Lab 8

Adriana Sham

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Load the `ggplot2` library and its dataset called `mpg`. Print out a summary of the dataset using `summary` and `str`.

```
pacman::p_load(ggplot2)
data(mpg)
mpg$drv = factor(mpg$drv)
mpg$manufacturer = factor(mpg$manufacturer)
mpg$model = factor(mpg$model)
mpg$fl = factor(mpg$fl)
mpg$class = factor(mpg$class)
mpg$cyl = factor(mpg$cyl)
summary(mpg)
```

```
##      manufacturer                 model         displ            year     
##  dodge     :37    caravan 2wd        : 11   Min.   :1.600   Min.   :1999  
##  toyota    :34    ram 1500 pickup 4wd: 10   1st Qu.:2.400   1st Qu.:1999  
##  volkswagen:27    civic              :  9   Median :3.300   Median :2004  
##  ford      :25    dakota pickup 4wd  :  9   Mean   :3.472   Mean   :2004  
##  chevrolet :19    jetta              :  9   3rd Qu.:4.600   3rd Qu.:2008  
##  audi      :18    mustang            :  9   Max.   :7.000   Max.   :2008  
##  (Other)   :74    (Other)            :177                                 
##  cyl       trans            drv          cty             hwy        fl     
##  4:81   Length:234         4:103   Min.   : 9.00   Min.   :12.00   c:  1  
##  5: 4   Class :character   f:106   1st Qu.:14.00   1st Qu.:18.00   d:  5  
##  6:79   Mode  :character   r: 25   Median :17.00   Median :24.00   e:  8  
##  8:70                              Mean   :16.86   Mean   :23.44   p: 52  
##                                    3rd Qu.:19.00   3rd Qu.:27.00   r:168  
##                                    Max.   :35.00   Max.   :44.00          
##                                                                           
##         class   
##  2seater   : 5  
##  compact   :47  
##  midsize   :41  
##  minivan   :11  
##  pickup    :33  
##  subcompact:35  
##  suv       :62  
```

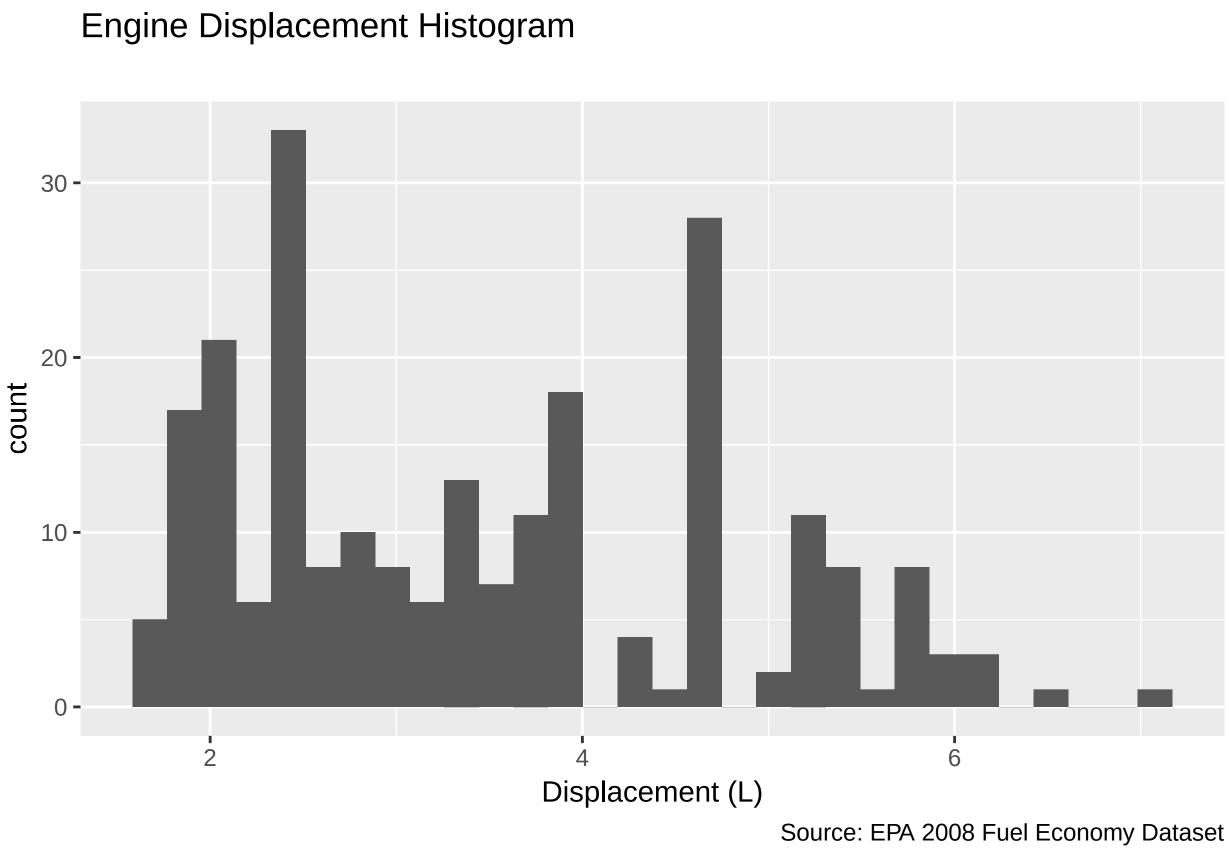
```
str(mpg)
```

```
## Classes 'tbl_df', 'tbl' and 'data.frame':    234 obs. of  11 variables:
##  $ manufacturer: Factor w/ 15 levels "audi","chevrolet",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ model       : Factor w/ 38 levels "4runner 4wd",..: 2 2 2 2 2 2 2 3 3 3 ...
##  $ displ       : num  1.8 1.8 2 2 2.8 2.8 3.1 1.8 1.8 2 ...
##  $ year        : int  1999 1999 2008 2008 1999 1999 2008 1999 1999 2008 ...
##  $ cyl         : Factor w/ 4 levels "4","5","6","8": 1 1 1 1 3 3 3 1 1 1 ...
##  $ trans       : chr  "auto(l5)" "manual(m5)" "manual(m6)" "auto(av)" ...
##  $ drv         : Factor w/ 3 levels "4","f","r": 2 2 2 2 2 2 2 1 1 1 ...
##  $ cty          : int  18 21 20 21 16 18 18 18 16 20 ...
##  $ hwy          : int  29 29 31 30 26 26 27 26 25 28 ...
##  $ fl           : Factor w/ 5 levels "c","d","e","p",..: 4 4 4 4 4 4 4 4 4 4 ...
##  $ class        : Factor w/ 7 levels "2seater","compact",..: 2 2 2 2 2 2 2 2 2 2 ...
```

