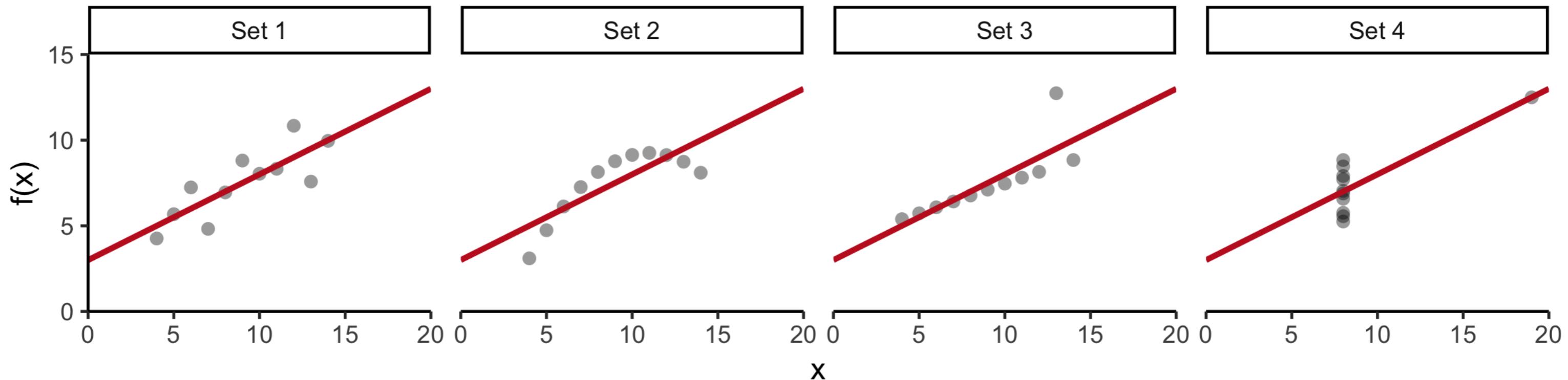


Anscombe's plots

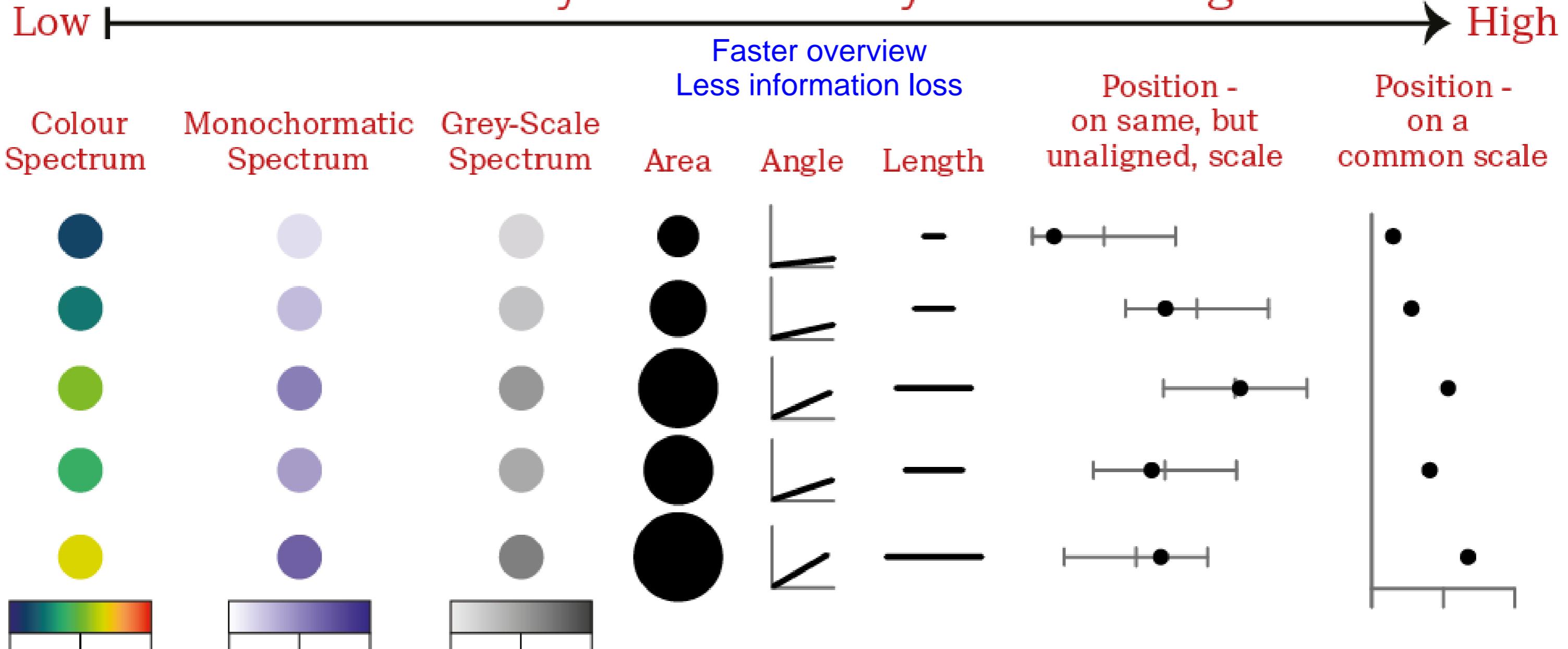


Typical visible aesthetics

Aesthetic	Description
x	X axis position
y	Y axis position
fill	Fill color
color	Color of points, outlines of other geoms
size	Area or radius of points, thickness of lines

Aesthetic	Description
alpha	Transparency
linetype	line dash pattern
labels	Text on a plot or axes
shape	Shape

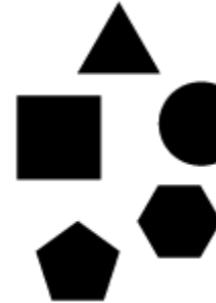
Efficiency and Accuracy of Decoding



Efficiency in Decoding Separate Groups

Low → High

Filled Shapes



Sequential Colours



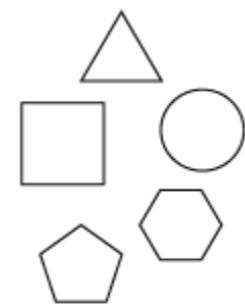
Qualitative Colours



Hatching



Shape Outlines



Labels

ANT1
FRG2
FRG1
Gapdh
DUX4

Line Width



Line Type



Line Colours



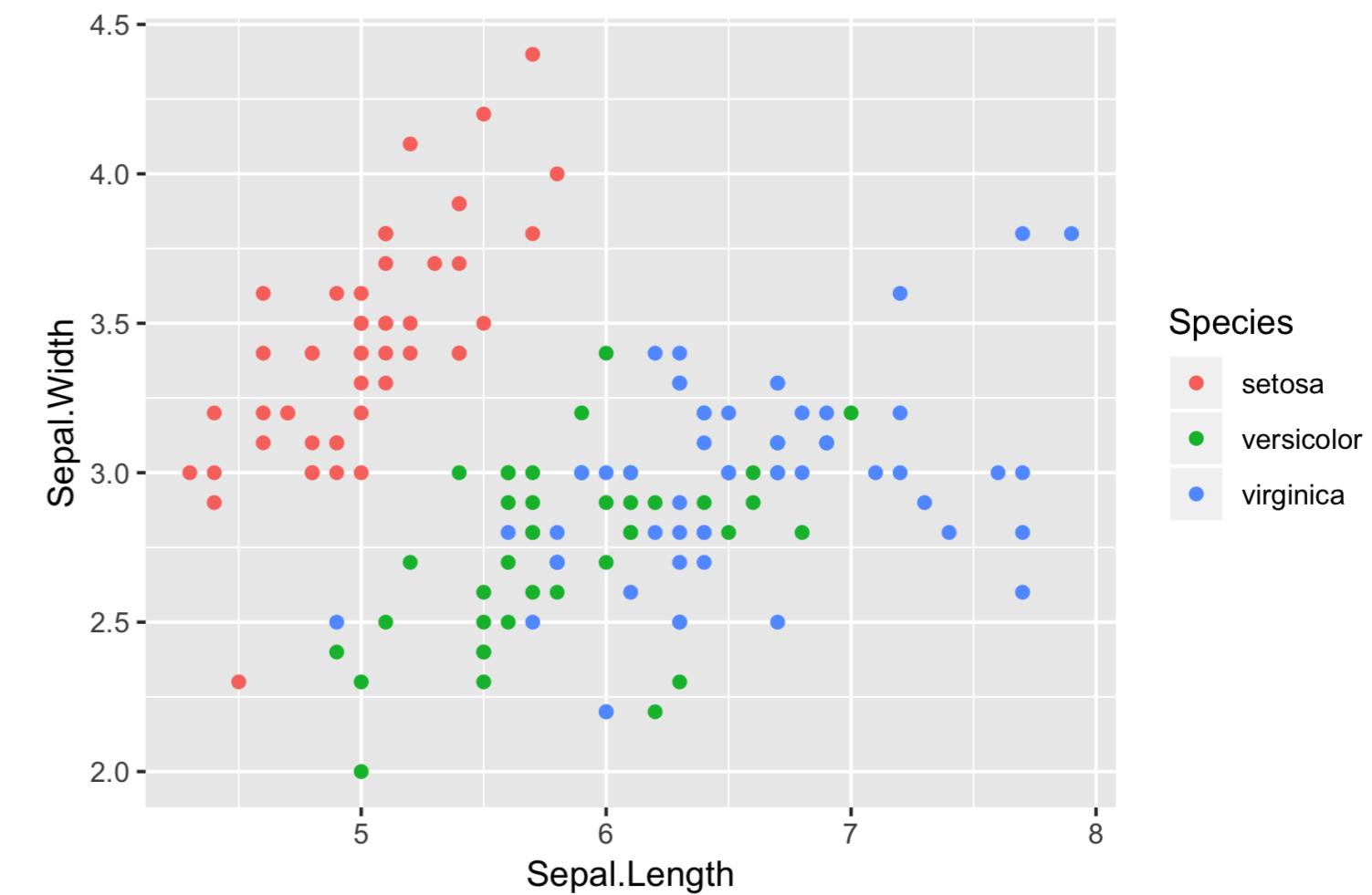
Positions

Adjustment for overlapping

- identity
- dodge
- stack
- fill
- jitter
- jitterdodge
- nudge

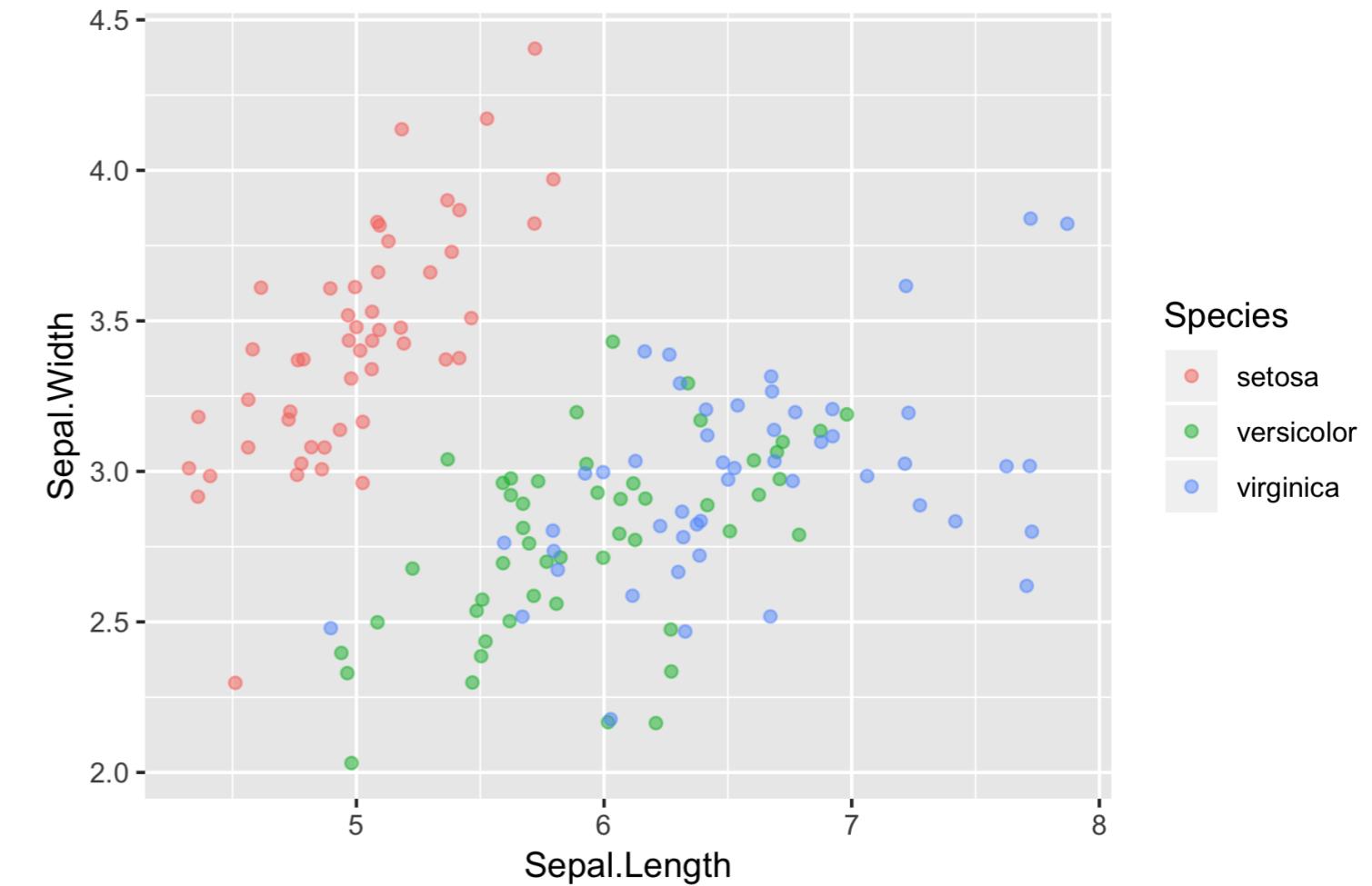
position = "identity" (default)

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  geom_point(position = "identity")
```



position = "jitter"

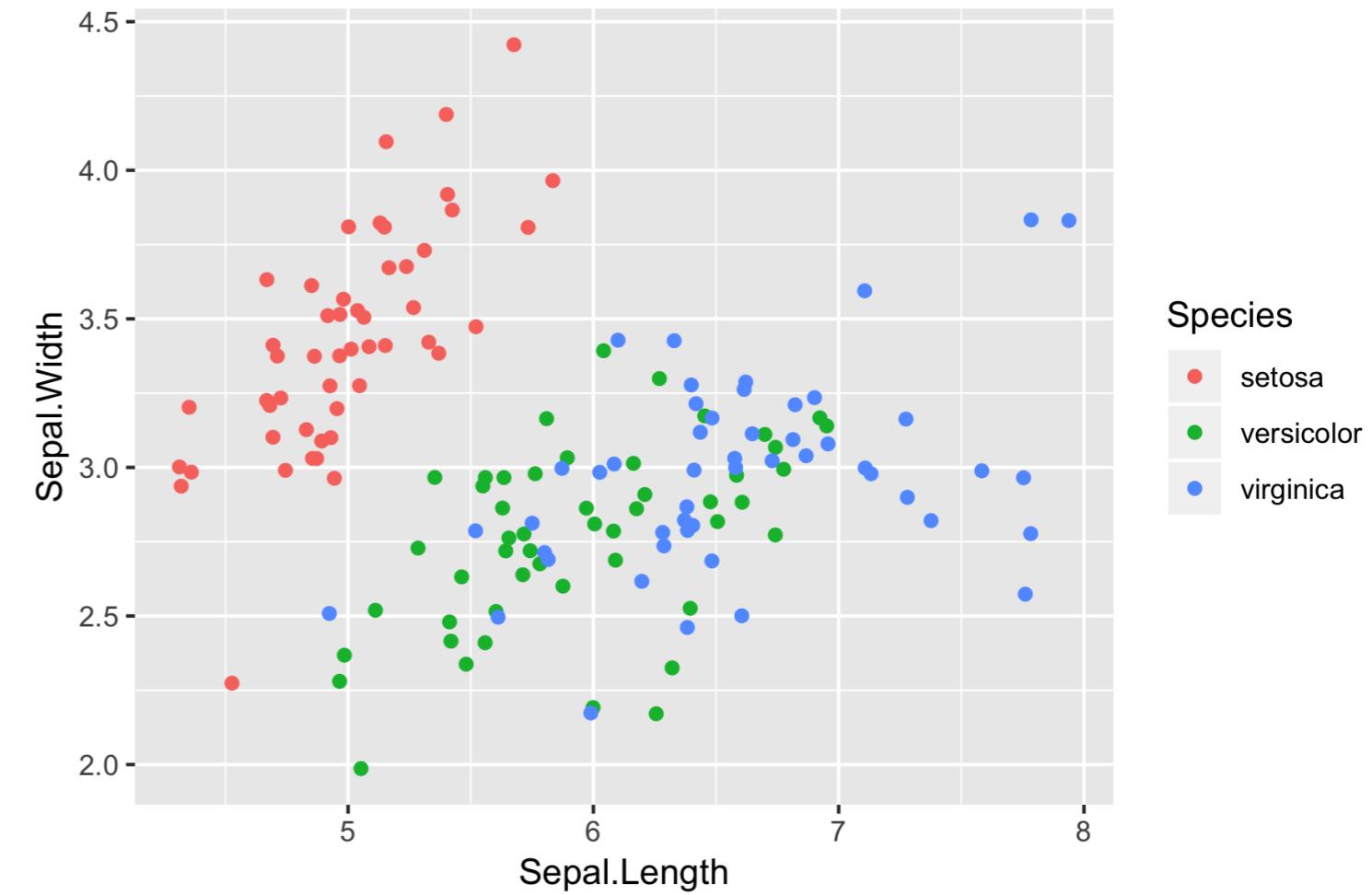
```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  geom_point(position = "jitter")
```



position_jitter()

```
posn_j <- position_jitter(0.1,  
                           seed = 136)  
  
ggplot(iris, aes(x = Sepal.Length,  
                  y = Sepal.Width,  
                  color = Species)) +  
  geom_point(position = posn_j)
```

- Set arguments for the position
- Consistency across plots & layers

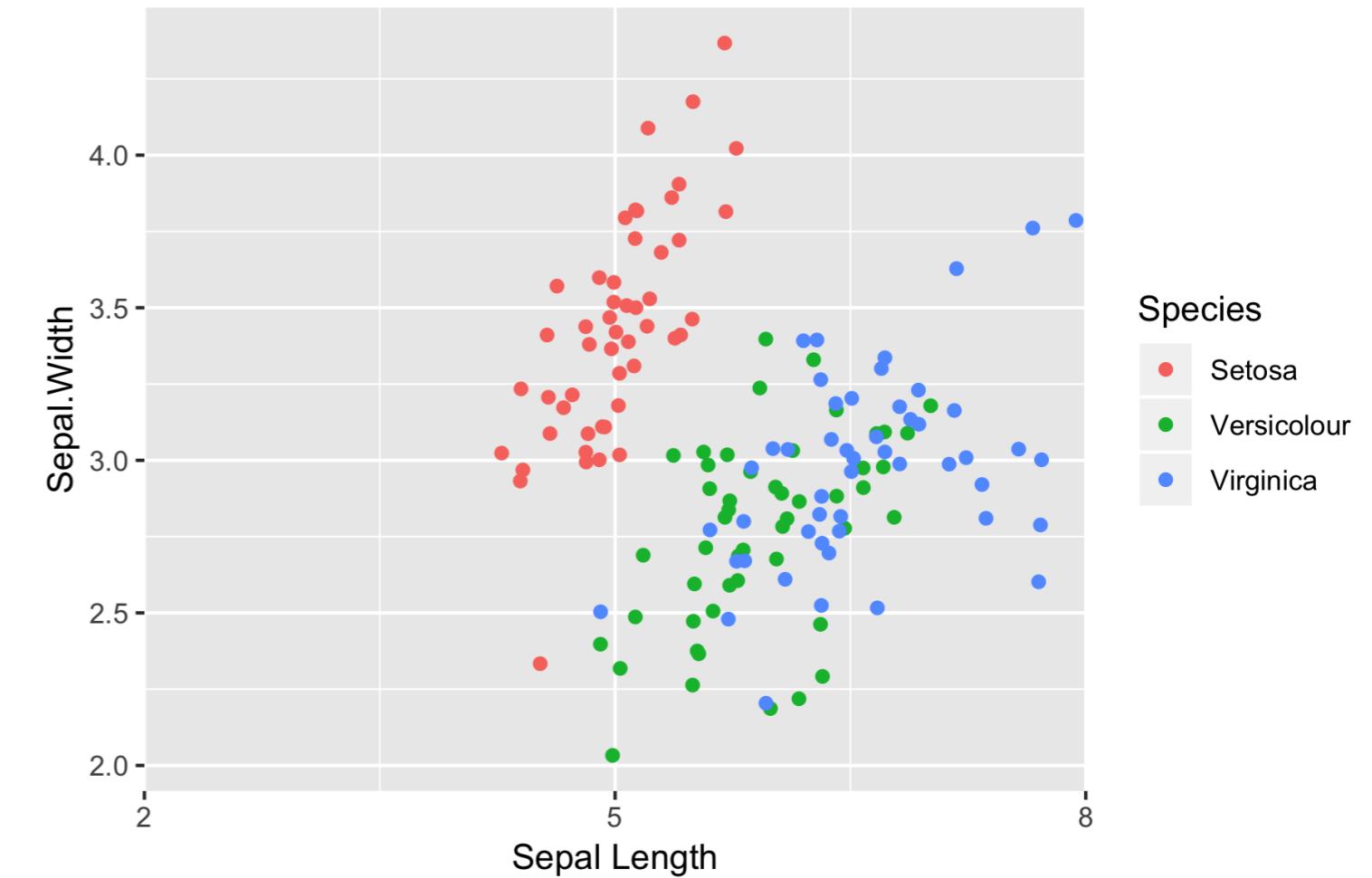


Scale functions

- `scale_x_continuous()`
- `scale_y_*`(`)`
- `scale_color_discrete()`
 - Alternatively, `scale_colour_*`(`)`
- `scale_fill_*`(`)`
- `scale_shape_*`(`)`
- `scale_linetype_*`(`)`
- `scale_size_*`(`)`

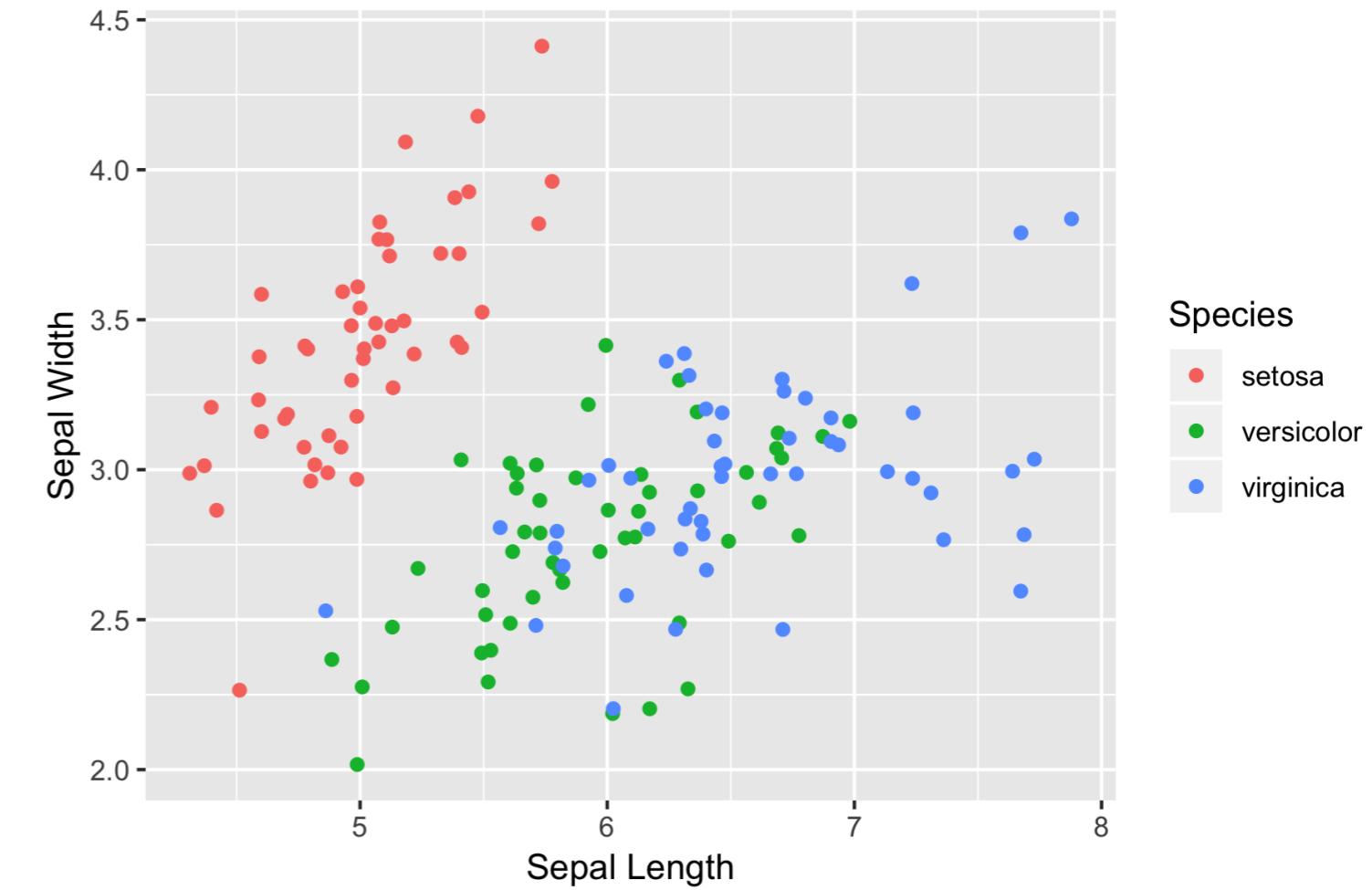
The labels argument

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  geom_point(position = "jitter") +  
  scale_x_continuous("Sepal Length",  
                     limits = c(2, 8),  
                     breaks = seq(2, 8, 3),  
                     expand = c(0, 0),  
                     labels = c("Setosa",  
                               "Versicolor",  
                               "Virginica")) +  
  scale_color_discrete("Species")
```

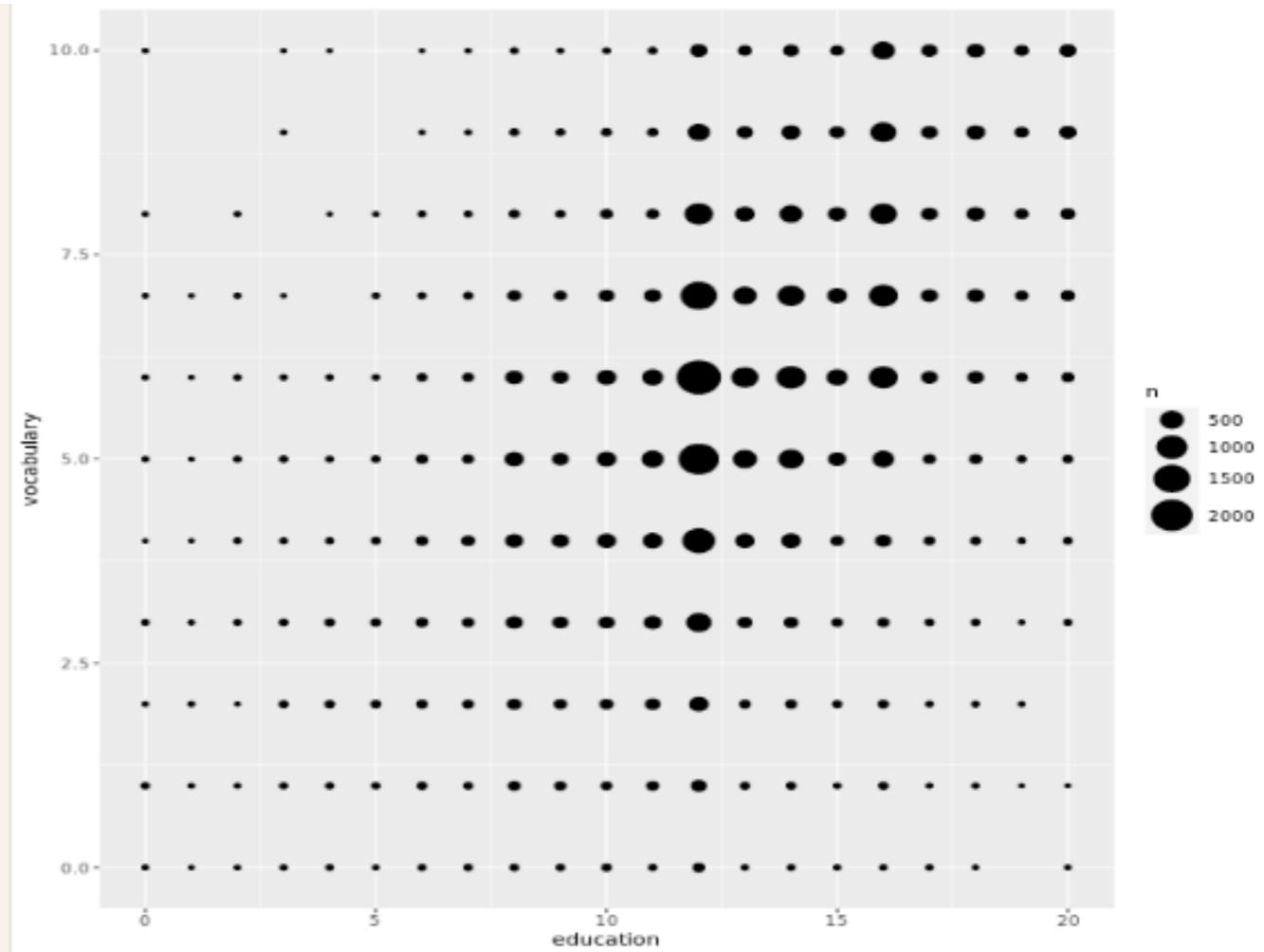


labs()

```
ggplot(iris, aes(x = Sepal.Length,  
                  y = Sepal.Width,  
                  color = Species)) +  
  geom_point(position = "jitter") +  
  labs(x = "Sepal Length",  
        y = "Sepal Width",  
        color = "Species")
```



```
ggplot(Vocab, aes(x = education, y =  
vocabulary)) +  
  stat_sum() +  
  # Add a size scale, from 1 to 10  
  scale_size(range = c(1,10))
```



48 geometries

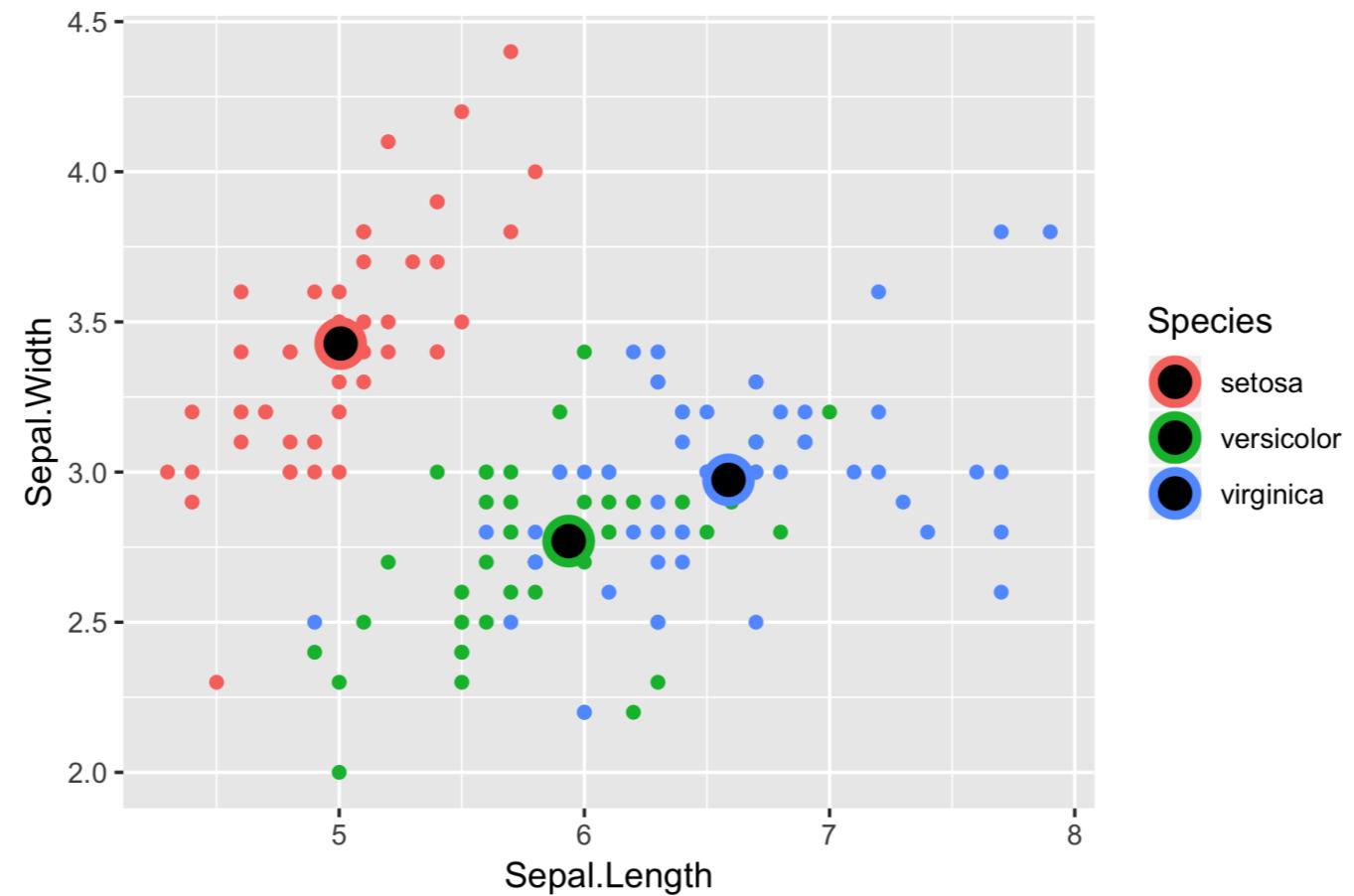
geom_*						
abline	contour	dotplot	jitter	pointrange	ribbon	spoke
area	count	errorbar	label	polygon	rug	step
bar	crossbar	errorbarh	line	qq	segment	text
bin2d	curve	freqpoly	linerange	qq_line	sf	tile
blank	density	hex	map	quantile	sf_label	violin
boxplot	density2d	histogram	path	raster	sf_text	vline
col	density_2d	hline	point	rect	smooth	

Shape attribute values



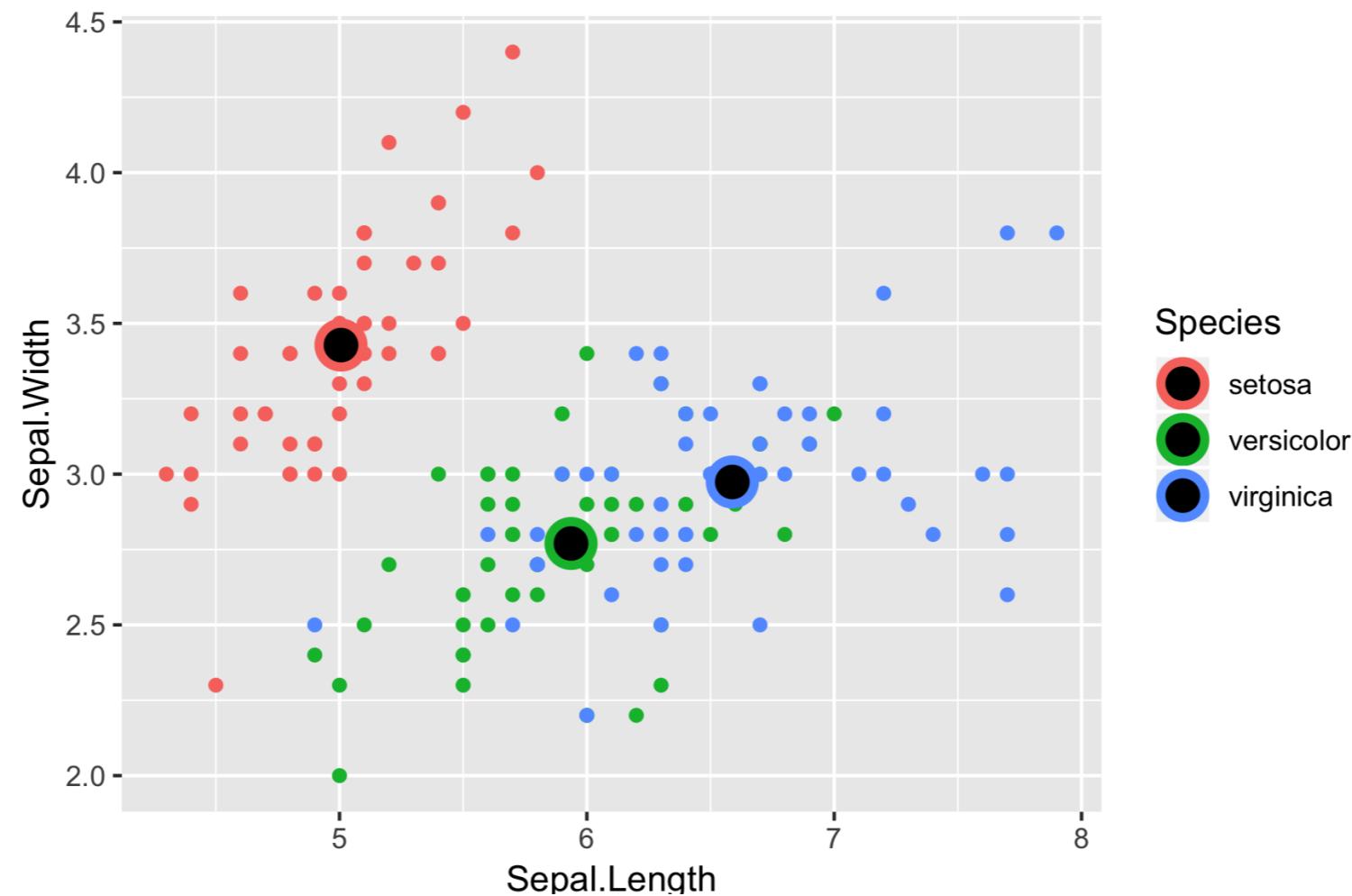
Example

```
ggplot(iris, aes(x = Sepal.Length, y = Sepal.Width, col = Species)) +  
  geom_point() +  
  geom_point(data = iris.summary, shape = 21, size = 5,  
             fill = "black", stroke = 2)
```



On-the-fly stats by ggplot2

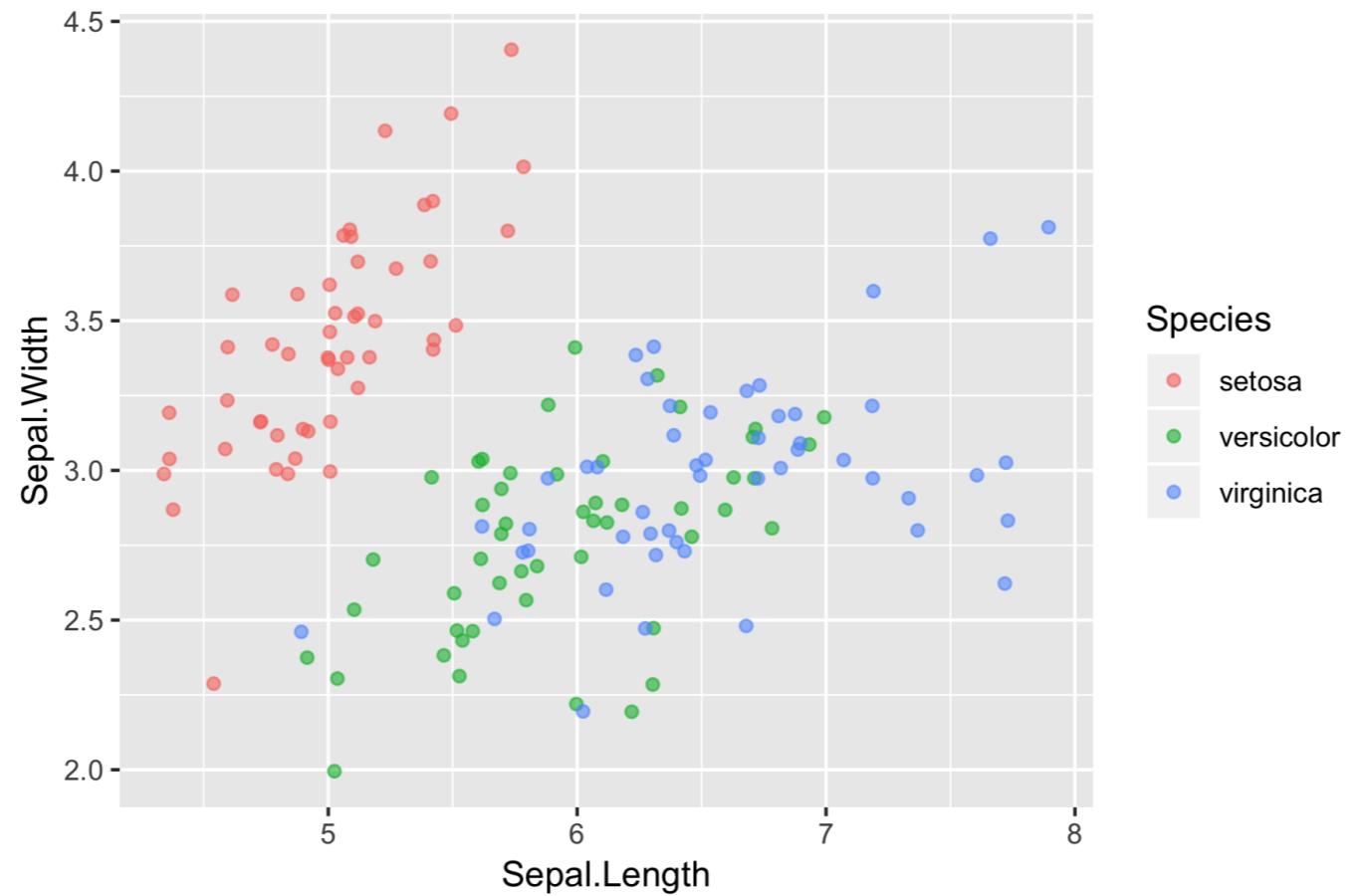
- See the second course for the stats layer.
- Note: Avoid plotting only the mean without a measure of spread, e.g. the standard deviation.



Don't forget to adjust alpha

- Combine jittering with alpha-blending if necessary

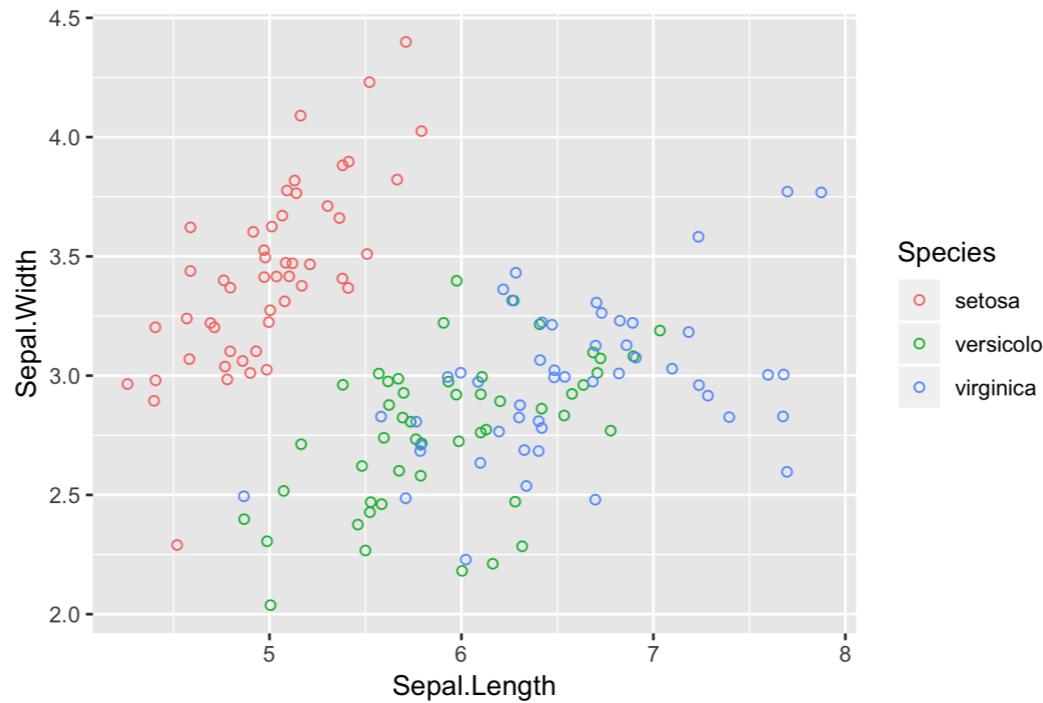
```
ggplot(iris, aes(x = Sepal.Length, y = Sepal.Width, col = Species)) +  
  geom_jitter(alpha = 0.6)
```



Hollow circles also help

- `shape = 1` is a. hollow circle.
- Not necessary to also use alpha-blending.

```
ggplot(iris, aes(x = Sepal.Length, y = Sepal.Width, col = Species)) +  
  geom_jitter(shape = 1)
```



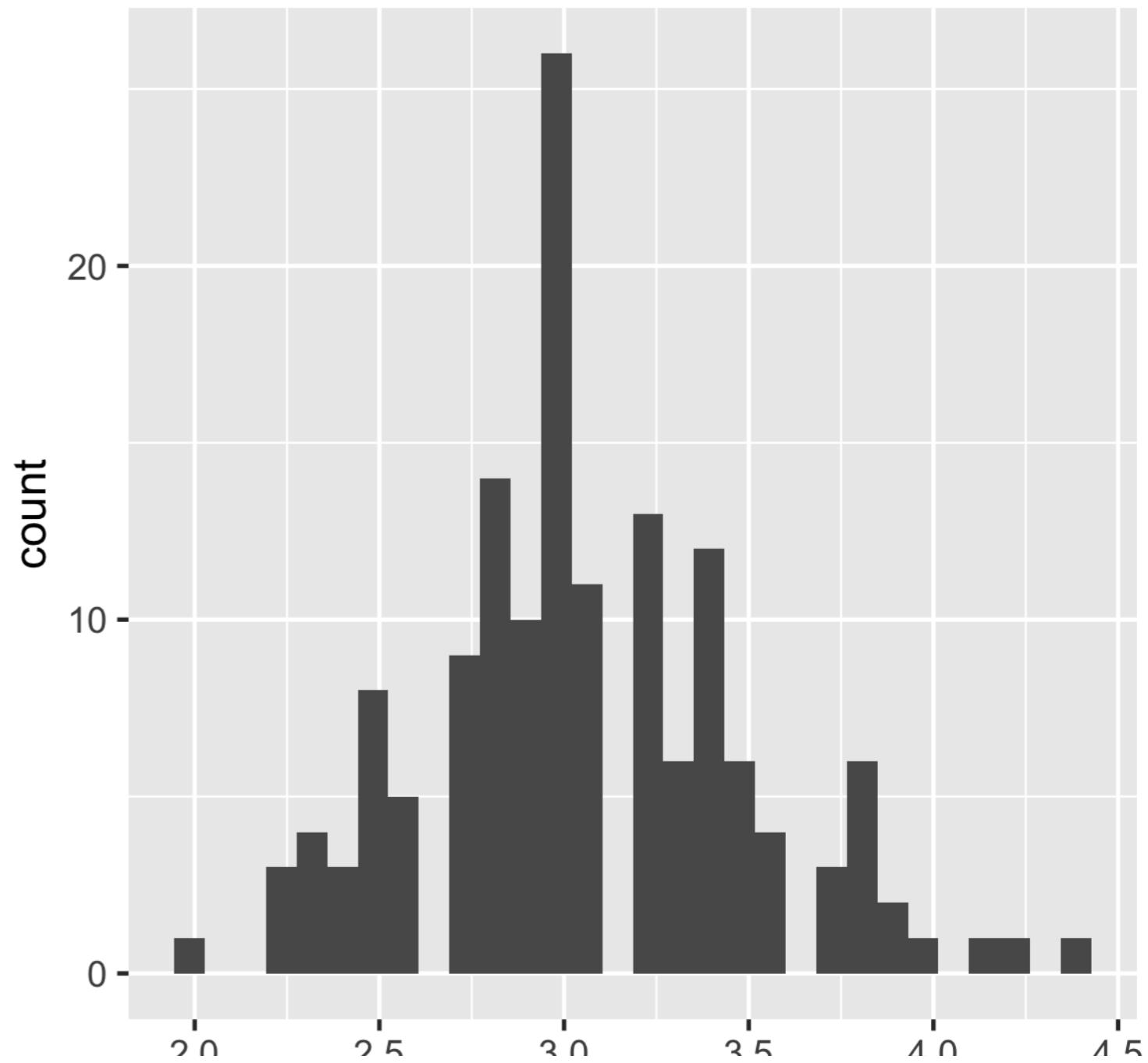
Default of 30 even bins

```
ggplot(iris, aes(x = Sepal.Width)) +  
  geom_histogram()
```

- A plot of binned values
 - i.e. a statistical function

```
# Default bin width:  
diff(range(iris$Sepal.Width))/30
```

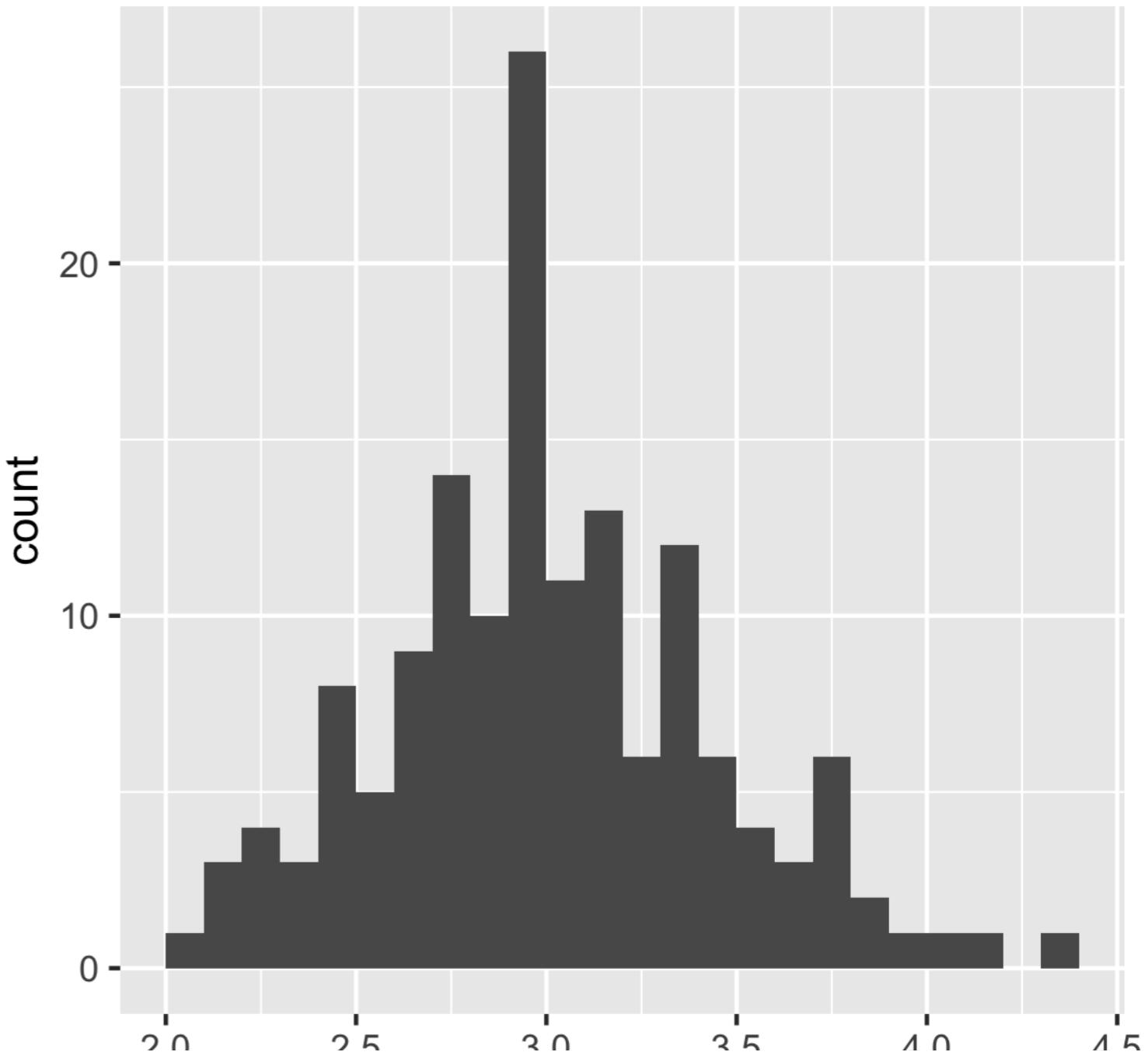
```
[1] 0.08
```



Re-position tick marks

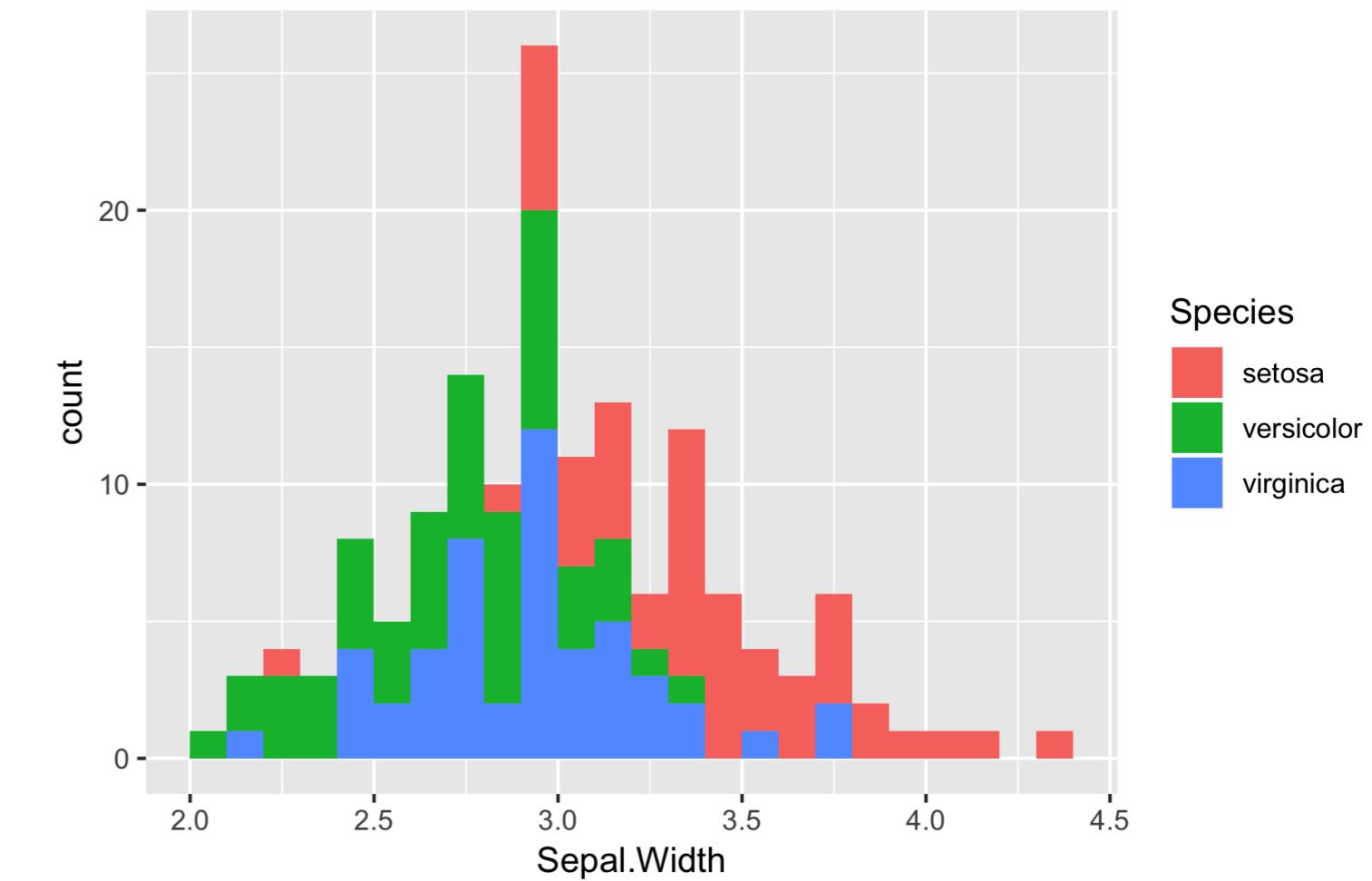
```
ggplot(iris, aes(x = Sepal.Width)) +  
  geom_histogram(binwidth = 0.1,  
                 center = 0.05)
```

- Always set a meaningful bin widths for your data.
- No spaces between bars.
- X axis labels are between bars.



