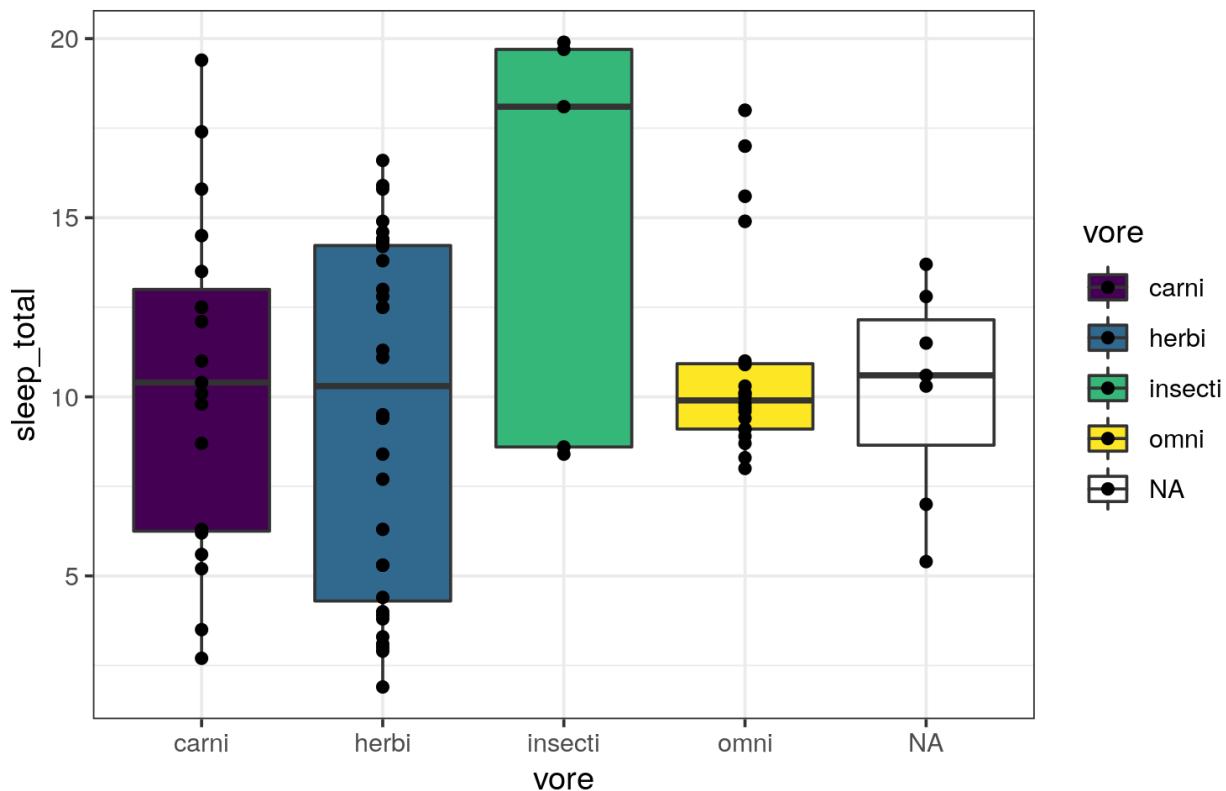


# Creating Figures as an Intro to R

Using the **ggplot2** package



# Introductions

## Dr. Steffi LaZerte

- Background in Biology (Animal Behaviour)
- Working with R since 2007
- Professional R programmer/consultant since 2017



# What about you?

- Name
- Background (Area of study, etc.)
- Familiarity with Computer Programming (C+, Java, HTML, PHP, python, SAS)
- Familiarity with R
  - I've heard of R
  - I've installed R (before this class)
  - I've used R
  - I've used R a lot
  - I use R all the time

# Outline

1. A little about R

2. Creating figures with **ggplot2**

- Basic plot
- Common plot types
- Plotting by categories
- Adding statistics
- Customizing plots
- Annotating plots

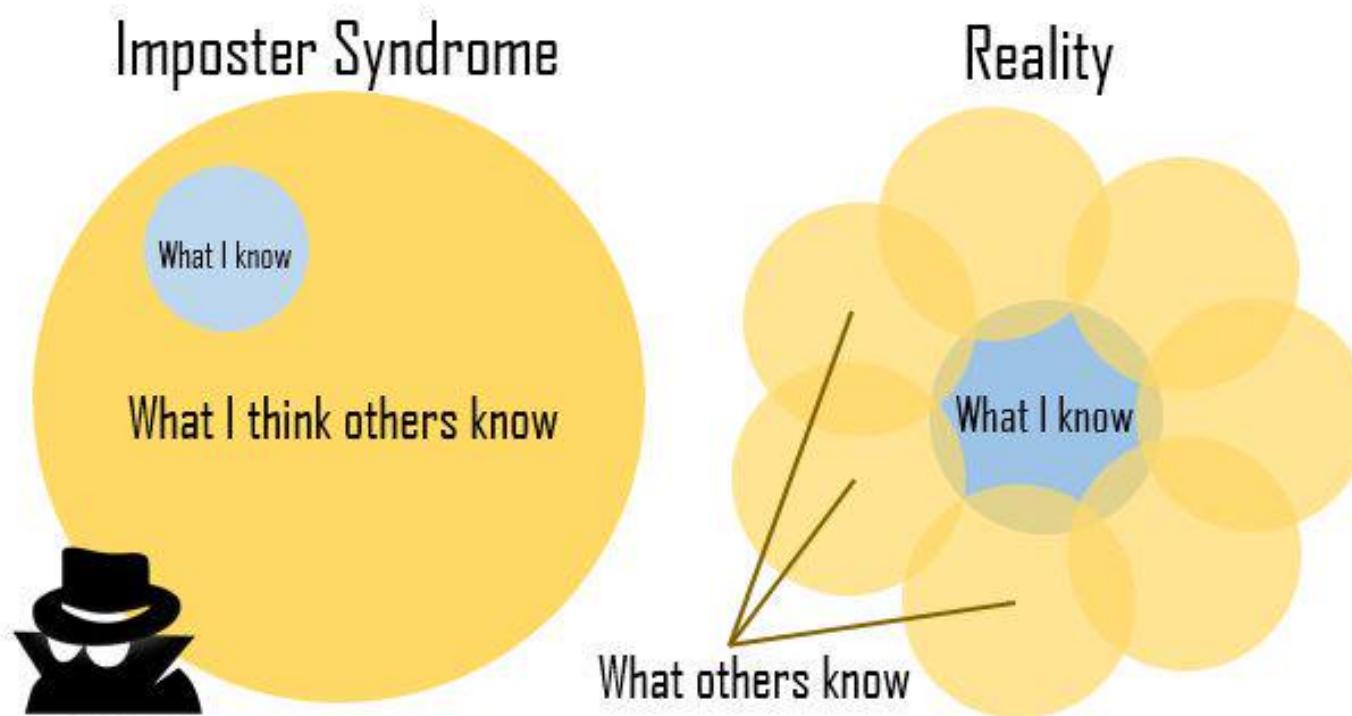
3. Saving figures

4. (EXTRA) Combining figures

# ImpostR Syndrome

ImpostOR  
Syndrome

# ImpostR Syndrome

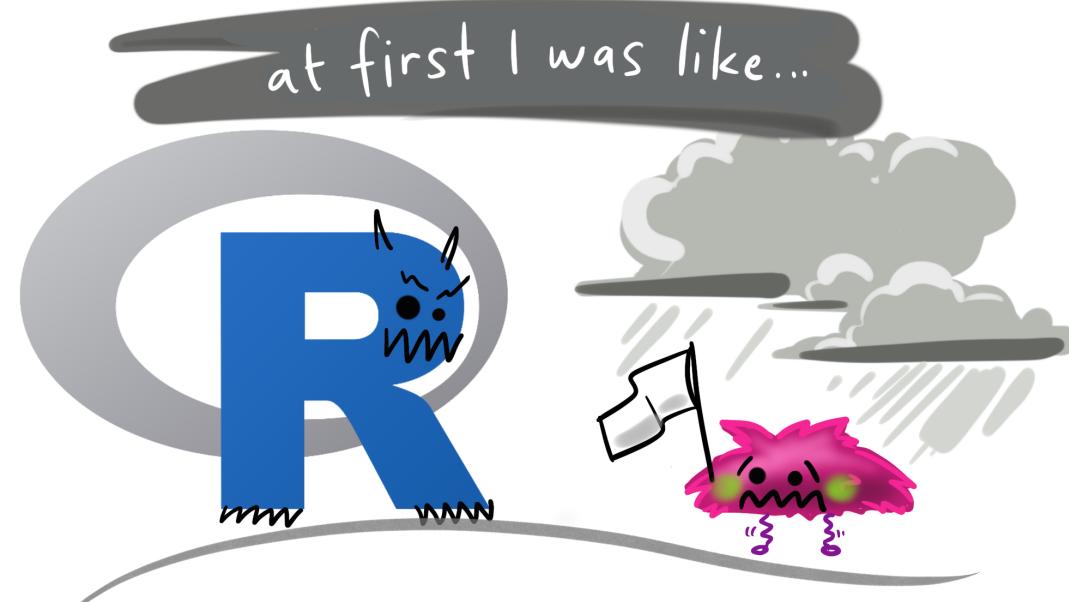


David Whittaker

Impost<sup>R</sup> Syndrome

**Moral of the story?**

Make friends, code in groups, learn together and don't beat yourself up



...but now it's like...



# Why R?

# Why R?

## R is hard

```
# Get in circle around city
circle <- data.frame()
cutoff <- 10
for(i in unique(gps$region)) {
  n <- nrow(gps[gps$region == i,]) ##number of IDs
  if(i == "wil") tmp <- geocode("Williams Lake, Canada")
  if(i == "kam") tmp <- geocode("Kamloops, Canada")
  if(i == "kel") tmp <- geocode("Kelowna, Canada")
  temp <- data.frame()
  for(a in 1:n){
    if(a <= cutoff) temp <- rbind(temp, gcDestination(lon = tmp$lon,
                                                       lat = tmp$lat,
                                                       bearing = (a*(360/(cutoff))-360/(cutoff)),
                                                       dist = 20,
                                                       dist.units = "km",
                                                       model = "WGS84"))
    if(a > cutoff) temp <- rbind(temp, gcDestination(lon = tmp$lon,
                                                       lat = tmp$lat,
                                                       bearing = ((a-cutoff)*(360/(max(table(gps$region
)))-10))-360/(max(table(gps$region))-cutoff)),
                                                       dist = 35,
                                                       dist.units = "km",
                                                       model = "WGS84"))
  }
  circle <- rbind(circle, cbind(temp,
                                 region = i,
                                 hab = gps$hab[gps$region == i],
                                 spl = gps$spl.orig[gps$region == i],
                                 lon = tmp$lon,
                                 lat = tmp$lat)))
}
circle
```

# Why R?

But R is powerful (and reproducible)!

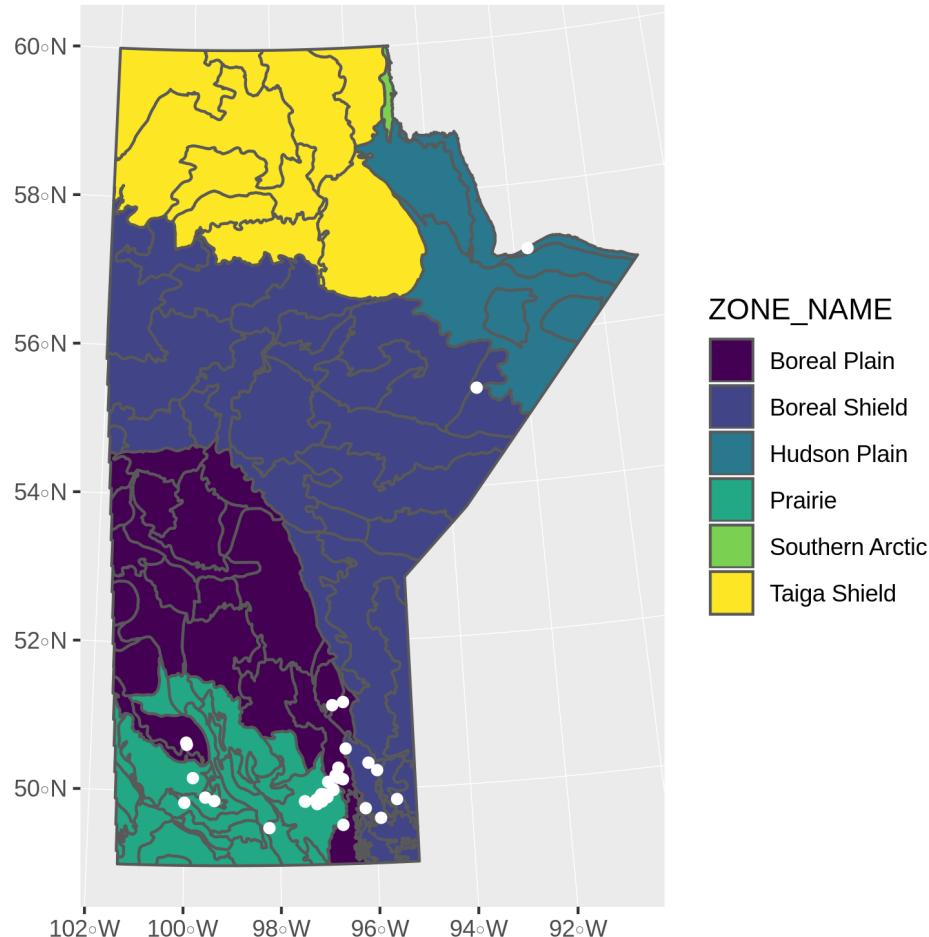
The screenshot shows the R Global Environment window. It has three main sections: Data, Values, and Functions.

- Data**:
  - `fish`: 172 obs. of 13 variables
  - `telem_total`: 12950046 obs. of 10 variables
- Values**:
  - `tz`: "Etc/GMT+8"
- Functions**:
  - `load_data`: function (x)

A green oval highlights the value for `telem_total`, which is 12950046 obs. of 10 variables.

# Why R?

R is also beautiful



# Why R?

## R is affordable (i.e. free!)

R is available as Free Software under the terms of the [Free Software Foundation's GNU General Public License](#) in source code form. It compiles and runs on a wide variety of UNIX platforms and similar systems (including FreeBSD and Linux), Windows and MacOS.

# What is R?

# R is Programming language

A programming **language** is a way to give instructions in order to get a computer to do something

- You need to know the language (i.e. the code)
- Computers don't know what you mean, only what you type (unfortunately)
- Spelling, punctuation, and capitalization all matter!

## For example

R, what is 56 times 5.8?

```
56 * 5.8
```

```
## [1] 324.8
```

# Use code to tell R what to do

R, what is the average of numbers 1, 2, 3, 4?

```
mean(c(1, 2, 3, 4))
```

```
## [1] 2.5
```

R, save this value for later

```
steffis_mean <- mean(c(1, 2, 3, 4))
```

R, multiply this value by 6

```
steffis_mean * 6
```

```
## [1] 15
```

# Code, Output, Scripts

## Code

- The actual commands

## Output

- The result of running code or a script

## Script

- A text file full of code that you want to run
- You should **always** keep your code in a script

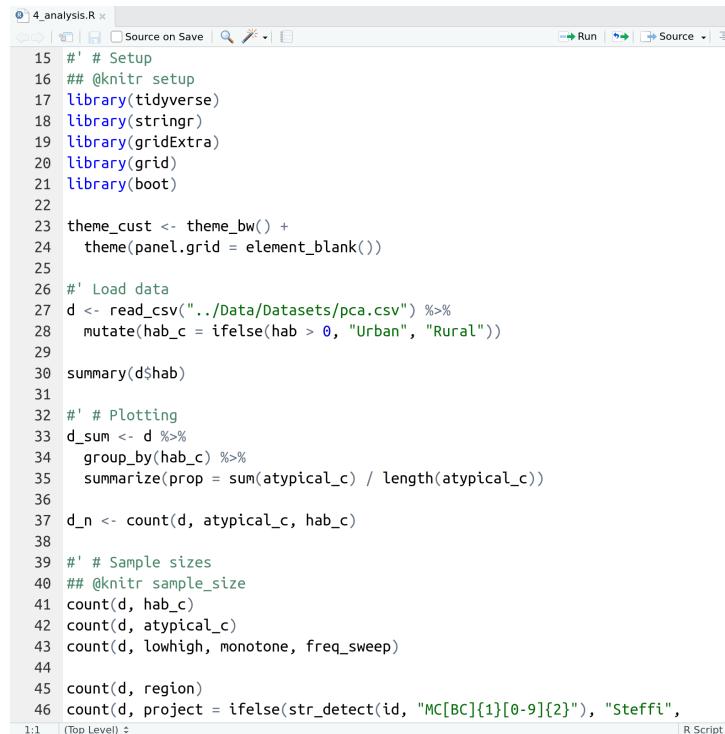
## For example:

```
mean(c(1, 2, 3, 4))
```

Code

```
## [1] 2.5
```

Output



```
15 #' # Setup
16 ## @knitr setup
17 library(tidyverse)
18 library(stringr)
19 library(gridExtra)
20 library(grid)
21 library(boot)
22
23 theme_cust <- theme_bw() +
24   theme(panel.grid = element_blank())
25
26 #' Load data
27 d <- read_csv("../Data/Datasets/pca.csv") %>%
28   mutate(hab_c = ifelse(hab > 0, "Urban", "Rural"))
29
30 summary(d$hab)
31
32 #' # Plotting
33 d_sum <- d %>%
34   group_by(hab_c) %>%
35   summarize(prop = sum(atypical_c) / length(atypical_c))
36
37 d_n <- count(d, atypical_c, hab_c)
38
39 #' # Sample sizes
40 ## @knitr sample_size
41 count(d, hab_c)
42 count(d, atypical_c)
43 count(d, lowhigh, monotone, freq_sweep)
44
45 count(d, region)
46 count(d, project = ifelse(str_detect(id, "MC[BC]{1}[0-9]{2}"), "Steffi",
```

Script

# RStudio vs. R



RStudio



R

- **RStudio** is not **R**
- RStudio is a User Interface or IDE (integrated development environment)
  - (i.e., Makes coding simpler)

# R Basics: Objects

Objects are *things* in the environment

(Check out the **Environment** pane in RStudio)

# functions() - Do things, Return things

`mean()`, `read_csv()`, `ggplot()`, `c()`, etc.

- Always have ()
- Can take **arguments** (think 'options')
  - `mean(x = c(2, 10, 45))`,
  - `mean(x = c(NA, 10, 2, 65), na.rm = TRUE)`
- Arguments defined by **name** or by **position**
- With correct position, do not need to specify by name

**By name:**

```
mean(x = c(1, 5, 10))
```

```
## [1] 5.333333
```

**By position:**

```
mean(c(1, 5, 10))
```

```
## [1] 5.333333
```

# R documentation

?mean

mean {base}

R Documentation

## Arithmetic Mean

### Description

Generic function for the (trimmed) arithmetic mean.

### Usage

```
mean(x, ...)  
## Default S3 method:  
mean(x, trim = 0, na.rm = FALSE, ...)
```

### Arguments

- x An R object. Currently there are methods for numeric/logical vectors and [date](#), [date-time](#) and [time interval](#) objects. Complex vectors are allowed for trim = 0, only.
- trim the fraction (0 to 0.5) of observations to be trimmed from each end of x before the mean is computed. Values of trim outside that range are taken as the nearest endpoint.
- na.rm a logical value indicating whether NA values should be stripped before the computation proceeds.
- ... further arguments passed to or from other methods.

# Data

Generally kept in **vectors** or **data.frames**

- These are objects with names (like functions)
- We can use `<-` to assign values to objects (assignment)

## Vector (1 dimension)

```
my_data <- c("a", 100, "c")  
my_data  
  
## [1] "a"    "100"   "c"
```

## Data frame (2 dimensions)

```
my_data <- data.frame(site = c("s1", "s2", "s3"),  
                      count = c(101, 102, 103),  
                      treatment = c("a", "b", "c"))  
  
my_data
```

```
##   site count treatment  
## 1   s1    101         a  
## 2   s2    102         b  
## 3   s3    103         c
```

rows x columns

# R Basics: Code

# Your first code

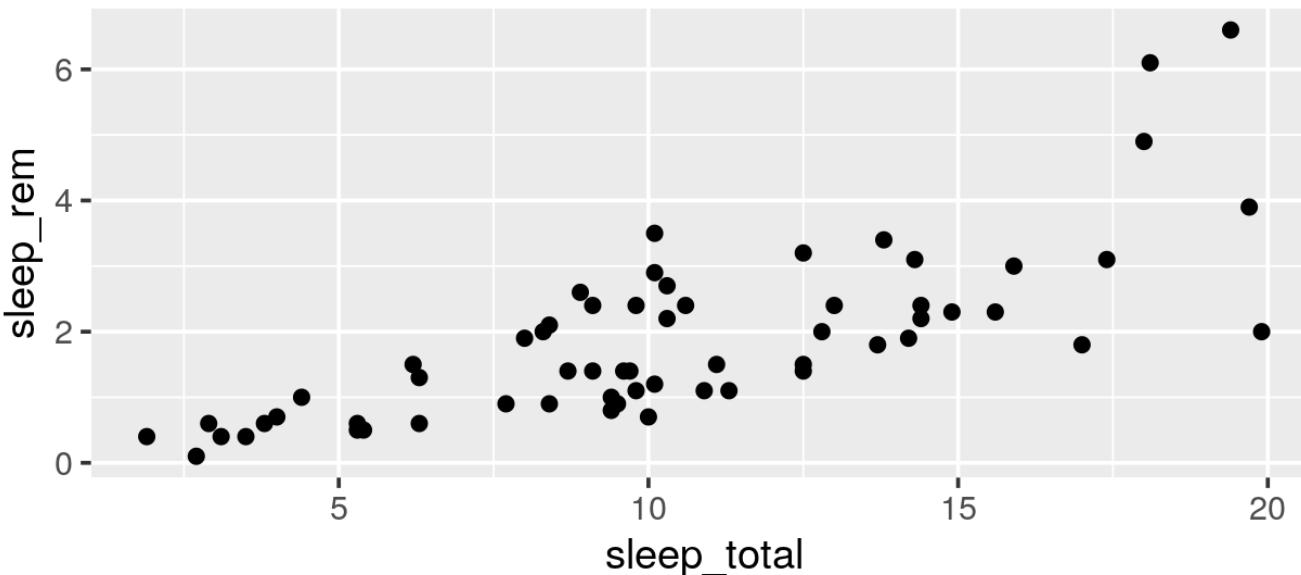
```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```

- Copy/paste or type this into the script window in RStudio
- Click anywhere on the first line of code
- Use the 'Run' button to run this code, **or** use the short-cut **Ctrl-Enter**
  - Repeat until all the code has run

# First Code

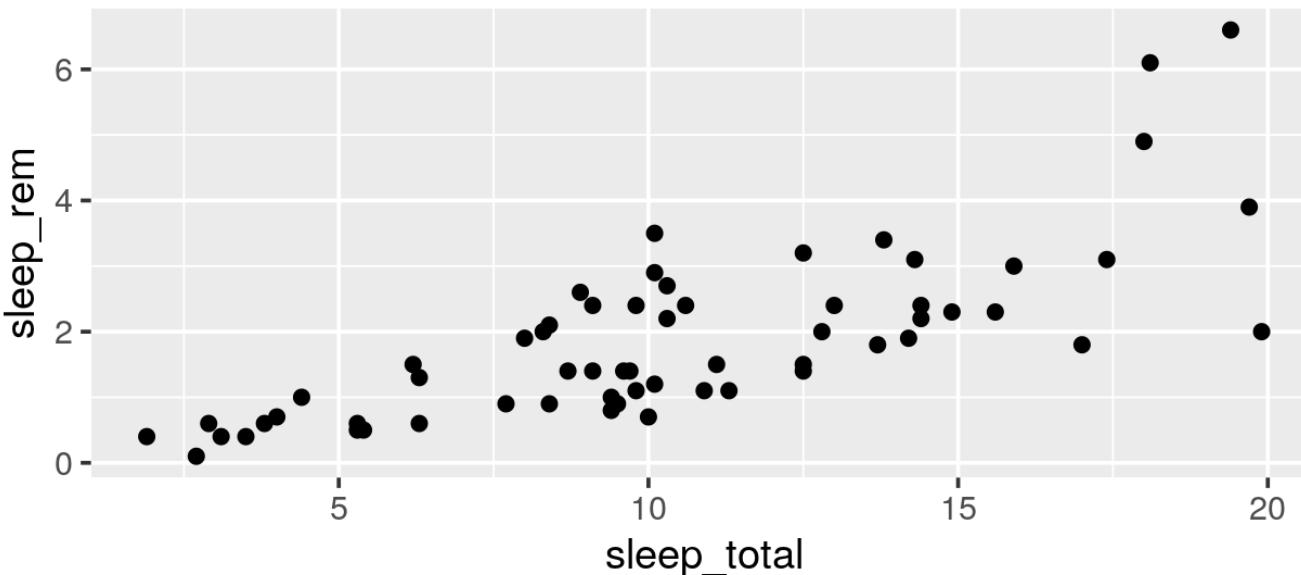
```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://raw.githubusercontent.com/rfordatascience/tidytuesday/master/data/sleep/sleep.csv")
# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```