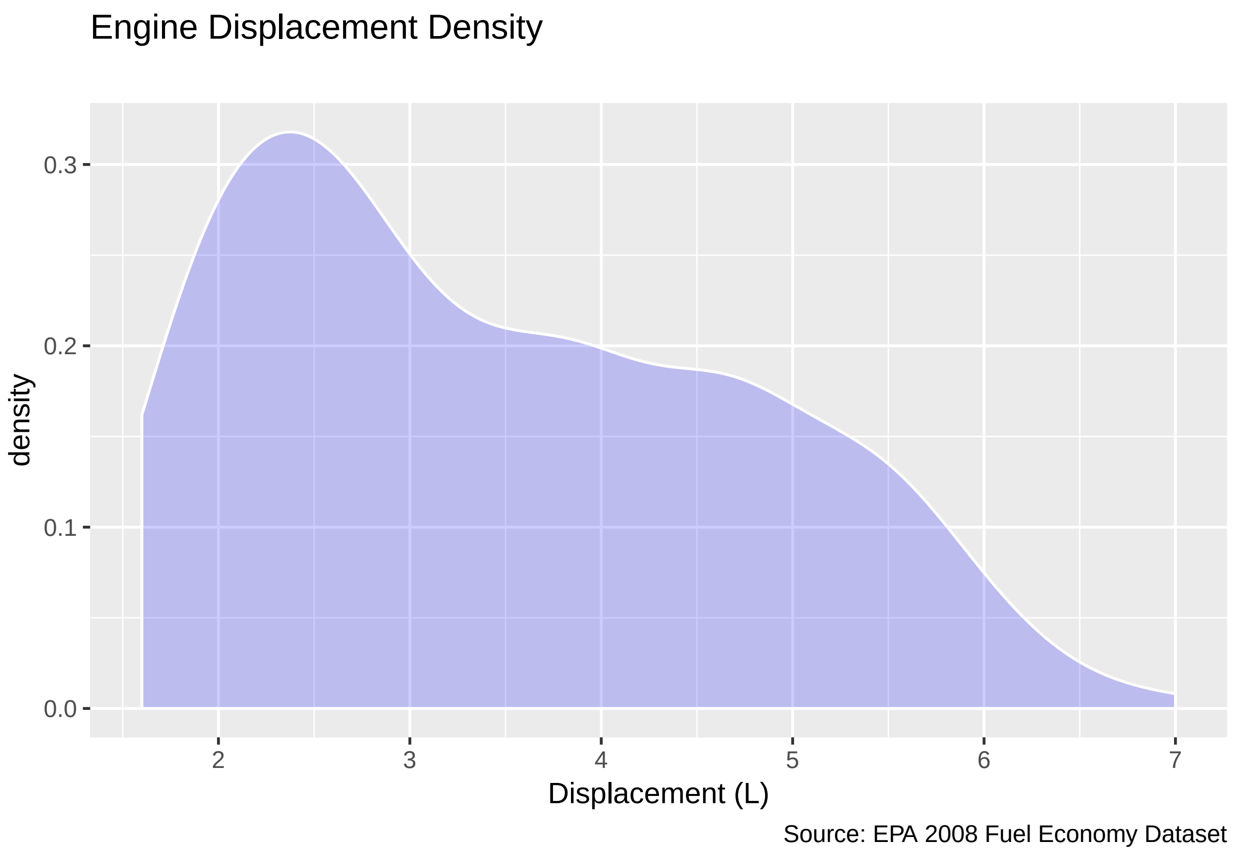
Visualize a histogram then a density estimate of the `displ` variable, the engine displacement. Use `labs` to create a `title`, `subtitle`, `caption` and x-label via `x` and y-label via `y`. Do this for every single illustration in this lab.

```r
ggplot(mpg) +
  aes(displ) +
  geom_histogram() +
  labs(title = "Engine Displacement Histogram" , subtitle = "", x = "Displacement (L)", caption = "Sour
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



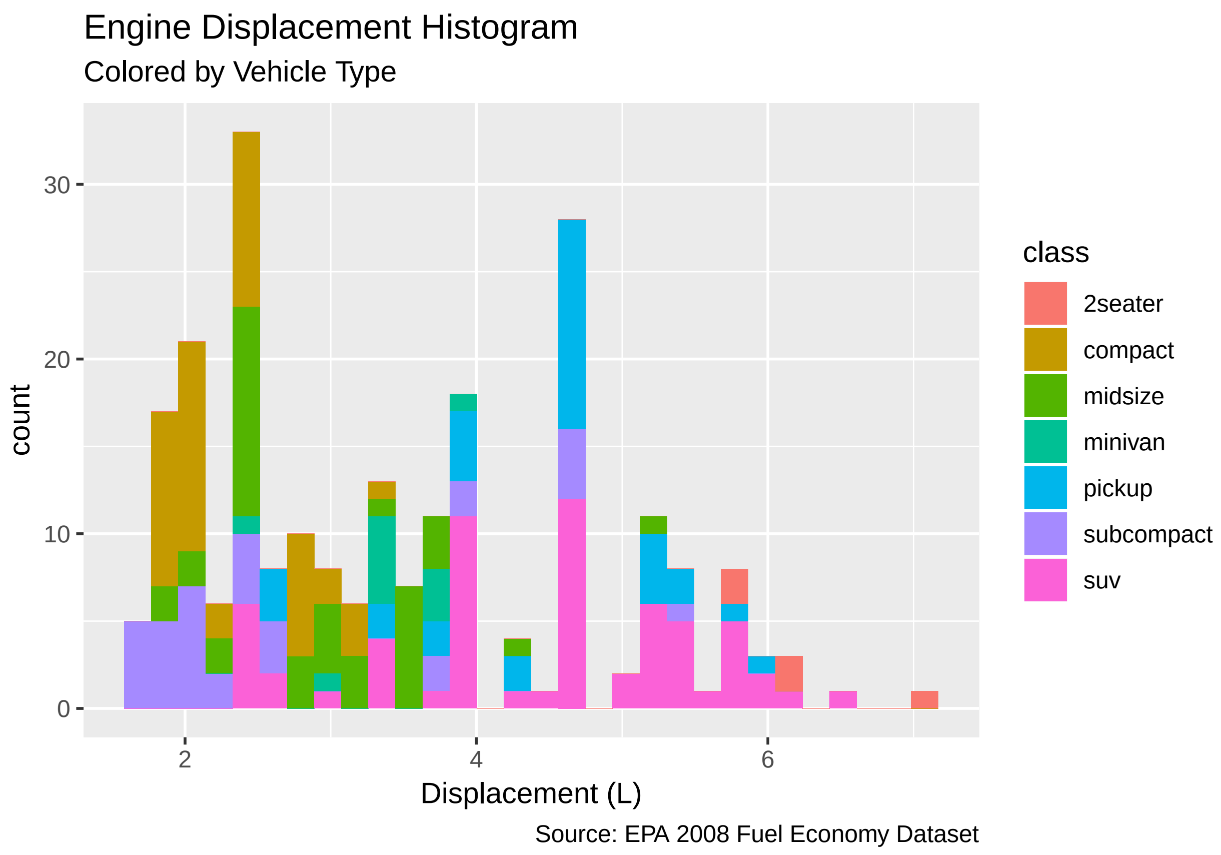
```r
ggplot(mpg) +
  aes(displ) +
  geom_density(fill = "blue", alpha = 0.2, col = "white") +
  labs(title = "Engine Displacement Density" , subtitle = "", x = "Displacement (L)", caption = "Source
```



Visualize a histogram the `displ` variable, but then fill the color of the bar by the `class` of the car. You will have to pass `class` in as the `fill` in the aesthetic of the histogram.

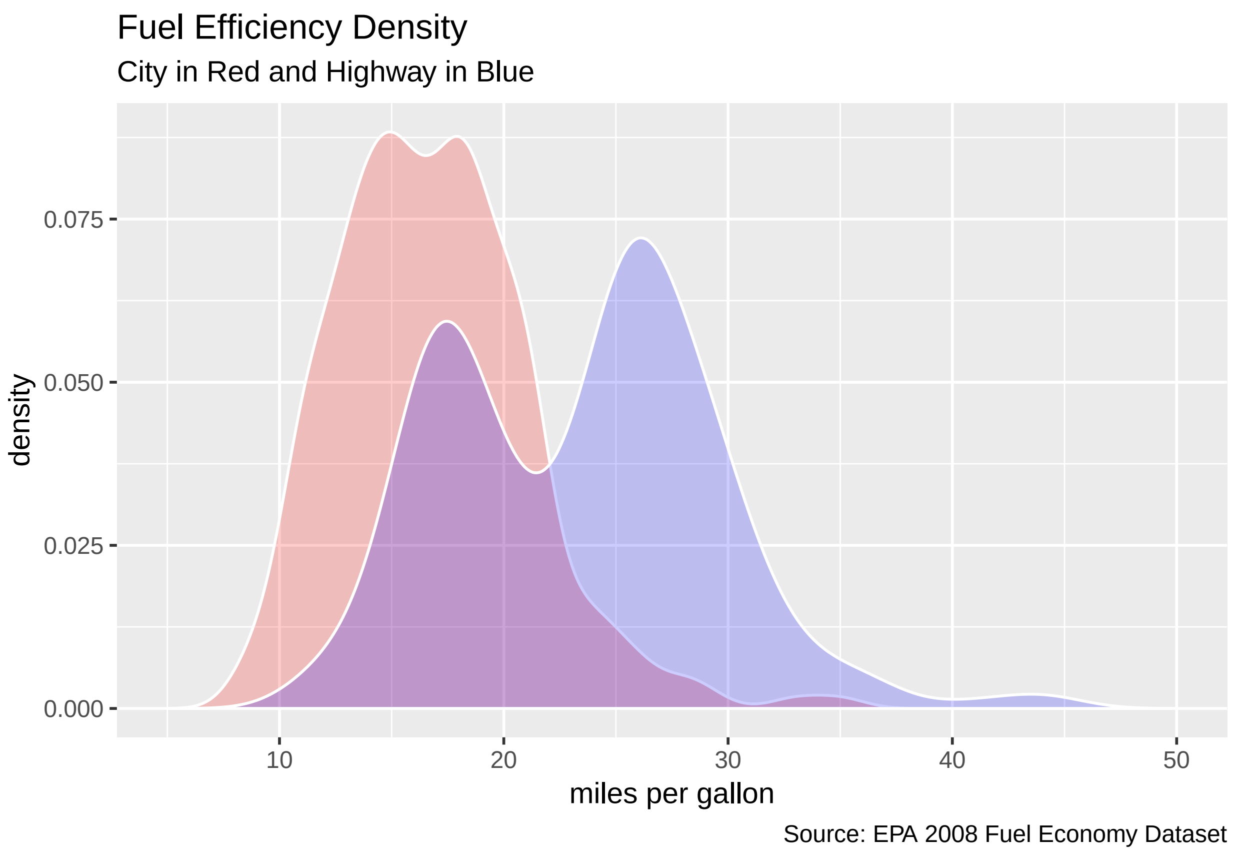
```
ggplot(mpg) +
  aes(displ) +
  geom_histogram(aes(fill = class)) +
  labs(title = "Engine Displacement Histogram" , subtitle = "Colored by Vehicle Type", x = "Displacemen
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



