# IS5 in R: Comparing Counts (Chapter 19)

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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. More information about the book can be found at http://wps.aw.com/aw_deveaux_stats_series. 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 (http://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 19: Comparing Counts

```
library(mosaic)
library(readr)
library(janitor)
Zodiac <- read_csv("http://nhorton.people.amherst.edu/is5/data/Zodiac.csv")
```

```
## Parsed with column specification:
## cols(
##   Month = col_character(),
##   Births = col_integer(),
##   Expected = col_double(),
##   Residual = col_double()
## )
```

By default, `read_csv()` prints the variable names. These messages can be suppressed using the `message=FALSE` code chunk option to save space and improve readability.

```
Zodiac %>%
  select(Month, Births)
```

```
## # A tibble: 12 x 2
##    Month       Births
##    <chr>        <int>
##  1 Pisces          29
##  2 Aquarius        24
##  3 Aries           23
##  4 Cancer          23
##  5 Capricorn       22
##  6 Scorpio         21
##  7 Taurus          20
##  8 Leo             20
##  9 Saggitarius     19
```

```
## 10 Virgo           19
## 11 Libra           18
## 12 Gemini          18
```

### Section 19.1: Goodness-of-Fit Tests

### Example 19.1: Finding Expected Counts

```
# page 611
BaseballBirths <- read_csv("http://nhorton.people.amherst.edu/is5/data/Ballplayer_births.csv") %>%
  clean_names() # doesn't contain national birth %
```

```
## Parsed with column specification:
## cols(
##   Month = col_integer(),
##   `Ballplayer Count` = col_integer()
## )
```

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).

```
natbirth <- c(.08, .07, .08, .08, .08, .08, .09, .09, .09, .09, .08, .09)
BaseballBirths <- cbind(BaseballBirths, natbirth) # adding a column for national birth %
totaln <- sum(~ ballplayer_count , data = BaseballBirths)
totaln
```

```
## [1] 1478
```

```
BaseballBirths <- BaseballBirths %>%
  mutate(expected = totaln * natbirth)
BaseballBirths %>%
  select(month, expected)
```

```
##    month expected
## 1      1   118.24
## 2      2   103.46
## 3      3   118.24
## 4      4   118.24
## 5      5   118.24
## 6      6   118.24
## 7      7   133.02
## 8      8   133.02
## 9      9   133.02
## 10    10   133.02
## 11    11   118.24
## 12    12   133.02
```

### Assumptions and Conditions

### Calculations

### Chi-Square P-values

```
# Examples of chisq p-values
qchisq(df = 2, p = .1, lower.tail = FALSE)
```

```
## [1] 4.60517
```

```r
qchisq(df = 10, p = .05, lower.tail = FALSE)
```

```
## [1] 18.30704
```

**Example 19.3: Doing a Goodness-of-Fit Test**

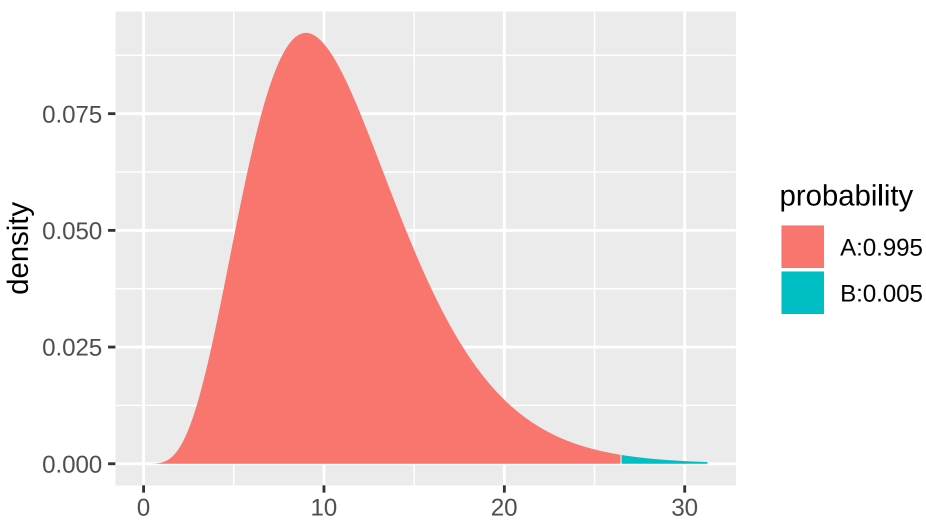
```r
# page 614
df <- nrow(BaseballBirths) - 1
df
```

