Lab 8

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```
rm(list=ls())
```

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
```

```
?mpg
```

```
## starting httpd help server ... done
```

```
str(mpg)
```

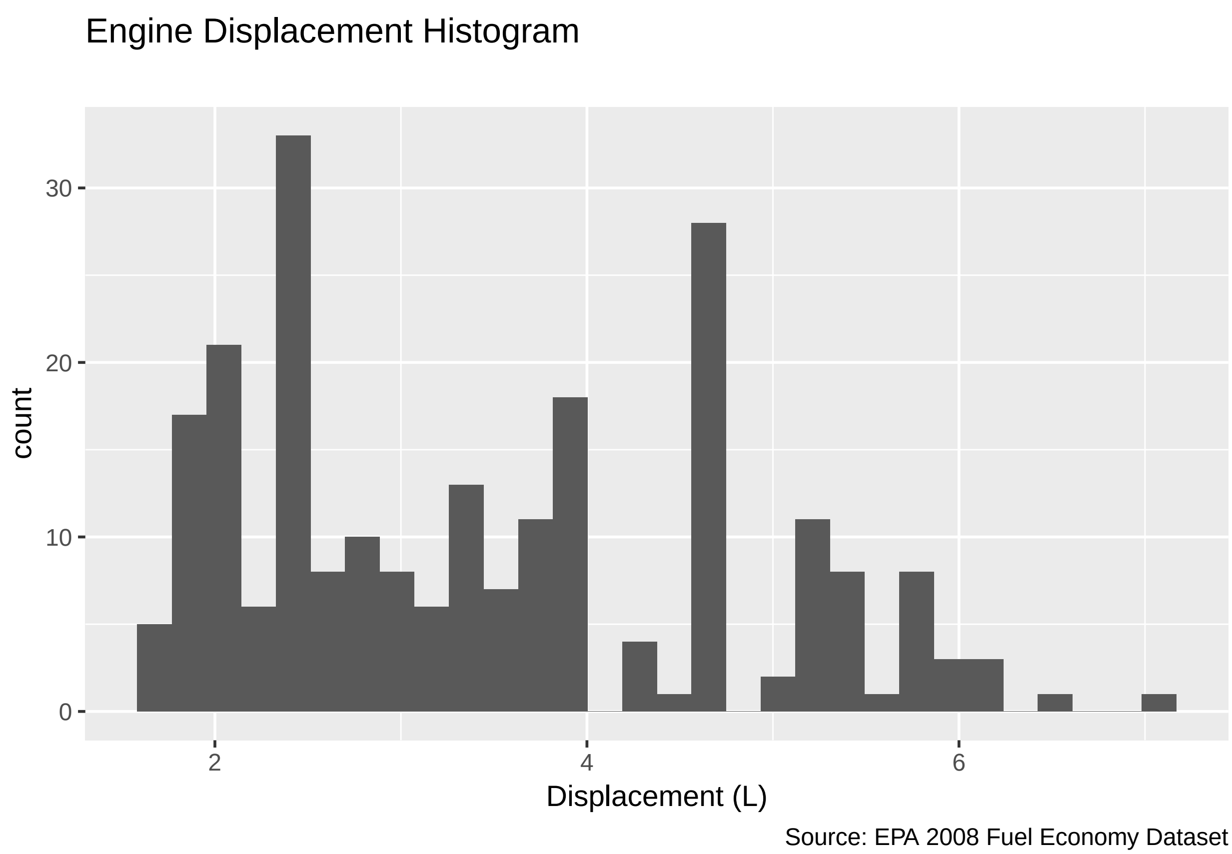
```
## Classes 'tbl_df', 'tbl' and 'data.frame':    234 obs. of  11 variables:
##  $ manufacturer: Factor w/ 15 levels "audi","chevrolet",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ model       : Factor w/ 38 levels "4runner 4wd",..: 2 2 2 2 2 2 2 3 3 3 ...
##  $ displ       : num  1.8 1.8 2 2 2.8 2.8 3.1 1.8 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 ...
```

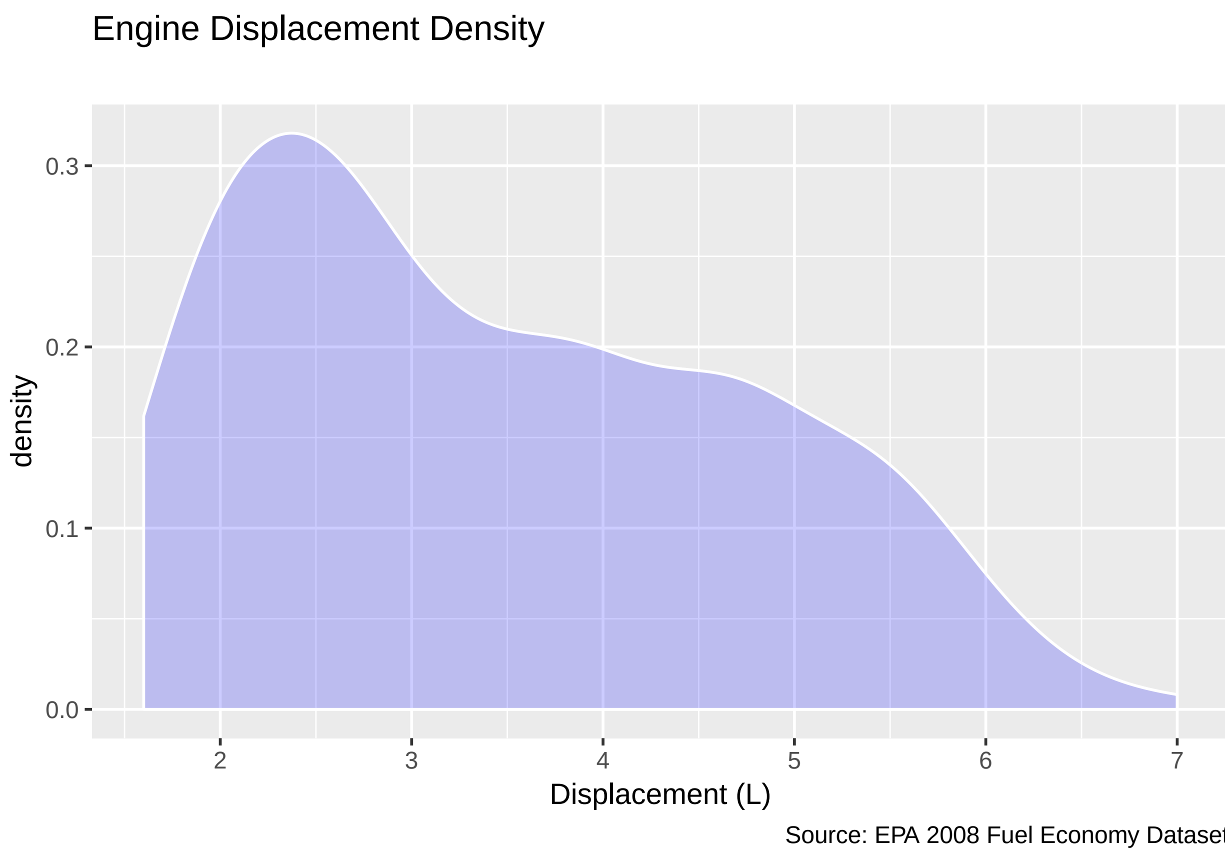
Visualize a histogram then a density estimate of the `displ` variable, the engine displacement. Use `labs` to create a `title`, `subtitle`, `caption` and x-label via `x` and y-label via `y`. Do this for every single illustration in this lab.

```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`.
```



