Tutorial 8: Line Charts

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Today's tutorial focuses on line charts. Line charts, as you should know from today's lecture, are for showing change over time.

We review summarizing, use of factor variables, and making data long (from wide). In addition, this tutorial has two versions of code to put a `ggplot()` call into a function. We also do some data cleaning to prepare a file to load.

Today's tutorial comes in four parts (after the intro in part A)

B. Basic line, with annotations: plotting DC population C. Grouped line: Population of multiple jurisdictions in the DC area D. Preparing data for a line chart: Bikeshare data E. Stacked area: Budget data

A. Load packages

Let's begin by loading packages. The only addition from what we've used before is `scales`, which helps put commas into numbers so they are legible, among other things.

```r
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(ggplot2)
library(scales)  # for making numbers with commas
library(tidyr)
```

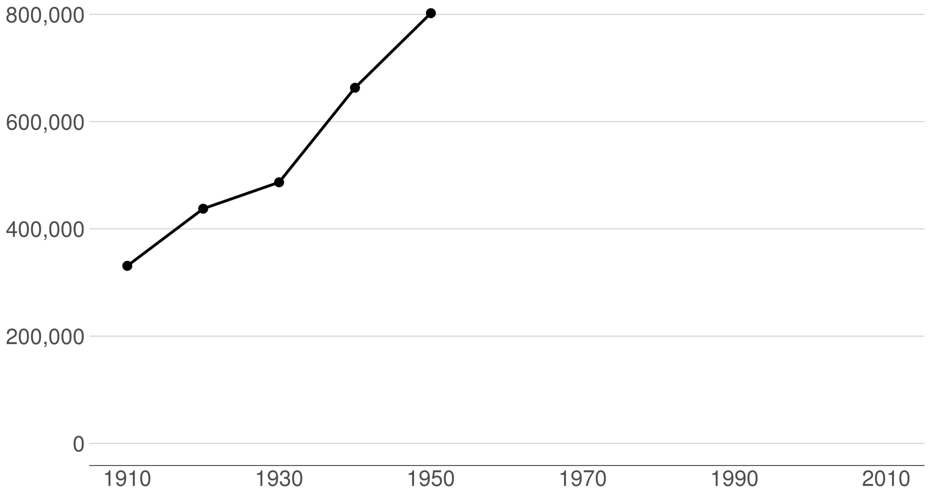
B. Basic line graph, with annotations

We are going to begin with a "simple" line graph. While it looks simple, it took a quite a bit of work to look reasonable.

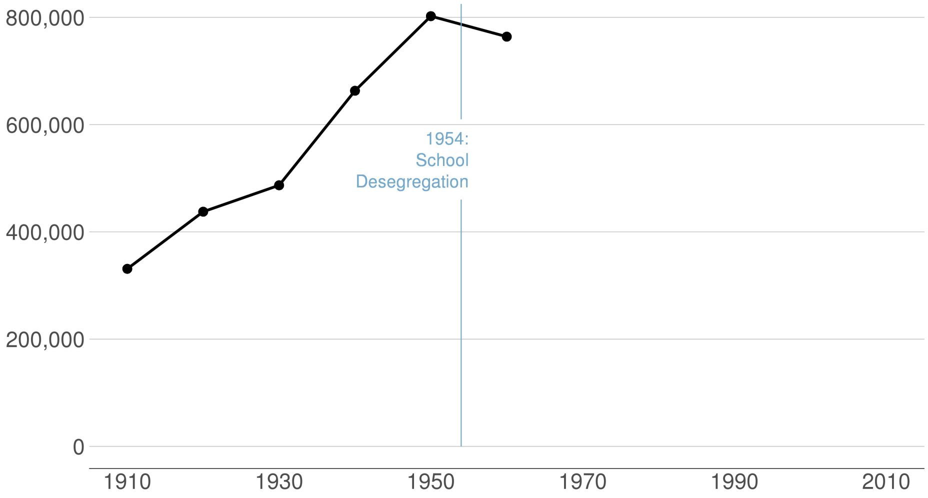
B.1. Look at the final product

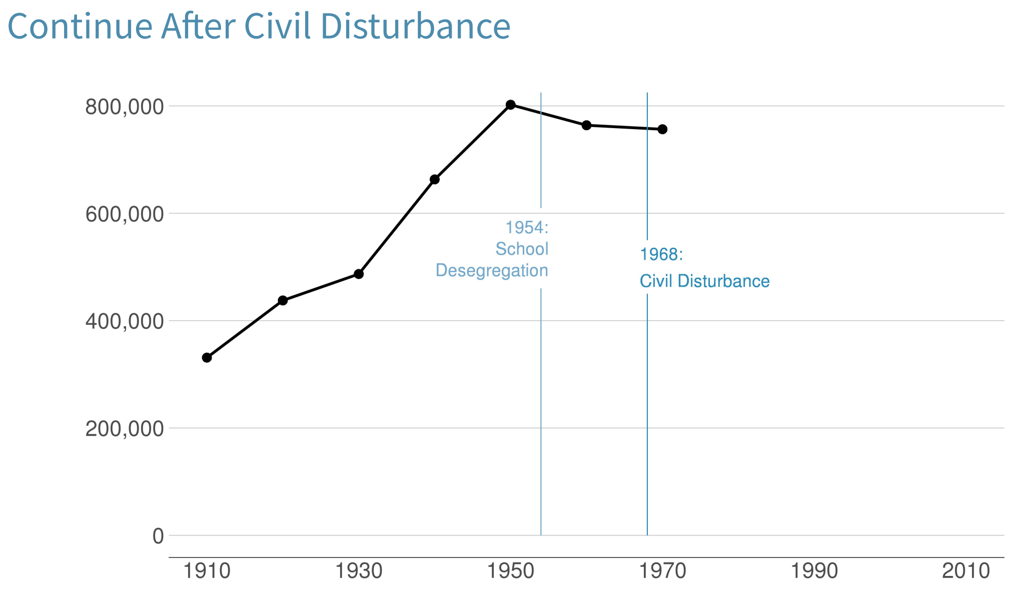
Here are the sequential slides that I used in my presentation of this graph.

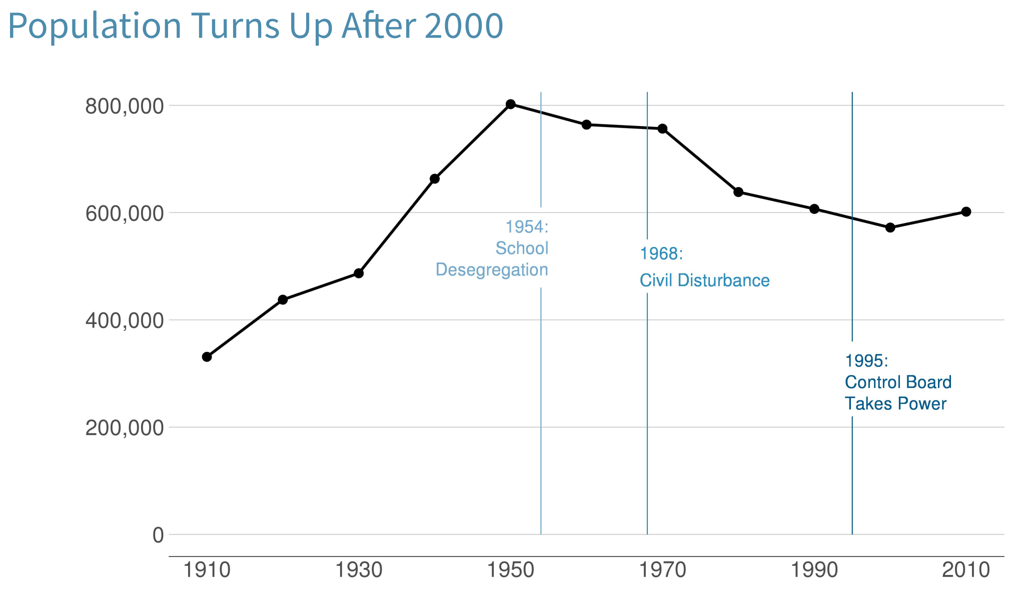
DC Gains Population Through 1950



Population Loses Start with Desegregation




Continue After Civil Disturbance


Population Turns Up After 2000

B.2 Load and prepare data

Let's begin by downloading data from here. These are county-level data on population 1910 to 2010 (among other variables).

Use `read.csv` to grab these data as we've done before.

```
# load data
counties <- read.csv("h:/pppa_data_viz/2019/tutorial_data/lecture08/counties_1910to2010_20180116.csv")
```

Now just limit the data to DC. You could do this in the `ggplot` call itself. However, in this case when we are only planning to use DC, this gives us a smaller dataset to work with and that speeds processing. This will also make the coding easier, since we won't have to subset in each graph.