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

```r
# XX Can't seem to get the right value
# Getting the chisq statistic
# with(chisq.test(tally(~ ballplayer_count | expected, data = BaseballBirths)), statistic)
# with(chisq.test(tally(natbirth ~ ballplayer_count, data = BaseballBirths)), statistic)
# Alternate method
BaseballBirths %>%
  mutate(chisq = ((ballplayer_count - expected)^2)/expected) %>%
  summarise(sum(chisq))
```

```
##   sum(chisq)
## 1   26.48442
```

```r
xpchisq(q = 26.5, df = df, lower.tail = FALSE)
```



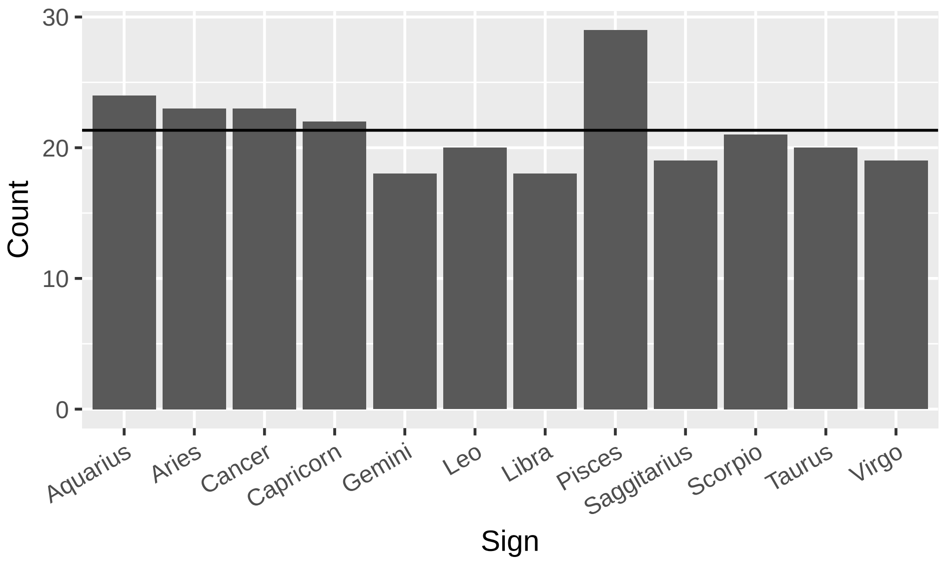

```
## [1] 0.005464563
```

**Step-By-Step Example: A Chi-Square Test for Goodness-of-Fit**

```r
expected <- mean(~ Births, data = Zodiac)
expected
```

```
## [1] 21.33333
```

```r
gf_col(Births ~ Month, data = Zodiac) %>%
  gf_hline(yintercept = expected) %>%
  gf_labs(x = "Sign", y = "Count") +
  theme(axis.text.x = element_text(angle = 30, hjust = 1)) # to adjust the angle of the x axis labels
```



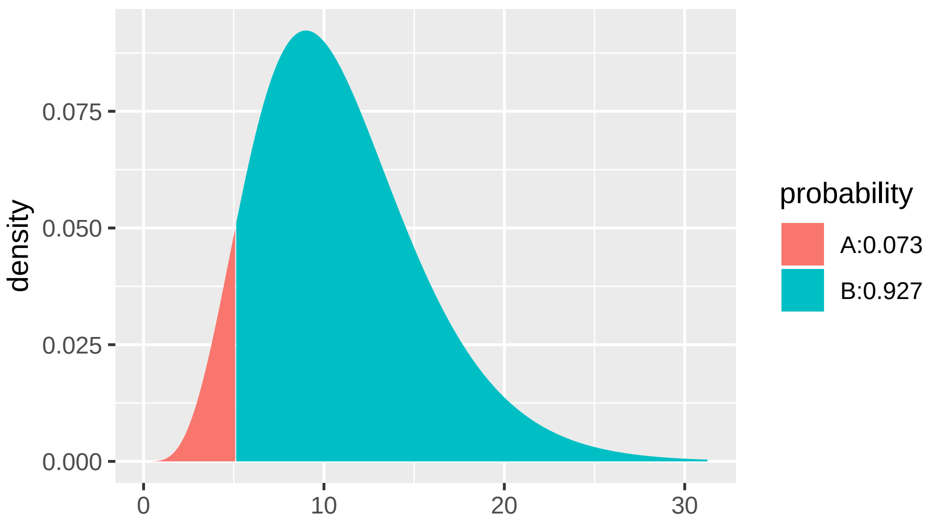

```
# Mechanics
df <- nrow(Zodiac) - 1
df
```

