm <- lm(price ~ log(age + 1), data = HousingPrices)
gf_point(resid(housinglm) ~ fitted(housinglm)) %>%
  gf_smooth() %>%
  gf_labs(x = "Predicted Values", y = "Residuals")
```

```
## `geom_smooth()` using method = 'gam'
```

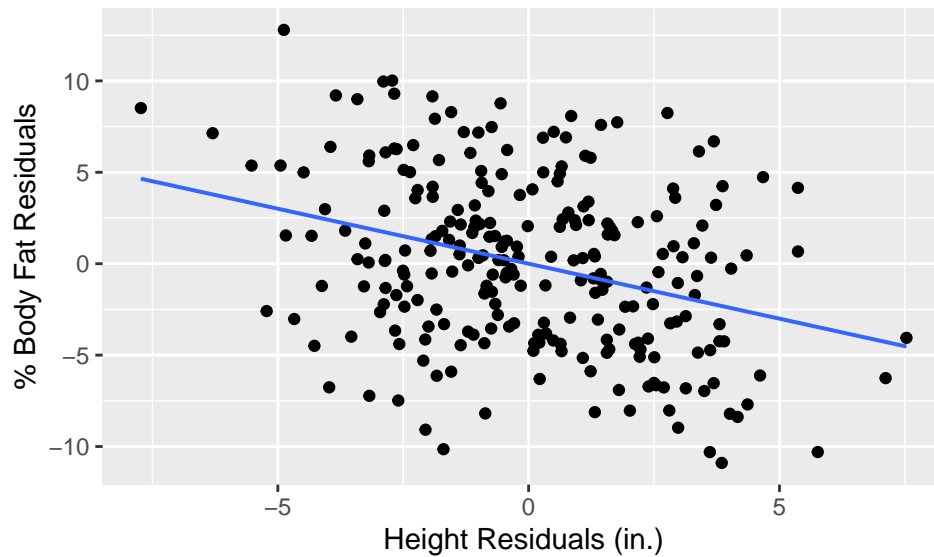



```
housinglm2 <- lm(price ~ living_area + log(age + 1) + bedrooms, data = HousingPrices)
msummary(housinglm2)
```

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  44797.165   8356.609   5.361 1.02e-07 ***
## living_area    87.260     3.365  25.928 < 2e-16 ***
## log(age + 1) -6270.813   1299.133  -4.827 1.59e-06 ***
## bedrooms     -5902.756   2773.934  -2.128 0.0336 *
##
## Residual standard error: 49620 on 1053 degrees of freedom
## Multiple R-squared:  0.5876, Adjusted R-squared:  0.5864
## F-statistic: 500.1 on 3 and 1053 DF,  p-value: < 2.2e-16
```

Section 9.4: Partial Regression Plots

```
# Figure 9.6 (instructions on 287)
# Step 1
otherthanheightlm <- lm(pct_bf ~ waist, data = BodyFat)
# Step 2
residualsoflm <- resid(otherthanheightlm)
# Step 3
yheightlm <- lm(height ~ waist, data = BodyFat)
# Step 4
residualsoflm2 <- resid(yheightlm)
# Step 5
gf_point(residualsoflm ~ residualsoflm2) %>%
  gf_lm() %>%
  gf_labs(x = "Height Residuals (in.)", y = "% Body Fat Residuals")
```



```
Hurricanes <- read_csv("http://nhorton.people.amherst.edu/is5/data/Hurricanes_2015.csv") %>%
  janitor::clean_names()
hurricanelm <- lm(max_wind_speed_kts ~ year + central_pressure_mb, data = Hurricanes)
msummary(hurricanelm)
```

Just Checking

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.032e+03  3.852e+01  26.789  <2e-16 ***
## year          -3.132e-04  9.075e-03  -0.035    0.973
## central_pressure_mb -9.750e-01  3.287e-02 -29.666  <2e-16 ***
##
## Residual standard error: 8.199 on 217 degrees of freedom
## (7 observations deleted due to missingness)
## Multiple R-squared:  0.8056, Adjusted R-squared:  0.8038
## F-statistic: 449.6 on 2 and 217 DF,  p-value: < 2.2e-16
```

Section 9.5: Indicator Variables

```
Coasters <- read_csv("http://nhorton.people.amherst.edu/is5/data/Coasters_2015.csv")
```