Take a look at the data after we subset to DC. Does it have the right number of observations?

```
# get just dc
dct <- counties[which(counties$statefips == 11),]
dim(dct)
```

```
## [1] 11 68
```

```
dct[,c("year","statefips","countyfips","cv1")]
```

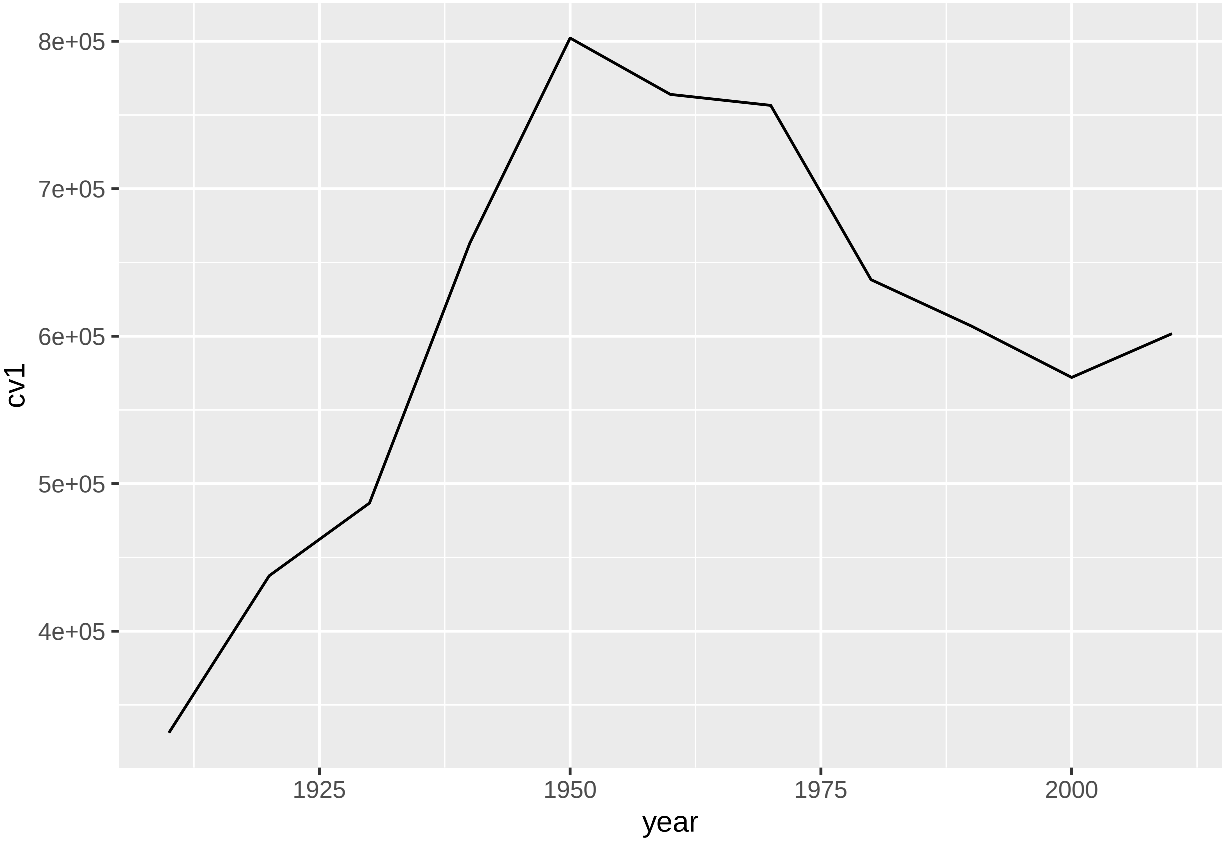
```
##       year statefips countyfips    cv1
## 285   1910        11          1 331069
## 3244  1920        11          1 437571
## 6314  1930        11          1 486869
## 9418  1940        11          1 663091
## 12520 1950        11          1 802178
## 15626 1960        11          1 763956
## 18764 1970        11          1 756510
## 21899 1980        11          1 638333
## 25039 1990        11          1 606900
## 28182 2000        11          1 572059
## 31326 2010        11          1 601723
```

We have only one state and one county in that state. We observe data from 1910 to 2010. This all looks good.

B.3. Make the simplest line graph

Now that you know many ggplot commands, it will not be a shock to hear that you make a line graph using geom_line(). As for all ggplot graphs, you should specify a dataframe and x and y variables. Below we make the simplest possible line graph.

```
b3 <- ggplot() +
  geom_line(data = dct,
            mapping = aes(x = year, y = cv1))
b3
```



Note that line graphs do not default to a y-axis baseline of zero.

B.4. Make some improvements

The line graph above is great for getting a sense of the data. It's not so good for communicating. The x-axis labels don't line up with the years in the data. The vertical axis labels are hard to read. And the grey background does not help tell the story.

We fix the horizontal axis to put 20-year labels with

```
scale_x_continuous(limits= c(1910, 2010), breaks = c(seq(1910,2010,20)))
```

This tells R to start in 1910, and stop in 2010. It also tells R to make breaks on the axis at 1910 and every 20 years until 2010.

We fix the vertical axis with

```
scale_y_continuous(labels = comma,  limits = c(0, 825000), breaks = c(seq(0,800000,200000)))
```

This tells R to use commas in the numbers, to start at 0 and end at 825,000, and to make value labels every 200,000.

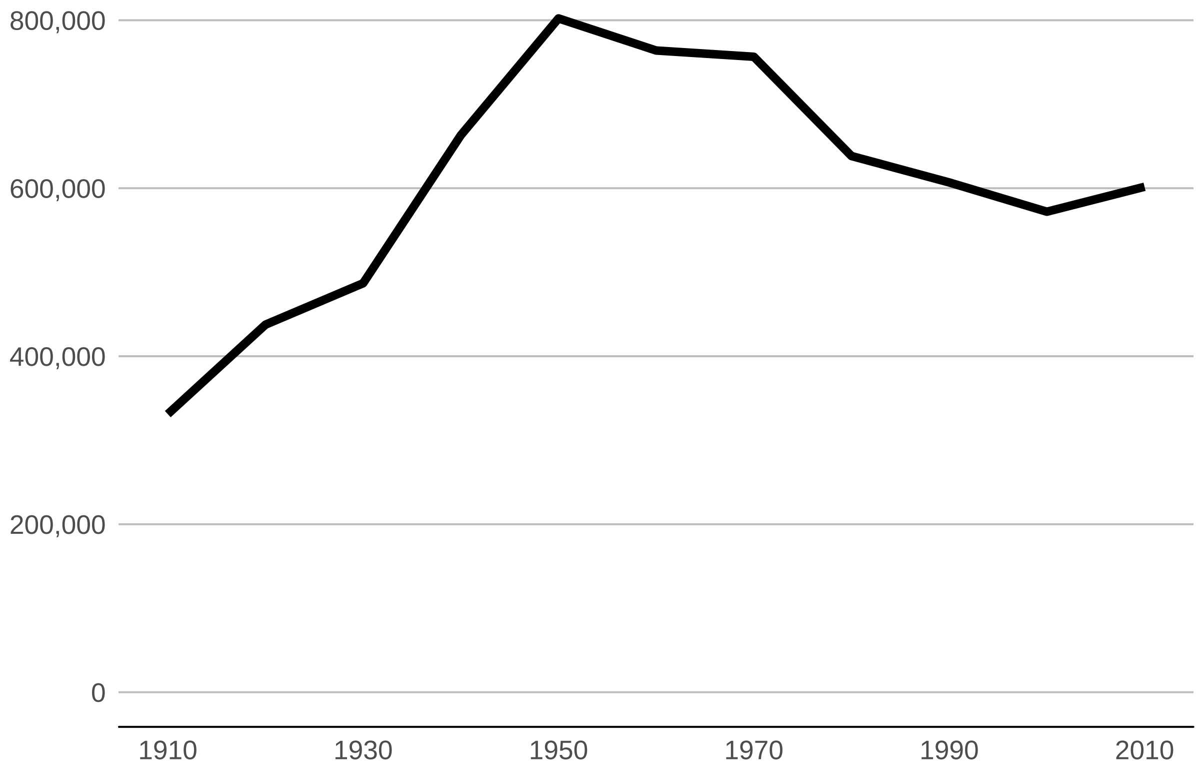
Generally, these line graphs are easier to read when the line is a bit wider. We adjust the line width with the `geom_line()` option of `size = 1.5`. Note that this goes outside of the `aes()` command. Things inside the `aes()` describe how "variables in the data are mapped to visual properties (aesthetics) of geoms" (see cite). Things outside of the `aes()` command are for more general settings.

In addition, we modify the theme to do the following:

- omit major gridlines: `panel.grid.major = element_blank()`
- omit minor gridlines: `panel.grid.minor = element_blank()`

- (FYI: you can also omit both major and minor at once with `panel.grid = element_blank()`)
- omit panel background: `panel.background = element_blank()`
- add back in y-axis gridlines: `panel.grid.major.y = element_line(color="gray")`
- omit legend: `legend.position = "none"`
- make the x-axis line black: `axis.line.x = element_line(color = "black")`
- get rid of x- and y-axis ticks: `axis.ticks = element_blank()`
- change size of axis text: `axis.text = element_text(size = 10)`

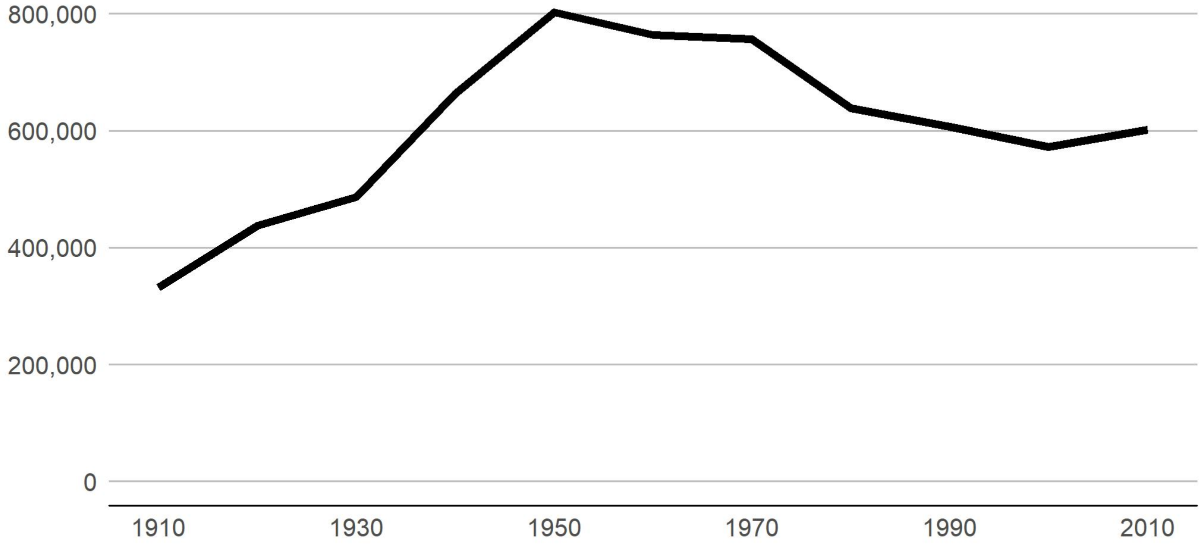
```r
done <-
  ggplot() +
  geom_line(data = dct,
            mapping = aes(x=year, y=cv1), size=1.5) +
  scale_y_continuous(labels = comma,  limits = c(0, 825000), breaks = c(seq(0,800000,200000))) +
  scale_x_continuous(limits= c(1910, 2010), breaks = c(seq(1910,2010,20))) +
  labs(x="", y="") +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank(),
        panel.grid.major.y = element_line(color="gray"),
        legend.position = "none",
        axis.line.x = element_line(color = "black"),
        axis.ticks = element_blank(),
        axis.text = element_text(size = 10))
done
```