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

```
# XX Need to get rid of tidyverse and find chisq statistic correctly
Zodiac %>%
  mutate(chisq = ((Births - Expected)^2)/Expected) %>%
  summarise(sum(chisq))
```

```
## # A tibble: 1 x 1
##   `sum(chisq)`
##          <dbl>
## 1         5.09
```

```
xpchisq(q = 5.09, df = df, lower.tail = FALSE)
```




```
## [1] 0.9267297
```

**The Chi-Square Calculation**

```
Zodiac %>%
  mutate(residsq = Residual^2) %>%
  mutate(component = residsq/Expected)
```

```
## # A tibble: 12 x 6
##    Month       Births Expected Residual residsq component
##    <chr>        <int>    <dbl>    <dbl>   <dbl>     <dbl>
##  1 Pisces          29     21.3    7.67   58.8     2.76
##  2 Aquarius        24     21.3    2.67    7.11    0.333
##  3 Aries           23     21.3    1.67    2.78    0.130
##  4 Cancer          23     21.3    1.67    2.78    0.130
##  5 Capricorn       22     21.3    0.667   0.445   0.0209
##  6 Scorpio         21     21.3   -0.333   0.111   0.00520
##  7 Taurus          20     21.3   -1.33    1.78    0.0833
##  8 Leo             20     21.3   -1.33    1.78    0.0833
##  9 Saggitarius     19     21.3   -2.33    5.44    0.255
## 10 Virgo           19     21.3   -2.33    5.44    0.255
## 11 Libra           18     21.3   -3.33   11.1     0.521
## 12 Gemini          18     21.3   -3.33   11.1     0.521
```

**The Trouble with Goodness-of-Fit Tests: What's the Alternative?**

**Section 19.2: Chi-Square Test of Homogeneity**

```
# Create the data set
Postgrad <- rbind(
  do(209) * data.frame(activity = "Employed", school = "Agriculture"),
  do(198) * data.frame(activity = "Employed", school = "Arts & Sciences"),
  do(177) * data.frame(activity = "Employed", school = "Engineering"),
  do(101) * data.frame(activity = "Employed", school = "ILR"),
  do(104) * data.frame(activity = "Grad School", school = "Agriculture"),
  do(171) * data.frame(activity = "Grad School", school = "Arts & Sciences"),
  do(158) * data.frame(activity = "Grad School", school = "Engineering"),
  do(33)  * data.frame(activity = "Grad School", school = "ILR"),
  do(135) * data.frame(activity = "Other", school = "Agriculture"),
  do(115) * data.frame(activity = "Other", school = "Arts & Sciences"),
  do(39)  * data.frame(activity = "Other", school = "Engineering"),
  do(16)  * data.frame(activity = "Other", school = "ILR")
)
```

```
# Table 19.1, page 618
tally(activity ~ school, data = Postgrad, margins = TRUE)
```

```
##                school
## activity      Agriculture Arts & Sciences Engineering ILR
##   Employed            209             198         177 101
##   Grad School         104             171         158  33
##   Other               135             115          39  16
##   Total               448             484         374 150
```

```
# Table 19.2
tally(activity ~ school, format = "percent", data = Postgrad, margins = TRUE)
```