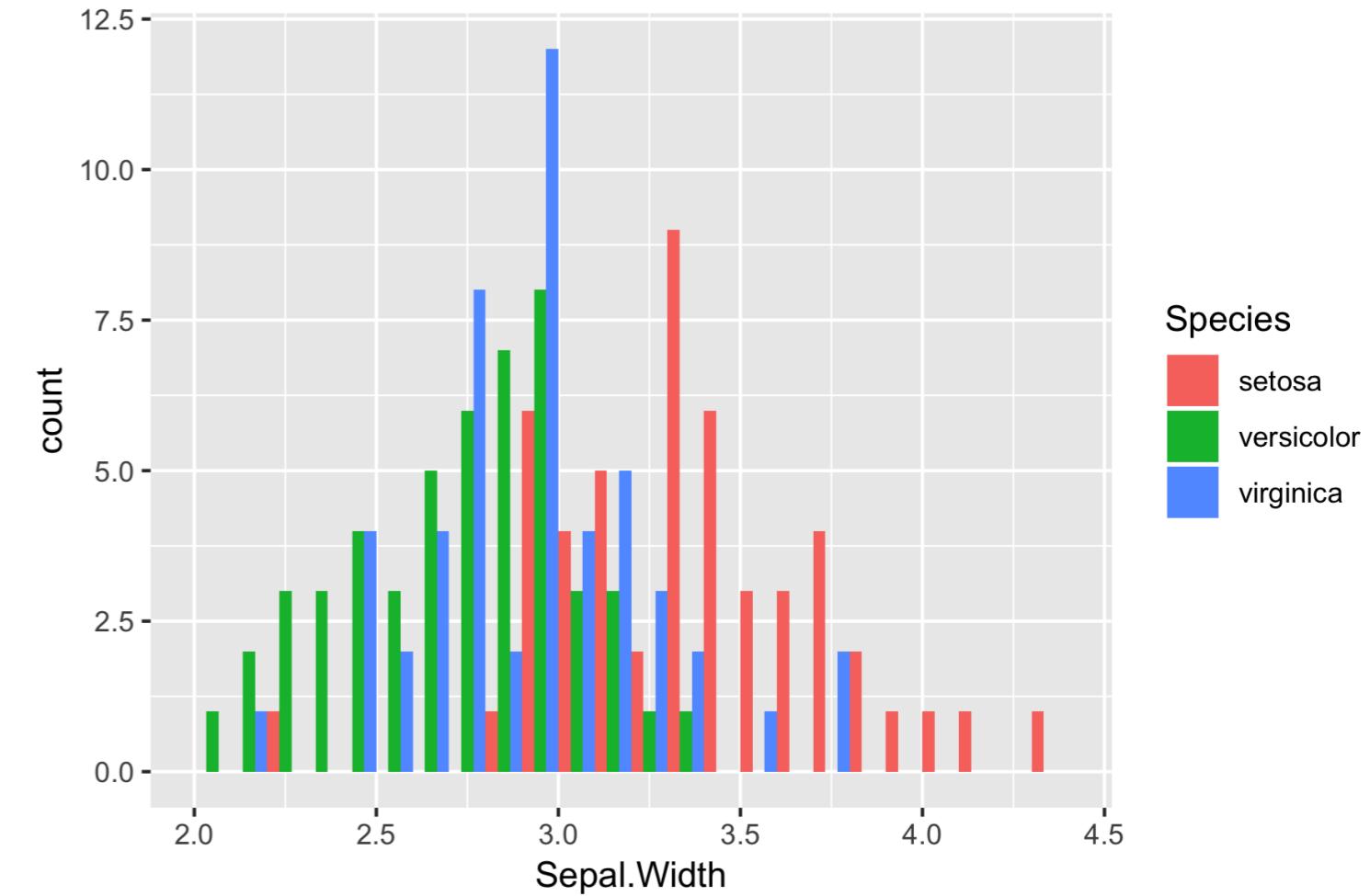
Default position is "stack"

```
ggplot(iris, aes(x = Sepal.Width,  
                  fill = Species)) +  
  geom_histogram(binwidth = .1,  
                 center = 0.05,  
                 position = "stack")
```



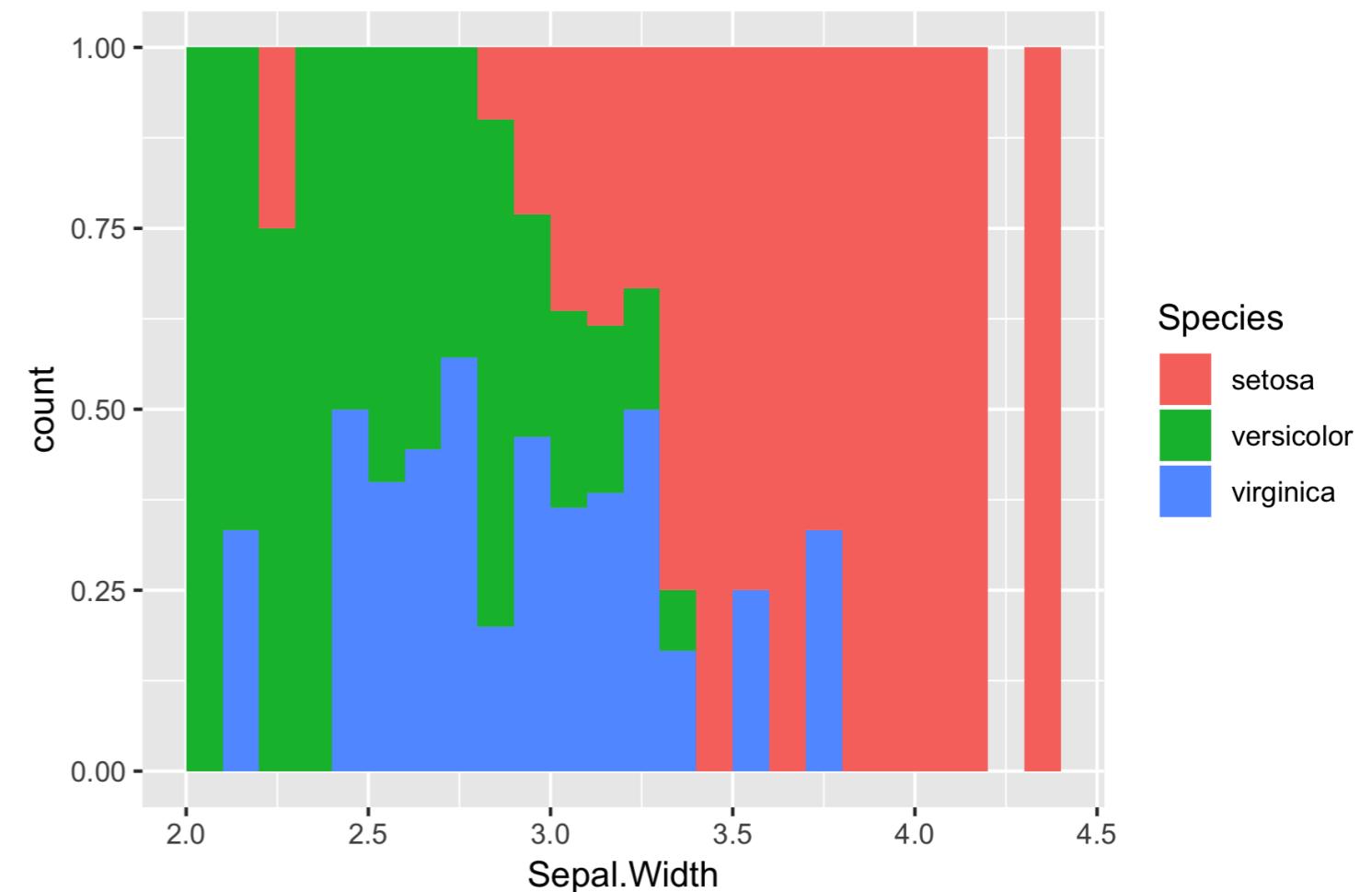
position = "dodge"

```
ggplot(iris, aes(x = Sepal.Width,  
                  fill = Species)) +  
  geom_histogram(binwidth = .1,  
                 center = 0.05,  
                 position = "dodge")
```



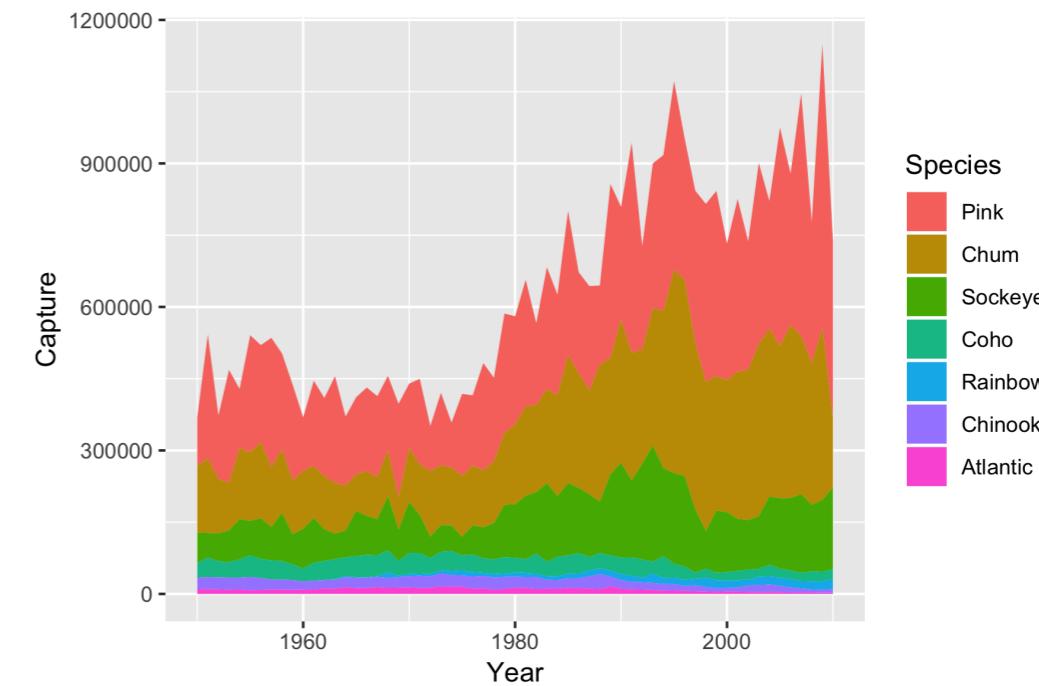
position = "fill"

```
ggplot(iris, aes(x = Sepal.Width,  
                 fill = Species)) +  
  geom_histogram(binwidth = .1,  
                 center = 0.05,  
                 position = "fill")
```



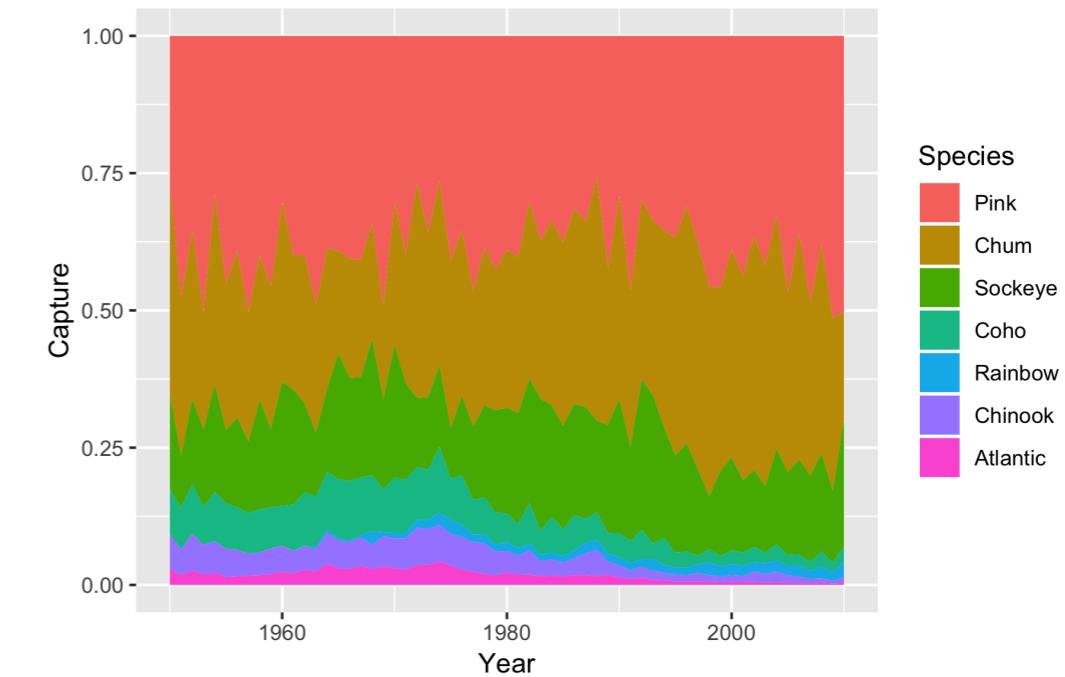
Fill aesthetic with geom_area()

```
ggplot(fish, aes(x = Year,  
                  y = Capture,  
                  fill = Species)) +  
  
  geom_area()
```



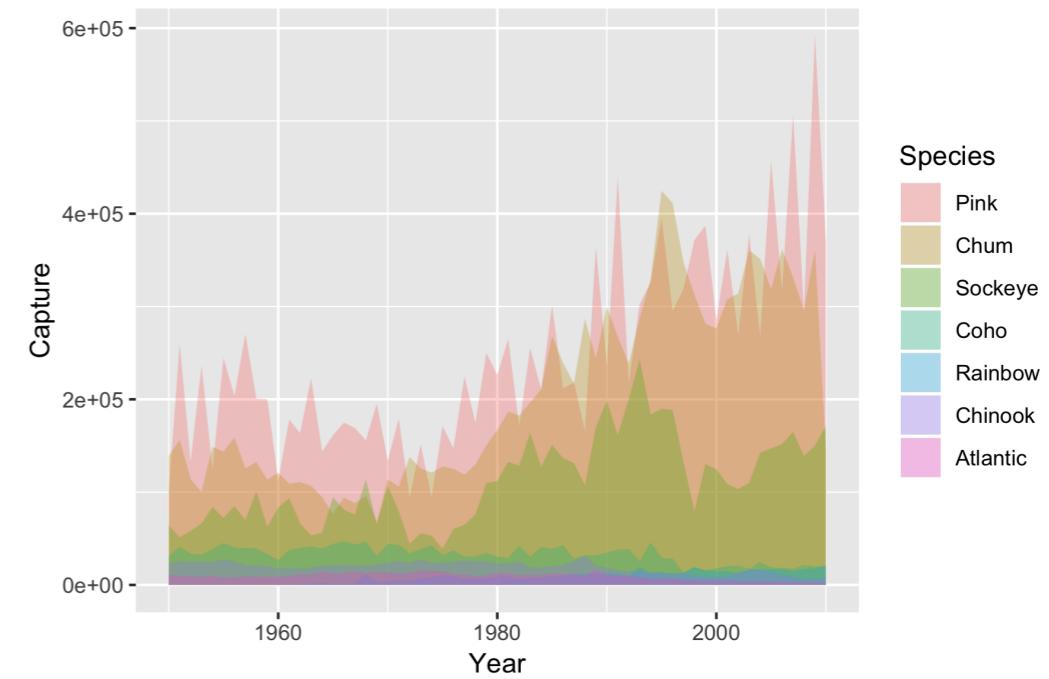
Using position = "fill"

```
ggplot(fish, aes(x = Year,  
                  y = Capture,  
                  fill = Species)) +  
  geom_area(position = "fill")
```

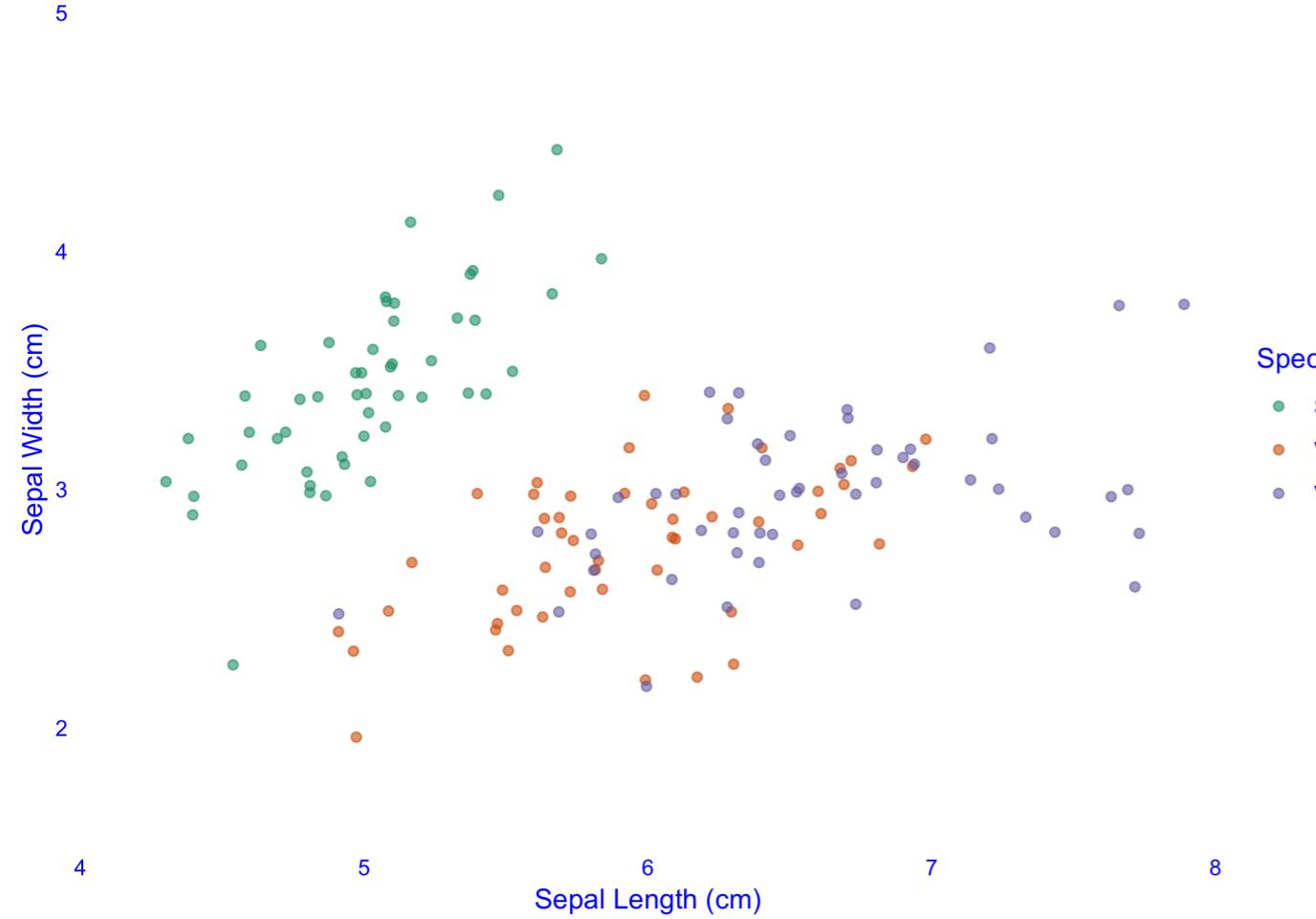


geom_ribbon()

```
ggplot(fish, aes(x = Year,  
                  y = Capture,  
                  fill = Species)) +  
  geom_ribbon(aes(ymax = Capture,  
                 ymin = 0),  
              alpha = 0.3)
```

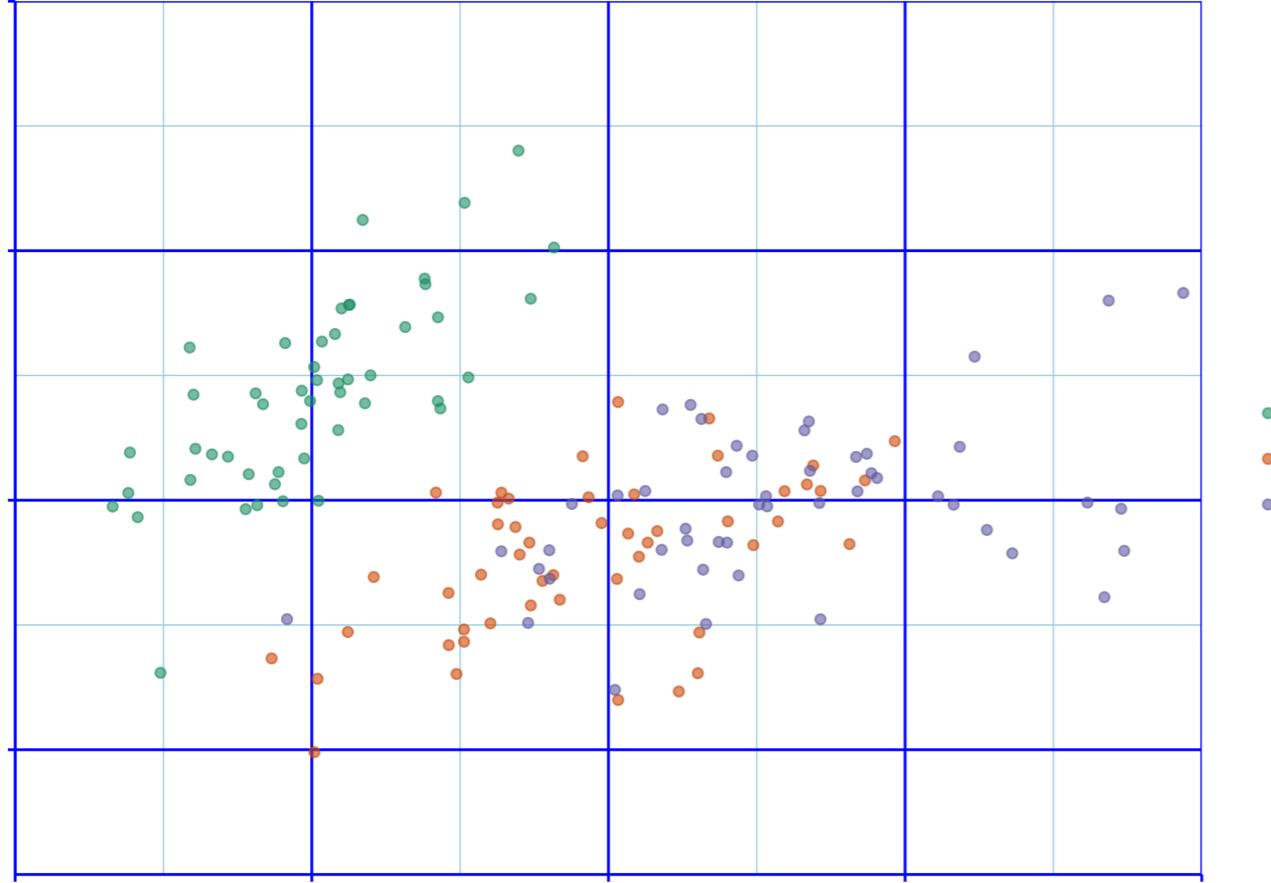


The text elements



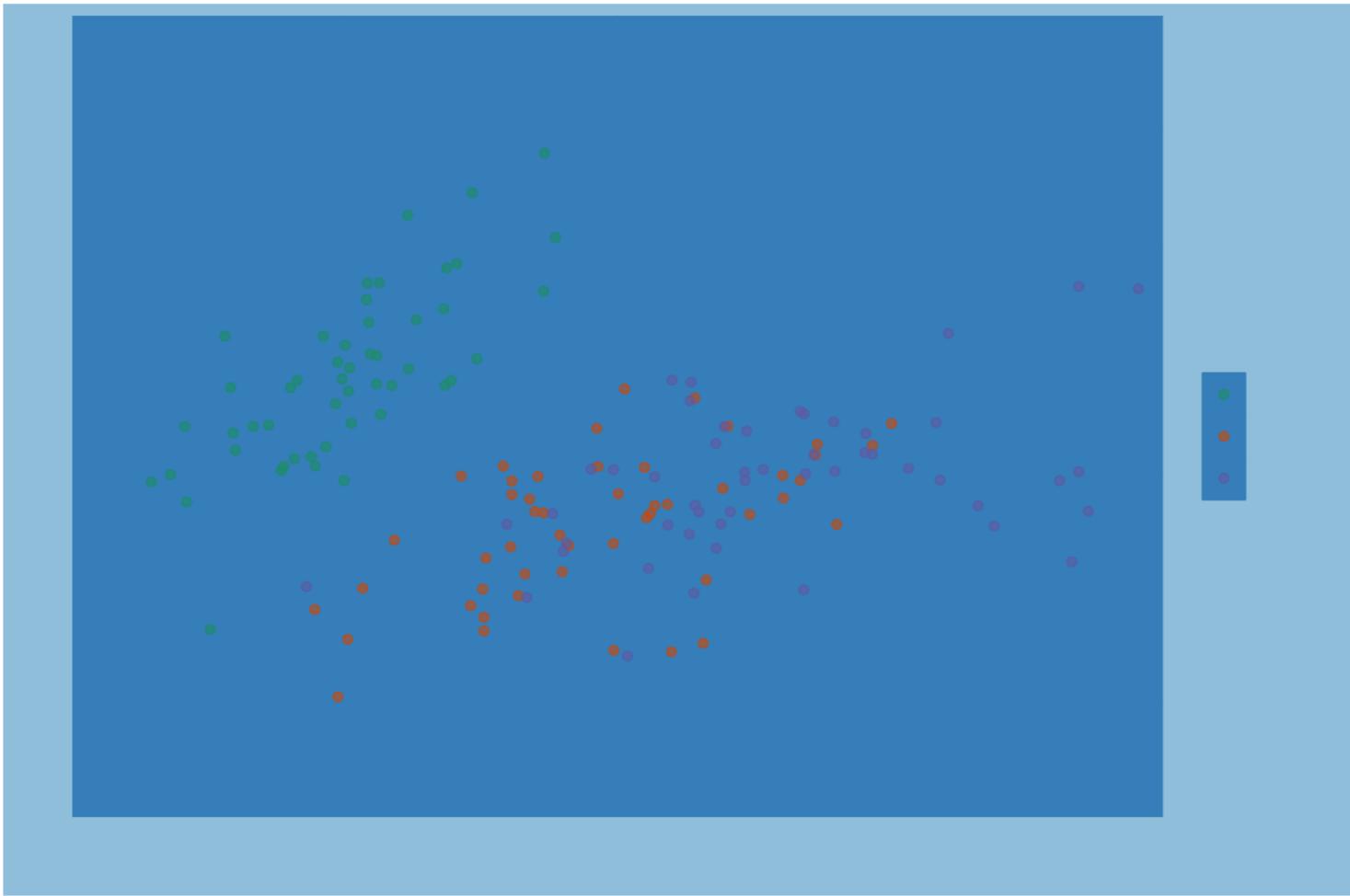
```
theme(  
  text,  
    axis.title,  
    axis.title.x,  
    axis.title.x.top,  
    axis.title.x.bottom,  
    axis.title.y,  
    axis.title.y.left,  
    axis.title.y.right,  
  title,  
    legend.title,  
    plot.title,  
    plot.subtitle,  
    plot.caption,  
    plot.tag,  
  axis.text,  
    axis.text.x,  
    axis.text.x.top,  
    axis.text.x.bottom,  
    axis.text.y,  
    axis.text.y.left,  
    axis.text.y.right,  
  legend.text,  
  strip.text,  
  strip.text.x,  
  strip.text.y)
```

Line elements



```
theme(  
  line,  
  axis.ticks,  
  axis.ticks.x,  
  axis.ticks.x.top,  
  axis.ticks.x.bottom,  
  axis.ticks.y,  
  axis.ticks.y.left,  
  axis.ticks.y.right,  
  axis.line,  
  axis.line.x,  
  axis.line.x.top,  
  axis.line.x.bottom,  
  axis.line.y,  
  axis.line.y.left,  
  axis.line.y.right,  
  panel.grid,  
  panel.grid.major,  
  panel.grid.major.x,  
  panel.grid.major.y,  
  panel.grid.minor,  
  panel.grid.minor.x,  
  panel.grid.minor.y)
```

Rect elements



```
theme(  
  rect,  
  legend.background,  
  legend.key,  
  legend.box.background,  
  panel.background,  
  panel.border,  
  plot.background,  
  strip.background,  
  strip.background.x,  
  strip.background.y)
```

Modifying whitespace

Whitespace means all the non-visible margins and spacing in the plot.

To set a single whitespace value, use `unit(x, unit)`, where `x` is the amount and `unit` is the unit of measure.

Borders require you to set 4 positions, so use

`margin(top, right, bottom, left, unit)`. To remember the margin order, think **T**Rou**B**Le.

The default unit is "pt" (points), which scales well with text. Other options include "cm", "in" (inches) and "lines" (of text).

`plt_mpg_vs_wt_by_cyl` is available. The panel and legend are wrapped in blue boxes so you can see how they change.

```
1 # View the original plot
2 plt_mpg_vs_wt_by_cyl
3
4 plt_mpg_vs_wt_by_cyl +
5   theme(
6     # Set the axis tick length to 2 lines
7     axis.ticks.length = unit(2,"lines")
8   )
```



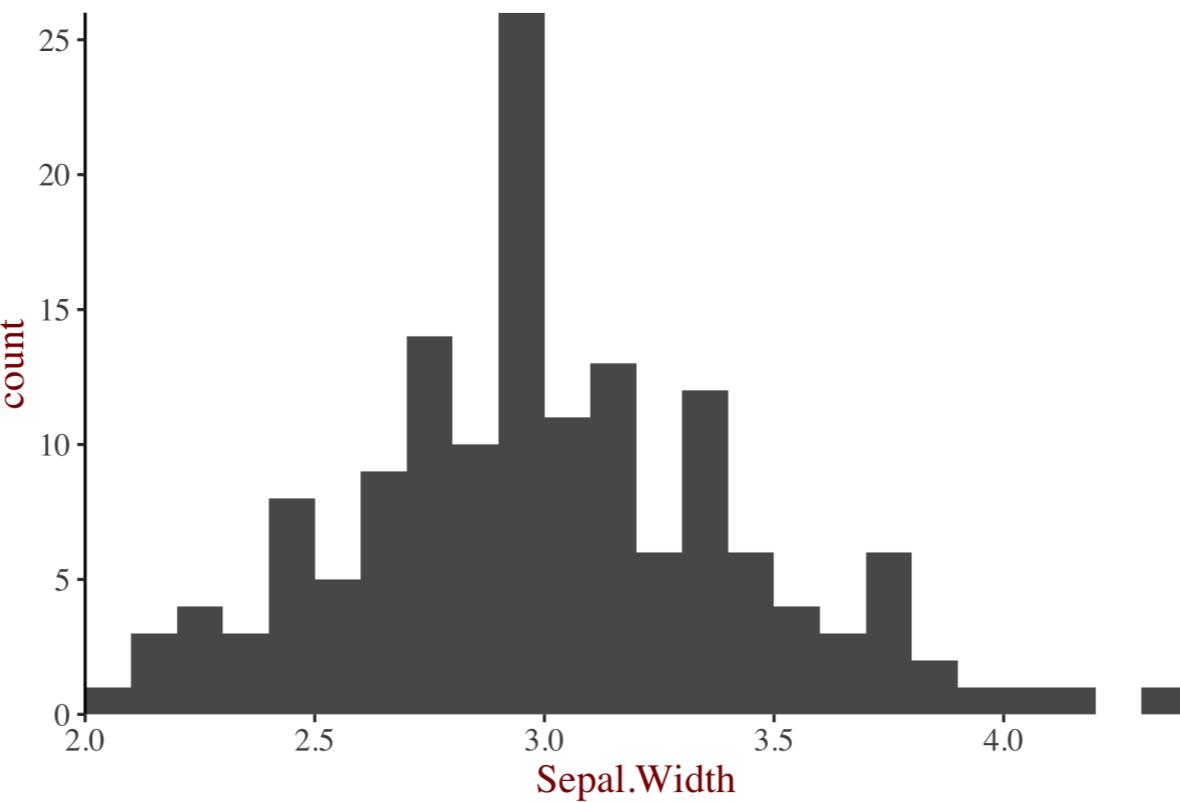
- Give the axis tick length, `axis.ticks.length`, a unit of 2 "lines".
- Give the legend key size, `legend.key.size`, a unit of 3 centimeters ("cm").
- Set the `legend.margin` to 20 points ("pt") on the top, 30 pts on the right, 40 pts on the bottom, and 50 pts on the left.
- Set the plot margin, `plot.margin`, to 10, 30, 50, and 70 millimeters ("mm").

Defining theme objects

```
theme_iris <- theme(text = element_text(family = "serif", size = 14),  
rect = element_blank(),  
panel.grid = element_blank(),  
title = element_text(color = "#8b0000"),  
axis.line = element_line(color = "black"))
```

Reusing theme objects

```
m +  
  theme_iris +  
  theme(axis.line.x = element_blank())
```

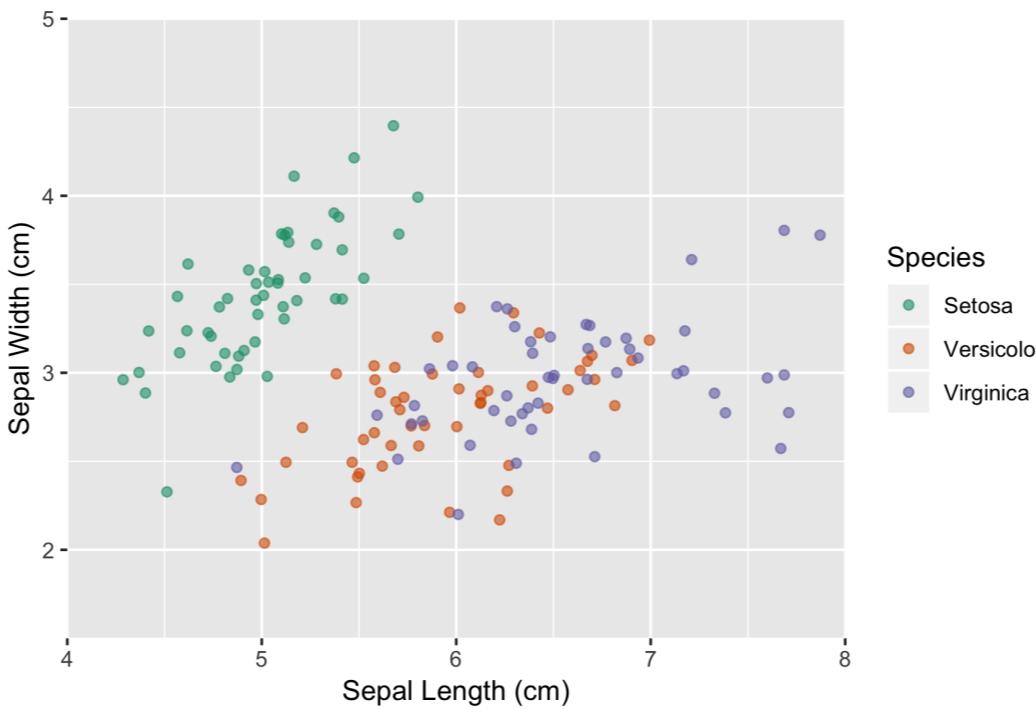


Setting themes

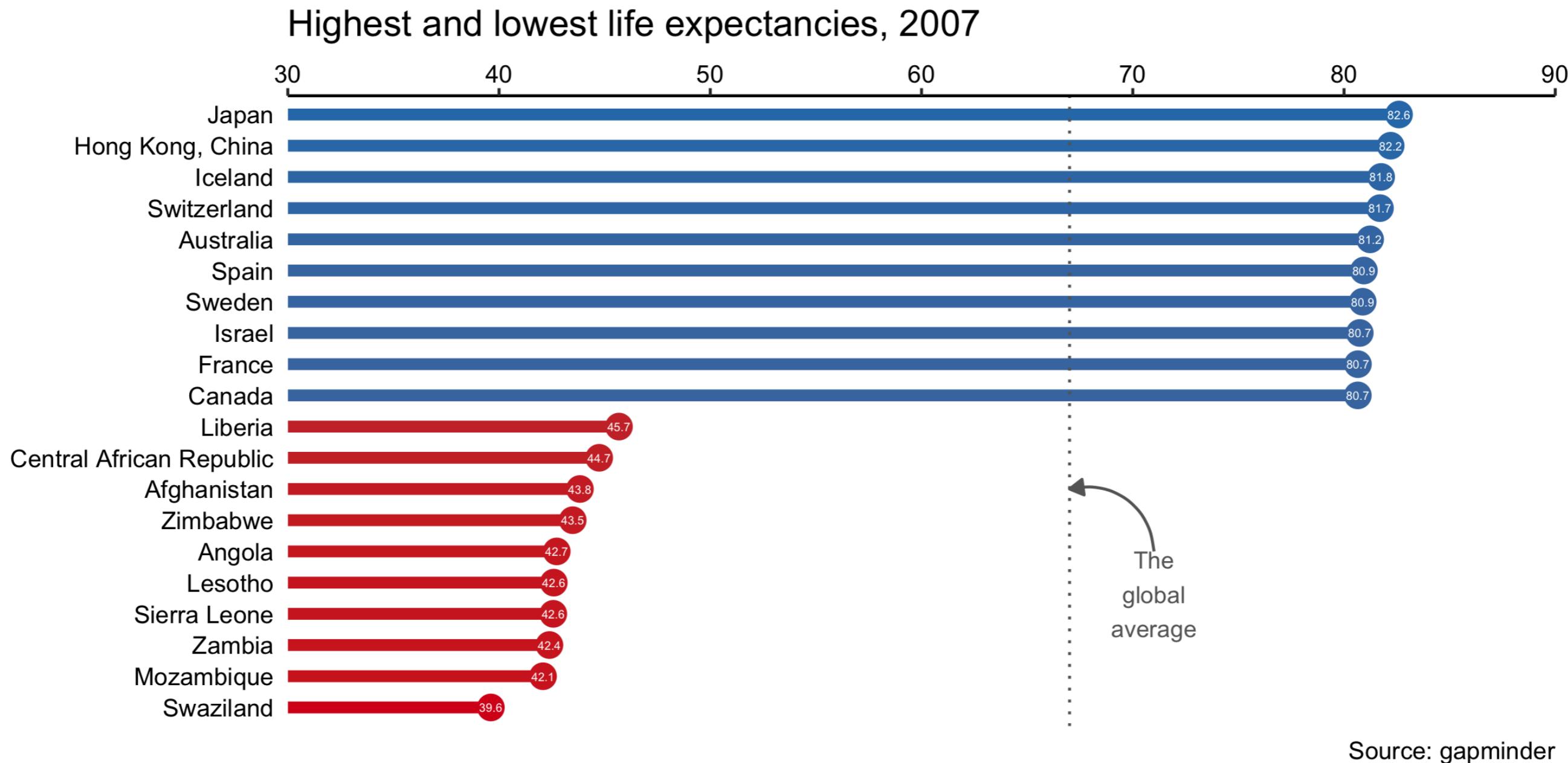
```
theme_set(original)
```

```
# Alternatively
```

```
# theme_set(theme_grey())
```



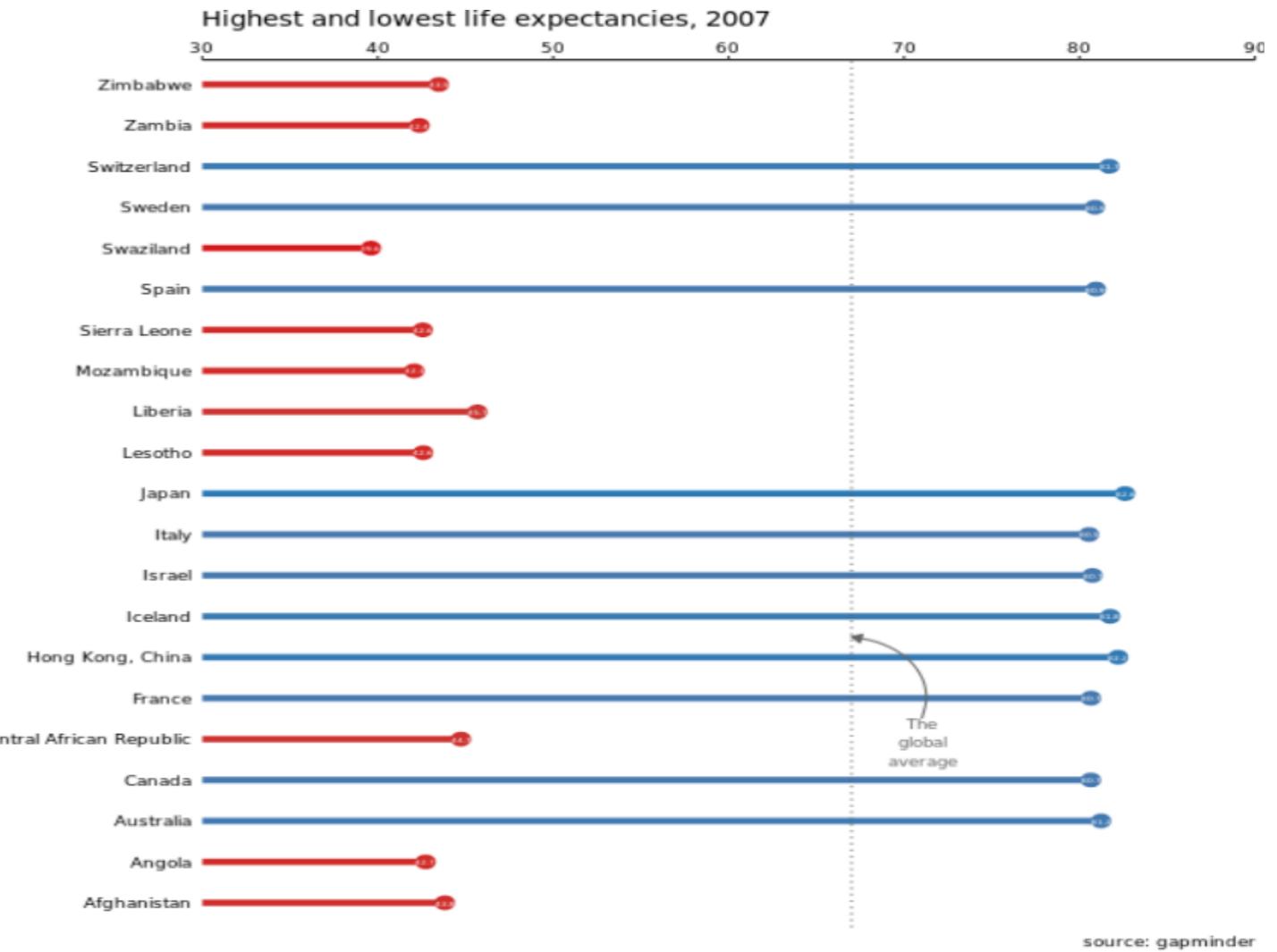
Add embellishments



```

# Add a curve
plt_country_vs_lifeExp +
  step_1_themes +
  geom_vline(xintercept = global_mean, color = "grey40", linetype = 3) +
  step_3_annotation +
  annotate(
    "curve",
    x = x_start, y = y_start,
    xend = x_end, yend = y_end,
    arrow = arrow(length = unit(0.2, "cm"), type = "closed"),
    color = "grey40"
)

```



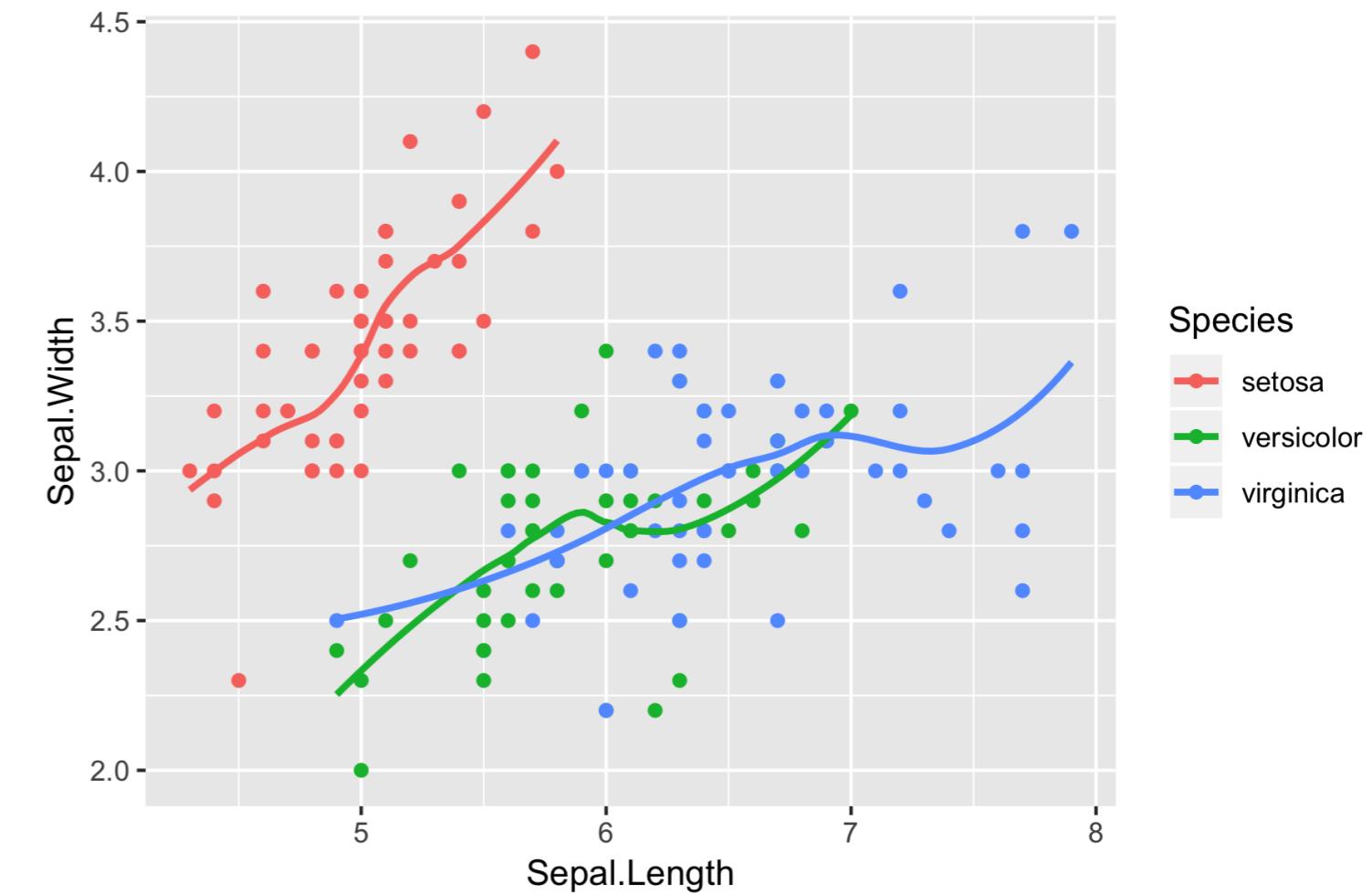
The geom_/stat_ connection

stat_	geom_
stat_bin()	geom_histogram() , geom_freqpoly()
stat_count()	geom_bar()