Beware that things can look different in the plot window and the final graphics output. To judge, save it in the proportions you'd like for a final product and then look at in with an image viewer. Here's code to save this one.

```
fn <- "H:/pppa_data_viz/2020/tutorials/tutorial_08/b4_testerv1.jpg"
ggsave(plot = done,
       file = fn,
       dpi = 300,
       units = c("in"),
       width = 7,
       height = 3.5)
```

Then I pull in the final image:



Different! When doing final edits, work with the properly-sized graph.

B.5 A few more improvements

I'd call the above plot functional, but the point of this graph is to point out specific historical moments that explain the shape of the plot. To do that we add text and lines to the plot.

We add data points on the line via `geom_point()`. This hints to readers that the data are only actually at the points. The line between the points is really just made up – or extrapolated if you'd like to be fancier.

To add "stuff" to your graph that is not data, use the `annotate` command. Until recently, I was under the incorrect impression that `annotate(geom = "text"))` and `geom_text()` did the same thing. I recently learned that `annotate()` is much more efficient, as it draws just once. In contrast, `geom_text()` will draw as many times as you have data points – again and again in the same place.

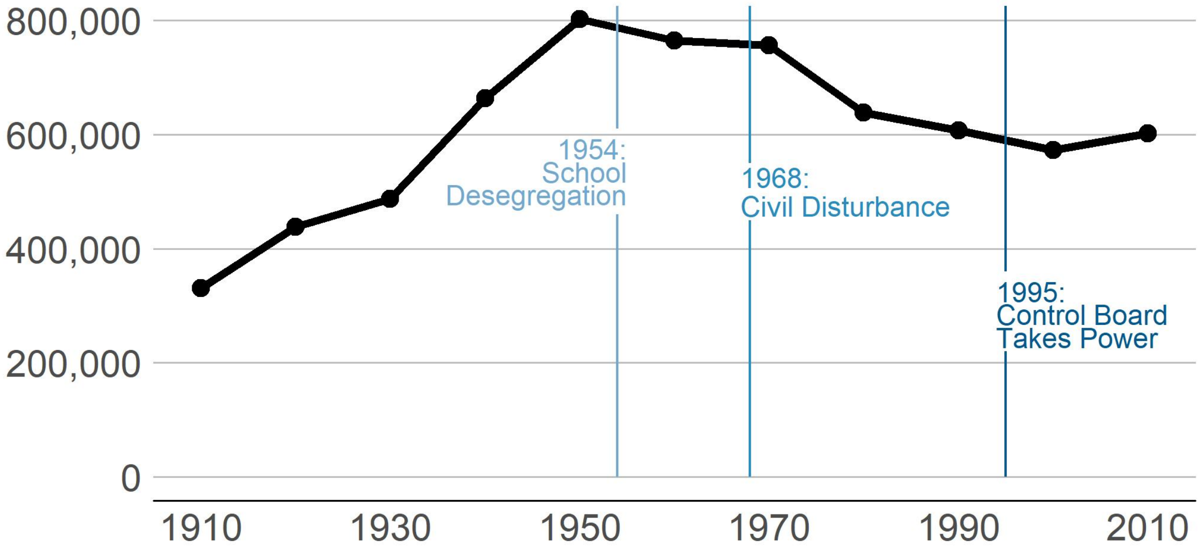
The `annotate()` command has some basic options. The first is `geom`, which is what you want to show. Choices include, but are not limited to, "segment", "rect", or "text". You specific the location with `x` and `y` for text, or, for rectangles and the like, `xmin`, `xmax`, `ymin`, and `ymax` (alternatively, `x` and `xend`, etc). You can also adjust other options such as size (`size=`) or justification (`hjust` and `vjust`; see here). See how to implement these in the example below.

Note that I set the on-graph-text size variable at the beginning (`on.g.text.size`). I use this for the size of the text that goes on the annotate command. That way if I don't like it, I change it once, rather than eight times.

```
on.g.text.size <- 4
done2 <-
  ggplot(dct) +
  geom_line(dct, mapping = aes(x=year, y=cv1), size=1.5) +
  geom_point(dct, mapping = aes(x=year, y=cv1), size=3) +
  scale_y_continuous(labels = comma,  limits = c(0, 825000), breaks = c(seq(0,800000,200000))) +
  scale_x_continuous(limits= c(1910, 2010), breaks = c(seq(1910,2010,20))) +
  labs(x="", y="") +
  theme(panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        panel.background = element_blank(),
        panel.grid.major.y = element_line(color="gray"),
        legend.position = "none",
        axis.line.x = element_line(color = "black"),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank(),
        axis.text = element_text(size = 15)) +
  annotate(geom = "segment", x=1995, y=0, xend=1995, yend=220000, color="#045a8d") +
  annotate(geom = "segment", x=1995, y=360000, xend=1995, yend=825000, color="#045a8d") +
  annotate(geom = "segment", x=1968, y=0, xend=1968, yend=450000, color = "#2b8cbe") +
  annotate(geom = "segment", x=1968, y=550000, xend=1968, yend=825000, color = "#2b8cbe") +
  annotate(geom = "segment", x=1954, y=0, xend=1954, yend=460000, color = "#74a9cf") +
  annotate(geom = "segment", x=1954, y=610000, xend=1954, yend=825000, color = "#74a9cf") +
  annotate(geom = "text", x=1955, y=575000, label="1954:", color = "#74a9cf",
           size=on.g.text.size, hjust=1) +
  annotate(geom = "text", x=1955, y=535000, label="School", color = "#74a9cf",
           size=on.g.text.size, hjust=1) +
  annotate(geom = "text", x=1955, y=495000, label="Desegregation", color = "#74a9cf",
           size=on.g.text.size, hjust=1) +
  annotate(geom = "text", x=1967, y=525000, label="1968:", color = "#2b8cbe",
           size=on.g.text.size, hjust=0) +
  annotate(geom = "text", x=1967, y=475000, label="Civil Disturbance", color = "#2b8cbe",
           size=on.g.text.size, hjust=0) +
  annotate(geom = "text", x=1994, y=325000, label="1995:", color="#045a8d",
           size=on.g.text.size, hjust=0) +
  annotate(geom = "text", x=1994, y=285000, label="Control Board", color="#045a8d",
           size=on.g.text.size, hjust=0) +
  annotate(geom = "text", x=1994, y=245000, label="Takes Power", color="#045a8d",
           size=on.g.text.size, hjust=0)

## save it
fn2 <- "H:/pppa_data_viz/2020/tutorials/tutorial_08/b4_testerv2.jpg"
ggsave(plot = done2,
       file = fn2,
       dpi = 300,
       units = c("in"),
       width = 7,
       height = 3.5)
```

Pulling in the final image:



C. Grouped Line Graph: Multiple counties

The section above graphs just DC. In this section, we graph multiple counties and make them distinguishable.

C.1 Keep just a few counties

Here we subset the `counties` data to just keep DC (state 11), Maryland's Montgomery and Prince George's counties (state 24, counties 31 and 33), and Virginia's Arlington, Alexandria and Fairfax jurisdictions (state 51, counties 13, 510 and 59).

We also make the year variable numeric for ease of plotting. And then to save space, we get rid of the counties dataframe with `rm(counties)`. You can use `rm()` for any objects that you no longer want.

```
dcm <- counties[which(counties$statefips == 11 |
                      counties$statefips == 24 & counties$countyfips %in% c(31,33) |
                      counties$statefips == 51 & counties$countyfips %in% c(13,510,59)),]
dcm$nyear <- as.numeric(dcm$year)
rm(counties)
```