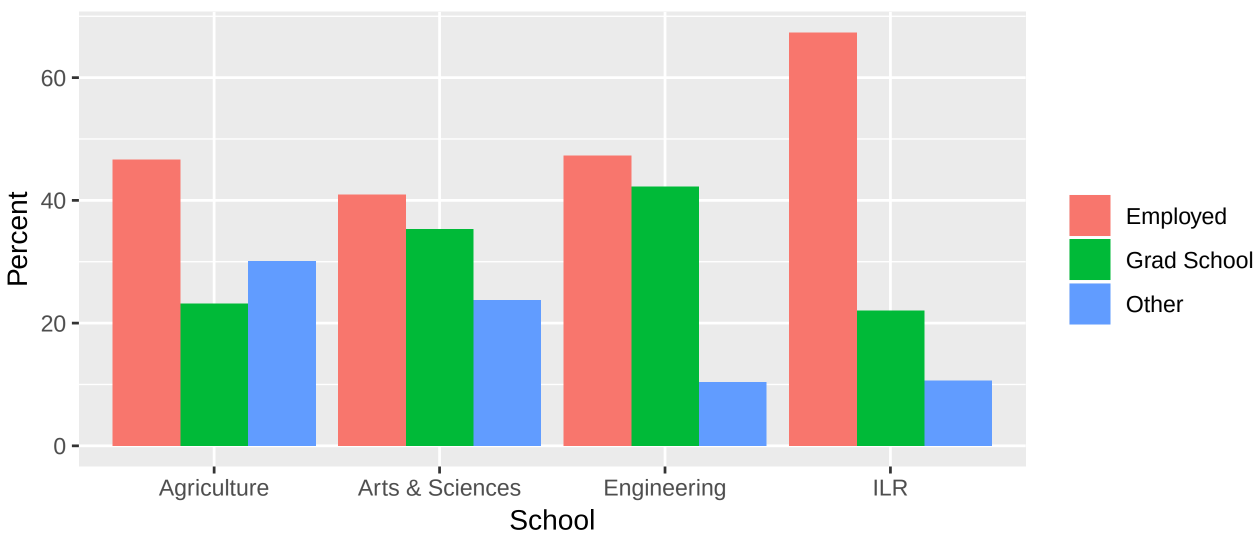
```
##                school
## activity        Agriculture Arts & Sciences Engineering       ILR
##   Employed         46.65179        40.90909    47.32620  67.33333
##   Grad School      23.21429        35.33058    42.24599  22.00000
##   Other            30.13393        23.76033    10.42781  10.66667
##   Total           100.00000       100.00000   100.00000 100.00000
```

```
# Table 19.3
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), expected)
```

```
##                school
## activity        Agriculture Arts & Sciences Engineering       ILR
##   Employed        210.76923        227.7060   175.95467  70.57005
##   Grad School     143.38462        154.9066   119.70055  48.00824
##   Other            93.84615        101.3874    78.34478  31.42170
##   Total           448.00000        484.0000   374.00000 150.00000
```

### Step-By-Step Example: A Chi-Square Test for Homogeneity

```
tally(activity ~ school, format = "percent", data = Postgrad) %>%
  data.frame() %>%
  gf_col(Freq ~ school, fill = ~ activity, position = "dodge") %>%
  gf_labs(x = "School", y = "Percent", fill = "")
```




```
# Mechanics
tally(activity ~ school, data = Postgrad, margins = TRUE)
```

```
##                school
## activity        Agriculture Arts & Sciences Engineering ILR
##   Employed              209             198         177 101
##   Grad School           104             171         158  33
##   Other                 135             115          39  16
##   Total                 448             484         374 150
```

```
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), expected)
```