`stat_smooth(se = FALSE)`

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  
  geom_point() +  
  geom_smooth(se = FALSE)
```

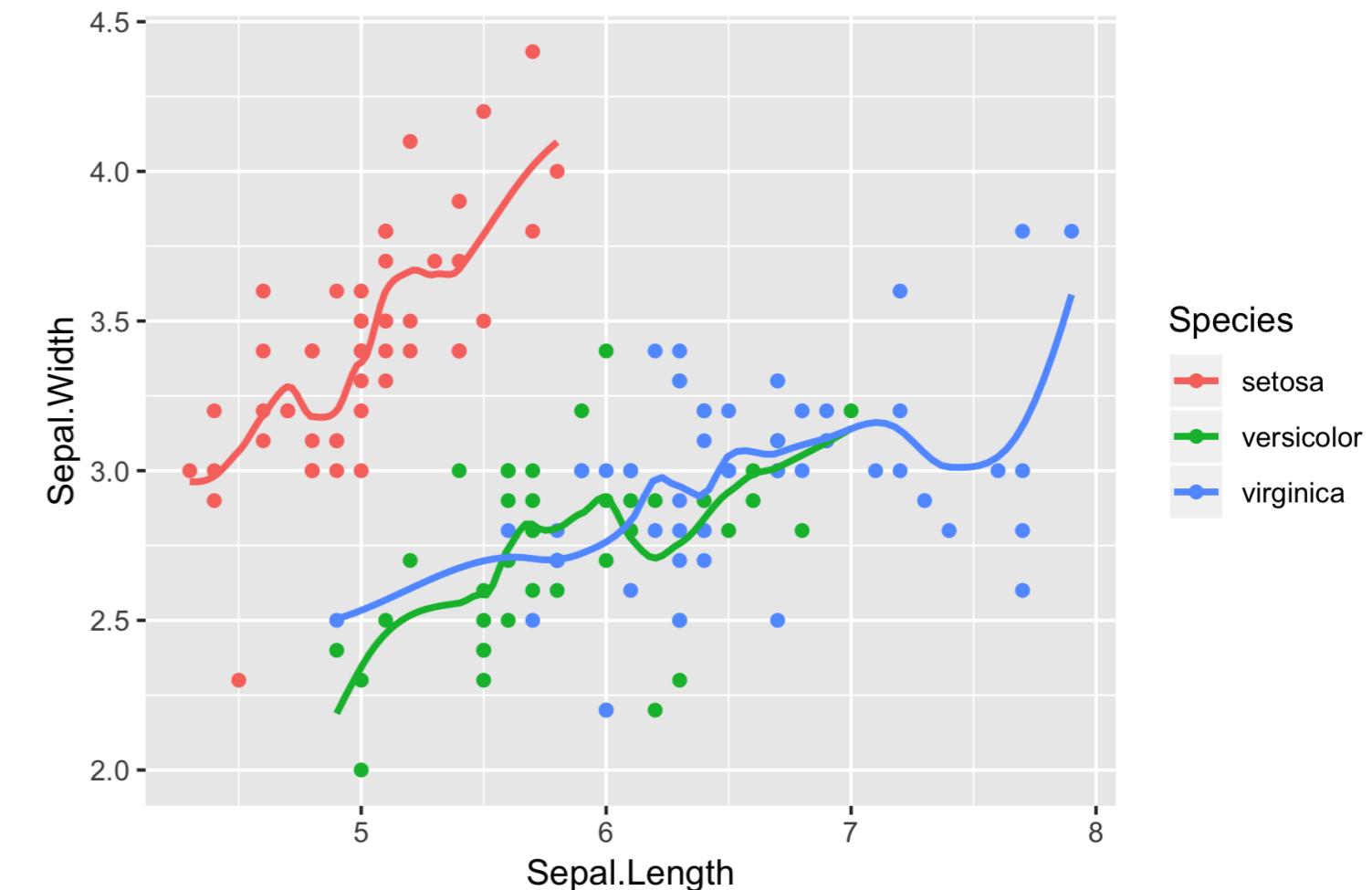
`geom_smooth()` using `method = 'loess'` and
`formula 'y ~ x'`



geom_smooth(span = 0.4)

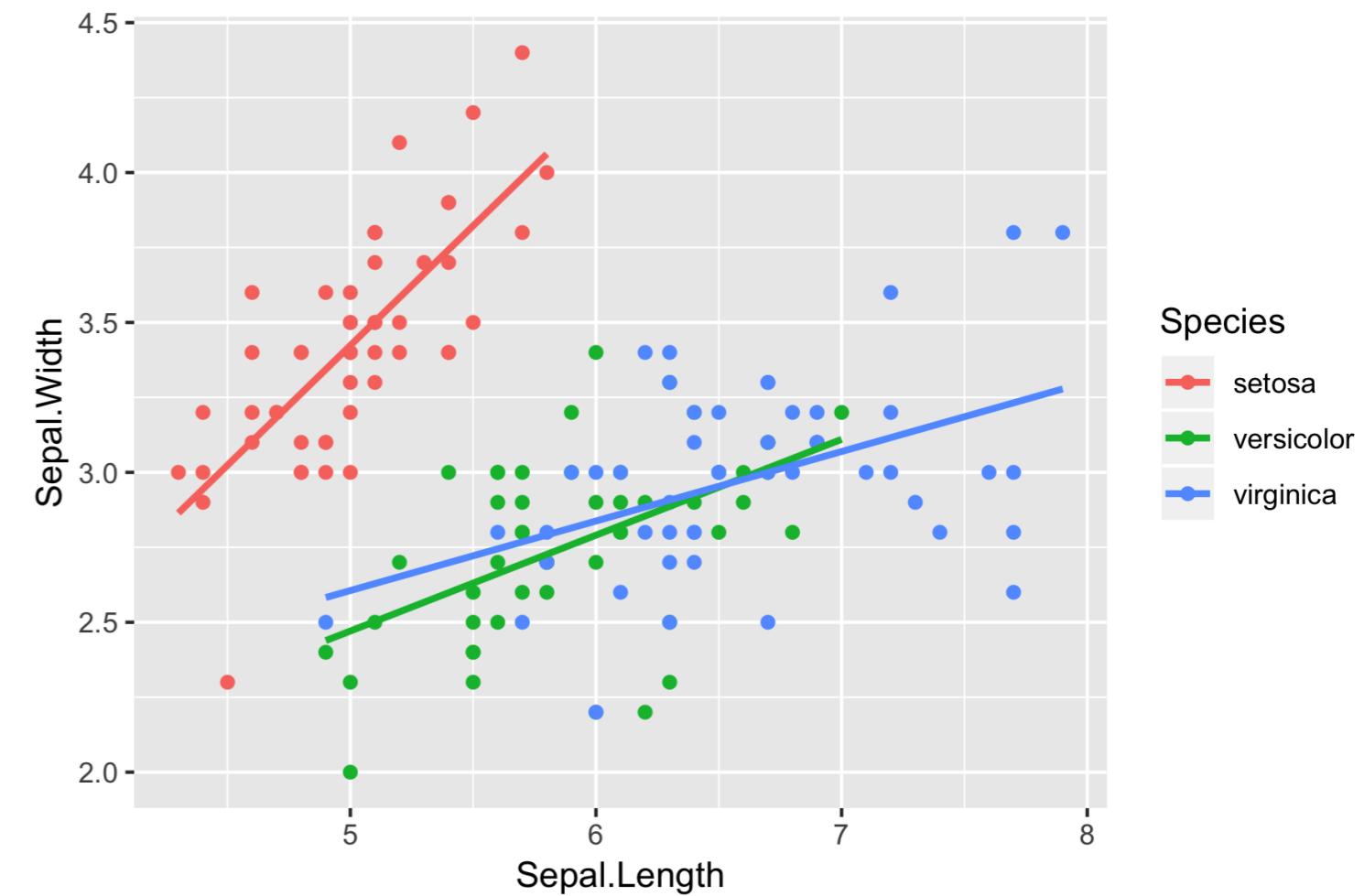
```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  geom_point() +  
  geom_smooth(se = FALSE, span = 0.4)
```

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



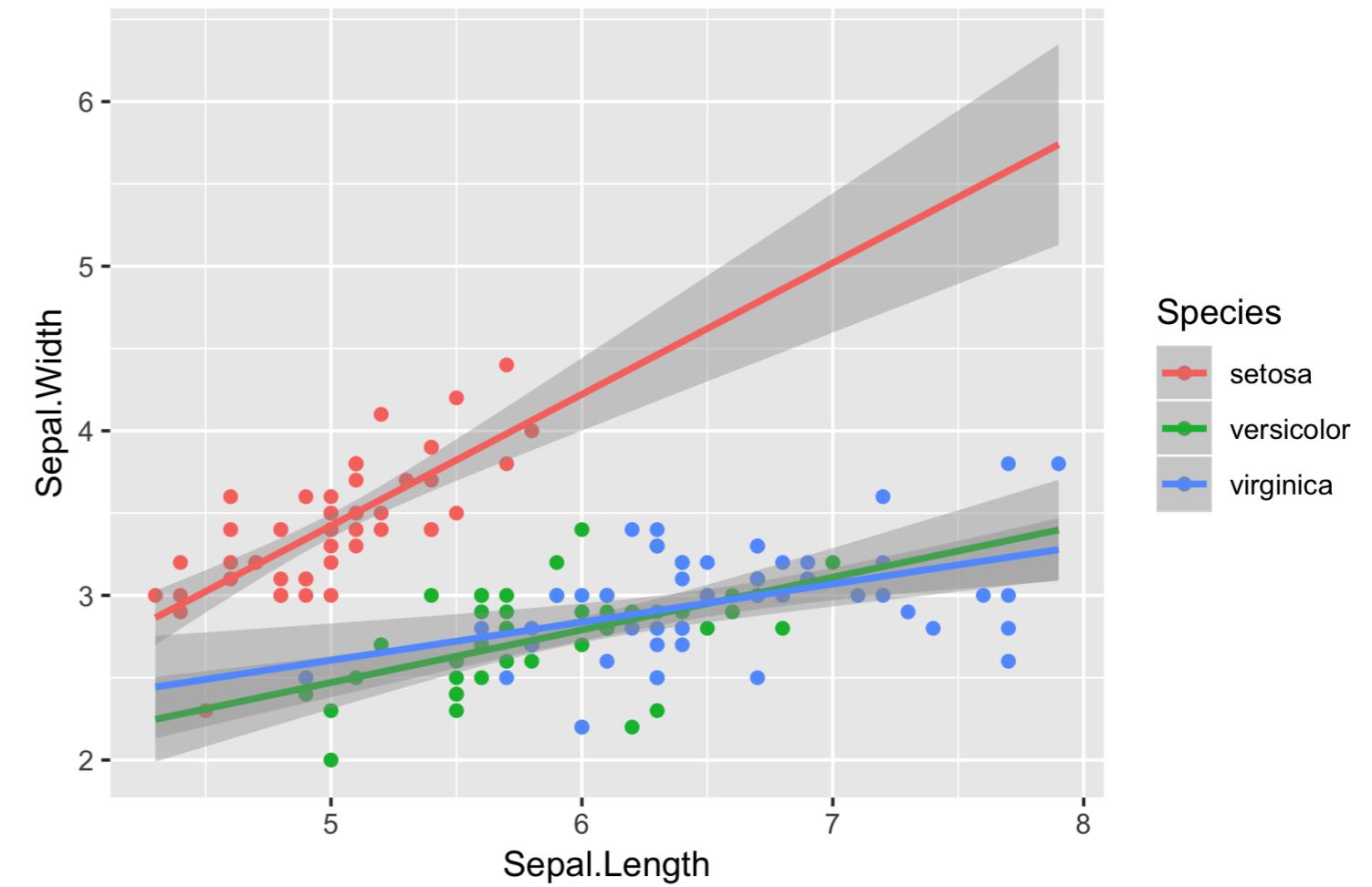
geom_smooth(method = "lm")

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  
  geom_point() +  
  
  geom_smooth(method = "lm", se = FALSE)
```

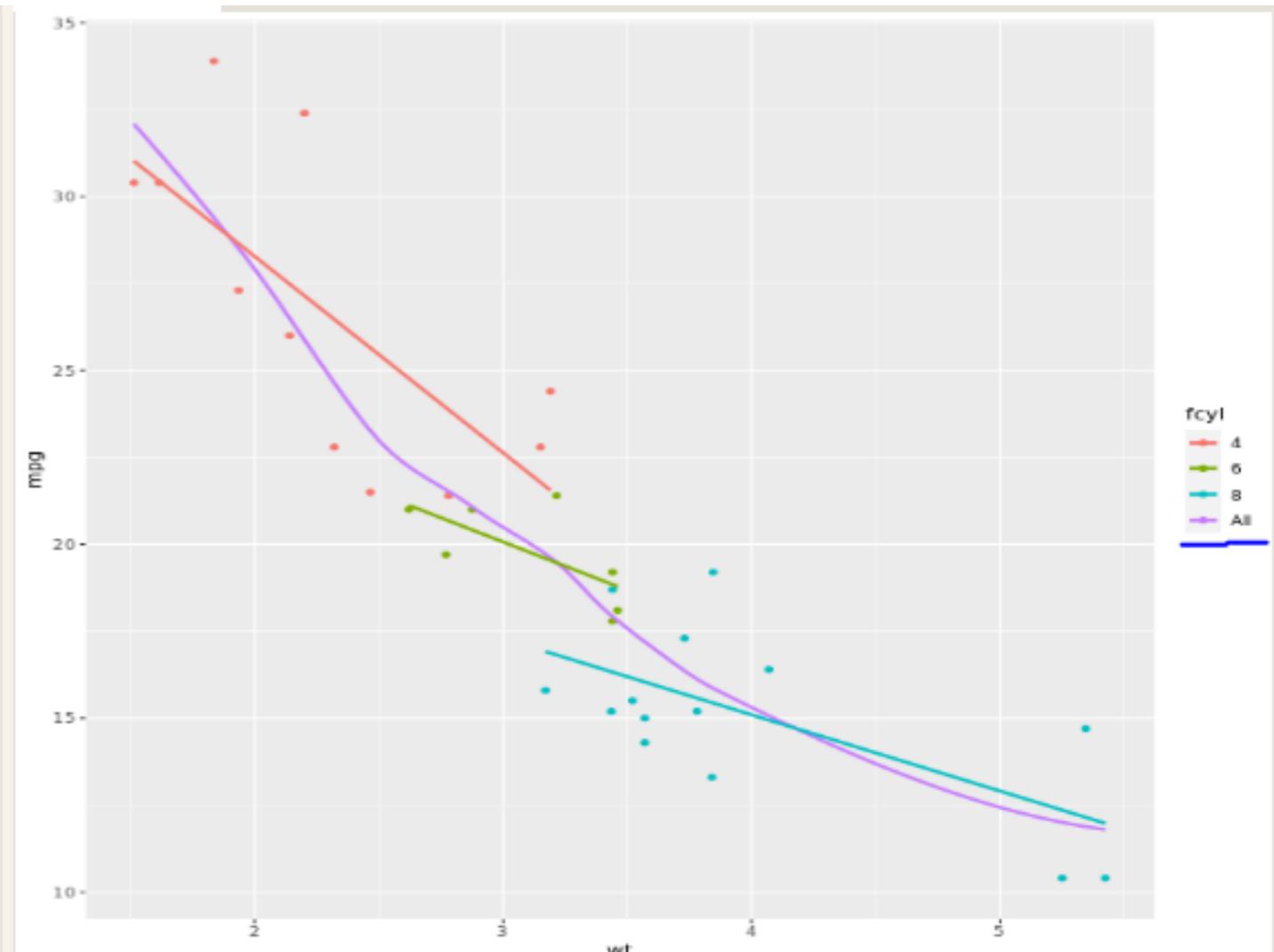


geom_smooth(fullrange = TRUE)

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  
  geom_point() +  
  geom_smooth(method = "lm",  
              fullrange = TRUE)
```



```
1 # Amend the plot
2 ggplot(mtcars, aes(x = wt, y = mpg,
3 |   color = fcyl)) +
4   geom_point() +
5   # Map color to dummy variable "All"
6   stat_smooth(aes(color = "All"),
7   |   |   |   |   se = FALSE) +
8   stat_smooth(method = "lm", se = FALSE)
```



Run Code

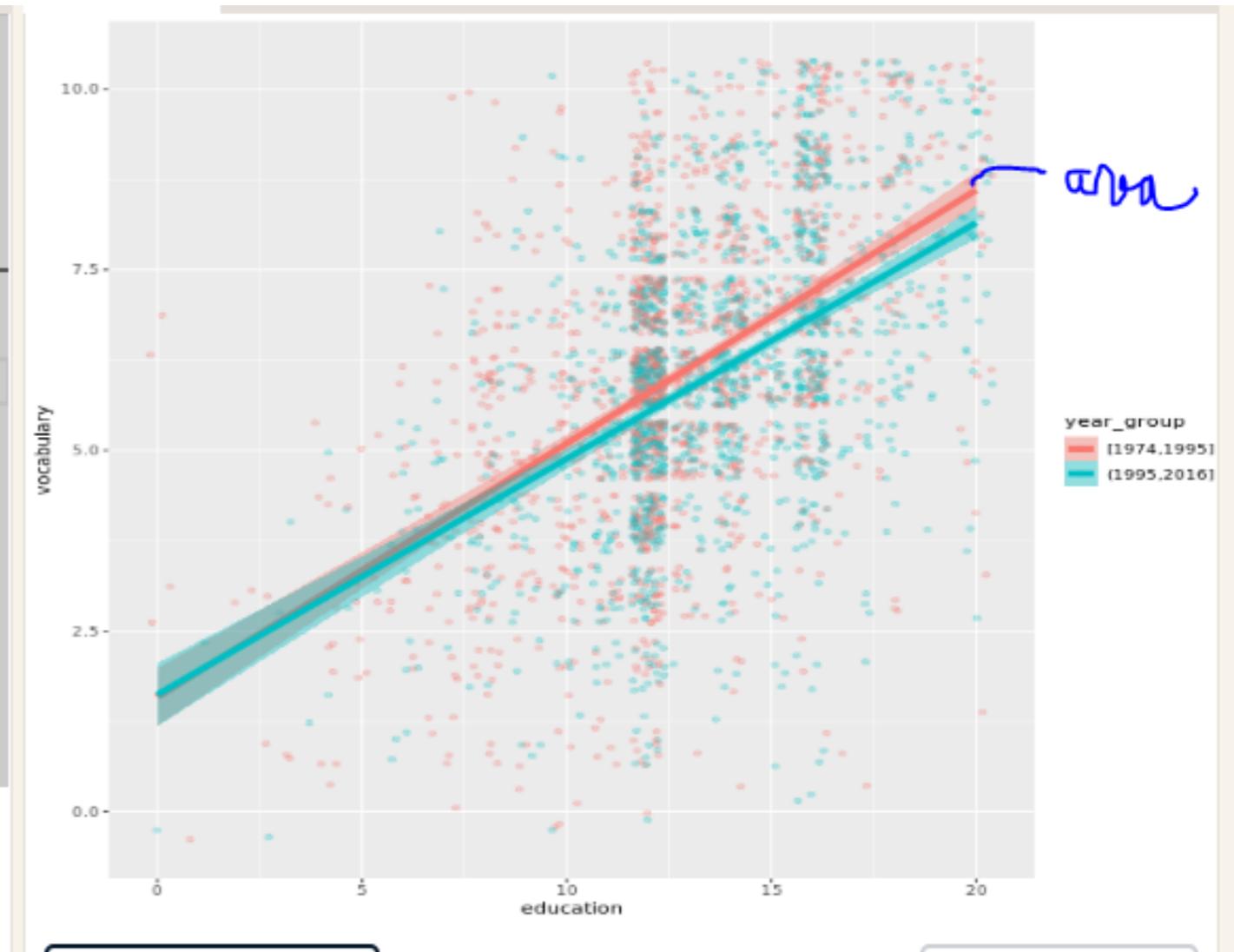
Submit Answer

← Previous Plot

4/4

→ Next Plot

```
1 # Amend the plot
2 ggplot(Vocab, aes(x = education, y =
3   vocabulary, color = year_group)) +
4   geom_jitter(alpha = 0.25) +
5   # Map the fill color to year_group, set
6   # the line size to 2
7   stat_smooth(aes(fill = year_group),
8   method = "lm", size = 2)
```



Other stat_ functions

stat_	geom_
stat_boxplot()	geom_boxplot()
stat_bindot()	geom_dotplot()
stat_bin2d()	geom_bin2d()
stat_binhex()	geom_hex()

Other stat_ functions

stat_	geom_
stat_boxplot()	geom_boxplot()
stat_bindot()	geom_dotplot()
stat_bin2d()	geom_bin2d()
stat_binhex()	geom_hex()
stat_contour()	geom_contour()
stat_quantile()	geom_quantile()
stat_sum()	geom_count()

Plot counts to overcome over-plotting

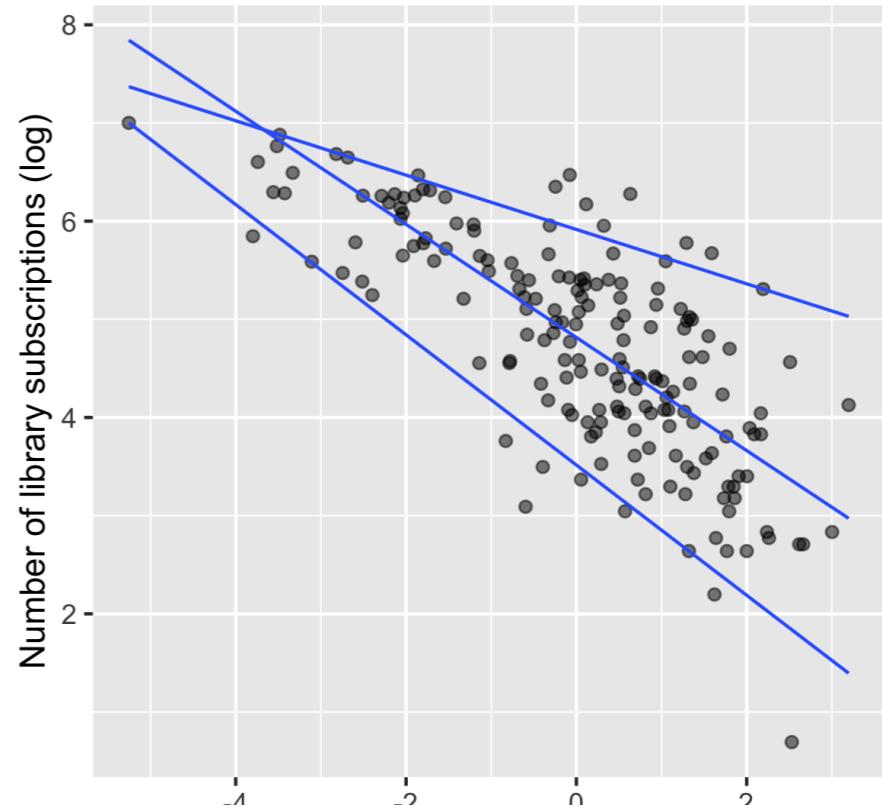
	Cause of Over-plotting	Solutions	Here...
1.	Large datasets	Alpha-blending, hollow circles, point size	<code>alpha = 0.5, shape = ":"</code> <code>shape = 16</code>
2.	Aligned values on a single axis	As above, plus change position	<code>position_jitter</code> <code>position_jitterdodge</code>
3.	Low-precision data	Position: jitter <code>geom_jitter(alpha = 0.5, width = 0.1)</code>	<code>geom_count()</code>
4.	Integer data	Position: jitter <code>geom_jitter(alpha = 0.2, shape = 1)</code>	<code>geom_count()</code>

geom_	stat_
<code>geom_count()</code>	<code>stat_sum()</code>

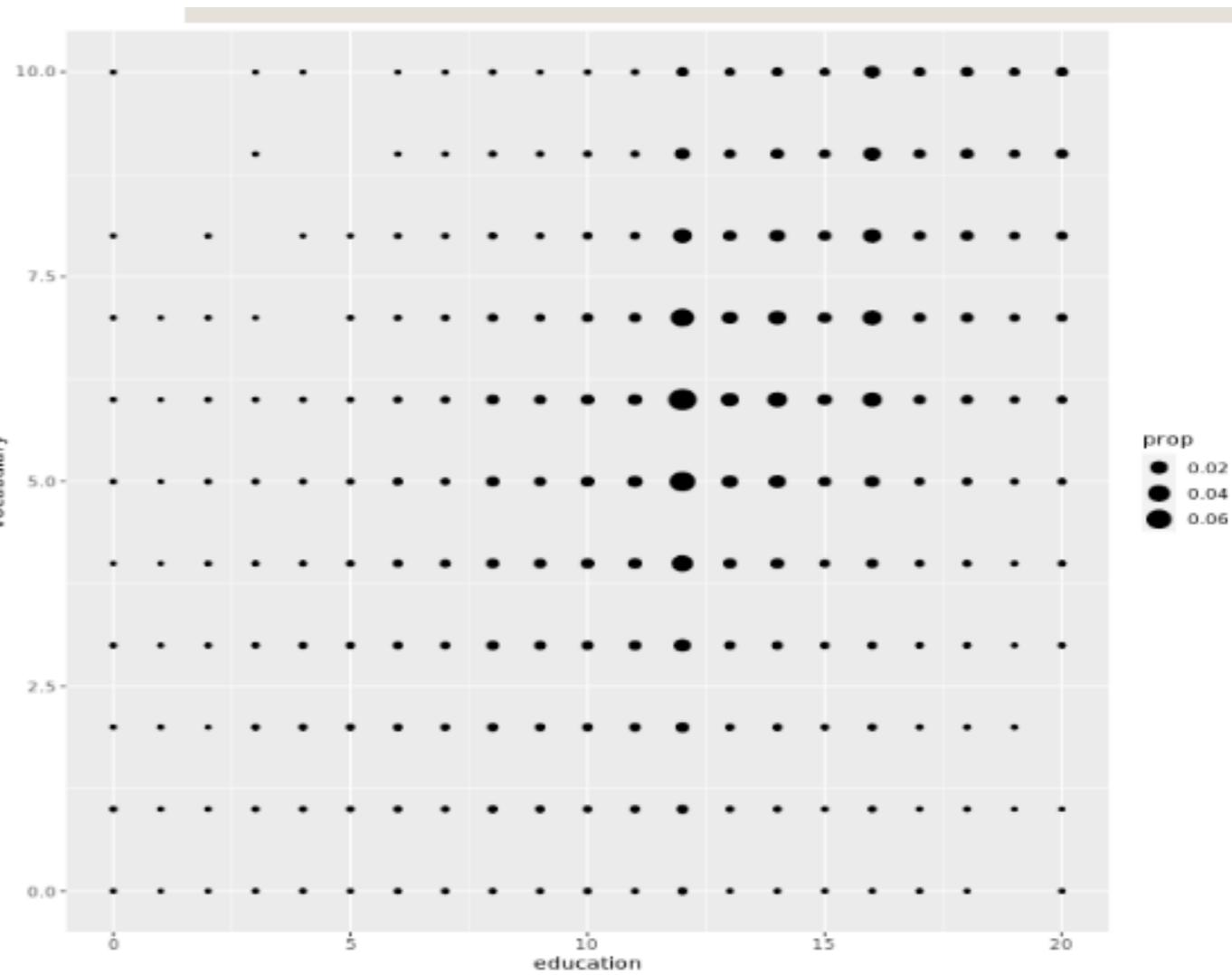
Dealing with heteroscedasticity

```
library(AER)  
data(Journals)  
  
p <- ggplot(Journals,  
             aes(log(price/citations),  
                  log(subs))) +  
  geom_point(alpha = 0.5) +  
  labs(...)  
  
p +  
  geom_quantile(quantiles =  
    c(0.05, 0.50, 0.95))
```

geom_	stat_
geom_count()	stat_sum()
geom_quantile()	stat_quantile()



```
# Amend the stat to use proportion sizes
ggplot(Vocab, aes(x = education, y =
vocabulary)) +
  stat_sum(aes(size = ..prop..))
```



Calculating statistics

```
set.seed(123)
xx <- rnorm(100)

# Hmisc
library(Hmisc)
smean.sdl(xx, mult = 1)
```

Mean	Lower	Upper
0.09040591	-0.82240997	1.00322179

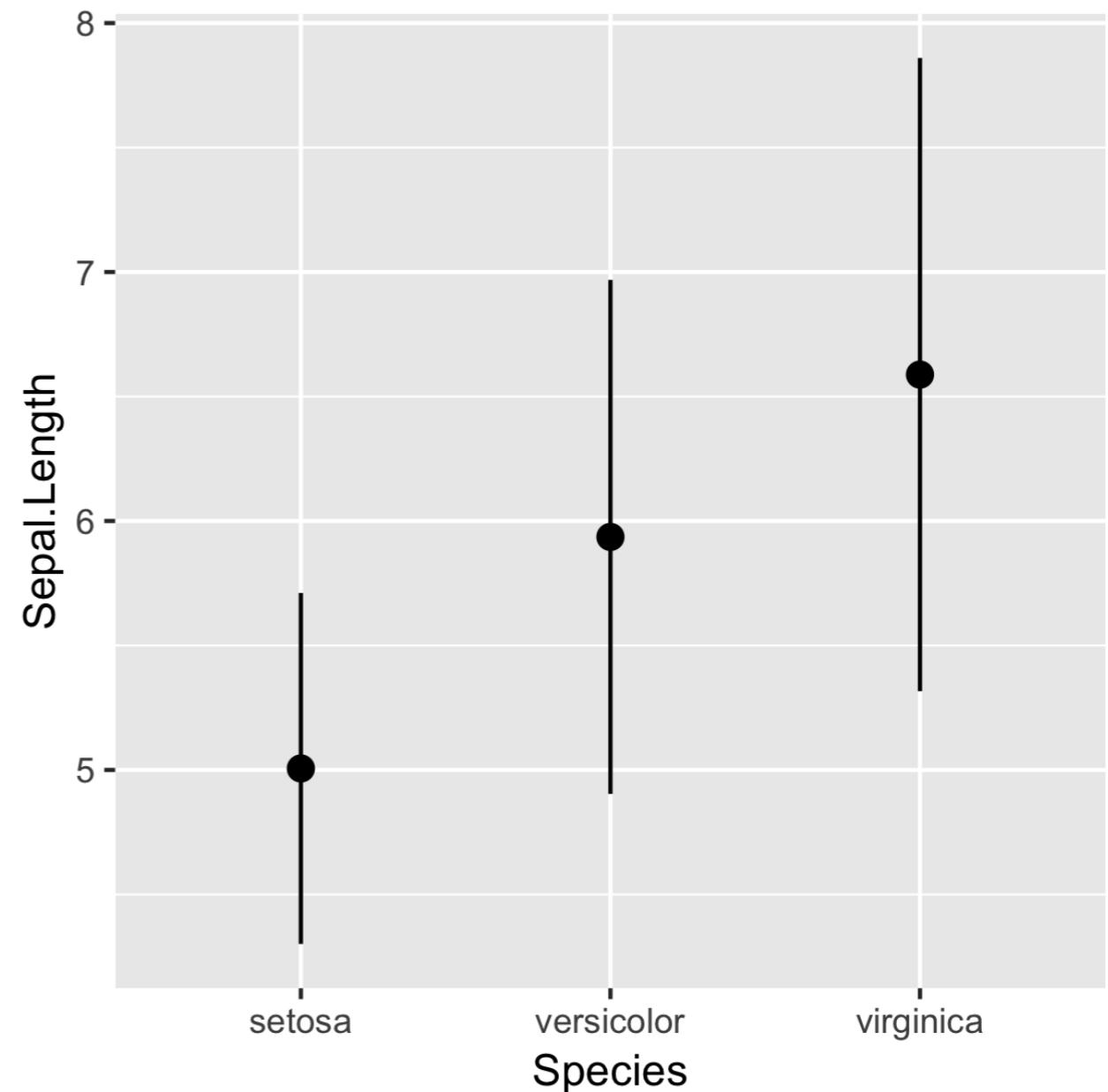
stat_summary()

```
# ggplot2  
mean_sdl(xx, mult = 1)
```

```
      y      ymin      ymax A data.frame with this columns  
1 0.09040591 -0.82241 1.003222
```

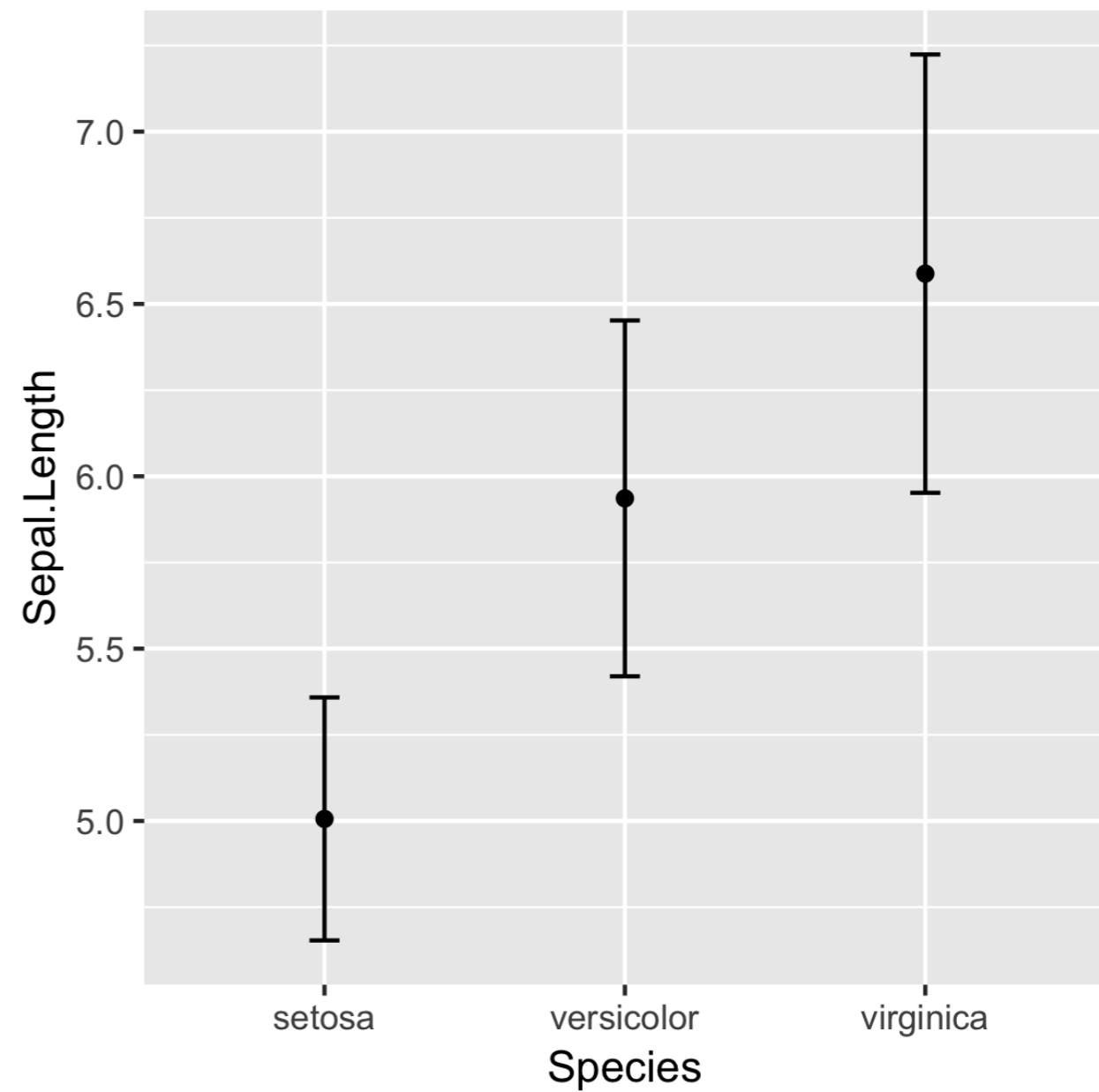
```
ggplot(iris, aes(x = Species,  
                  y = Sepal.Length)) +  
  stat_summary(fun.data = mean_sdl,  
               fun.args = list(mult = 1))
```

- Uses `geom_pointrange()` by default



stat_summary()

```
ggplot(iris, aes(x = Species,  
                  y = Sepal.Length)) +  
  stat_summary(fun.y = mean,  
              geom = "point") +  
  stat_summary(fun.data = mean_sdl,  
              fun.args = list(mult = 1),  
              geom = "errorbar",  
              width = 0.1)
```



95% confidence interval

```
ERR <- qt(0.975, length(xx) - 1) * (sd(xx) / sqrt(length(xx)))  
mean(xx)
```

```
0.09040591
```

```
mean(xx) + (ERR * c(-1, 1)) # 95% CI
```

```
-0.09071657 0.27152838
```

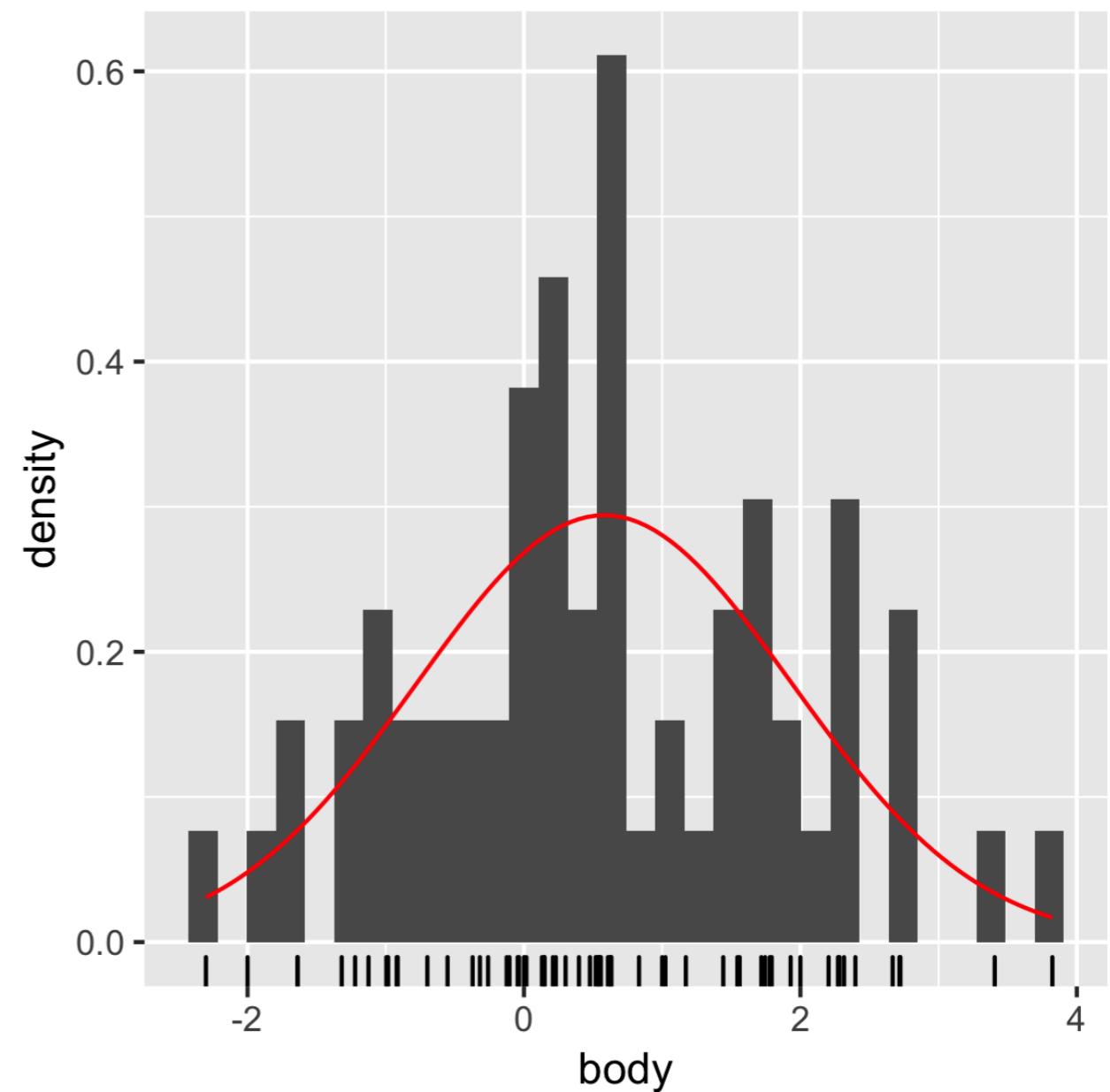
```
mean_cl_normal(xx)
```

y	ymin	ymax
0.09040591	-0.09071657	0.2715284

Normal distribution

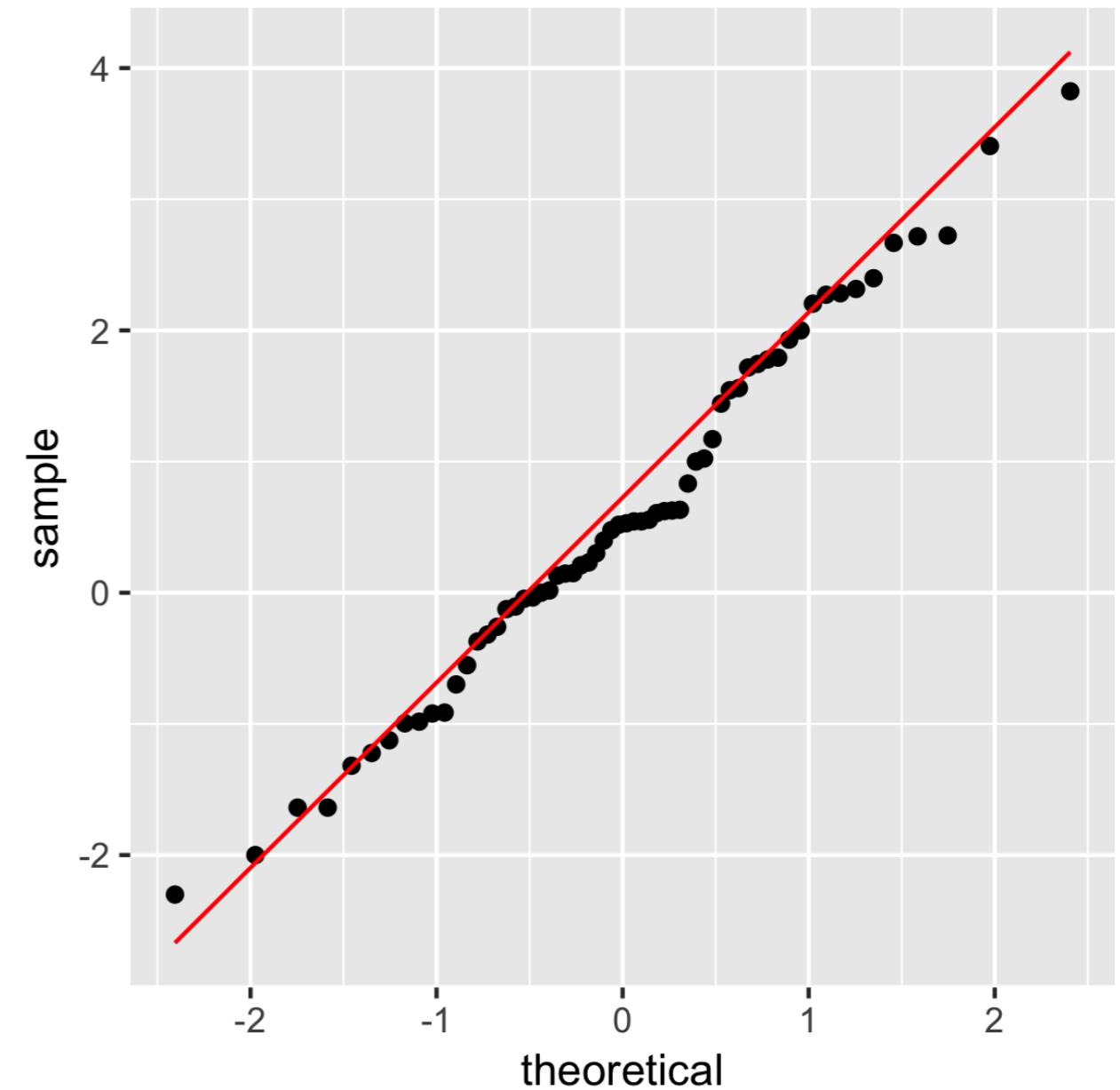
```
mam.new <- data.frame(body = log10(mammals$body))

ggplot(mam.new, aes(x = body)) +
  geom_histogram(aes( y = ..density..)) +
  geom_rug() +
  stat_function(fun = dnorm, color = "red",
                args = list(mean = mean(mam.new$body),
                            sd = sd(mam.new$body)))
```



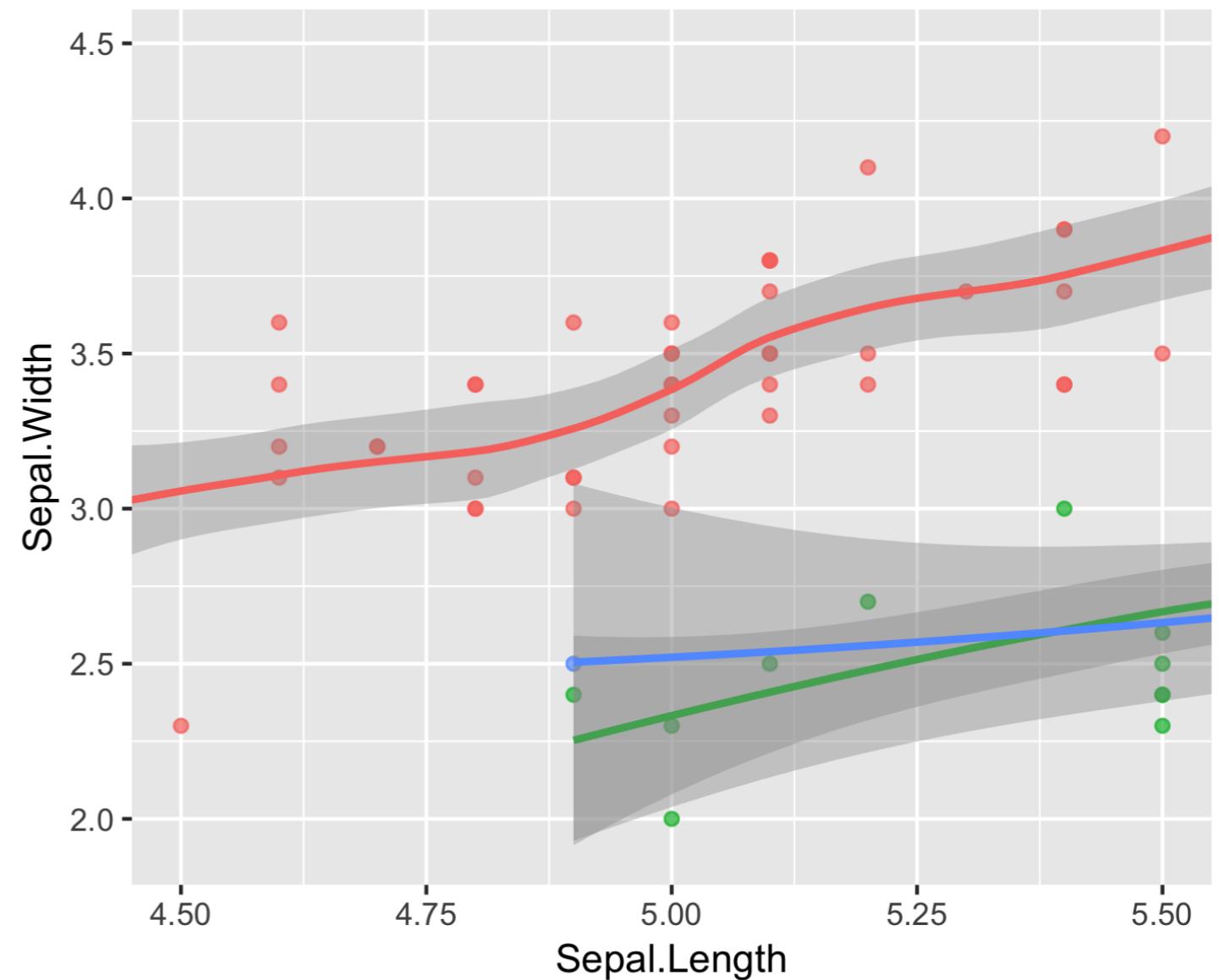
QQ plot

```
ggplot(mam.new, aes(sample = body)) +  
  stat_qq() +  
  geom_qq_line(col = "red")
```



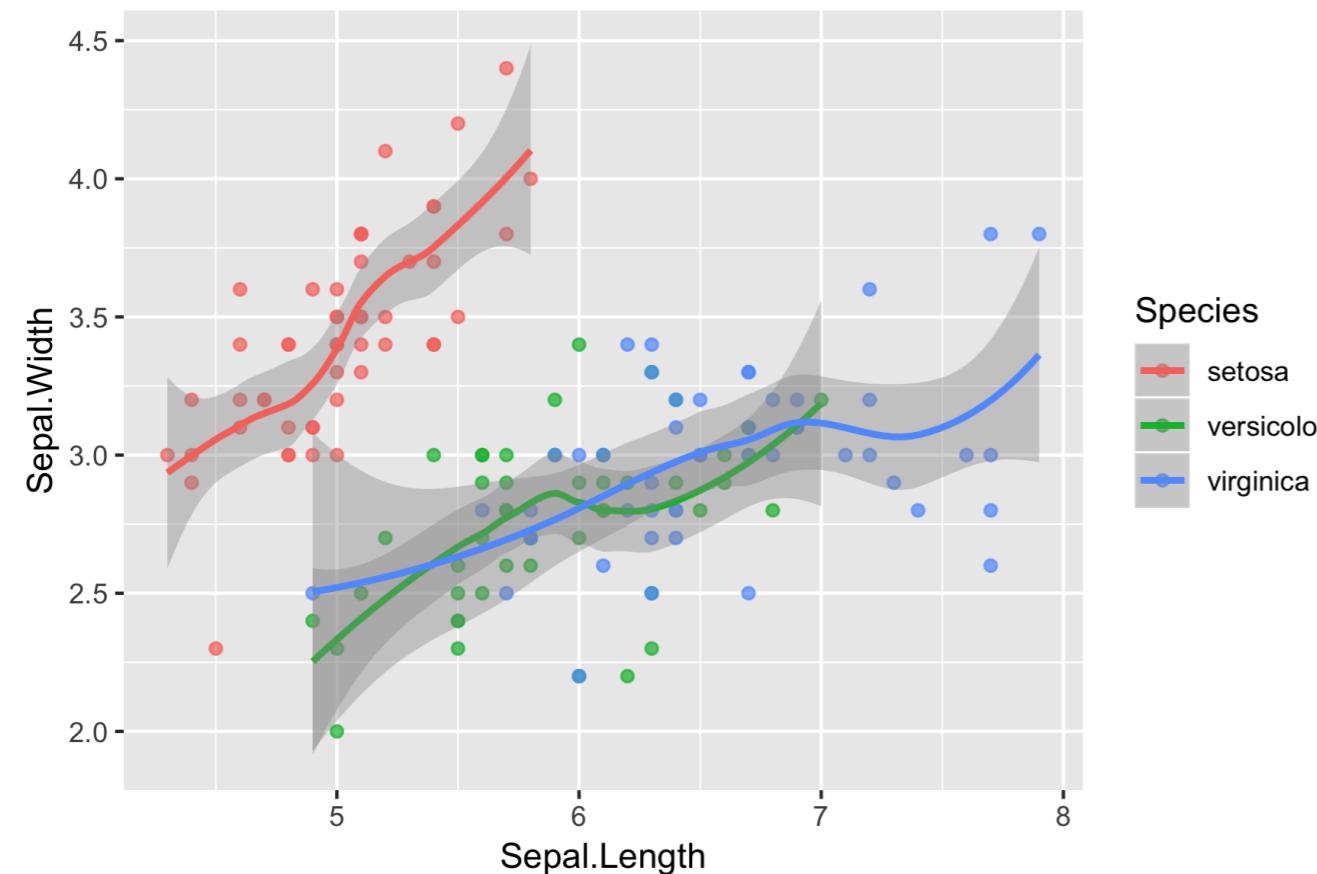
coord_cartesian()