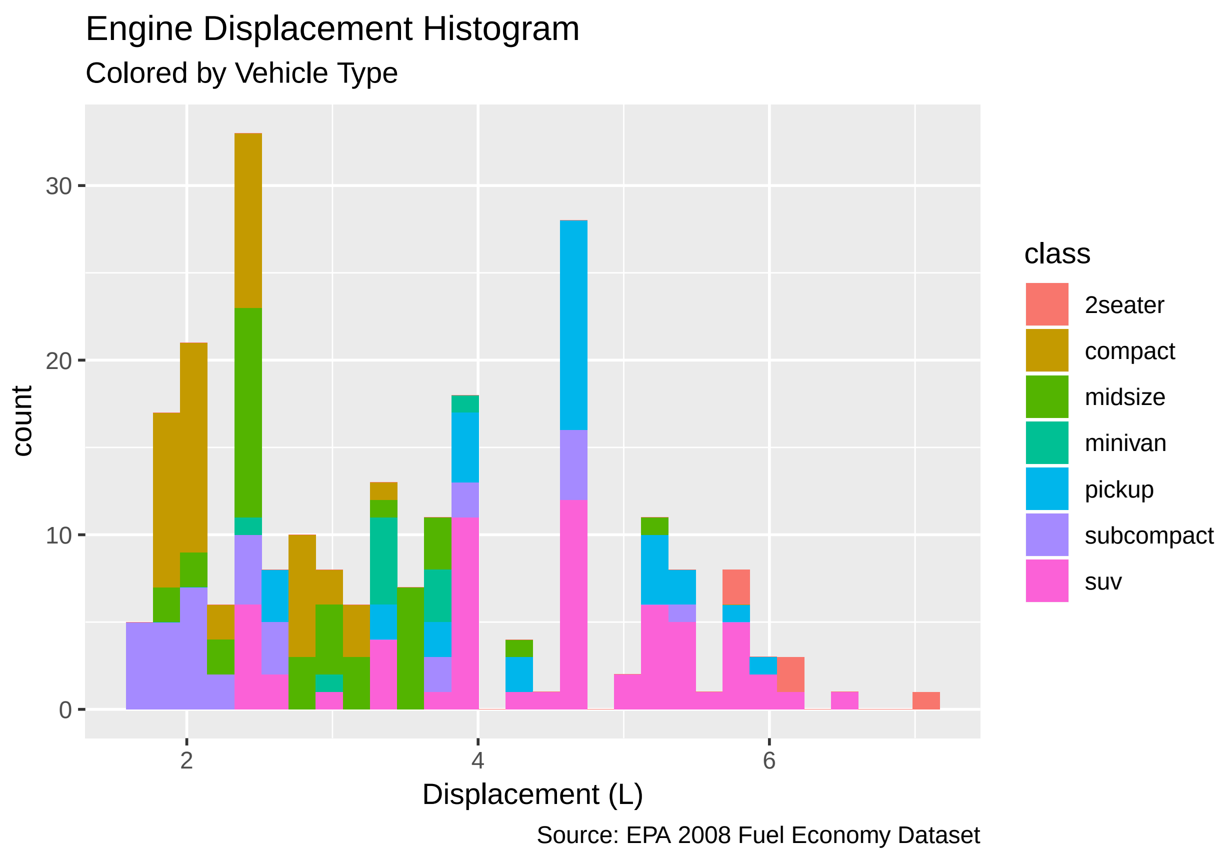

```r
ggplot(mpg) +
  aes(displ) +
  geom_density(fill = "blue", alpha = 0.2, col = "white") +
  labs(title = "Engine Displacement Density" , subtitle = "", x = "Displacement (L)", caption = "Source
```



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.

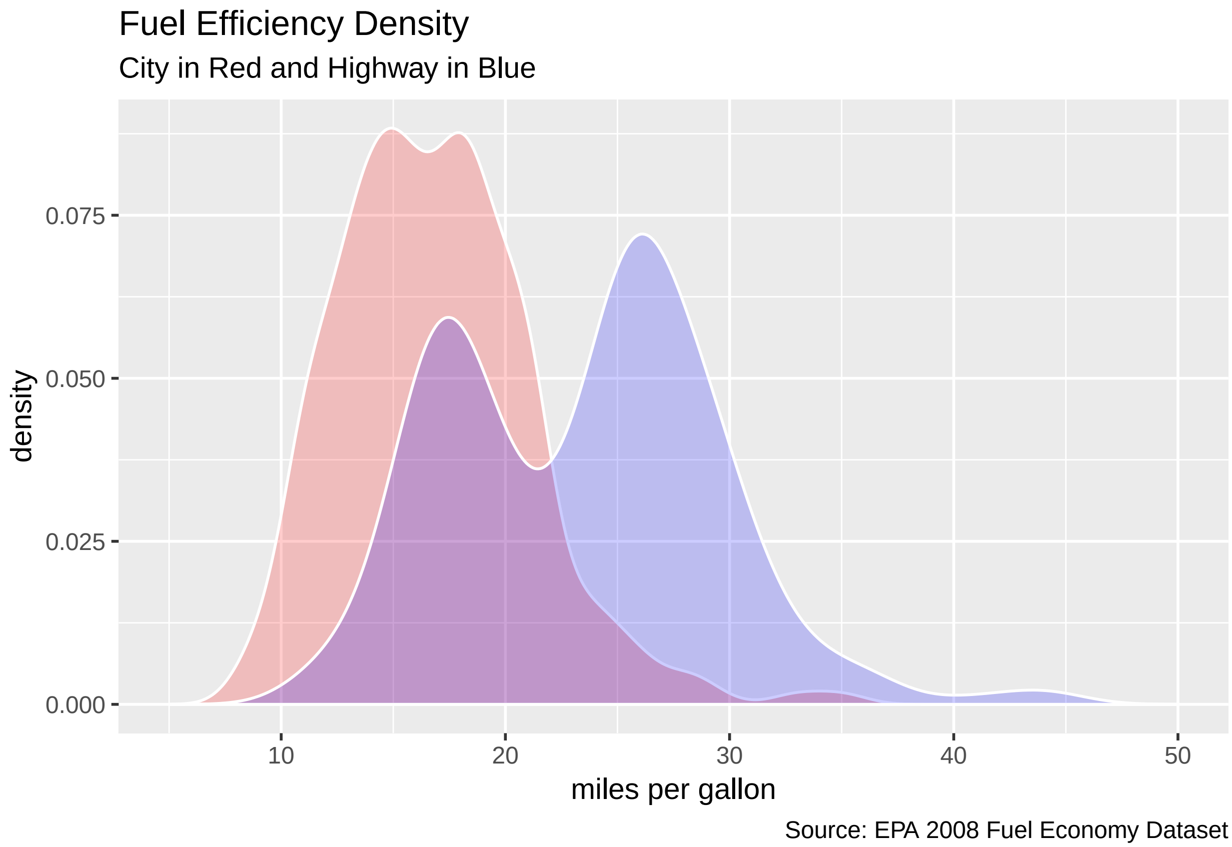
```
ggplot(mpg) +
  aes(displ) +
  geom_histogram(aes(fill = class)) +
  labs(title = "Engine Displacement Histogram" , subtitle = "Colored by Vehicle Type", x = "Displacemen
```