```
##
## -- Column specification -----
## cols(
##   Name = col_character(),
##   Park = col_character(),
##   Track = col_character(),
##   Speed = col_double(),
##   Height = col_double(),
##   Drop = col_double(),
##   Length = col_double(),
##   Duration = col_double(),
##   Inversions = col_double()
## )
```

Table 9.2, page 288
 head(Coasters)

```
## # A tibble: 6 x 9
##   Name      Park      Track Speed Height Drop Length Duration Inversions
##   <chr>    <chr>    <chr> <dbl> <dbl> <dbl> <dbl>    <dbl>    <dbl>
## 1 Top Thrill ~ Cedar Point Steel  120  420  400  2800    NA      0
## 2 Superman Th~ Six Flags Ma~ Steel  100  415  328.  1235    NA      0
## 3 Millennium ~ Cedar Point Steel   93  310  300  6595   165     0
## 4 Goliath    Six Flags Ma~ Steel   85  235  255  4500   180     0
## 5 Titan      Six Flags Ov~ Steel   85  245  255  5312   210     0
## 6 Phantom's R~ Kennywood Pa~ Steel   82  160  228  3200    NA      0
```

Figure 9.7

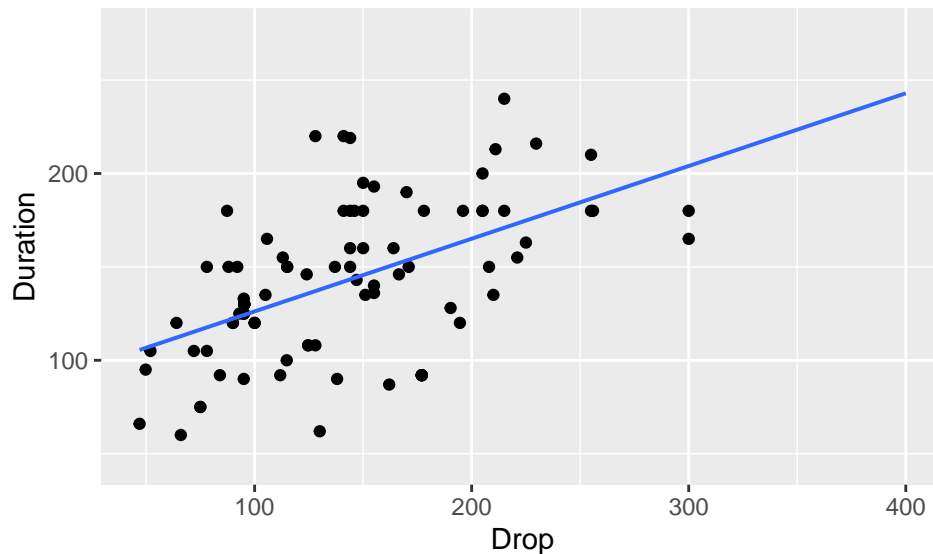
Tower of Terror isn't included by the book

```
Coasters <- Coasters %>%
  filter(Name != "Tower of Terror") %>%
  mutate(Inversions = as.factor(Inversions))

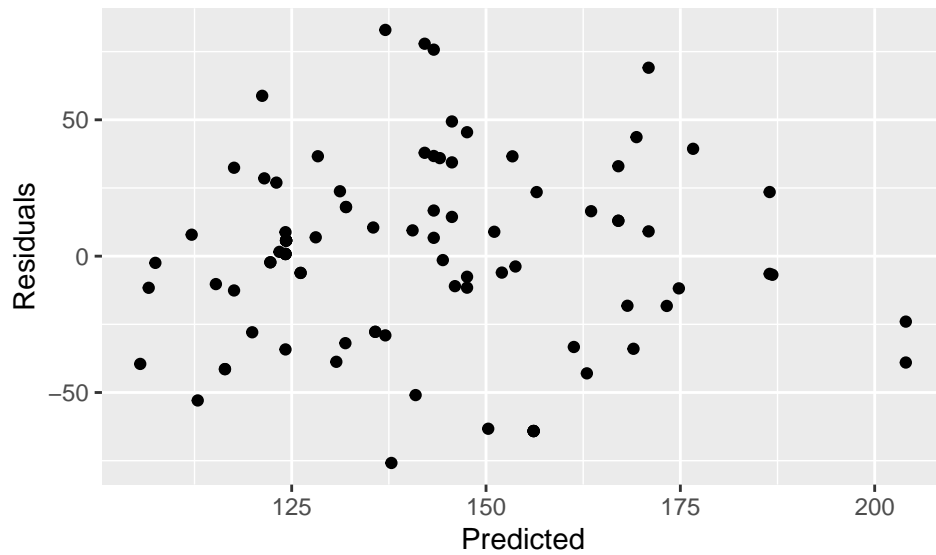
gf_point(Duration ~ Drop, data = Coasters) %>%
  gf_lm()
```

Warning: Removed 150 rows containing non-finite values (stat_lm).

Warning: Removed 150 rows containing missing values (geom_point).