```
iris.smooth +  
  coord_cartesian(xlim = c(4.5, 5.5))
```

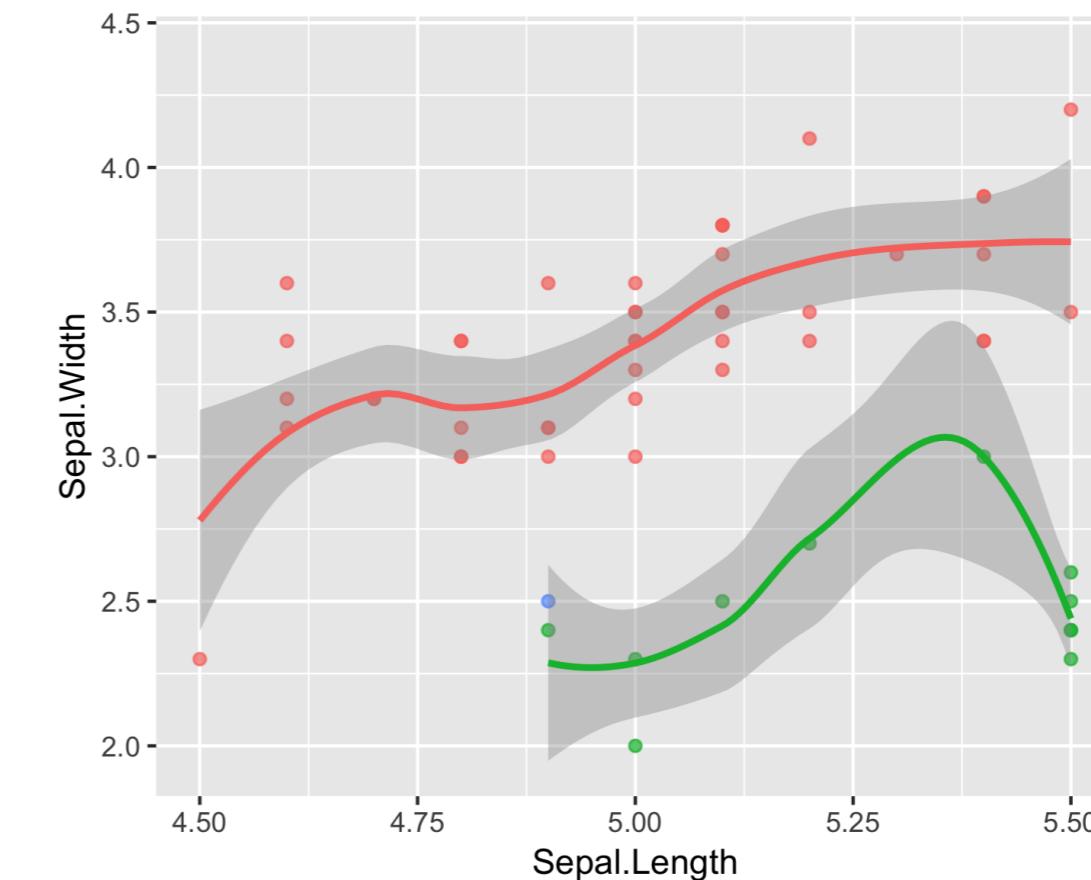


scale_x_continuous()

Original plot



Zoom in with `scale_x_continuous()`

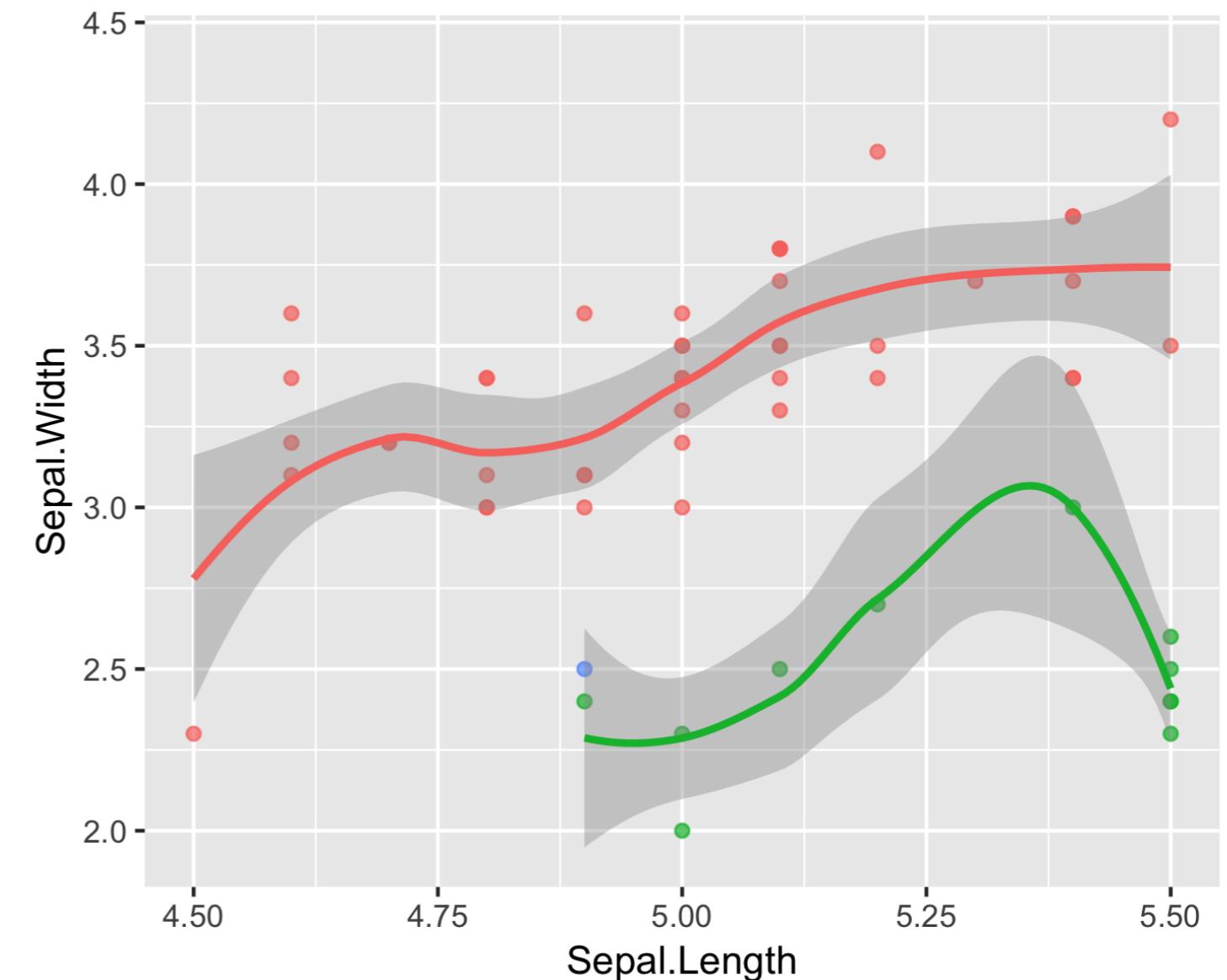


Part of original data is filtered out!

xlim()

```
iris.smooth +  
  xlim(c(4.5, 5.5))
```

Removed 95 rows containing non-finite values
(stat_smooth).
Removed 95 rows containing missing values
(geom_point).



Aspect ratio

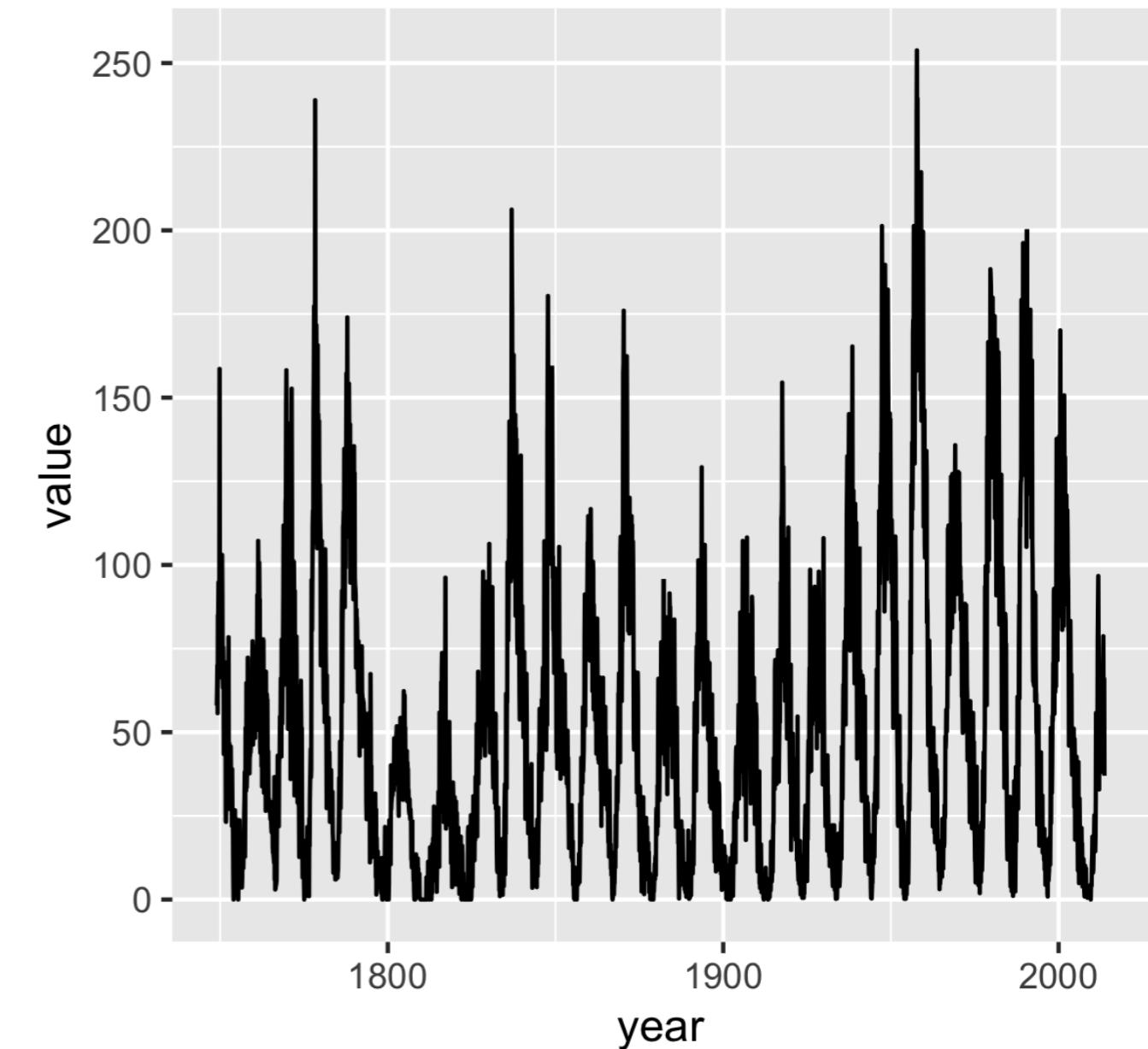
-
-
-

Sunspots

```
library(zoo)
sunspots.m <- data.frame(
  year = index(sunspot.month),
  value = reshape2::melt(sunspot.month)$value)
)

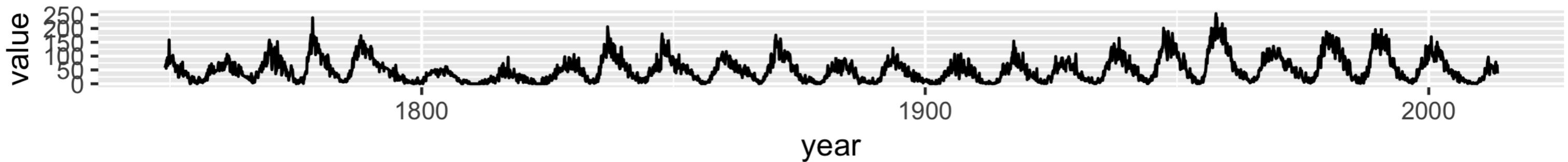
ggplot(sunspots.m, aes(x = year, y = value)) +
  geom_line() +
  coord_fixed() # default to 1:1 aspect ratio
```

- Typically use 1:1 if data is on the same scale



Sunspots

```
ggplot(sunspots.m, aes(x = year, y = value)) +  
  geom_line() +  
  coord_fixed(0.055)
```



Coordinates vs. scales

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

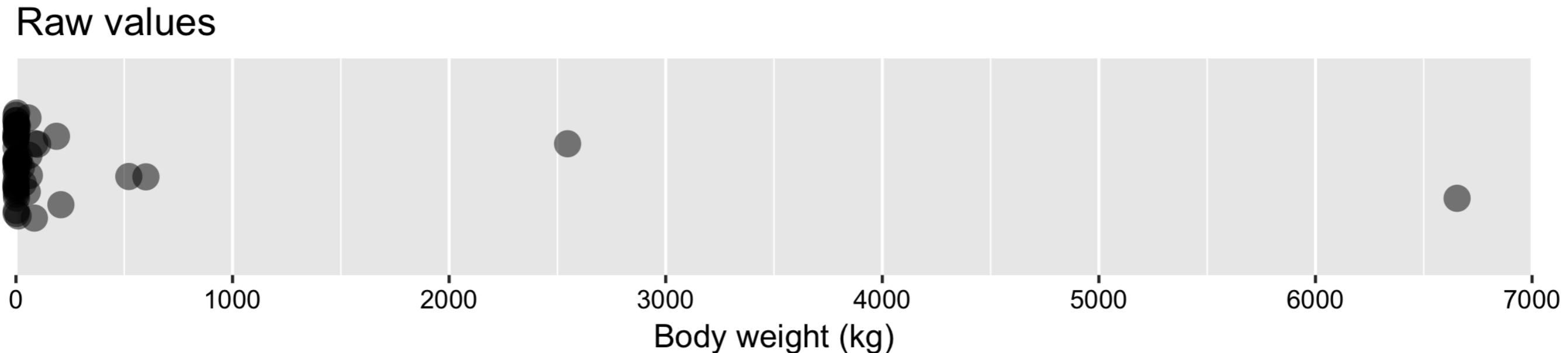


Rick Scavetta

Founder, Scavetta Academy

Plot the raw data

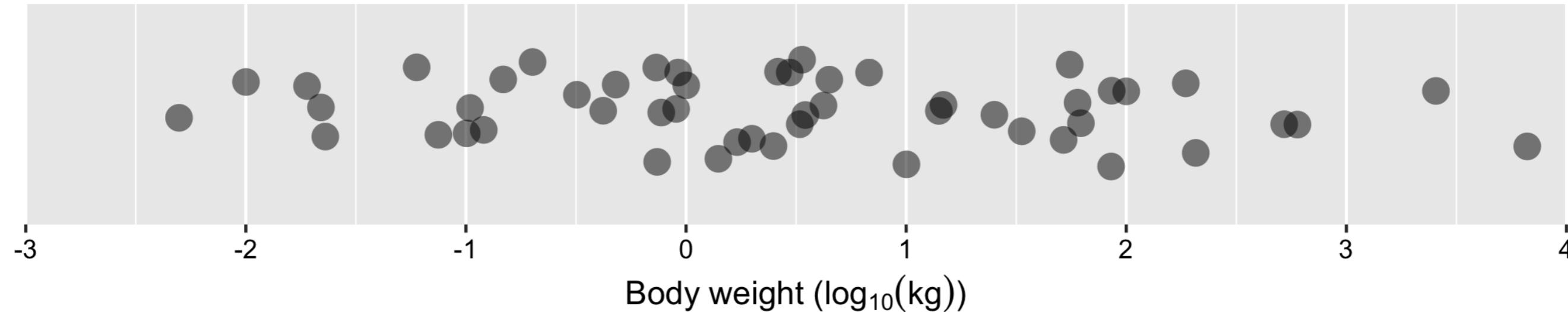
```
ggplot(msleep, aes(bodywt, y = 1)) +  
  geom_jitter() +  
  scale_x_continuous(limits = c(0, 7000),  
                      breaks = seq(0, 7000, 1000))
```



Transform the raw data

```
ggplot(msleep, aes(log10(bodywt), y = 1)) +  
  geom_jitter() +  
  scale_x_continuous(limits = c(-3, 4),  
                     breaks = -3:4)
```

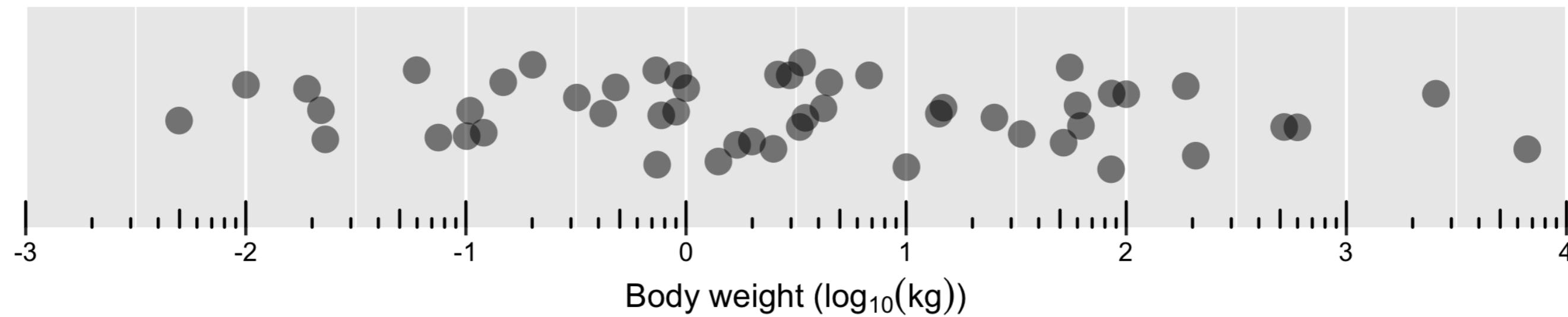
log10 trans of raw values



Add logtick annotation

```
ggplot(msleep, aes(log10(bodywt), y = 1)) +  
  geom_jitter() +  
  scale_x_continuous(limits = c(-3, 4),  
                      breaks = -3:4) +  
  annotation_logticks(sides = "b")
```

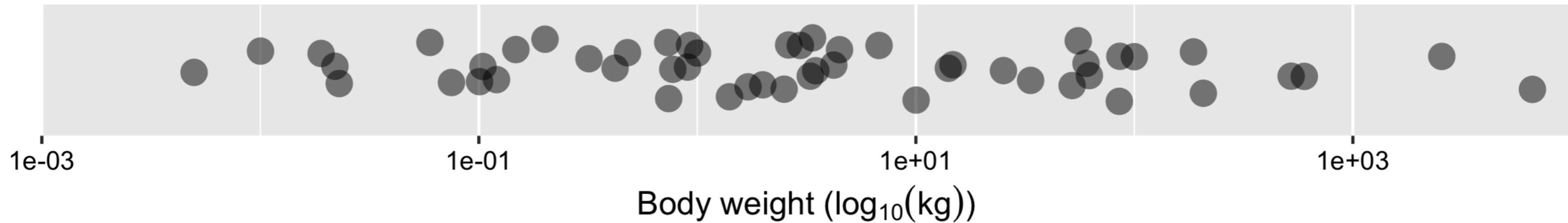
log10 trans of raw values



Use `scale_x_log10()`

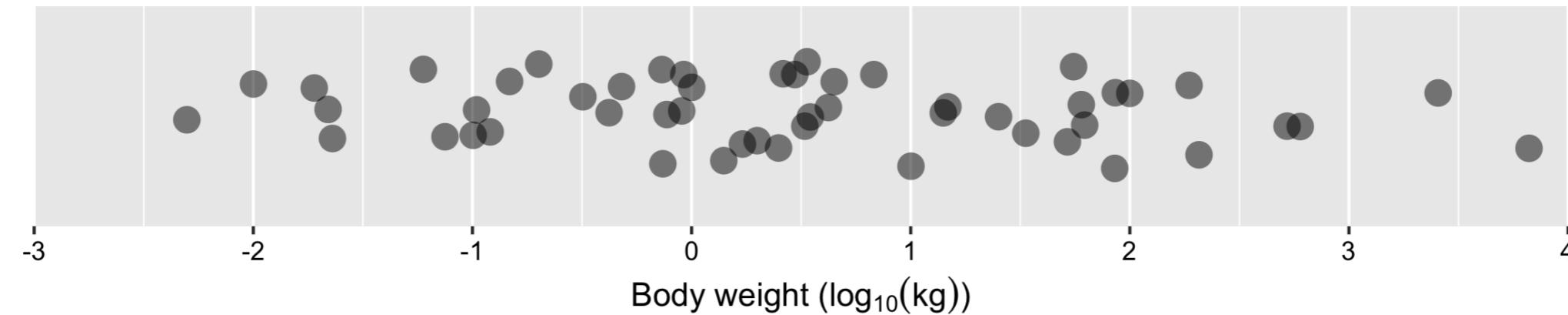
```
ggplot(msleep, aes(bodywt, y = 1)) +  
  geom_jitter() +  
  scale_x_log10(limits = c(1e-03, 1e+04))
```

log10 trans using `scale_x_log10()`

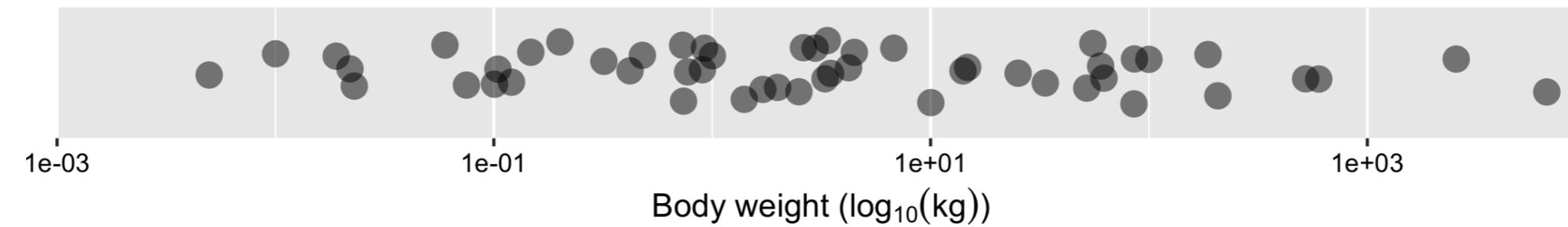


Compare direct transform and `scale_*_log10()` output

log10 trans of raw values



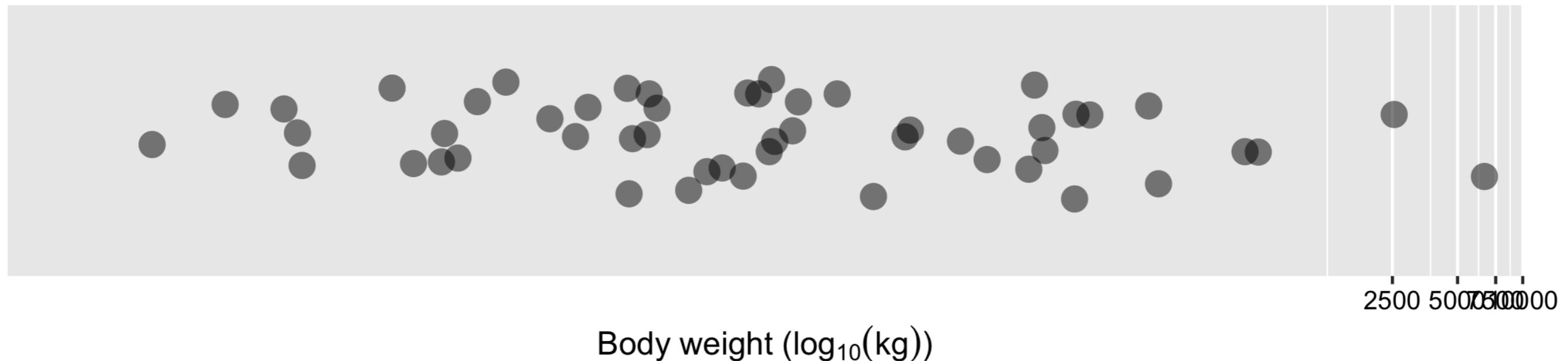
log10 trans using `scale_x_log10()`



Use `coord_trans()`

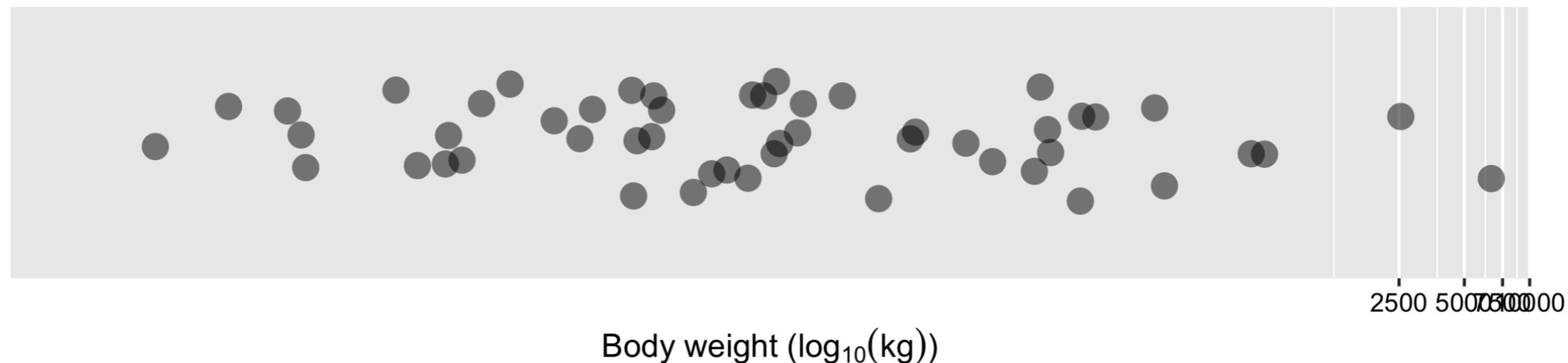
```
ggplot(msleep, aes(bodywt, y = 1)) +  
  geom_jitter() +  
  coord_trans(x = "log10")
```

log10 trans using `coord_trans()`

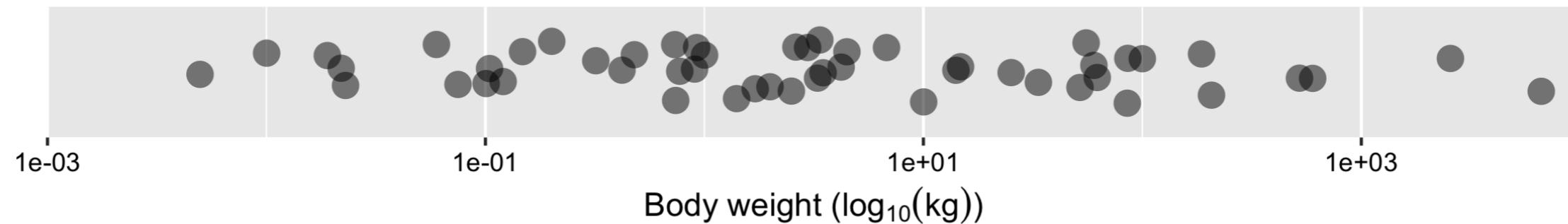


Compare `scale_*_log10()` and `coord_trans()` output

log10 trans using `coord_trans()`

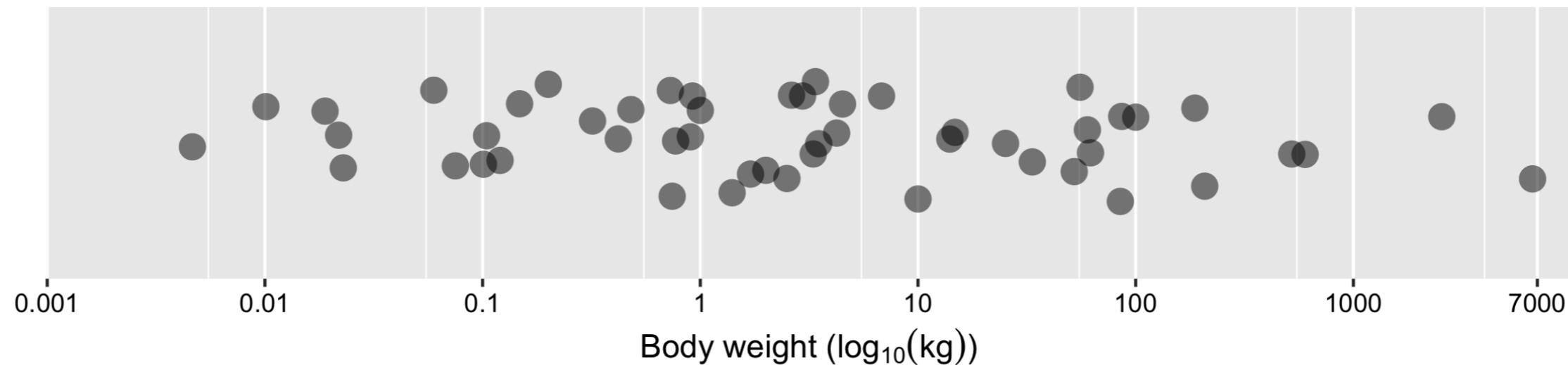


log10 trans using `scale_x_log10()`

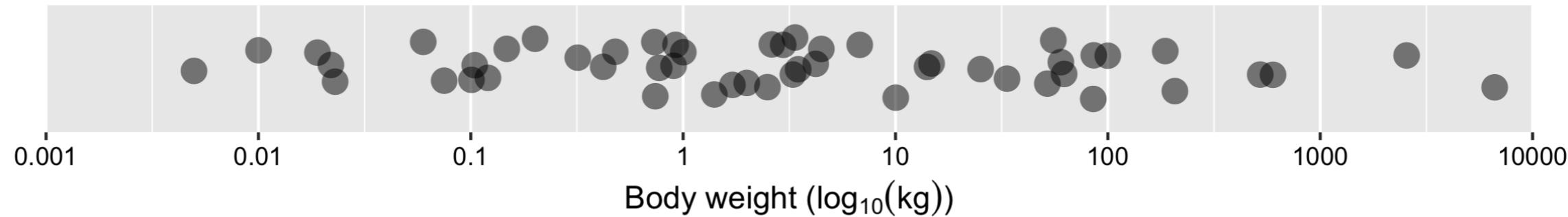


Adjusting labels

log10 trans using `coord_trans()`



log10 trans using `scale_x_log10()`



Time for exercises

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Double and flipped axes

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2



Rick Scavetta

Founder, Scavetta Academy

Typical axis modifications

- Aspect ratios (see video 1)
 - Adjust for best perspective
- Transformation functions (e.g. log, see video 2)
 - Adjust if original scale is inappropriate
- Double x or y axes
 - Add raw and transformed values
- Flipped axes
 - Change direction of dependencies
 - Change geometry orientation

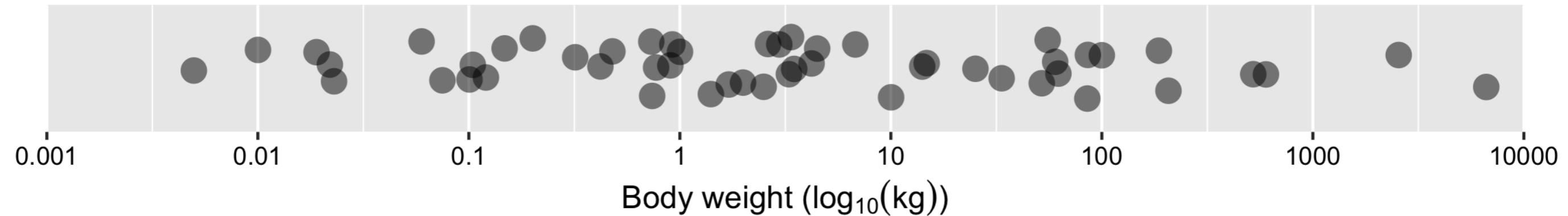
Typical axis modifications

- Aspect ratios (see video 1)
 - Adjust for best perspective
- Transformation functions (e.g. log, see video 2)
 - Adjust if original scale is inappropriate
- **Double x or y axes**
 - **Add raw and transformed values**
- Flipped axes
 - Change direction of dependencies
 - Change geometry orientation

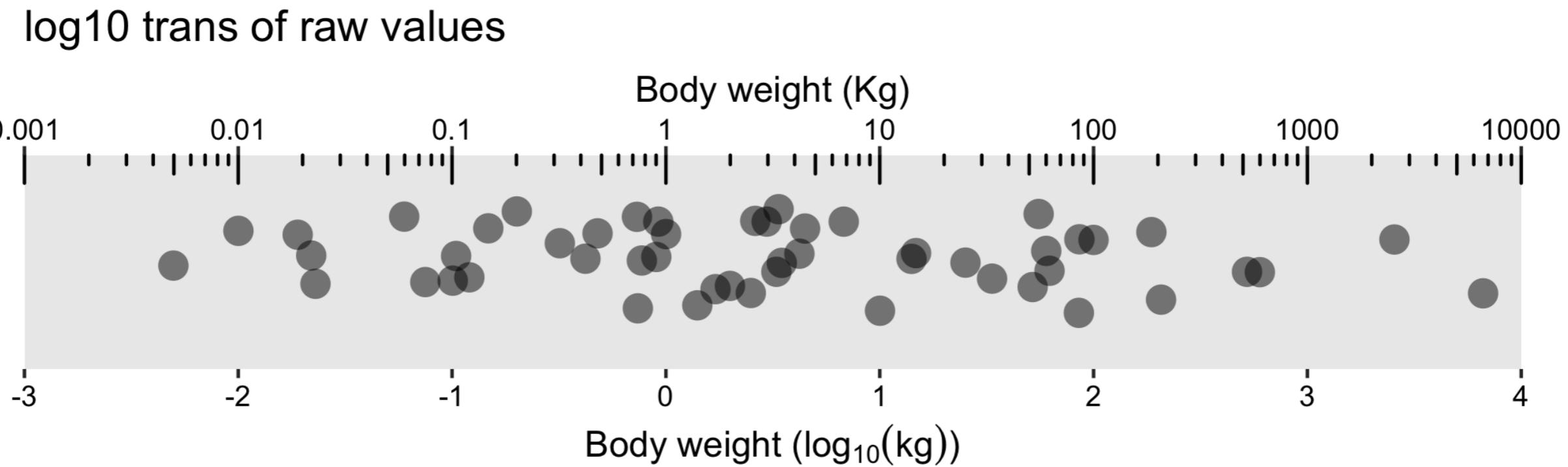
¹ See chapter 4, video 3 for more discussion on double x and y-axes.

Double axes

log10 trans using `scale_x_log10()`



Adding raw and transformed axes

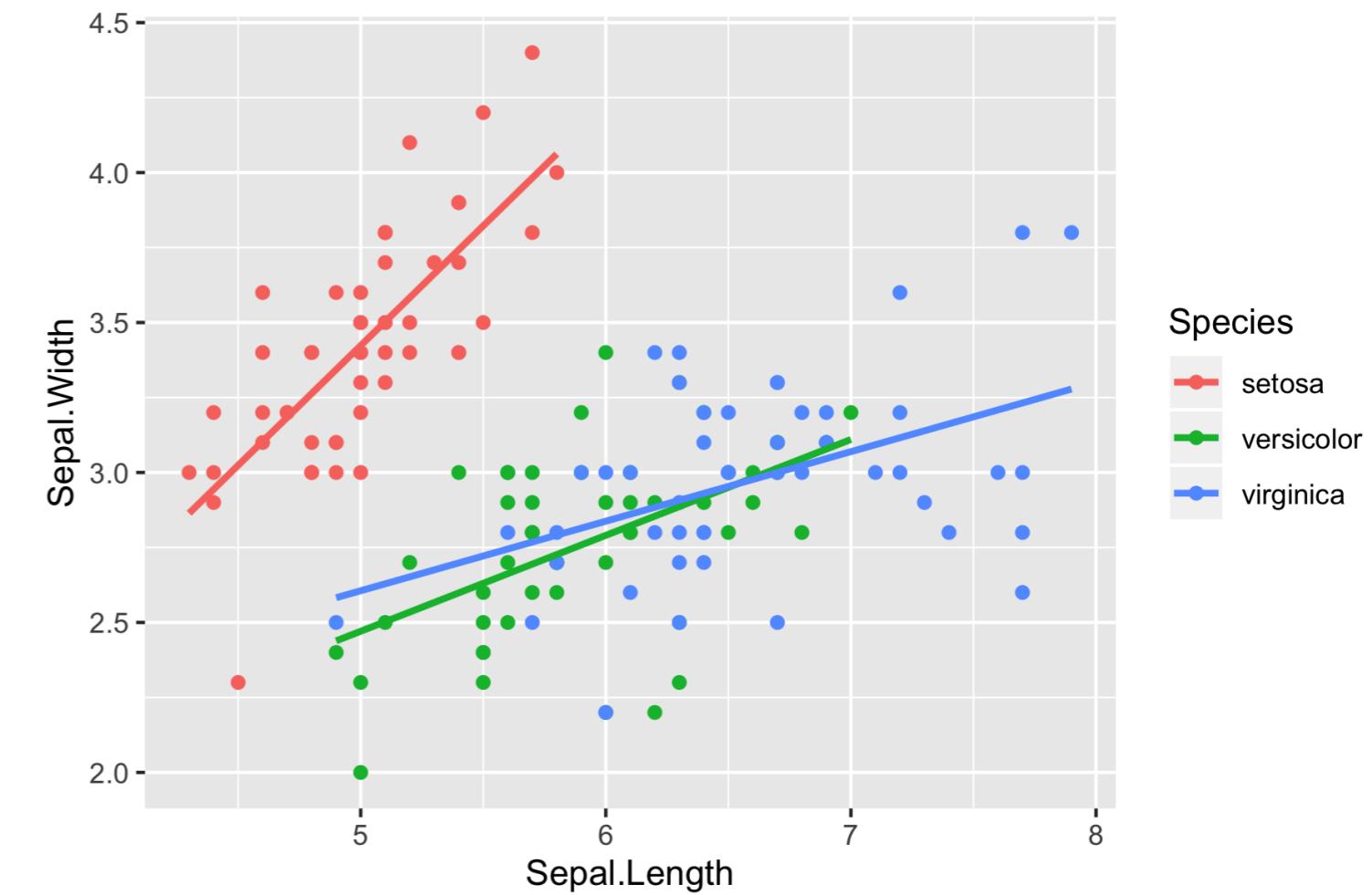


Typical axis modifications

- Aspect ratios (see video 1)
 - Adjust for best perspective
- Transformation functions (e.g. log, see video 2)
 - Adjust if original scale is inappropriate
- Double x or y axes
 - Add raw and transformed values
- Flipped axes
 - Change direction of dependencies
 - Change geometry orientation

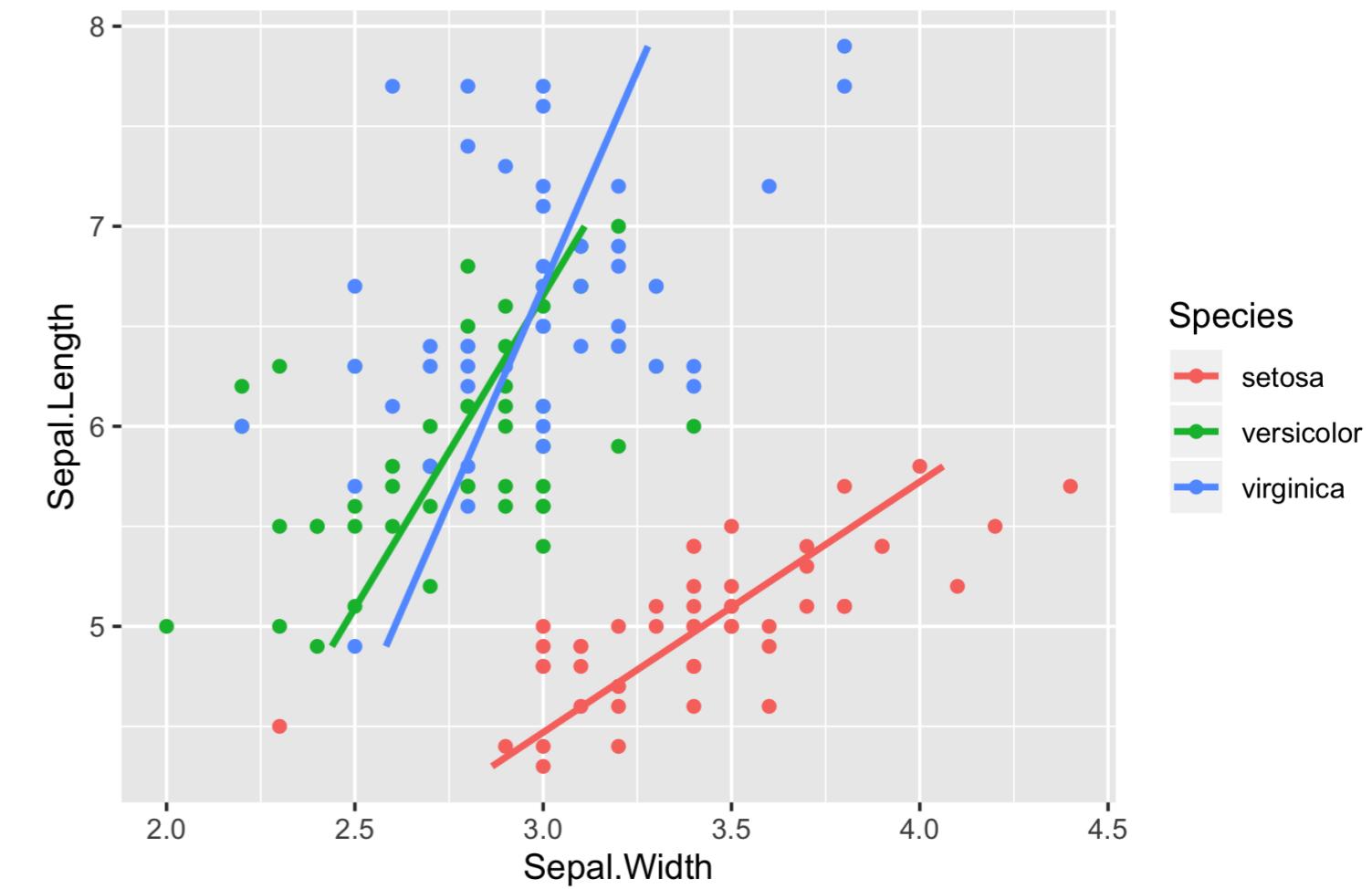
Flipping axes

```
ggplot(iris, aes(x = Sepal.Length,  
                  y = Sepal.Width,  
                  color = Species)) +  
  geom_point() +  
  geom_smooth(method = "lm",  
              se = FALSE)
```



coord_flip()