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



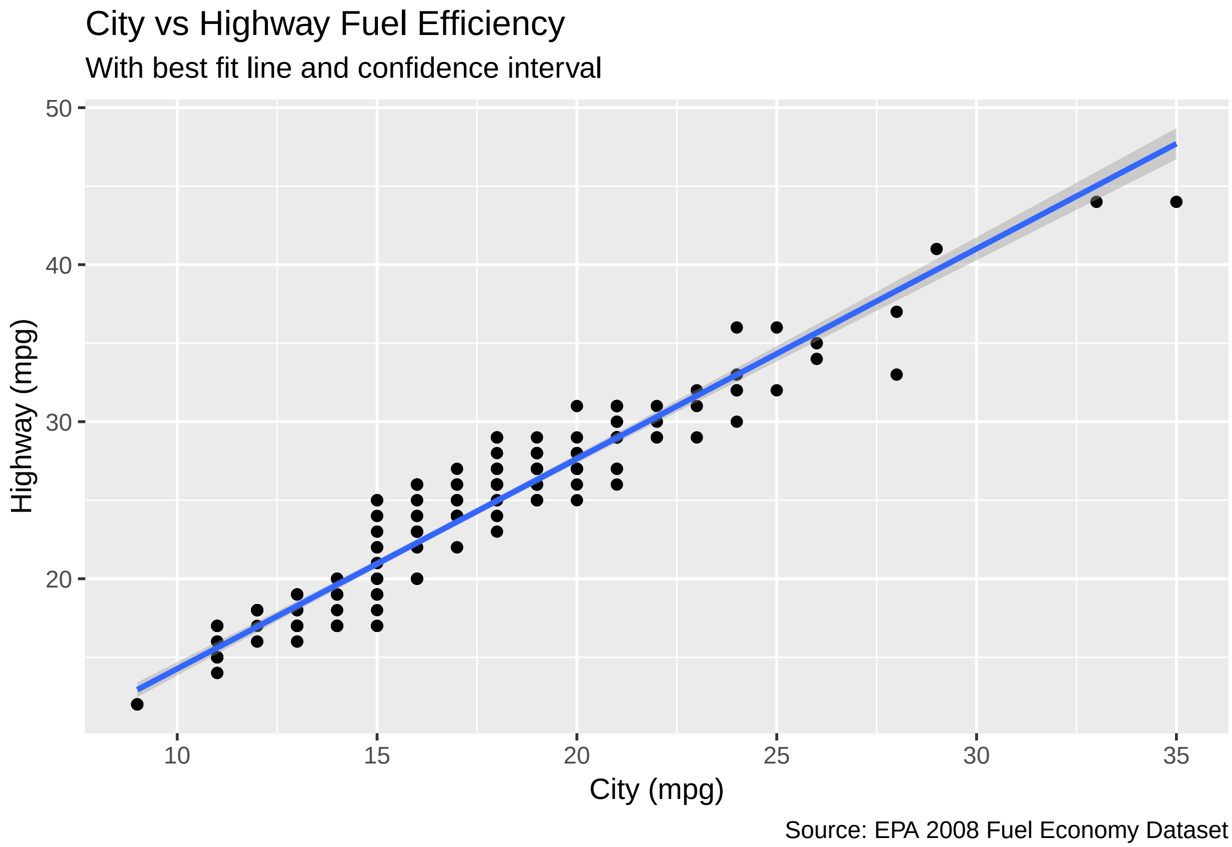
Visualize overlapping densities of `cty` (city miles per gallon) and `hwy` (highway miles per gallon) using two colors with an alpha blend.

```
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.

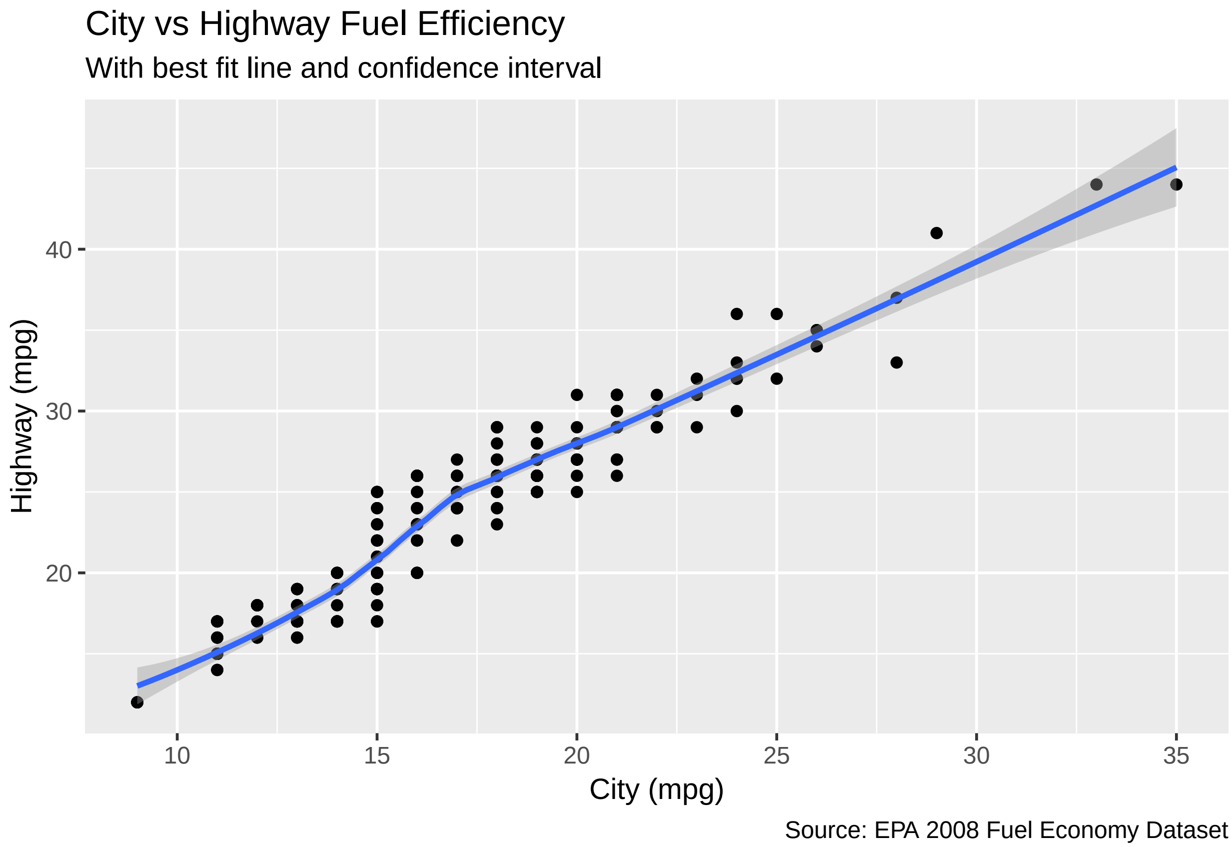
```
ggplot(mpg, aes(x = cty, y = hwy)) +
  geom_point() +
  geom_smooth(method = "lm") +
  labs(title = "City vs Highway Fuel Efficiency", subtitle = "With best fit line and confidence interva
```



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.

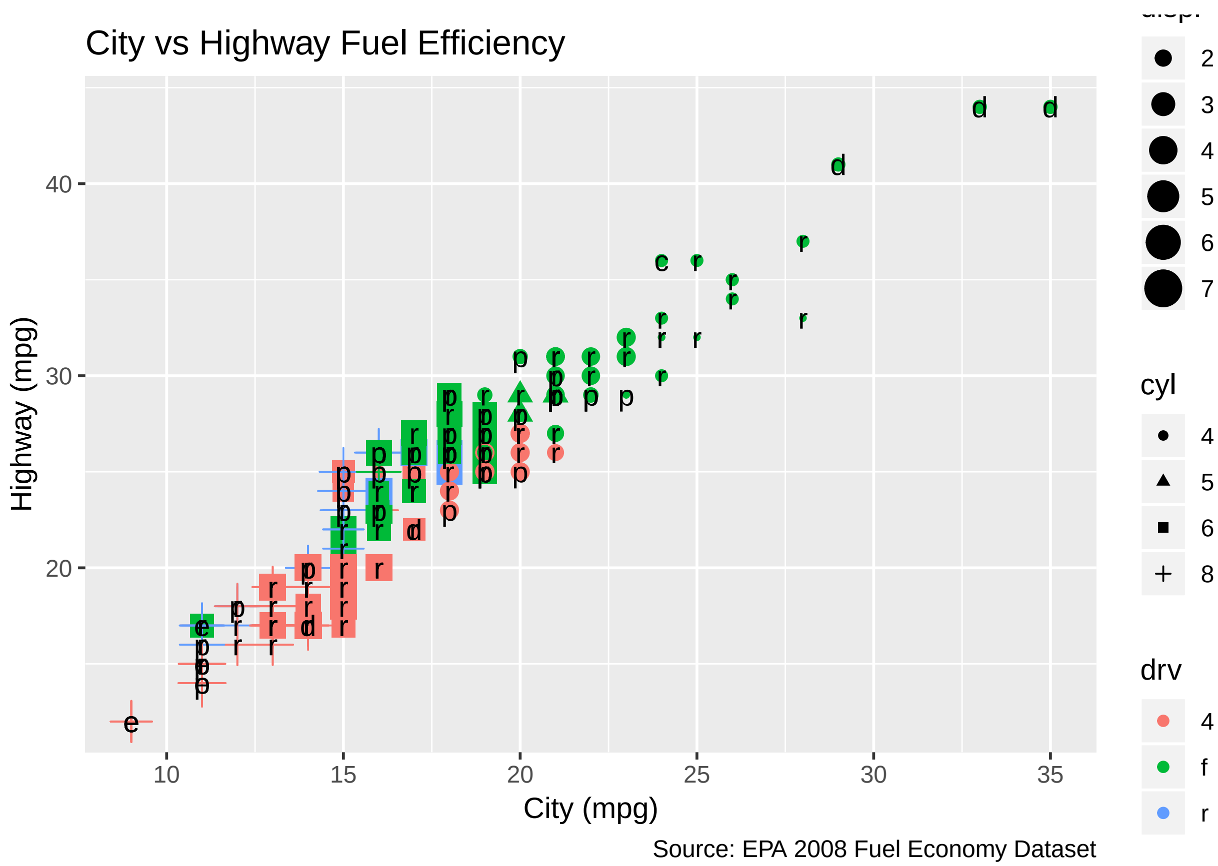
```
ggplot(mpg, aes(x = cty, y = hwy)) +
  geom_point() +
  geom_smooth() +
  labs(title = "City vs Highway Fuel Efficiency", subtitle = "With best fit line and confidence interval
```

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



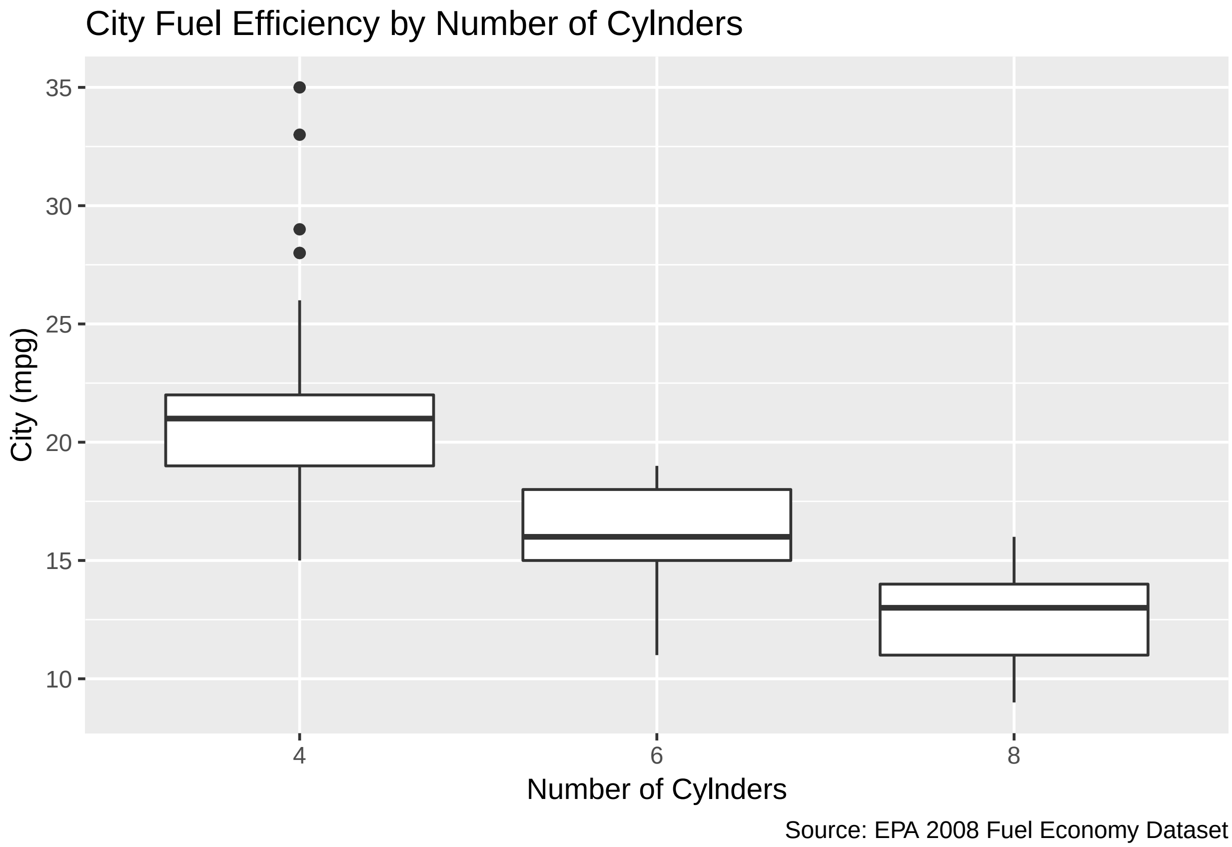
Plot `cty` (city miles per gallon) vs `hwy` (highway miles per gallon) and then try to visualize *as many other variables* as you can visualize effectively on the same plot. Try text, color, size, shape, etc.