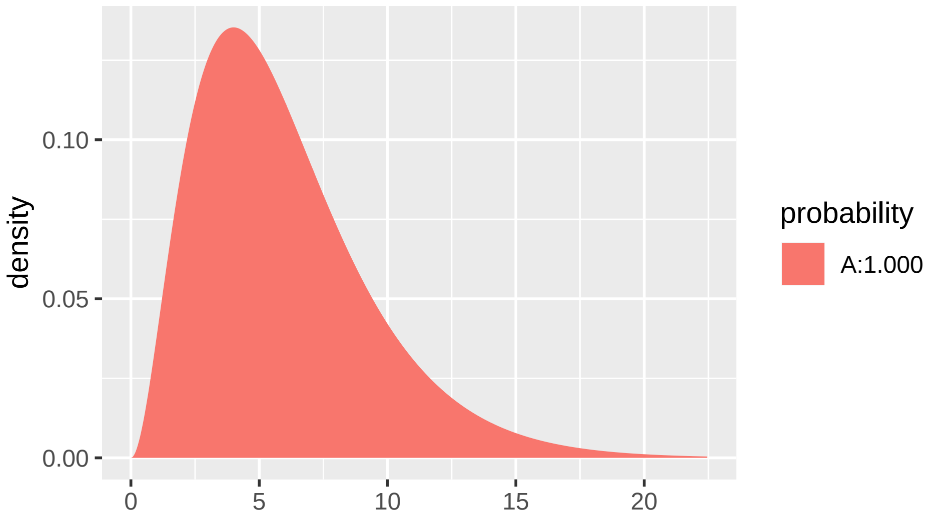
```
##                school
## activity        Agriculture Arts & Sciences Engineering       ILR
##   Employed        210.76923        227.7060   175.95467  70.57005
```

```
##   Grad School   143.38462        154.9066   119.70055  48.00824
##   Other          93.84615        101.3874    78.34478  31.42170
##   Total         448.00000        484.0000   374.00000 150.00000
```

```r
with(chisq.test(tally(activity ~ school, data = Postgrad)), statistic)
```

```
## X-squared
##  93.65667
```

```r
xpchisq(q = 93.7, df = 6, lower.tail = FALSE)
```




```
## [1] 5.154981e-18
```

**Section 19.3: Examining the Residuals**

```r
# Table 19.4, page 622
with(chisq.test(tally(activity ~ school, data = Postgrad, margins = TRUE)), residuals)
```

```
##              school
## activity      Agriculture Arts & Sciences Engineering         ILR
##   Employed    -0.12186553     -1.96860027  0.07880484  3.62235442
##   Grad School -3.28908677      1.29304319  3.50061599 -2.16606715
##   Other        4.24817296      1.35191804 -4.44510568 -2.75117035
##   Total        0.00000000      0.00000000  0.00000000  0.00000000
```

**Example 19.4: Looking at $\chi^2$, Residuals**

```r
BaseballBirths %>%
  mutate(residuals = (ballplayer_count - expected)/(expected^.5)) %>%
  select(month, residuals)
```

```
##    month   residuals
## 1      1  1.72524439
## 2      2  1.72442119
## 3      3 -0.20599933
## 4      4  0.25382060
## 5      5  0.71364054
## 6      6 -0.38992730
```

```
## 7       7 -2.68957291
## 8       8  2.77280921
## 9       9  0.08497039
## 10     10 -1.56241469
## 11     11 -1.21760318
## 12     12 -0.95548335
```

### Section 19.4: Chi-Square Test of Independence

```r
Tattoos <- read_csv("http://nhorton.people.amherst.edu/is5/data/Tattoos.csv", skip = 1) %>%
  clean_names() # skip = 1 because first row is "Col1", "Col2"
```

```
## Parsed with column specification:
## cols(
##   Location = col_character(),
##   `Has hepatitis C` = col_character()
## )
```

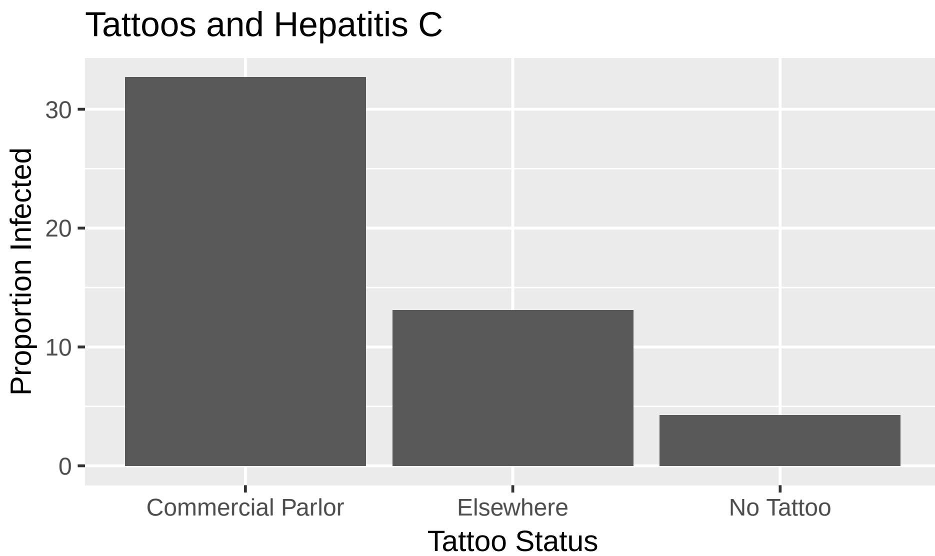
```r
# Table 19.5, page 623
tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)
```

```
##                    has_hepatitis_c
## location             No Yes
##   Commercial Parlor  35  17
##   Elsewhere          53   8
##   No Tattoo         491  22
##   Total             579  47
```