```
ggplot(iris, aes(x = Sepal.Length,  
                 y = Sepal.Width,  
                 color = Species)) +  
  geom_point() +  
  geom_smooth(method = "lm",  
              se = FALSE) +  
  coord_flip()
```



Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Polar coordinates

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

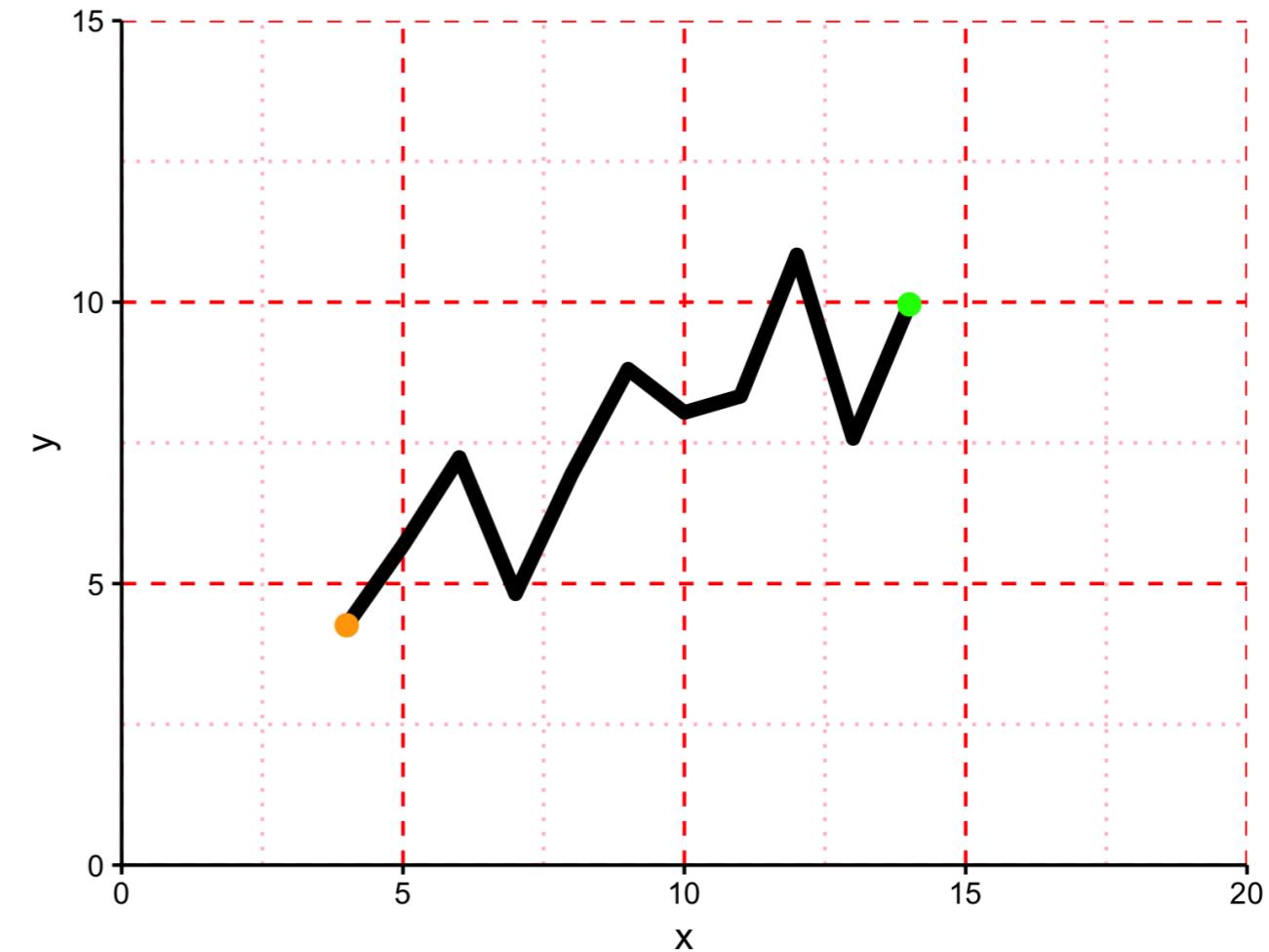


Rick Scavetta

Founder, Scavetta Academy

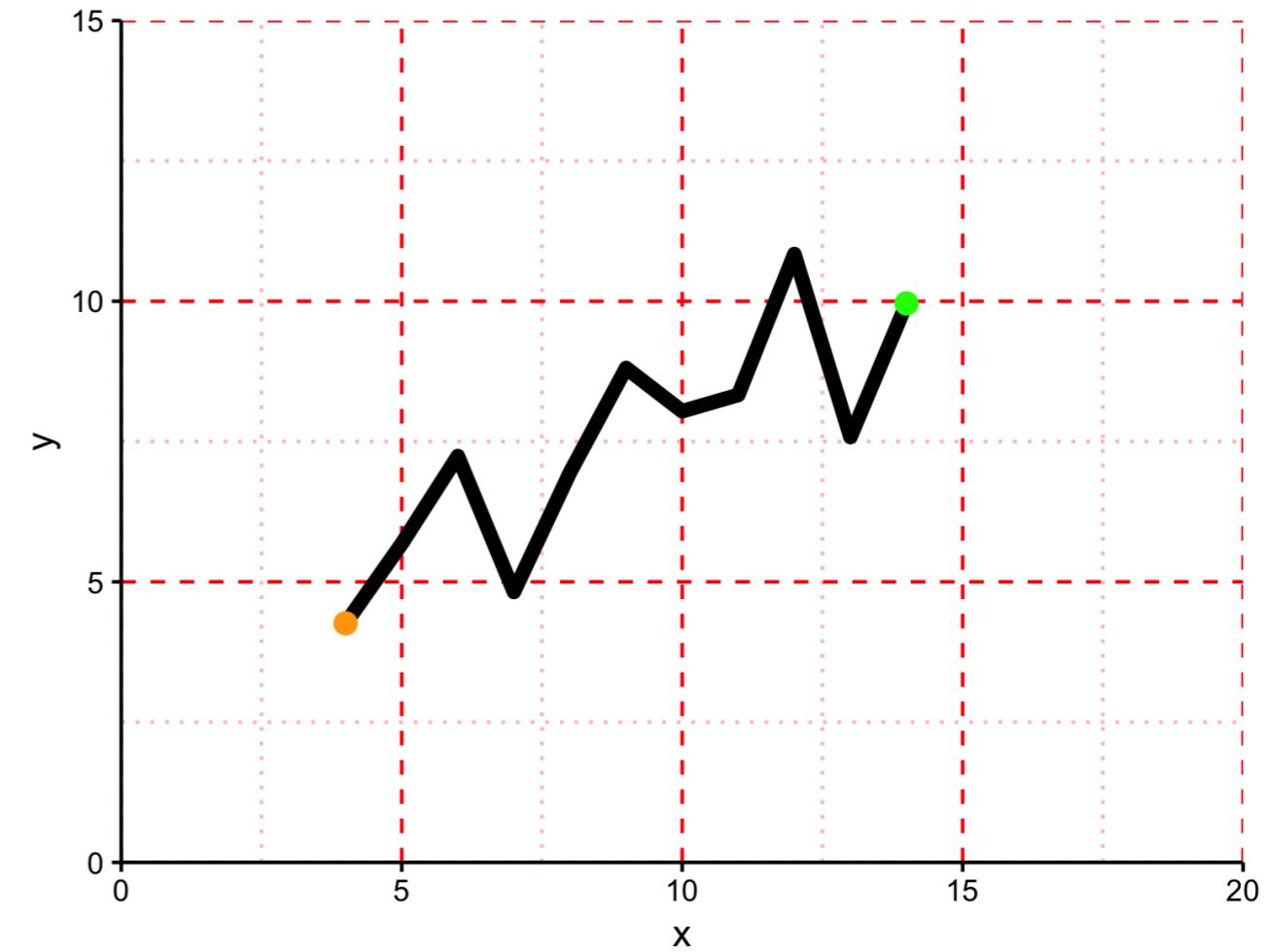
Projections control perception

- Cartesian (2d)
 - Orthogonal x and y-axes
 - Modify axis limits and aspect ratio



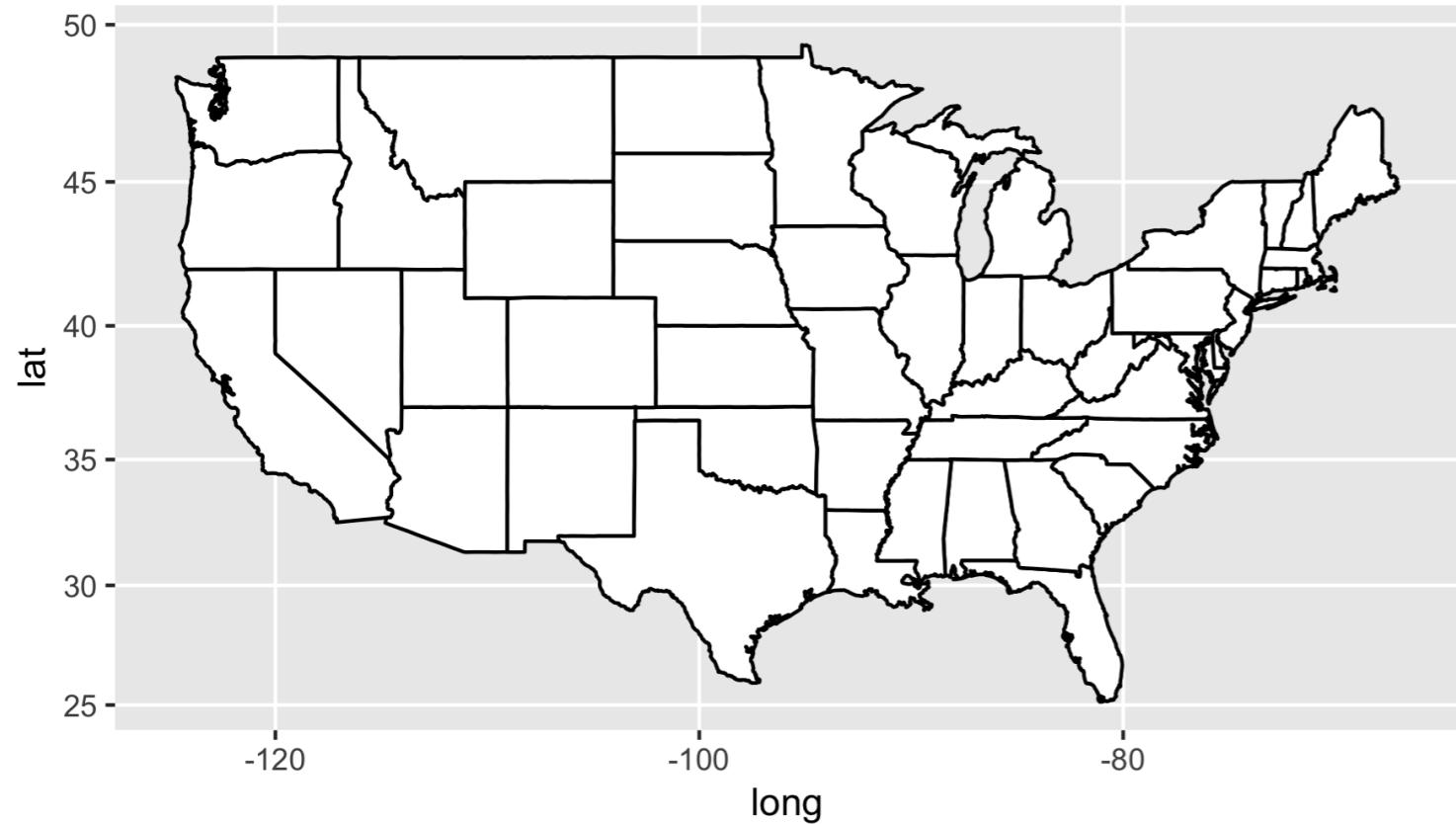
Projections control perception

- Cartesian (2d)
 - Orthogonal x and y-axes
 - Modify axis limits and aspect ratio
- Maps
 - Many possible projections
 - See next course

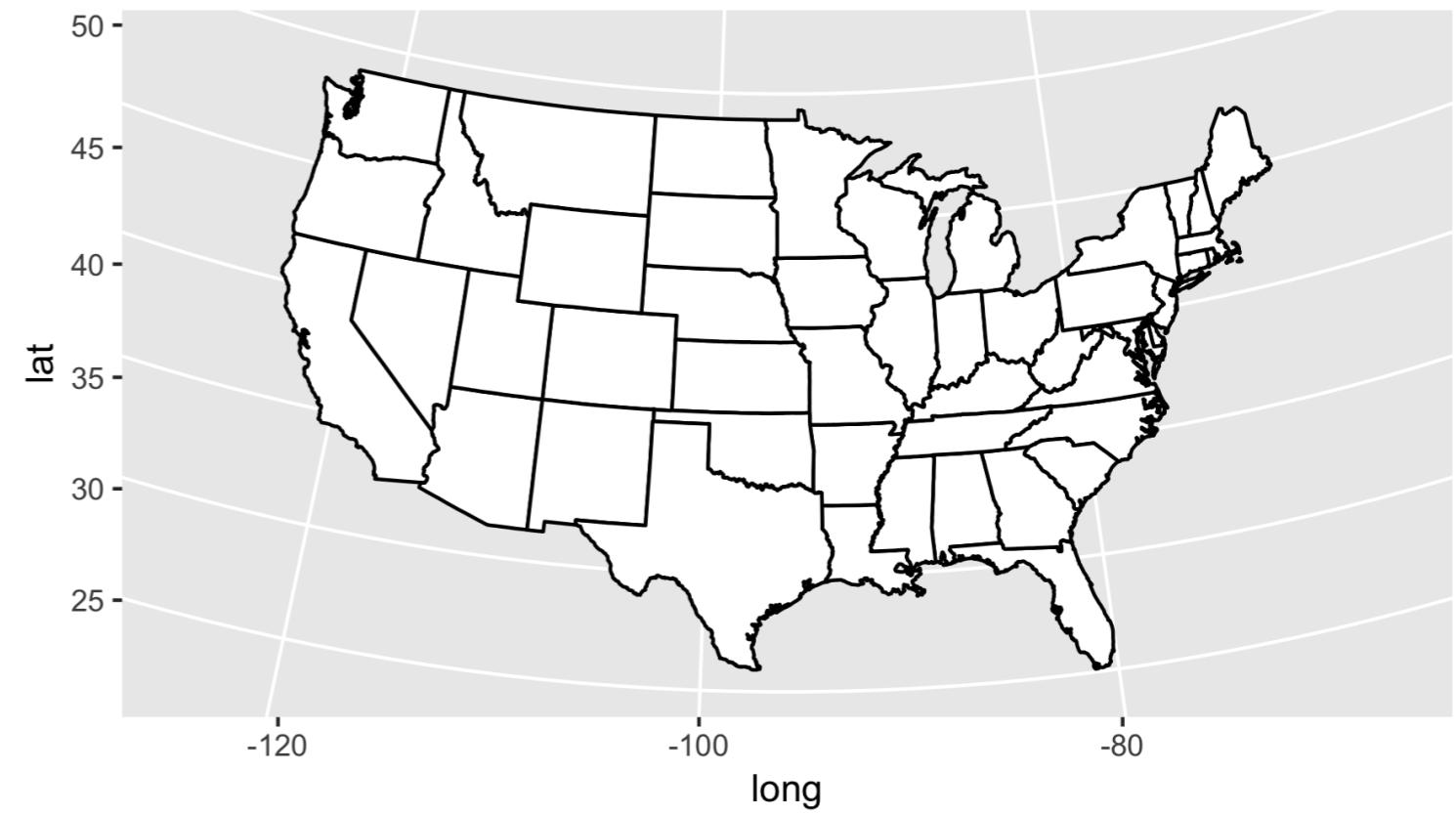


A preview of map projections

The Mercator Projection



The Conic Projection

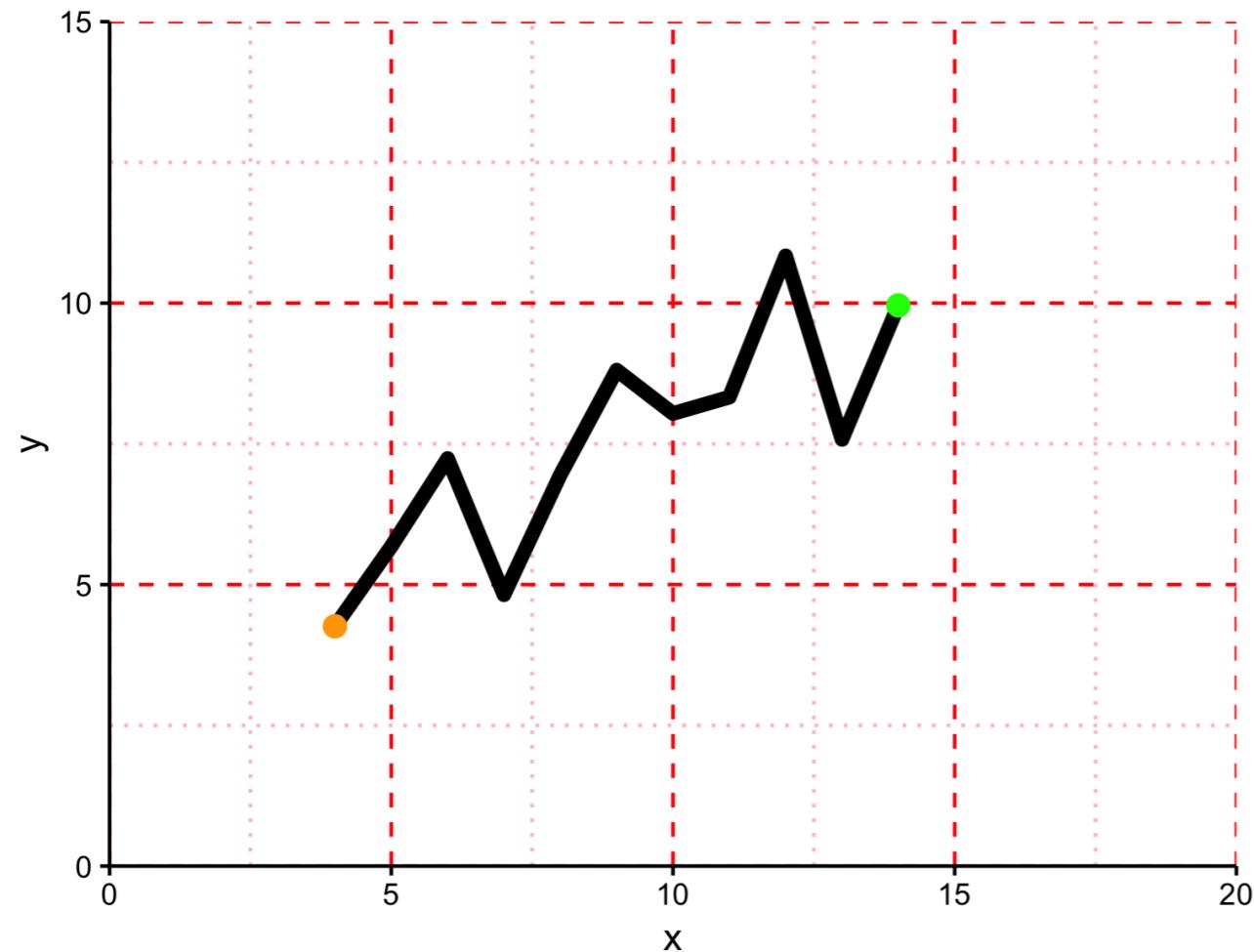


Polar coordinates

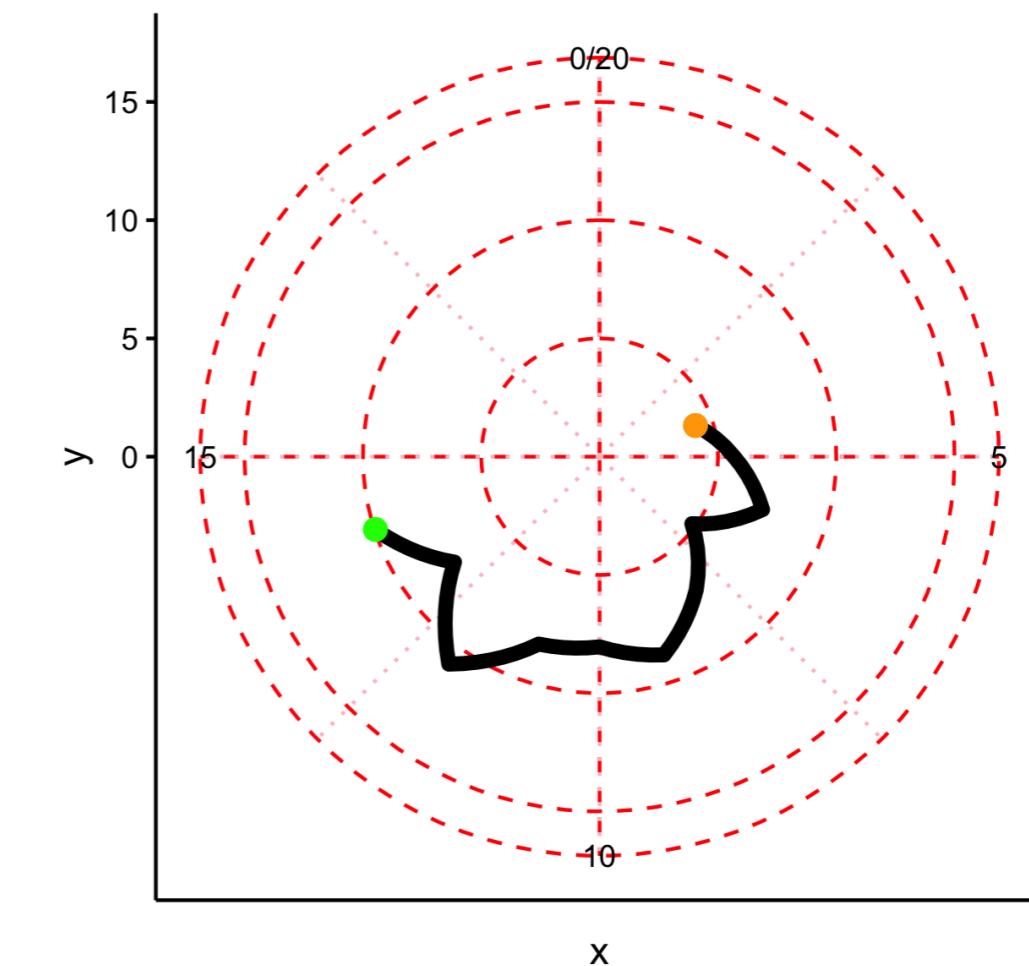
- Cartesian (2d)
 - Orthogonal x and y-axes.
- Maps
 - Many projections, see next course
- Polar
 - Transformed Cartesian space

coord_polar()

p + coord_fixed()

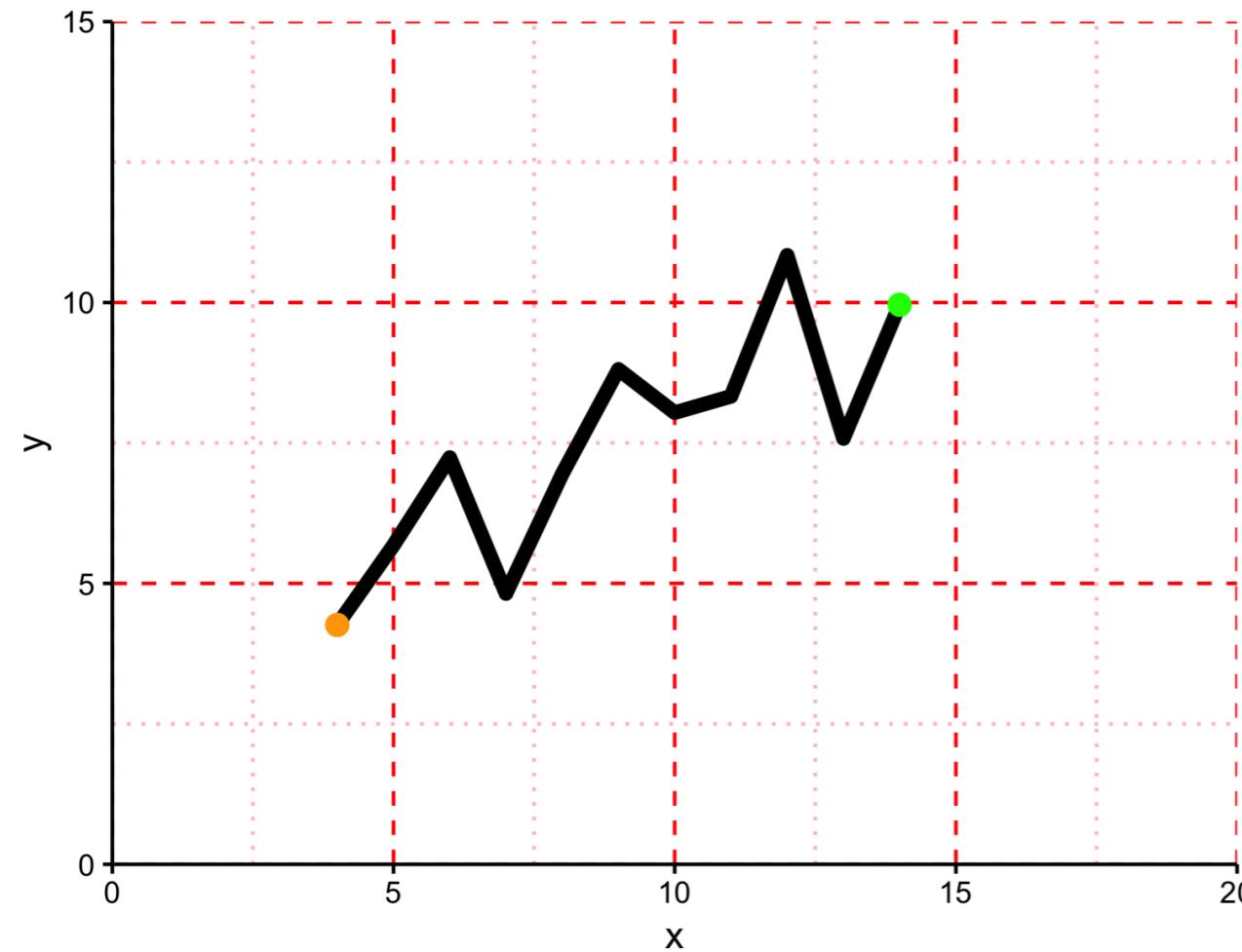


p + coord_polar()

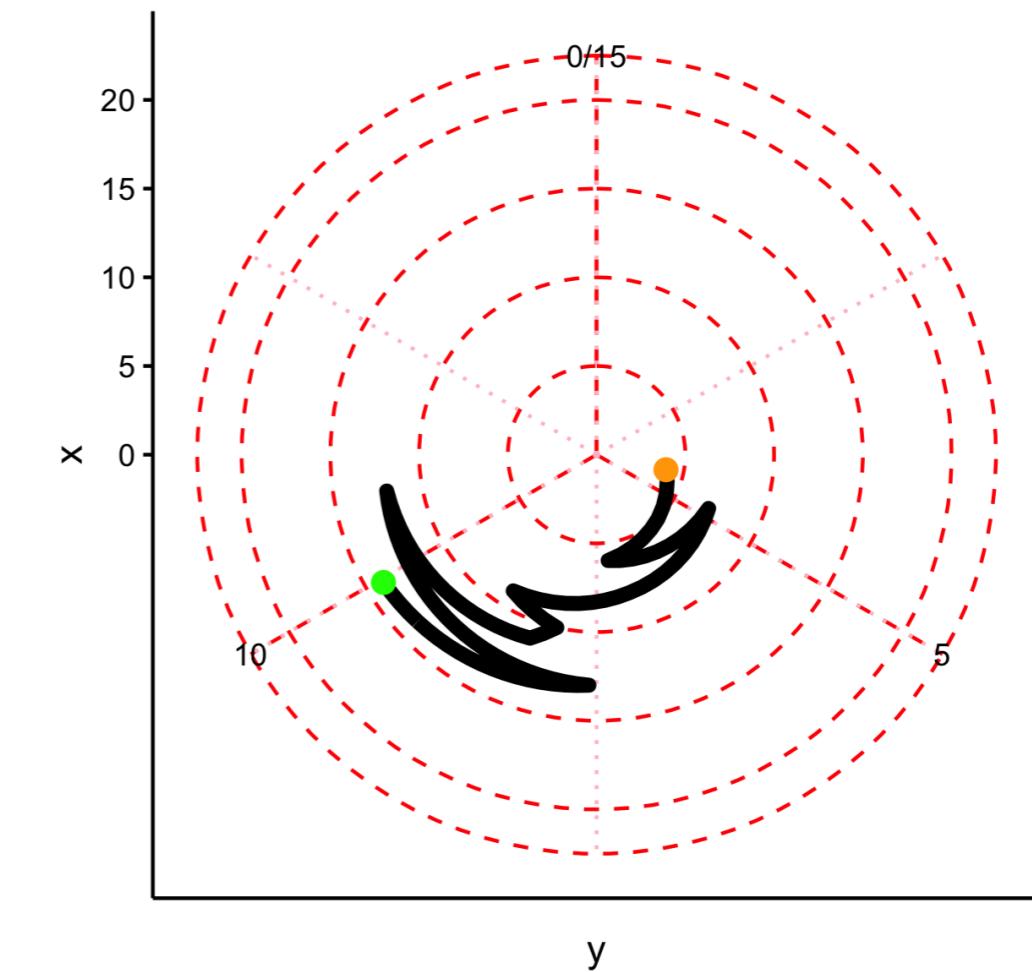


`coord_polar(theta = "y")`

`p + coord_fixed()`



`p + coord_polar(theta = "y")`



Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

The facets layer

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

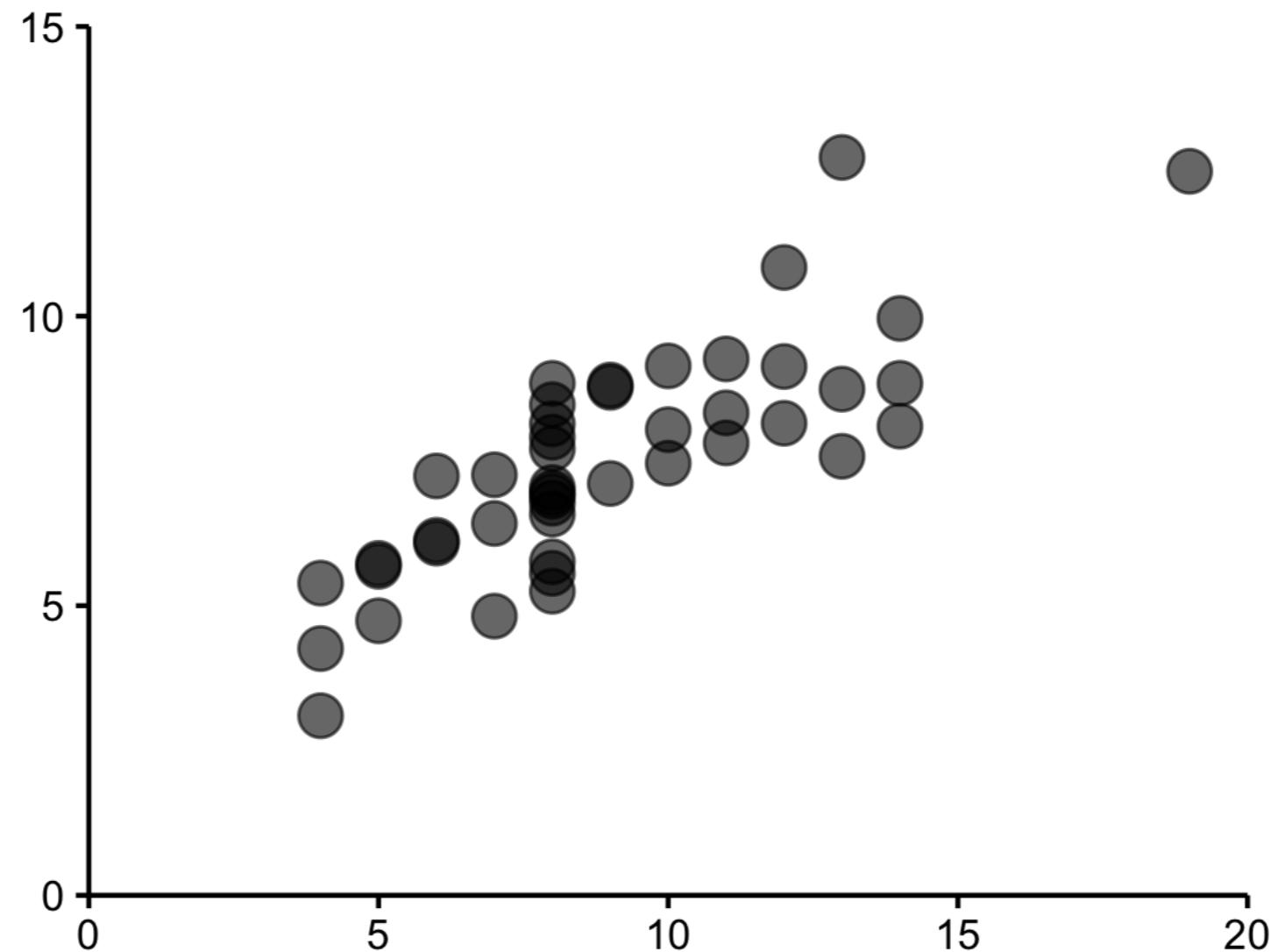


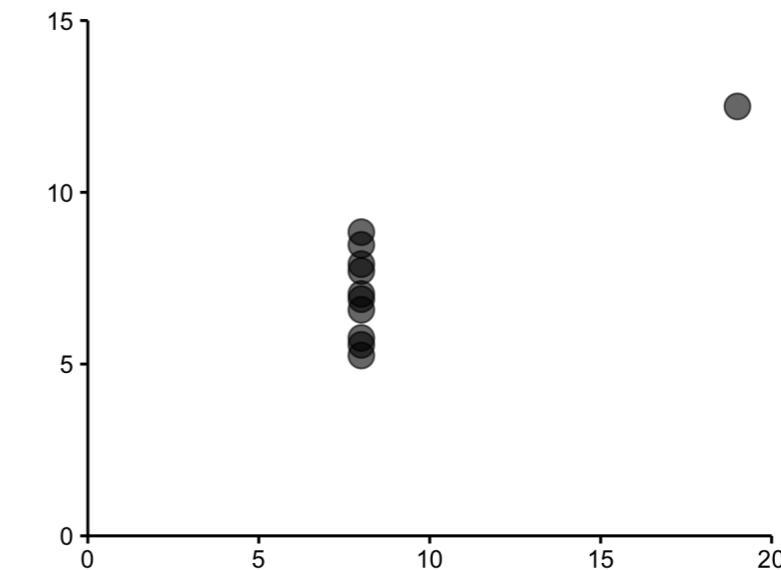
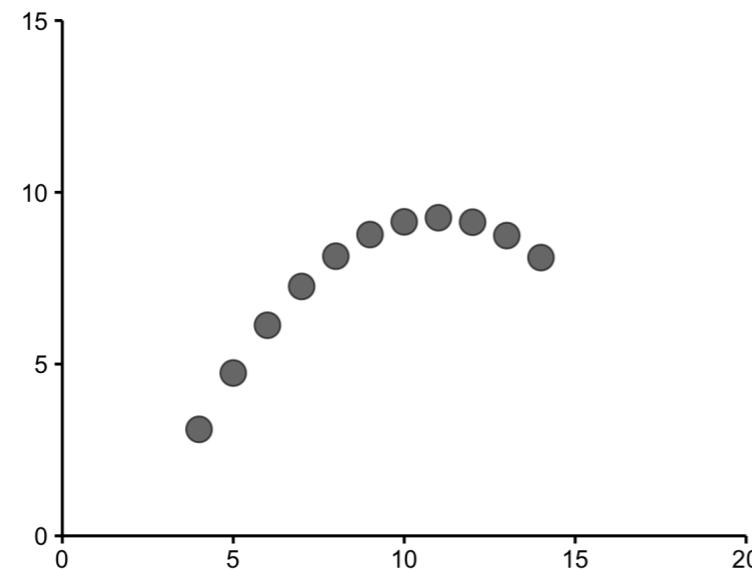
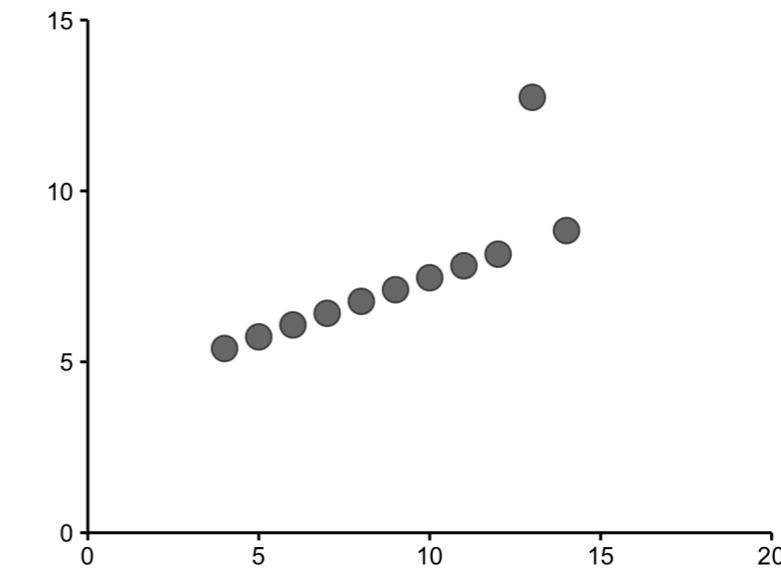
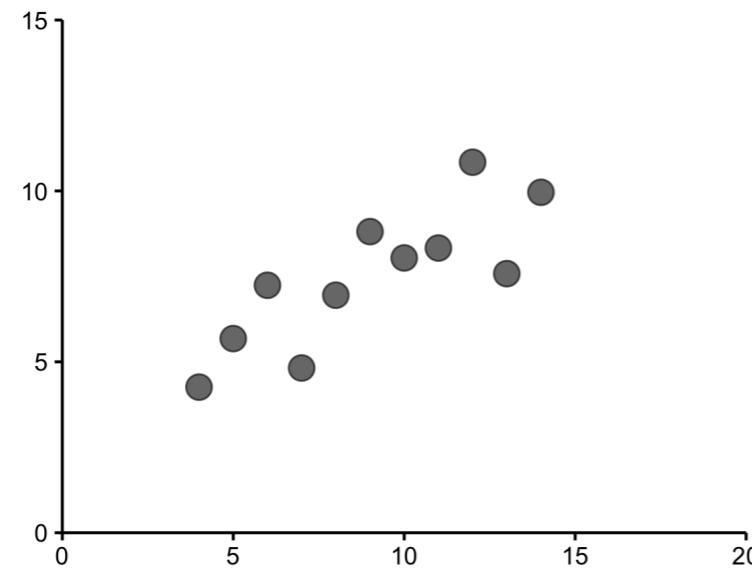
Rick Scavetta

Founder, Scavetta Academy

Facets

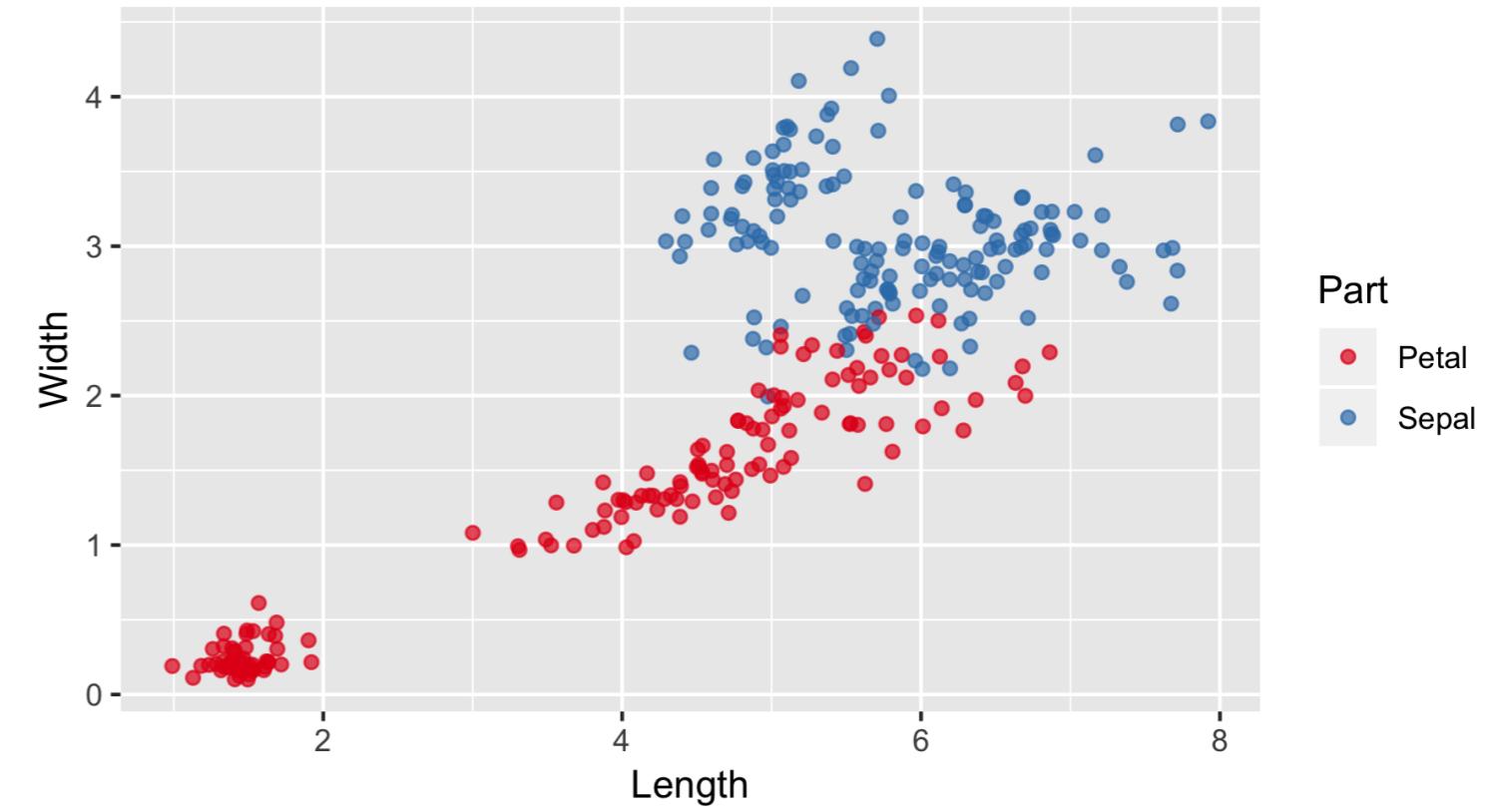
- Straight-forward yet useful
- Concept of Small Multiples
 - Popularized by Edward Tufte
 - Visualization of Quantitative Information, 1983





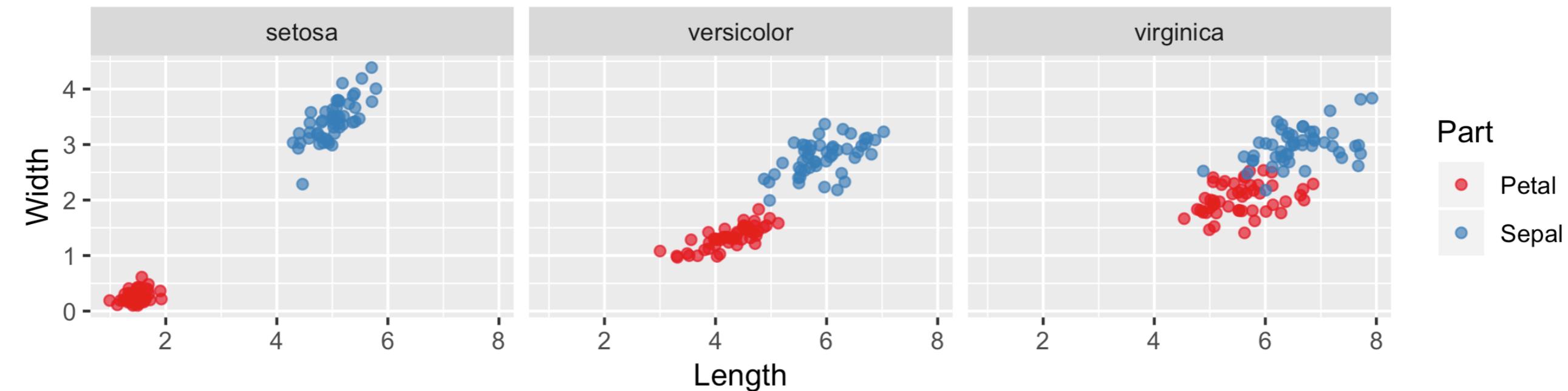
iris.wide

```
p <- ggplot(iris.wide, aes(x = Length,  
                           y = Width,  
                           color = Part)) +  
  geom_jitter(alpha = 0.7) +  
  scale_color_brewer(palette = "Set1") +  
  coord_fixed()  
  
p
```



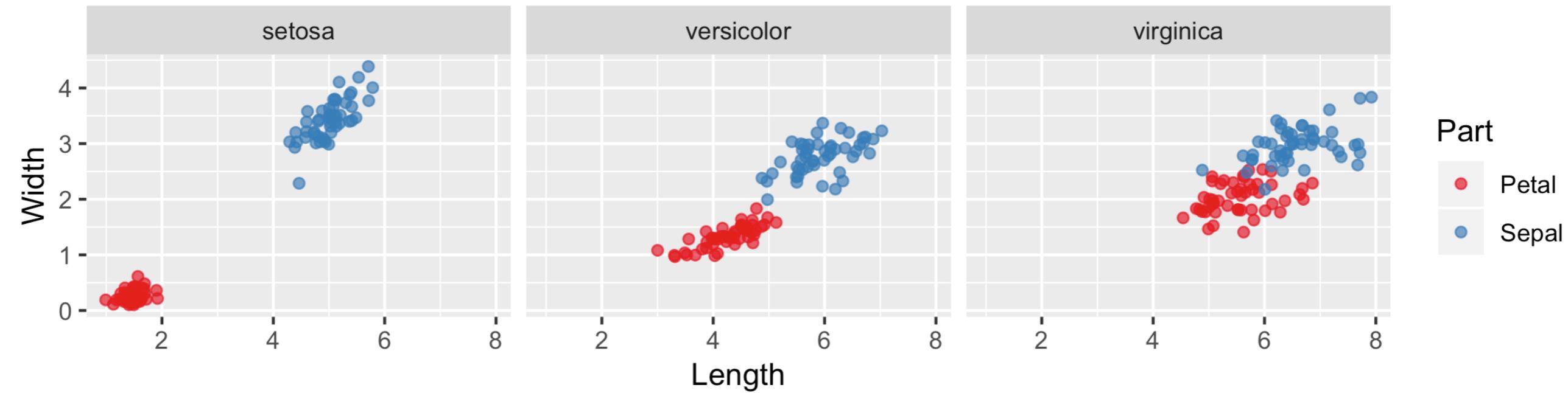
iris.wide & facet_grid()

```
p <- ggplot(iris.wide, aes(x = Length, y = Width, color = Part)) +  
  geom_jitter(alpha = 0.7) +  
  scale_color_brewer(palette = "Set1") +  
  coord_fixed()  
p + facet_grid(cols = vars(Species))
```



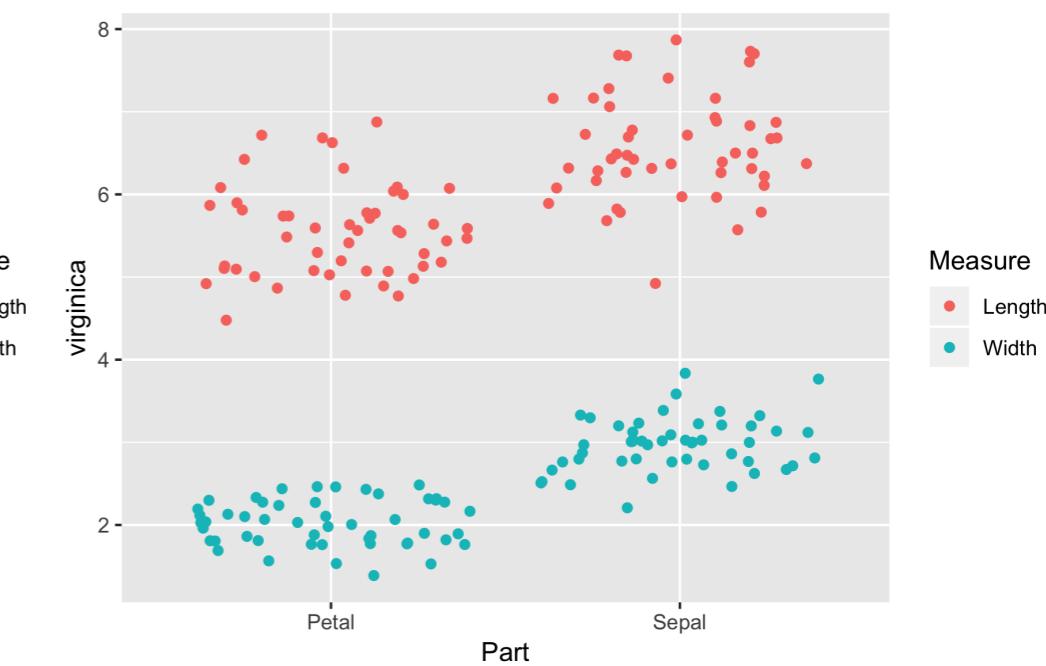
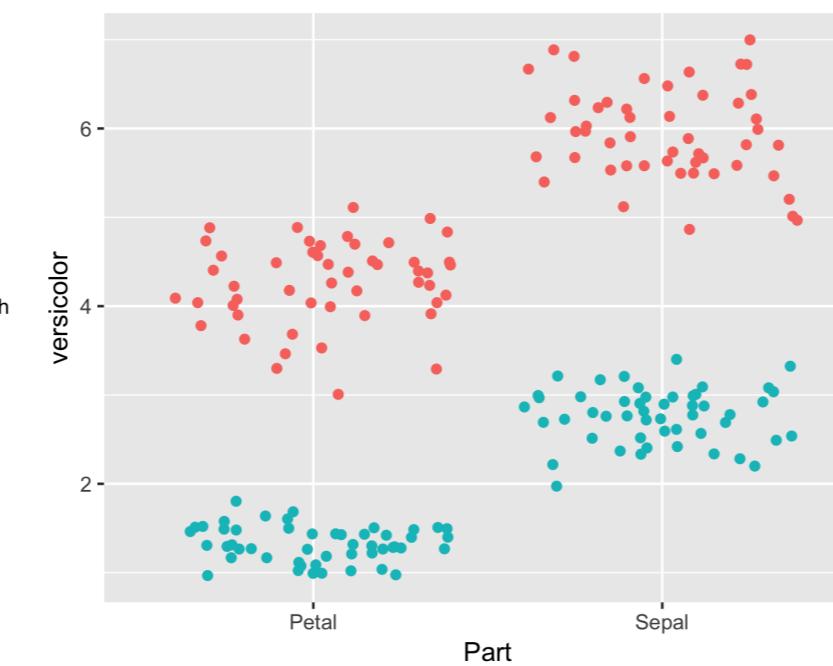
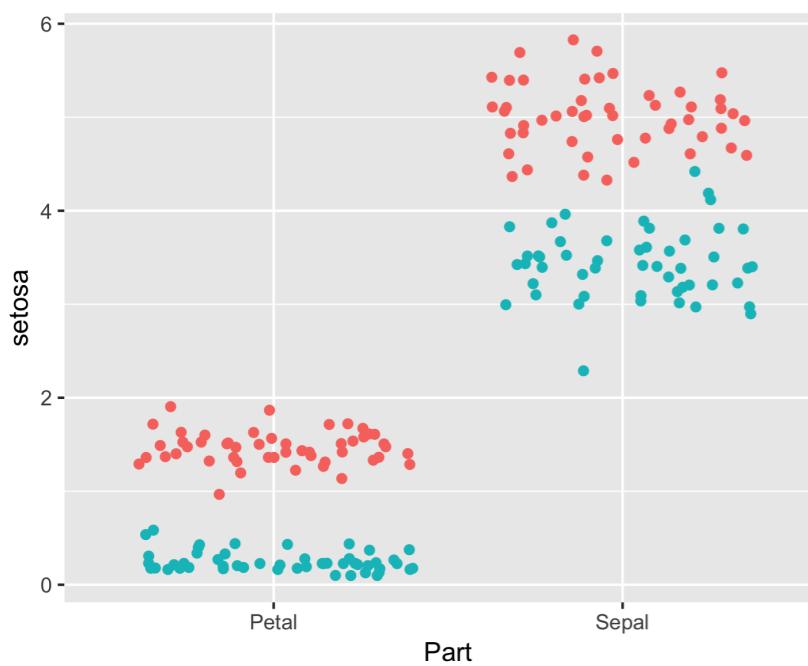
Formula notation

```
p <- ggplot(iris.wide, aes(x = Length, y = Width, color = Part)) +  
  geom_jitter(alpha = 0.7) +  
  scale_color_brewer(palette = "Set1") +  
  coord_fixed()  
p + facet_grid(. ~ Species)
```



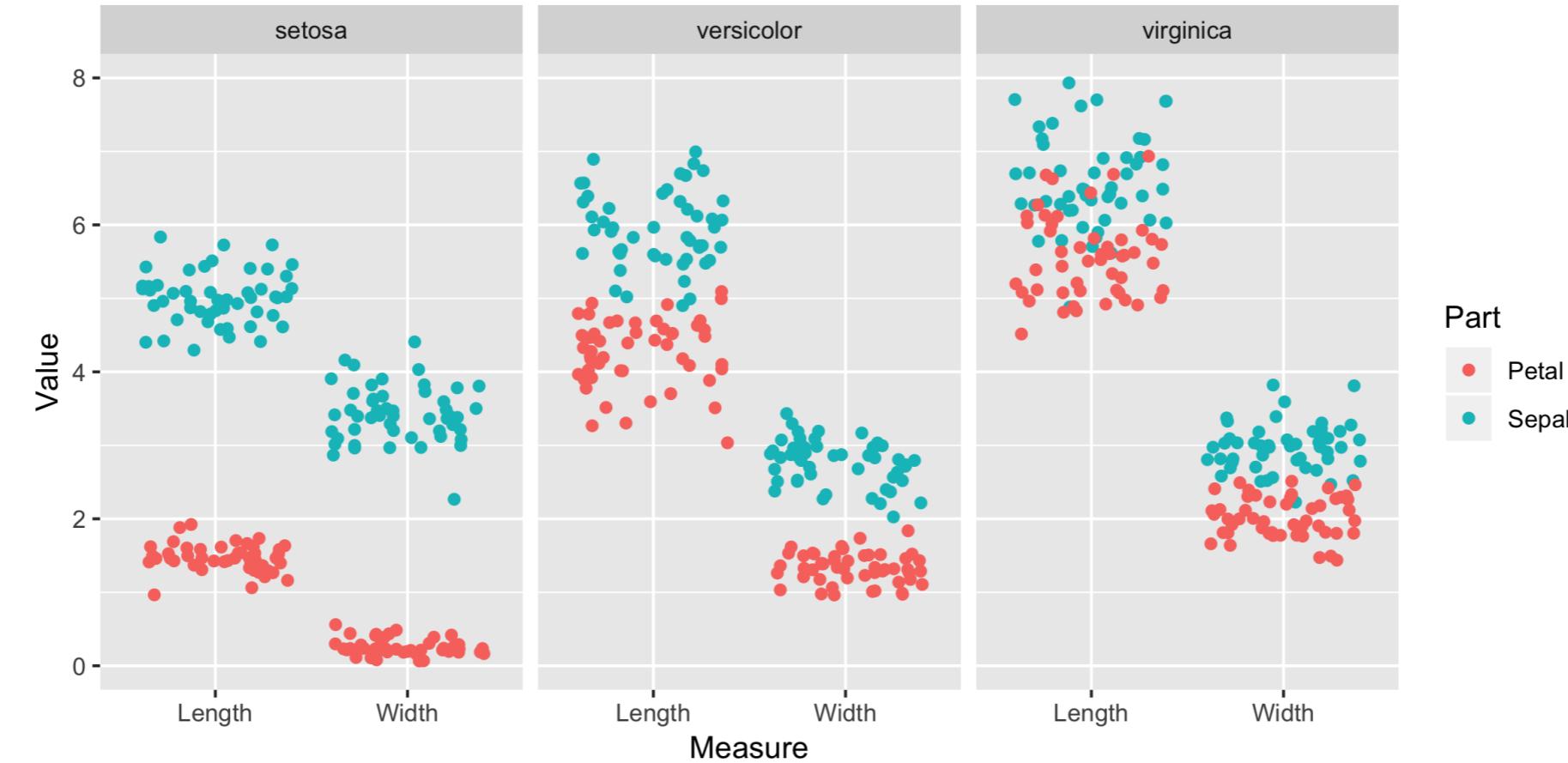
iris.wide2

```
ggplot(iris.wide2, aes(x = Part, y = setosa, color = Measure)) +  
  geom_jitter()  
  
ggplot(iris.wide2, aes(x = Part, y = versicolor, color = Measure)) +  
  geom_jitter()  
  
ggplot(iris.wide2, aes(x = Part, y = virginica, color = Measure)) +  
  geom_jitter()
```



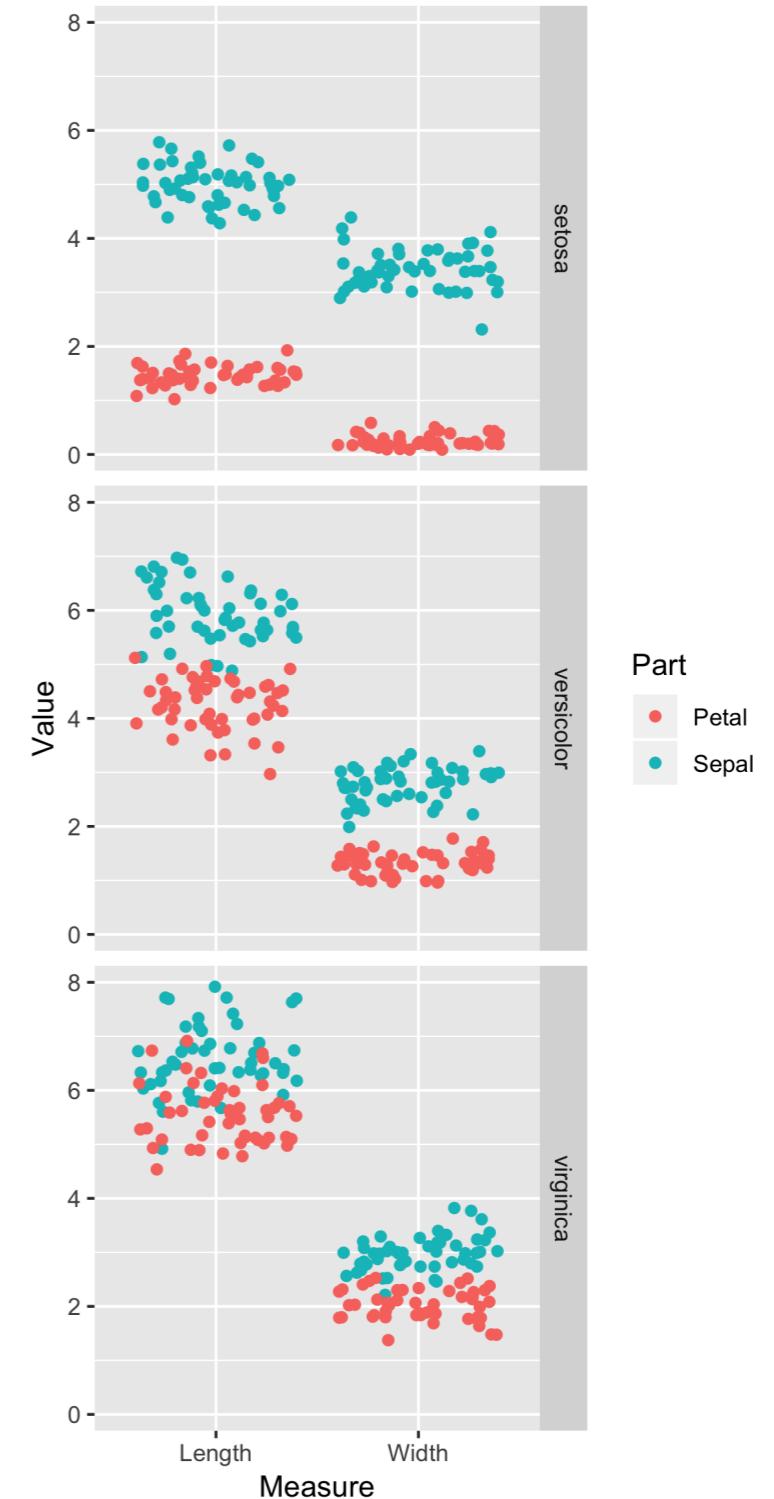
iris.tidy