```
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)"
```

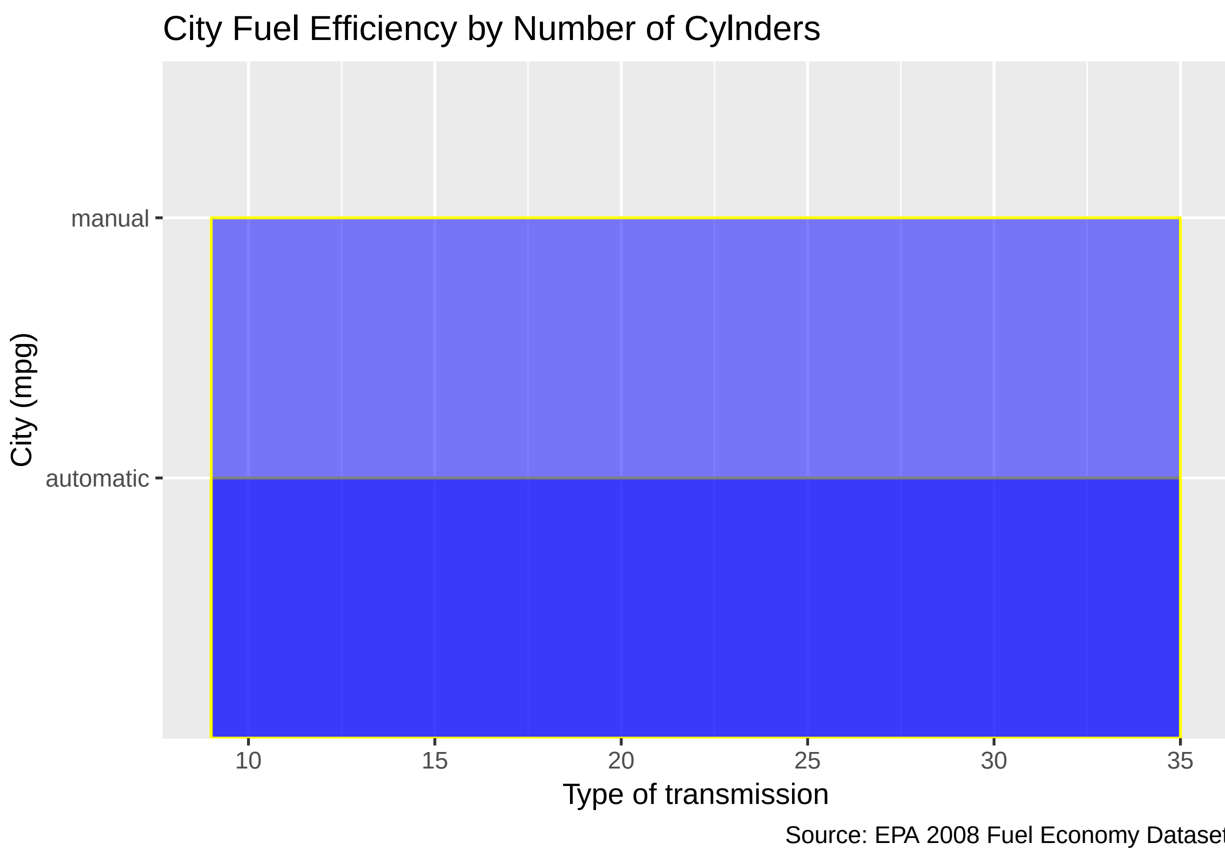


Load the `stringr` library. Use the `str_detect` function in this libary to rewrite the `trans` variable in the data frame to be just "manual" or "automatic".

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

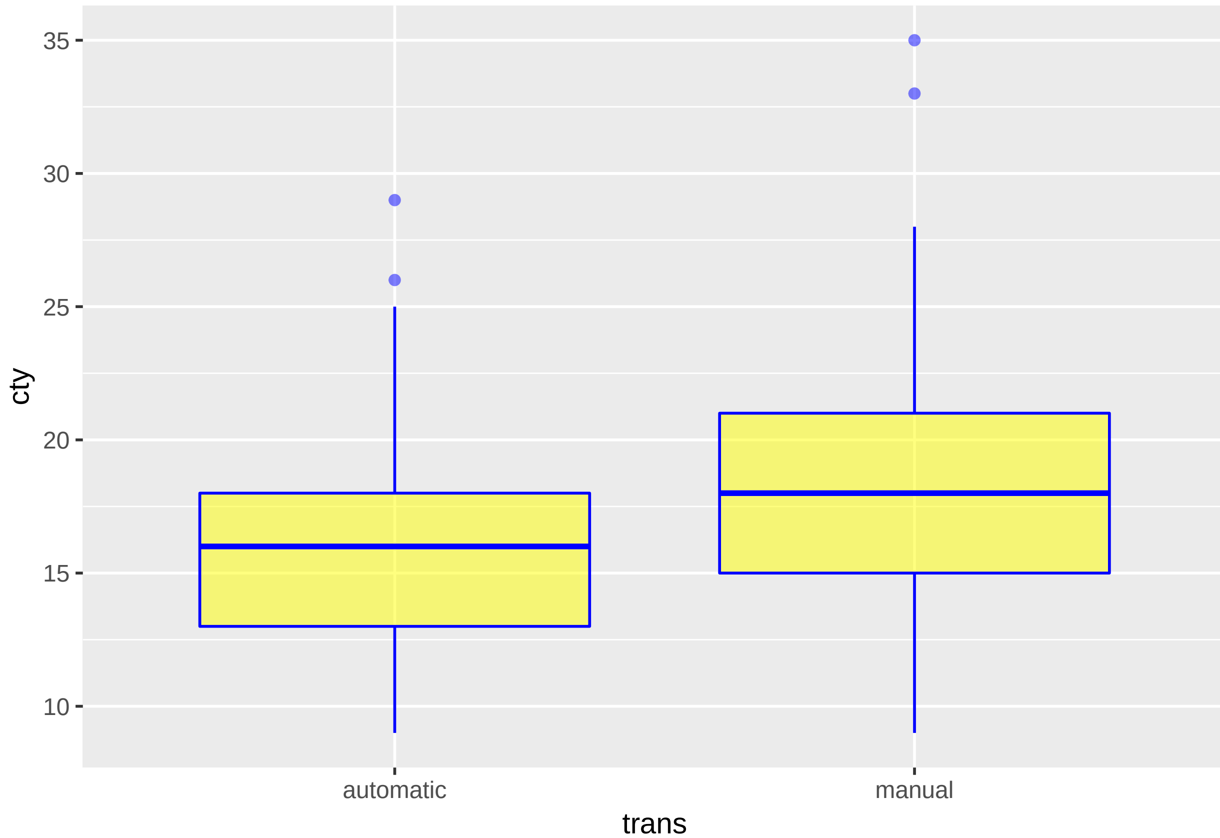
Now visualize `cty` by `trans` via two overlapping alpha-blended densities.