```
coasterlm <- lm(Duration ~ Drop, data = Coasters)
gf_point(resid(coasterlm) ~ fitted(coasterlm)) %>%
  gf_labs(x = "Predicted", y = "Residuals")
```



```
msummary(coasterlm)
```

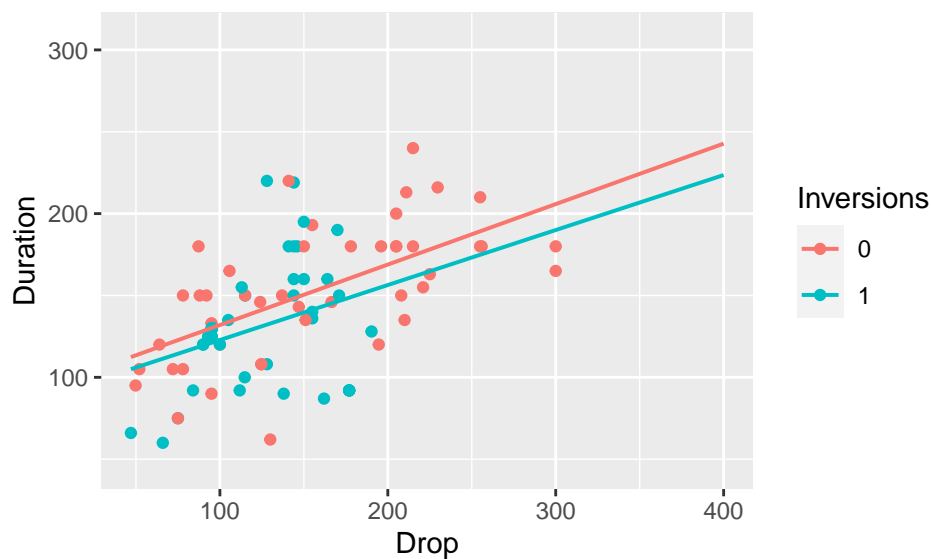
```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 87.22005    9.73524   8.959 4.98e-14 ***
## Drop        0.38928    0.06428   6.056 3.36e-08 ***
##
## Residual standard error: 34.06 on 88 degrees of freedom
## (150 observations deleted due to missingness)
## Multiple R-squared:  0.2942, Adjusted R-squared:  0.2862
## F-statistic: 36.68 on 1 and 88 DF,  p-value: 3.356e-08
```

Figure 9.8

```
gf_point(Duration ~ Drop, color = ~Inversions, data = Coasters) %>%
  gf_lm() %>%
  gf_labs(color = "Inversions")
```