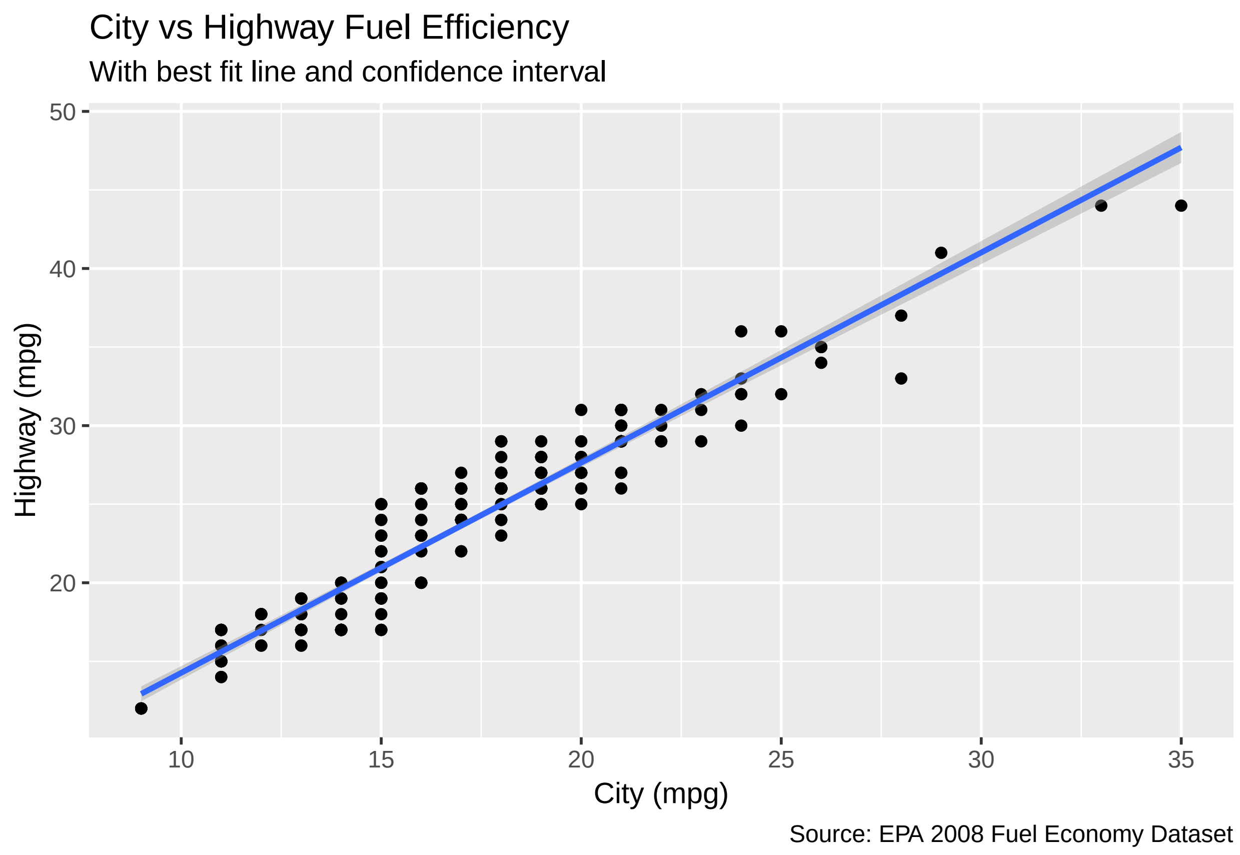
Visualize overlapping densities of `cty` (city miles per gallon) and `hwy` (highway miles per gallon) using two colors with an alpha blend.

```
ggplot(mpg) +
  geom_density(aes(cty), fill = "red", col = "white", alpha = 0.2) +
  geom_density(aes(hwy), fill = "blue", col = "white", alpha = 0.2) +
  xlim(5, 50) +
  labs(title = "Fuel Efficiency Density" , subtitle = "City in Red and Highway in Blue", x = "miles per
```



Plot `cty` (city miles per gallon) vs `hwy` (highway miles per gallon) and draw a best fit line with a confidence region of that line.

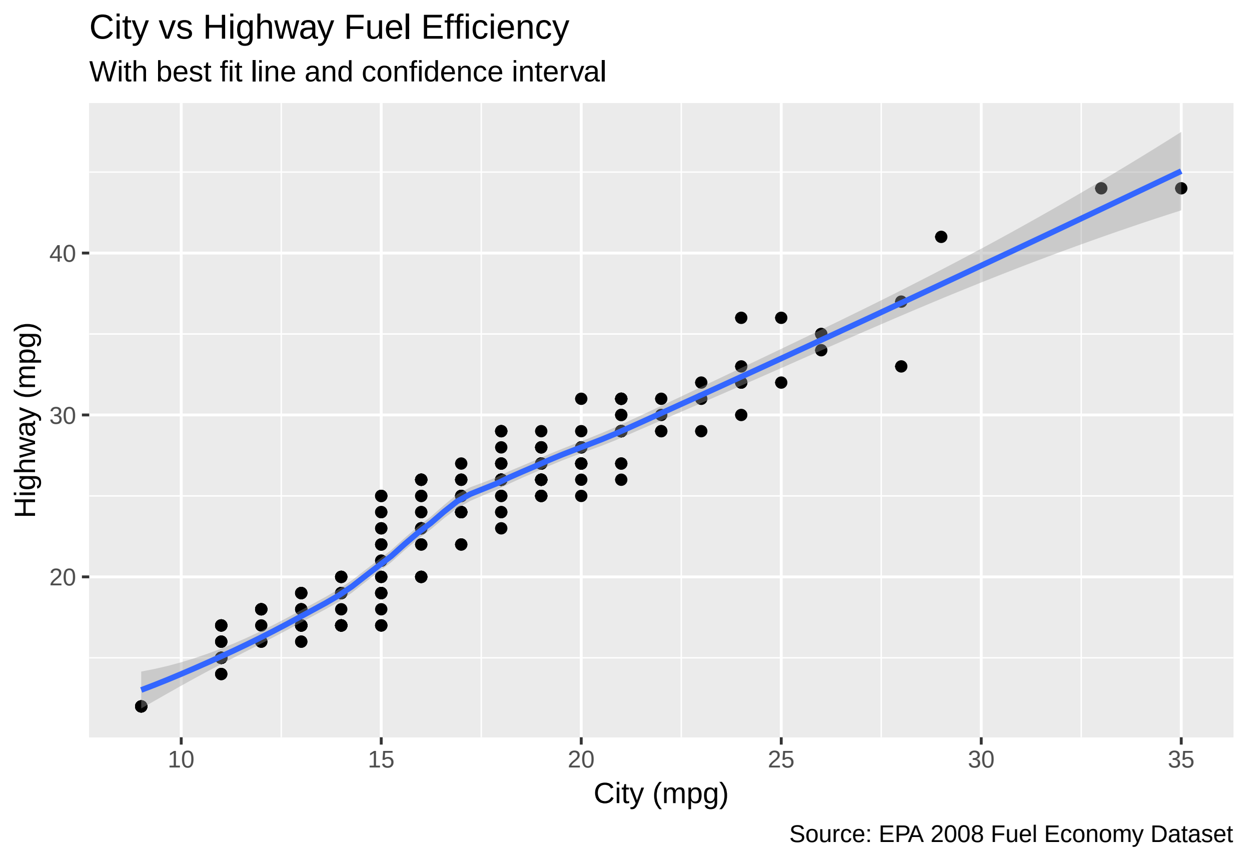
```
ggplot(mpg, aes(x = cty, y = hwy)) +
  geom_point() +
  geom_smooth(method = "lm") +
  labs(title = "City vs Highway Fuel Efficiency", subtitle = "With best fit line and confidence interval
```



Plot `cty` (city miles per gallon) vs `hwy` (highway miles per gallon) and draw a best fit non-parametric functional relationship with a confidence region of that relationship.