```
ggplot(mpg,aes(cty,trans))+
  geom_density(aes(cty), fill = "blue", col = "yellow", alpha = 0.5) +
  labs(title = "City Fuel Efficiency by Number of Cylnders", x = "Type of transmission",
       y = "City (mpg)", caption = "Source: EPA 2008 Fuel Economy Dataset")
```



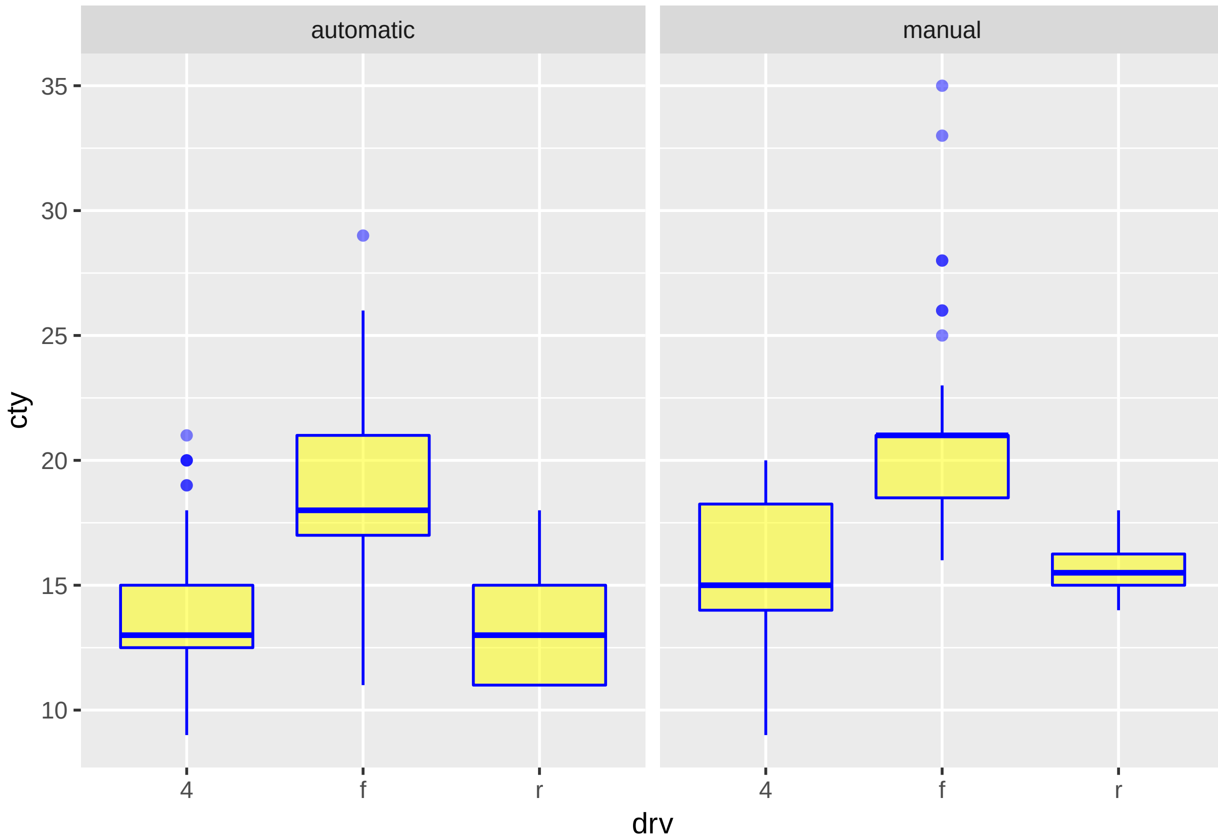
Now visualize `cty` by `trans` via a box and whisker plot.