```
## Warning: Removed 150 rows containing non-finite values (stat_lm).
```

```
## Warning: Removed 150 rows containing missing values (geom_point).
```



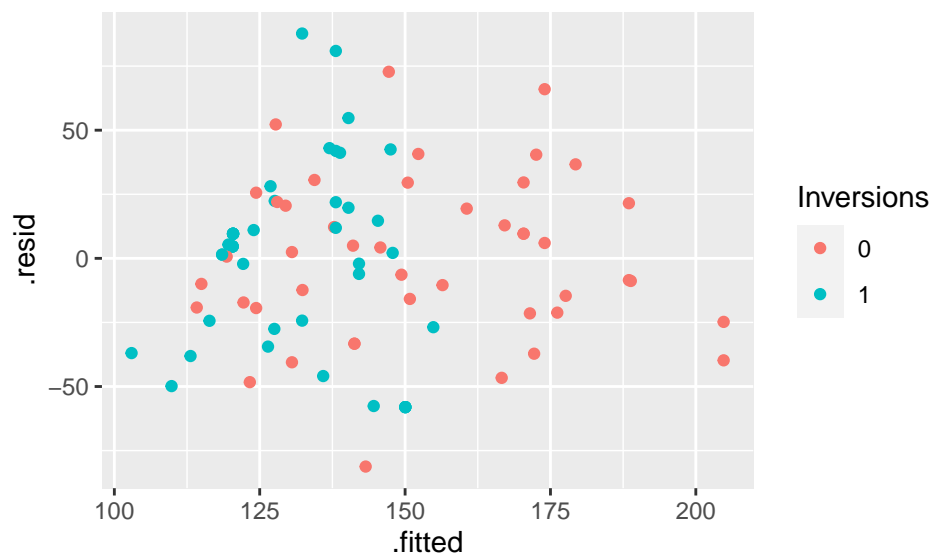
```
coasterlm2 <- lm(Duration ~ Drop + Inversions, data = Coasters)
msummary(coasterlm2)
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  96.14026   11.69140   8.223 1.74e-12 ***
## Drop         0.36215    0.06699   5.406 5.58e-07 ***
## Inversions1 -10.20093    7.48401  -1.363  0.176
##
## Residual standard error: 33.9 on 87 degrees of freedom
## (150 observations deleted due to missingness)
## Multiple R-squared:  0.3089, Adjusted R-squared:  0.293
## F-statistic: 19.45 on 2 and 87 DF,  p-value: 1.045e-07
```

```
coasterlm2asdata <- augment(coasterlm2)
glance(coasterlm2) %>% data.frame()
```

```
##   r.squared adj.r.squared   sigma statistic    p.value df    logLik    AIC
## 1 0.3089346    0.293048 33.89636  19.44628 1.04492e-07  2 -443.2766 894.5532
##      BIC deviance df.residual nobs
## 1 904.5524 99959.82          87   90
```

```
gf_point(.resid ~ .fitted, color = ~Inversions, data = coasterlm2asdata)
```



The `augment()` function creates a data frame from a linear model that includes a column for residuals, fitted values, etc. Here we use `names()` to check out the column names and `glance()` to view the structure of the data set.

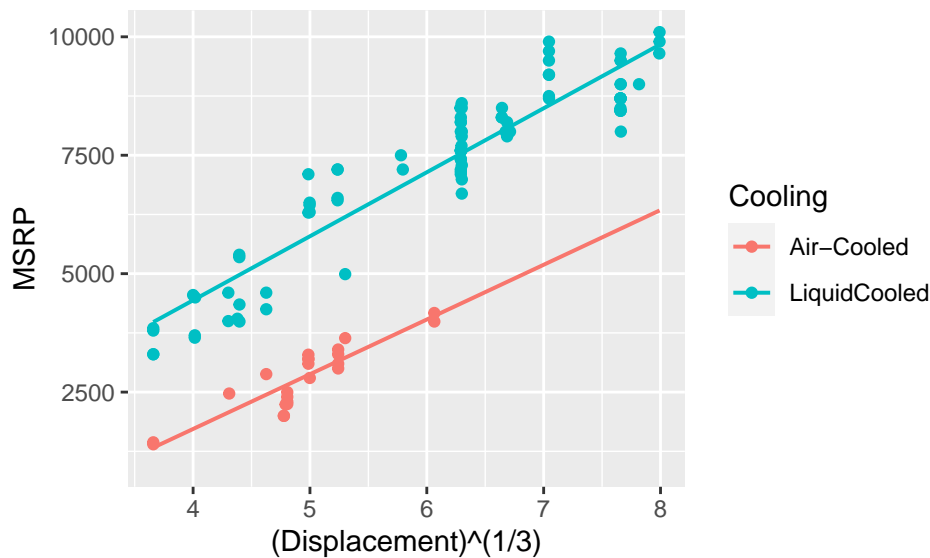
```
DirtBikes <- read_csv("http://nhorton.people.amherst.edu/is5/data/Dirt_bikes_2014.csv")
```

Example 9.3: Using Indicator Variables

```
##
## -- Column specification -----
## cols(
##   .default = col_character(),
##   Year = col_double(),
##   MSRP = col_double(),
```

```
## Displacement = col_double(),
## `Wheel Base` = col_double(),
## Bore = col_double(),
## Stroke = col_double(),
## Ratio = col_double(),
## Weight = col_double(),
## Rake = col_double(),
## Trail = col_double(),
## Tank = col_double(),
## `Engine cooling` = col_double()
## )
## i Use `spec()` for the full column specifications.
```