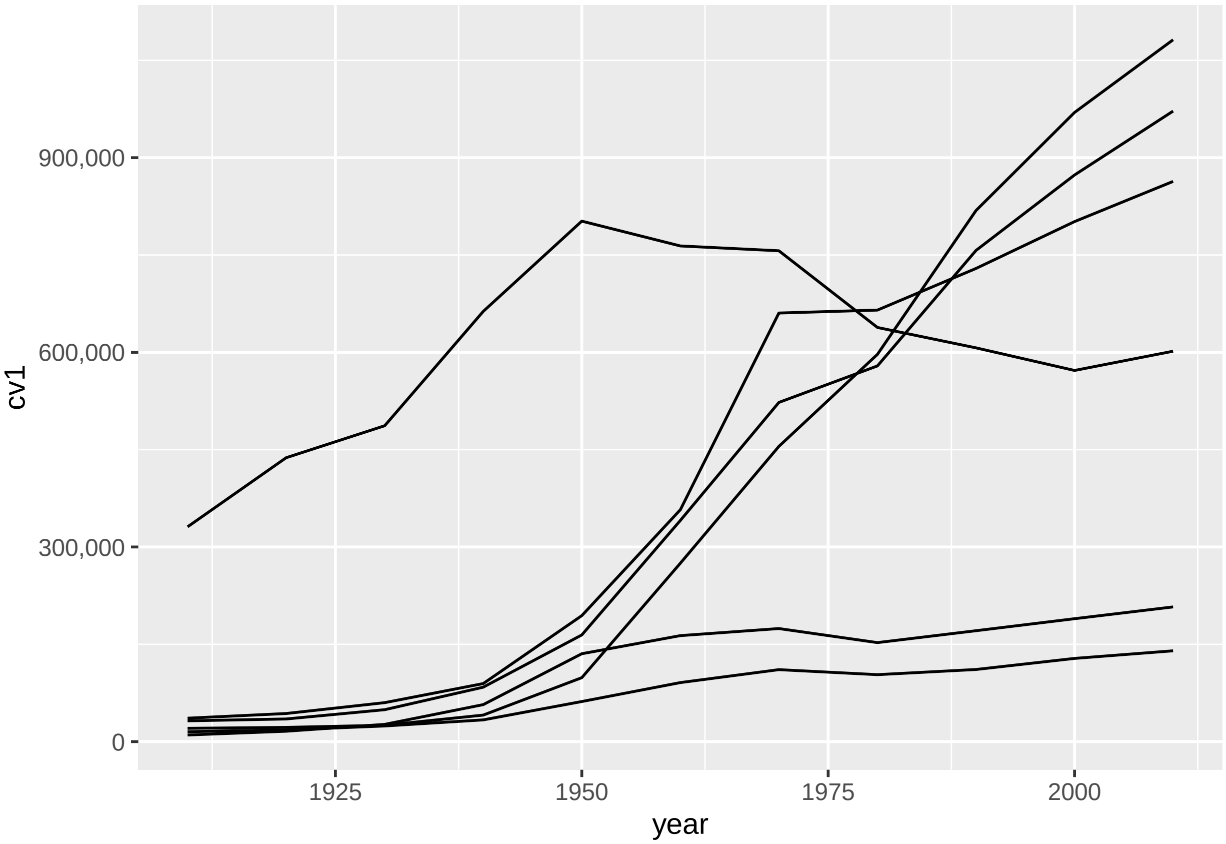
Finally, to identify a county in `ggplot`, we need both the state and county variables together. I use "paste0" to concatenate the state and county variables.

```
# make a state+county variable
dcm$stc <- paste0(dcm$statefips,dcm$countyfips)
```

C.2. Plot all counties

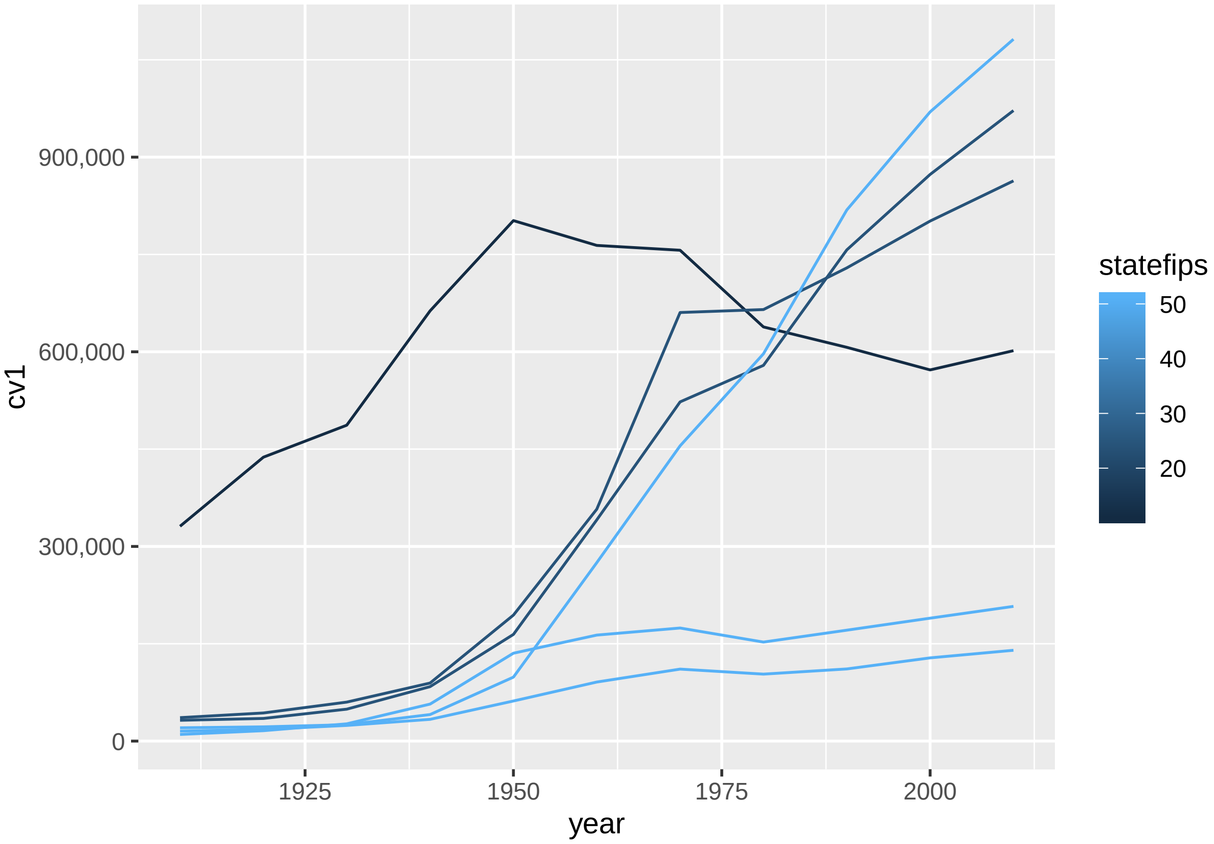
To plot multiple counties at one time, we use the `group()` command and tell R that the groups are by the `stc` variable. For legibility, I add commas in the y-axis values.

```
# all counties
ac <- ggplot() +
  geom_line(data = dcm, aes(x=year, y=cv1, group = stc)) +
  scale_y_continuous(labels = comma)
ac
```



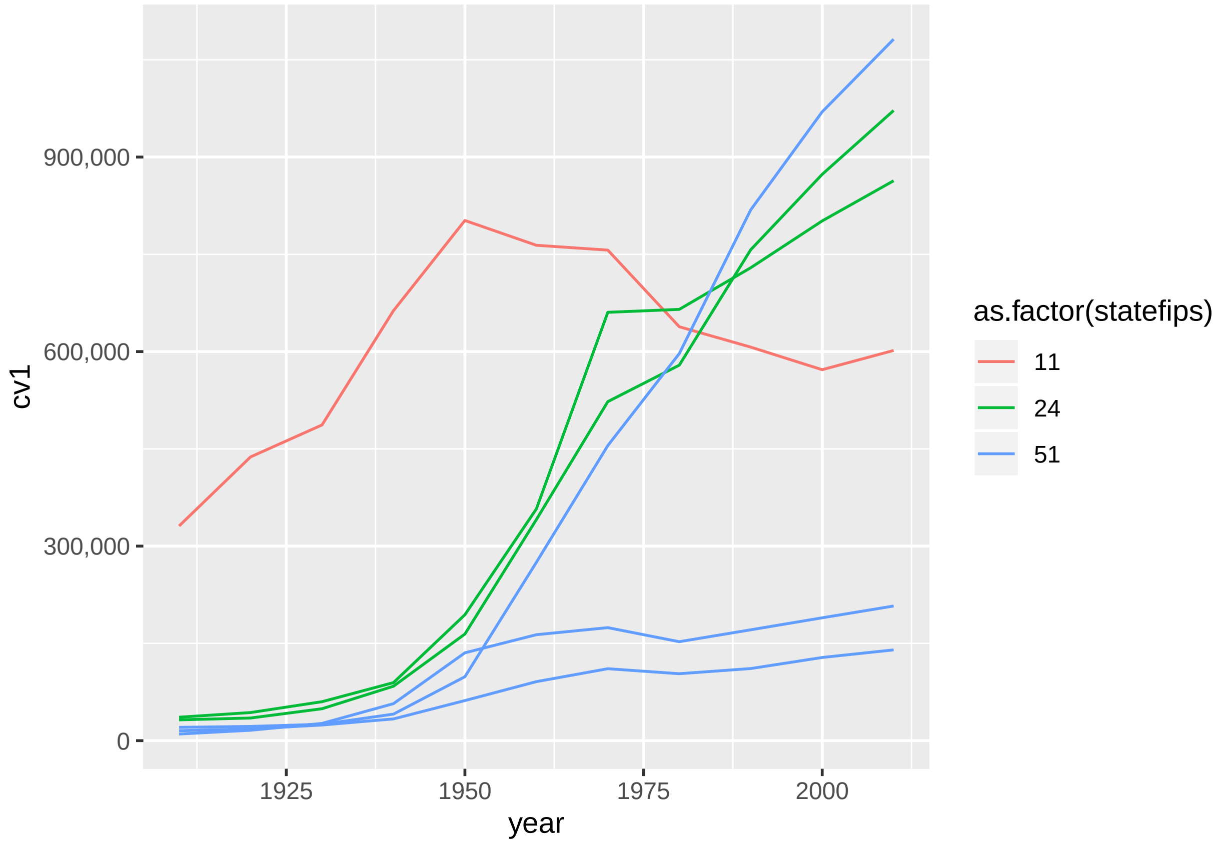
Of course, without a legend or identifying features, this graph is very hard to interpret. We add `color = statefips` so that we can see which states are where on the graph.

```r
# color by state
ac <- ggplot() +
  geom_line(data = dcm, aes(x=year, y=cv1, group = stc, color = statefips)) +
  scale_y_continuous(labels = comma)
ac
```



This graph is an improvement, but it has the very unfortunate feature that it presents the state code as if it were a continuous variable. I use `as.factor()` around the state variable to let R kow it is categorical.

```
# color by state, itemized legend
ac <- ggplot() +
  geom_line(data = dcm, aes(x=year, y=cv1, group = as.factor(stc), color = as.factor(statefips))) +
  scale_y_continuous(labels = comma)
ac
```



There are still many improvements we could make to this graph. For basic legibility, we should made the state codes names rather than numbers. You can do this by making a state factor variable and assigning it a level. (We have done this is in a previous tutorial.) Even better, and depending on the point of the graph, omit the legend and put the jurisdiction names directly on the graph using `annotate()`.