```
ggplot(iris.tidy, aes(x = Measure, y = Value, color = Part)) +  
  geom_jitter() +  
  facet_grid(cols = vars(Species))
```



iris.tidy faceting done wrong:

```
ggplot(iris.tidy, aes(x = Measure,  
                      y = Value,  
                      color = Part)) +  
  
  geom_jitter() +  
  
  facet_grid(rows = vars(Species))
```



Other options

- Split according to rows and columns

Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Facet labels and order

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

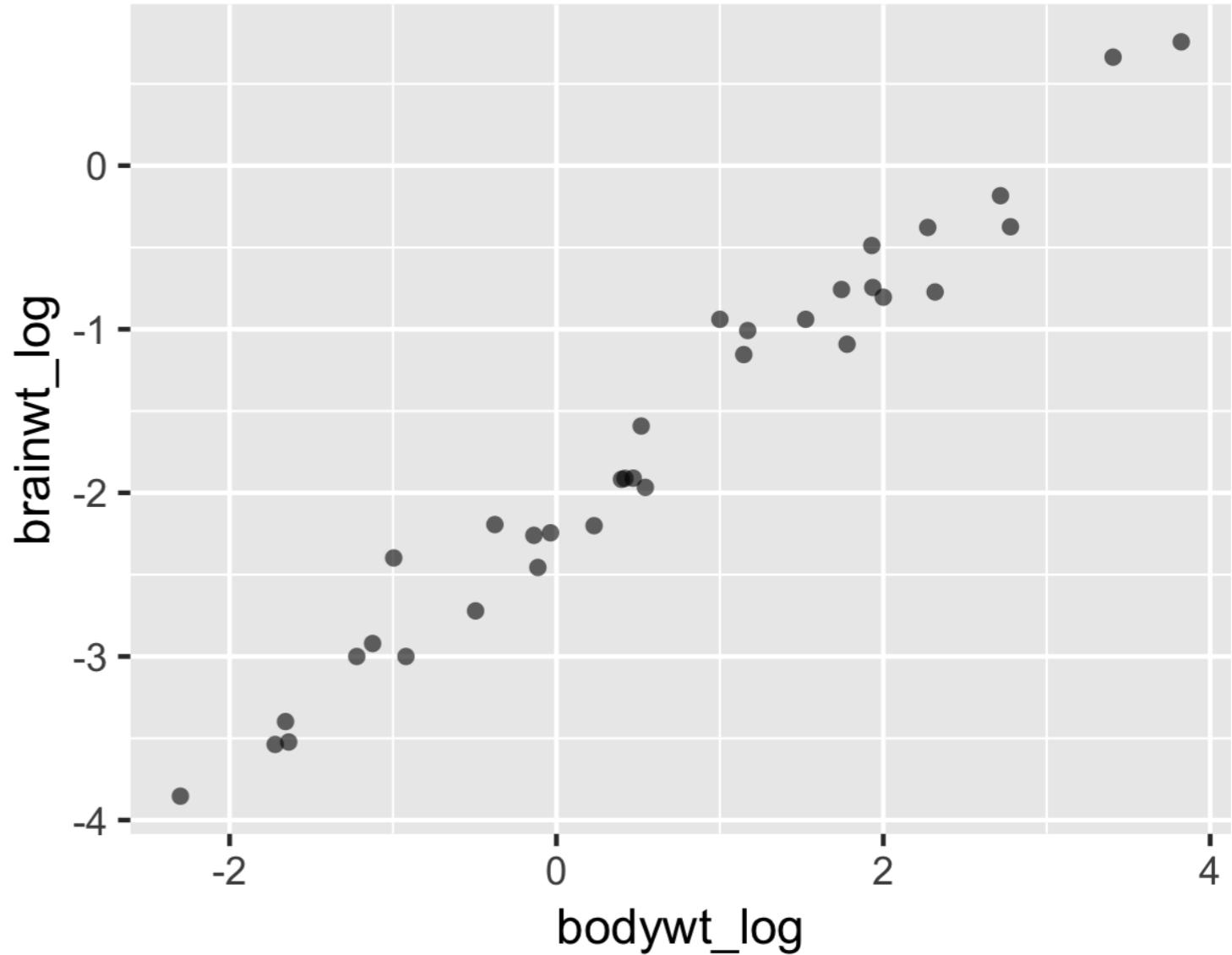


Rick Scavetta

Founder, Scavetta Academy

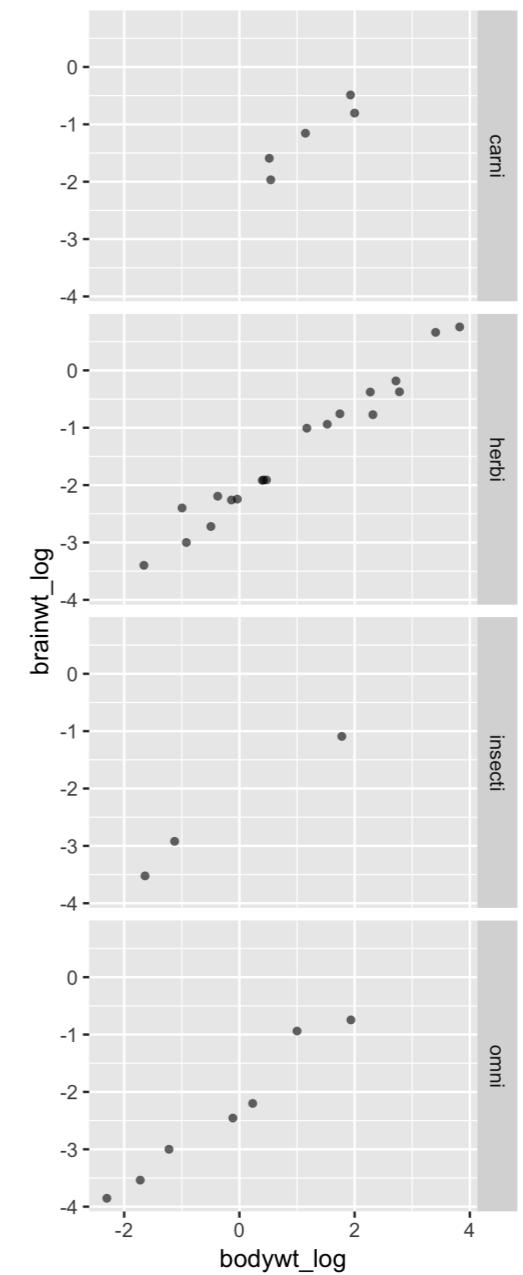
A new dataframe

```
# Plot  
p <- ggplot(msleep2, aes(bodywt_log,  
                           brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  coord_fixed()  
  
p
```



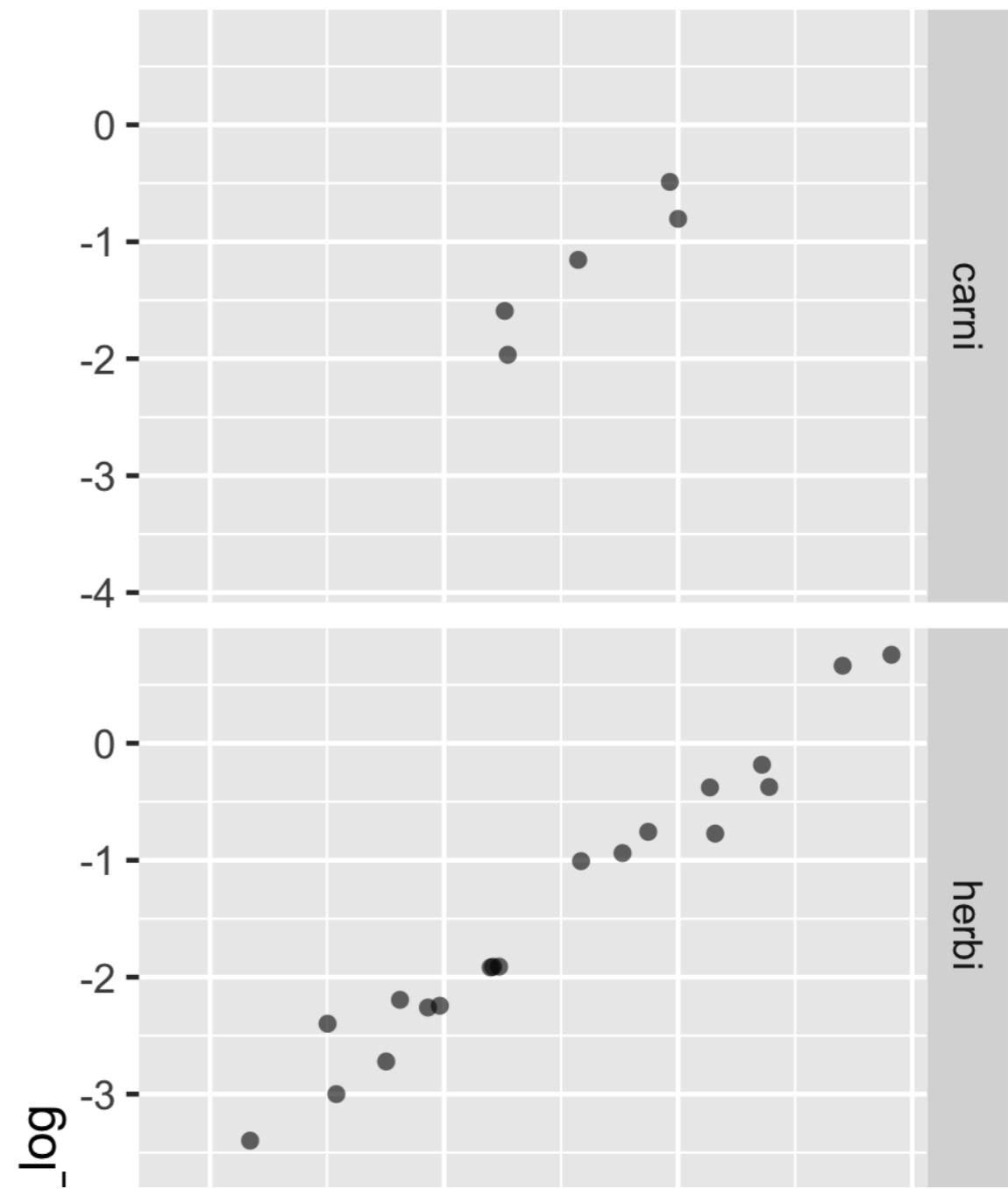
A new dataframe, with facets

```
p +  
  facet_grid(rows = vars(vore))
```



A new dataframe, with facets

```
p +  
  facet_grid(rows = vars(vore))
```

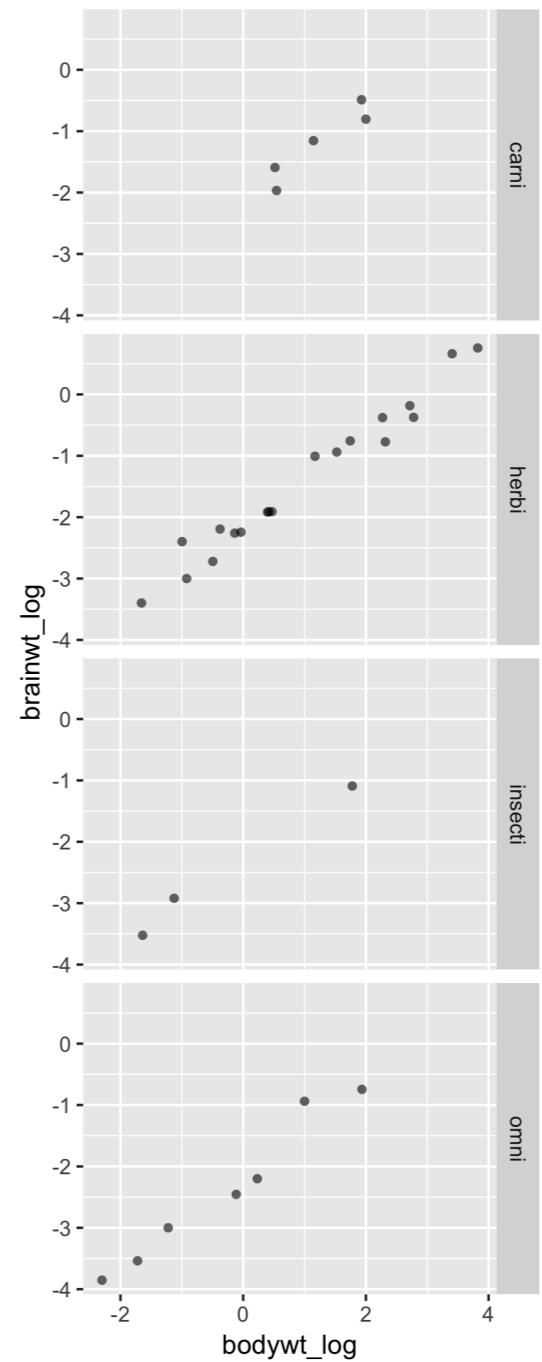


Poor labels and order

```
p +  
  facet_grid(rows = vars(vore))
```

Two typical problems with facets:

- Poorly labeled (e.g. non descriptive)
- Wrong or inappropriate order

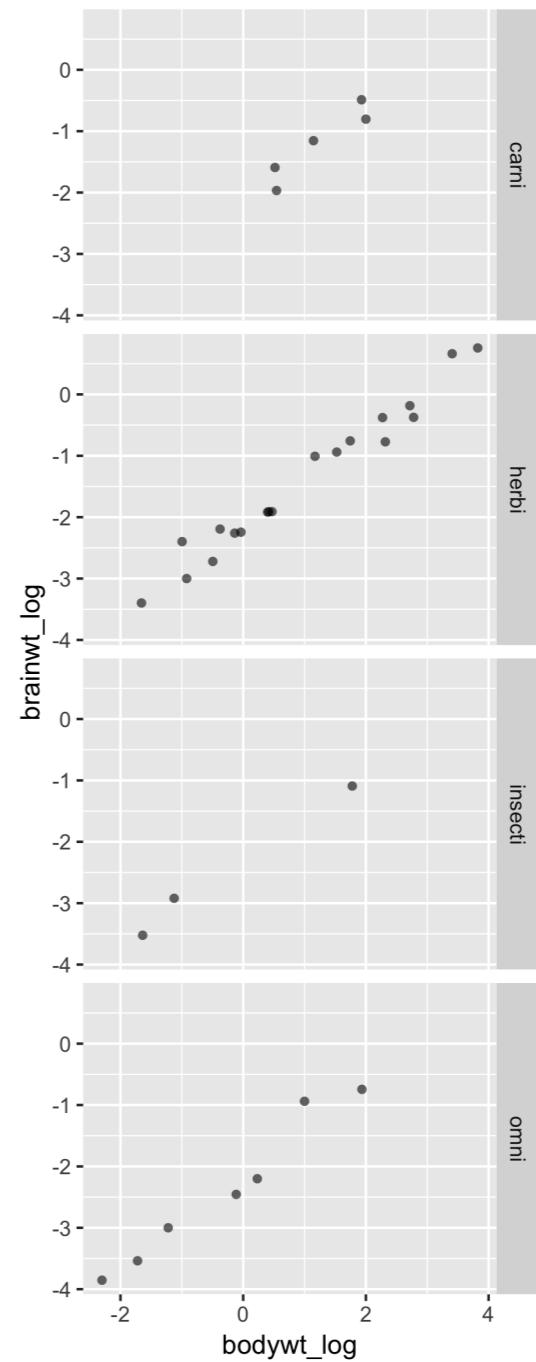


Poor labels and order

```
p +  
  facet_grid(rows = vars(vore))
```

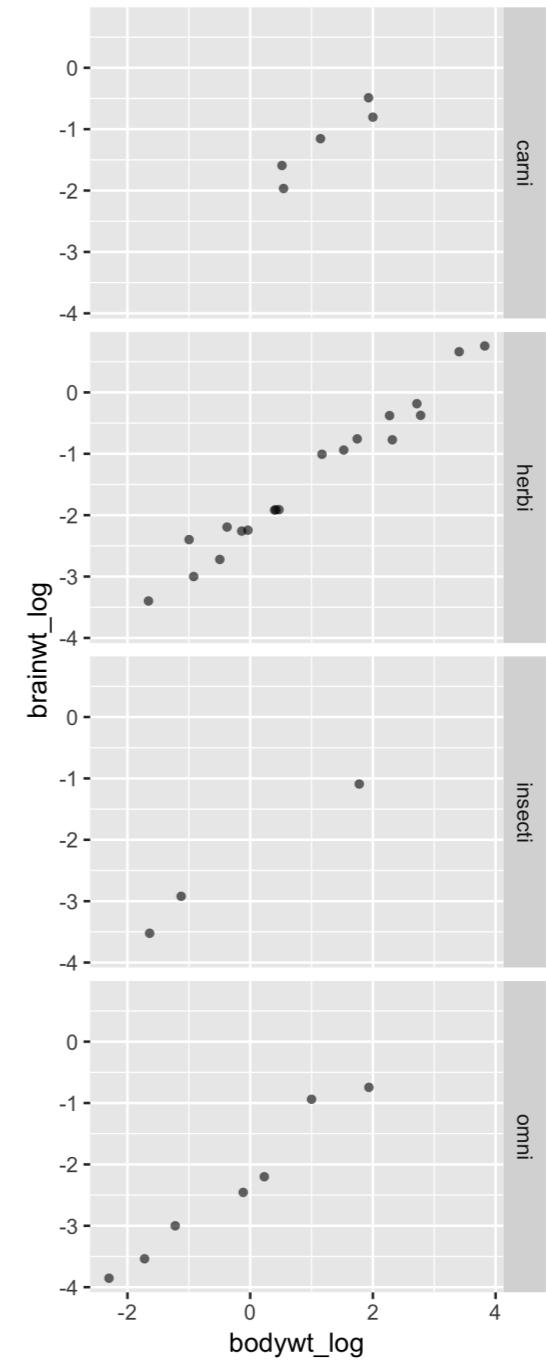
Solutions:

- Easy: Add labels in ggplot
- Better: Relabel and rearrange factor variables in your dataframe



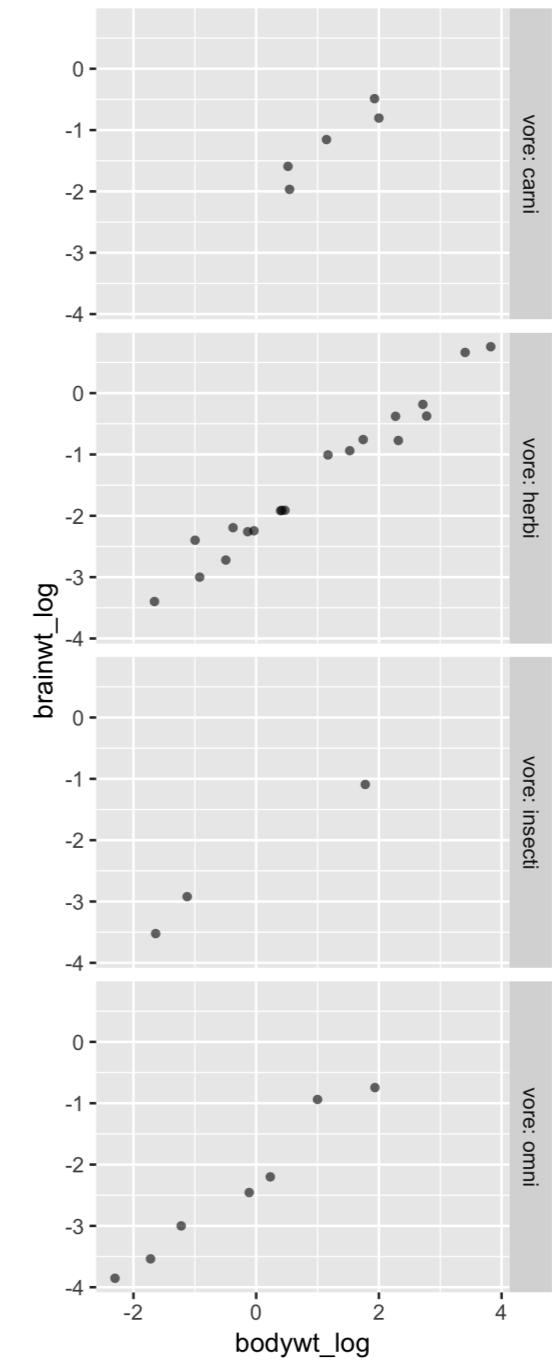
The labeller argument

```
# Default is to label the value  
p +  
  facet_grid(rows = vars(vore),  
             labeller = label_value)
```



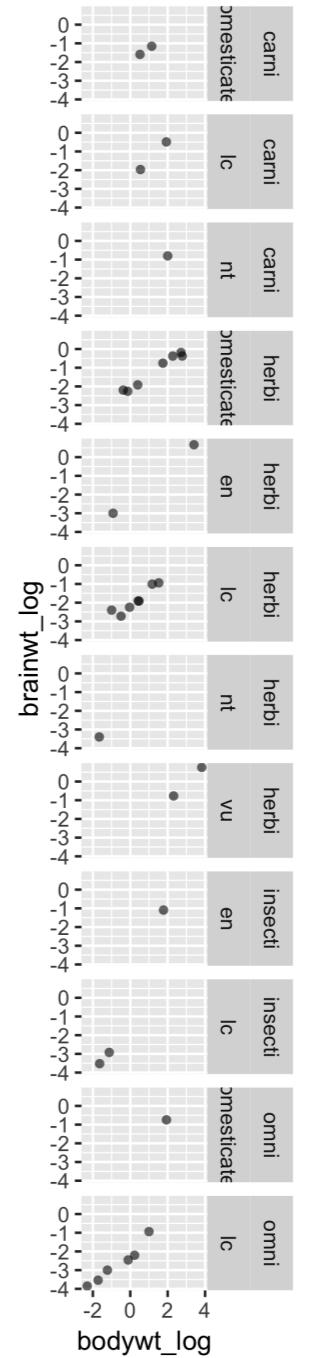
Using `label_both` adds the variable name

```
# Print variable name also  
p +  
  facet_grid(rows = vars(vore),  
             labeller = label_both)
```



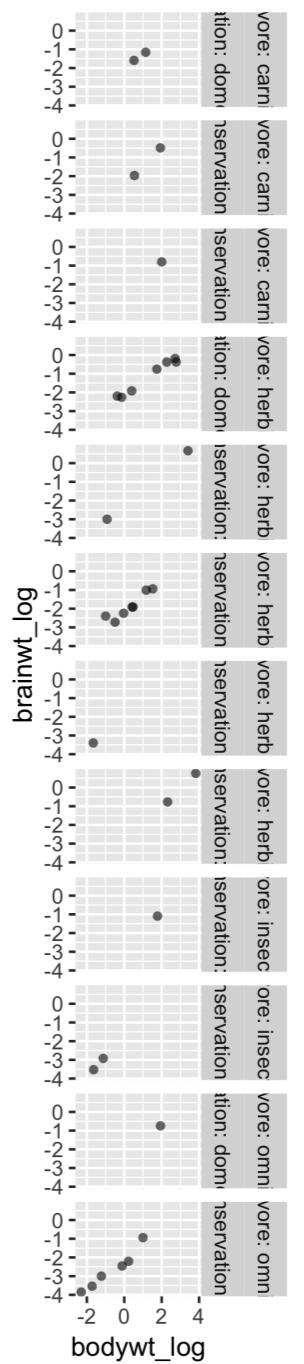
Two variables on one side

```
p +  
  facet_grid(rows = vars(vore,  
                         conservation))
```



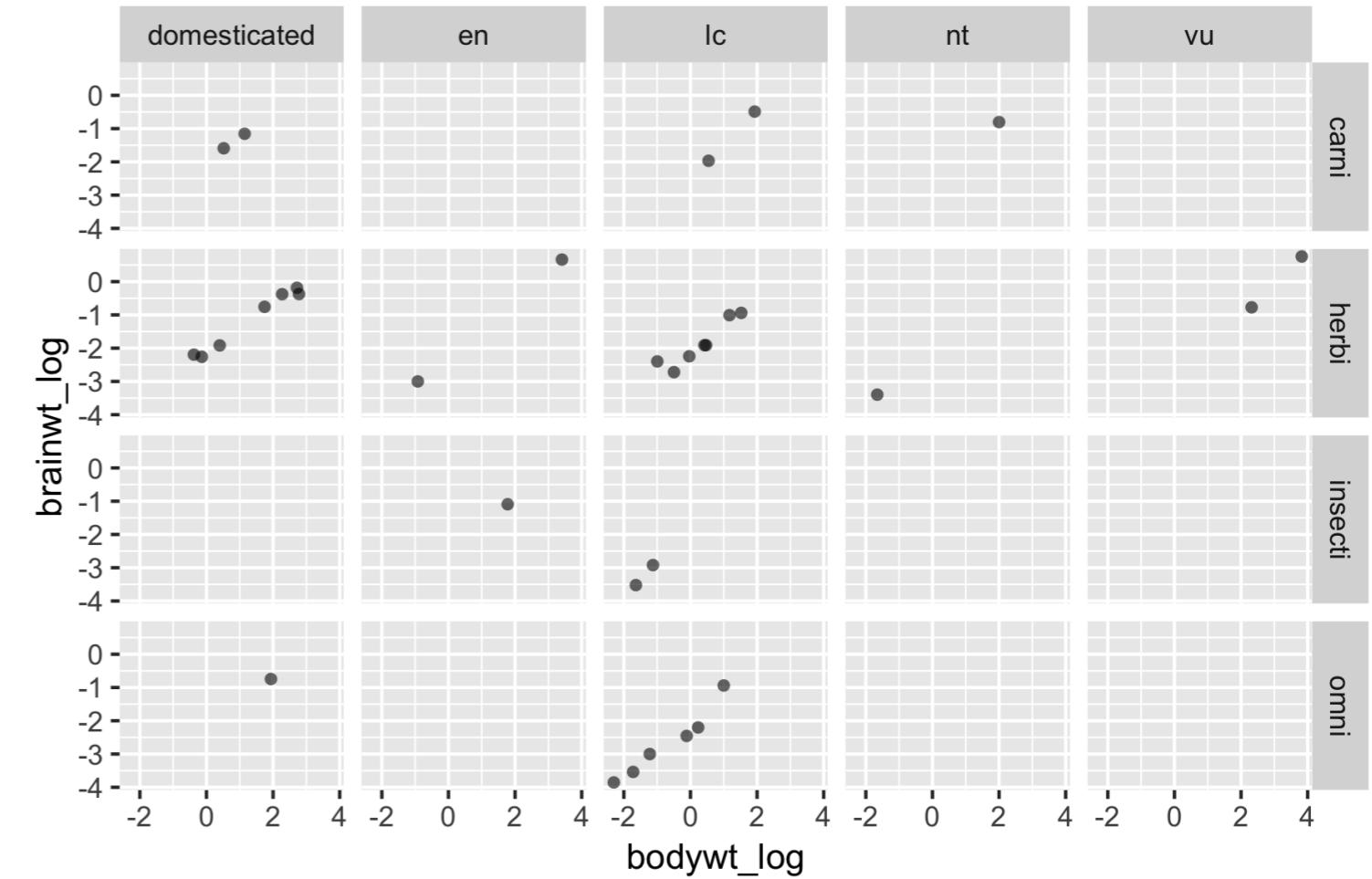
Using `label_context` avoids ambiguity

```
p +  
  facet_grid(rows = vars(vore,  
                         conservation),  
             labeller = label_context)
```



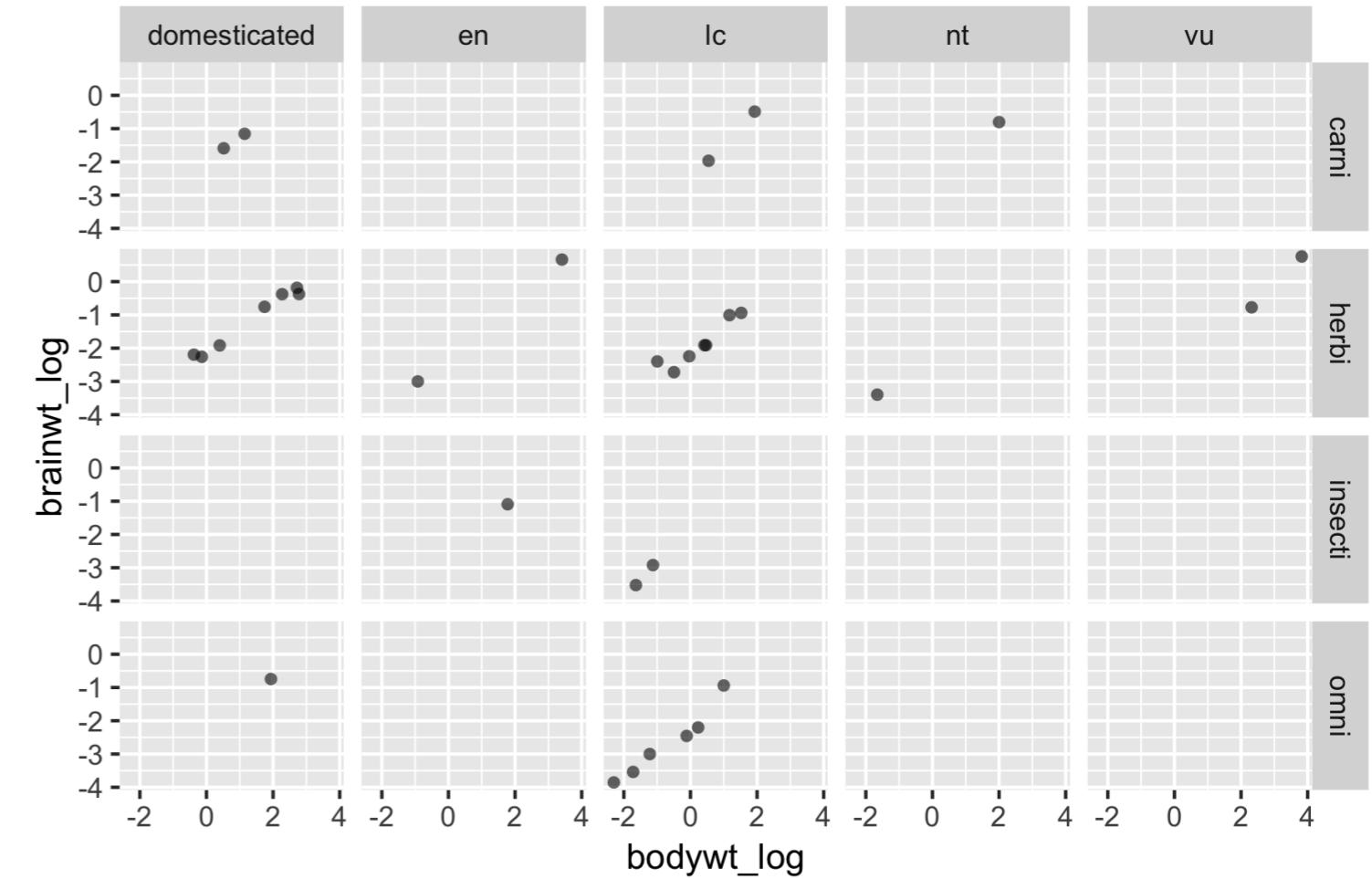
Use rows and columns when appropriate

```
p +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             labeller = label_context)
```

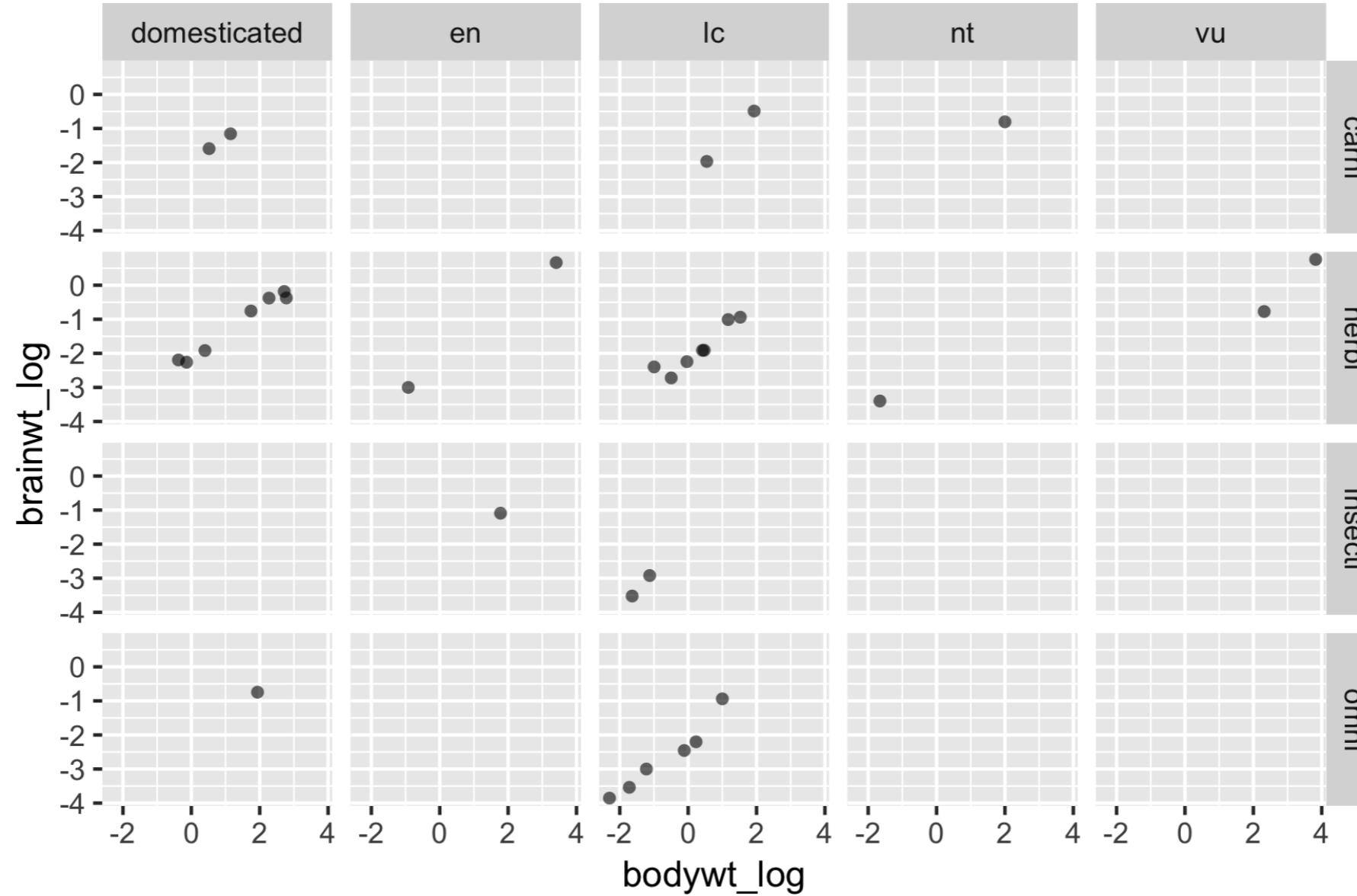


Use rows and columns when appropriate

```
p +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation))
```



Use rows and columns when appropriate

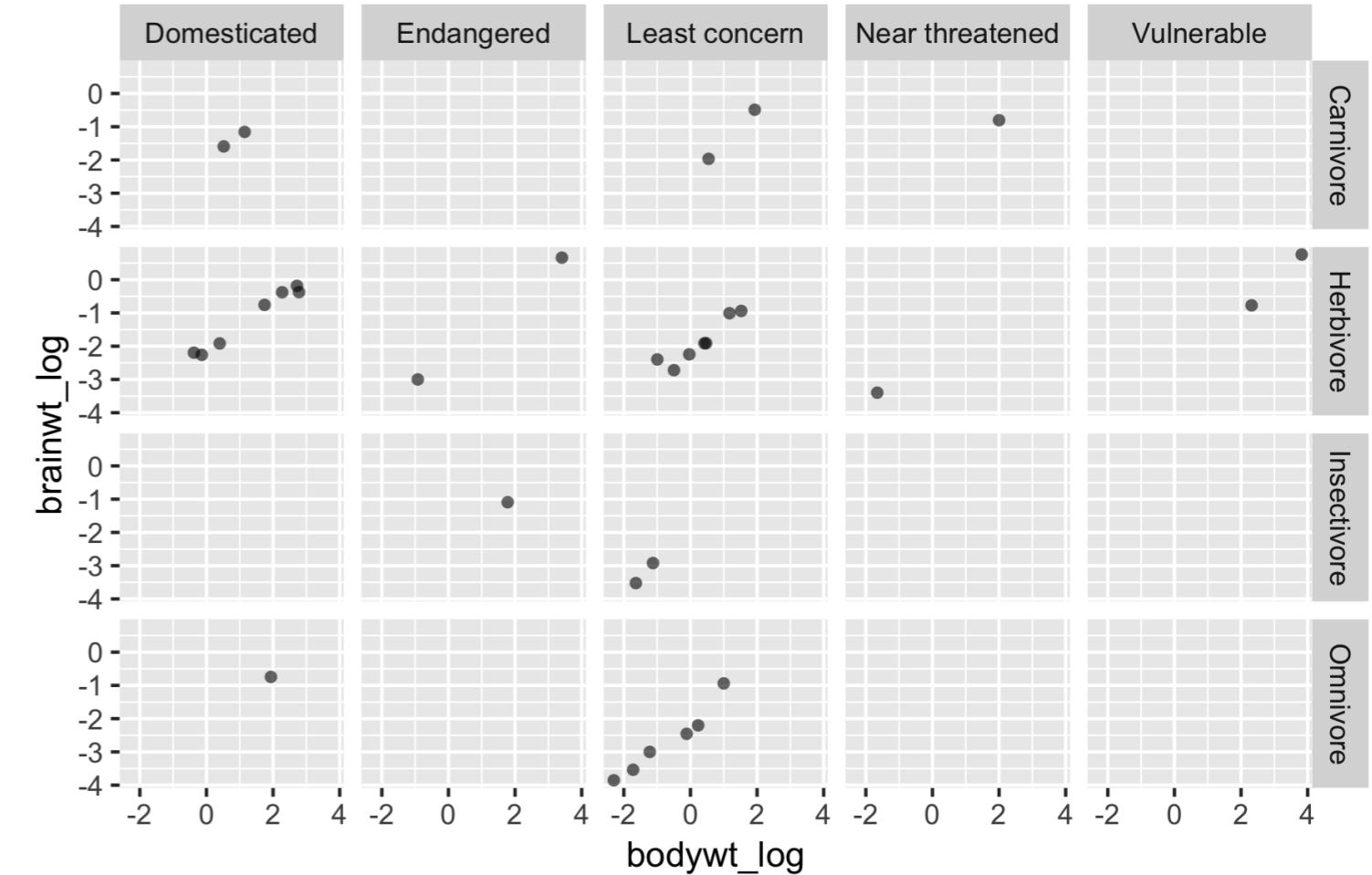


Relabeling and reordering factors

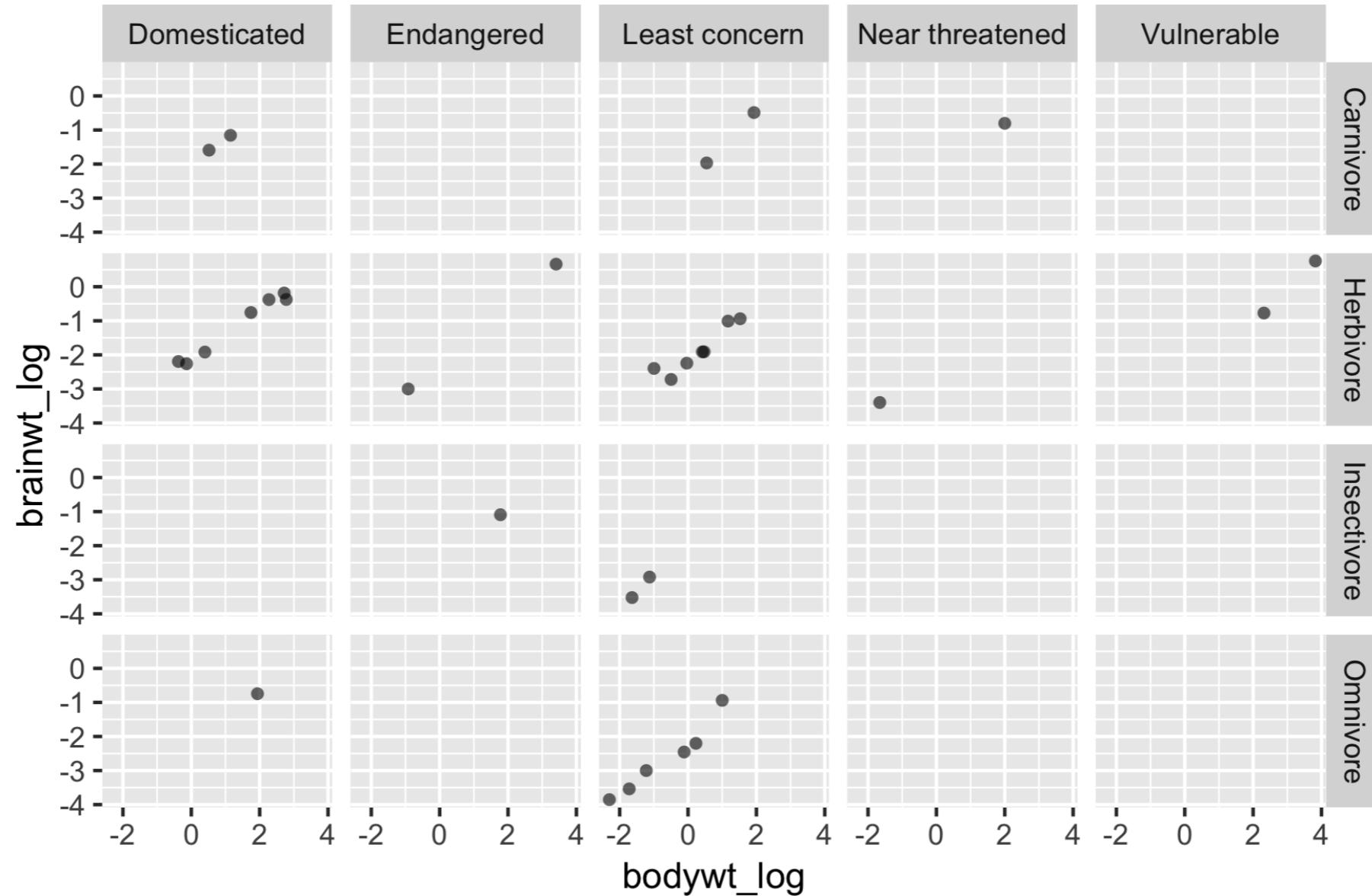
```
msleep2$conservation <- fct_recode(msleep2$conservation,  
                                     Domesticated = "domesticated",  
                                     `Least concern` = "lc",  
                                     `Near threatened` = "nt",  
                                     Vulnerable = "vu",  
                                     Endangered = "en")  
  
msleep2$vore = fct_recode(msleep2$vore,  
                           Carnivore = "carni",  
                           Herbivore = "herbi",  
                           Insectivore = "insecti",  
                           Omnivore = "omni")
```

Reinitialize plot with new labels

```
# Plot  
p <- ggplot(msleep2, aes(bodywt_log,  
                           brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  coord_fixed()  
  
p +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation))
```



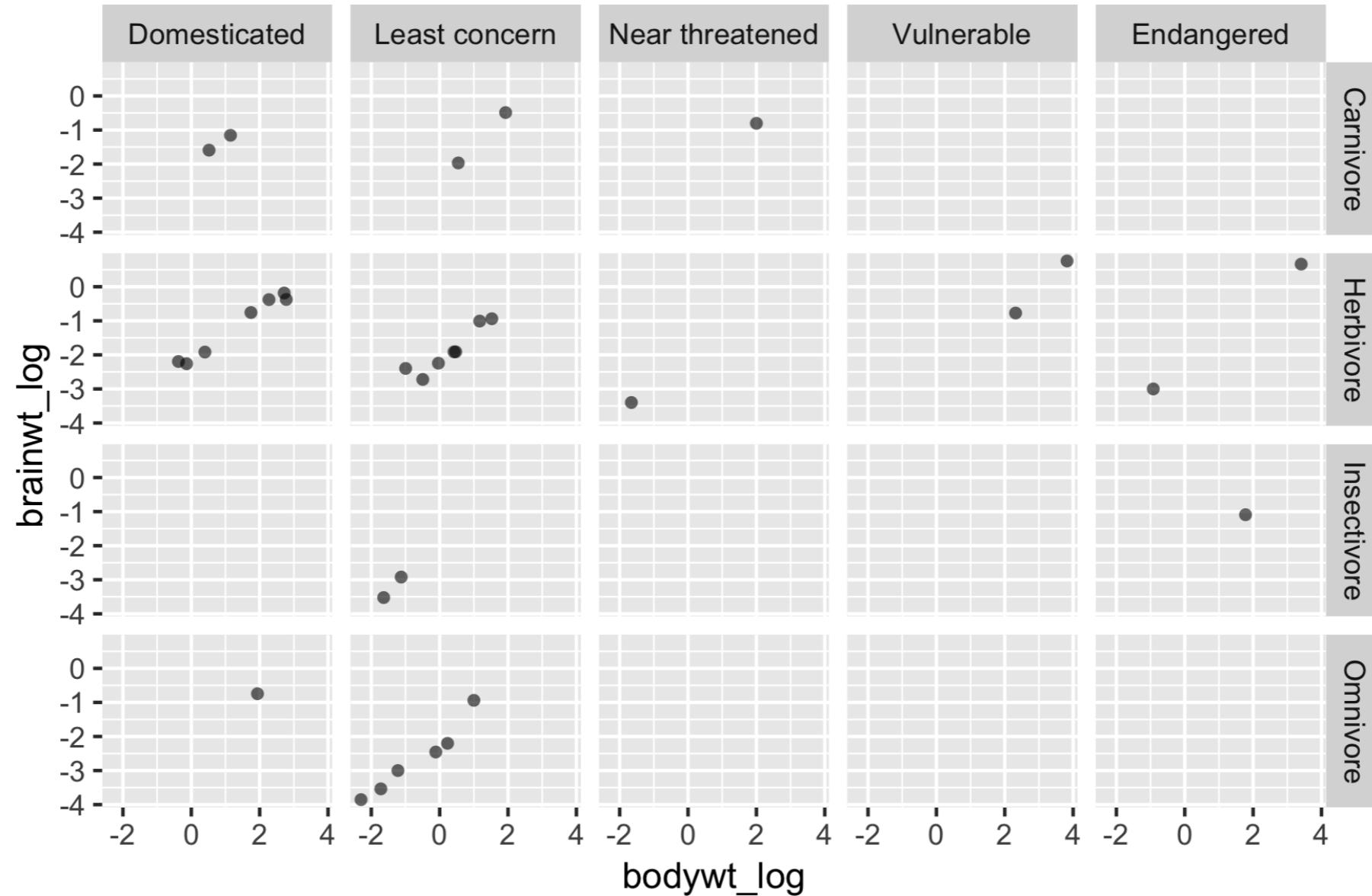
Reinitialize plot with new labels



Changing the order of levels

```
# Change order of levels:  
msleep2$conservation = fct_relevel(msleep2$conservation,  
                                     c("Domesticated",  
                                       "Least concern",  
                                       "Near threatened",  
                                       "Vulnerable",  
                                       "Endangered"))
```

Reinitialize plot with new order



Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Facet plotting spaces

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2



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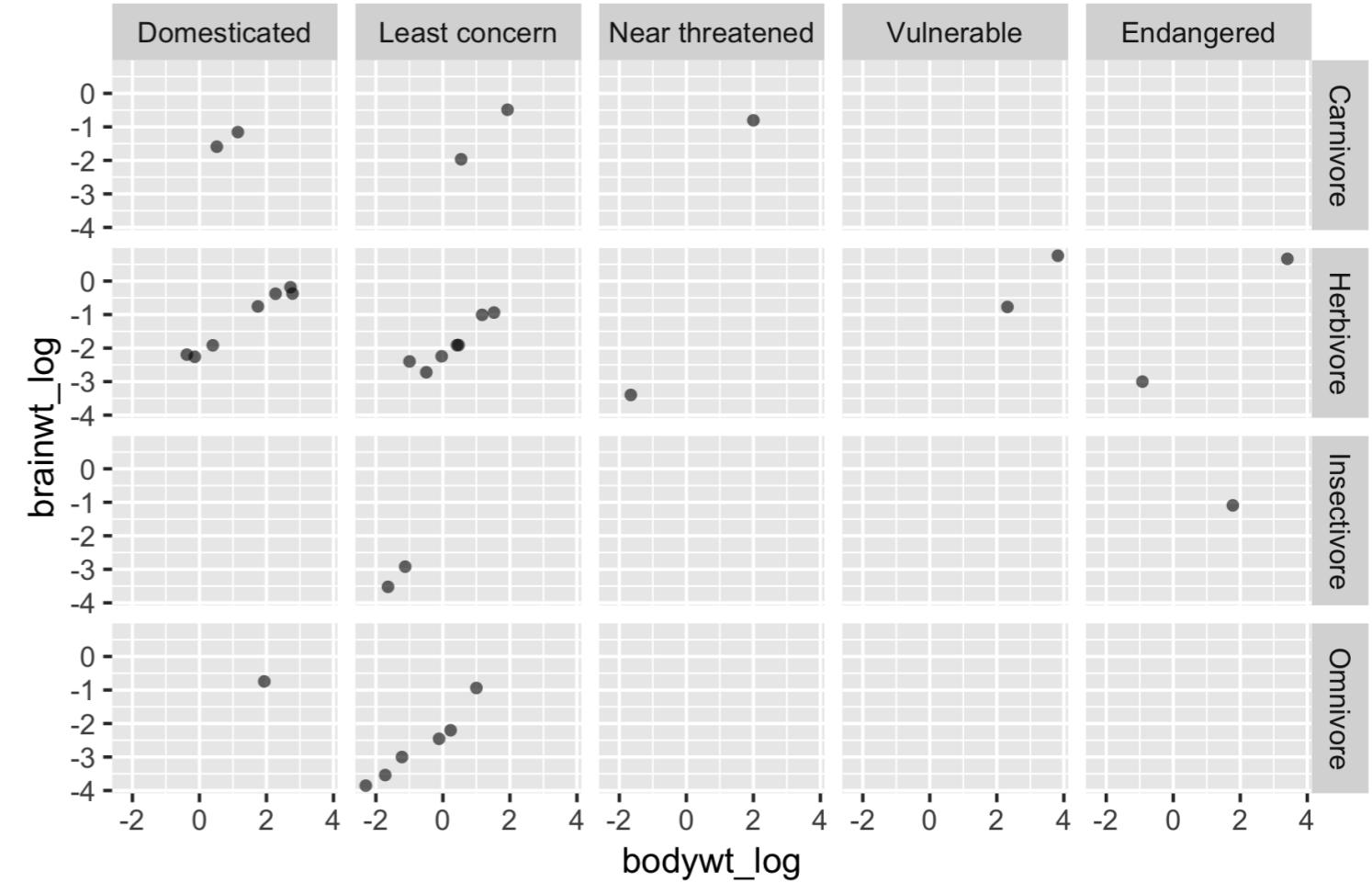
Facets and variable plotting spaces

Reasons to not use consistent plotting spaces:

Variable type	Subsets contains
Continuous	Wildly different ranges
Categorical	Different groups

Adjusting the plotting space...

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  coord_fixed() +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation))
```