```
DirtBikes <- DirtBikes %>%
  filter(Cooling != "NA") %>%
  mutate(Cooling = ifelse(Cooling == "Air-Cooled", "Air-Cooled", "LiquidCooled"))
gf_point(MSRP ~ (Displacement)^(1 / 3), color = ~Cooling, data = DirtBikes) %>%
  gf_lm()
```



```
bikeslm <- lm(MSRP ~ I(Displacement^(1 / 3)) + Cooling, data = DirtBikes)
msummary(bikeslm)
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -3814.9      278.0  -13.72  <2e-16 ***
## I(Displacement^(1/3))  1341.4       50.4   26.61  <2e-16 ***
## CoolingLiquidCooled    2908.1      154.0   18.88  <2e-16 ***
##
## Residual standard error: 602.7 on 106 degrees of freedom
## Multiple R-squared:  0.9423, Adjusted R-squared:  0.9413
## F-statistic: 866.3 on 2 and 106 DF,  p-value: < 2.2e-16
```

The I() function is used to keep the class of an object the same. Here we use it to keep the variable Displacement “as is” to prevent an error.

```
BurgerKing <- read_csv("http://nhorton.people.amherst.edu/is5/data/Burger_King_items.csv") %>%
  clean_names()
```

Adjusting for Different Slopes

```
##  
## -- Column specification -----  
## cols(  
##   Item = col_character(),  
##   Serving.size = col_double(),  
##   Calories = col_double(),  
##   Fat.Cal = col_double(),  
##   `Protein(g)` = col_double(),  
##   `Fat(g)` = col_double(),  
##   `Sat.Fat(g)` = col_double(),  
##   `Trans.fat(g)` = col_double(),  
##   `Chol(mg)` = col_double(),  
##   `Sodium(mg)` = col_double(),  
##   `Carbs(g)` = col_double(),  
##   `Fiber(g)` = col_double(),  
##   `Sugar(g)` = col_double(),  
##   Meat = col_double(),  
##   Breakfast = col_double(),  
##   `Not Breakfast` = col_double(),  
##   CarbsxMeat = col_double()  
## )
```

Figure 9.9, page 292

```
gf_point(calories ~ carbs_g, data = BurgerKing) %>%  
  gf_labs(x = "Carbs (g)", y = "Calories")
```

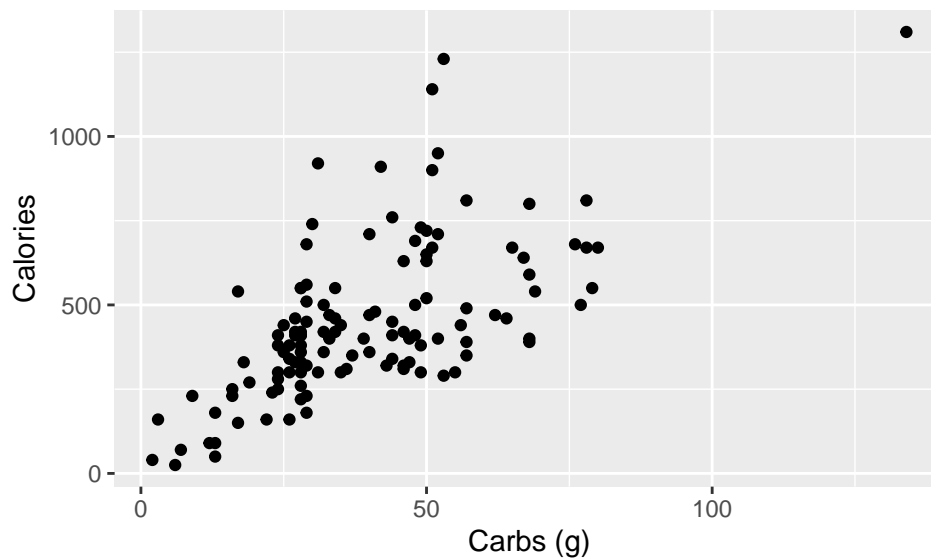
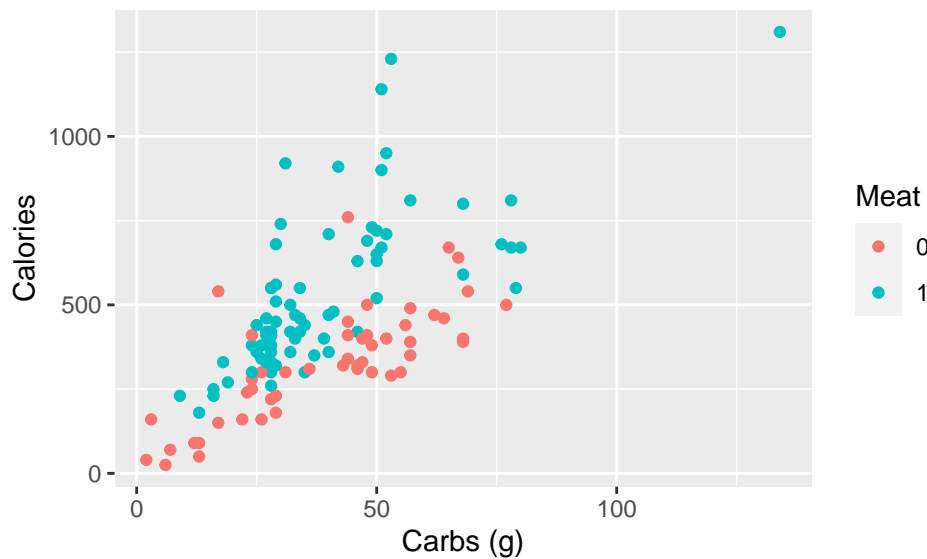


Figure 9.10