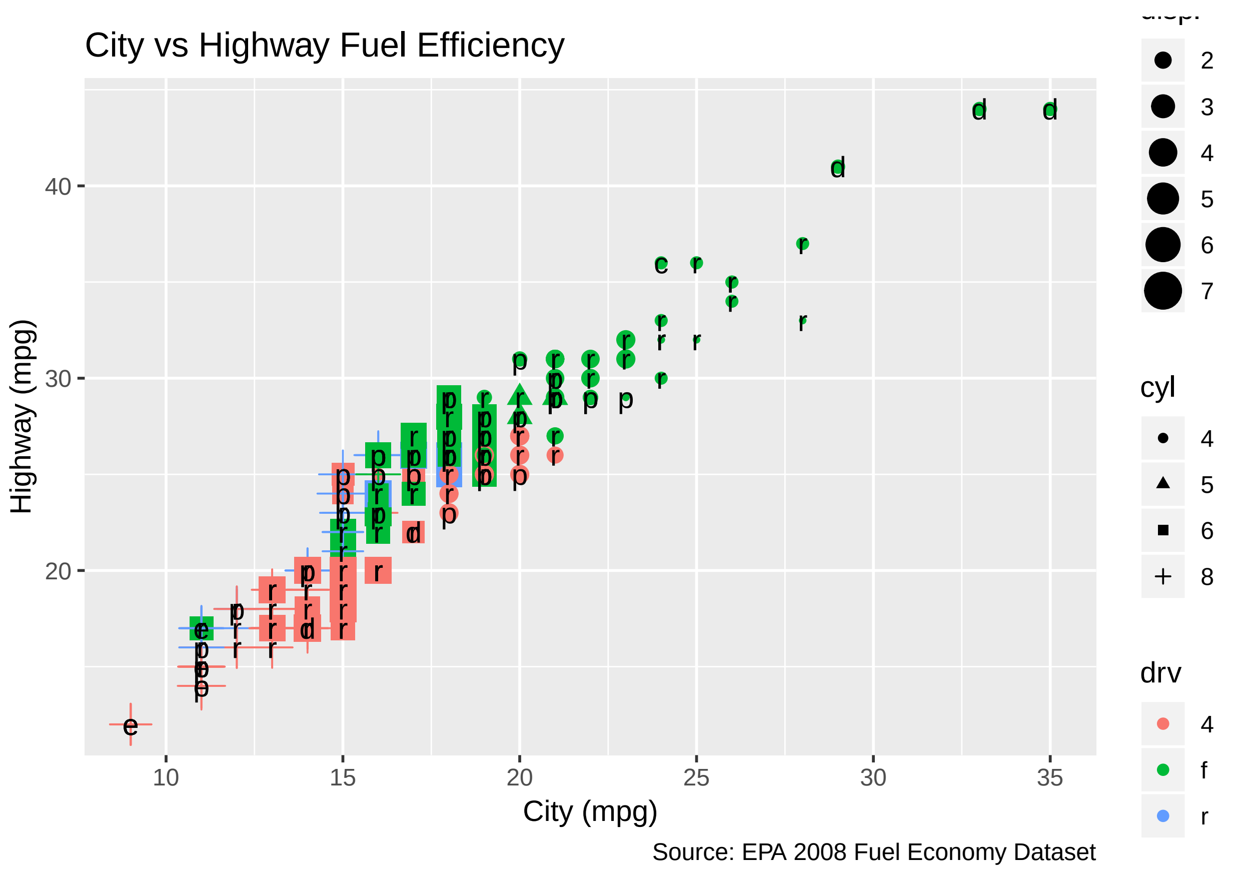
```
ggplot(mpg, aes(x = cty, y = hwy)) +
  geom_point() +
  geom_smooth() +
  labs(title = "City vs Highway Fuel Efficiency", subtitle = "With best fit line and confidence interva
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



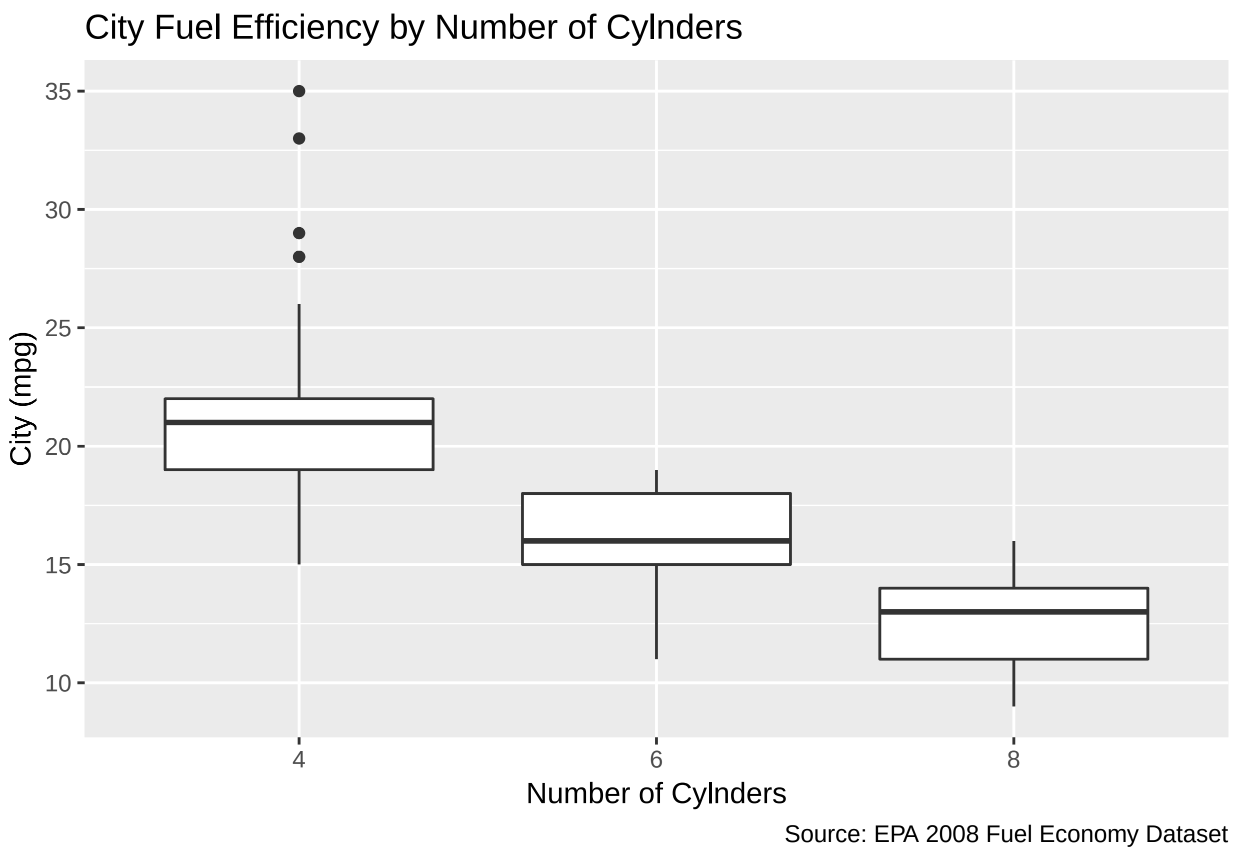
Plot `cty` (city miles per gallon) vs `hwy` (highway miles per gallon) and then try to visualize *as many other variables* as you can visualize effectively on the same plot. Try text, color, size, shape, etc.

```
ggplot(mpg, aes(x = cty, y = hwy)) +
  geom_point(aes(col = drv, shape = cyl, size = displ)) +
  geom_text(aes(label = fl)) +
  labs(title = "City vs Highway Fuel Efficiency", x = "City (mpg)", y = "Highway (mpg)", caption = "Sou
```



Convert `cyl` to an ordinal factor. Then use the package `dplyr` to retain only cars with 4, 6, 8 cylinders in the dataset. Then make a canonical illustration of `cty` by `cyl`.