D. Preparing Data for Line Graphs

D.1 Capital Bikeshare data

This section walks you through the kind of prep work you might need to do to get to a line graph. Specifically, we

- practice with functions
- work with date variables
- summarize data

First, download the 2019/02 Capital bikeshare data from here. Use `read.csv()` to load these data.

```
cabi.201901 <- read.csv("H:/pppa_data_viz/2019/tutorial_data/lecture08/201902-capitalbikeshare-tripdata/

head(cabi.201901)
```

```
##   Duration          Start.date            End.date Start.station.number
## 1      206 2019-02-01 00:00:20 2019-02-01 00:03:47                31509
## 2      297 2019-02-01 00:04:40 2019-02-01 00:09:38                31203
## 3      165 2019-02-01 00:06:34 2019-02-01 00:09:20                31303
## 4      176 2019-02-01 00:06:49 2019-02-01 00:09:45                31400
## 5      105 2019-02-01 00:10:41 2019-02-01 00:12:27                31270
## 6      757 2019-02-01 00:12:37 2019-02-01 00:25:14                31503
##                                Start.station End.station.number
## 1                   New Jersey Ave & R St NW              31636
## 2                 14th & Rhode Island Ave NW              31519
## 3 Tenleytown / Wisconsin Ave & Albemarle St NW              31308
## 4               Georgia & New Hampshire Ave NW              31401
## 5                               8th & D St NW              31256
## 6                      Florida Ave & R St NW              31126
##                           End.station Bike.number Member.type
## 1 New Jersey Ave & N St NW/Dunbar HS      W21713      Member
## 2                      1st & O St NW      E00013      Member
## 3                 39th & Veazey St NW      W21703      Member
## 4               14th St & Spring Rd NW      W21699      Member
## 5                       10th & E St NW      W21710      Member
## 6                 11th & Girard St NW      W22157      Member
```

These data show us one row per CaBi trip.

To get these data ready for a line chart, we need to get the time variable into a useful format. Currently the time data are text. Text variables are categorical, not quantitative, so they will not line up properly along the x axis.

We also need to shrink the size of these data through summary statistics since 150,000 is too many to plot. We'll do each of these in turn.

D.2. Prepare bikeshare data

Let's begin with calculating date variables. Date variables are a special kind of variable. They store time and date as the number of days since January 1, 1970. To convert the string variables `Start.date` and `End.date`, we use the `as.POSIXct` command, which takes character variables and makes a R date.

We also use `strptime()` which makes appropriate character variables (to get ready for `as.POSIXct`) from a date and time string. For `strptime`, you tell R what parts of the string correspond to which parts of the date.

```
cabi.201901$time.start <- as.POSIXct(strptime(x = cabi.201901$Start.date,
                                              format = "%Y-%m-%d %H:%M:%S"))
cabi.201901$time.stop  <- as.POSIXct(strptime(x = cabi.201901$End.date,
                                              format = "%Y-%m-%d %H:%M:%S"))
```

D.3. Use date variables for duration calculation

Now that we have two date variables, we can make our own measure of duration and check the bikeshare's measure.

```
# my duration calculation
cabi.201901$my.duration <- cabi.201901$time.stop - cabi.201901$time.start
```

```
# comparing my results to built-in results
summary(cabi.201901$my.duration)
```

```
##   Length    Class     Mode
##   158130 difftime  numeric
```

Wait – this variable is not returning a normal summary output. We need to tell R that is is a numeric variable in the `summary()` command.

```
summary(as.numeric(cabi.201901$my.duration))
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
##    1.000    5.817    9.633   14.939   15.967 1435.000
```

```
summary(as.numeric(cabi.201901$Duration))
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    60.0   349.0   577.0   895.9   957.0 86100.0
```

This looks similar, but our calculated duration measure is in minutes and the bikeshare's measure is in seconds. I could divide `cabi$Duration` by 60 to see if they are the same. I can also look at the correlation between the two measures using `cor()`. Here is the correlation method:

```
# look at the correlation -- looks like 1
cor(x = as.numeric(cabi.201901$my.duration),
    y = as.numeric(cabi.201901$Duration),
    method = c("pearson"))
```

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

I find that the correlation between the two measures is 1. This makes we suspect that the bikeshare people calculated the duration in the exact way we did.

Now I do the other check: divide our measure by 60.

```
cabi.201901$Duration.minutes <- cabi.201901$Duration / 60
summary(cabi.201901$Duration.minutes)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
##    1.000    5.817    9.617   14.931   15.950 1435.000
```

OK – it's the same.

D.4. Make hour level summary statistics

The trick to successfully plotting these data is to reduce their dimensionality. The dataframe has about 150,000 observations – way too many to show on any plot.

Our goal is to have a dataframe that is by hour, rather than by ride. For each hour, we find the average number of rides and the average duration of rides.

To do this, we first need a variable that tells us the hour of the trip. We extract the hour component from the date variable using the date notation. We can use the `format()` function because we already created a date variable called `time.start`. We then check the output using both `summary()` and `table()`.

```
# get the hour out of the date variable
cabi.201901$start.hour <- as.numeric(format(cabi.201901$time.start, "%H"))
summary(cabi.201901$start.hour)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    0.00    9.00   14.00   13.63   17.00   23.00
```

```
table(cabi.201901$start.hour)
```

```
##
##     0     1     2     3     4     5     6     7     8     9    10    11    12
##   949   539   383   162   284  1369  3931  9314 15908  9409  6123  6818  8025
##    13    14    15    16    17    18    19    20    21    22    23
##  8304  8311  9728 12994 18785 13846  8570  5713  4082  2904  1679
```

From the summary command, we see that mean start hour is about 1:30 (13.6 hours). That seems fine, as does the max start hour of 11 pm (23 hours) and the min start hour of 0 (midnight).

Looking at the table output, the hour with the single largest number of rides is 17 – or 5 pm. This also seems reasonable.

Now that we are reassured the times are ok, we use `group_by()` and `summarize()` to find hourly traveling information. We calculate both the number of rides (`no_rides`) and the average duration of those rides (`mean_dur`).

```
# summarize to hourly data
cabi.201901 <- group_by(cabi.201901, start.hour)
cabisum <- summarize(.data = cabi.201901, no_rides = n(), mean_dur = mean(Duration))
dim(cabisum)
```

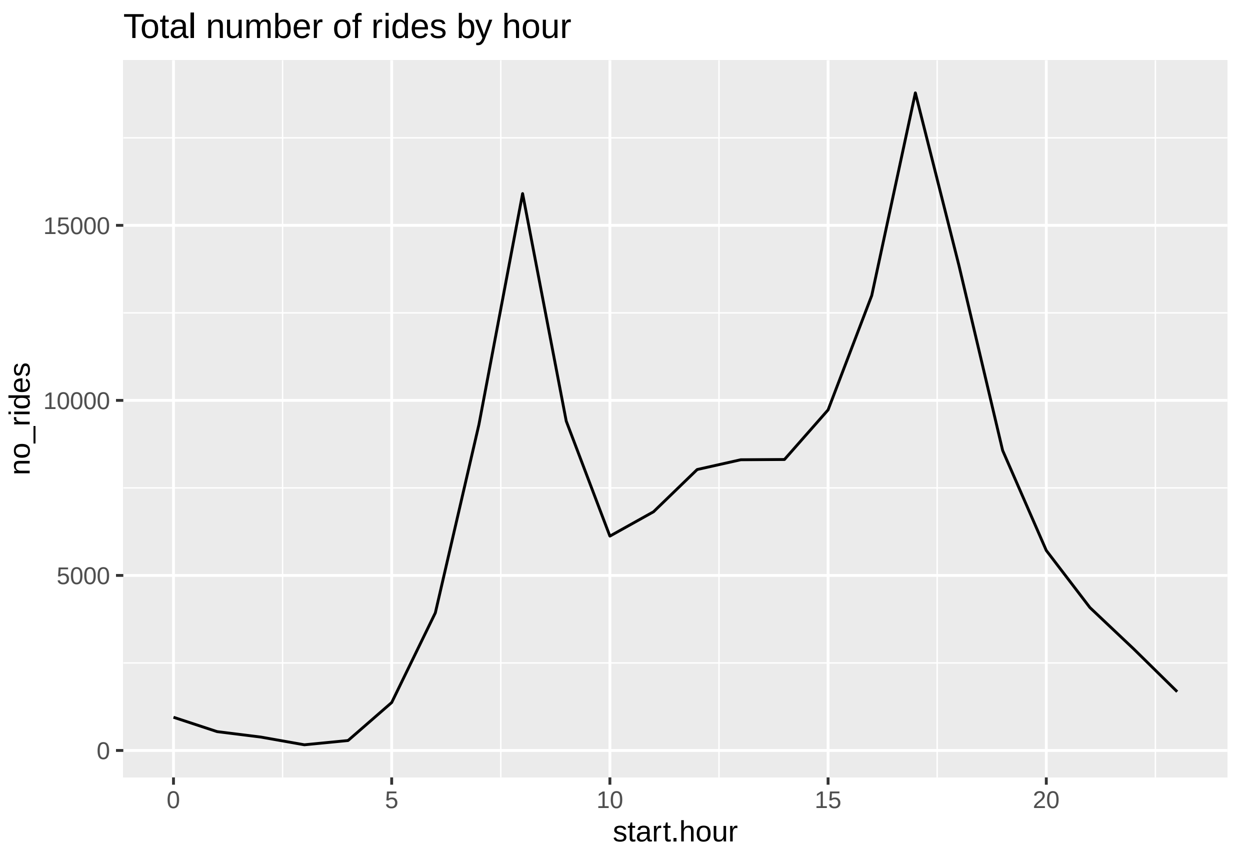
```
## [1] 24  3
```

D.5. Plot of number of rides and mean duration

Now we'll plot the results, which is another reasonability check on the data. We also want to make a function to plot both variables. However, the first rule of functions is to get the code working outside of a function first.