Package  
**tidyverse**

# First Code

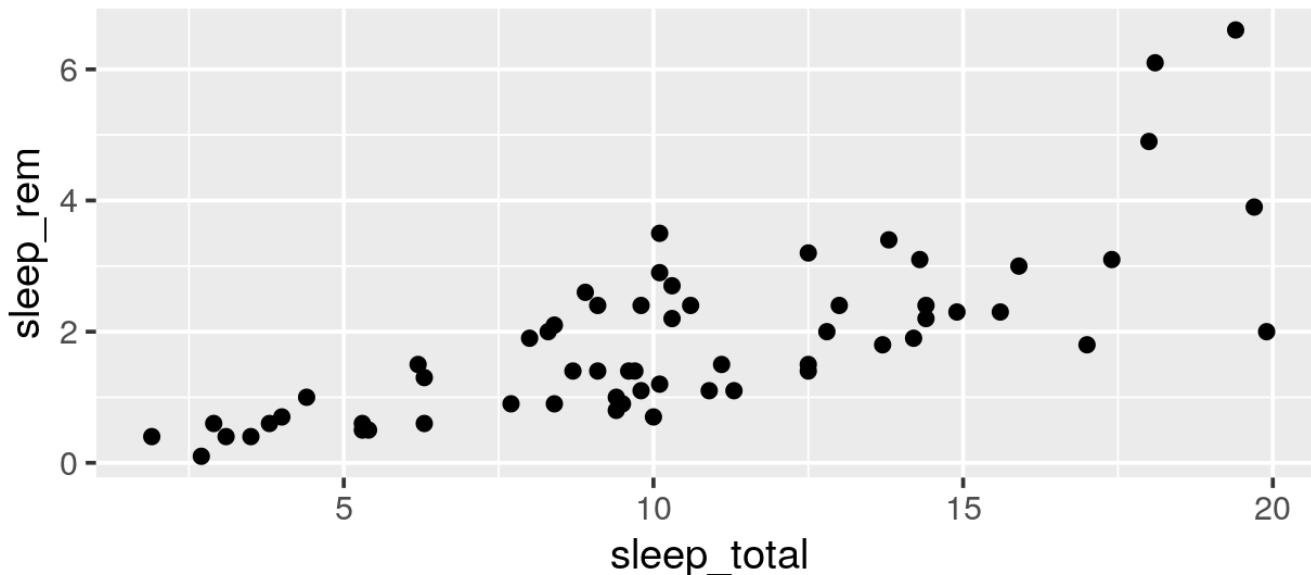
```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://raw.githubusercontent.com/rfordatascience/tidytuesday/master/data/sleep/sleep.csv")
# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```



Function  
**library()**

# First Code

```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF") Function  
read_csv()
# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```

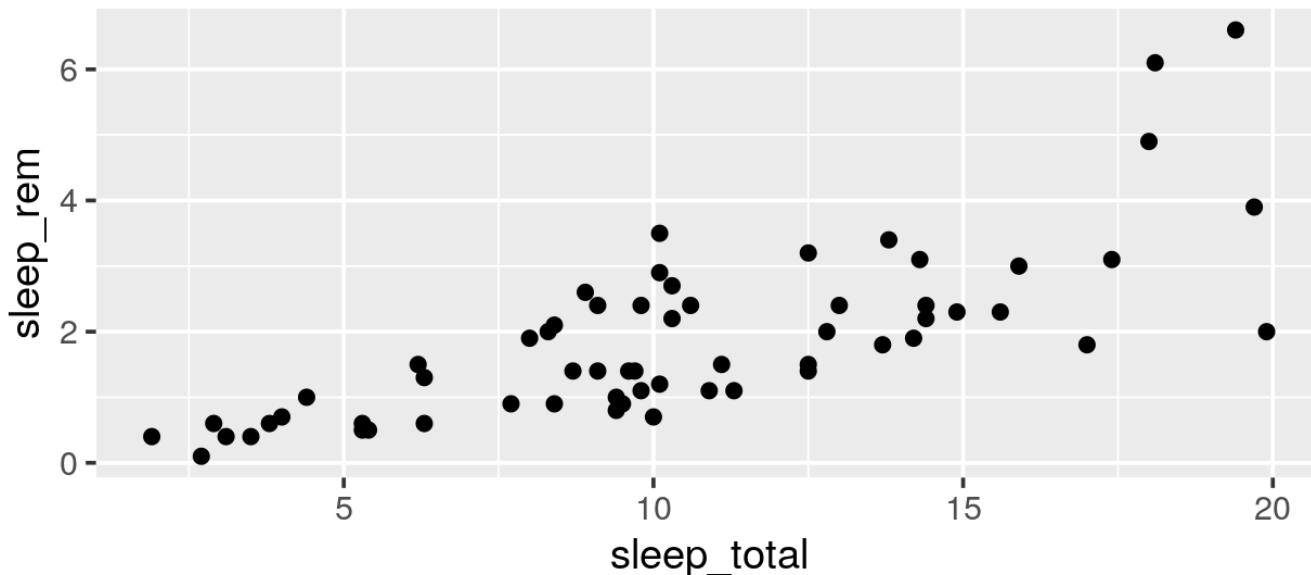


# First Code

```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```

Function  
**ggplot()**

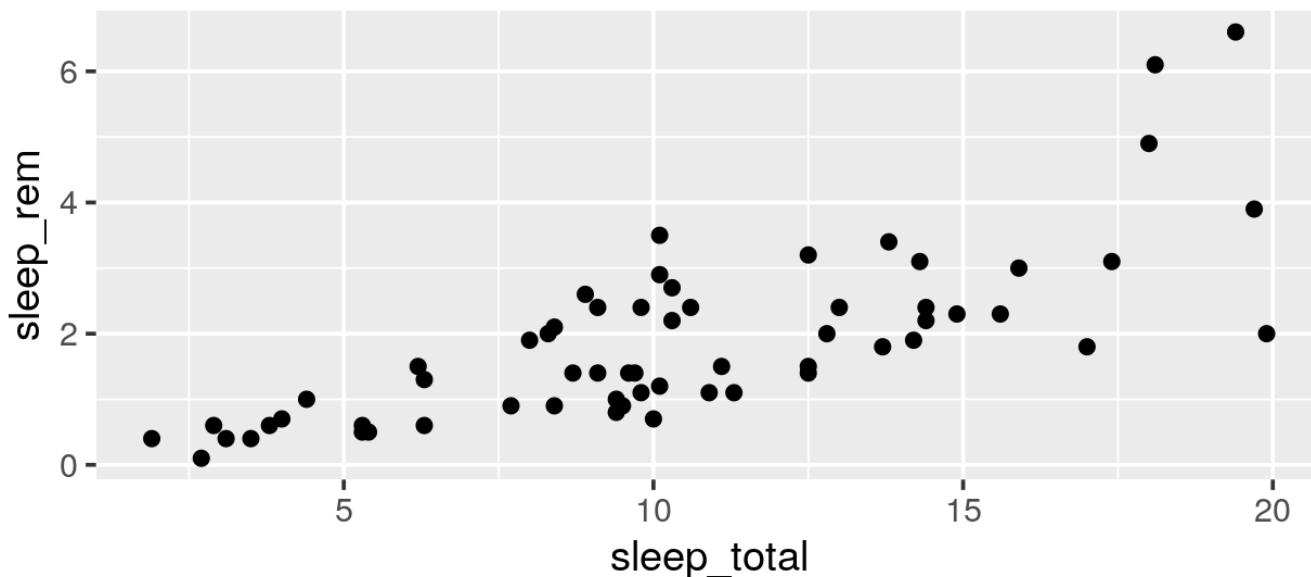


# First Code

```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```

Function  
**aes()**



# First Code

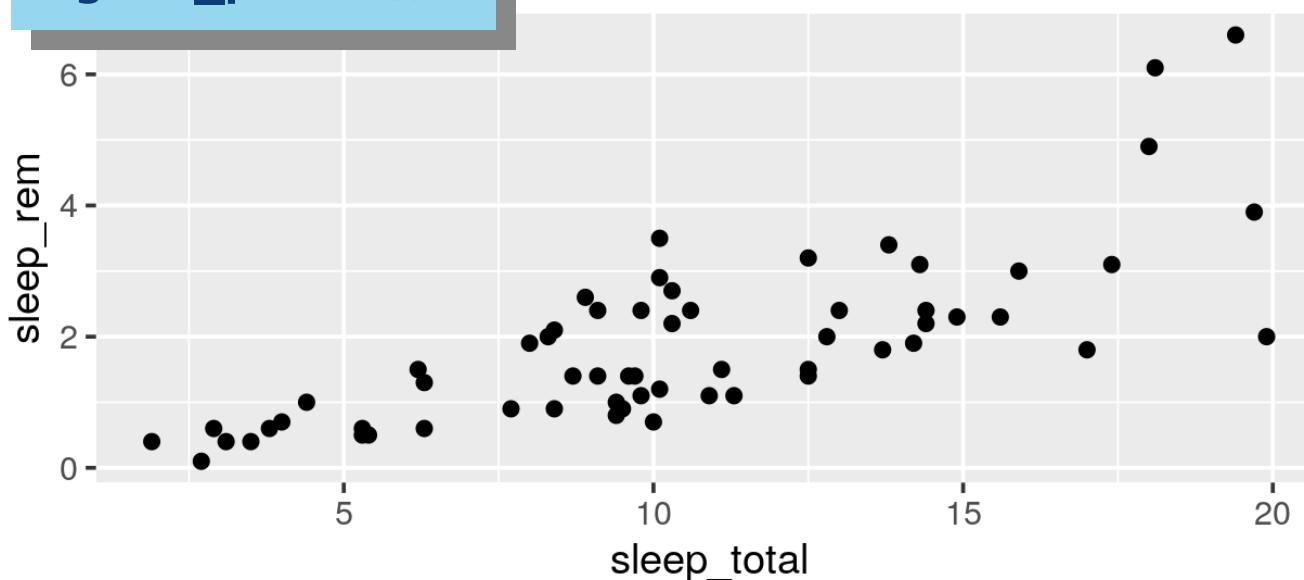
```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")
```

# Now create the figure

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
```

geom\_point()

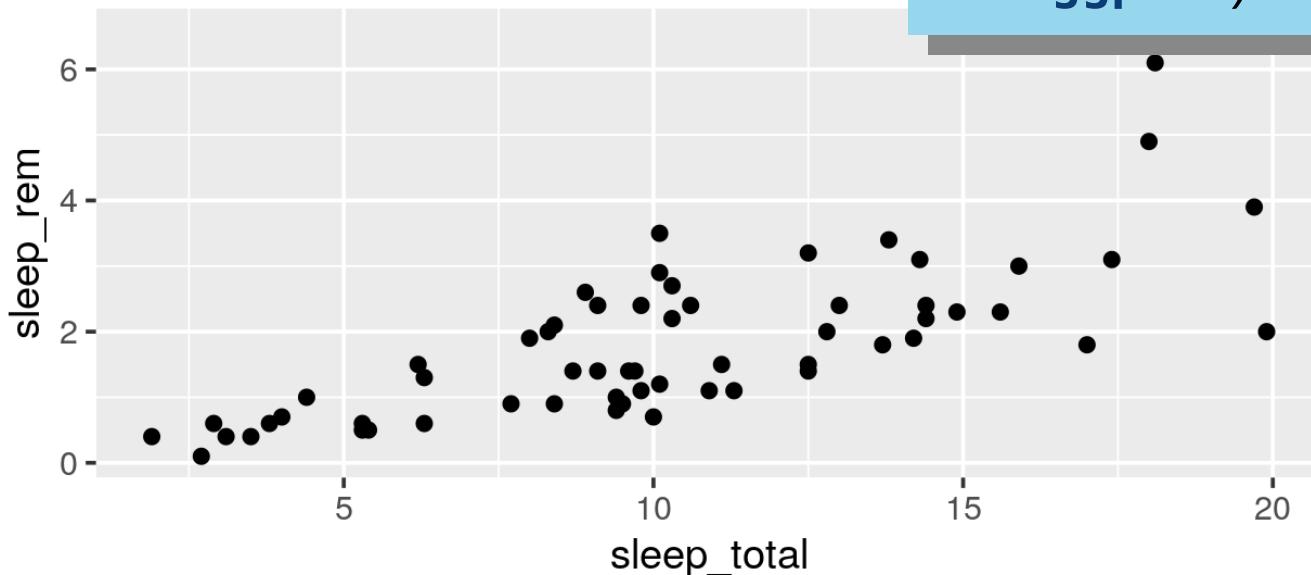
Function  
**geom\_point()**



# First Code

```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point()
```

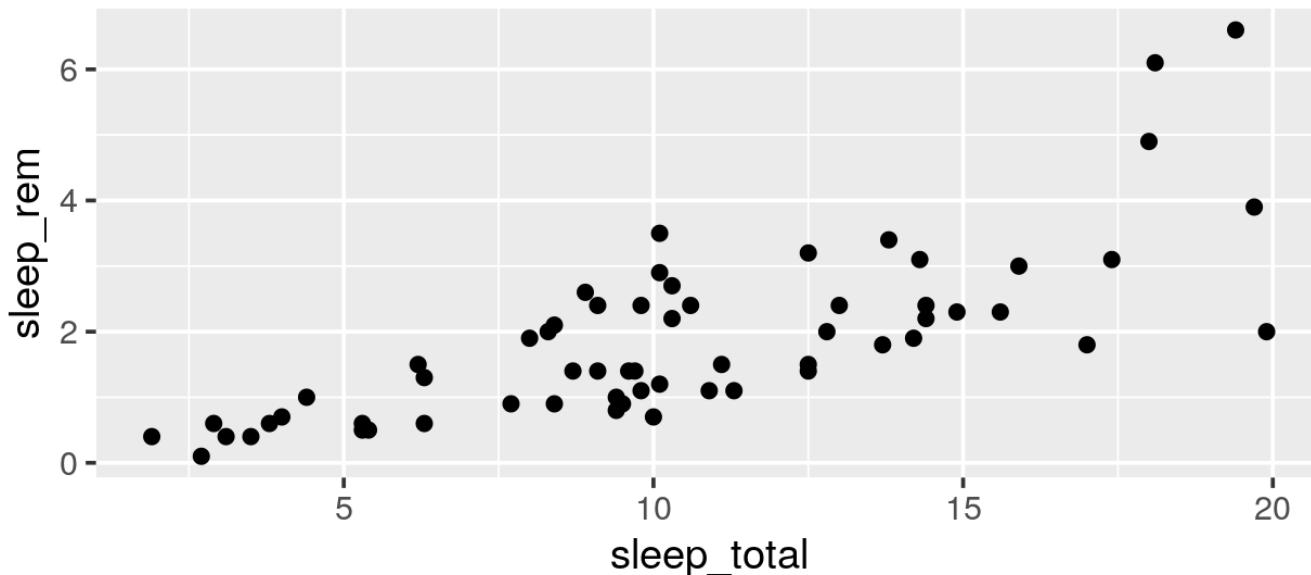


+  
(Specific to  
**ggplot**)

# First Code

```
# First load the package and data
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```



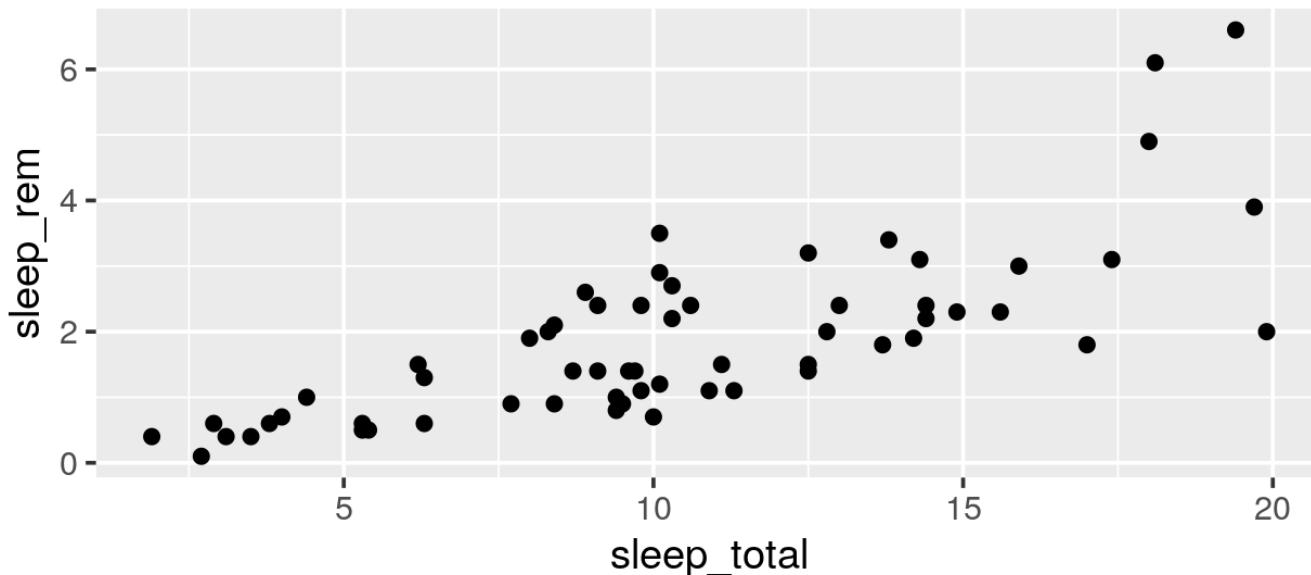
Figure!

# First Code

```
# First load the package
library(tidyverse)
sleep <- read_csv("https://git.io/Je6DF")

# Now create the figure
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +
  geom_point()
```

Comments



# Hooray!

## Time for Figures!

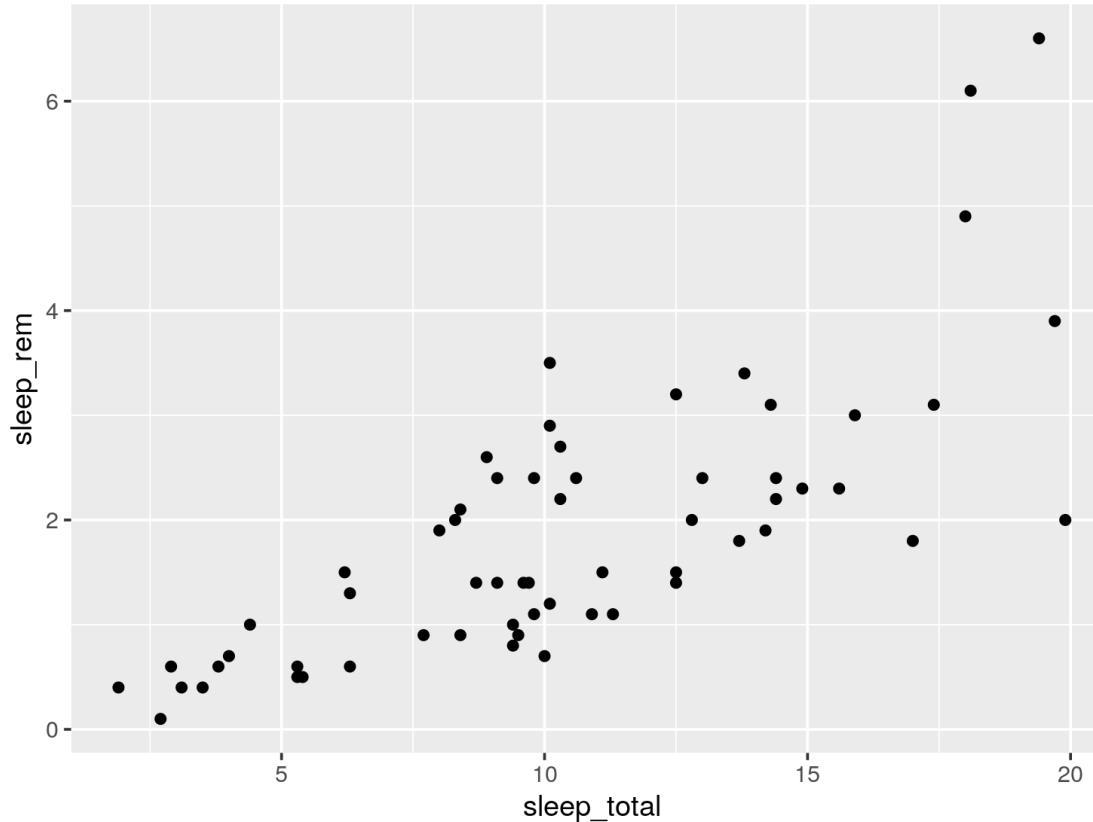
# ggplot2:

Build a data  
MASTERpiece



# A basic plot

```
library(ggplot2) # Also inside the tidyverse  
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point()
```



# Break it down

```
library(ggplot2) # Also inside the tidyverse  
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point()
```

**ggplot(data = sleep, aes(x = sleep\_total, y = sleep\_rem))**

- Load the **ggplot2** (or **tidyverse**) package
- Set the attributes of your plot
- **data** = Dataset
- **aes** = Aesthetics (how the data are used)
- Think of this as your plot defaults

# Break it down

```
library(ggplot2) # Also inside the tidyverse  
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point()
```

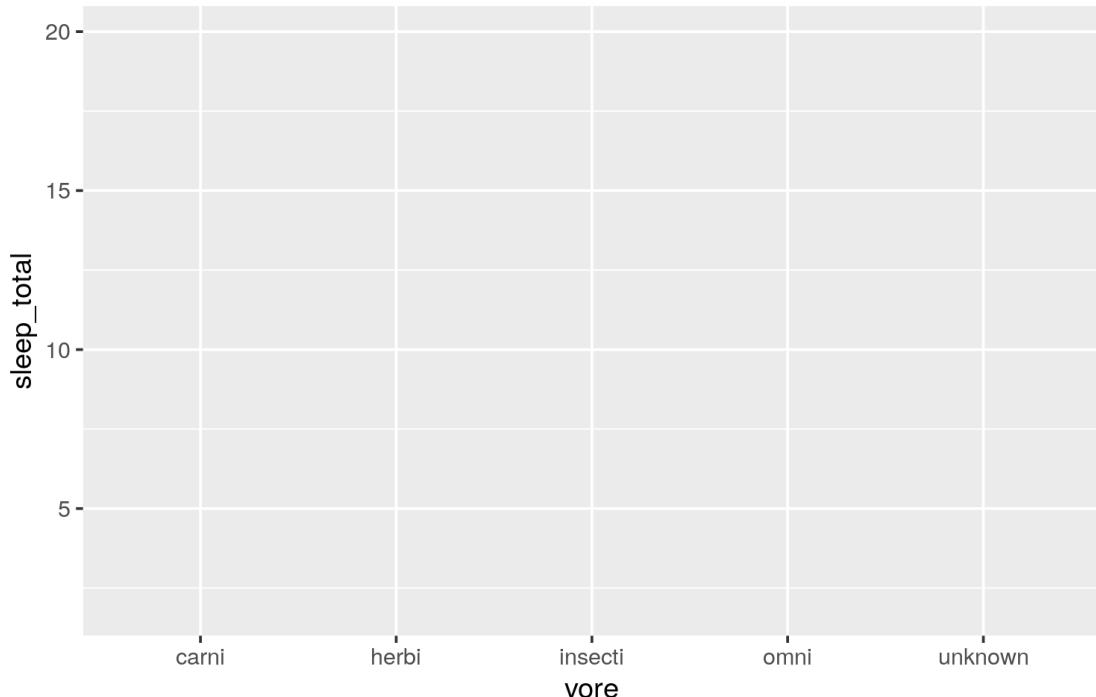
## **geom\_point()**

- Choose a **geom** function to display the data
- Always *added* to a **ggplot()** call with **+**

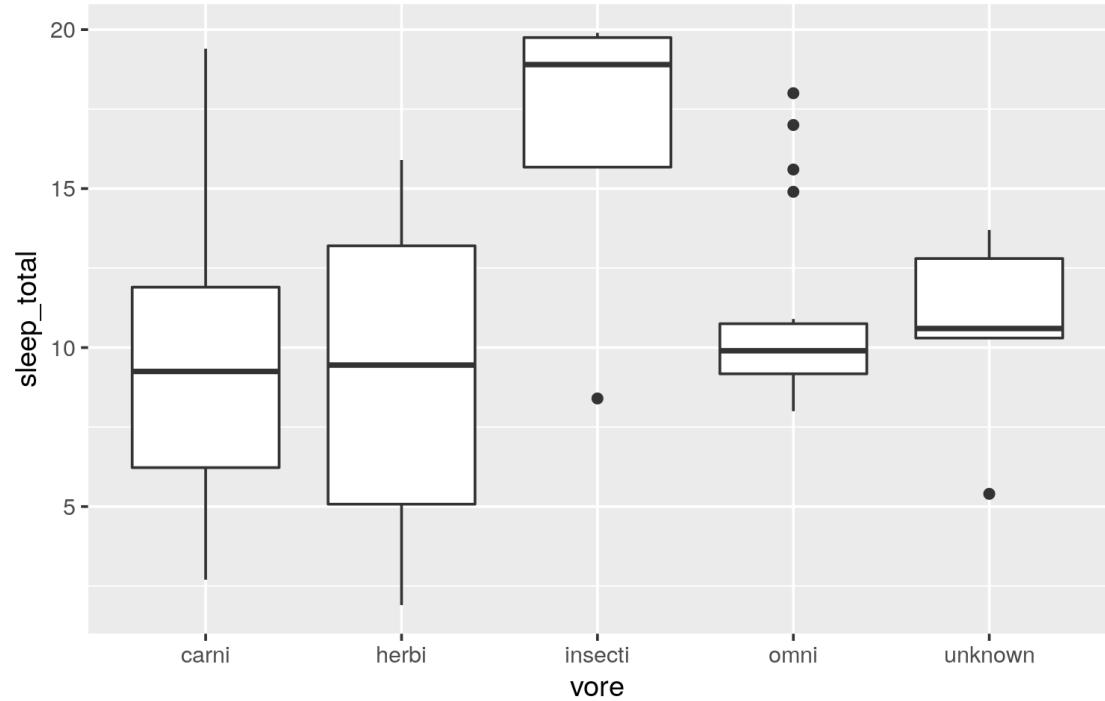
ggplots are essentially layered objects, starting with a call to **ggplot()**