```
mpg$cyl = factor(mpg$cyl, ordered = TRUE)
pacman::p_load(dplyr)
mpg = mpg %>%
  filter(cyl %in% c(4, 6, 8))
ggplot(mpg, aes(x = cyl, y = cty)) +
  geom_boxplot() +
  labs(title = "City Fuel Efficiency by Number of Cylnders", x = "Number of Cylnders", y = "City (mpg)"
```

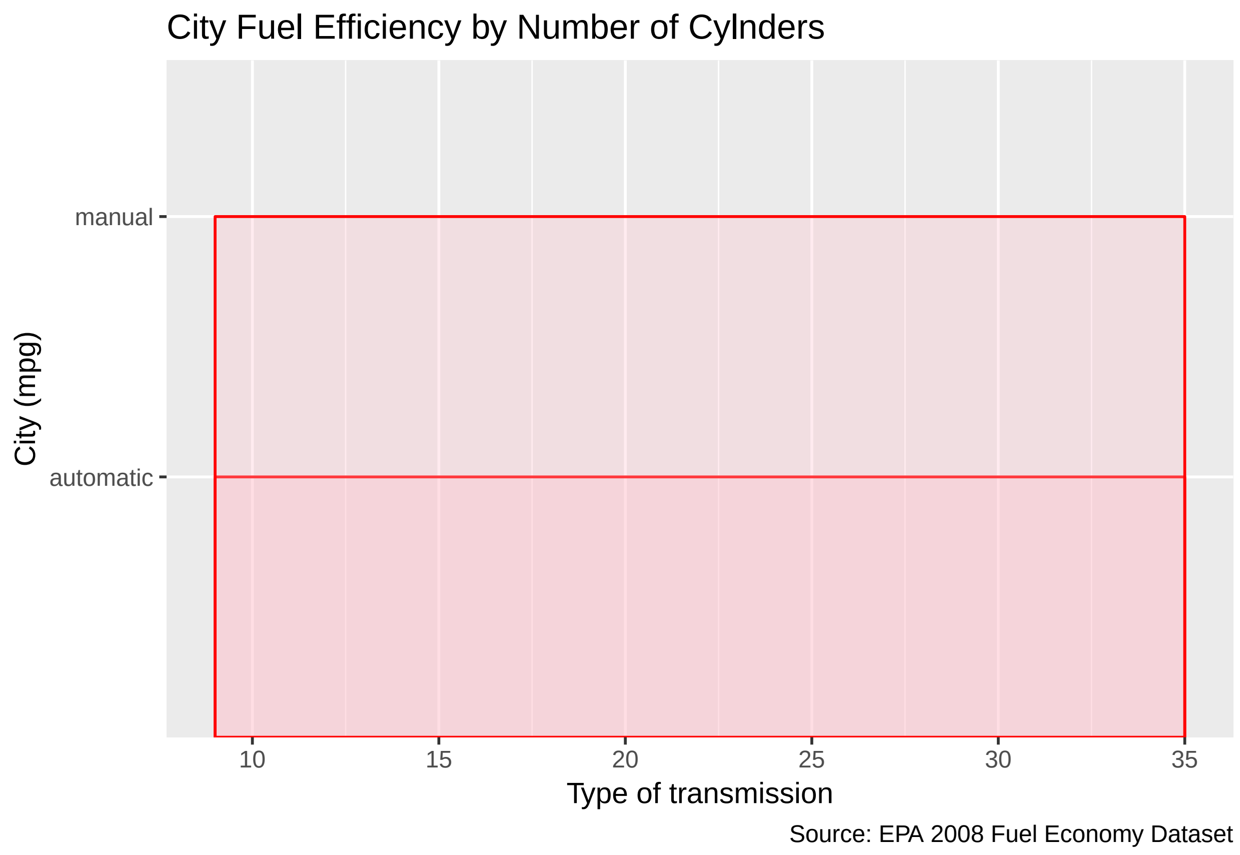


Load the `stringr` library. Use the `str_detect` function in this libary to rewrite the `trans` variable in the data frame to be just “manual” or “automatic”.

```
pacman::p_load(stringr)
mpg$trans = ifelse(str_detect(mpg$trans, "^a"), 'automatic', 'manual')
```

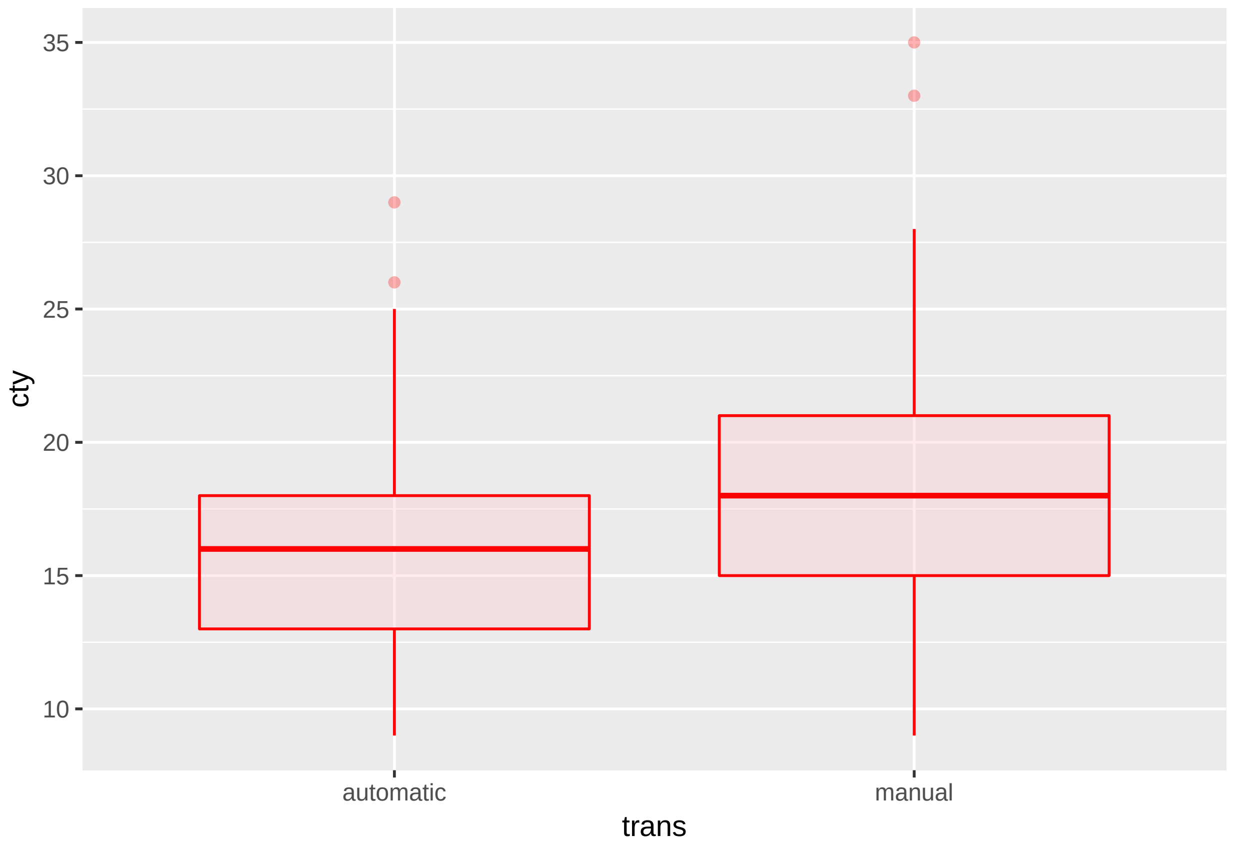
Now visualize `cty` by `trans` via two overlapping alpha-blended densities.