Following this commandment, we plot the number of rides by hour.

```
# get it to work outside of a function
c3 <- ggplot() +
  geom_line(data = cabisum, mapping = aes(x = start.hour, y = no_rides)) +
  labs(title = "Total number of rides by hour")
c3
```



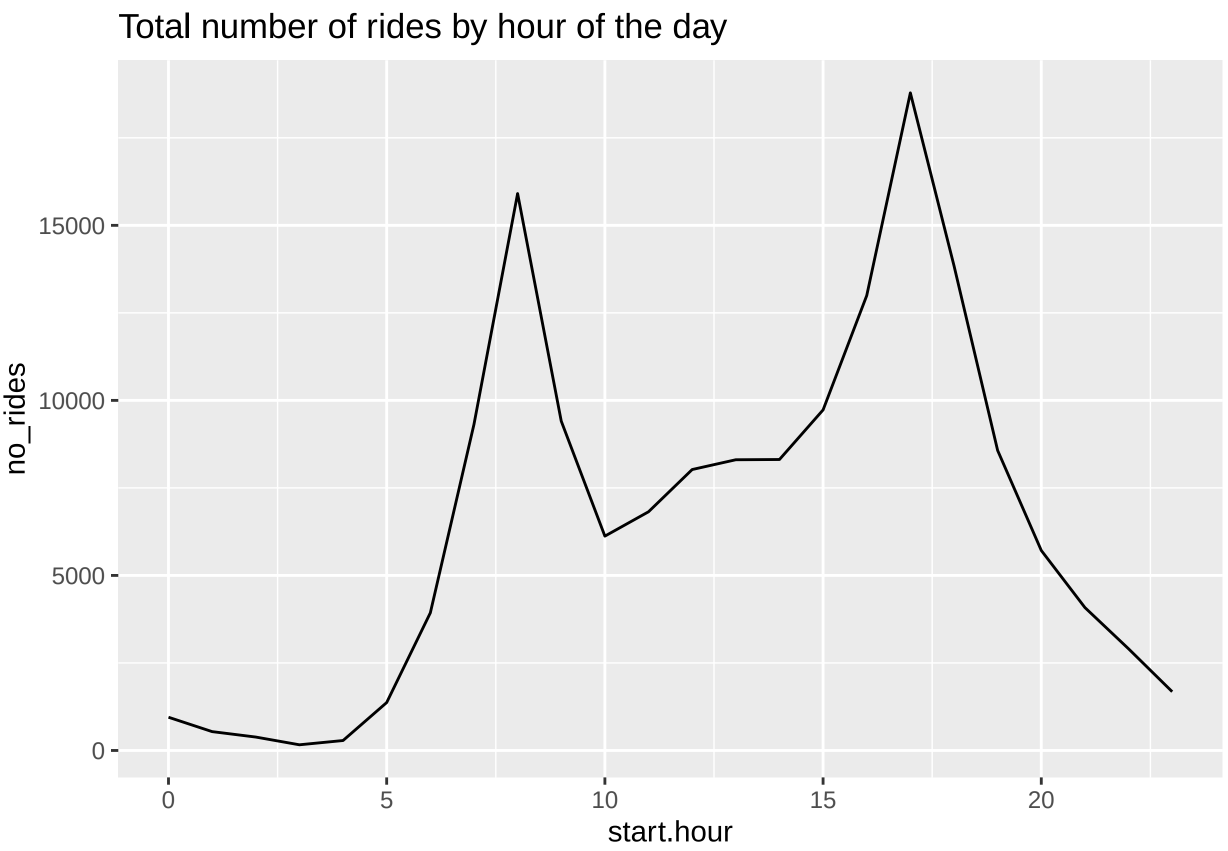
This seems to have gone smoothly. We see morning and afternoon peaks, which seems entirely reasonable.

For making multiple graphs, we'd prefer not to copy and paste this code for reasons we discussed in class. Instead, make a function. The below shows you how to iterate through `ggplot` with a function. This document explains the why this is not as straightforward as you might think.

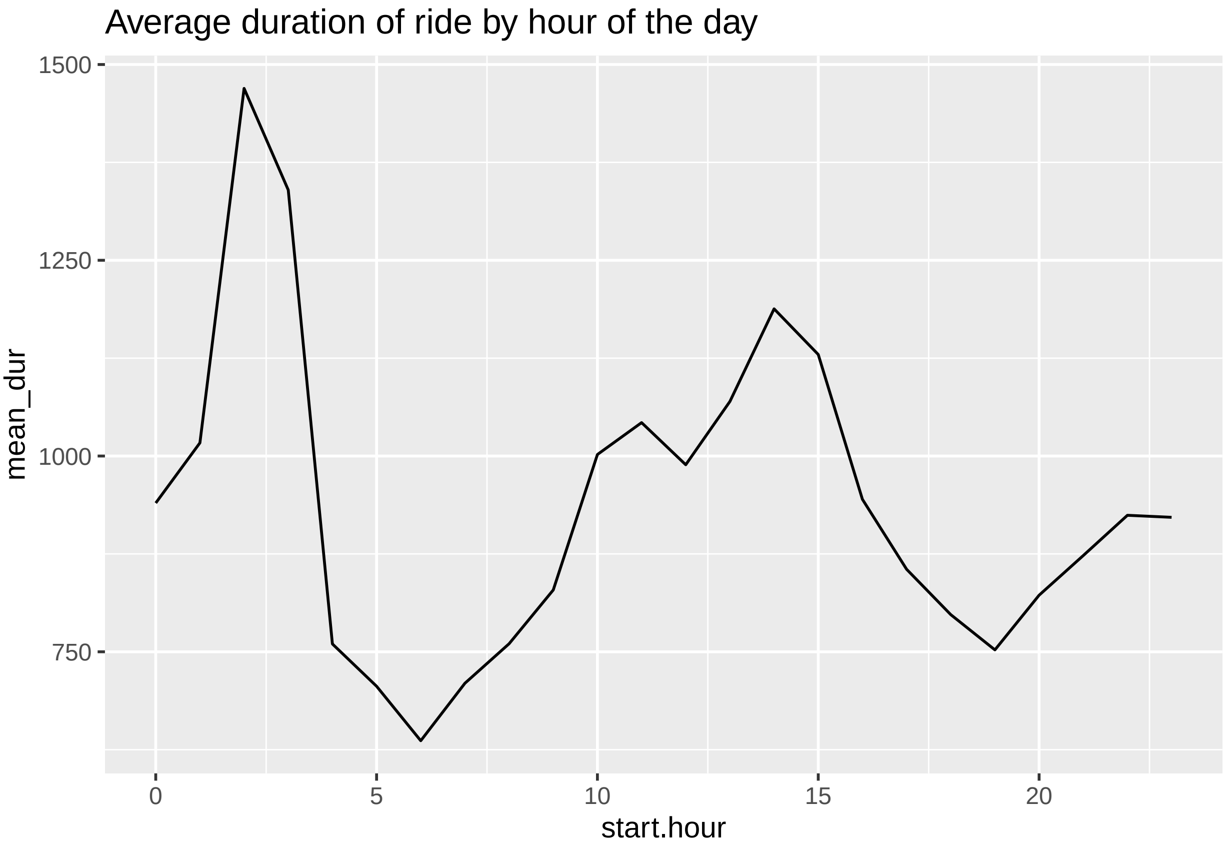
Importantly, `ggplot()` uses non-standard evaluation, so it takes in text in a different way than base R commands. Thus, to replace text in a `ggplot` command, you need to input it with `quo()` and get rid of the `quo()` with `!!` before the new text.

```
# write a simple function for two variables
# see examples here
# https://dplyr.tidyverse.org/articles/programming.html
c3func <- function(varin,vardescp){
  c3 <- ggplot() +
    geom_line(data = cabisum, mapping = aes(x = start.hour, y = !! varin)) +
    labs(title = vardescp)
  print(c3)
}

c3a <- c3func(varin = quo(no_rides), "Total number of rides by hour of the day")
```



```
c3a <- c3func(varin = quo(mean_dur), "Average duration of ride by hour of the day")
```



Alternatively, you could use the `aes_string()` code. To do this, write

```
c3func <- function(varin,vardescp){
  c3 <- ggplot() +
    geom_line(data = cabisum,
              mapping = aes_string(x = "start.hour", y = varin)) +
    labs(title = vardescp)
  # omitting the print for space
  #print(c3)
}

c3a <- c3func(varin = "no_rides", vardescp = "Total number of rides by hour of the day")
c3a <- c3func(varin = "mean_dur", vardescp = "Average duration of ride by hour of the day")
```

E. Stacked lines, useful for money

The final type of line graph we're trying today is a stacked line chart, which can sometimes be very helpful to convey change over time along with the relative importance of categories.