# Plots are layered

```
ggplot(data = sleep, aes(x = vore, y = sleep_total))
```

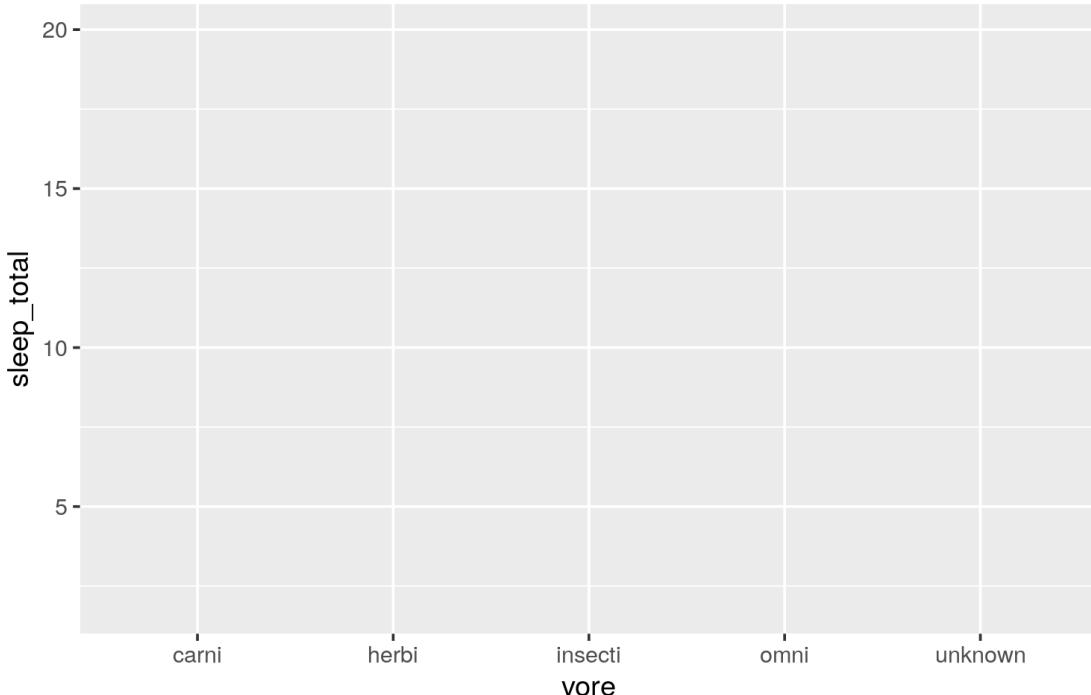


```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  geom_boxplot()
```

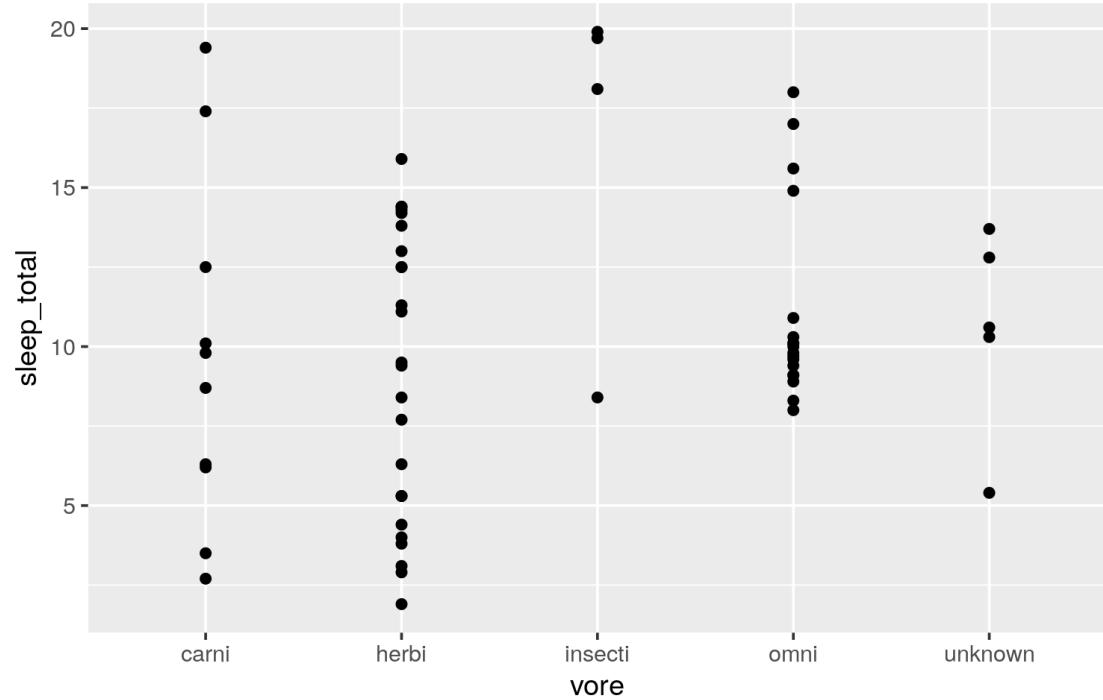


# Plots are layered

```
ggplot(data = sleep, aes(x = vore, y = sleep_total))
```

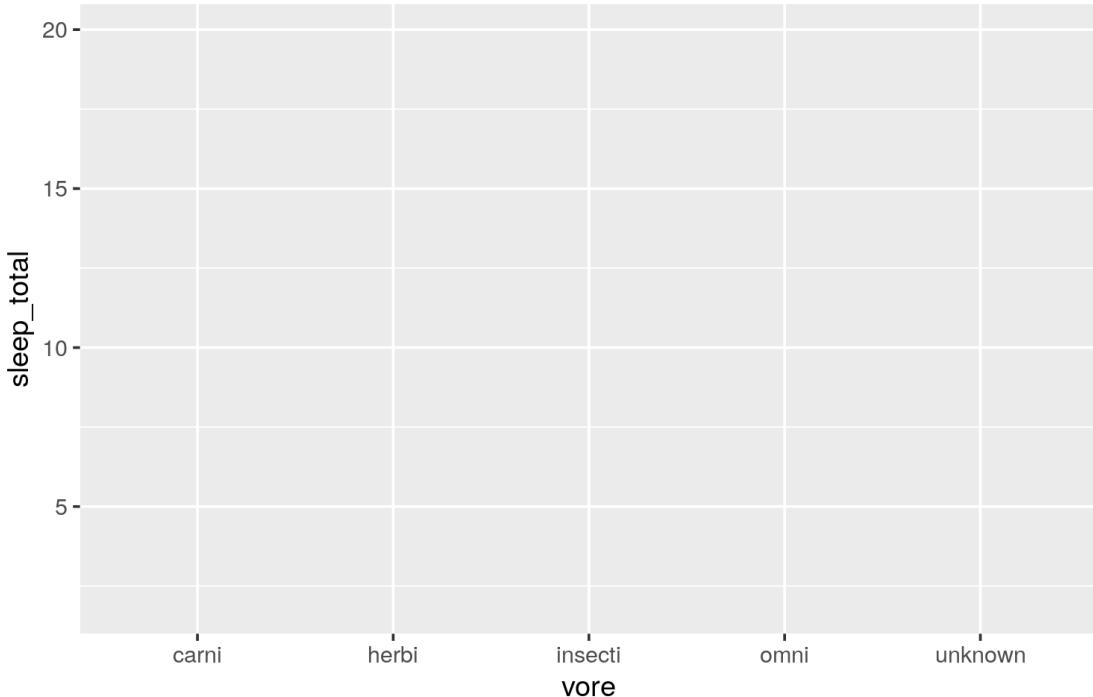


```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  geom_point()
```

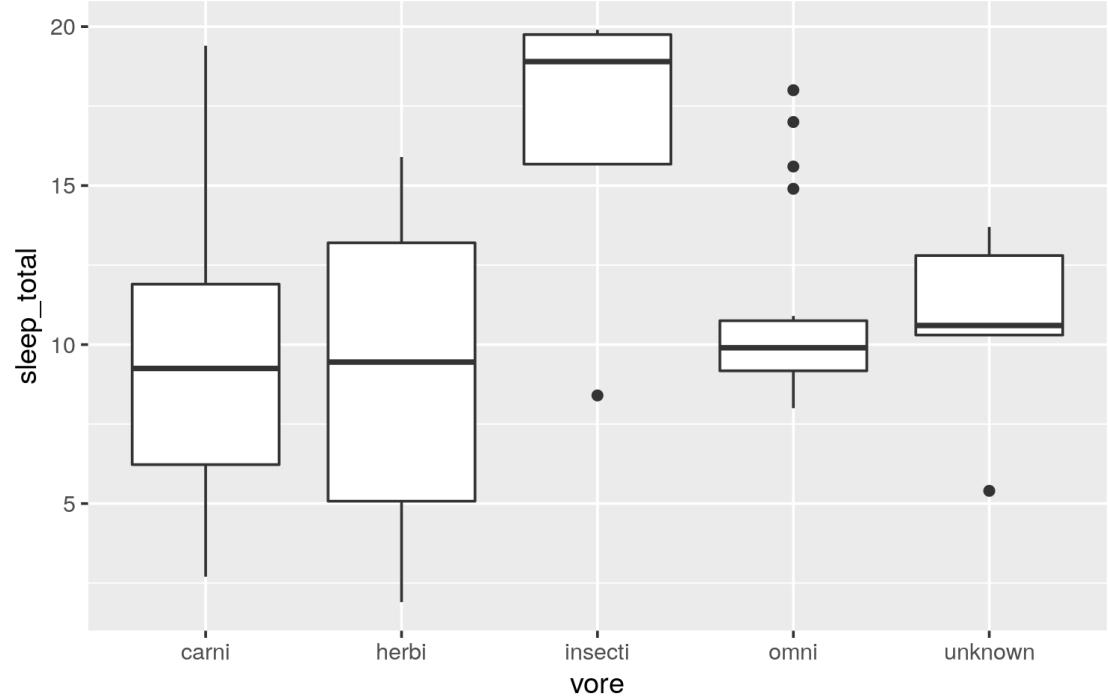


# Plots are layered

```
ggplot(data = sleep, aes(x = vore, y = sleep_total))
```

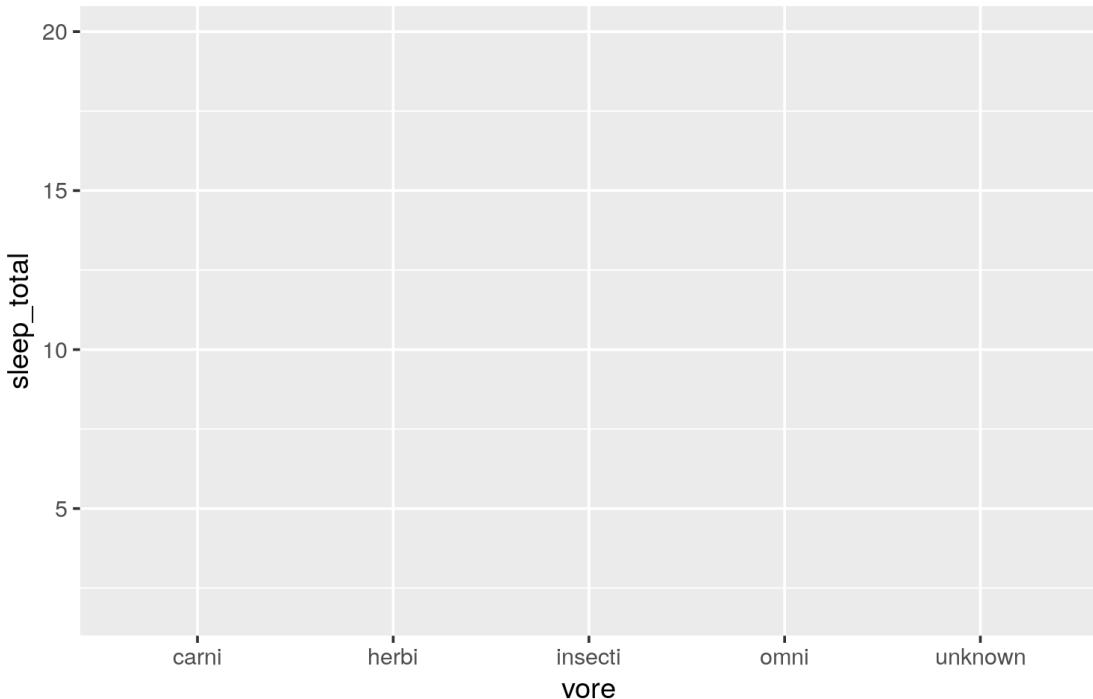


```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  geom_boxplot()
```

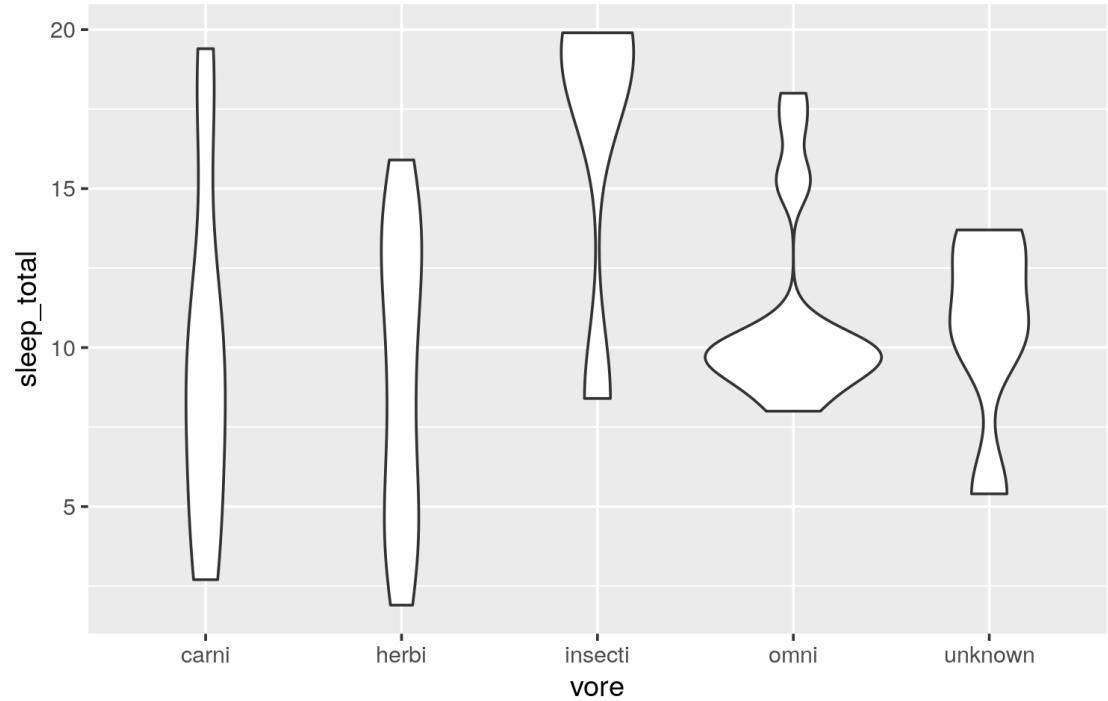


# Plots are layered

```
ggplot(data = sleep, aes(x = vore, y = sleep_total))
```



```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  geom_violin()
```

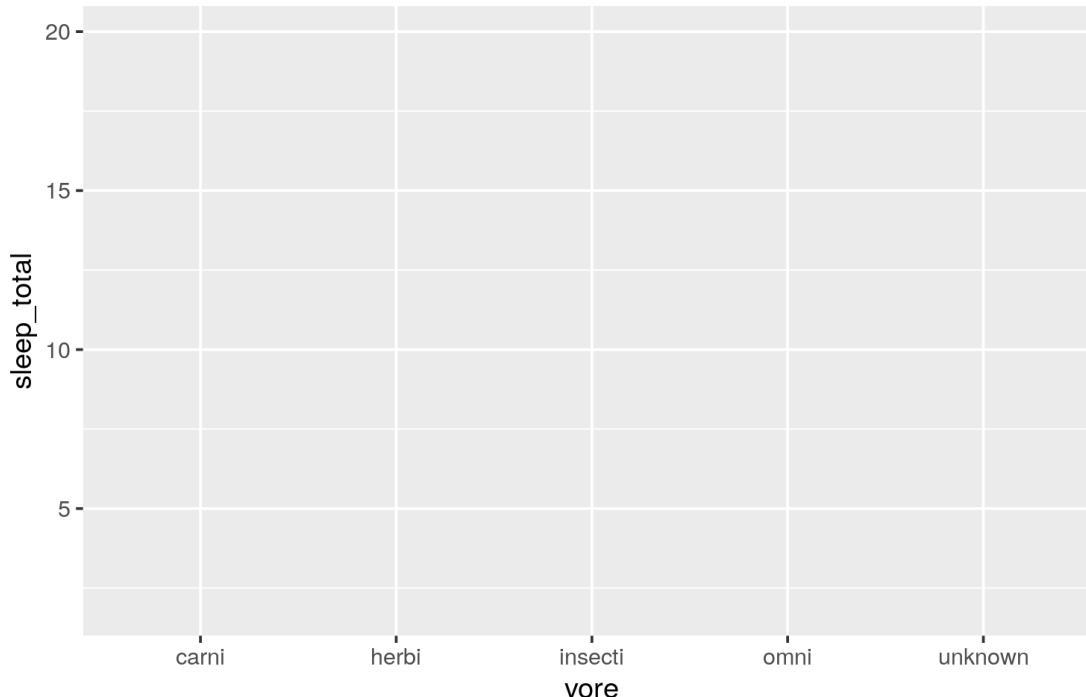


# Plots are objects

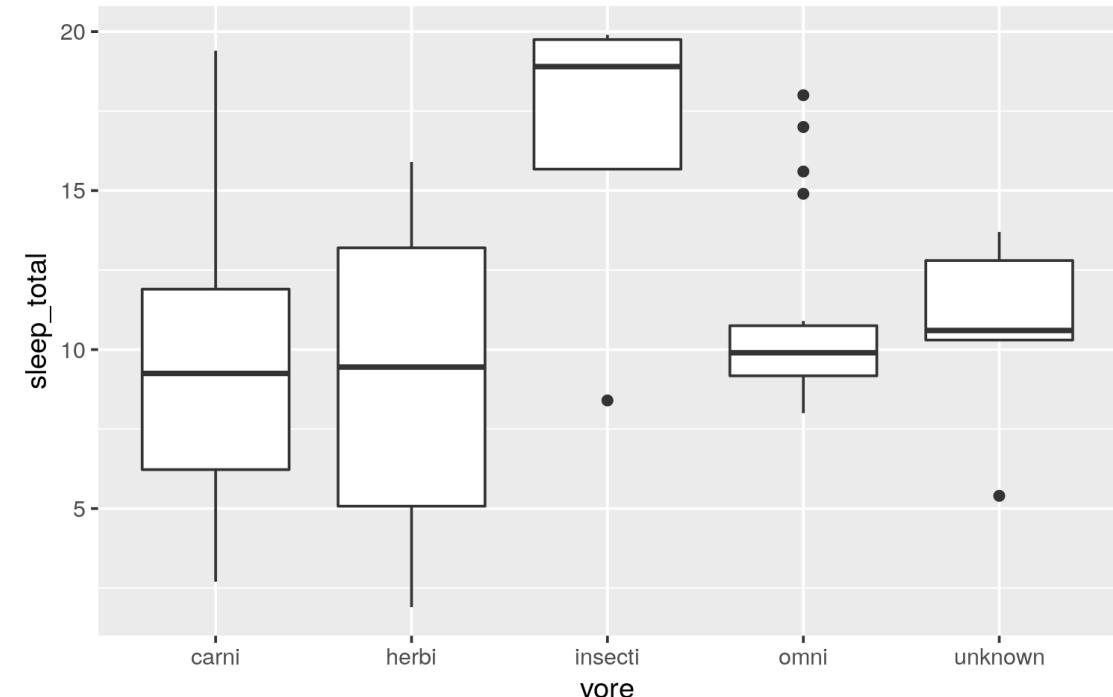
Any ggplot can be saved as an object

```
g <- ggplot(data = sleep, aes(x = vore, y = sleep_total))
```

```
g
```



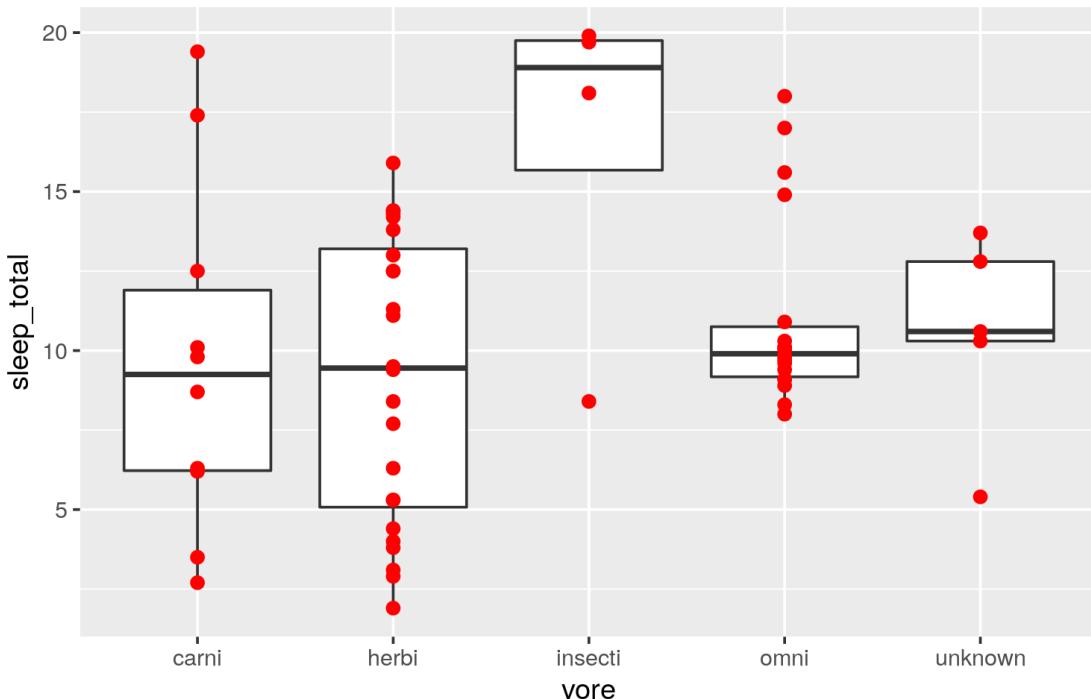
```
g + geom_boxplot()
```



# Layering

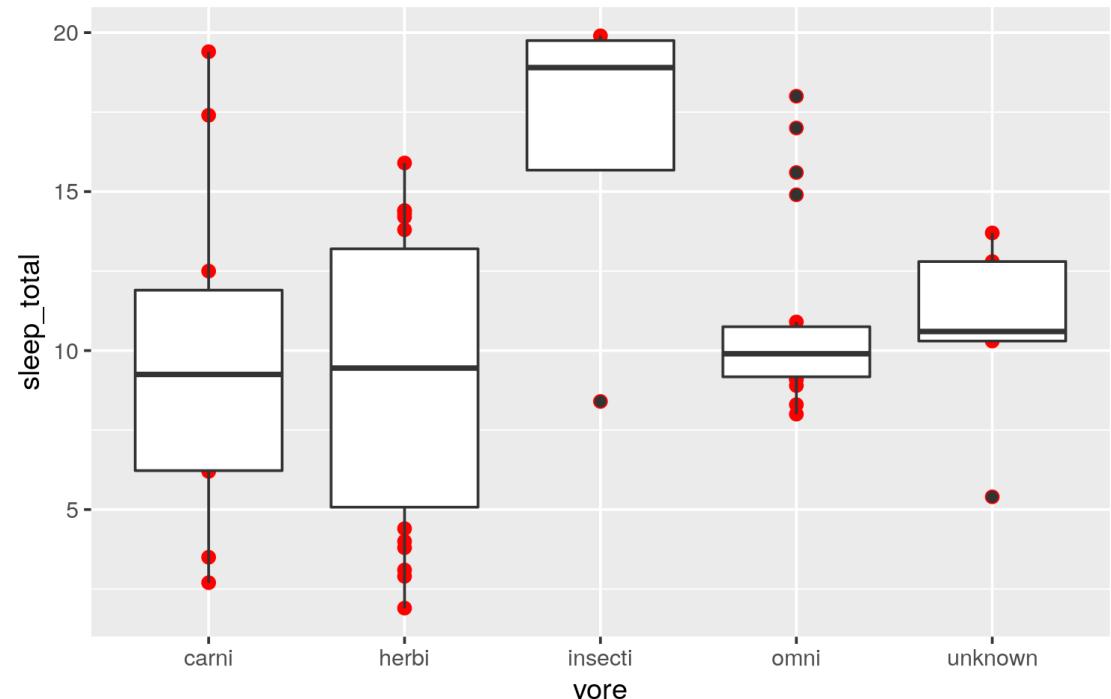
You can add multiple layers

```
g +  
  geom_boxplot() +  
  geom_point(size = 2, colour = "red")
```



Order matters

```
g +  
  geom_point(size = 2, colour = "red") +  
  geom_boxplot()
```

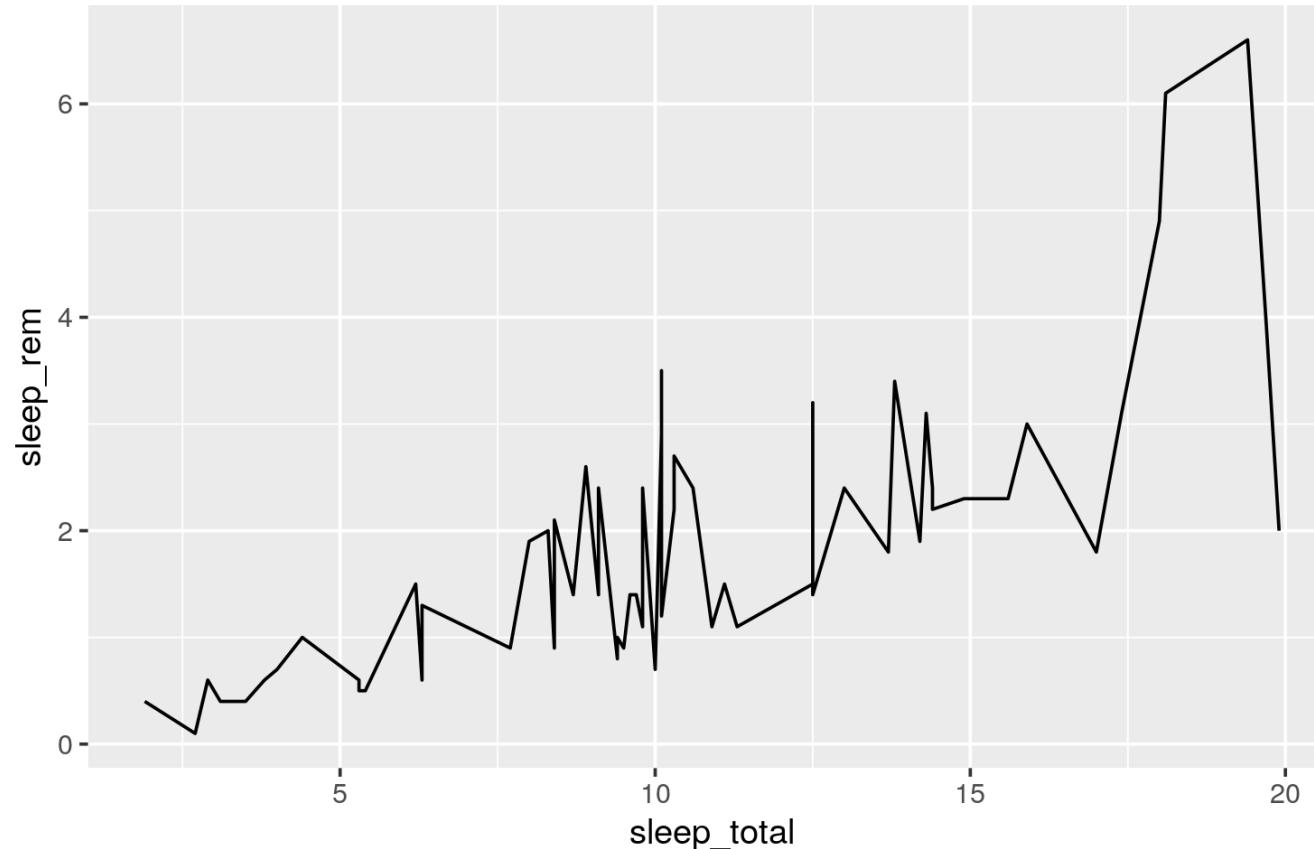


# More Geoms

(Plot types)