```
ggplot(mpg,aes(cty, trans)) +
  geom_density(aes(cty), fill = "pink", col = "red", alpha = 0.3) +
  labs(title = "City Fuel Efficiency by Number of Cylnders", x = "Type of transmission",
       y = "City (mpg)", caption = "Source: EPA 2008 Fuel Economy Dataset")
```



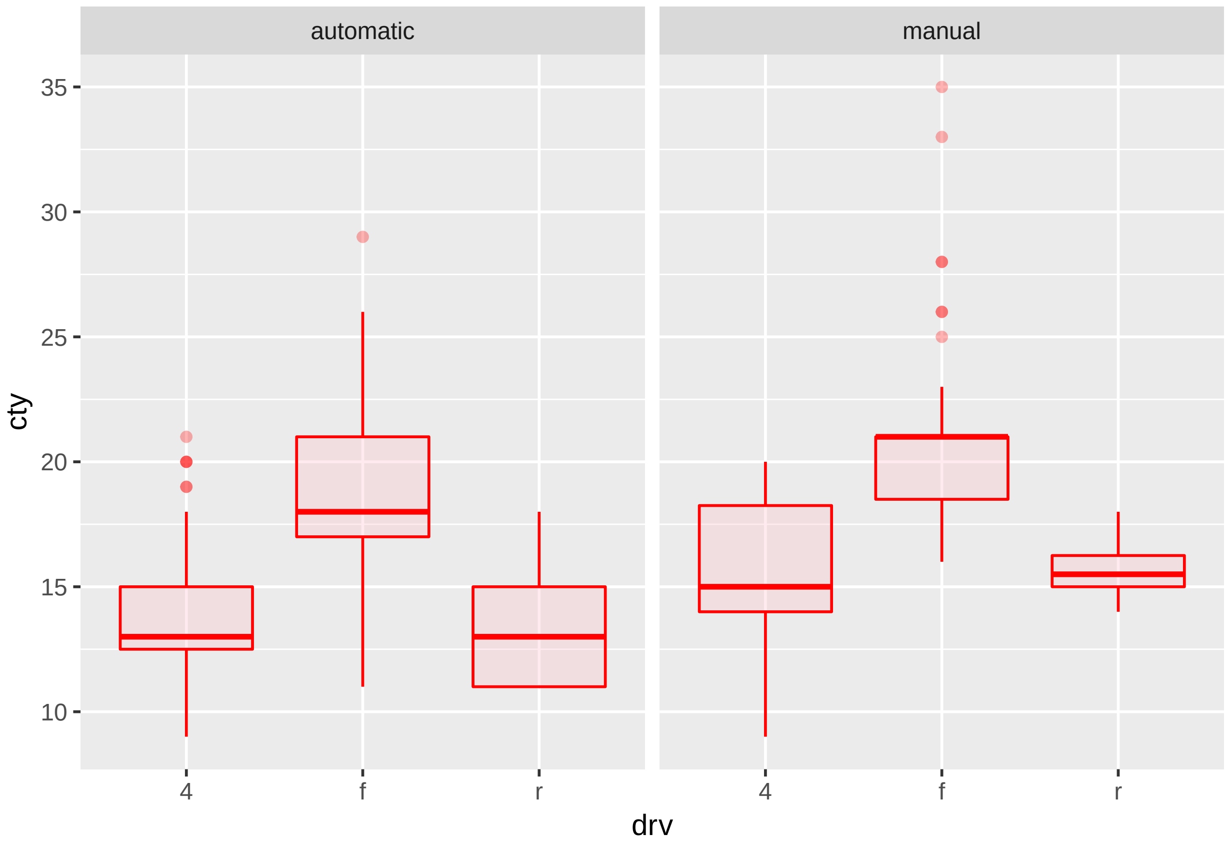
Now visualize `cty` by `trans` via a box and whisker plot.

```r
ggplot(mpg, aes(x = trans, y = cty)) +
  geom_boxplot(col = "red", fill = "pink", alpha = 0.3)
```



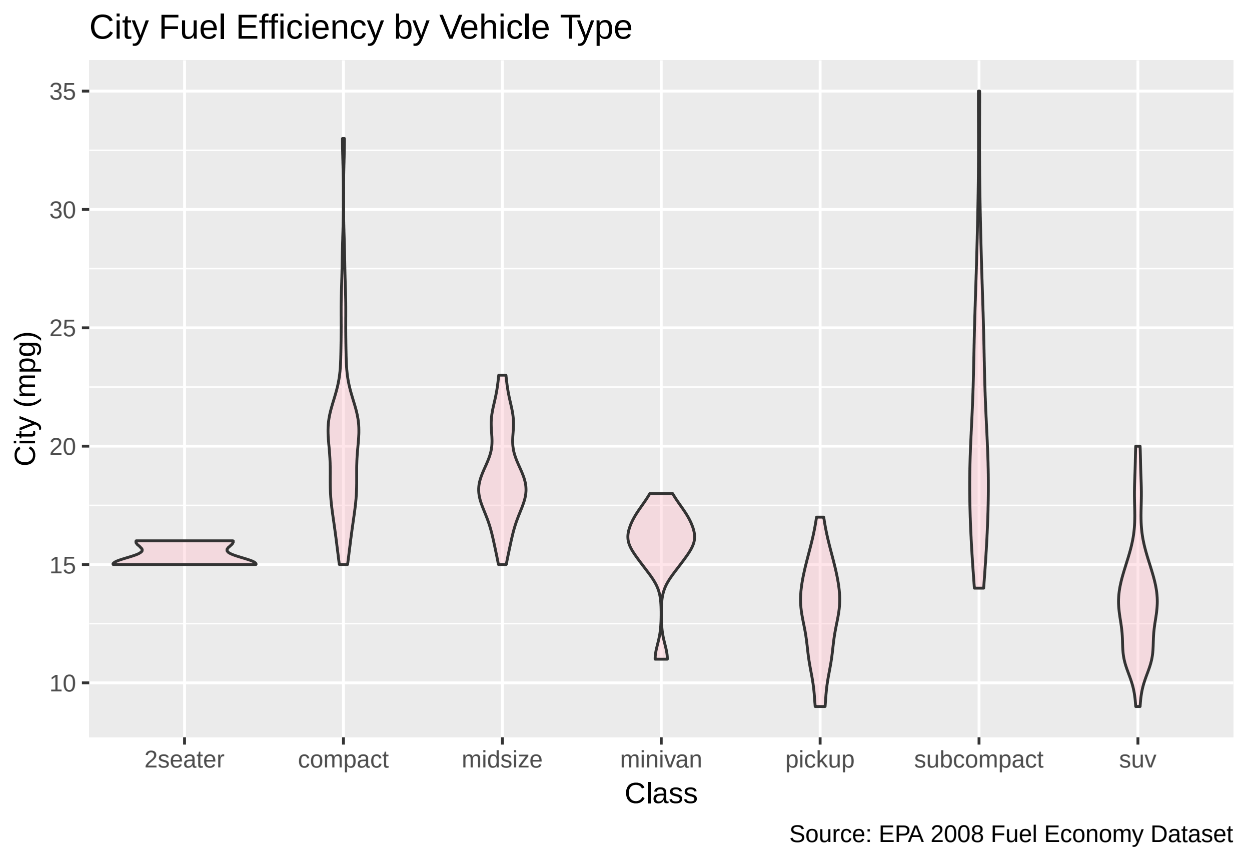
Now visualize `cty` by `drv` by `trans` via two box and whisker plots horizontally laid out.