```
ggplot(mpg, aes(x = trans, y = cty)) +
  geom_boxplot(col = "blue", fill = "yellow", alpha = 0.5)
```



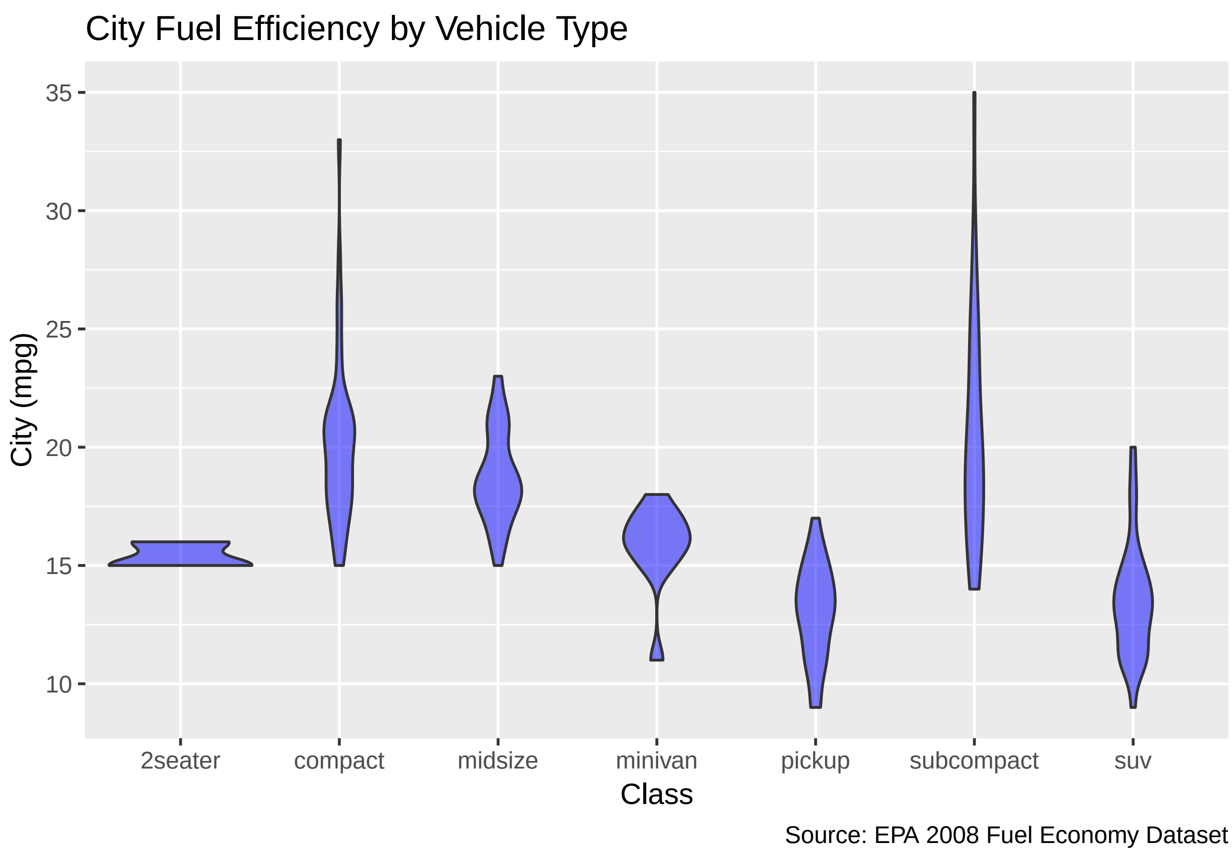
Now visualize `cty` by `drv` by `trans` via two box and whisker plots horizontally laid out.