```
gf_point(calories ~ carbs_g, color = ~ as.factor(meat), data = BurgerKing) %>%  
  gf_labs(x = "Carbs (g)", y = "Calories", color = "Meat")
```



```
msummary(lm(calories ~ carbs_g * as.factor(meat), data = BurgerKing))
```

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)      83.533     46.955   1.779   0.0778 .
## carbs_g           6.255      1.063   5.885 3.81e-08 ***
## as.factor(meat)1  120.220     60.694   1.981   0.0499 *
## carbs_g:as.factor(meat)1  2.145      1.378   1.557   0.1222
##
## Residual standard error: 146.5 on 118 degrees of freedom
## Multiple R-squared:  0.6072, Adjusted R-squared:  0.5972
## F-statistic:  60.8 on 3 and 118 DF,  p-value: < 2.2e-16
```

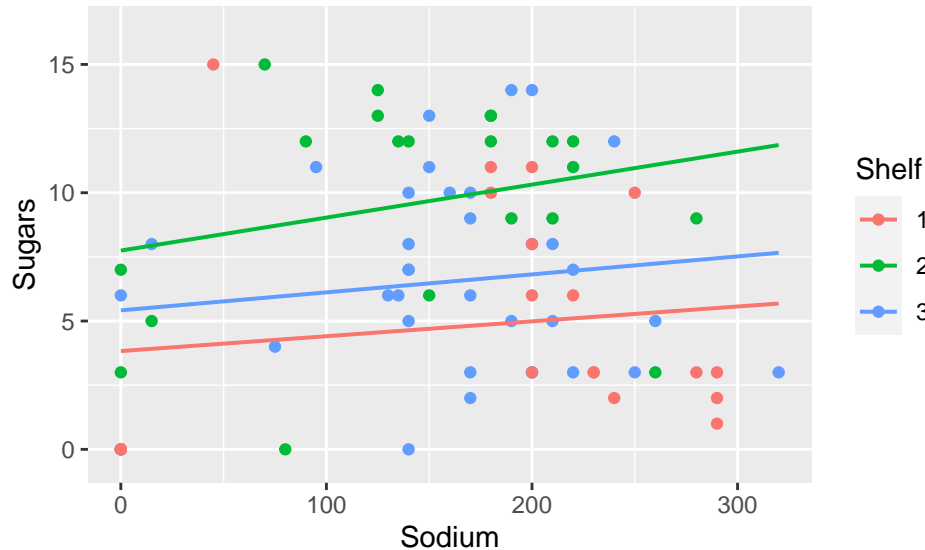
```
Cereal <- read_csv("http://nhorton.people.amherst.edu/is5/data/Cereals.csv")
```