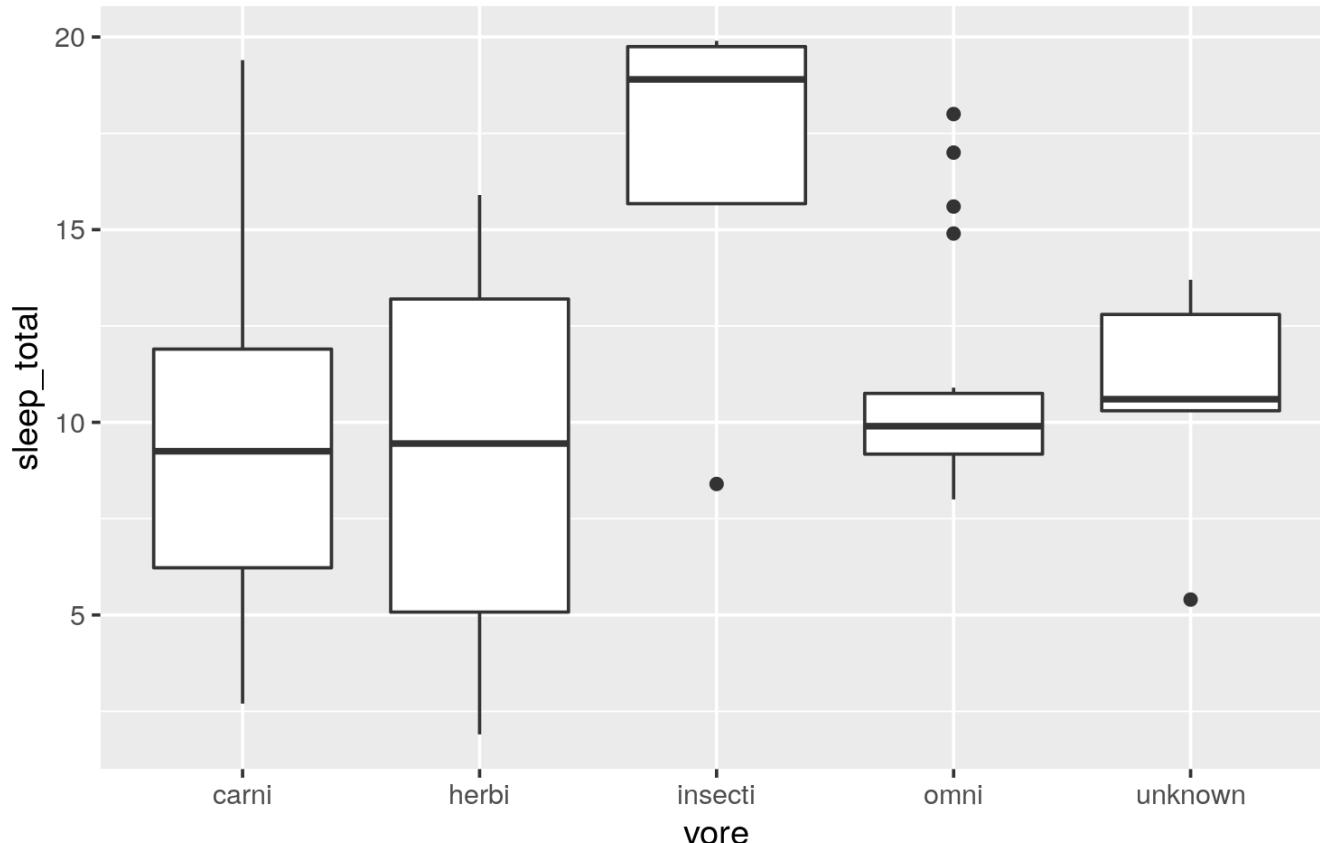
# Geoms: Lines

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_line()
```



# Geoms: Boxplots

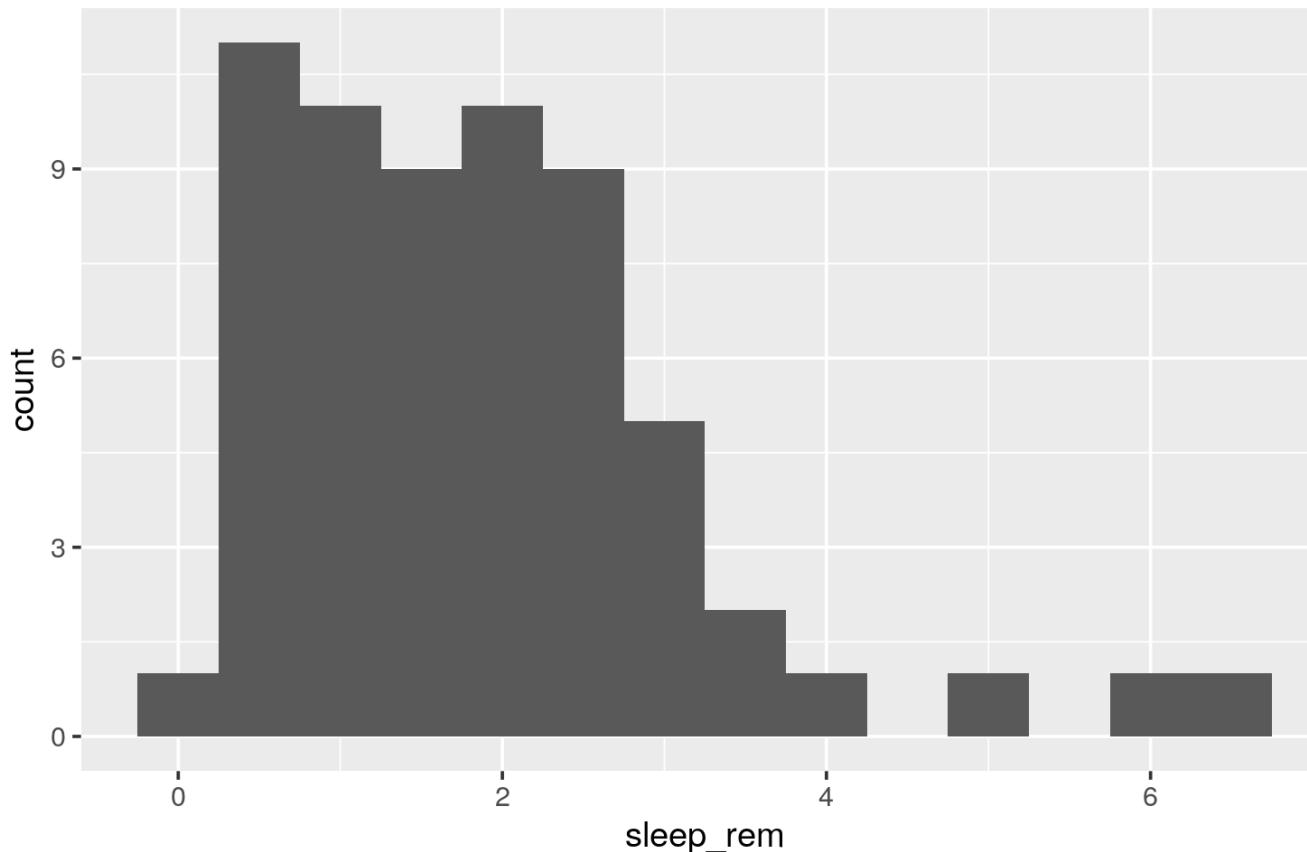
```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  geom_boxplot()
```



# Geoms: Histogram

```
ggplot(data = sleep, aes(x = sleep_rem)) +  
  geom_histogram(binwidth = 0.5)
```

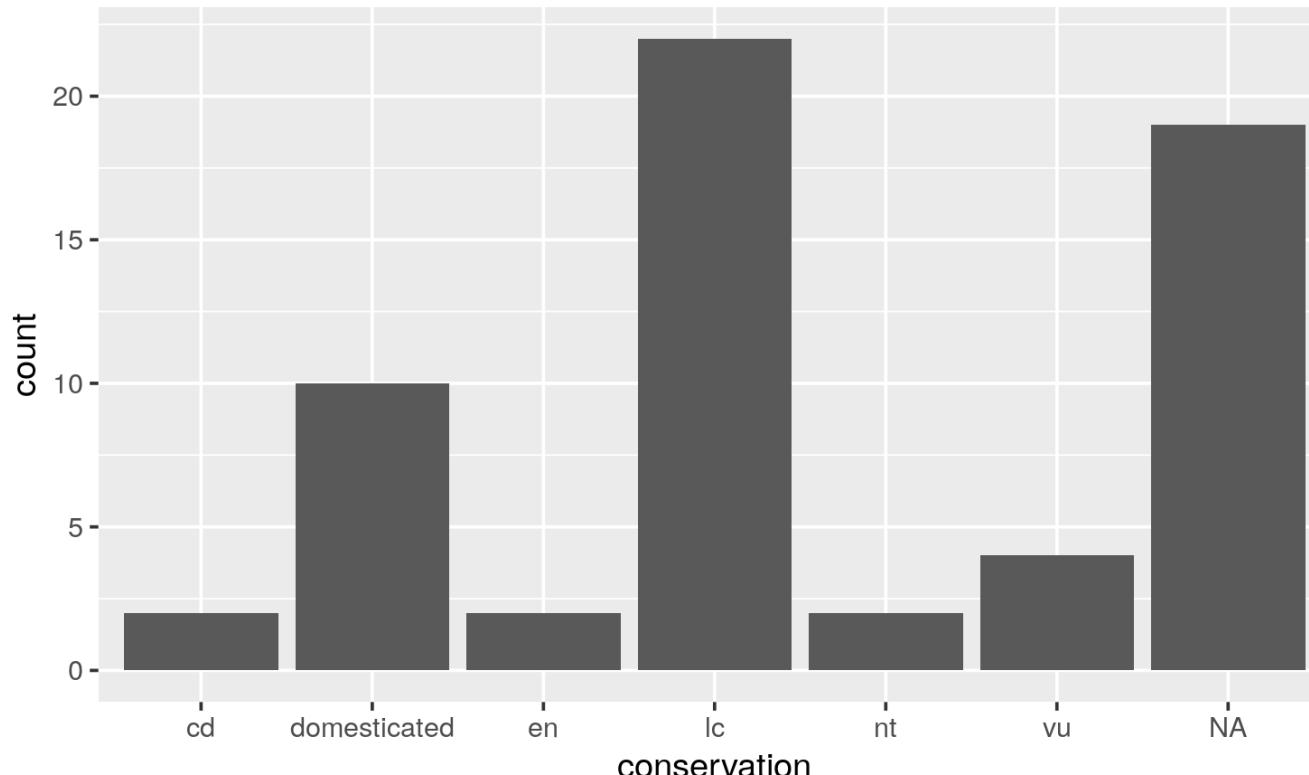
**Note:** We only need 1 aesthetic here (x)



# Geoms: Barplots

Let **ggplot** count your data

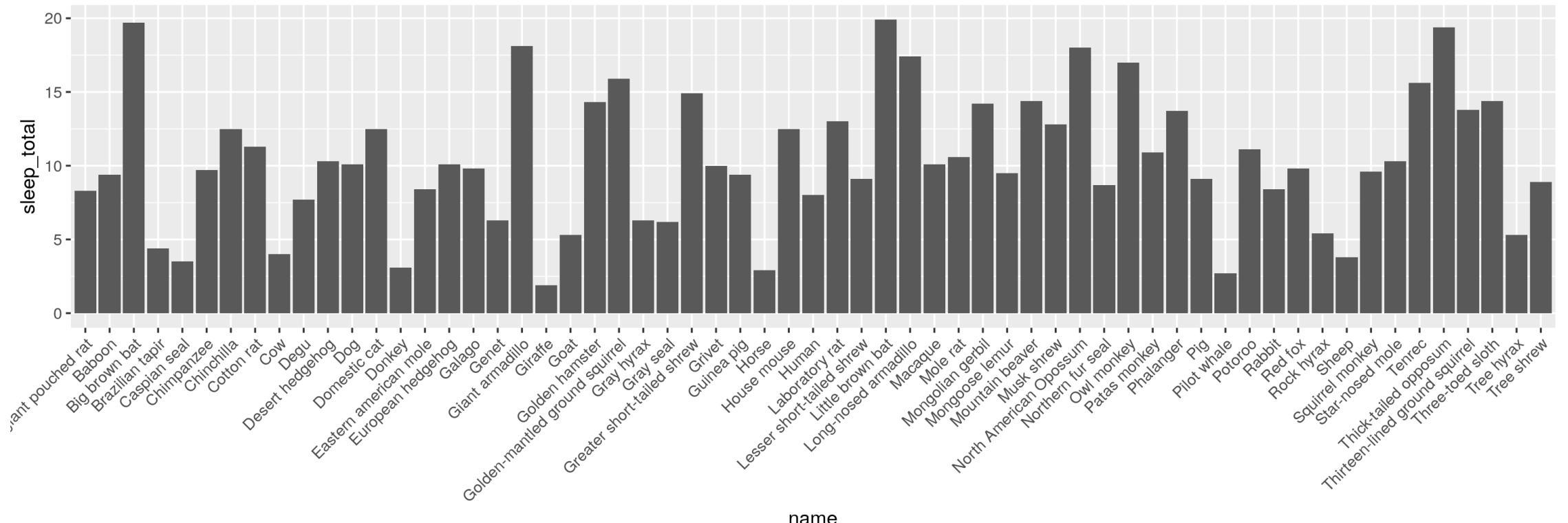
```
ggplot(data = sleep, aes(x = conservation)) +  
  geom_bar()
```



# Geoms: Barplots

You can also provide the counts

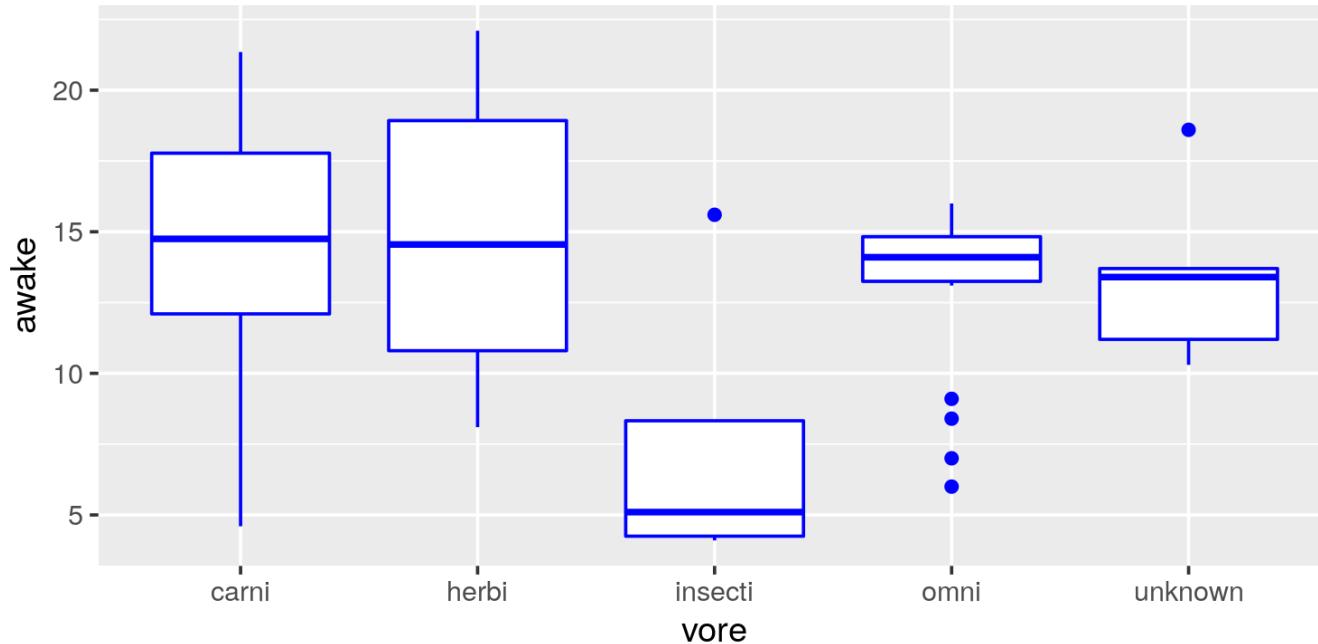
```
ggplot(data = sleep, aes(x = name, y = sleep_total)) +  
  geom_bar(stat = "identity") +  
  theme(axis.text.x = element_text(angle = 45, hjust =1))
```



# Your Turn: Create this plot

```
library(ggplot2)

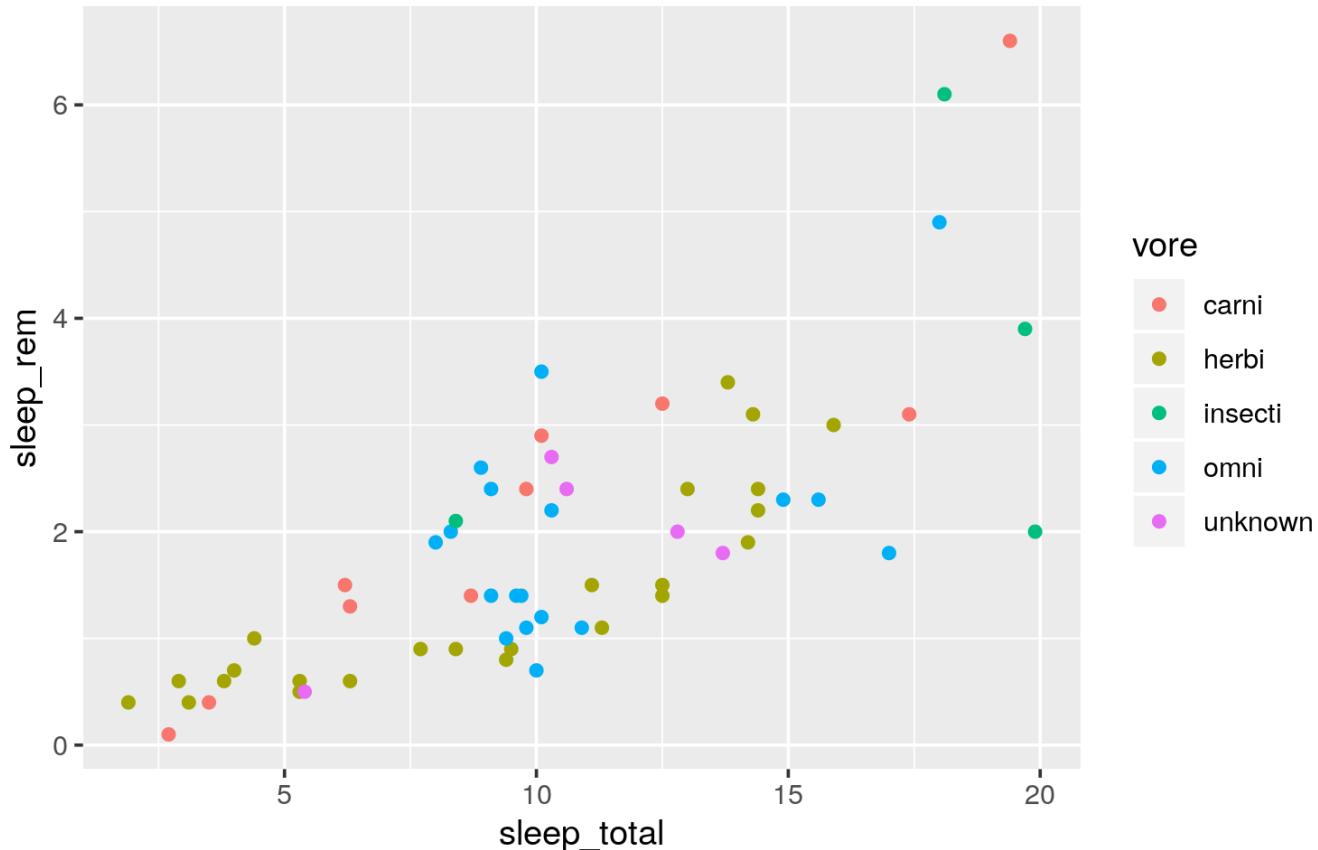
ggplot(data = ???, aes(x = ???, y = ???)) +
  geom_????(????)
```



# Showing data by group

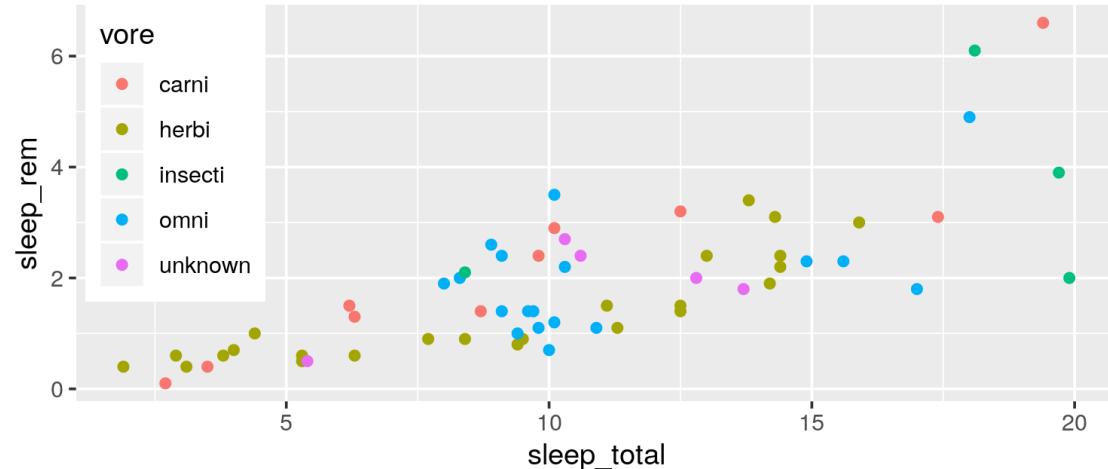
# Mapping aesthetics

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point()
```