E.1. Load data

Since this is a policy class, it seems fitting to graph at least some budget data. We are introducing a new dataset: US federal budget statistics. You can find the data from the Office of Management and Budget here. Download the zip file from the top of the page and unzip it.

I am not prepping these data for you, since I want to make sure you learn how to put raw data into R. You will find that there are many small issues that cause trouble. This is not atypical, and I want to be sure you know how to handle them.

Unzip the file you downloaded, and you'll see a bunch of files in this new folder. They follow the naming convention on the page from which you downloaded. Open up Tables 1.3 (hist01z3.xls; for homework) and 2.3 (hist02z3.xls; for now) in Excel.

From Table 2.3, we want the year and columns B, C, D, G, H and I. Create a new excel document with just this information, and make one row at top with names that you'll understand. Keep just through 2017, and make sure that you don't have any junk at the bottom of the table. Save this file as csv (file, save as, choose "csv" option for file type). If there are numeric variables that take the value `*`, make them ".", which is code for missing.

Load the csv file you just created into R.

```
### makeup of receipts ####
hist02z3 <- read.csv("H:/pppa_data_viz/2018/tutorials/lecture05/omb_data/hist02z3.csv")
names(hist02z3)
```

```
## [1] "year"          "income.taxes" "corp.taxes"   "social.ins"   "excise"
## [6] "other"         "total"
```

Begin by making sure that what you've imported into R is what you expect.

We'll start with the `year` variable, using `tables()`.

```
# make sure year is always ok
table(hist02z3$year)
```

```
##
##      1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948
##    6    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
## 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964
##    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
## 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980
##    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
## 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996
##    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
## 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
##    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
## 2013 2014 2015 2016 2017   TQ
##    1    1    1    1    1    1
```

Notice that there are some odd things here. A few observations with no year at all, and one observation where year is "TQ". Let's fix this.

We use subset the data to get rid of the strange years and then create a numeric variable from a facgtor using an alternative method. We use `summary()` to make sure this cleaned up variable takes on reasonable values.

```
hist02z3 <- hist02z3[which(hist02z3$year != ""),]
hist02z3 <- hist02z3[which(hist02z3$year != "TQ"),]
hist02z3$nyear <- as.numeric(levels(hist02z3$year))[hist02z3$year]
```

```
## Warning: NAs introduced by coercion
```

```
summary(hist02z3$nyear)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1934    1955    1976    1976    1996    2017
```

Good – the year variable now seems to have just numeric years.

E.2. Make data long

To make a stacked line (or really, any multiple line), the data needs to be long, not wide. As a refresher, wide data look like this, with one observation per unit:

```
wide <- data.frame(state = c("6","36","48"), female_pop = c("10","12","14"), male_pop = c("11","13","12
wide
```

```
##   state female_pop male_pop
## 1     6         10       11
## 2    36         12       13
## 3    48         14       12
```

Long data look like this, with one observation per unit and type:

```
long <- data.frame(state = c("6","36","48","6","36","48"),
                   pop = c("10","12","14","11","13","12"),
                   sex = c("female","female","female","male","male","male"))
long
```

```
##   state pop    sex
## 1     6  10 female
## 2    36  12 female
## 3    48  14 female
## 4     6  11   male
## 5    36  13   male
## 6    48  12   male
```

Note how this dataset requires a variable that tells you which type of population the row contains.

Neither data format is “right.” If you were doing a regression and wanted to control for male and female population, you’d need the wide format. However, to make a line graph with multiple lines in R, you need a long dataset.

To make the data long, first I tried the code below

```
## make this wide dataset long
head(hist02z3)
r.long <- pivot_longer(data = hist02z3,
                       cols = c("income.taxes","corp.taxes","social.ins","excise","other","total"),
                       names_to = "revenue_type",
                       values_to = "revenue")
r.long[1:15,]
```

This code delivers this error message: Error: No common type for ‘income.taxes‘ <double> and ‘social.ins‘ <factor<1c022».

This error message is telling us that not all our income variables are the same type. Check this:

```
str(hist02z3)
```

```
## 'data.frame':    84 obs. of  8 variables:
##  $ year        : Factor w/ 86 levels "","1934","1935",..: 2 3 4 5 6 7 8 9 10 11 ...
##  $ income.taxes: num  0.7 0.7 0.8 1.2 1.4 1.1 0.9 1.1 2.2 3.5 ...
##  $ corp.taxes  : num  0.6 0.8 0.9 1.2 1.4 1.2 1.2 1.8 3.2 5.2 ...
##  $ social.ins  : Factor w/ 41 levels "",".","0.1","0.7",..: 2 2 3 4 8 9 9 8 8 7 ...
##  $ excise      : num  2.2 2 2 2.1 2.1 2.1 2 2.2 2.3 2.2 ...
##  $ other       : num  1.3 1.5 1.1 0.9 0.9 0.7 0.7 0.7 0.5 0.4 ...
##  $ total       : num  4.8 5.1 4.9 6.1 7.5 7 6.7 7.5 9.9 13 ...
##  $ nyear       : num  1934 1935 1936 1937 1938 ...
```

Sadly, it seems that `social.ins` is a factor variable – all other taxes are numeric. So let's fix this.

We fix `social.ins` by doing

```
hist02z3$social.ins <- as.numeric(as.character(hist02z3$social.ins))
```

```
## Warning: NAs introduced by coercion
```

```
str(hist02z3$social.ins)
```

```
##  num [1:84] NA NA 0.1 0.7 1.7 1.8 1.8 1.7 1.7 1.6 ...
```

The new structure says `social.ins` is now a numeric variable.

Now try the `pivot_longer()` command again:

```
## make this wide dataset long
r.long <- pivot_longer(data = hist02z3,
                       cols = c("income.taxes","corp.taxes","social.ins","excise","other","total"),
                       names_to = "revenue_type",
                       values_to = "revenue")
r.long[1:15,]
```

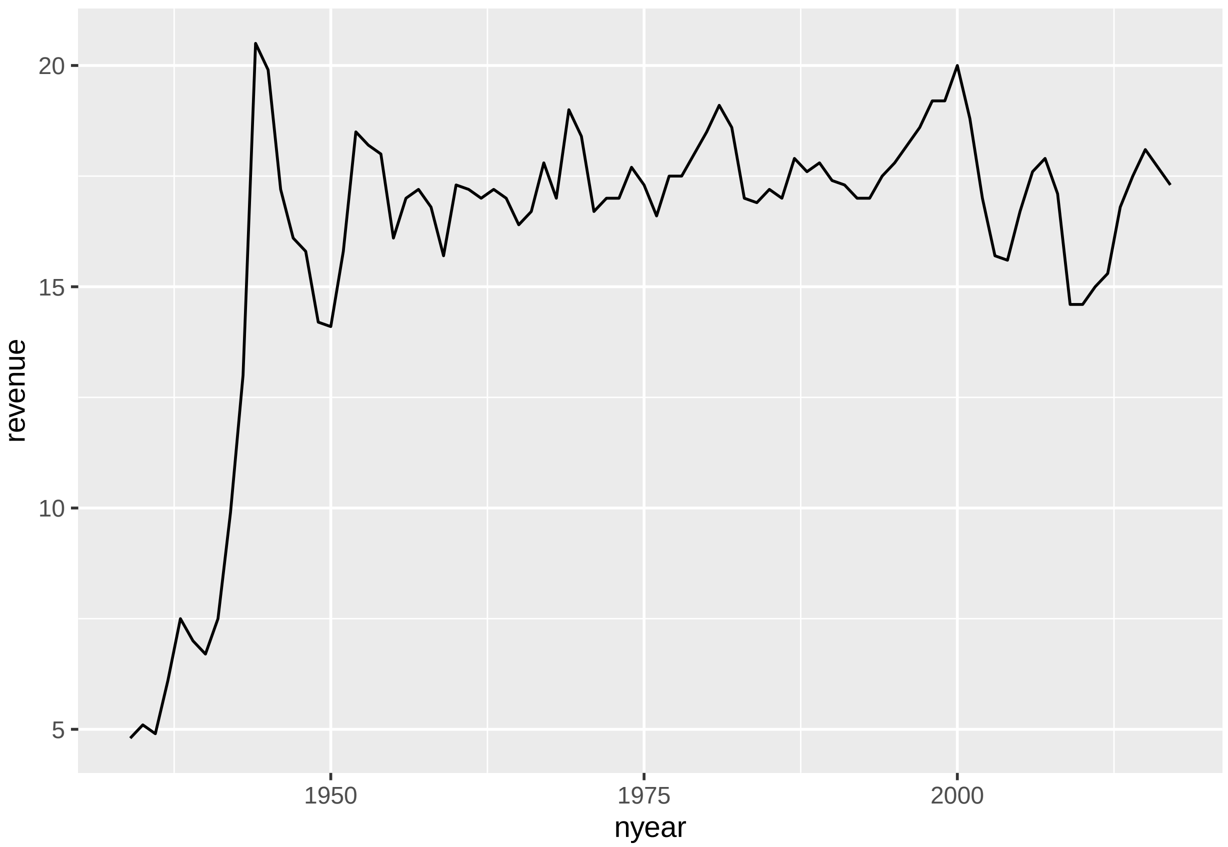
```
## # A tibble: 15 x 4
##    year  nyear revenue_type revenue
##    <fct> <dbl> <chr>          <dbl>
##  1 1934   1934 income.taxes     0.7
##  2 1934   1934 corp.taxes       0.6
##  3 1934   1934 social.ins      NA
##  4 1934   1934 excise           2.2
##  5 1934   1934 other            1.3
##  6 1934   1934 total            4.8
##  7 1935   1935 income.taxes     0.7
##  8 1935   1935 corp.taxes       0.8
##  9 1935   1935 social.ins      NA
## 10 1935   1935 excise           2
## 11 1935   1935 other            1.5
## 12 1935   1935 total            5.1
## 13 1936   1936 income.taxes     0.8
## 14 1936   1936 corp.taxes       0.9
## 15 1936   1936 social.ins       0.1
```

This looks like what we want. Notice that there are `NA` values for social insurance spending in the 1930s. If you go back to your original download, you can see that this isn't a mistake. In 1935, there was no social insurance spending.