One, Two, Many

```
##
## -- Column specification -----
## cols(
##   name = col_character(),
##   mfr = col_character(),
##   calories = col_double(),
##   sugars = col_double(),
##   carbo = col_double(),
##   protein = col_double(),
##   fat = col_double(),
##   sodium = col_double(),
##   fiber = col_double(),
##   potass = col_double(),
##   shelf = col_double(),
##   Middle = col_character(),
##   shelf_1 = col_double(),
##   shelf_2 = col_double(),
##   shelf_3 = col_double()
## )
```



```
cereallm <- lm(sugars ~ sodium + as.factor(shelf), data = Cereal)
gf_point(sugars ~ sodium, color = ~ as.factor(shelf), data = Cereal) %>%
  gf_lm() %>%
  gf_labs(x = "Sodium", y = "Sugars", color = "Shelf")
```



```
msummary(cereallm)
```

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    3.446740   1.345111   2.562 0.012457 *
## sodium         0.007962   0.005620   1.417 0.160818
## as.factor(shelf)2 5.012166   1.283154   3.906 0.000207 ***
## as.factor(shelf)3 1.818214   1.139384   1.596 0.114857
##
## Residual standard error: 4.07 on 73 degrees of freedom
## Multiple R-squared:  0.1866, Adjusted R-squared:  0.1532
## F-statistic: 5.583 on 3 and 73 DF,  p-value: 0.001669
```

```
Diamonds <- read_csv("http://nhorton.people.amherst.edu/is5/data/Diamonds.csv") %>%
  clean_names()
```

Example 9.4: Indicators for Variables with Several Levels

```
##
## -- Column specification -----
## cols(
##   Price = col_double(),
##   `Carat Size` = col_double(),
##   Color = col_character(),
##   Clarity = col_character(),
##   Cut = col_character()
## )
# Parallel Slopes
diamondlm <- lm(sqrt(price) ~ carat_size + color, data = Diamonds)
msummary(diamondlm)
```

```
##               Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) 13.1946      0.5488 24.043 < 2e-16 ***
## carat_size  61.2491      0.5032 121.722 < 2e-16 ***
## colorE      -2.1027      0.5399 -3.895 0.000101 ***
## colorF      -2.8640      0.5576 -5.136 3.00e-07 ***
## colorG      -3.6320      0.5769 -6.296 3.57e-10 ***
## colorH      -7.8948      0.5858 -13.477 < 2e-16 ***
## colorI     -11.8542      0.6261 -18.932 < 2e-16 ***
## colorJ     -16.6404      0.6637 -25.071 < 2e-16 ***
## colorK     -21.3577      0.8282 -25.787 < 2e-16 ***
##
## Residual standard error: 7.218 on 2681 degrees of freedom
## Multiple R-squared:  0.8583, Adjusted R-squared:  0.8579
## F-statistic: 2030 on 8 and 2681 DF,  p-value: < 2.2e-16

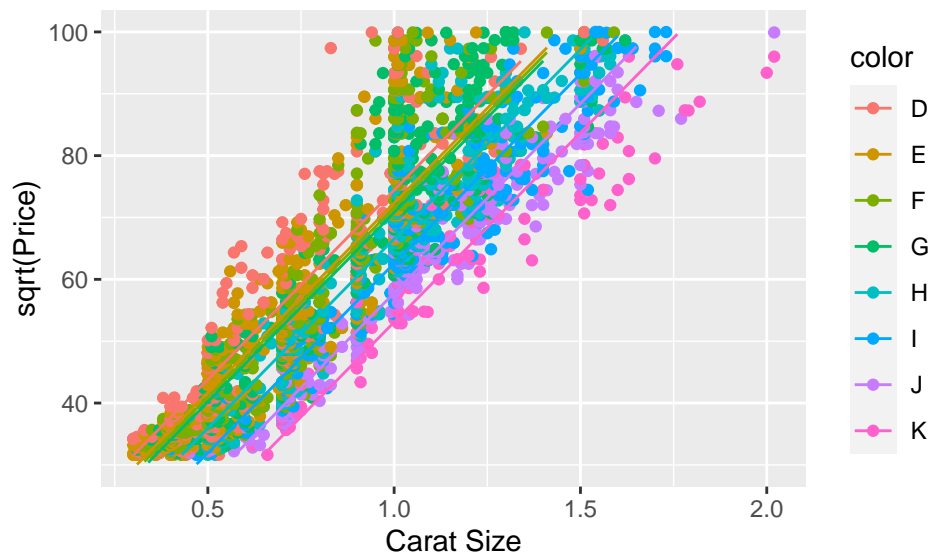
diamondpredict <- makeFun(diamondlm)

diamonddata <- augment(diamondlm) %>% # To get fitted values
  clean_names()
str(diamonddata)