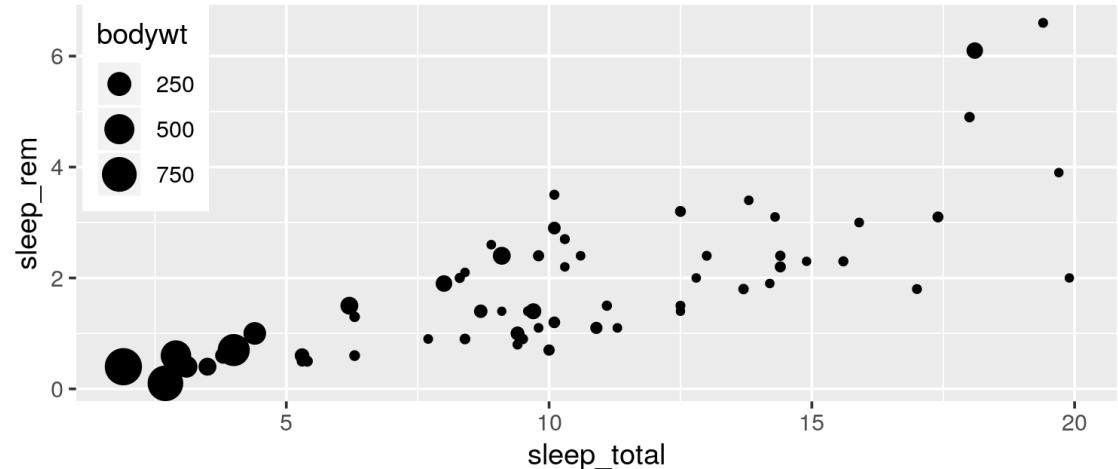


# Mapping aesthetics

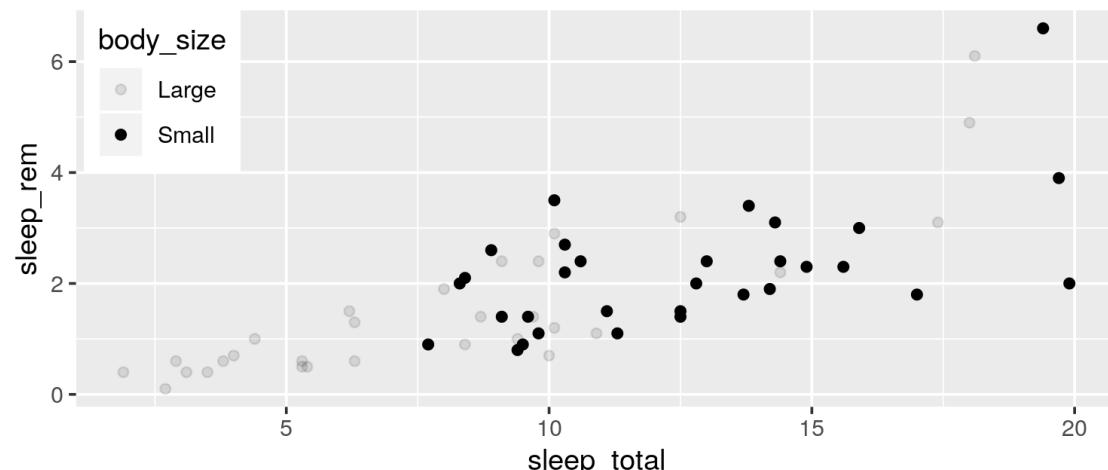
colour = vore



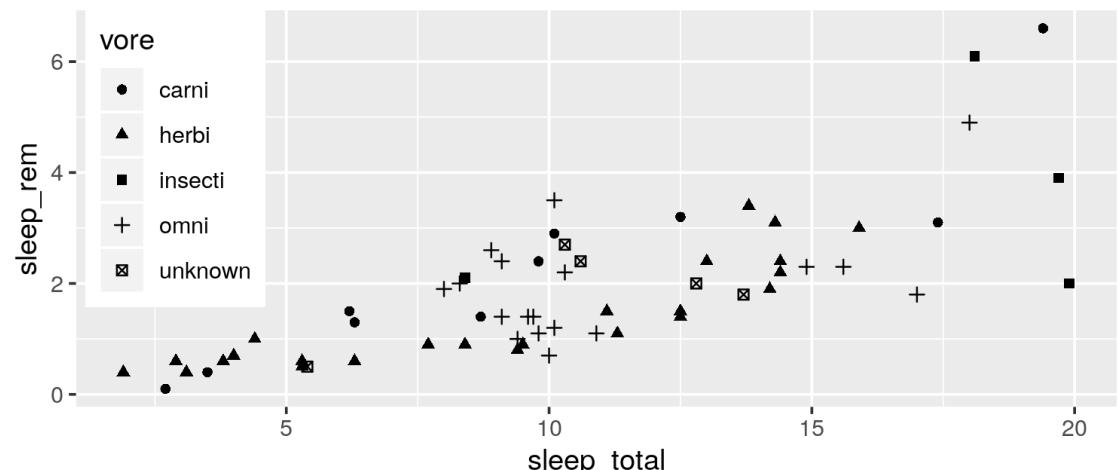
size = bodywt



alpha = body\_size



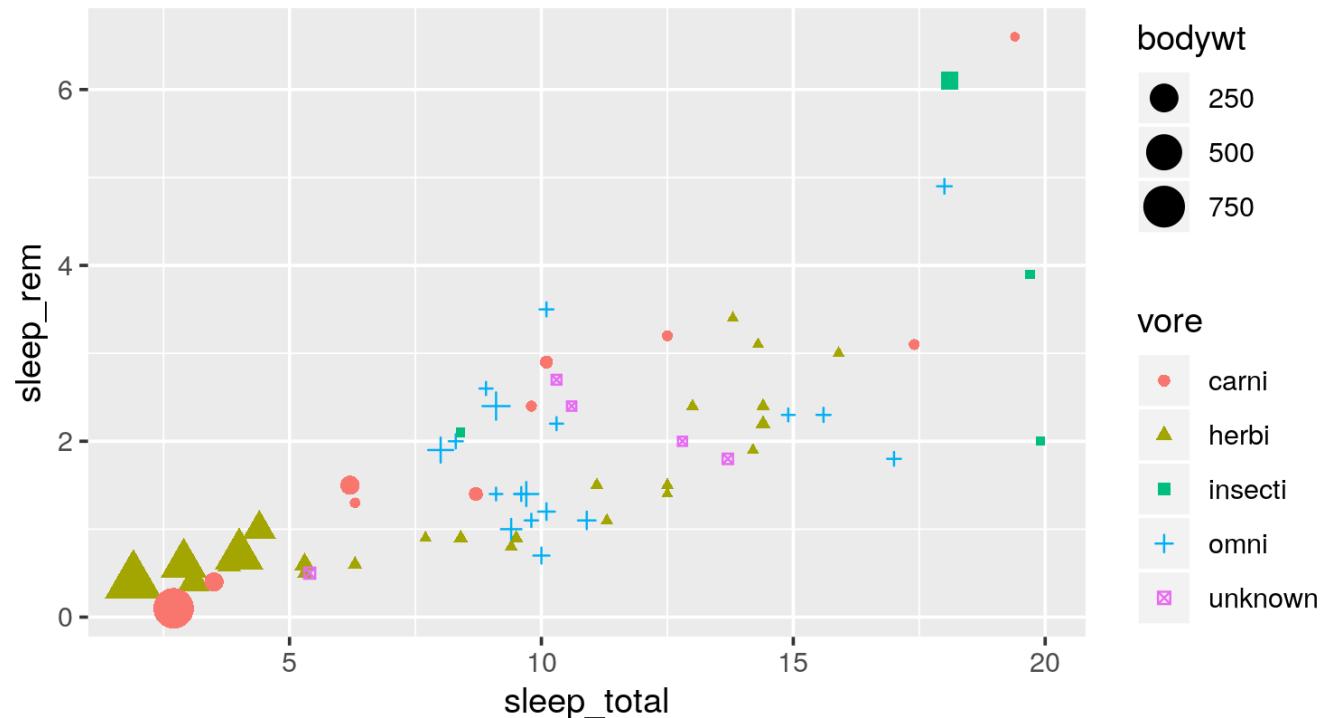
shape = vore



# Mapping aesthetics

**ggplot** automatically populates the legends (combining where it can)

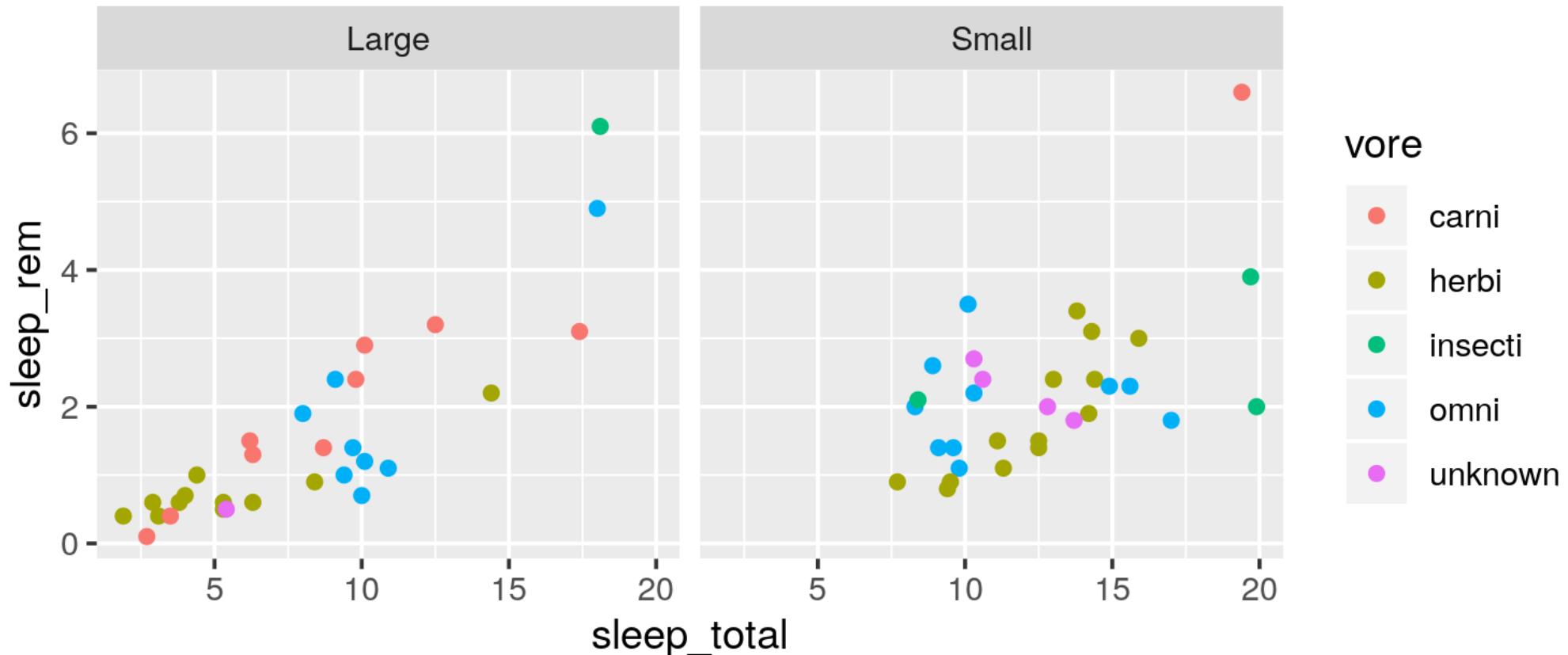
```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem,
                           colour = vore, shape = vore, size = bodywt)) +
  geom_point()
```



# Faceting: `facet_wrap()`

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point() +  
  facet_wrap(~ body_size, nrow = 1)
```

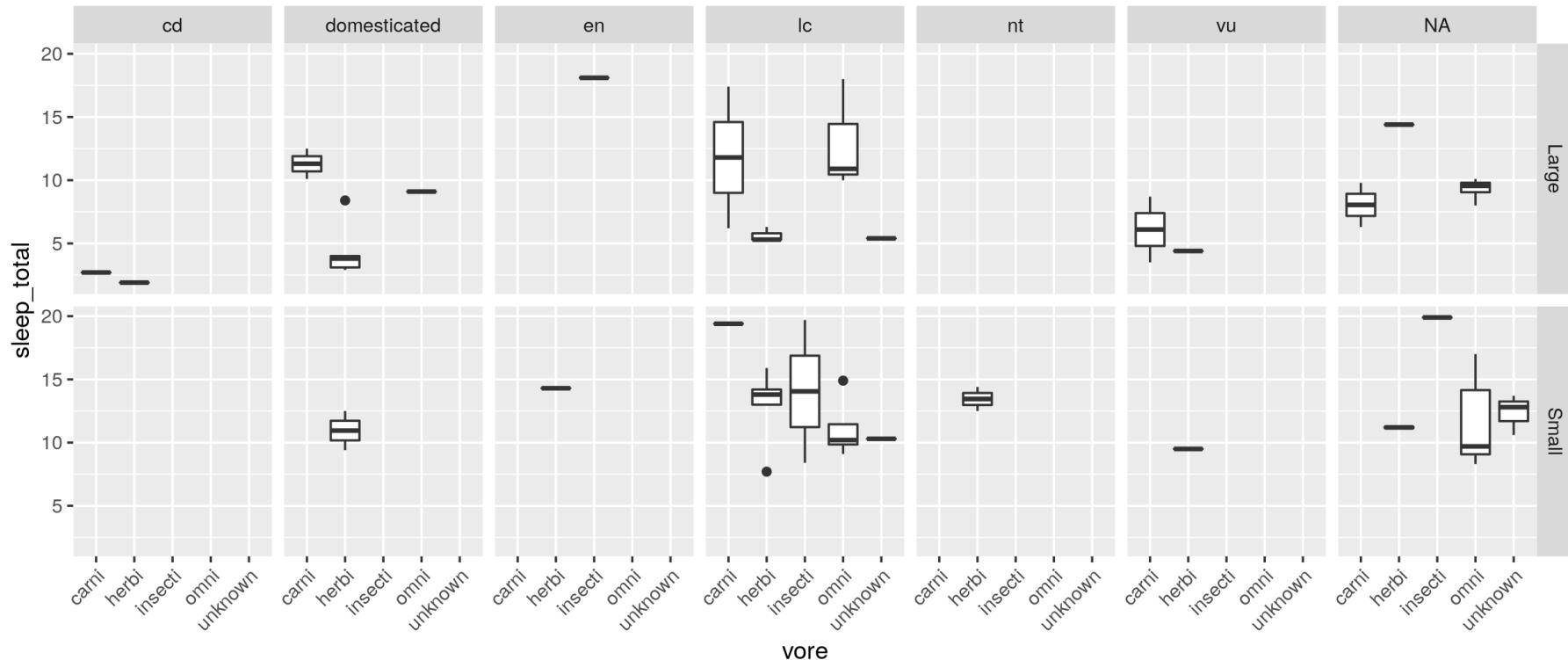
Split plots by **one** grouping variable



# Faceting: facet\_grid()

```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +  
  geom_boxplot() +  
  facet_grid(body_size ~ conservation)
```

Split plots by **two** grouping variables



# Your Turn: Create this plot

```
ggplot(data = ???, aes(????)) +  
  ??? +  
  ???
```



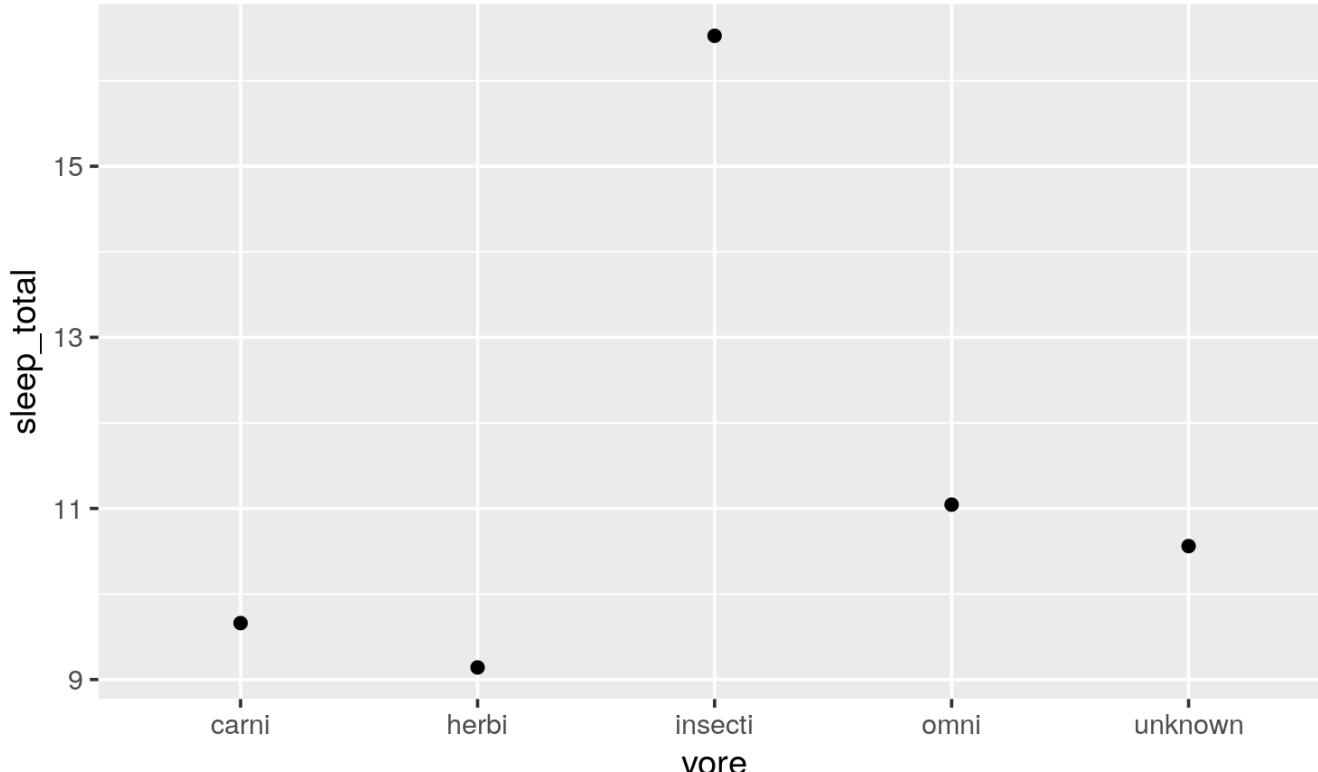
**Hint:** **colour** is for outlining with a colour, **fill** is for 'filling' with a colour

# Adding Statistics to Plots

# Using stats: Summarizing data

## Add data means as points

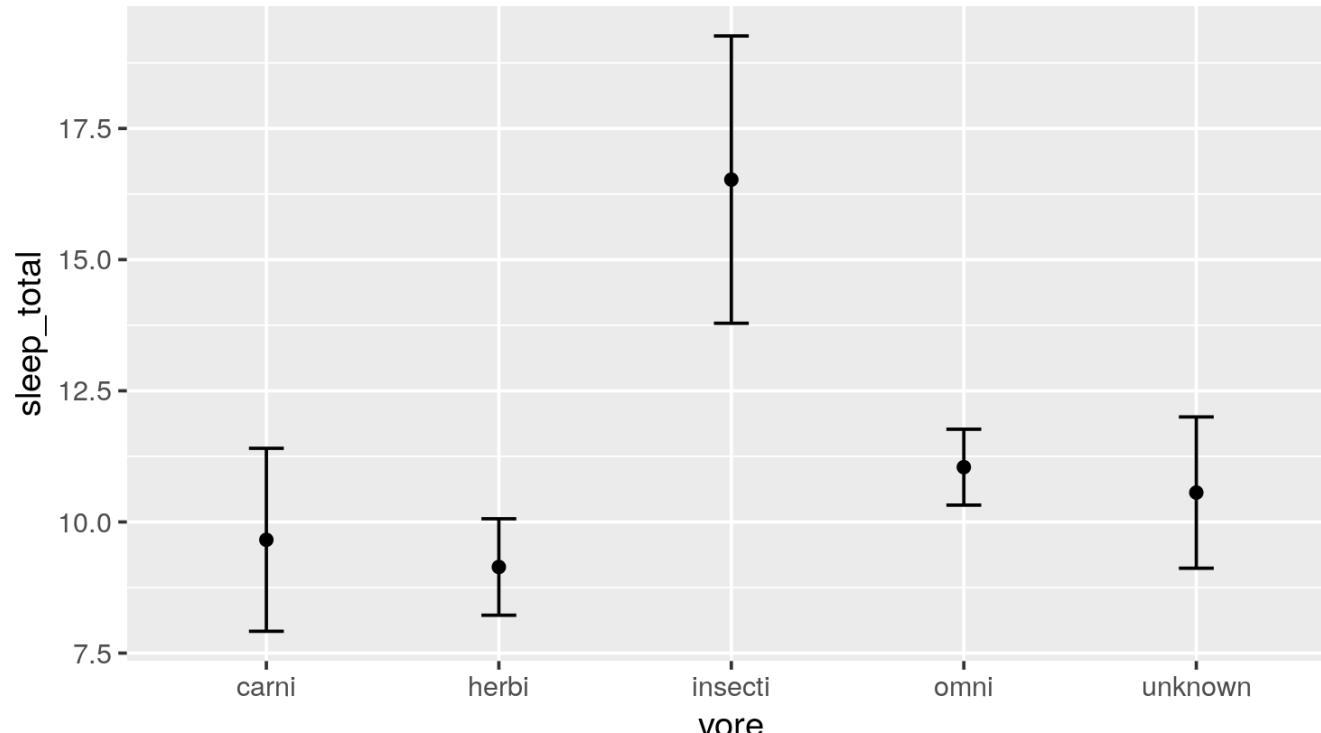
```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  stat_summary(geom = "point", fun.y = mean)
```



# Using stats: Summarizing data

Add error bars, calculated from the data

```
ggplot(data = sleep, aes(x = vore, y = sleep_total)) +  
  stat_summary(geom = "point", fun.y = mean) +  
  stat_summary(geom = "errorbar", width = 0.15, fun.data = mean_se)
```

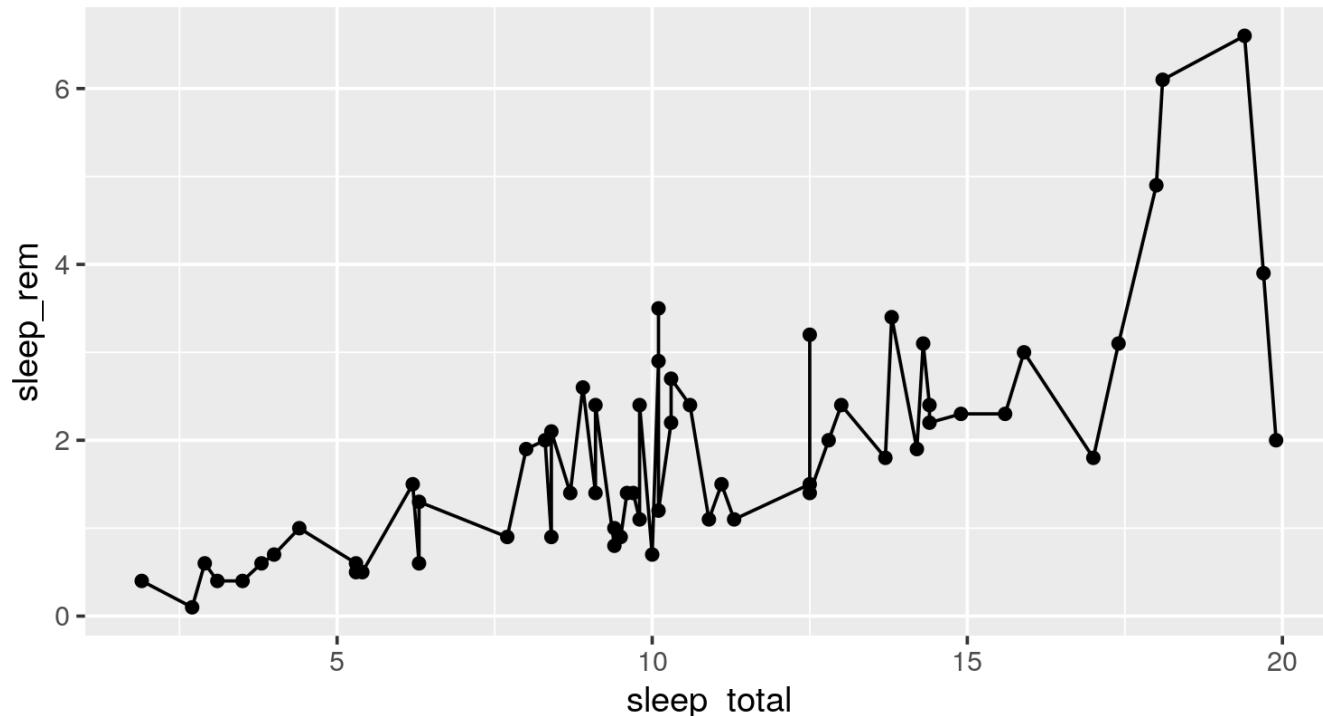


# Using stats: Trendlines

**geom\_line() is connect-the-dots, not a trend or linear model**

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point() +  
  geom_line()
```

Not what we're  
looking for

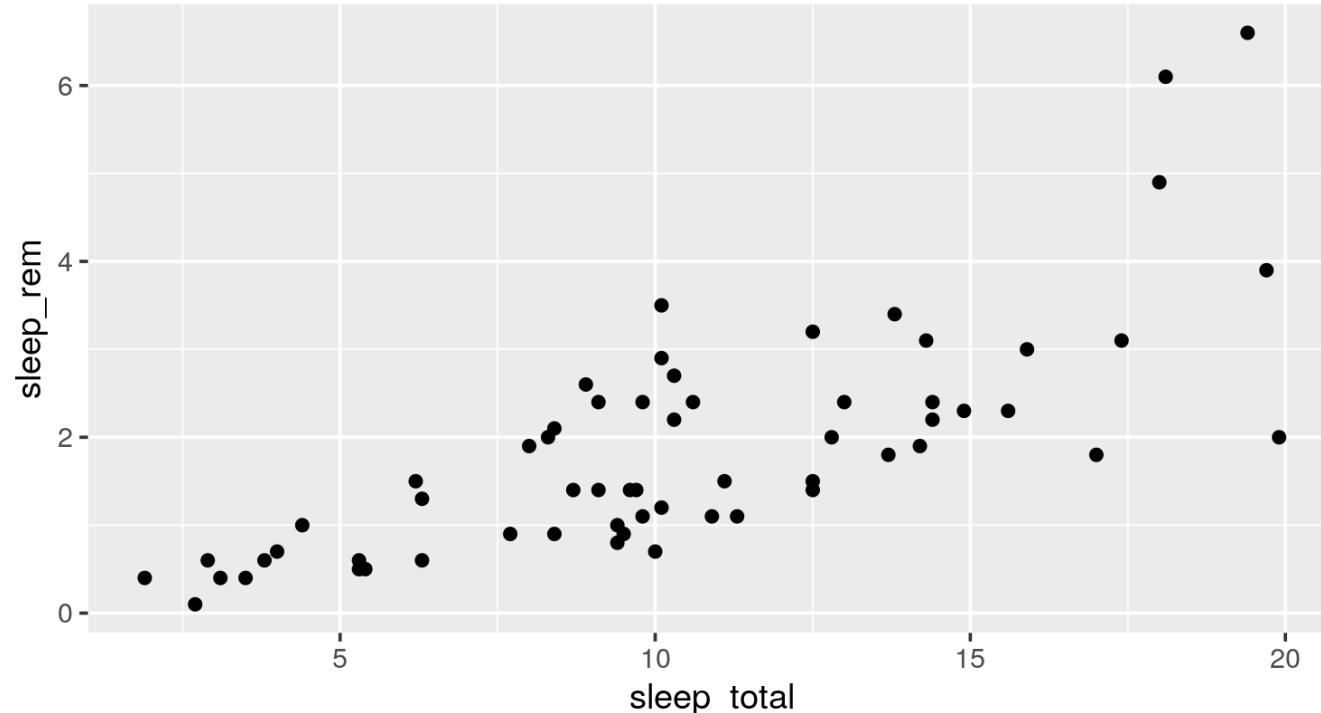


# Using stats: Trendlines

Let's add a trend line properly

Start with basic plot:

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point()
```

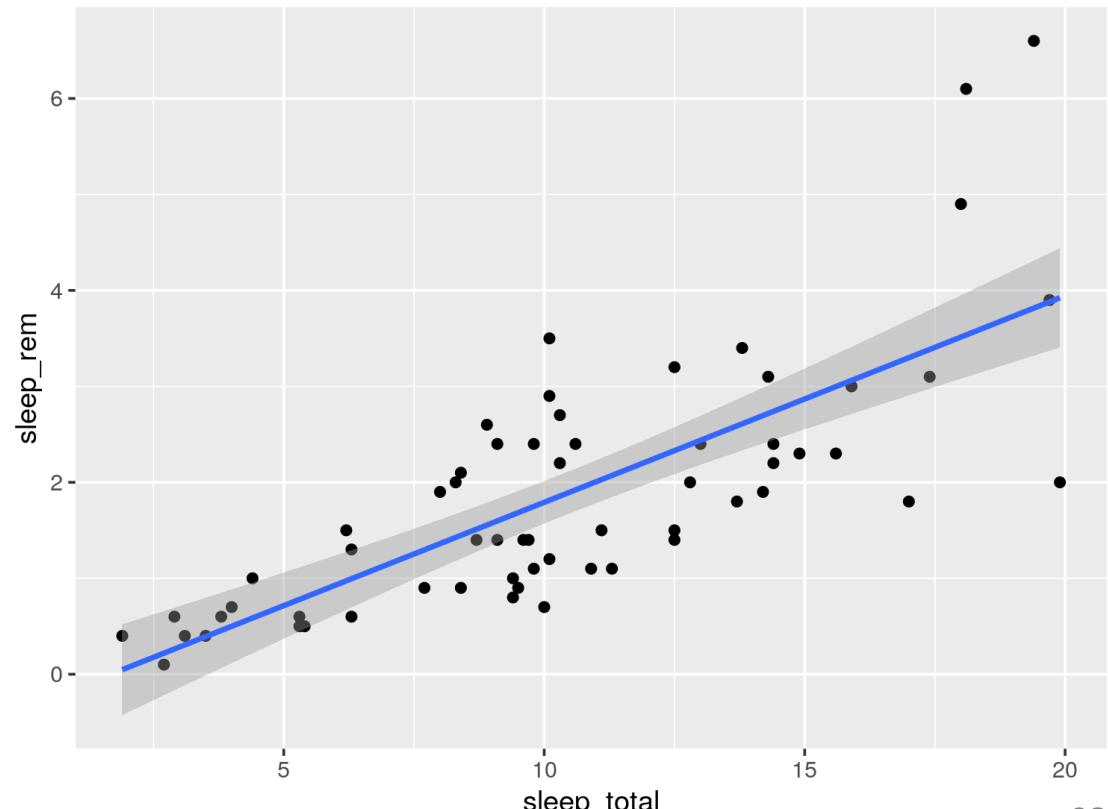


# Using stats: Trendlines

## Add the `stat_smooth()`

- `lm` is for "linear model" (i.e. trendline)
- the grey area represents the standard error

```
ggplot(data = sleep,  
       aes(x = sleep_total, y = sleep_rem)) +  
  geom_point() +  
  stat_smooth(method = "lm")
```

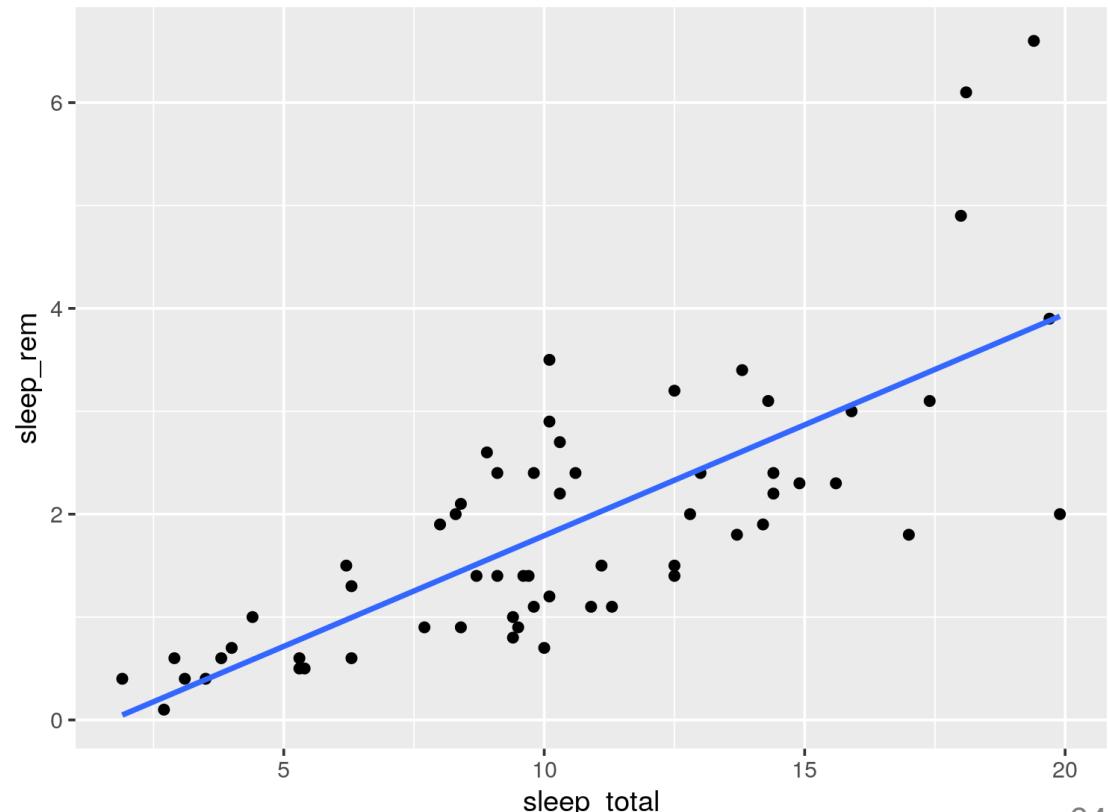


# Using stats: Trendlines

## Add the `stat_smooth()`

- `lm` is for "linear model" (i.e. trendline)
- the grey area represents the standard error
- remove the grey area with `se = FALSE`

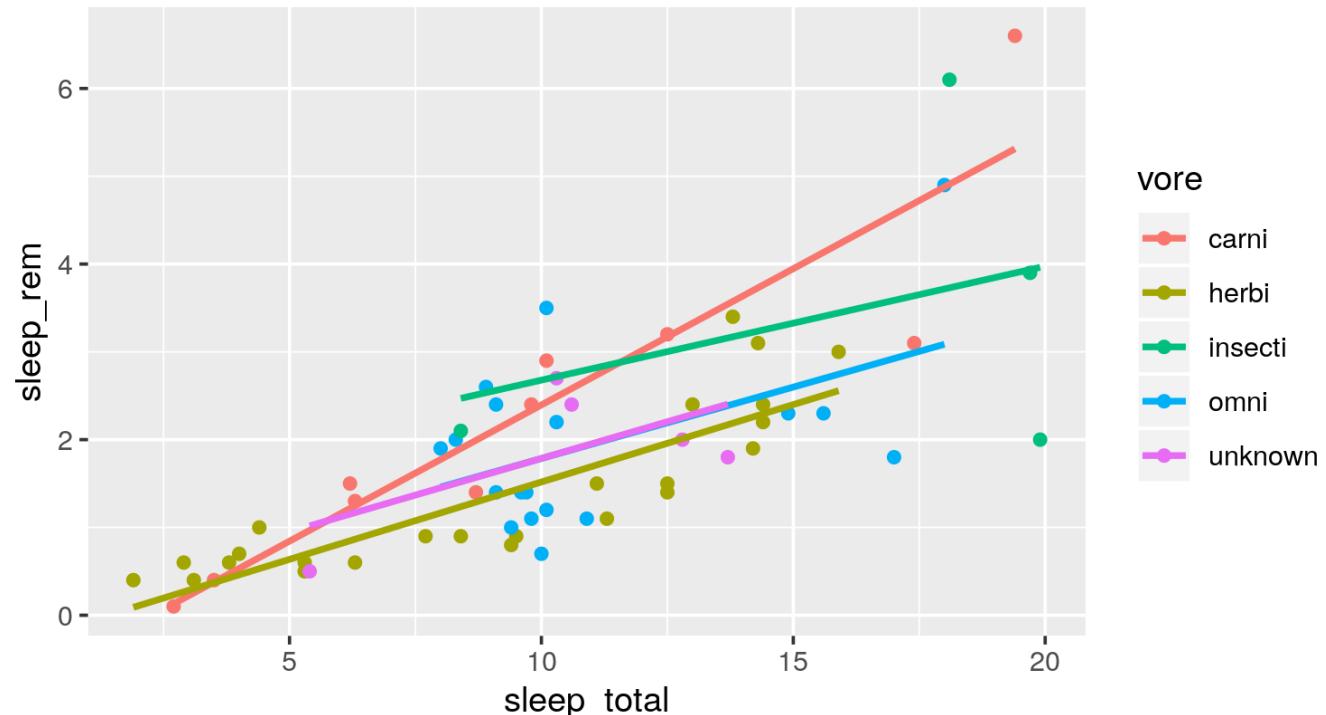
```
ggplot(data = sleep,  
       aes(x = sleep_total, y = sleep_rem)) +  
  geom_point() +  
  stat_smooth(method = "lm", se = FALSE)
```



# Using stats: Trendlines

A line for each group

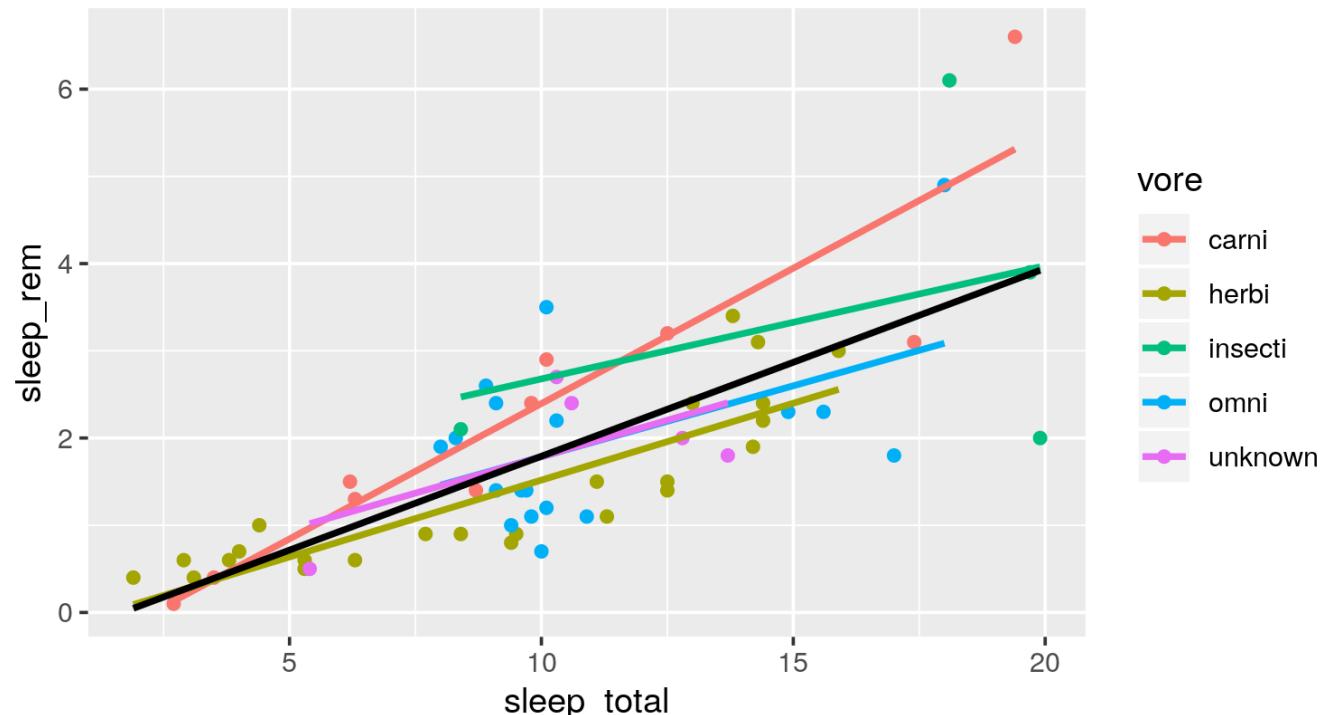
```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point() +  
  stat_smooth(method = "lm", se = FALSE)
```



# Using stats: Trendlines

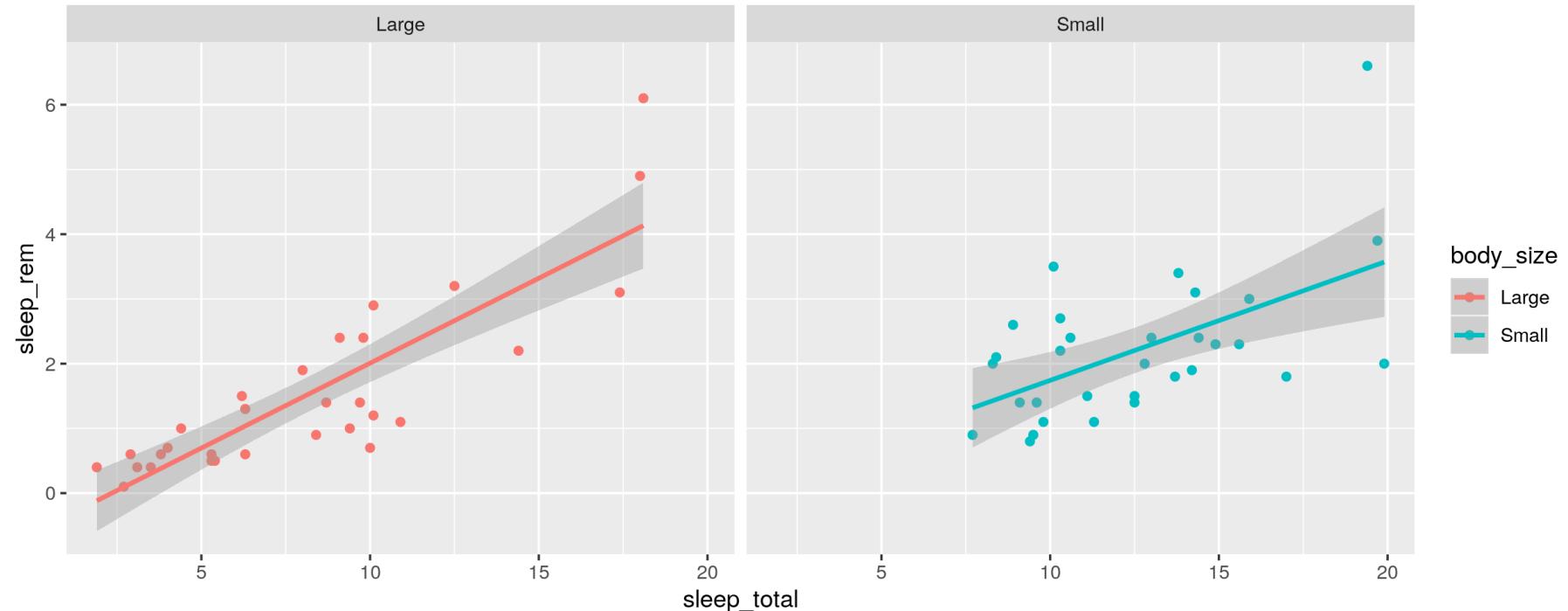
A line for each group AND overall

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point() +  
  stat_smooth(method = "lm", se = FALSE) +  
  stat_smooth(method = "lm", se = FALSE, colour = "black")
```



# Your Turn: Create this plot

```
ggplot(data = ???, aes(x = ???, y = ???, ??? = ???)) +  
  ??? +  
  ??? +  
  ???
```

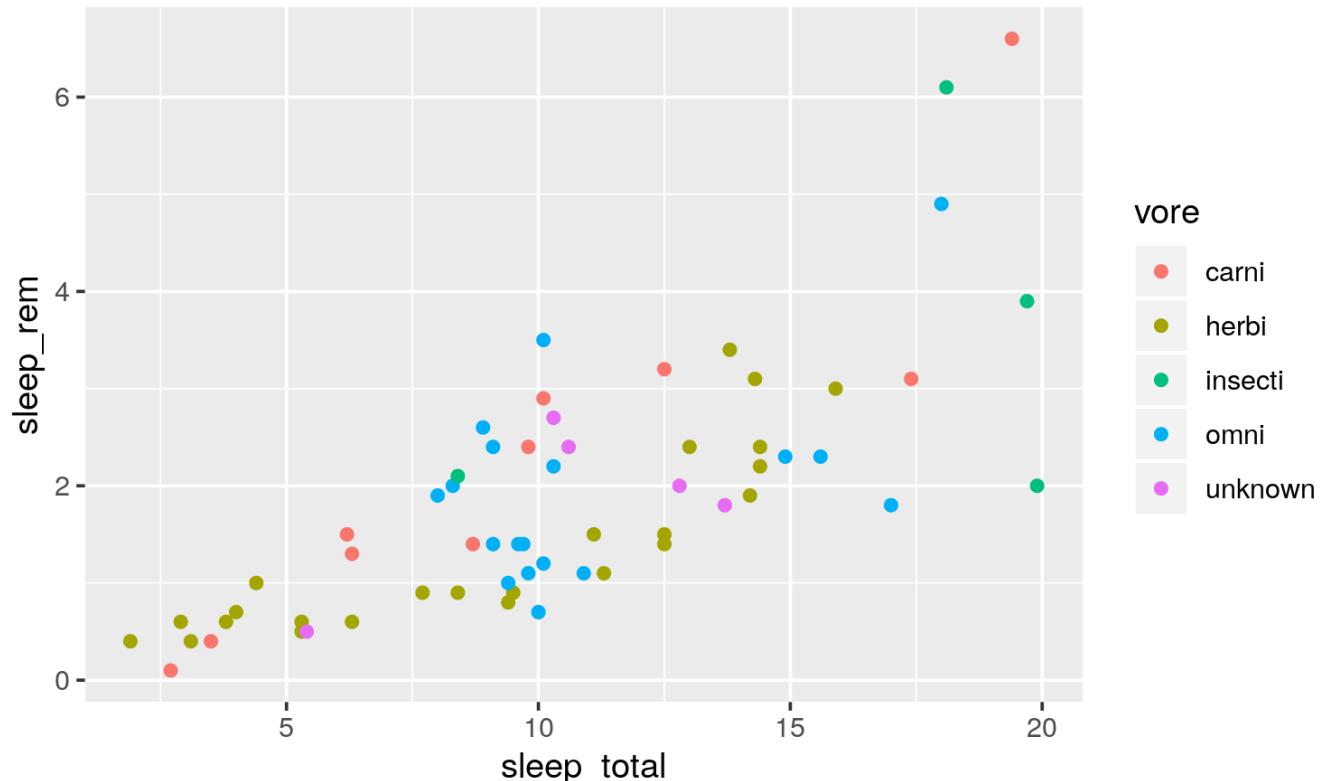


# Customizing plots

# Customizing: Starting plot

Let's work with this plot

```
g <- ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point()
```

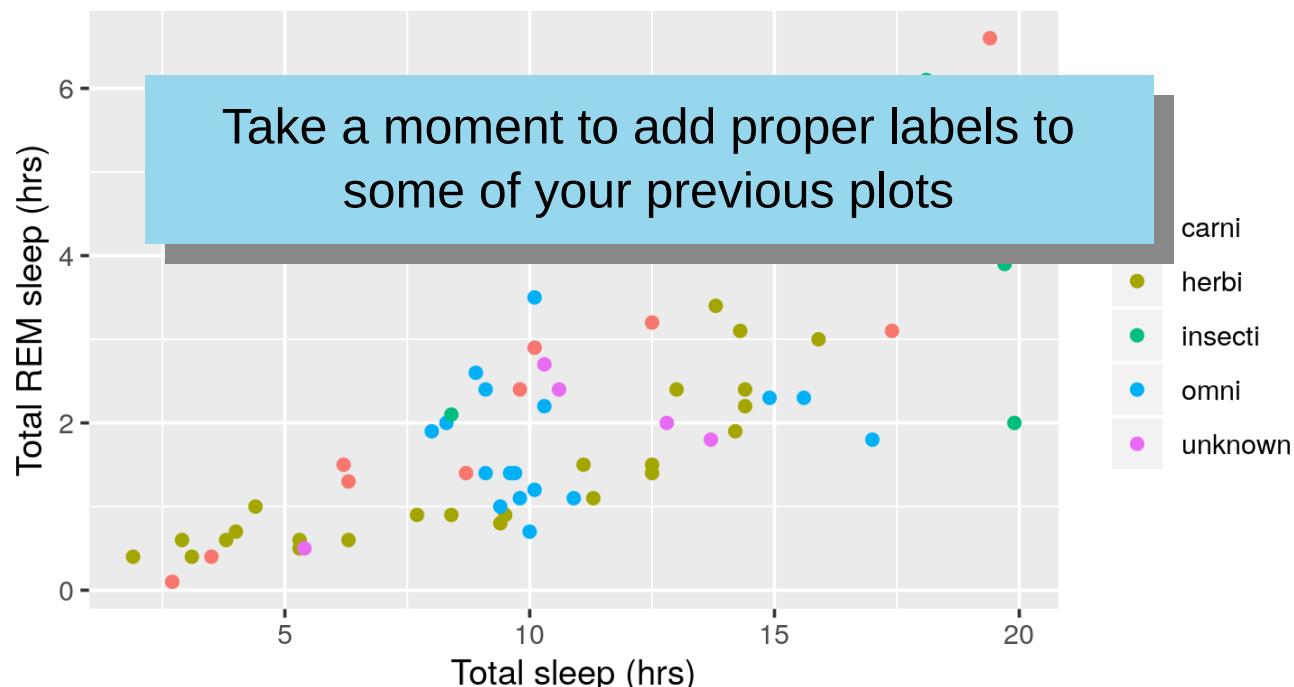


# Customizing: Labels

```
g + labs(title = "Total REM vs. overall sleep",
         x = "Total sleep (hrs)",
         y = "Total REM sleep (hrs)",
         colour = "Diet", tag = "A")
```