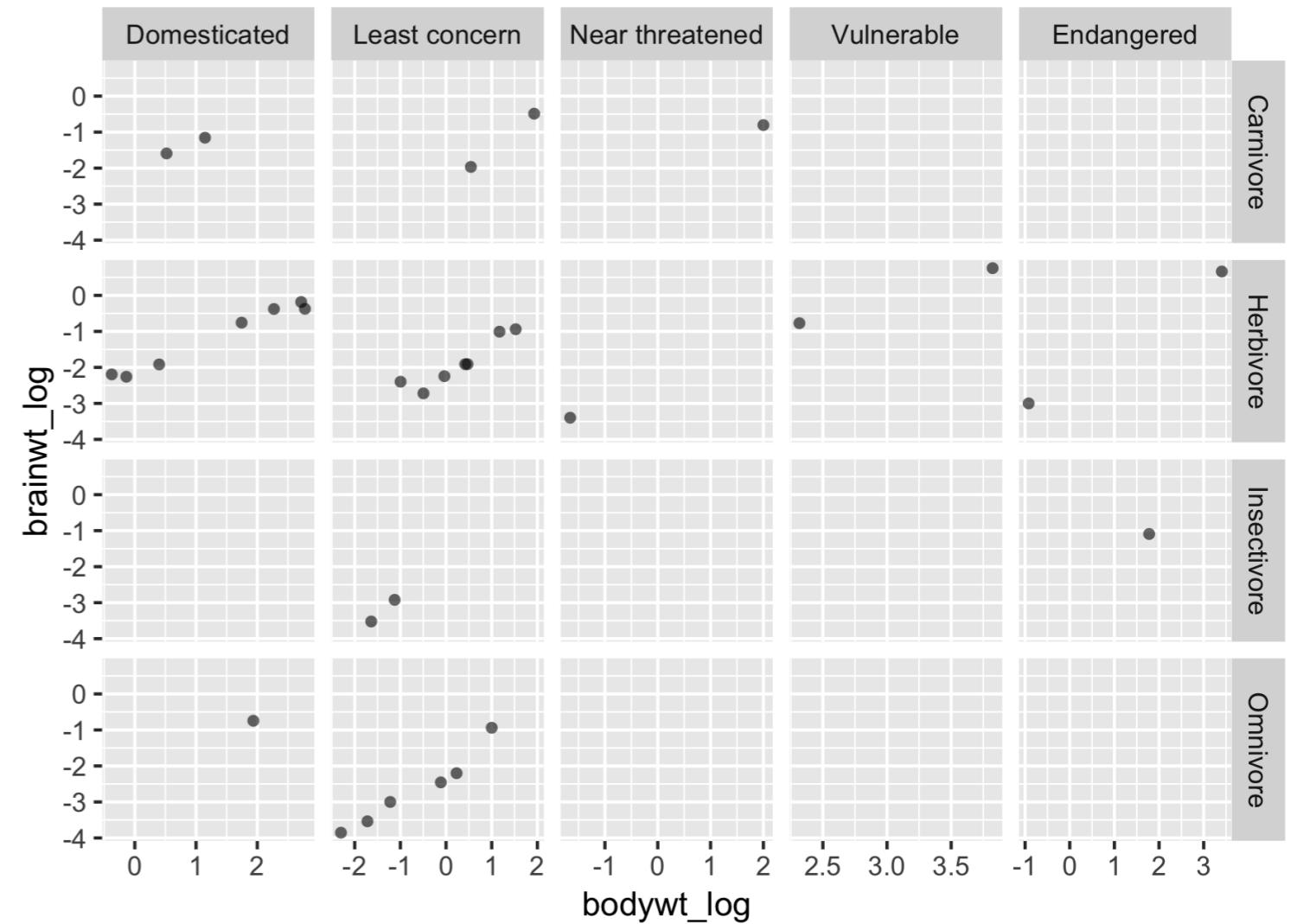
... but not with fixed scales

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  coord_fixed() +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free_x")
```

Error: coord_fixed doesn't support free scales

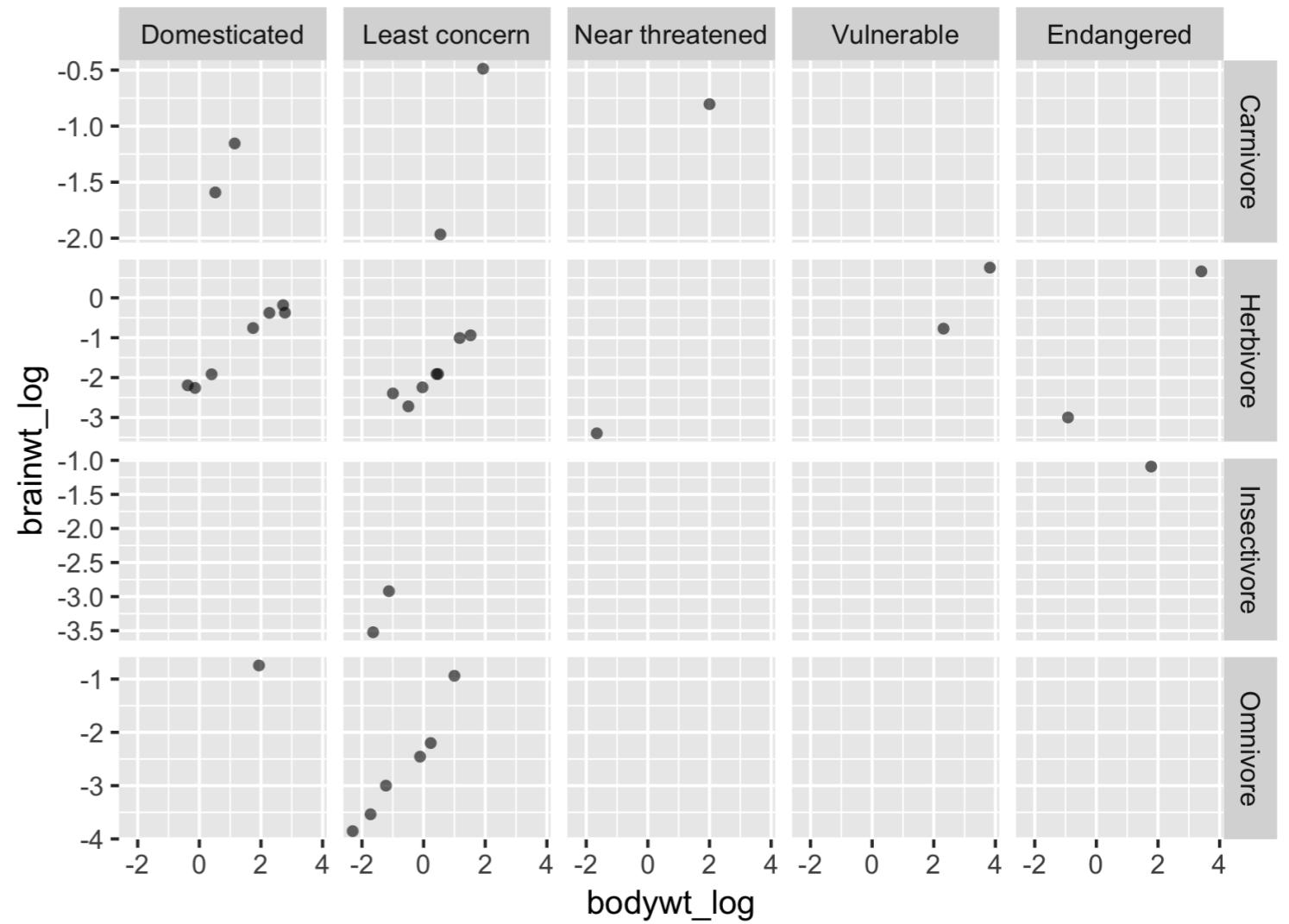
Adjusting the plotting space

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free_x")
```



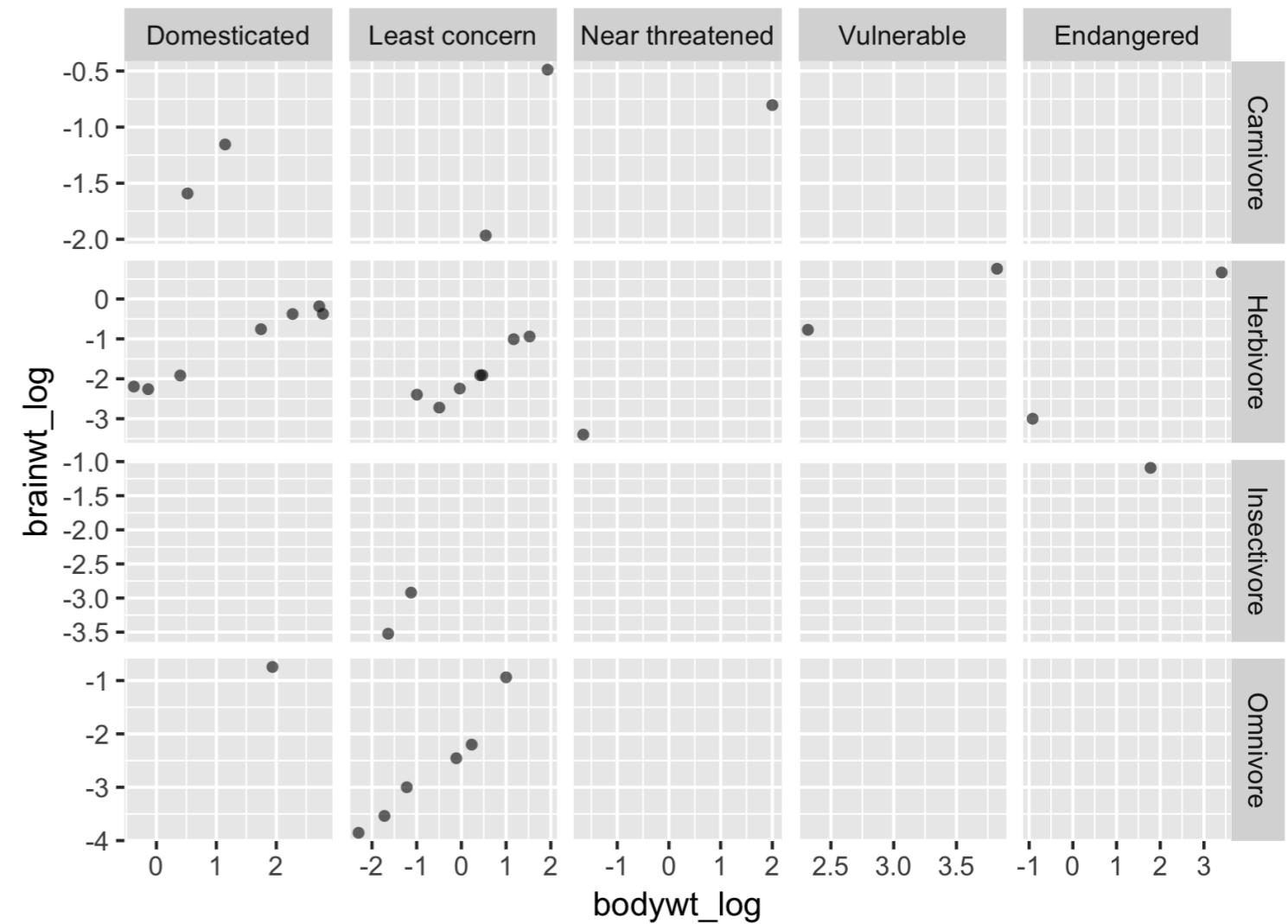
Adjusting the plotting space

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free_y")
```



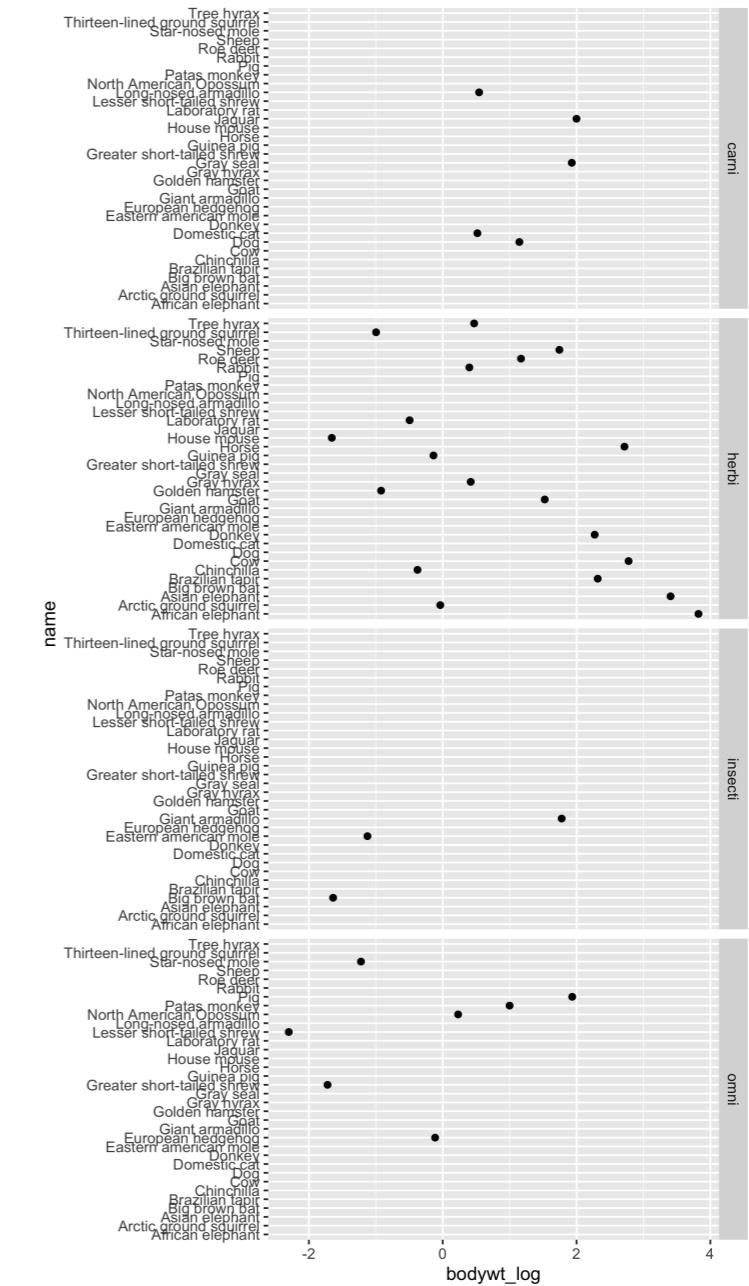
Adjusting the plotting space

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free")
```



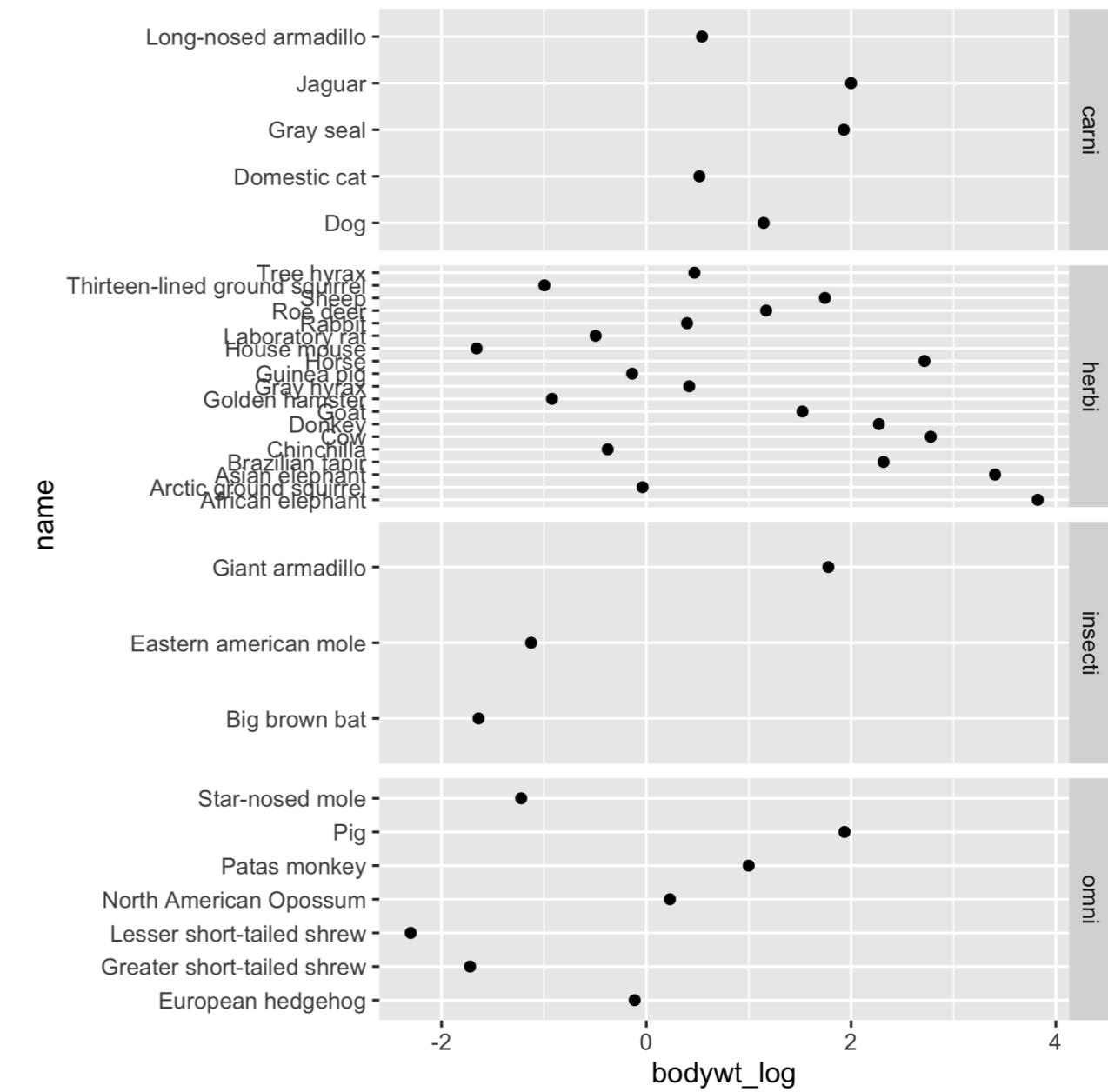
Adjusting the plotting space

```
ggplot(msleep2, aes(x = bodywt_log,  
                     y = name)) +  
  
  geom_point() +  
  
  facet_grid(rows = vars(vore))
```



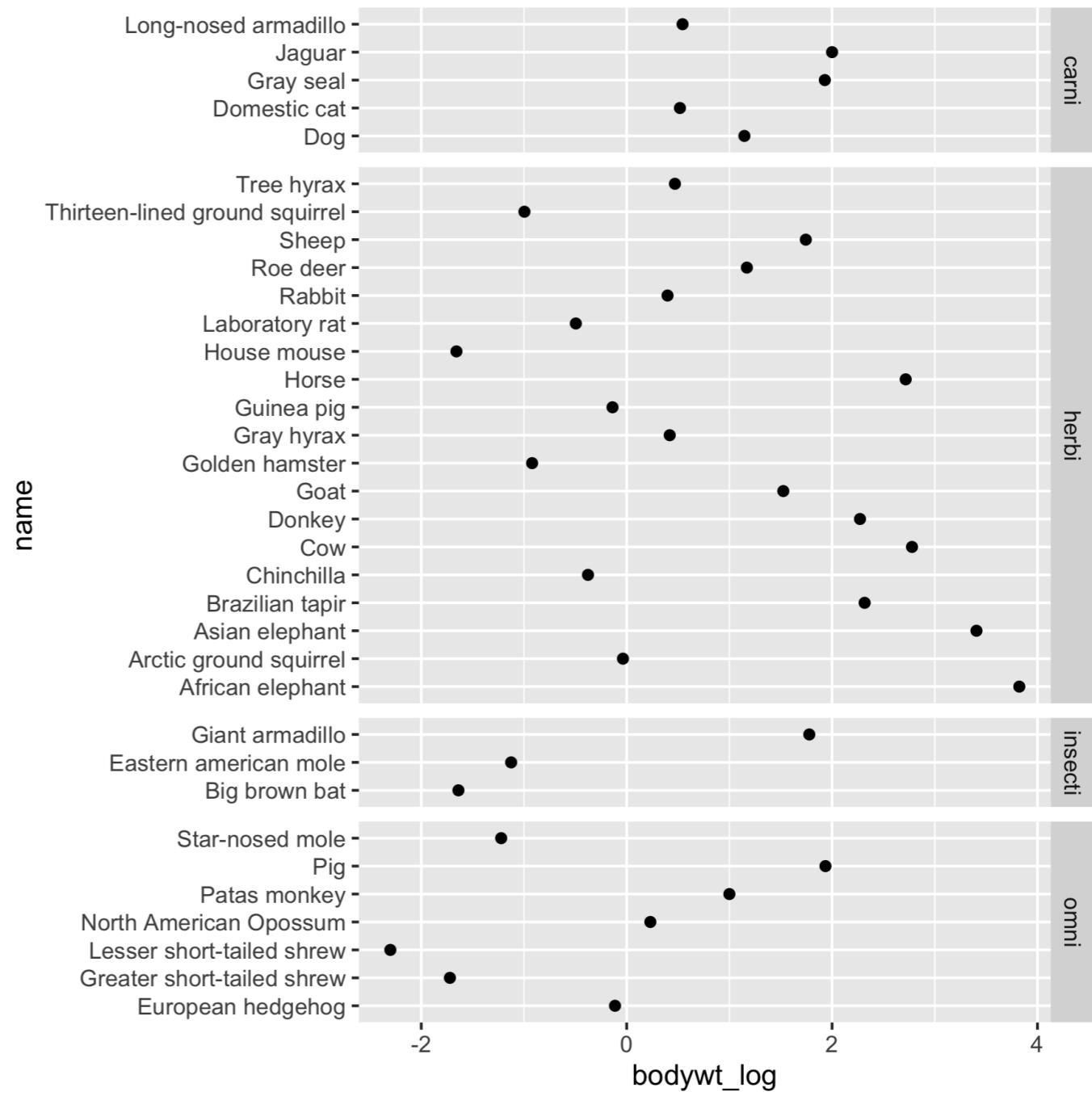
Adjusting the plotting space

```
ggplot(msleep2, aes(x = bodywt_log,  
                    y = name)) +  
  
  geom_point() +  
  
  # Free the y scales and space  
  facet_grid(rows = vars(vore),  
             scales = "free_y")
```



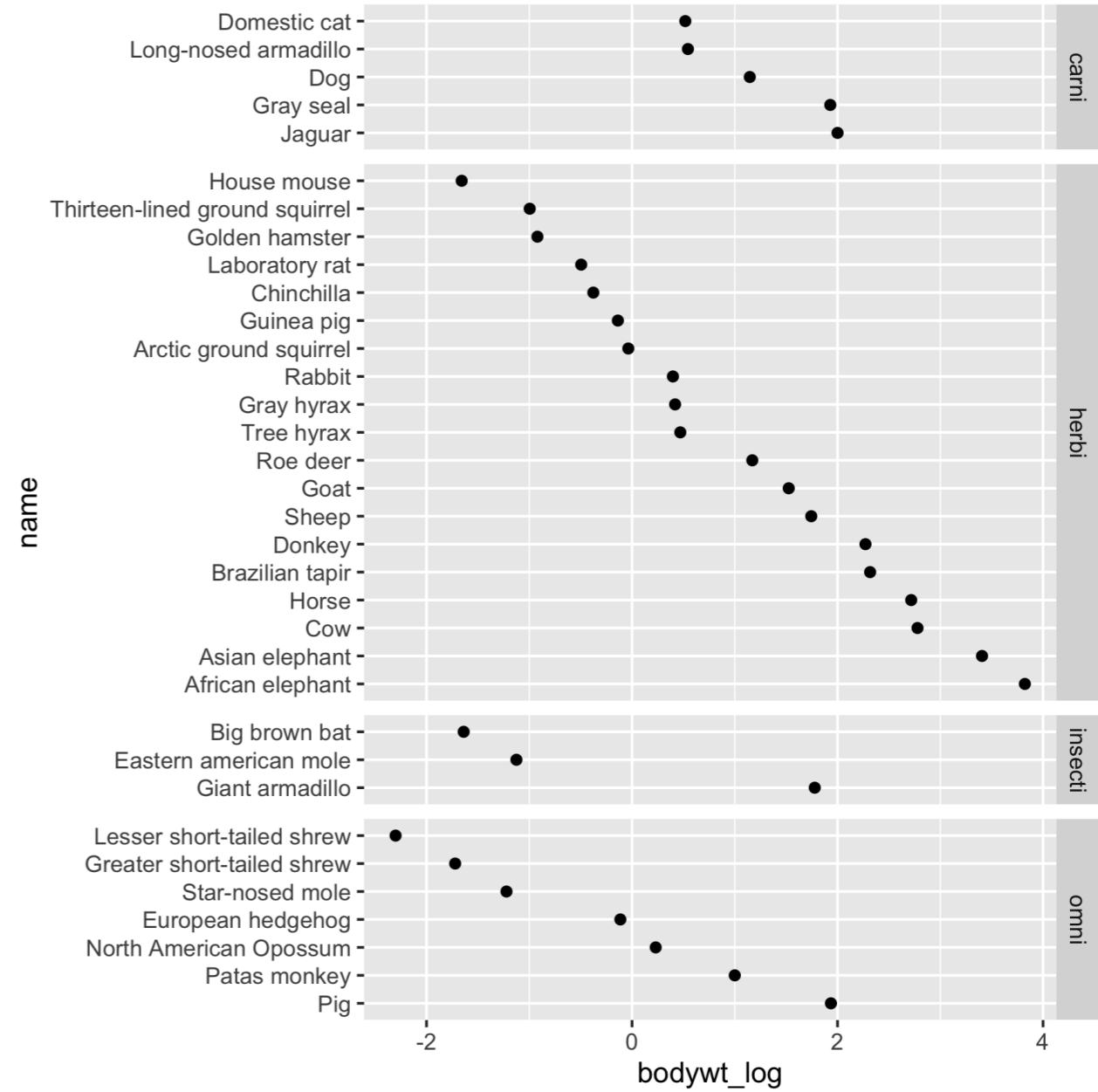
Adjusting the plotting space

```
ggplot(msleep2, aes(x = bodywt_log,  
                    y = name)) +  
  
  geom_point() +  
  
  # Free the y scales and space  
  facet_grid(rows = vars(vore),  
             scales = "free_y",  
             space = "free_y")
```



Final adjustments

```
msleep2 <- msleep2 %>%  
  # Arrange from lo to hi weight  
  arrange(-bodywt_log) %>%  
  # Redefine factor levels in order  
  mutate(name = as_factor(name))  
  
# New order is reflected in y axis  
ggplot(msleep2, aes(x = bodywt_log,  
                     y = name)) +  
  geom_point() +  
  # Free the y scales and space  
  facet_grid(rows = vars(vore),  
             scales = "free_y",  
             space = "free_y")
```



Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Facet wrap & margins

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

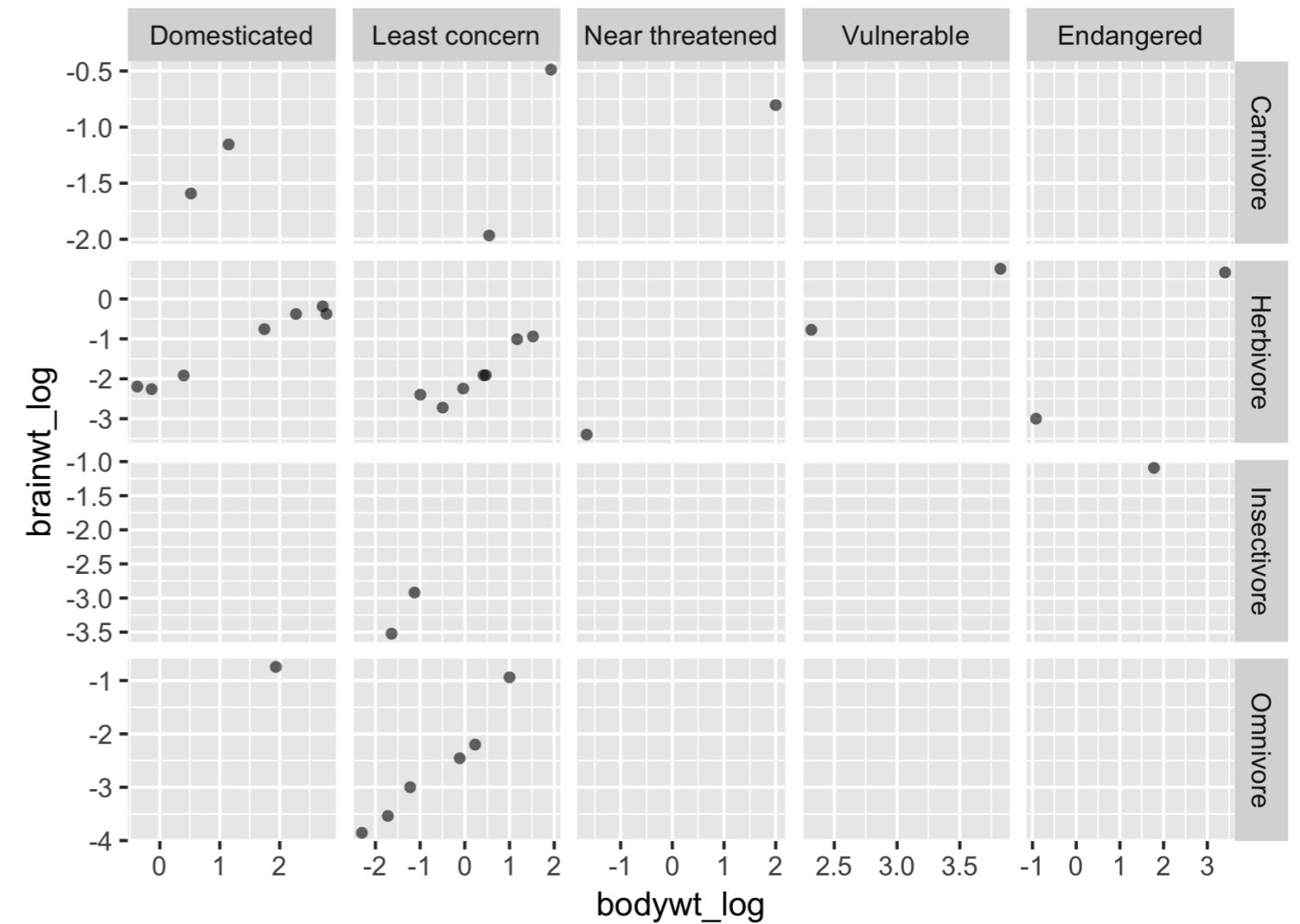


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Adjusting the plotting space

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free")
```



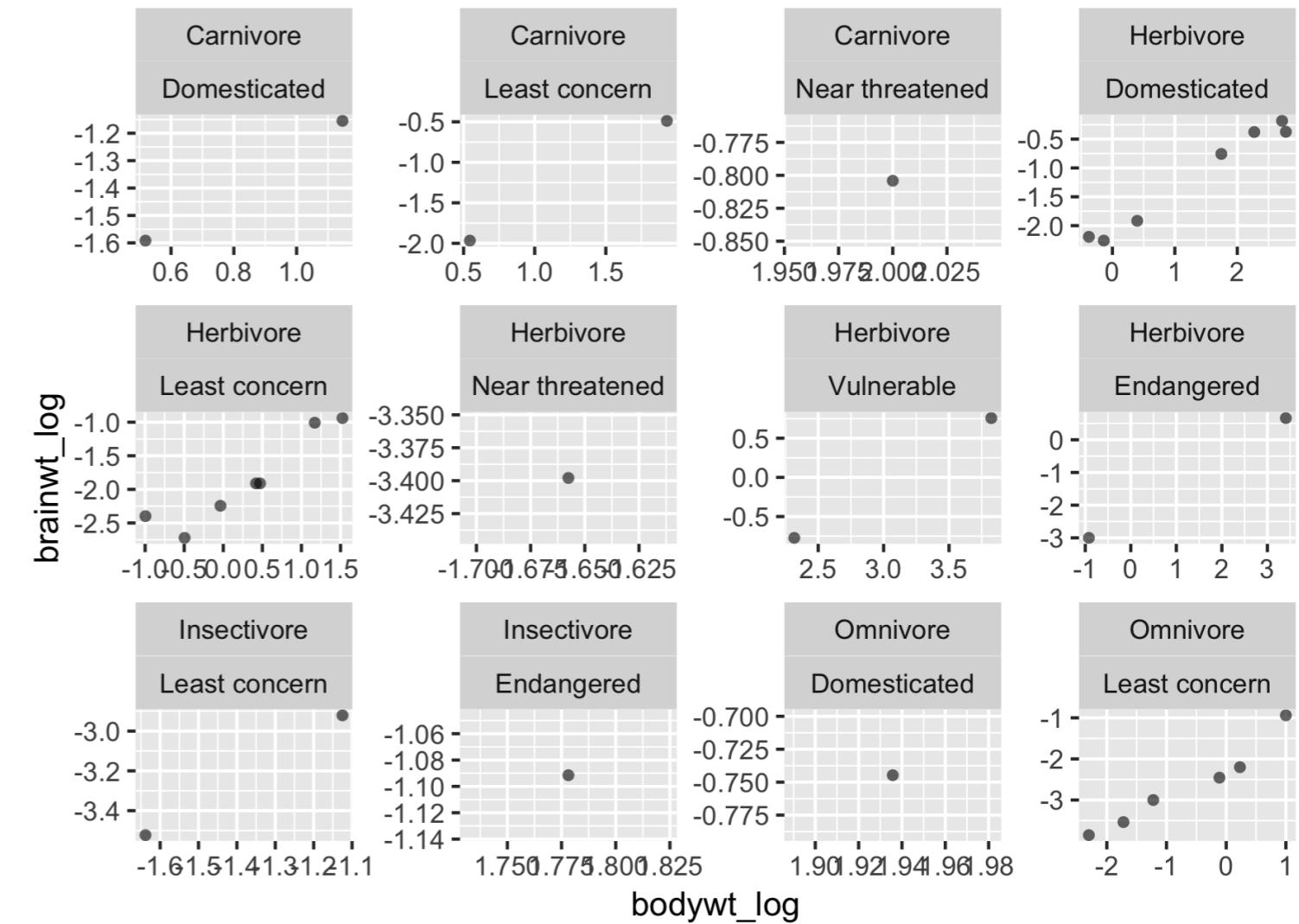
Using `facet_wrap()`

Use cases:

1. When you want both x and y axes to be free on every individual plot
 - i.e. Not just per row or column as per `facet_grid()`

Using facet_wrap() - Scenario 1

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_wrap(vars(vore, conservation),  
             scales = "free")
```



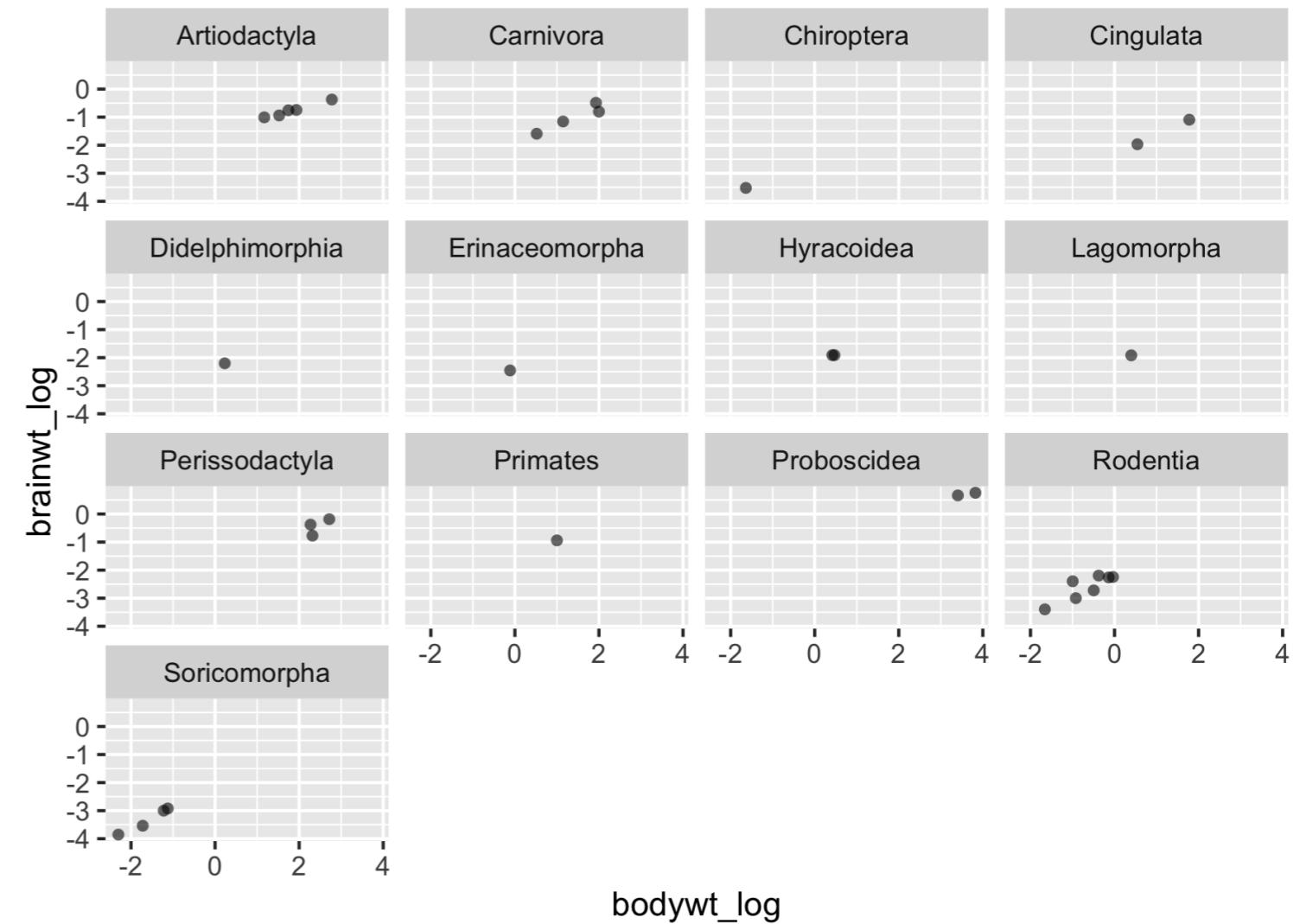
Using `facet_wrap()`

Use cases:

1. When you want both x and y axes to be free on every individual plot
 - i.e. Not just per row or column as per `facet_grid()`
2. When your categorical (factor) variable has many groups (levels)
 - i.e. too many sub plots for column or row-wise faceting
 - A more typical scenario

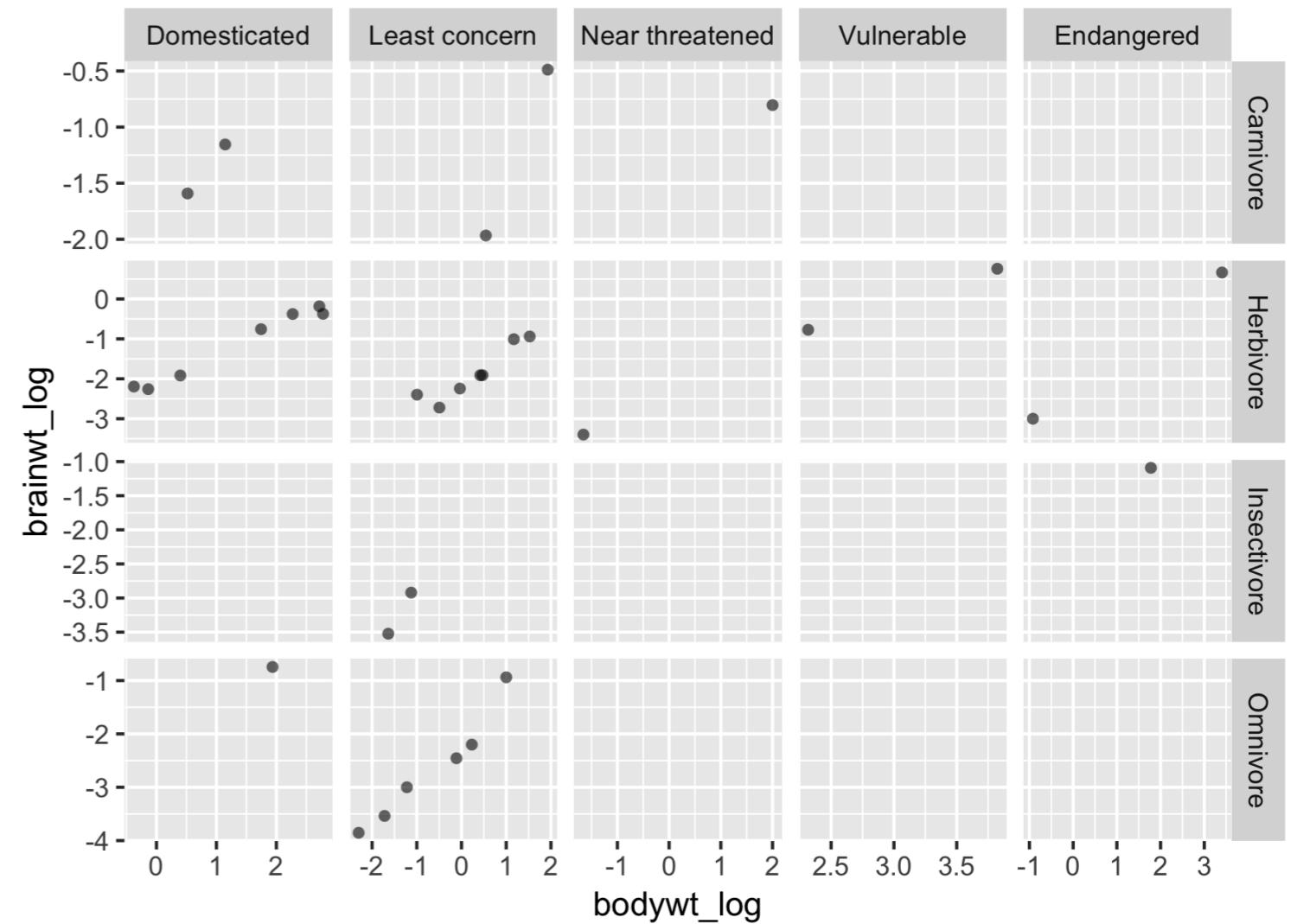
Using `facet_wrap()` - Scenario 2

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_wrap(vars(order))
```



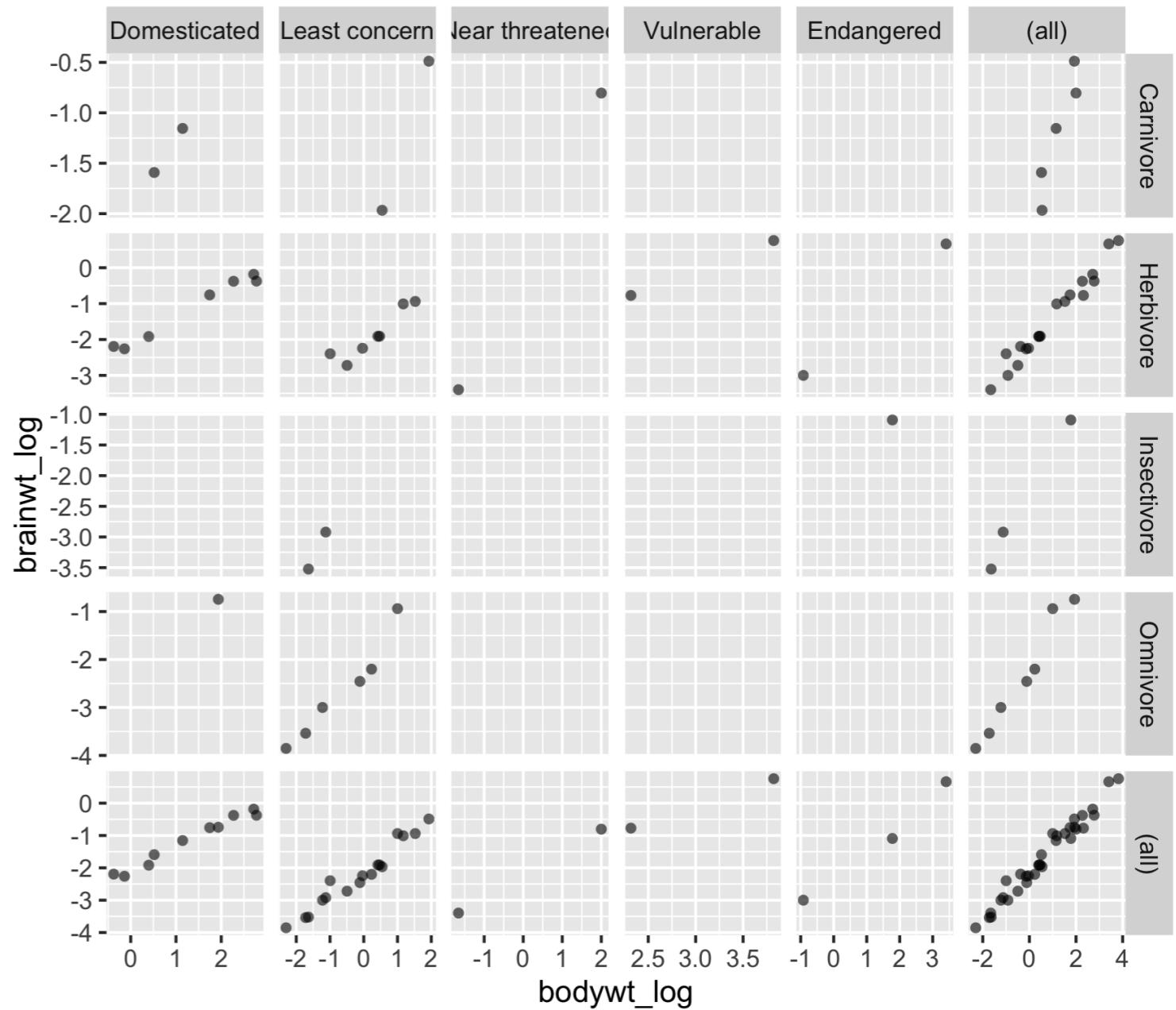
Using margin plots

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free")
```



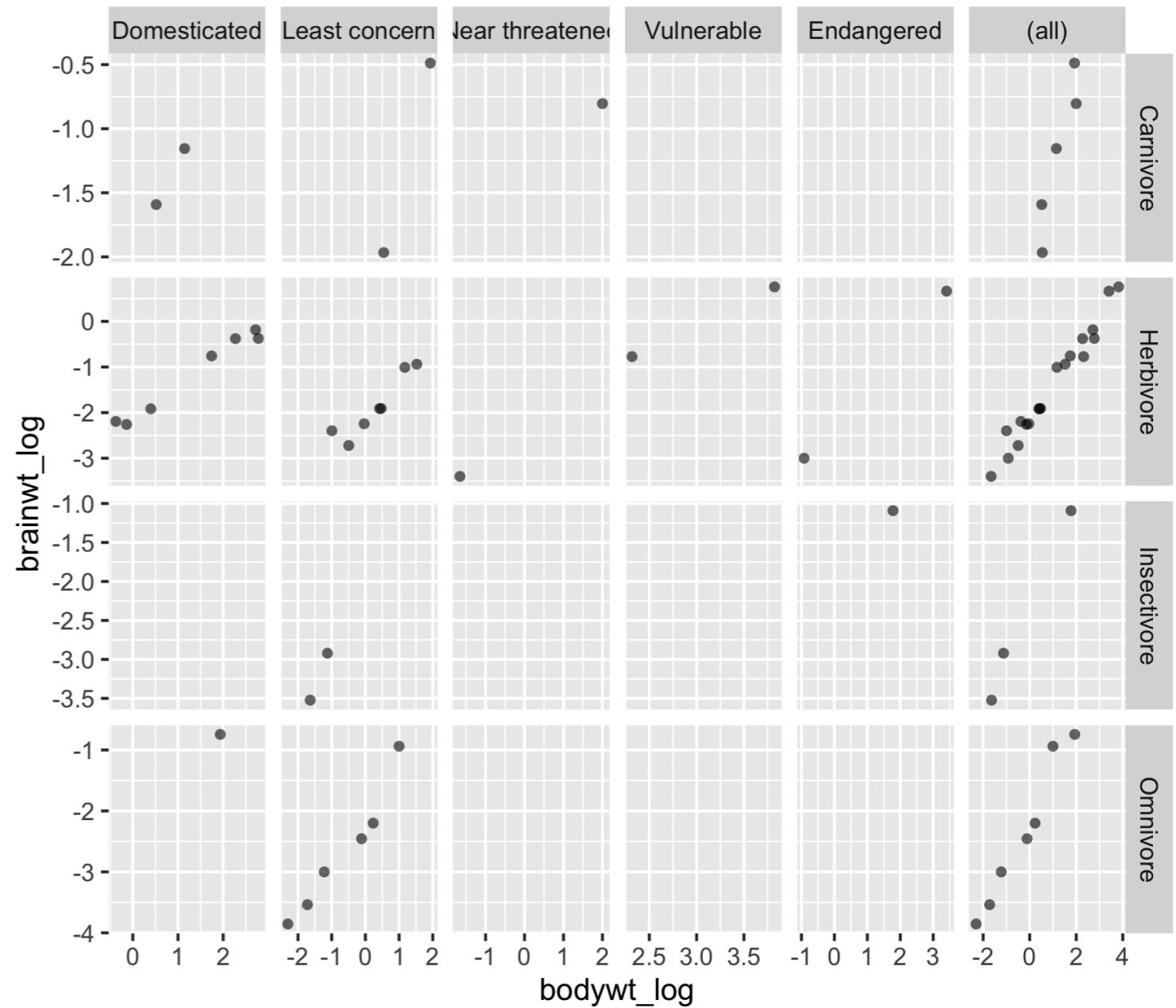
Using margin plots

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free",  
             margins = TRUE)
```



Using margin plots

```
ggplot(msleep2, aes(bodywt_log,  
                      brainwt_log)) +  
  geom_point(alpha = 0.6, shape = 16) +  
  facet_grid(rows = vars(vore),  
             cols = vars(conservation),  
             scales = "free",  
             margins = "conservation")
```



Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Best practices: bar plots

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2



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Founder, Scavetta Academy

In this chapter

- Common pitfalls in Data Viz
- Best way to represent data
 - For effective explanatory (communication), and
 - For effective exploratory (investigation) plots

Bar plots

- Two types
 - Absolute values
 - Distributions

Mammalian sleep

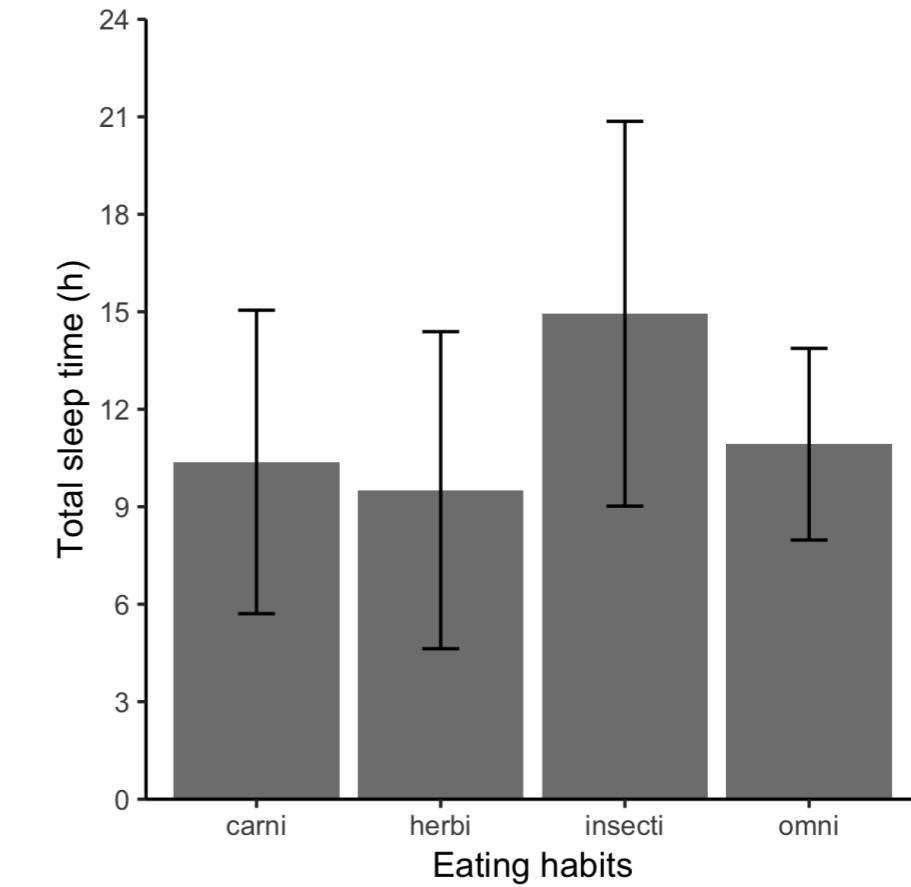
Observations: 76

Variables: 3