```
ggplot(mpg, aes(x = drv, y = cty)) +
  geom_boxplot(col = "red", fill = "pink", alpha = 0.3) +
  facet_grid(. ~ trans)
```



Now visualize `cty` by `class` via a violin plot. Look at the ggplot cheatsheet!

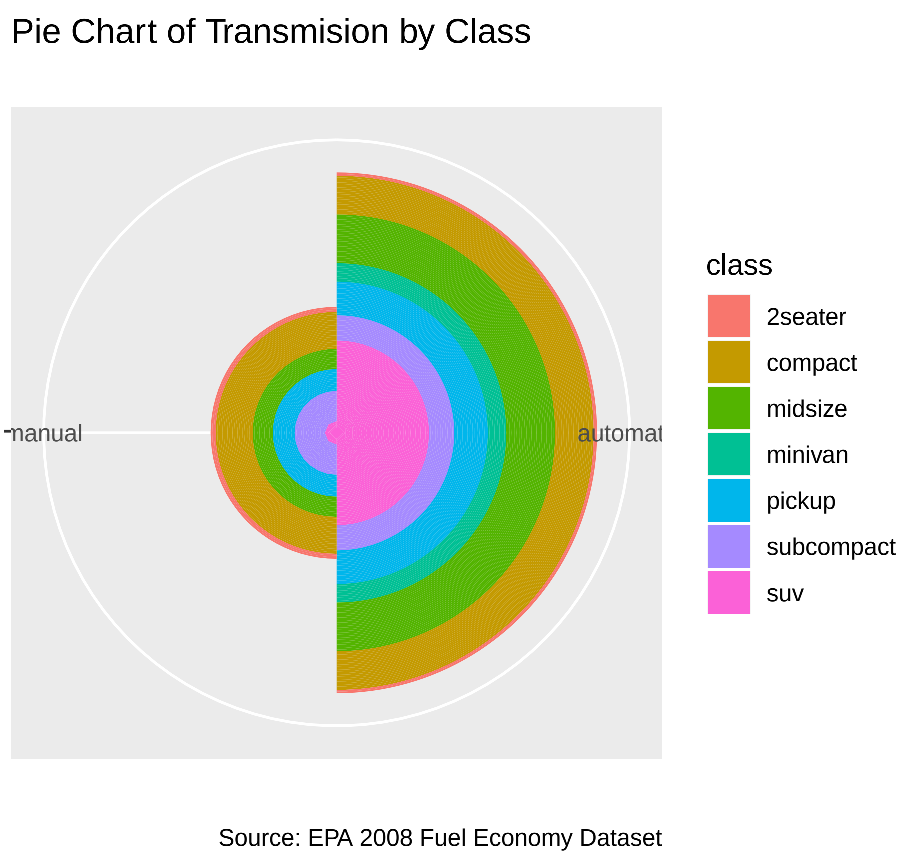
```
ggplot(mpg, aes(x = class, y = cty)) +
  geom_violin(fill = "pink", alpha = 0.4) +
  labs(title = "City Fuel Efficiency by Vehicle Type", x = "Class", y = "City (mpg)", caption = "Source
```



Make a pie chart of `class`.

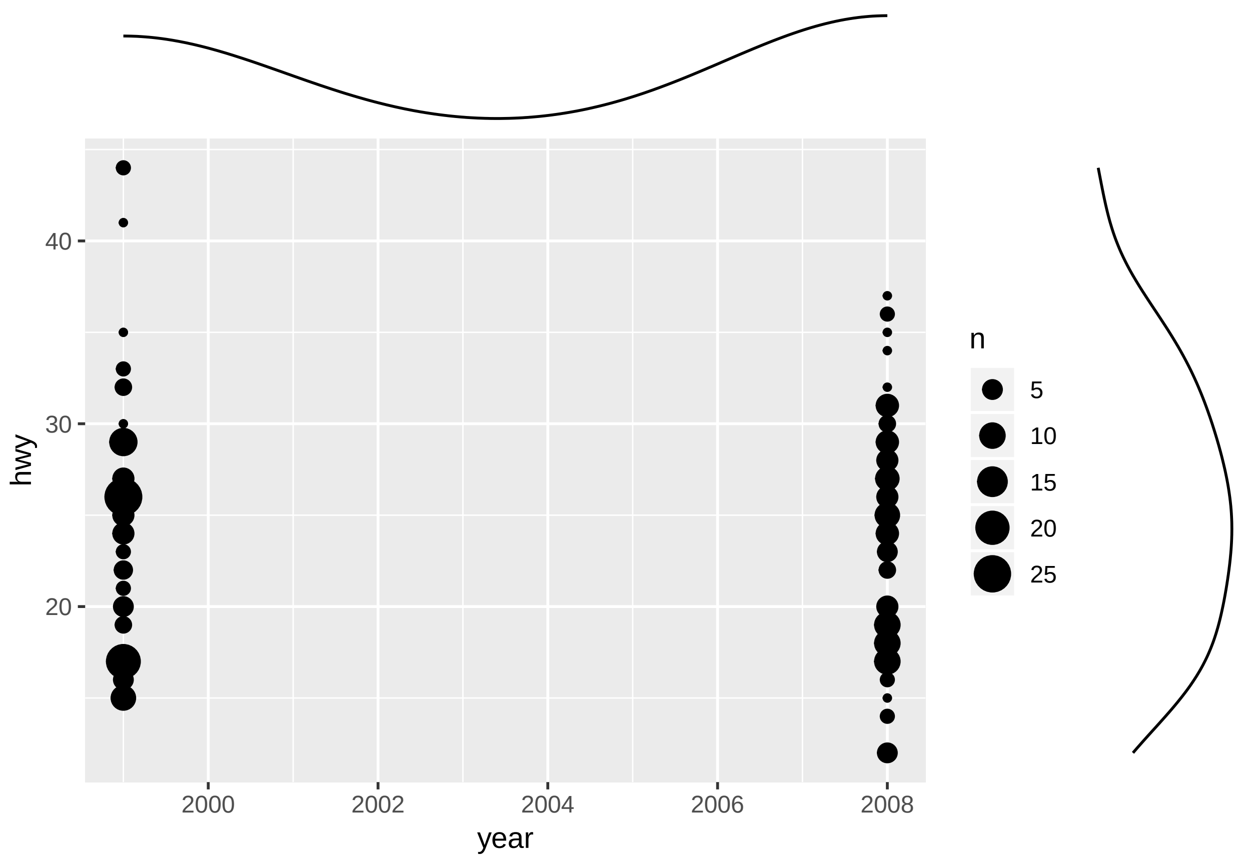
Visualize `trans` vs `class`. Look at the ggplot cheatsheet!

```
ggplot(mpg, aes(x = trans , y = "", fill = class)) +
  geom_bar(width = 1, stat = "identity") +
  coord_polar("x", start = 0) +
    labs(title = "Pie Chart of Transmision by Class" , subtitle = "", x = " ", y = " ", caption = "Sour
```



Using the package `ggExtra`'s `ggMarginal` function, look at the `hwy` by `year` and plot the marginal density on both the x and y axes.

```r
pacman::p_load(ggExtra)
g = ggplot(mpg, aes(year, hwy)) +
  geom_count()
ggMarginal(g, type = "density", fill = "transparent")
```

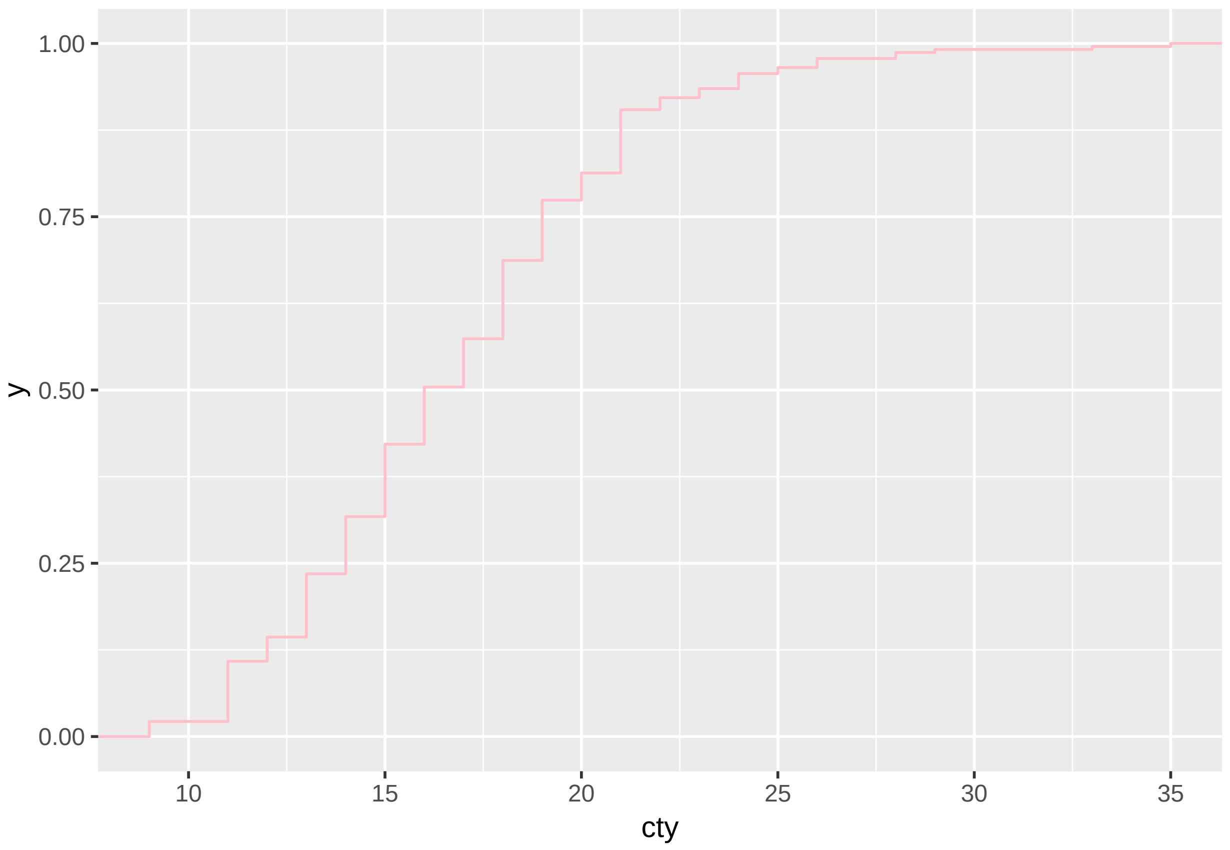


Using the package `ggcorrplot`'s `ggcorrplot` function, look at the correlations for all variables in this dataset that are legal in a corrrelogram. Use dplyr to `select_if` the variable is appropriate.