## tibble [2,690 x 8] (S3: tbl_df/tbl/data.frame)
## $ sqrt_price: num [1:2690] 31.6 31.6 31.6 31.6 31.6 ...
## $ carat_size: num [1:2690] 0.3 0.44 0.31 0.66 0.47 0.4 0.36 0.52 0.53 0.43 ...
## $ color      : chr [1:2690] "E" "E" "E" "K" ...
## $ fitted      : num [1:2690] 29.5 38 30.1 32.3 34.1 ...
## $ std_resid   : num [1:2690] 0.2991 -0.8902 0.2141 -0.0889 -0.342 ...
## $ hat         : num [1:2690] 0.00269 0.00226 0.00265 0.00959 0.00375 ...
## $ sigma       : num [1:2690] 7.22 7.22 7.22 7.22 7.22 ...
## $ cooks      : num [1:2690] 2.68e-05 2.00e-04 1.35e-05 8.51e-06 4.89e-05 ...
## - attr(*, "terms")=Classes 'terms', 'formula' language sqrt(price) ~ carat_size + color
## .. ..- attr(*, "variables")= language list(sqrt(price), carat_size, color)
## .. ..- attr(*, "factors")= int [1:3, 1:2] 0 1 0 0 0 1
## .. ..- attr(*, "dimnames")=List of 2
## .. .. ..$ : chr [1:3] "sqrt(price)" "carat_size" "color"
## .. .. ..$ : chr [1:2] "carat_size" "color"
## .. ..- attr(*, "term.labels")= chr [1:2] "carat_size" "color"
## .. ..- attr(*, "order")= int [1:2] 1 1
## .. ..- attr(*, "intercept")= int 1
## .. ..- attr(*, "response")= int 1
## .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
## .. ..- attr(*, "predvars")= language list(sqrt(price), carat_size, color)
## .. ..- attr(*, "dataClasses")= Named chr [1:3] "numeric" "numeric" "character"
## .. ..- attr(*, "names")= chr [1:3] "sqrt(price)" "carat_size" "color"

gf_point(sqrt_price ~ carat_size, color = ~color, data = diamonddata) %>%
  gf_line(fitted ~ carat_size) %>%
  gf_labs(x = "Carat Size", y = "sqrt(Price)") +
  ylim(30, 100)

## Warning: Removed 79 row(s) containing missing values (geom_path).
```



```
# With interaction
diamondlm2 <- lm(sqrt(price) ~ carat_size * color, data = Diamonds)
msummary(diamondlm2)
```

```
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)      9.3239     1.2142   7.679 2.23e-14 ***
## carat_size      67.0408     1.7025  39.379 < 2e-16 ***
## colorE          -0.5392     1.5075  -0.358  0.72063
## colorF          -2.3716     1.5627  -1.518  0.12922
## colorG          -2.6709     1.6643  -1.605  0.10867
## colorH          -3.9177     1.8248  -2.147  0.03189 *
## colorI          -2.5481     1.9301  -1.320  0.18689
## colorJ          -5.4176     2.0716  -2.615  0.00897 **
## colorK           0.5976     2.7815   0.215  0.82991
## carat_size:colorE -2.4007     2.0999  -1.143  0.25305
## carat_size:colorF -1.3211     2.0954  -0.630  0.52843
## carat_size:colorG -2.5457     2.0868  -1.220  0.22260
## carat_size:colorH -5.9017     2.1774  -2.710  0.00676 **
## carat_size:colorI -10.9139     2.1812  -5.004  5.99e-07 ***
## carat_size:colorJ -12.4948     2.2531  -5.546  3.22e-08 ***
## carat_size:colorK -21.4477     2.6978  -7.950  2.72e-15 ***
```

```
##
## Residual standard error: 7.058 on 2674 degrees of freedom
## Multiple R-squared:  0.8649, Adjusted R-squared:  0.8641
## F-statistic: 1141 on 15 and 2674 DF, p-value: < 2.2e-16
```

```
gf_point(sqrt(price) ~ carat_size, color = ~color, data = Diamonds) %>%
  gf_lm() %>%
  gf_labs(x = "Carat Size", y = "sqrt(Price)") +
  ylim(30, 100)
```

```
## Warning: Removed 204 rows containing missing values (geom_lm).
```