```
ggplot(mpg, aes(x = drv, y = cty)) +
  geom_boxplot(col = "blue", fill = "yellow", alpha = 0.5) +
  facet_grid(. ~ trans)
```



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

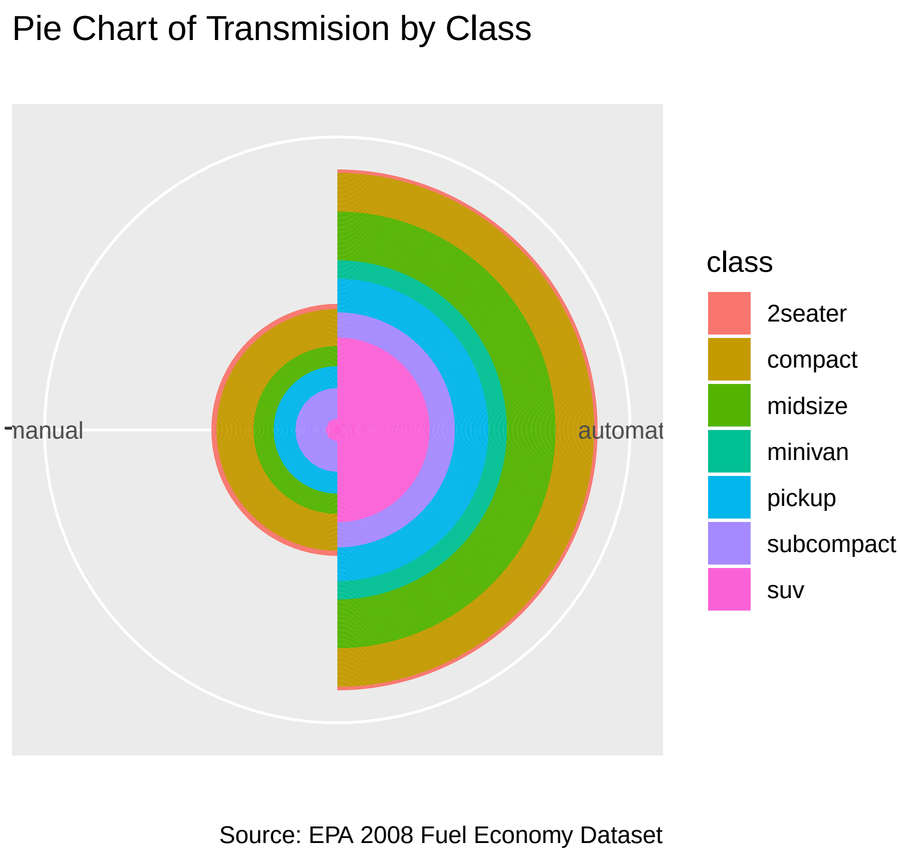
```
ggplot(mpg, aes(x = class, y = cty)) +
  geom_violin(fill = "blue", alpha = 0.5) +
  labs(title = "City Fuel Efficiency by Vehicle Type", x = "Class", y = "City (mpg)", caption = "Source
```



Make a pie chart of `class`.

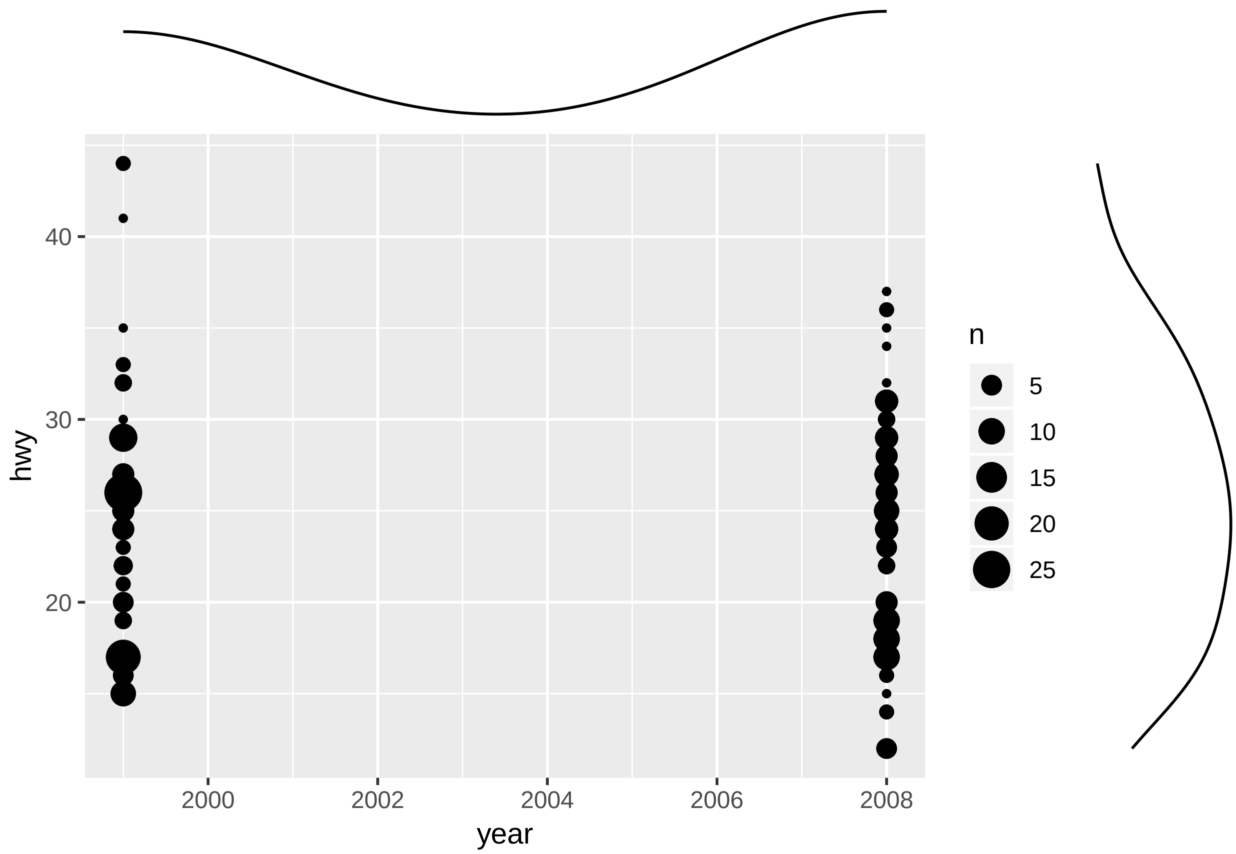
Visualize `trans` vs `class`. Look at the ggplot cheatsheet!

```
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.

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

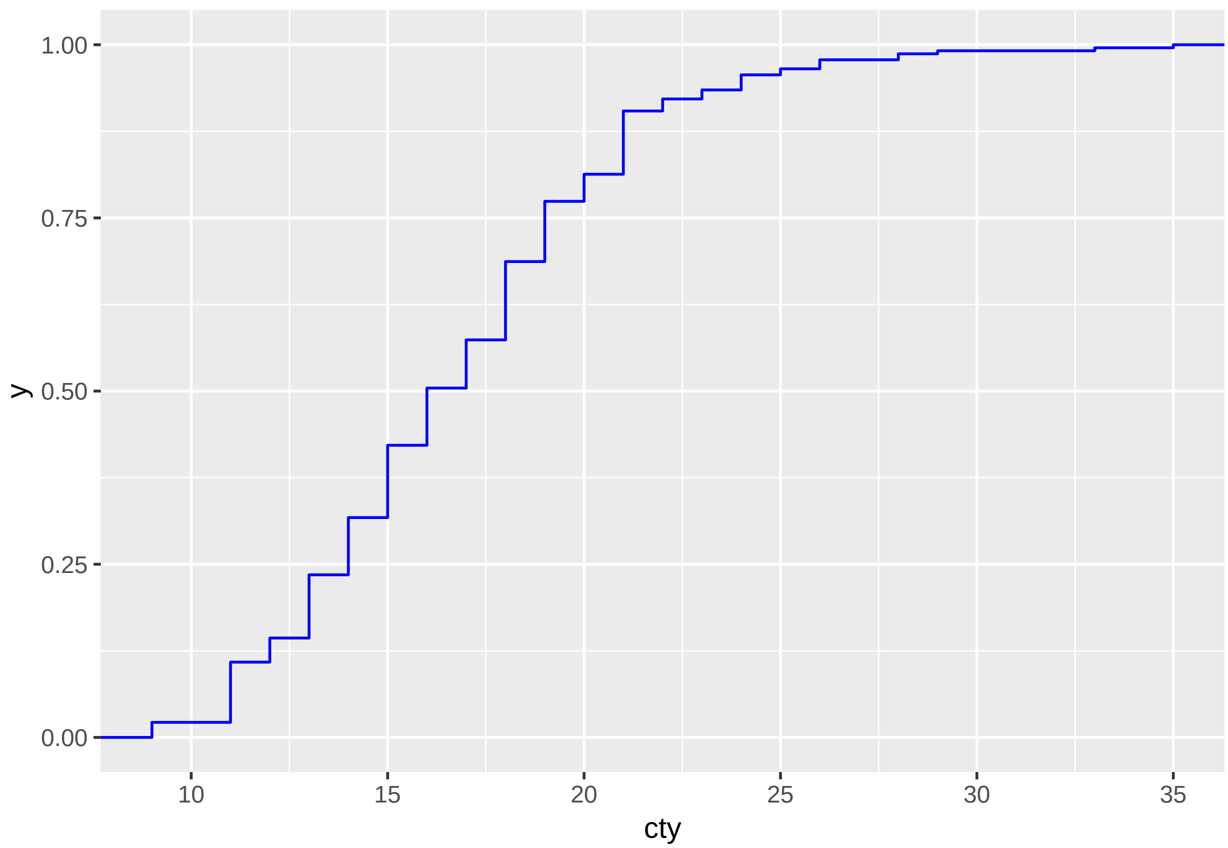


Using the package `ggcorrplot`'s `ggcorrplot` function, look at the correlations for all variables in this dataset that are legal in a corrrelogram. Use dplyr to `select_if` the variable is appropriate.