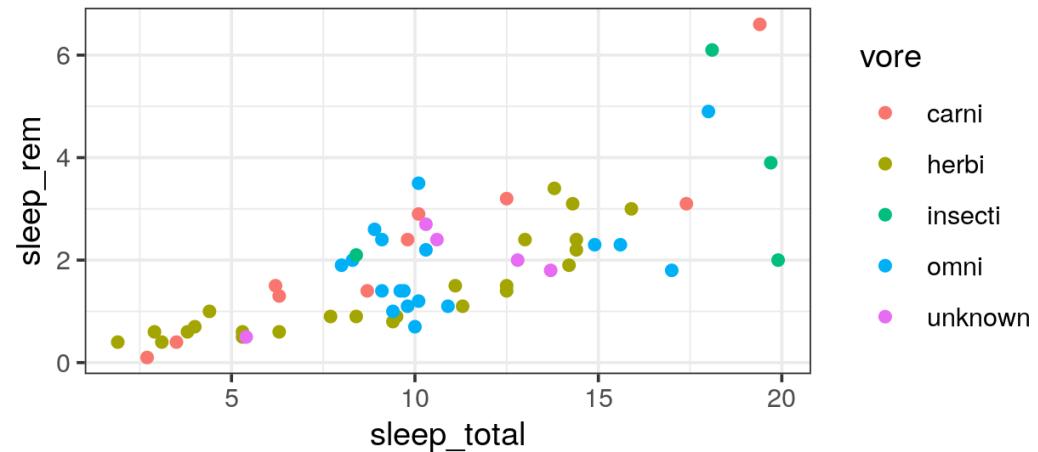
A

Total REM vs. overall sleep

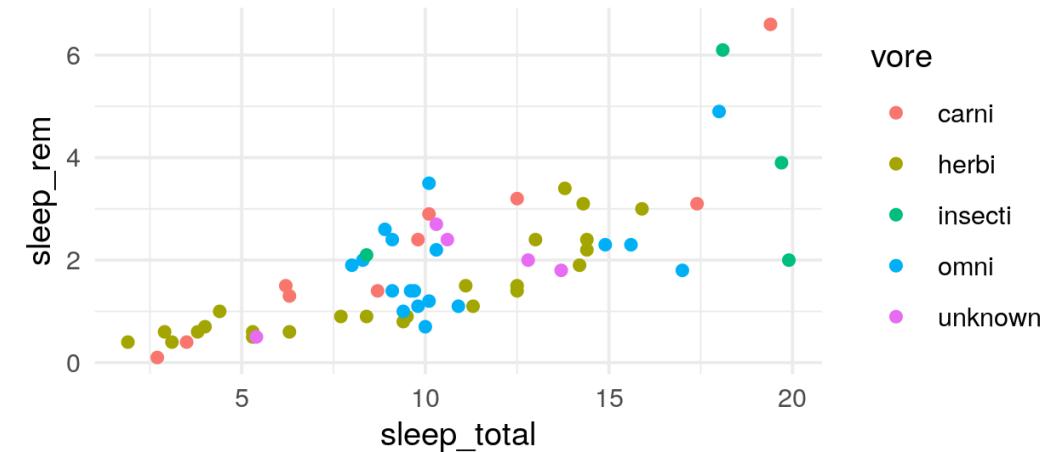


# Customizing: Built-in themes

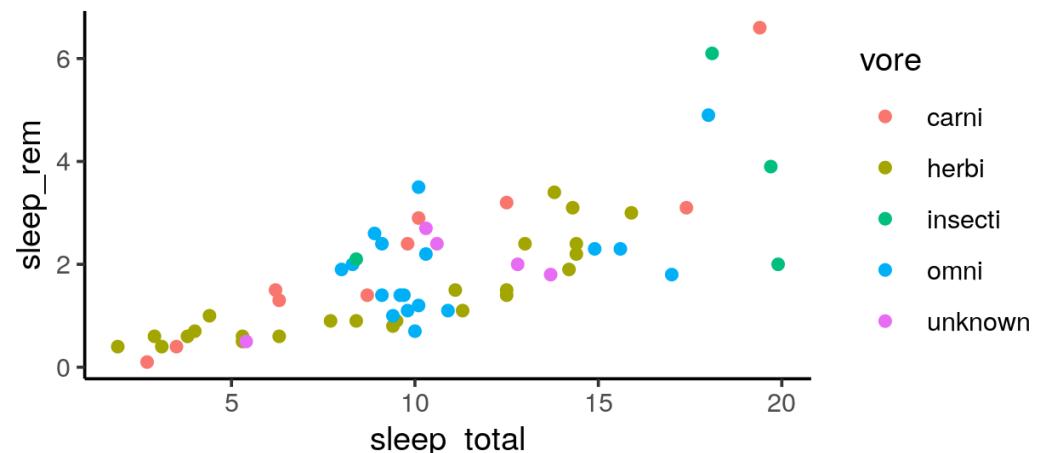
`g + theme_bw()`



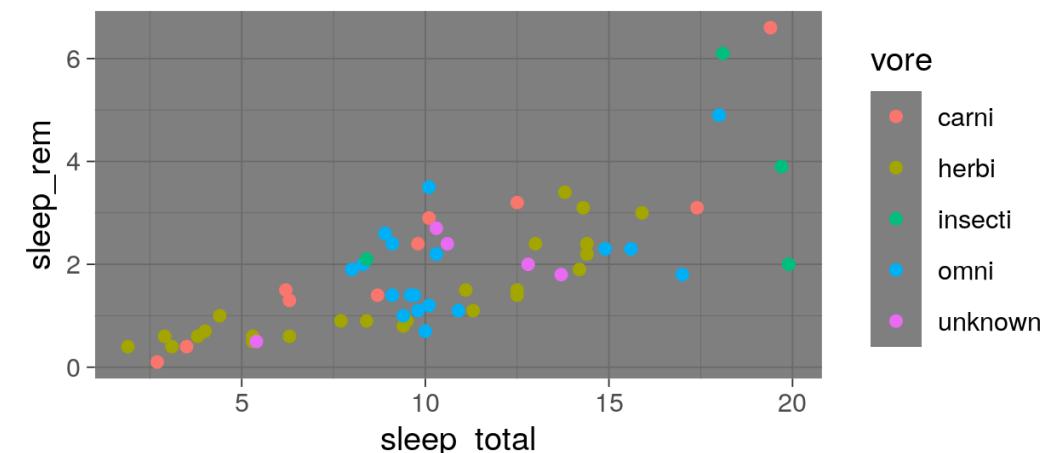
`g + theme_minimal()`



`g + theme_classic()`



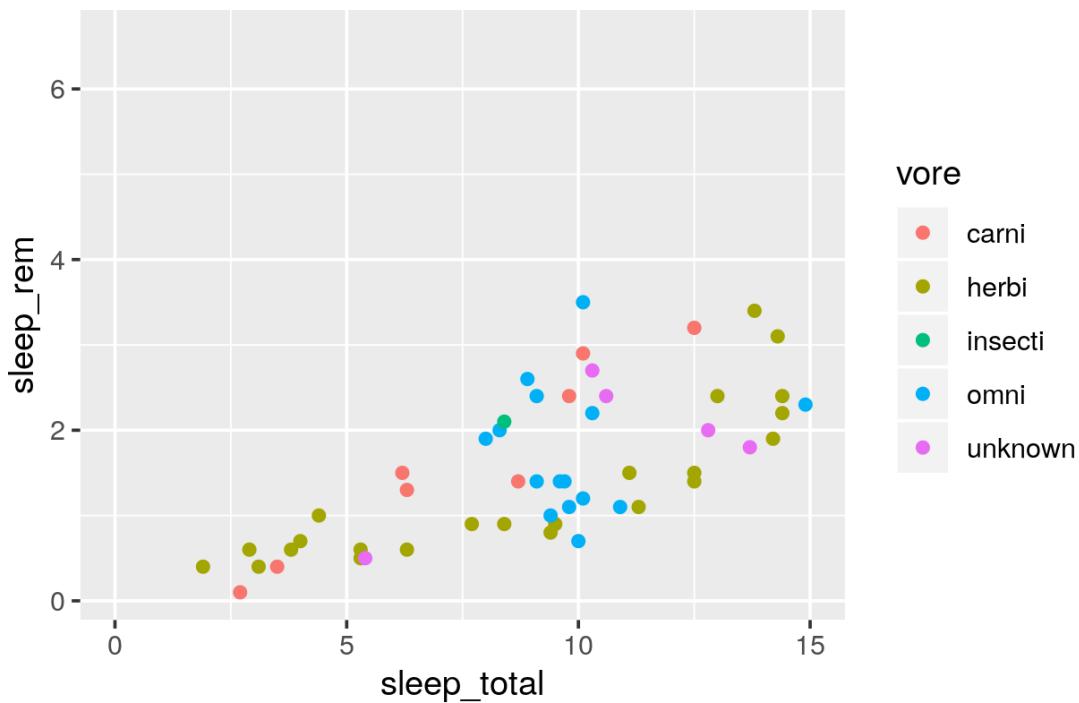
`g + theme_dark()`



# Customizing: Data range

## Limit the data (exclude data)

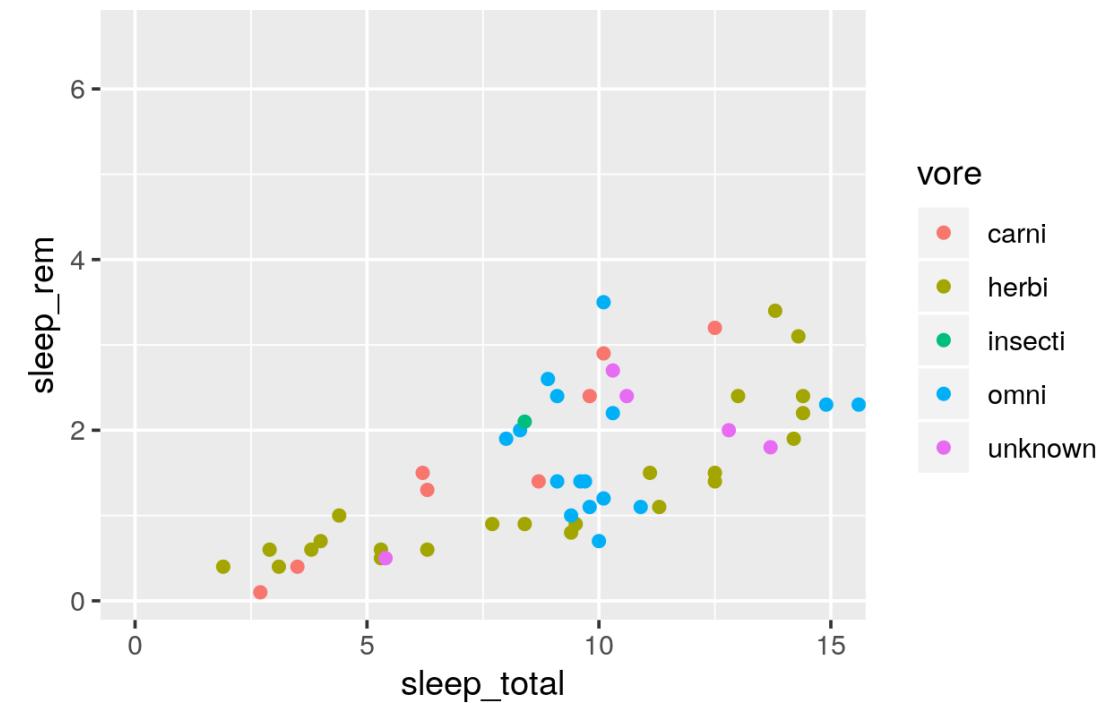
```
g + xlim(c(0, 15))
```



```
## Warning: Removed 9 rows containing missing  
values (geom_point).
```

## Limit the view (zoom)

```
g + coord_cartesian(xlim = c(0, 15))
```



# Customizing: Axes

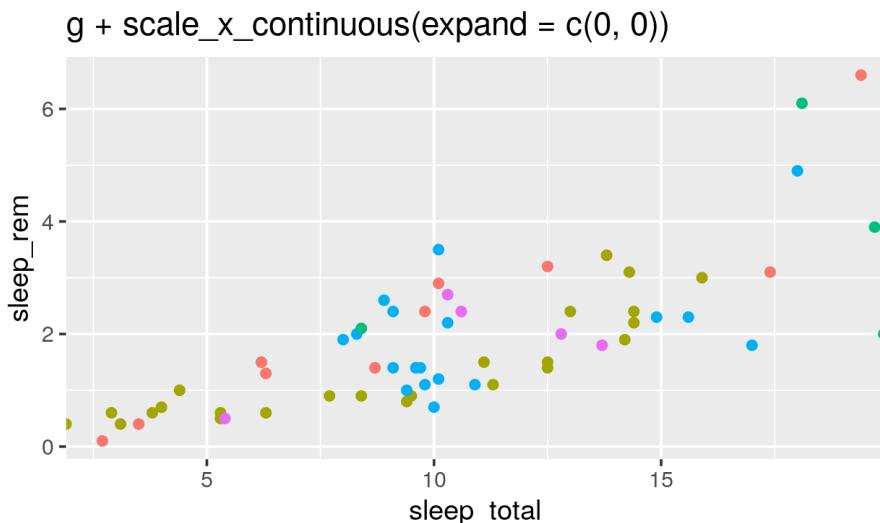
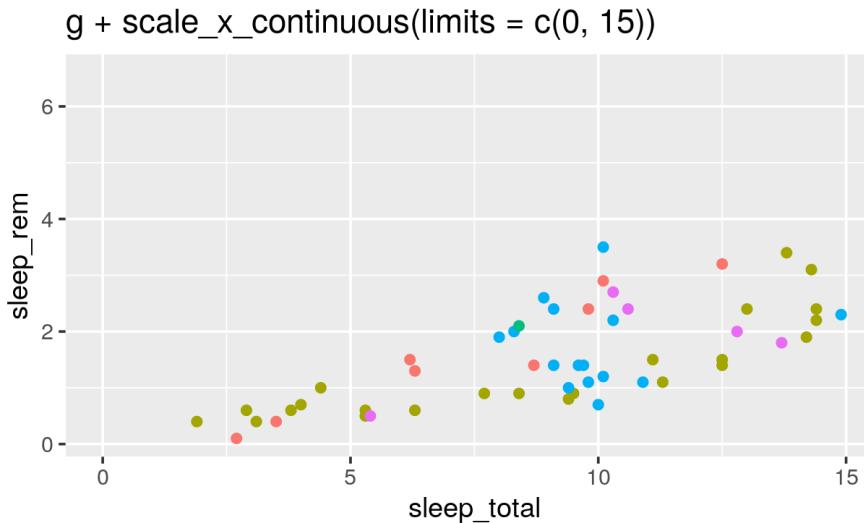
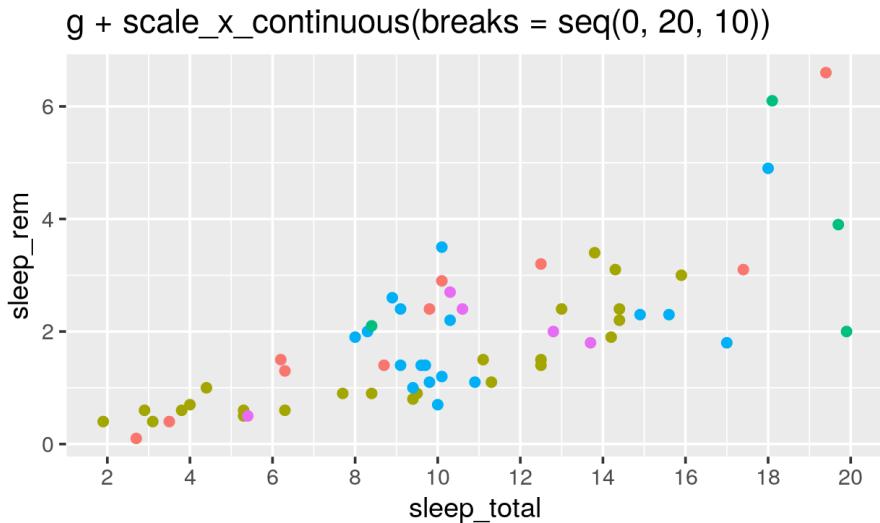
`scale_` + (x or y) + type (continuous, discrete, date, datetime)

- `scale_x_continuous()`
- `scale_y_discrete()`
- etc.

## Common arguments

```
g + scale_x_continuous(breaks = seq(0, 20, 10)) # Tick breaks  
g + scale_x_continuous(limits = c(0, 15))         # xlim() is a shortcut for this  
g + scale_x_continuous(expand = c(0, 0))          # Space between axis and data
```

# Customizing: Axes

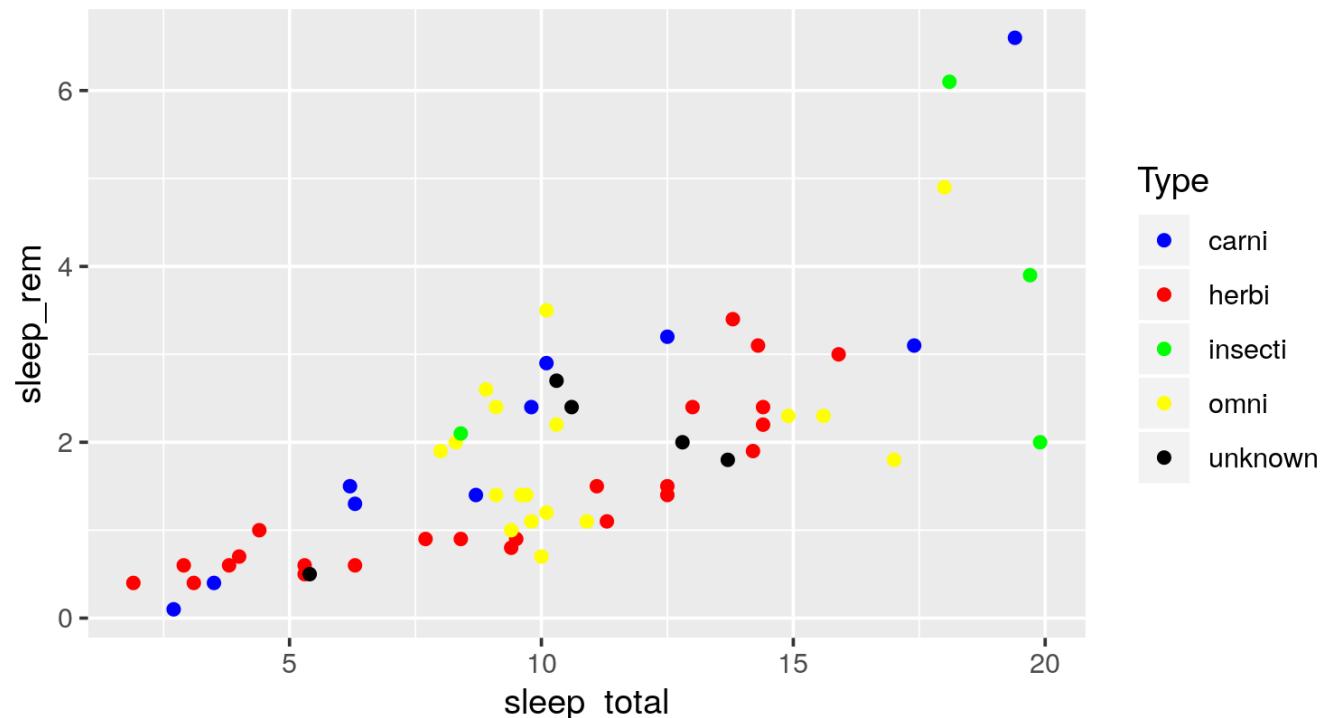


# Customizing: Aesthetics

## Using scales

`scale_` + aesthetic (`colour`, `fill`, `size`, etc.) + type (`manual`, `continuous`, `datetime`, etc.)

```
g + scale_colour_manual(name = "Type",  
                         values = c("blue", "red", "green", "yellow", "black"))
```

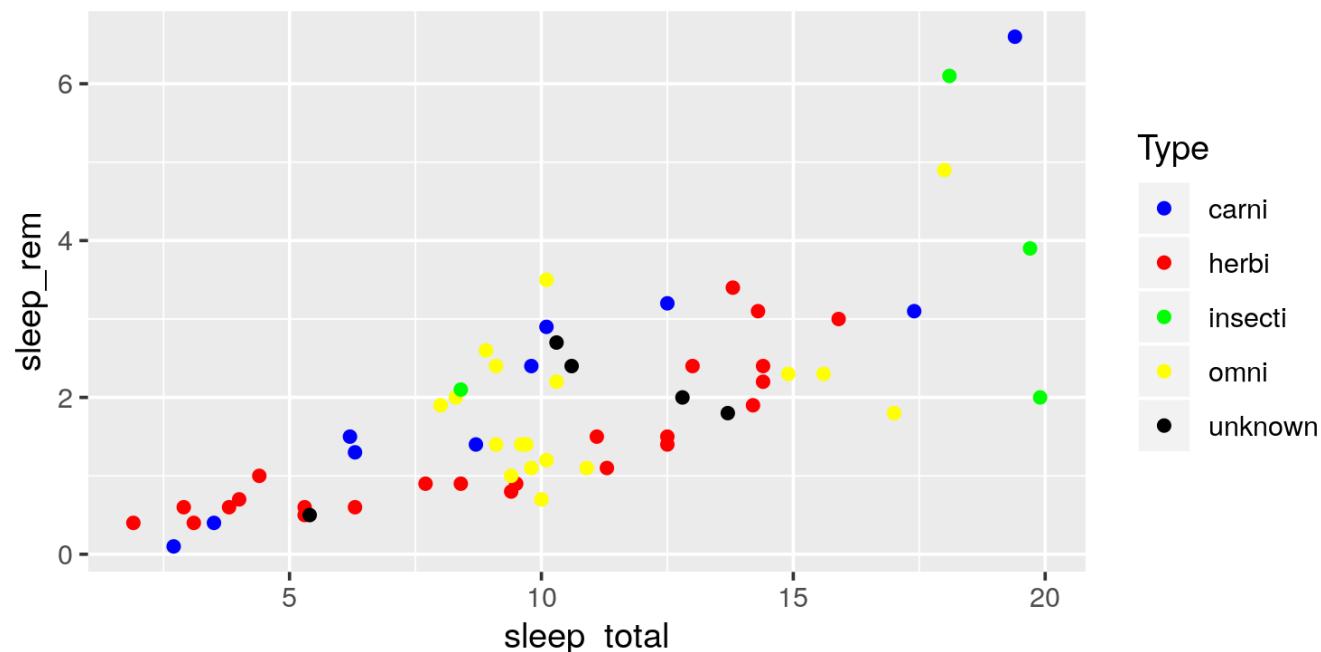


# Customizing: Aesthetics

## Using scales

Or be very explicit:

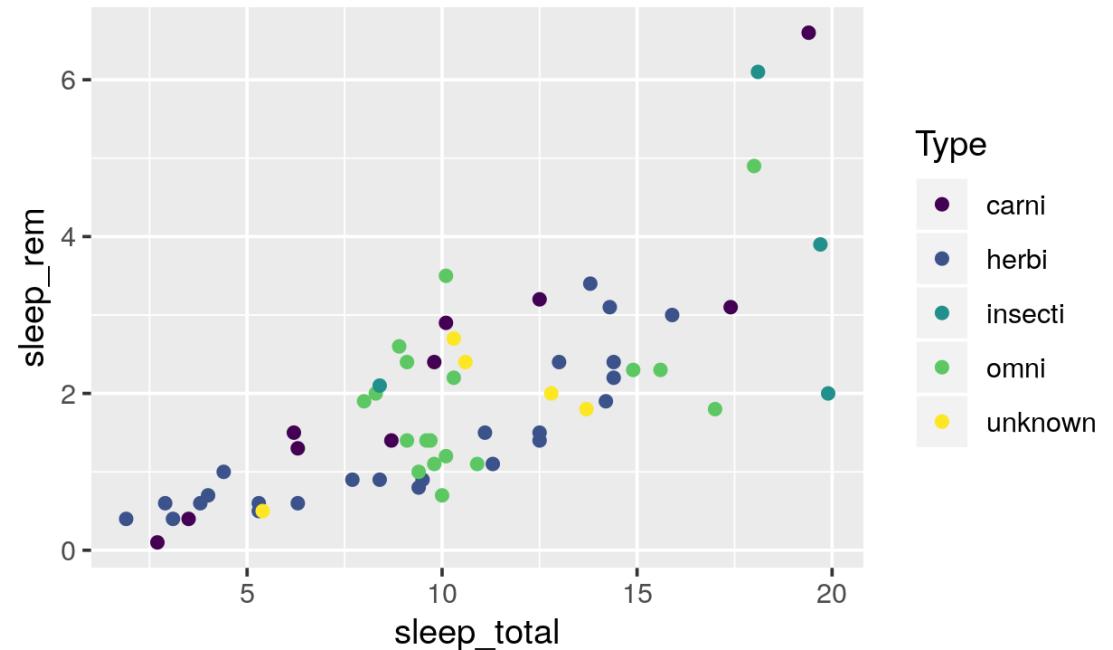
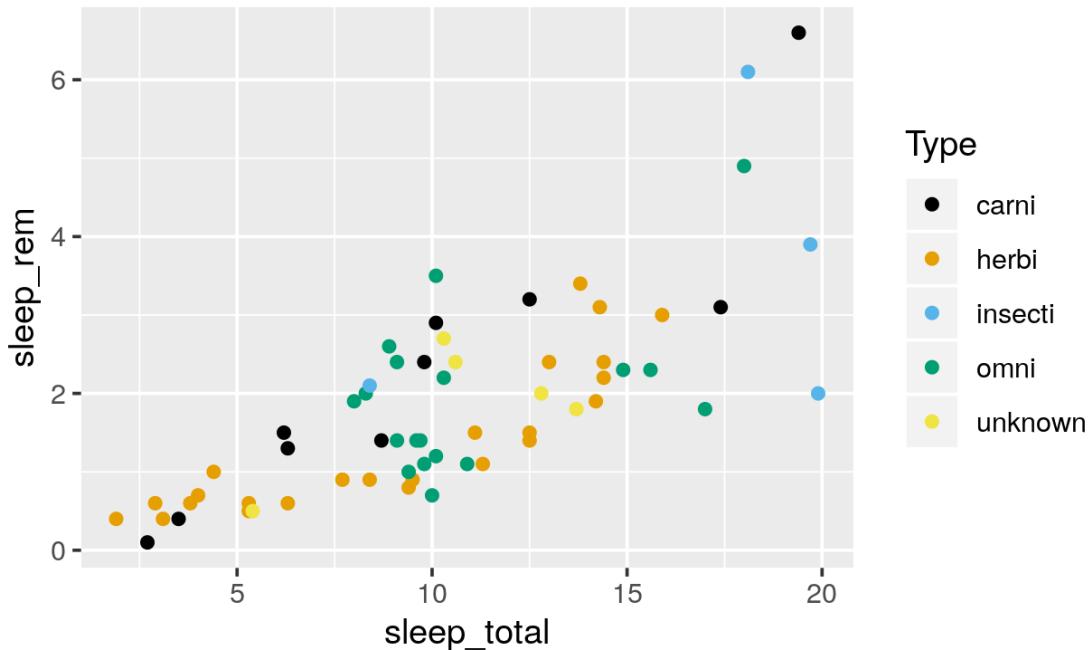
```
g + scale_colour_manual(name = "Type",  
                        values = c("carni" = "blue", "herbi" = "red", "insecti" = "green",  
                                  "omni" = "yellow", "unknown" = "black"))
```



# Customizing: Aesthetics

For colours, consider colour-blind-friendly scales

```
library(ggthemes)  
g + scale_colour_colorblind(name = "Type")  
g + scale_colour_viridis_d(name = "Type")
```