E.3. Graphs

Let's start with total tax revenue over time. As in the previous section, we need to note `group=1`, and recall that total is `r.long$rtype == 6`.

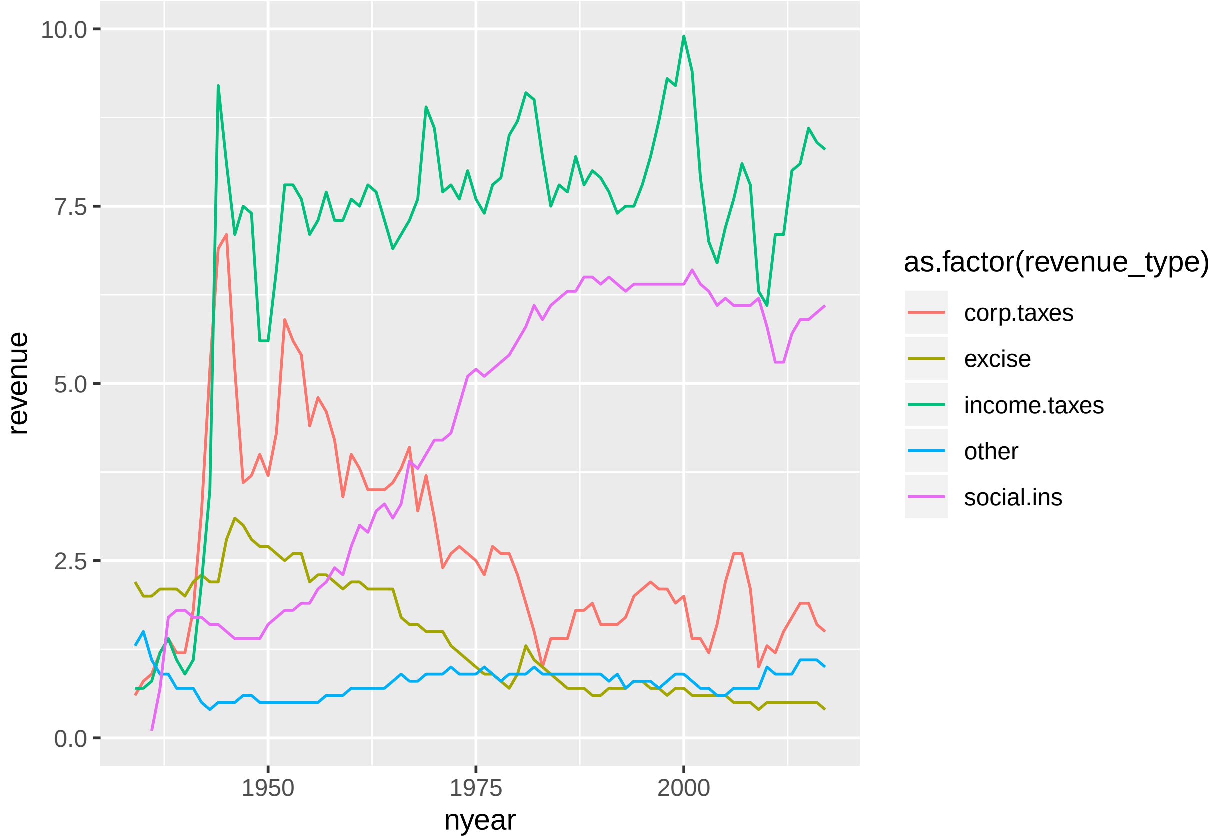
```
#### line chart of total receipts
g4.1 <-
  ggplot() +
  geom_line(data = r.long[which(r.long$revenue_type=="total"),],
            mapping = aes(x=nyear, y=revenue, group=1))
g4.1
```


revenue
20
15
10
5
1950
1975
2000
nyear

Now we'll modify the chart to have all the categories but the total. I do this by subetting `r.long` into all record types that are not total revenue. In addition, I tell R that the group by which we want to make the graph is a variable called `revenue_type`, which R should treat as a factor. We also tell r to color the lines by `revenue_type`, taken as a factor.

```
#### line chart of total receipts by type ###
g4.2 <-
  ggplot() +
  geom_line(data = r.long[which(r.long$revenue_type != "total"),],
            mapping = aes(x=nyear, y=revenue,
                          group=as.factor(revenue_type),
                          color=as.factor(revenue_type)))
g4.2
```

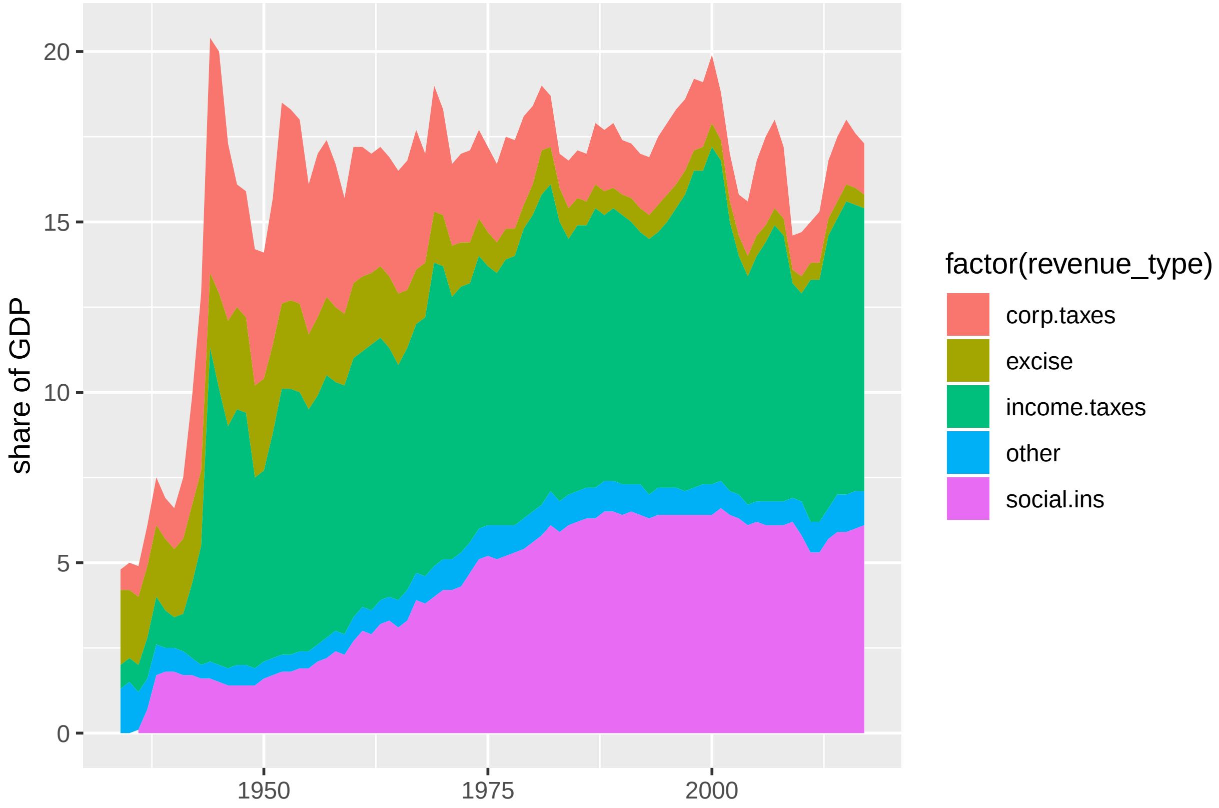
```
## Warning: Removed 2 rows containing missing values (geom_path).
```



This graph is very hard to read. There are too many lines, and we don't get a sense of the total, which may be a key point. An alternative is a stacked line. Stacked likes highlight the total amount, and give readers some sense of the relative share of different categories.

```r
#### stacked chart of total receipts by type ###
## without factor() this doesnt work
g4.3 <- ggplot() +
  geom_area(data = r.long[which(r.long$revenue_type != "total"),],
            mapping = aes(x=nyear, y=revenue, group=factor(revenue_type), fill=factor(revenue_type)),
            position="stack") +
  labs(x="", y="share of GDP")
g4.3
```

```
## Warning: Removed 2 rows containing missing values (position_stack).
```



If you do this, it is freqently wise to put labels on the area portions of the graph and omit the legend. If the areas are too small to label, consider whether you need then individually.

These charts have the same downsides of stacked bars: the numbers for only the bottom category are directly legible from the graph.

E. Homework

1. Modify your code to make the three steps of my DC population over time chart.
2. Using the bikeshare data, re-do one of the by-hour pictures as a minute-by-minute picture. Use one of the y variables we used on an alternative one. Add some annotations to your graph to point out salient features.

3. More stacked areas

Now you try to load your own budget data!

Use Table 1.3 (his01z3.xls), from which we want the year and columns E, F, G and columns I, J and K. Create a new excel document with just this information, and make one row at top with names that you'll understand. Keep just through 2017, and make sure that you don't have any junk at the bottom of the table. Save this file as csv (file, save as, choose "csv" option for file type).

Load it into R and make a stacked area graph of receipts, outlays and deficits over time.

Having done this myself, here are a few suggestions

- make long data, as we did above
- make year numeric, as we did for the social insurance revenue above
- get rid of commas in the data. My command to do this, for one variable, is

```
hist01z3$b1 <- as.numeric(gsub(",", "", hist01z3$cd.receipts, fixed = TRUE))
```