```r
pacman::p_load(ggcorrplot)
library(ggcorrplot)
```

Use the `stat_ecdf` function to plot the estimated cumulative distribution of 'cty'.

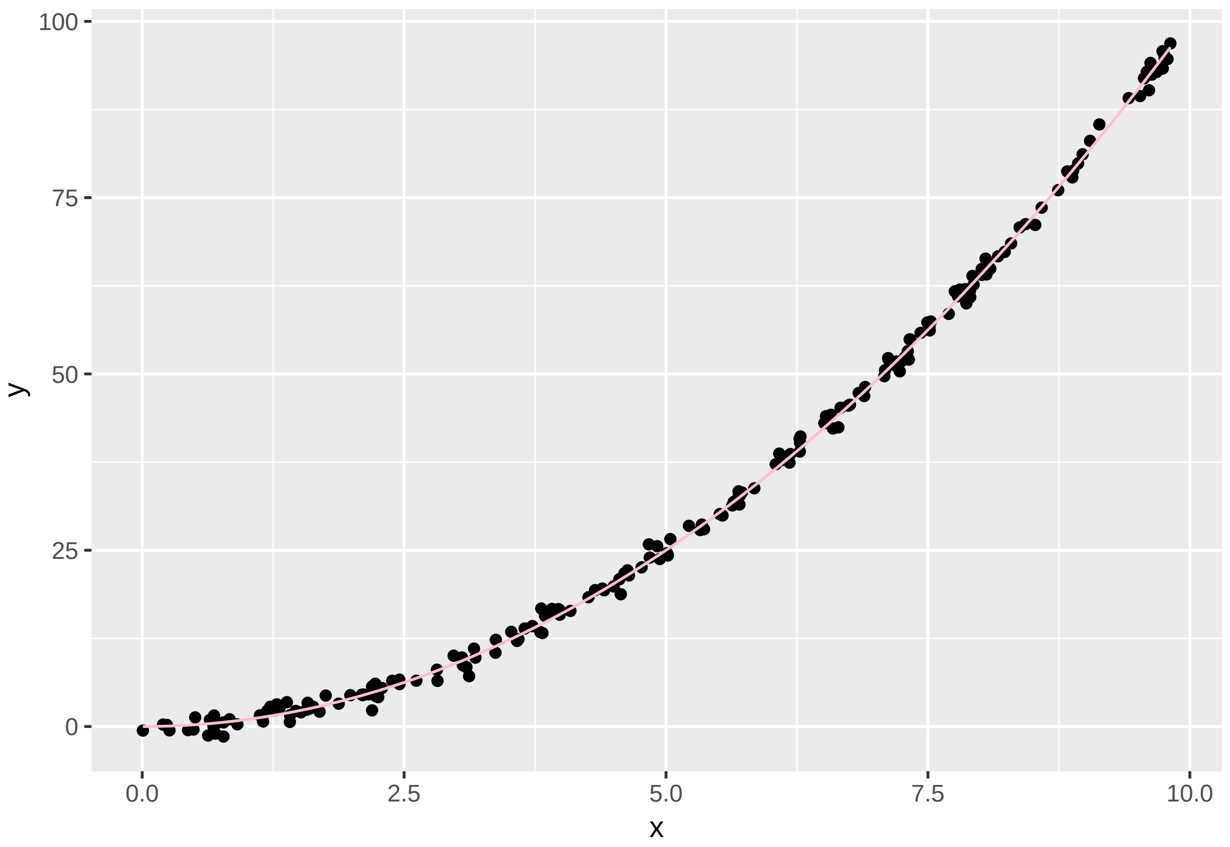
```r
ggplot(mpg, aes(cty)) +
  stat_ecdf(geom = "step", col= "pink")
```



Create a data generating process where x is uniform between 0 and 10 and y is x^2 plus $N(0, 1)$ noise. Plot $n = 200$ points and then plot the quadratic relationship $y = x^2$ using the function `stat_function`.

```
n = 200
x = runif(n, min = 0, max = 10)
noise = rnorm(n , 0, 1)
y = x^2 + noise
df = data.frame(x = x, y = y)

ggplot(df, aes(x, y)) +
  geom_point() +
  stat_function(fun = function(x){y=x^2}, col= "pink")
```



We now move to Rcpp. Load the library.

```
library(Rcpp)
```

Write an R function `is_odd` and a C++ function `is_odd_cpp` that evaluates if a number is odd and returns true if so.

```
is_odd = function(n){
  n %% 2 == 1
}

cppFunction('
  bool is_odd_cpp (int n){
    return n % 2 == 1;
  }
')
```

Using 'system.time', run both functions 1,000,000 times on the numbers 1, 2, . . . , 1000000. Who is faster and by how much?

R function is faster and by 3.5

```
system.time(
  for(i in 1 : 1e6){
    is_odd(i)
  }
)
```

```
##    user  system elapsed
##   0.723   0.009   0.735
```

```r
system.time(
  for(i in 1 : 1e6){
    is_odd_cpp(i)
  }
)
```

```
##    user  system elapsed 
##   2.532   0.700   3.249
```

Write an R function `fun` and a C++ function `fun_cpp` that takes a natural number returns n if n is 0 or 1 otherwise the result of the function on $n - 1$ and $n - 2$. This is the function that returns the nth Fibonacci number.

```r
fun = function(n){
  if (n == 0 | n == 1) n
  fun (n - 2) + fun (n - 1)
}

cppFunction('
  int fun_cpp(int n){
    if(n == 0 || n == 1) return n;
    return fun_cpp( n - 2) + fun_cpp( n - 1 );
  }
')
```

Using 'system.time', run both functions on the numbers 1, 2, . . . , 100. Who is faster and by how much?

my computer would crash when R is run for all i's, but code works totally fine when I run it in cpp. Therefore I can conclude that cpp is a lot faster than R. (can't knit because of this R code for some reason)

system.time(for(i in 1:100){ fun(1) }) system.time(for(i in 1:100){ fun_cpp(1) })

Write an R function `logs` and a C++ function `logs_cpp` that takes a natural number n and returns an array of $ln(1), ln(2), ..., ln(n)$.

```r
log = function(n){
  array(log (1 : n), n)
}

cppFunction('
  NumericVector log_cpp(int n){
    NumericVector v(n);
    for(int i=1; i<=n; i++){
      v[i] = log(i);
    }
    return v;
  }
')
```

Using 'system.time', run both functions on the numbers 1, 2, . . . , 1000000. Who is faster and by how much?

(can't knit because of this R code for some reason)

system.time(log(1)) system.time(log_cpp(1e6))

Write an R function `max_distances` and a C++ function `max_distances_cpp` that takes an $n \times p$ matrix X and returns an $n \times n$ matrix called D of NA's where the upper triangular portion above the diagonal is the max distances between the elements of the i, jth rows of X.

```r
max_distances = function(X){
  n = nrow(X)
  p = ncol(X)
  D = matrix(NA,nrow = n, ncol = n)
  for(i_1 in 1:(n - 1)){
    for(i_2 in (i_1 + 1):n){
      sqd_diff = 0
      for(j in 1:p){
        sqd_diff = sqd_diff + (X[i_1, j] - X[i_2, j])^2
      }
      D[i_1, i_2] = sqrt(sqd_diff)
    }
  }
  D
}
cppFunction('
NumericMatrix max_distances_cpp(NumericMatrix X) {
int n = X.nrow();
int p = X.ncol();
NumericMatrix D(n, n);
std::fill(D.begin(), D.end(), NA_REAL);
for (int i_1 = 0; i_1 < (n - 1); i_1++){
  for (int i_2 = i_1 + 1; i_2 < n; i_2++){
    int sqd_diff = 0;
    for (int j = 0; j < p; j++){
      sqd_diff += pow(X(i_1, j) - X(i_2, j), 2); //by default the cmath library in std is loaded
    }
    D(i_1, i_2) = sqrt(sqd_diff); //by default the cmath library in std is loaded
  }
}
return D;
}'
)
```

Create a matrix X of $n = 1000$ and $p = 20$ filled with iid $N(0, 1)$ realizations. Using 'system.time', calculate D using both functions. Who is faster and by how much?

cpp is faster and by 2.5 seconds

```r
n = 1000
p = 20
X = matrix(rnorm(n * p), nrow = n, ncol = p)
system.time(
  max_distances(X)
)
```

```
##    user  system elapsed
##   2.345   0.016   2.368
```

```r
system.time(
  max_distances_cpp(X)
)
```

```
##    user  system elapsed
##   0.034   0.001   0.034
```