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

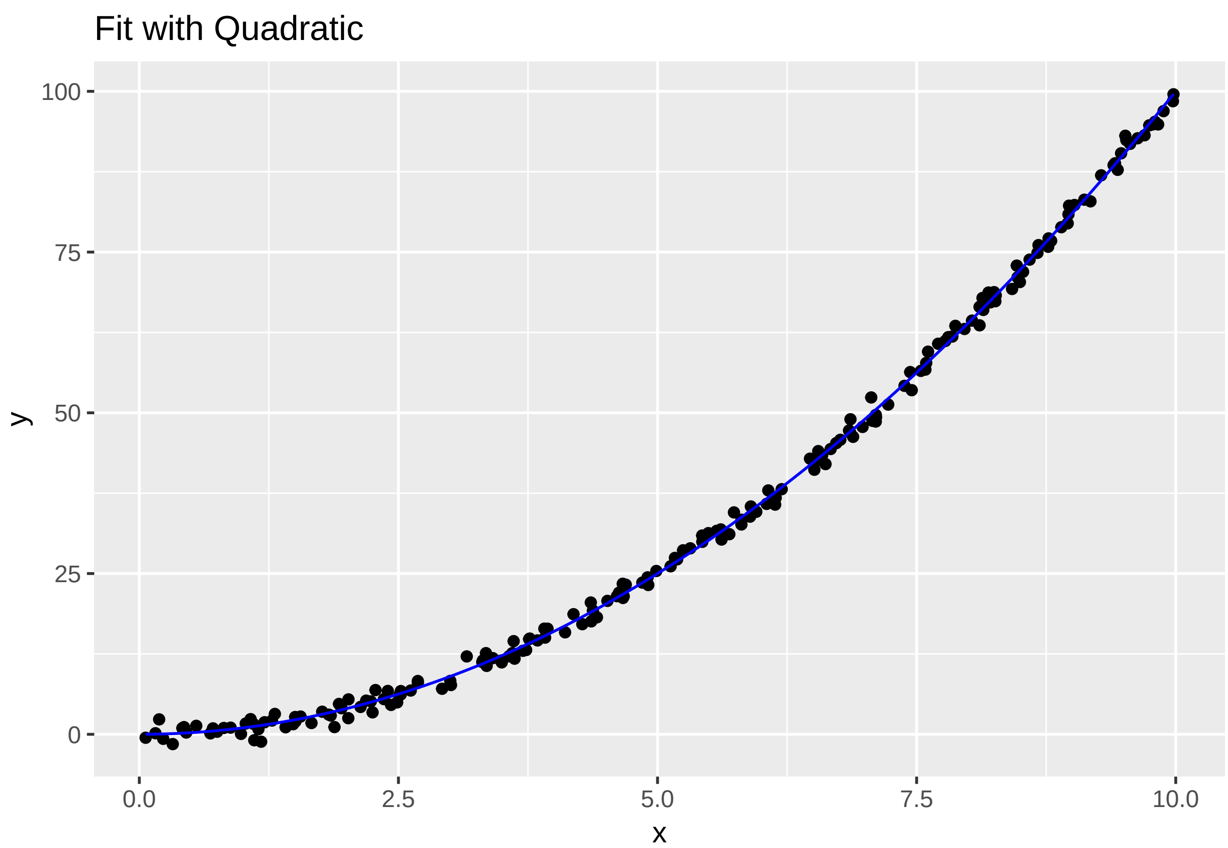
Use the `stat_ecdf` function to plot the estimated cumulative distribution of 'cty'.

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



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= "blue") +
  labs(title = "Fit with Quadratic  " )
```



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

```
## Error in sourceCpp(code = code, env = env, rebuild = rebuild, cacheDir = cacheDir, : Error 1 occurre
```

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

```
Rcpp::evalCpp("2+2")
```

```
## Error in sourceCpp(code = code, env = env, rebuild = rebuild, cacheDir = cacheDir, : Error 1 occurre
```

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

```
##    user  system elapsed
##    0.53    0.00    0.53
```

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

```
## Error in is_odd_cpp(i): could not find function "is_odd_cpp"
```

```
## Timing stopped at: 0 0 0
```

```
# r takes 0.5 secs and cpp takes 1.39 seconds
```

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.

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

```
## Error in sourceCpp(code = code, env = env, rebuild = rebuild, cacheDir = cacheDir, : Error 1 occurre
```

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

```
system.time({
  for(i in 1:25)
    fun(i)
})
```

```
##    user  system elapsed
##    0.28    0.00    0.28
```

```
system.time({
  for(i in 1:25)
    fun_cpp(i)
})
```

```
## Error in fun_cpp(i): could not find function "fun_cpp"
```

```
## Timing stopped at: 0 0 0
```

```
#,02 in cpp and .34 secs in r
```

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

```
logs = function(n){
  array(log(1:n))
}
cppFunction('
```

```
  NumericVector logs_cpp(int n){
    NumericVector ans(n);
    for (int i = 1; i <= n; i++){
      ans[i-1] = log(i);
    }
    return ans;
  }
')
```

```
## Error in sourceCpp(code = code, env = env, rebuild = rebuild, cacheDir = cacheDir, : Error 1 occurre
```

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

```
system.time({
  for(i in 1:1e4)
    logs(i)
})
```

```
##    user  system elapsed
##    1.69    0.03    1.72
```

```
system.time({
  for(i in 1:1e4)
    logs_cpp(i)
})
```

```
## Error in logs_cpp(i): could not find function "logs_cpp"
```

```
## Timing stopped at: 0 0 0
```

```
#Rcpp is slightly faster
```

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.

```
max_distances = function(X){
  n = nrow(X)
  D = matrix(NA, n, n)
  for(i in 1:n){
    for (j in (i+1):n){
      if (j > n)
        j = n
      max_dist = 0
      for (k in 1:ncol(X)){
        ij_dist = abs(X[i,k] - X[j,k])
        if ( ij_dist > max_dist){
          max_dist = ij_dist
        }
      }
      D[i,j] = max_dist
    }
  }
  return(D)
}
cppFunction('
  NumericMatrix max_distances_cpp(NumericMatrix X){
    int n = X.nrow();
```

```
    int p = X.ncol();
    NumericMatrix D(n,n);
    for(int i = 0; i <= n; i++){
      for(int j = i+1; j <= n; j++){
        if ( j == n+1 )
          j = n;
        double max_dist = 0;
        for(int k = 0; k <= p; k++){
          double ij_dist = abs( X(i,k) - X(j,k) );
          if( ij_dist > max_dist  )
            max_dist = ij_dist;
        }
        D(i,j) = max_dist;
      }
    }
    return D;
  }
')
```

```
## Error in sourceCpp(code = code, env = env, rebuild = rebuild, cacheDir = cacheDir, : Error 1 occurre
```

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?

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

```
##    user  system elapsed
##    2.33    0.00    2.33
```

```
system.time({
  max_distances_cpp(X)
})
```

```
## Error in max_distances_cpp(X): could not find function "max_distances_cpp"
```

```
## Timing stopped at: 0 0 0
```

```
# R takes 2.25 and Rcpp takes .01 secs so 300x faster
```