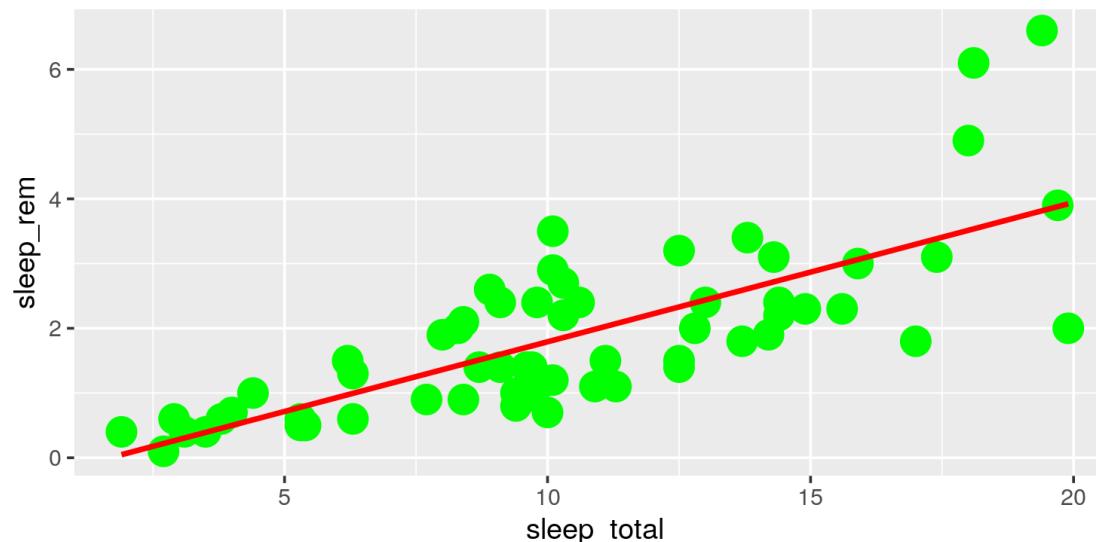


# Customizing: Aesthetics

## Forcing

Remove the association between a variable and an aesthetic

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point(colour = "green", size = 5) +  
  stat_smooth(method = "lm", se = FALSE, colour = "red")
```

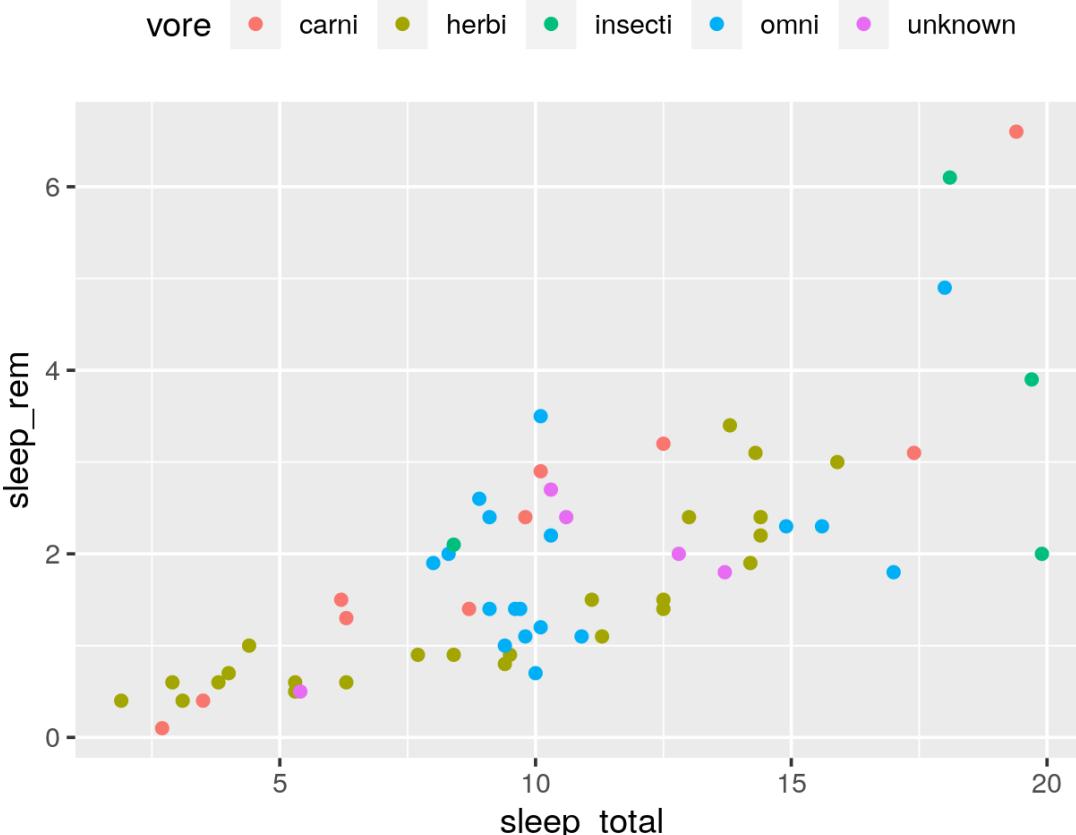


**Note:** When forcing,  
aesthetic is not inside  
`aes()`

# Customizing: Legends placement

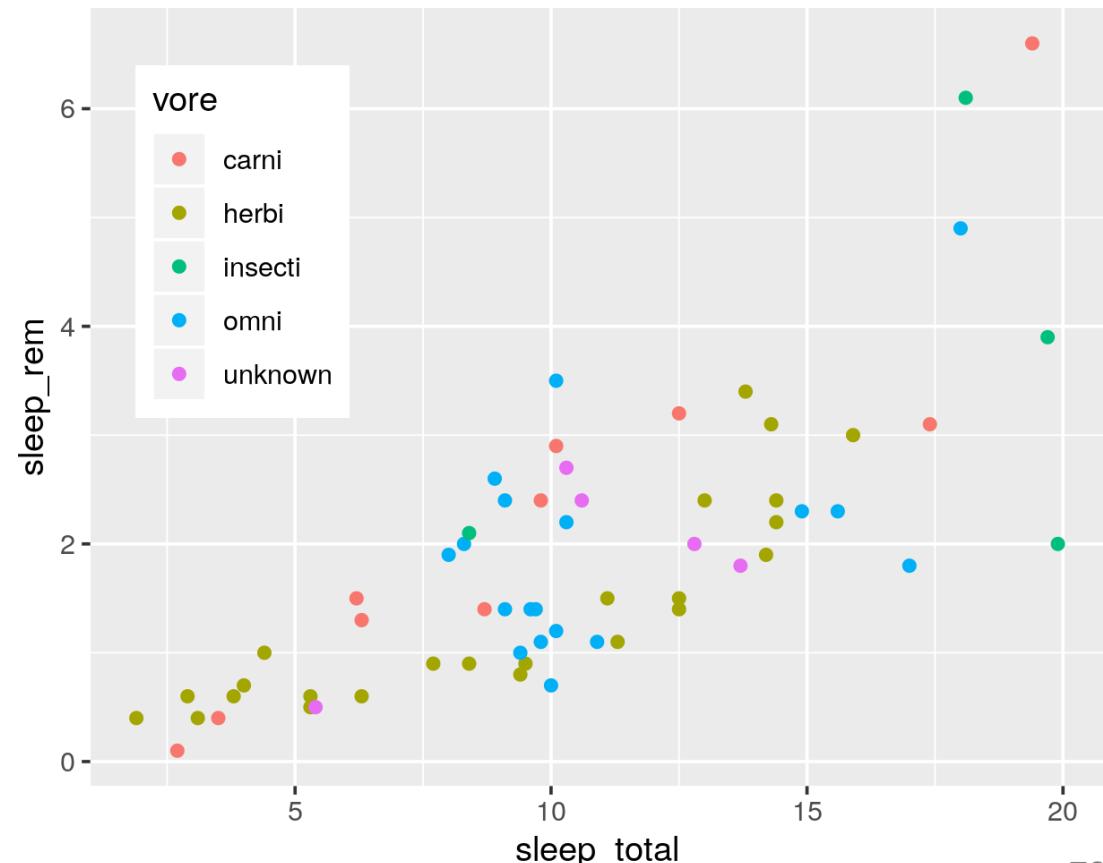
At the: top, bottom, left, right

```
g + theme(legend.position = "top")
```

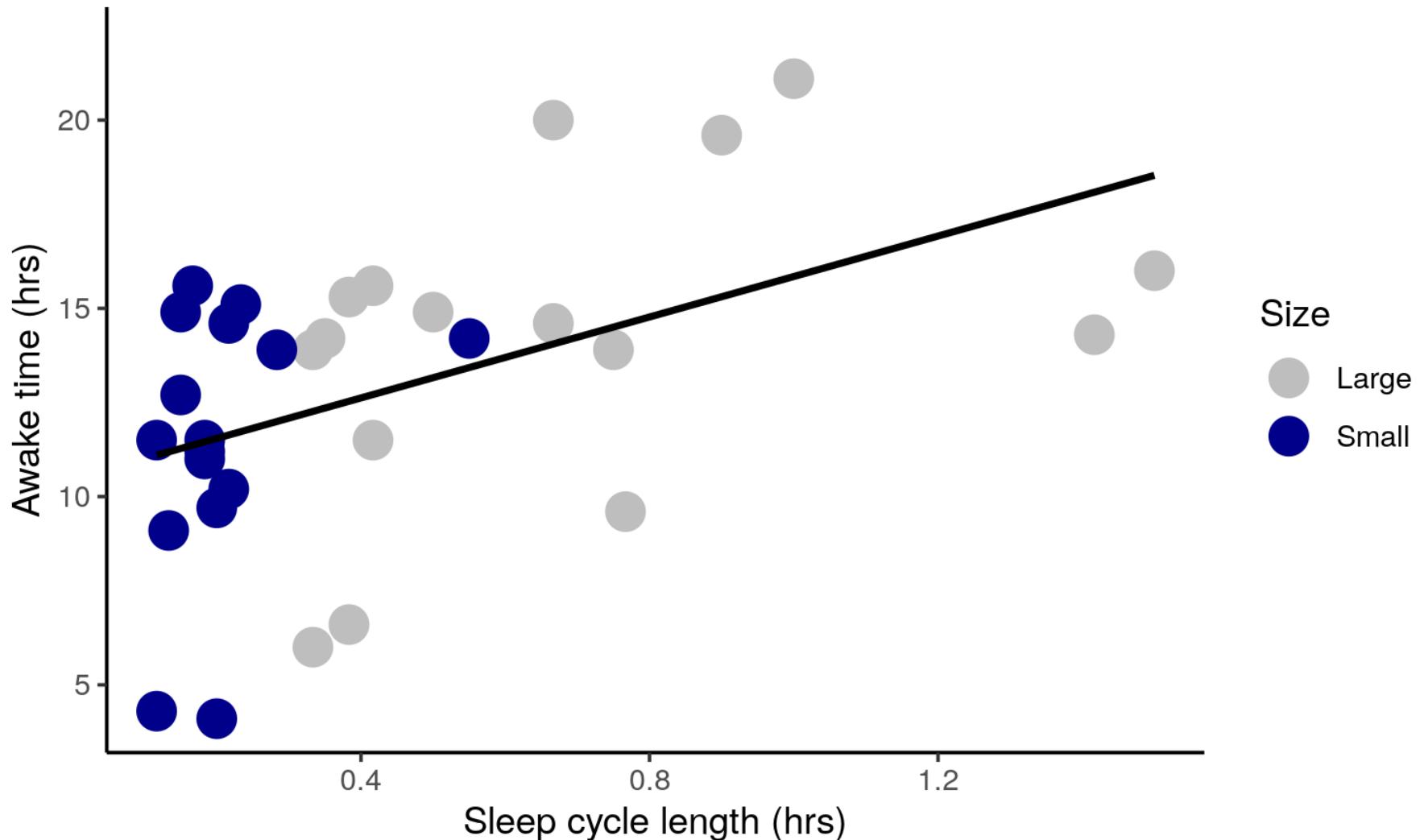


Exactly here

```
g + theme(legend.position = c(0.15, 0.7))
```



# Your Turn: Create this plot

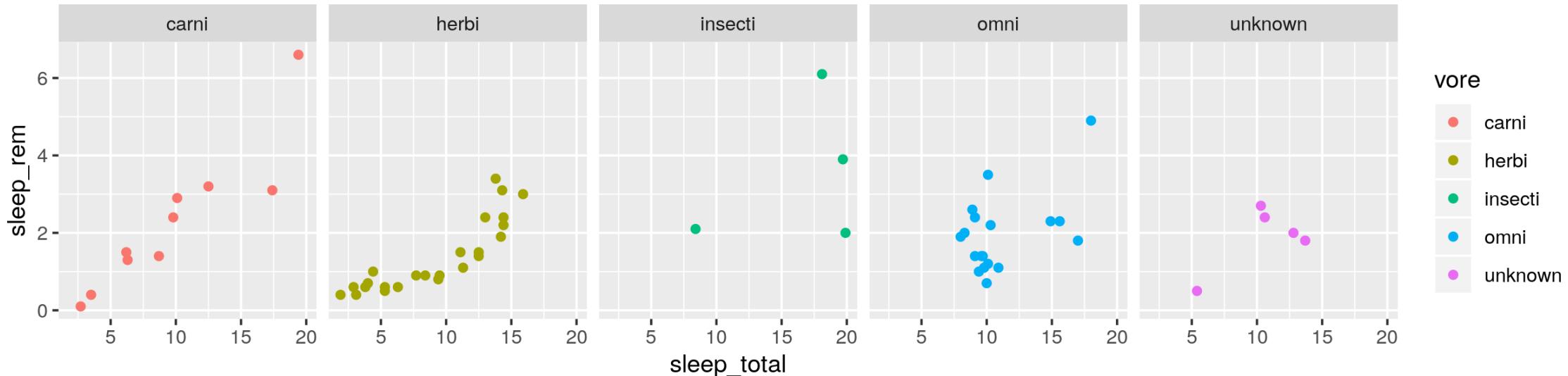


# Annotating plots

# Annotating

**Plot to be annotated: Let's add sample sizes**

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point() +  
  facet_grid(~ vore)
```



# Annotating

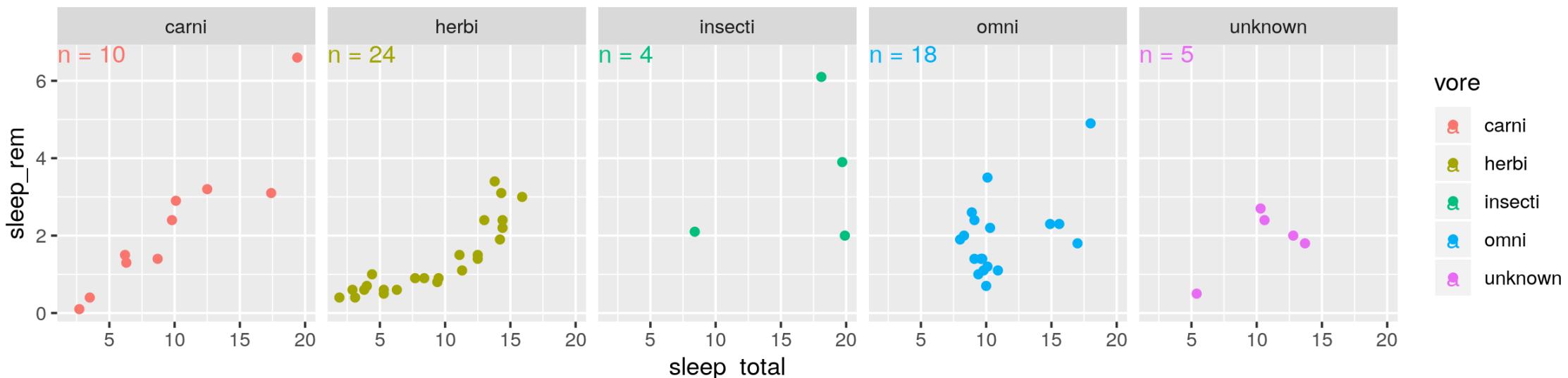
## Create data to use in our annotations

```
n <- data.frame(vore = c("carni", "herbi", "insecti", "omni", "unknown"),
                 text = c("n = 10", "n = 24", "n = 4", "n = 18", "n = 5"))
n
```

```
##      vore   text
## 1    carni n = 10
## 2    herbi n = 24
## 3 insecti n = 4
## 4     omni n = 18
## 5 unknown n = 5
```

# Annotating

```
ggplot(data = sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +  
  geom_point() +  
  facet_grid(~ vore) +  
  geom_text(data = n,  
            x = -Inf, y = +Inf,  
            aes(label = text),  
            hjust = 0, vjust = 1)      # Use 'n' data (not the `sleep` data)  
                                # Hard coded location (left, top)  
                                # Map 'text' to label  
                                # Adjust horizontal and vertical placement
```



ggplot will automatically apply aesthetics in the `ggplot()` line to all data included

# Saving plots

# Saving plots

## RStudio Export

### Demo

### ggsave()

```
g <- ggplot(sleep, aes(x = vore, y = sleep_total)) +  
  geom_boxplot()  
  
ggsave(filename = "sleep_boxplot.png", plot = g)
```

```
## Saving 6 x 3.9 in image
```

# Saving plots

## Publication quality plots

- Many publications require 'lossless' (pdf, svg, eps, ps) or high quality formats (tiff, png)
- Specific sizes corresponding to columns widths
- Minimum resolutions

```
g <- ggplot(sleep, aes(x = vore, y = sleep_total)) +  
  geom_boxplot() +  
  labs(x = "Carnivore", y = "Total sleep (hrs)") +  
  theme(axis.text.x = element_text(angle = 45, hjust = 1))  
  
ggsave(filename = "sleep_boxplot_sm.pdf", plot = g, dpi = 300,  
       height = 80, width = 129, units = "mm")
```

# Wrapping Up!

# Wrapping up: Common mistakes

- The package is **ggplot2**, the function is just **ggplot()**
- Did you remember to put the **+** at the **end** of the line?
- Order matters! If you're using custom **theme()**'s, make sure you put these lines **after** bundled themes like **theme\_bw()**, or they will be overwritten

# Wrapping up: Common mistakes

I get an error regarding a missing aesthetic? But I know it's there!

You are probably trying to plot two different datasets, and you make references to variables in the `ggplot()` call that don't exist in one of the datasets:

Here, `conservation` only exists in the `sleep` dataset, not in the `n` dataset

```
n <- dplyr::count(sleep, vore)

ggplot(sleep, aes(x = sleep_total, y = sleep_rem, colour = conservation)) +
  geom_point() +
  facet_grid(~ vore) +
  geom_text(data = n, aes(label = n),
            x = -Inf, y = +Inf, hjust = 0, vjust = 1)

## Error in FUN(X[[i]], ...): object 'conservation' not found
```

# Wrapping up: Common mistakes

I get an error regarding a missing aesthetic? But I know it's there!

Either move the aesthetic...

```
ggplot(sleep, aes(x = sleep_total, y = sleep_rem)) +  
  geom_point(aes(colour = conservation)) +  
  facet_grid(~ vore) +  
  geom_text(data = n, aes(label = n),  
            x = -Inf, y = +Inf, hjust = 0, vjust = 1)
```

Or assign it to NULL where it is missing...

```
ggplot(sleep, aes(x = sleep_total, y = sleep_rem, colour = conservation)) +  
  geom_point() +  
  facet_grid(~ vore) +  
  geom_text(data = n, aes(label = n, colour = NULL),  
            x = -Inf, y = +Inf, hjust = 0, vjust = 1)
```

# Wrapping up

## R is hard: But have no fear!

- Don't expect to remember everything!
- Copy/Paste is your friend (never apologize for using it!)
- Consider this workshop a resource to return to ([Answers to Activities](#))

## Further reading

- RStudio > Help > Cheatsheets > Data Visualization with ggplot2
- [R for Data Science: Chapter 3](#)
- [Cookbook for R](#) - by Winston Chang
  - See also R Graphics Cookbook by Winston Chang
- [ggplot2 book v2 Hadley Wickham](#)
  - You can compile it yourself from GitHub, or ask me for my compiled version (pdf)
- [gridExtra Vignette: Arranging Multiple Grobs](#)

# EXTRA: Combining multiple plots

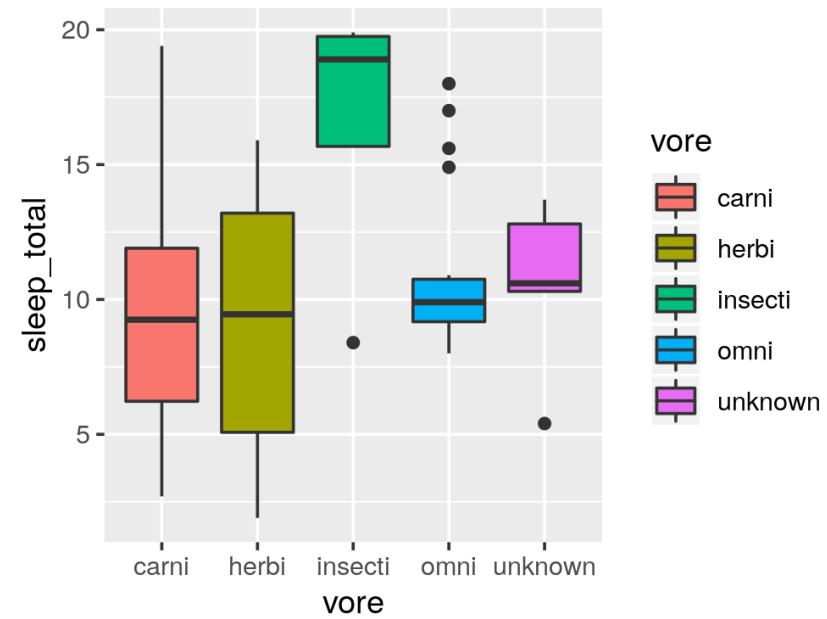
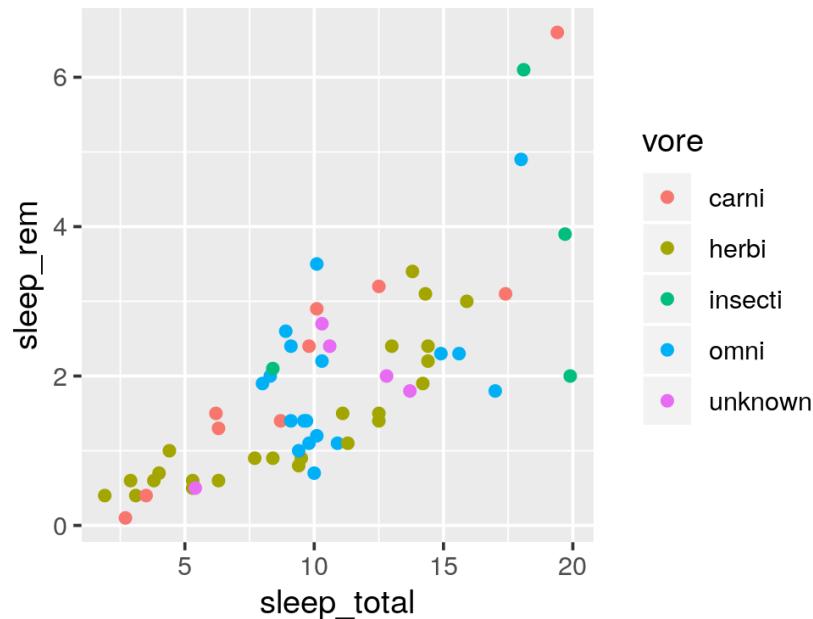
# Combining with gridExtra

```
library(gridExtra)

g1 <- ggplot(sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +
  geom_point()

g2 <- ggplot(sleep, aes(x = vore, y = sleep_total, fill = vore)) +
  geom_boxplot()

grid.arrange(g1, g2, nrow = 1)
```



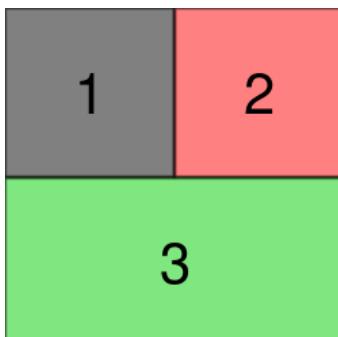
# Combining multiple plots

```
library(gridExtra)
g1 <- ggplot(sleep, aes(x = body_size, y = sleep_total)) +
  geom_boxplot()

g2 <- ggplot(sleep, aes(x = sleep_total, y = sleep_rem, colour = vore)) +
  geom_point()

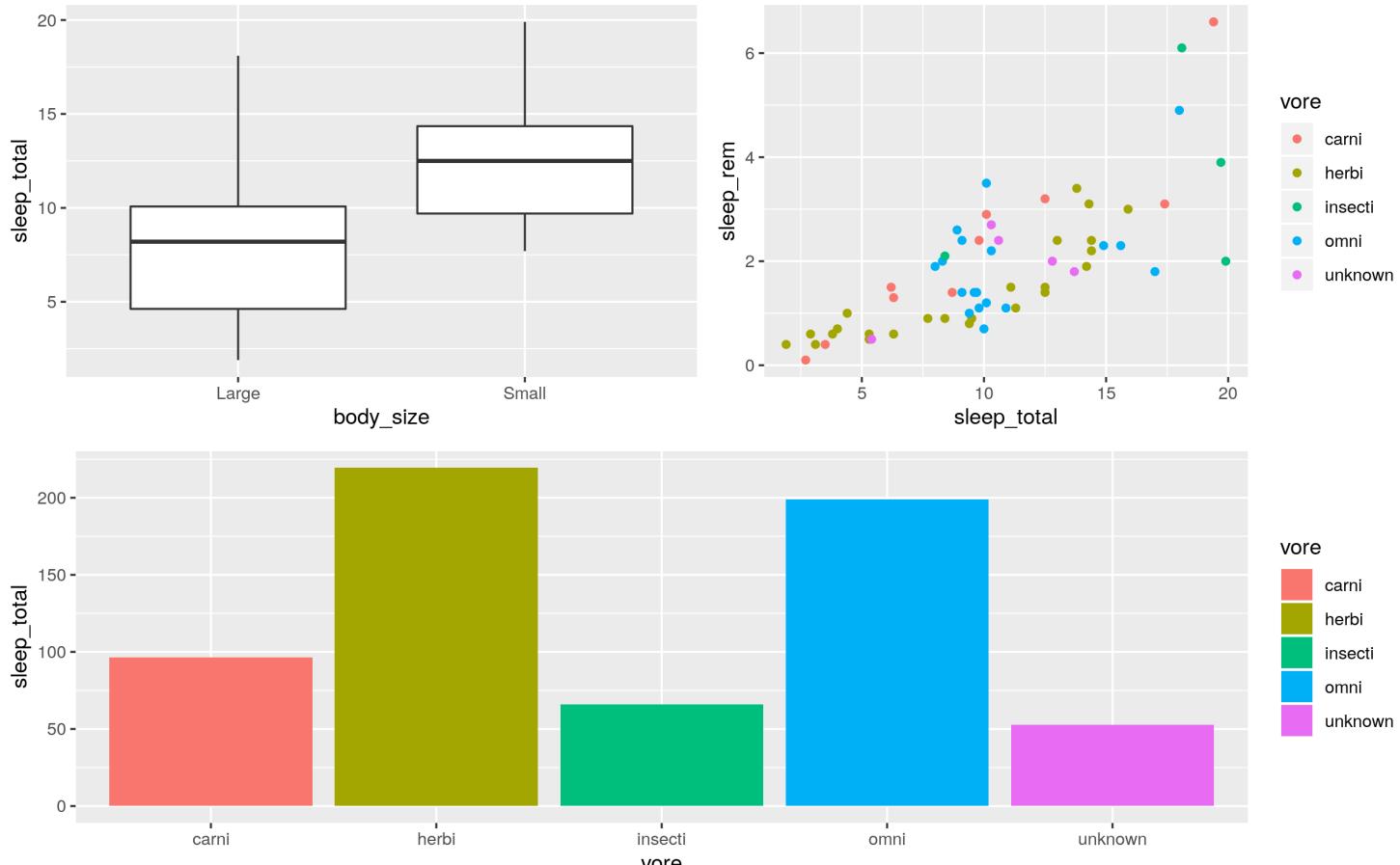
g3 <- ggplot(sleep, aes(x = vore, y = sleep_total, fill = vore)) +
  geom_bar(stat = "identity")

layout <- rbind(c(1,2),
                c(3,3))
```



# Combining multiple plots

```
grid.arrange(g1, g2, g3, layout_matrix = layout)
```



# Your turn

## Combine any 3 figures

- feel free to try out the layout matrix option if you wish

```
library(gridExtra) # you'll probably have to install this first!  
  
g1 <- ???  
g2 <- ???  
g3 <- ???  
  
grid.arrange(???)
```