### Assumptions and Conditions

### Step-By-Step Example: A Chi-Square Test for Independence

```r
tally(has_hepatitis_c ~ location, format = "percent", data = Tattoos) %>%
  data.frame() %>%
  filter(has_hepatitis_c == "Yes") %>%
  gf_col(Freq ~ location) %>%
  gf_labs(x = "Tattoo Status", y = "Proportion Infected", title = "Tattoos and Hepatitis C")
```




```r
# Observed
tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)
```

```
##                     has_hepatitis_c
## location              No Yes
##   Commercial Parlor   35  17
##   Elsewhere           53   8
##   No Tattoo          491  22
##   Total              579  47
```

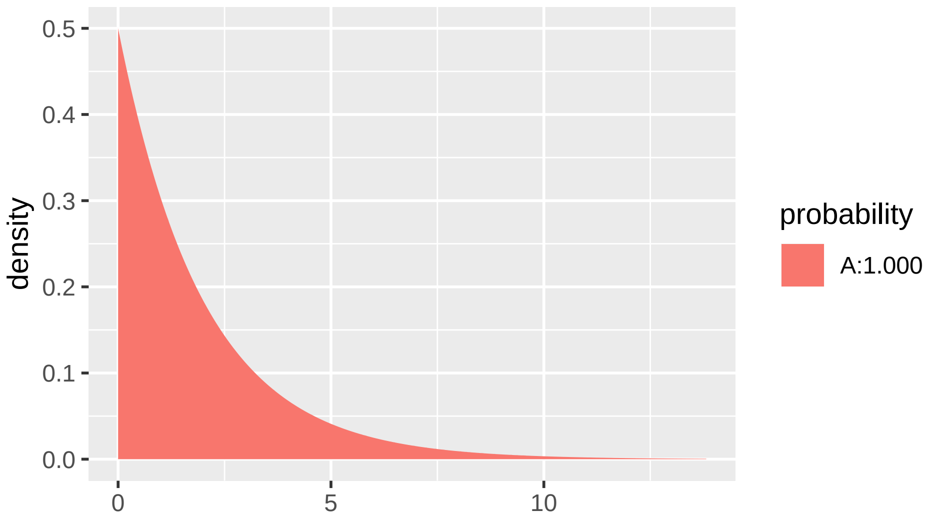
```r
# Expected
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos, margins = TRUE)), expected)
```

```
## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos, :
## Chi-squared approximation may be incorrect

##                     has_hepatitis_c
## location                    No       Yes
##   Commercial Parlor   48.09585  3.904153
##   Elsewhere           56.42013  4.579872
##   No Tattoo          474.48403 38.515974
##   Total              579.00000 47.000000
```

```r
# Mechanics
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)), statistic)
```

```
## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)):
## Chi-squared approximation may be incorrect

## X-squared
##  57.91217
```

```r
xpchisq(q = 57.9, df = 2, lower.tail = FALSE)
```




```
## [1] 2.674082e-13
```

### Examine the Residuals

```
# Table 19.6, page 627
with(chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)), residuals)
```

```
## Warning in chisq.test(tally(location ~ has_hepatitis_c, data = Tattoos)):
## Chi-squared approximation may be incorrect
```

```
##                     has_hepatitis_c
## location                     No        Yes
##   Commercial Parlor -1.8883383  6.6278115
##   Elsewhere         -0.4553290  1.5981431
##   No Tattoo          0.7582168 -2.6612383
```

```
# Table 19.7, page 628
Tattoos <- Tattoos %>%
  mutate(tattoo = ifelse(location == "No Tattoo", "None", "Tattoo"))
tally(tattoo ~ has_hepatitis_c, margins = TRUE, data = Tattoos)
```

```
##         has_hepatitis_c
## tattoo    No Yes
##   None   491  22
##   Tattoo  88  25
##   Total  579  47
```

### Chi-Square and Causation