```
$ vore  <chr> "carni", "omni", "herbi", "omni", "herbi", "herbi", "carni", ...
$ total <dbl> 12.1, 17.0, 14.4, 14.9, 4.0, 14.4, 8.7, 10.1, 3.0, 5.3, 9.4, ...
$ rem   <dbl> NA, 1.8, 2.4, 2.3, 0.7, 2.2, 1.4, 2.9, NA, 0.6, 0.8, 0.7, 1.5...
```

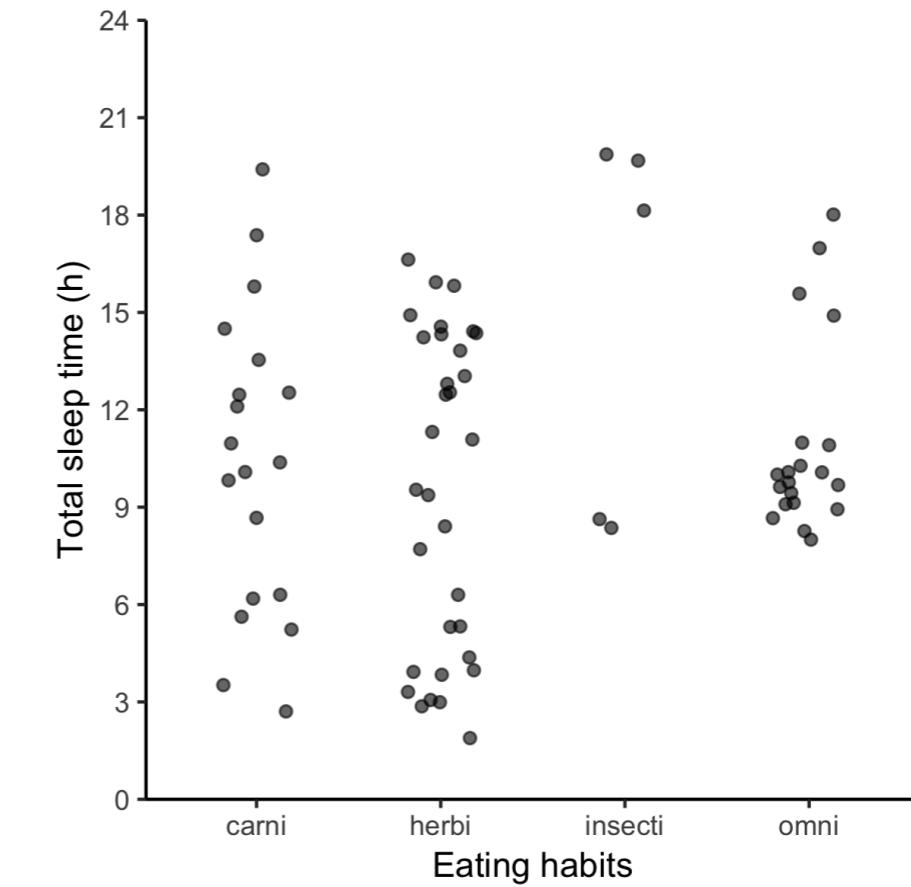
Dynamite plot

```
d <- ggplot(sleep, aes(vore, total)) +  
  # ...  
  
d +  
  stat_summary(fun.y = mean,  
               geom = "bar",  
               fill = "grey50") +  
  stat_summary(fun.data = mean_sdl,  
               fun.args = list(mult = 1),  
               geom = "errorbar",  
               width = 0.2)
```



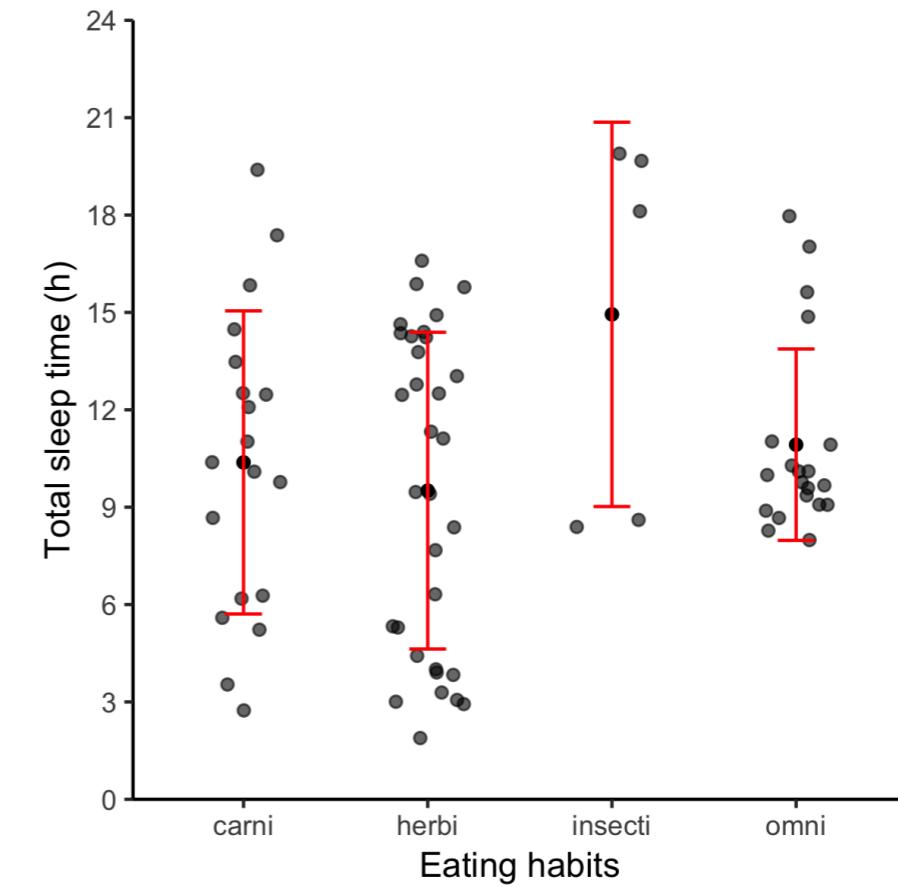
Individual data points

```
# position  
posn_j <- position_jitter(width = 0.2)  
  
# plot  
d +  
  geom_point(alpha = 0.6,  
             position = posn_j)
```



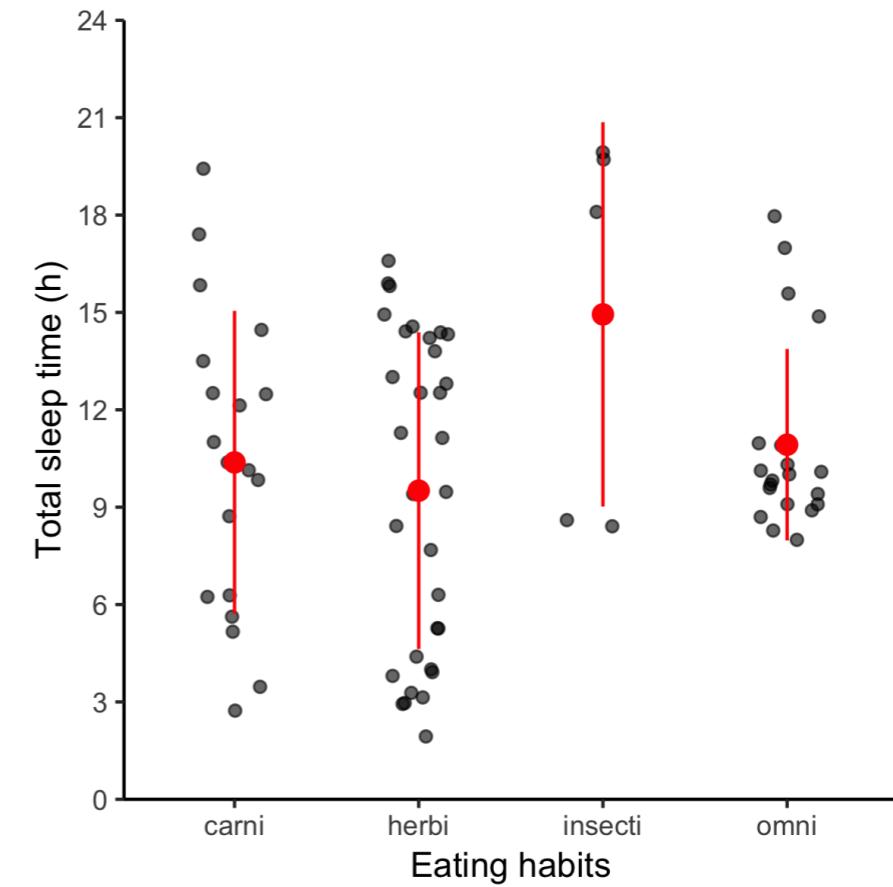
geom_errorbar()

```
d +
  geom_point(...) +
  stat_summary(fun.y = mean,
              geom = "point",
              fill = "red") +
  stat_summary(fun.data = mean_sdl,
              fun.args = list(mult = 1),
              geom = "errorbar",
              width = 0.2,
              color = "red")
```



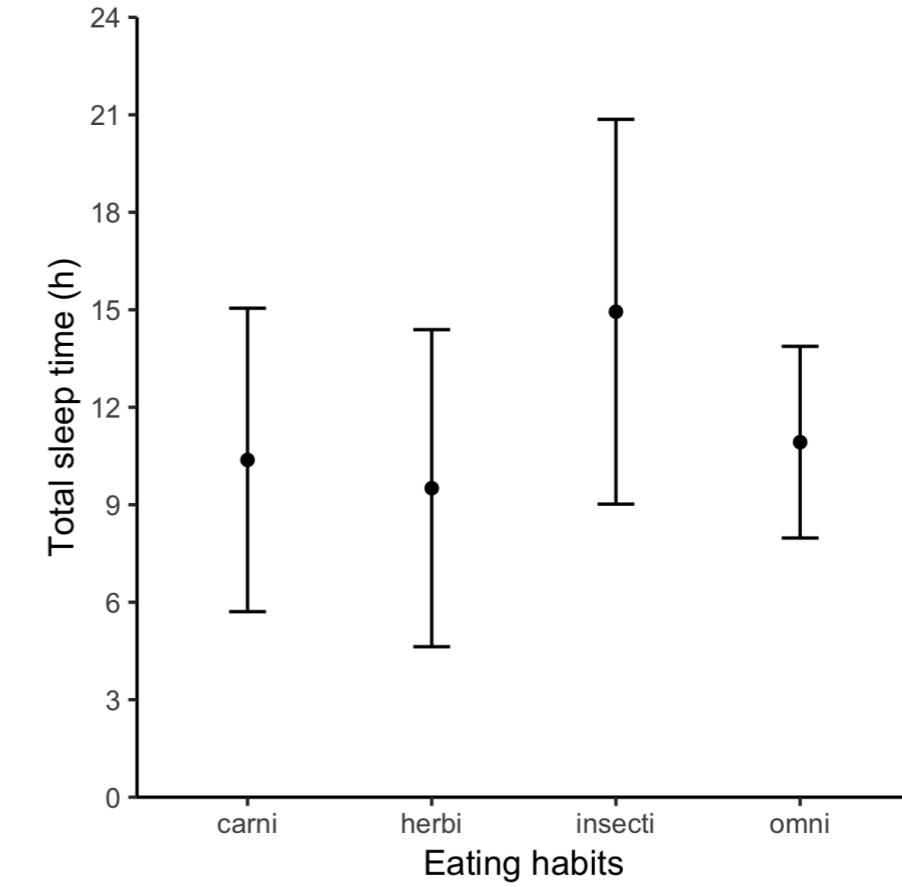
geom_pointrange()

```
d +  
  geom_point(...) +  
  stat_summary(fun.data = mean_sdl,  
               mult = 1,  
               width = 0.2,  
               color = "red")
```

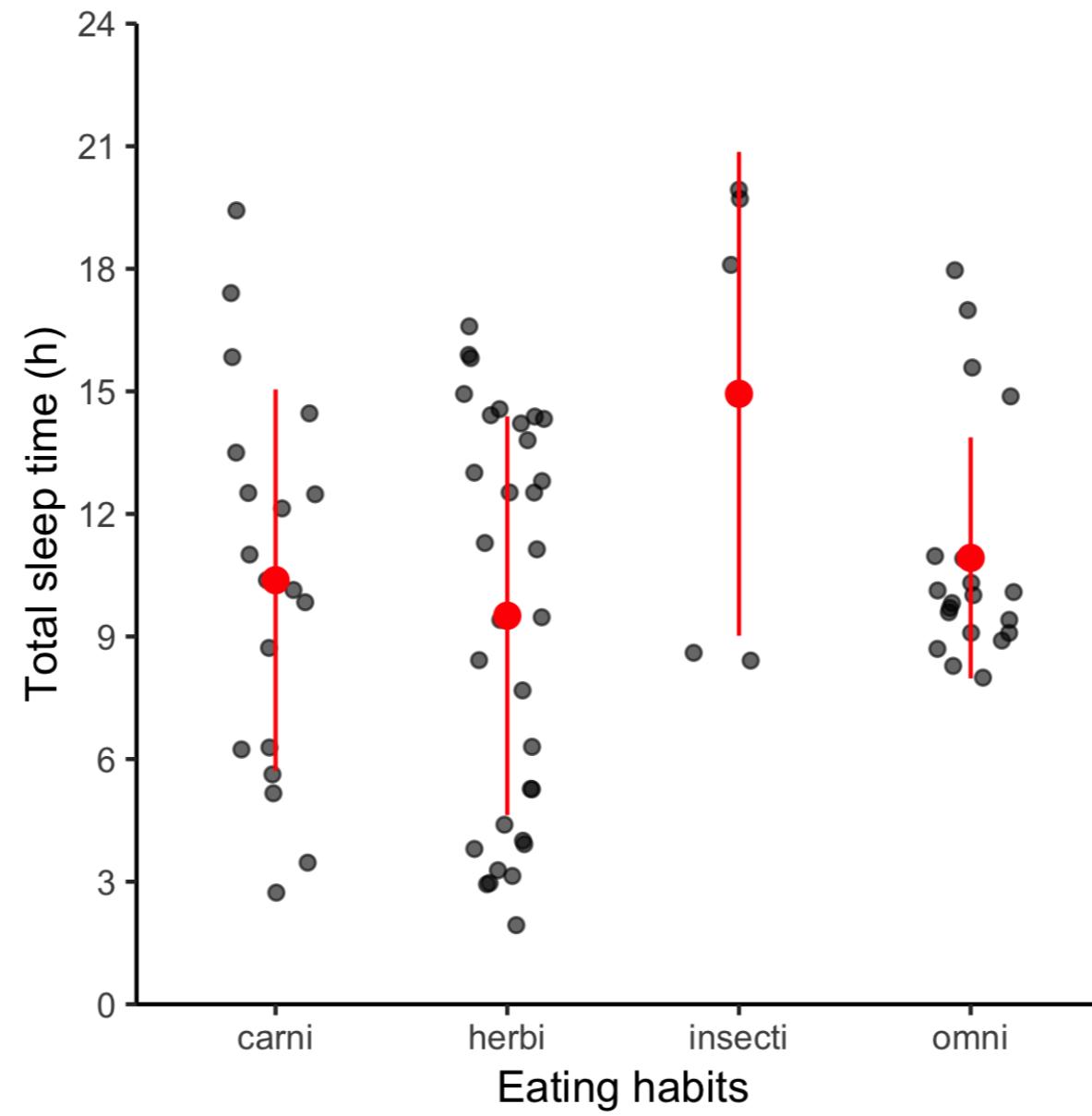


Without data points

```
d +  
  stat_summary(fun.y = mean,  
               geom = "point") +  
  stat_summary(fun.data = mean_sdl,  
               fun.args = list(mult = 1),  
               geom = "errorbar",  
               width = 0.2)
```



Bars are not necessary



Ready for exercises!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

Heatmaps use case scenario

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2



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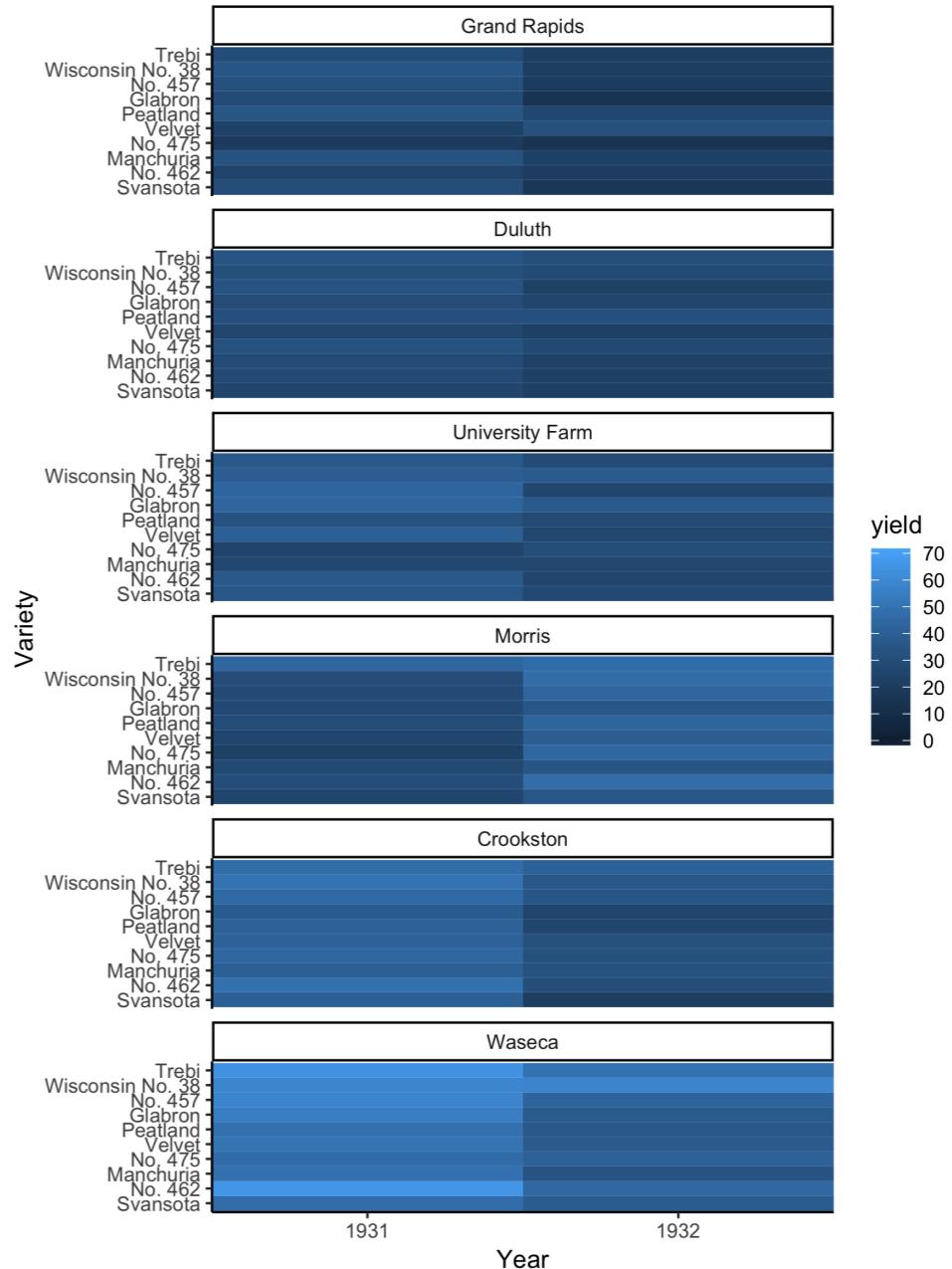
The barley dataset

```
head(barley, 9)
```

	yield	variety	year	site
1	27.00000	Manchuria	1931	University Farm
2	48.86667	Manchuria	1931	Waseca
3	27.43334	Manchuria	1931	Morris
4	39.93333	Manchuria	1931	Crookston
5	32.96667	Manchuria	1931	Grand Rapids
6	28.96667	Manchuria	1931	Duluth
7	43.06666	Glabron	1931	University Farm
8	55.20000	Glabron	1931	Waseca
9	28.76667	Glabron	1931	Morris

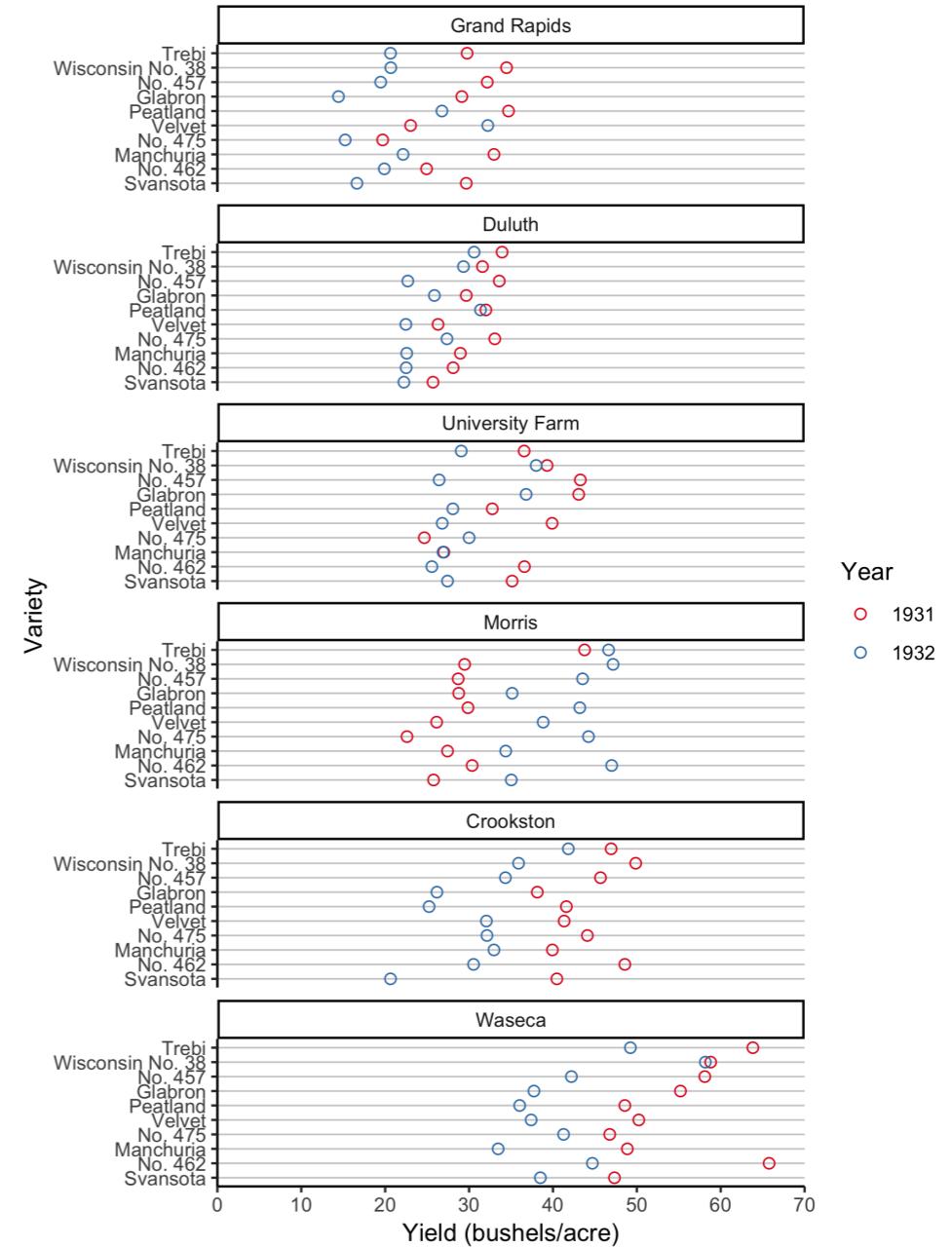
A basic heat map

```
ggplot(barley, aes(year, variety,  
                   fill = yield)) +  
  
  geom_tile() +  
  
  facet_wrap(vars(site), ncol = 1) +  
  
  ...
```



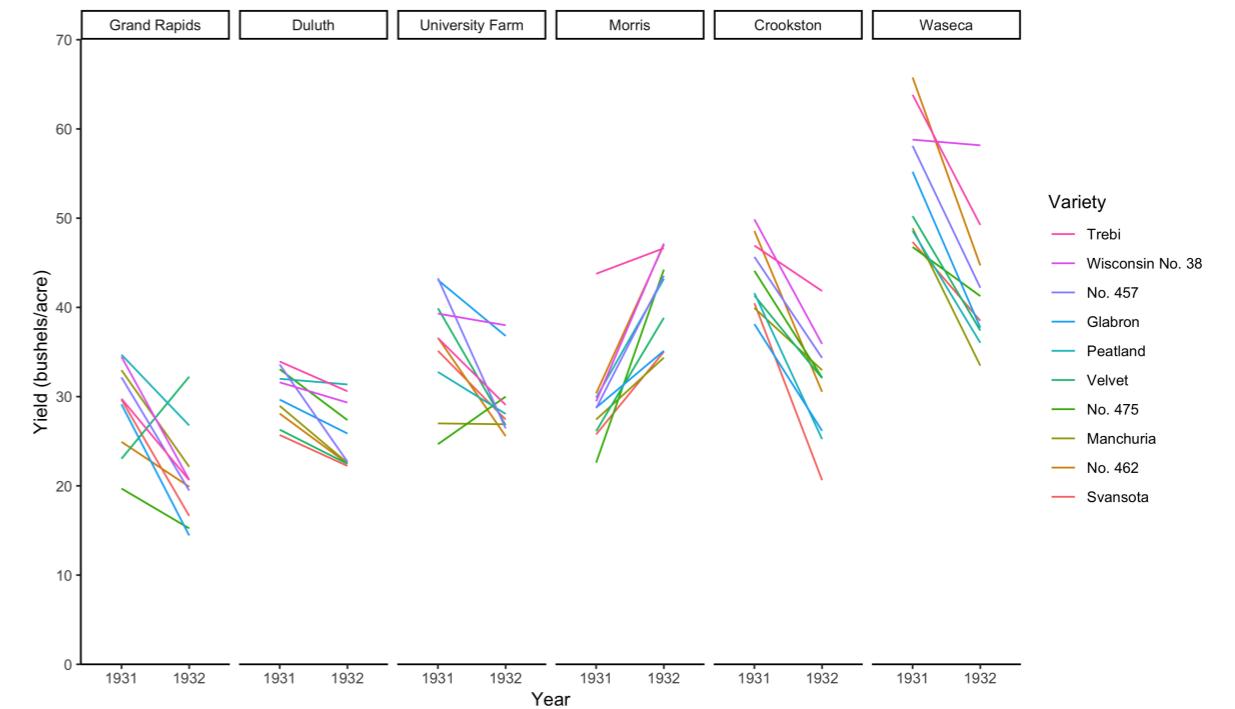
A dot plot

```
ggplot(barley, aes(yield, variety,  
                    color = year)) +  
  
  geom_point(...) +  
  
  facet_wrap(vars(site), ncol = 1) +  
  
  ...
```



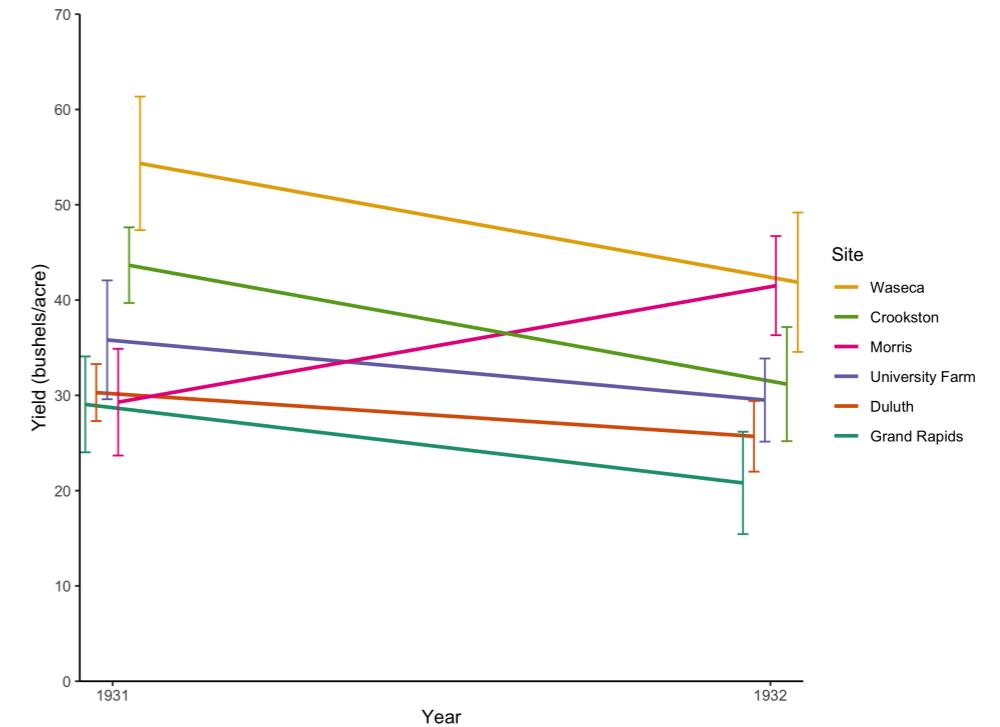
As a time series

```
ggplot(barley, aes(year, yield,  
                    group = variety,  
                    color = variety)) +  
  
  geom_line() +  
  
  facet_wrap(vars(site), nrow = 1) +  
  
  ...
```



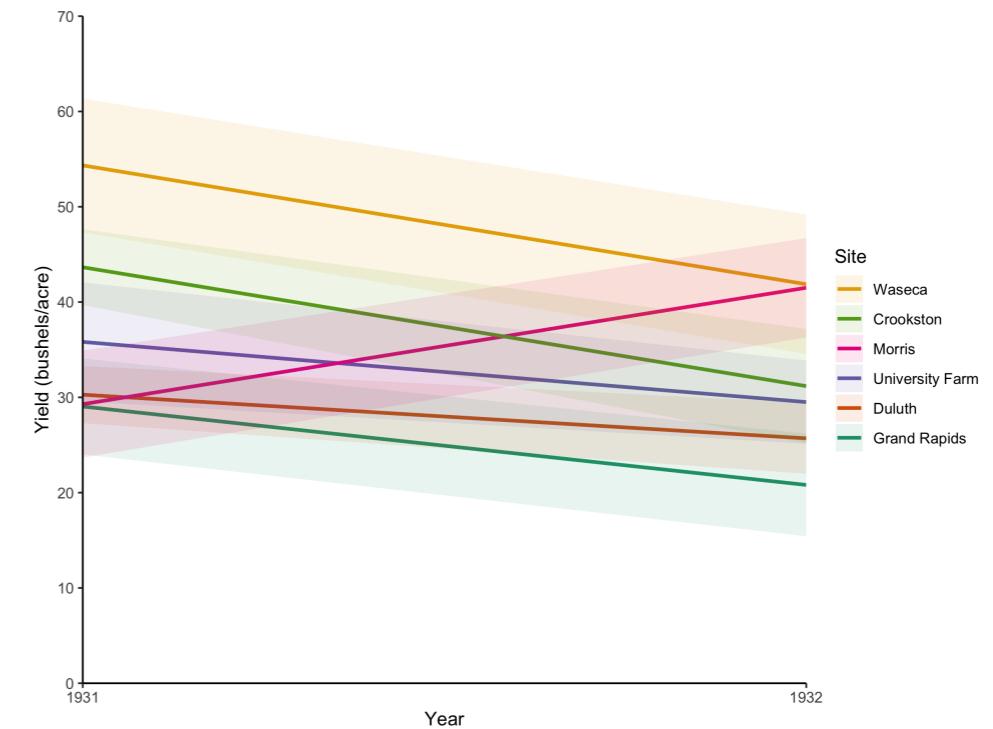
Using dodged error bars

```
ggplot(barley, aes(x = year, y = yield,  
                    group = site,  
                    color = site)) +  
  
  stat_summary(fun.y = mean,  
              geom = "line", ...) +  
  
  stat_summary(fun.data = mean_sdl,  
              geom = "errorbar", ...) +  
  
  ...
```



Using ribbons for error

```
ggplot(barley, aes(x = year, y = yield,  
                    group = site,  
                    color = site)) +  
  
  stat_summary(fun.y = mean,  
               geom = "line", ...) +  
  
  stat_summary(fun.data = mean_sdl,  
               geom = "ribbon", ...) +  
  
  ...
```



Coding Time!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2

When good data makes bad plots

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2



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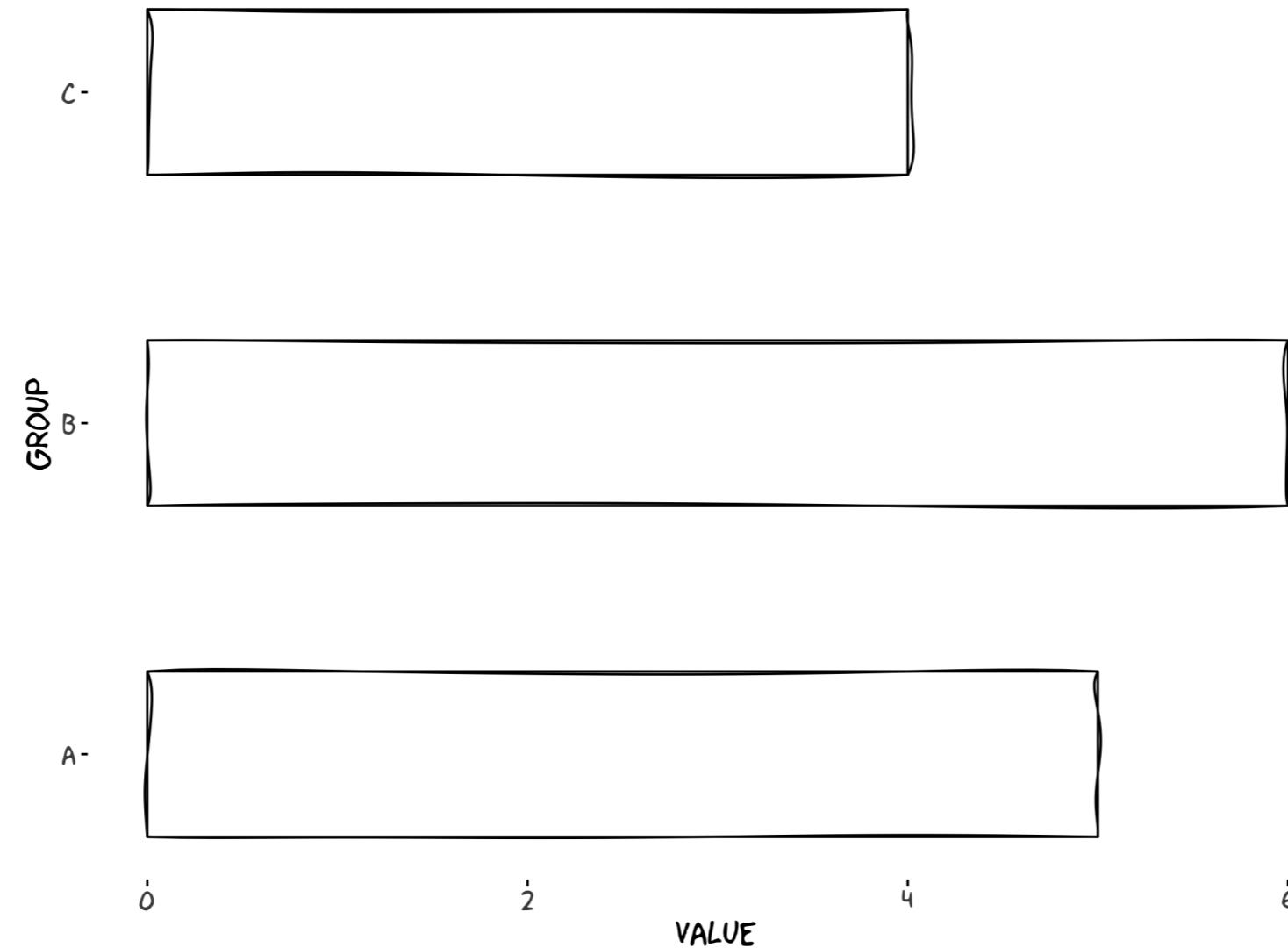
Bad plots: style

- Color
 - Not color-blind-friendly (e.g. primarily red and green)
 - Wrong palette for data type (remember sequential, qualitative and divergent)
 - Indistinguishable groups (i.e. colors are too similar)
 - Ugly (high saturation primary colors)
- Text
 - Illegible (e.g. too small, poor resolution)
 - Non-descriptive (e.g. "length" -- of what? which units?)
 - Missing
 - Inappropriate (e.g. comic sans)

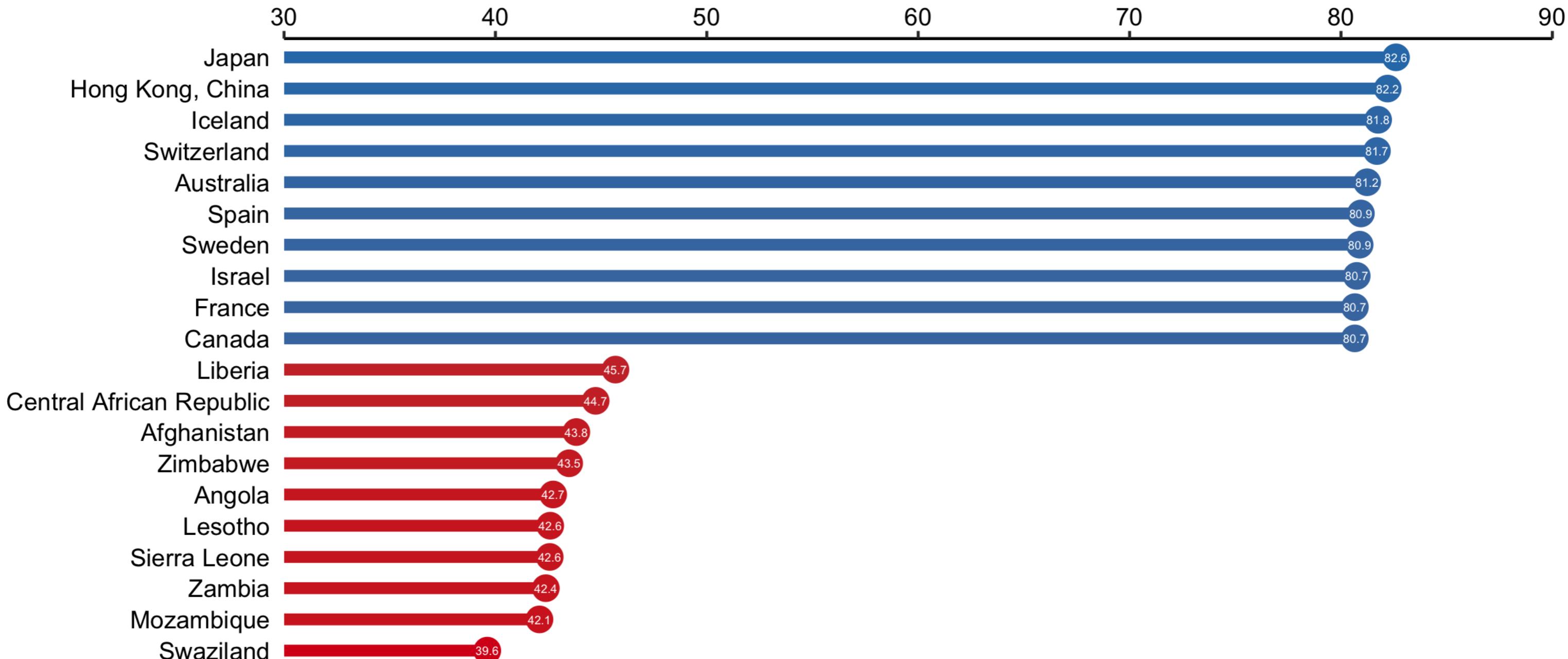
Bad plots: structure and content

- Information content
 - Too much information (TMI)
 - Too little information (TLI)
 - No clear message or purpose
- Axes
 - Poor aspect ratio
 - Suppression of the origin
 - Broken x or y axes
 - Common, but unaligned scales
 - Wrong or no transformation
- Statistics
 - Visualization doesn't match actual statistics
- Geometries
 - Wrong plot type
 - Wrong orientation
- Non-data Ink
 - Inappropriate use
- 3D plots
 - Perceptual problems
 - Useless 3rd axis

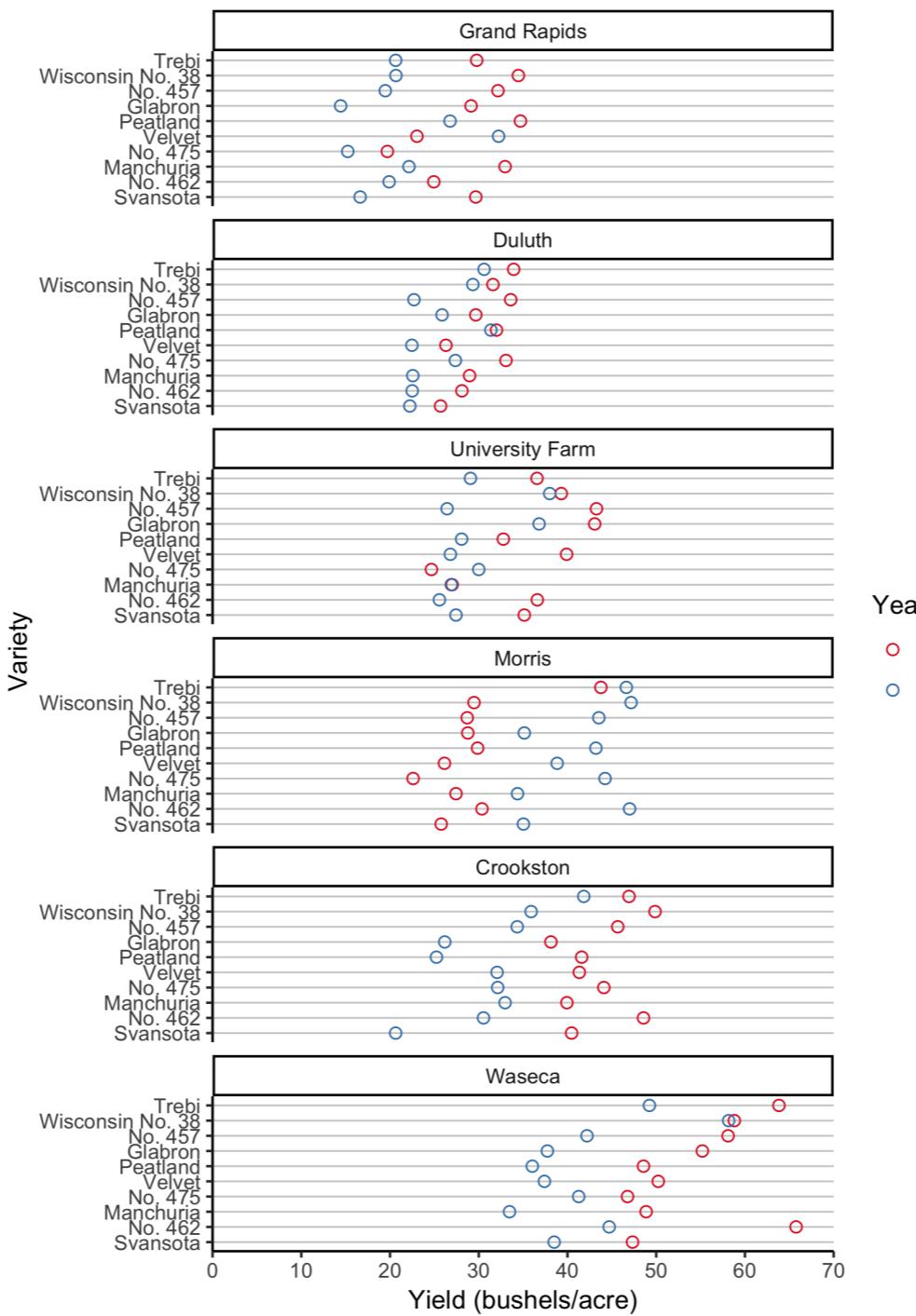
Wrong orientation



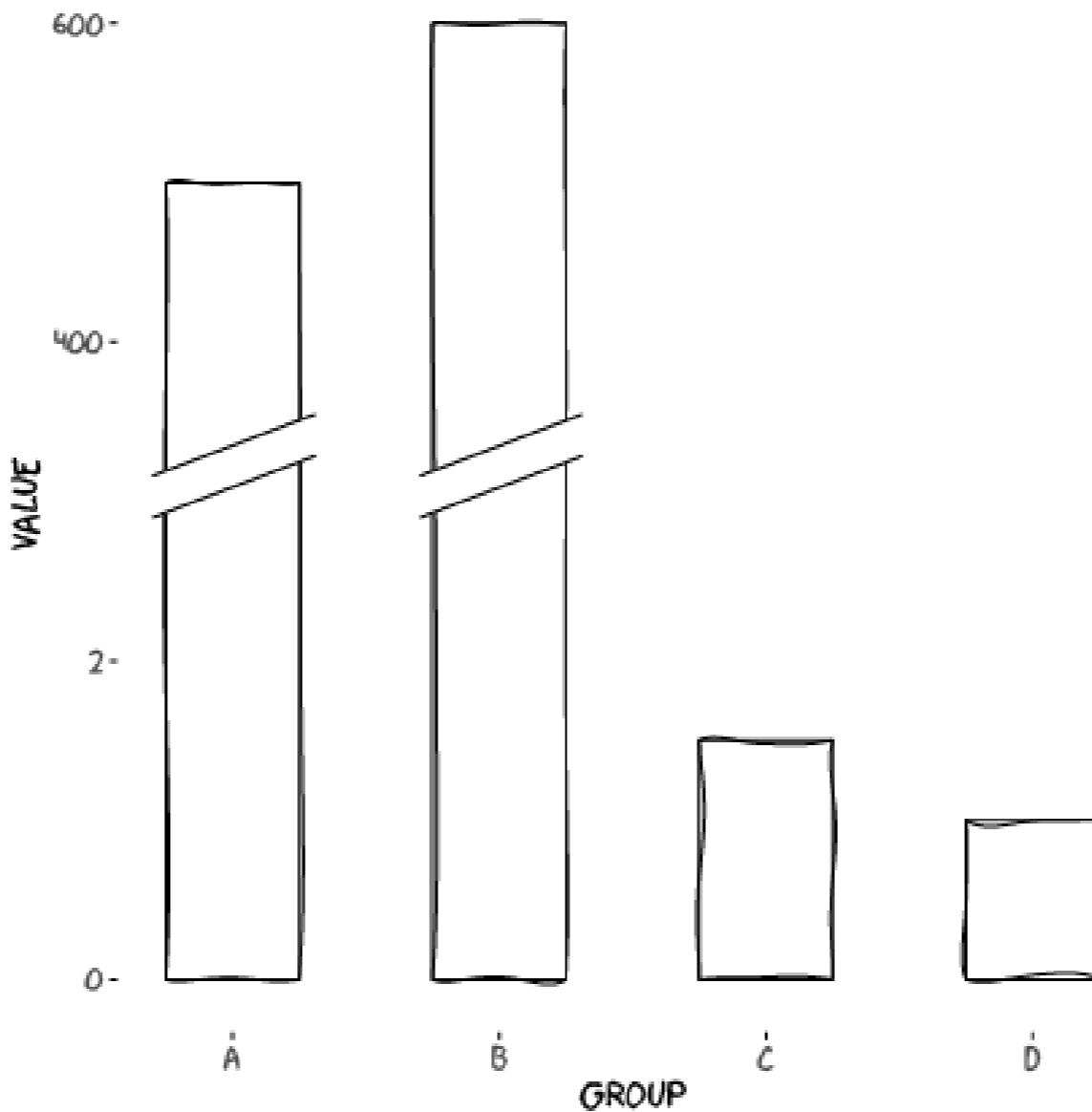
Highest and lowest life expectancies, 2007



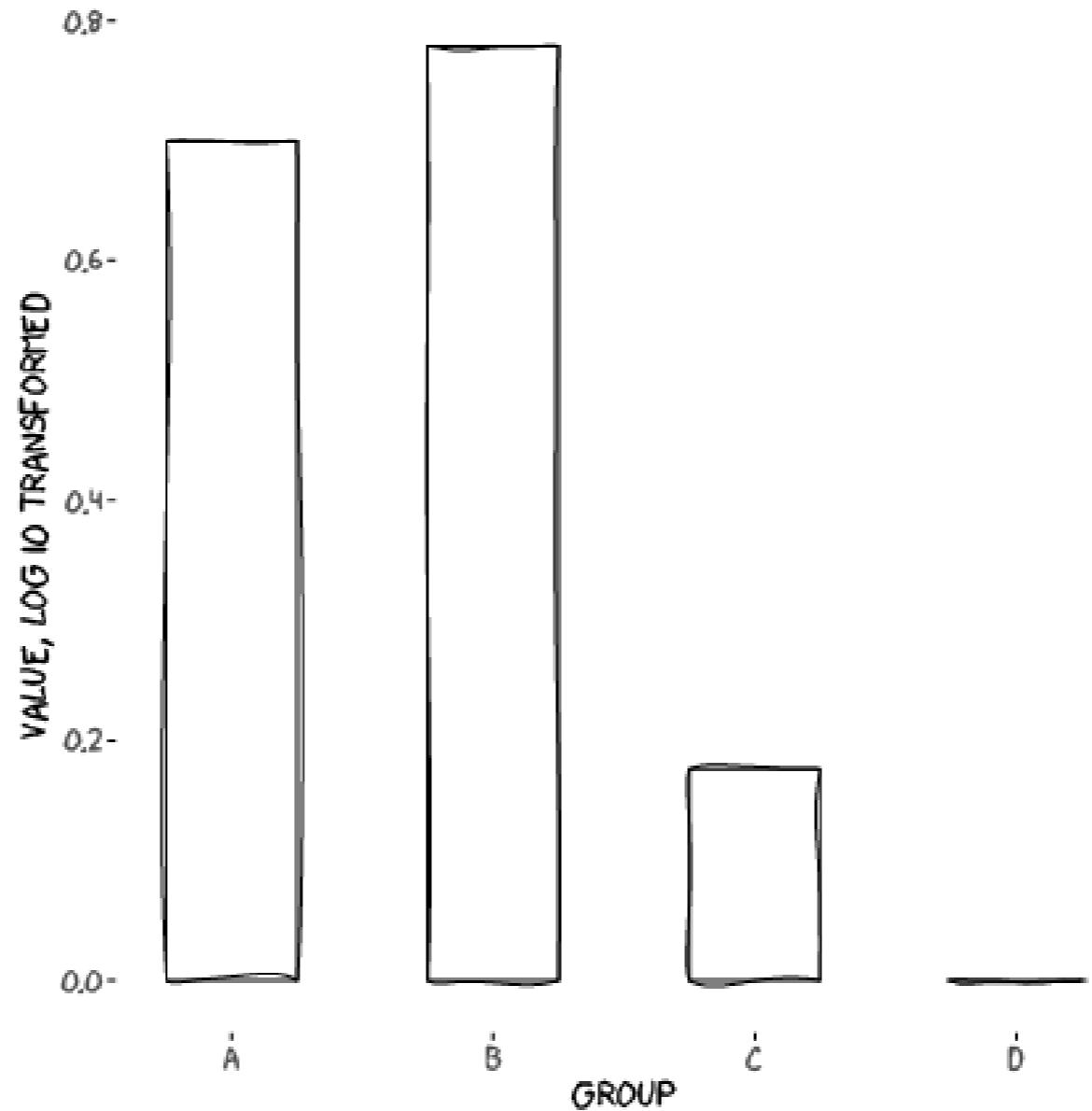
Source: gapminder



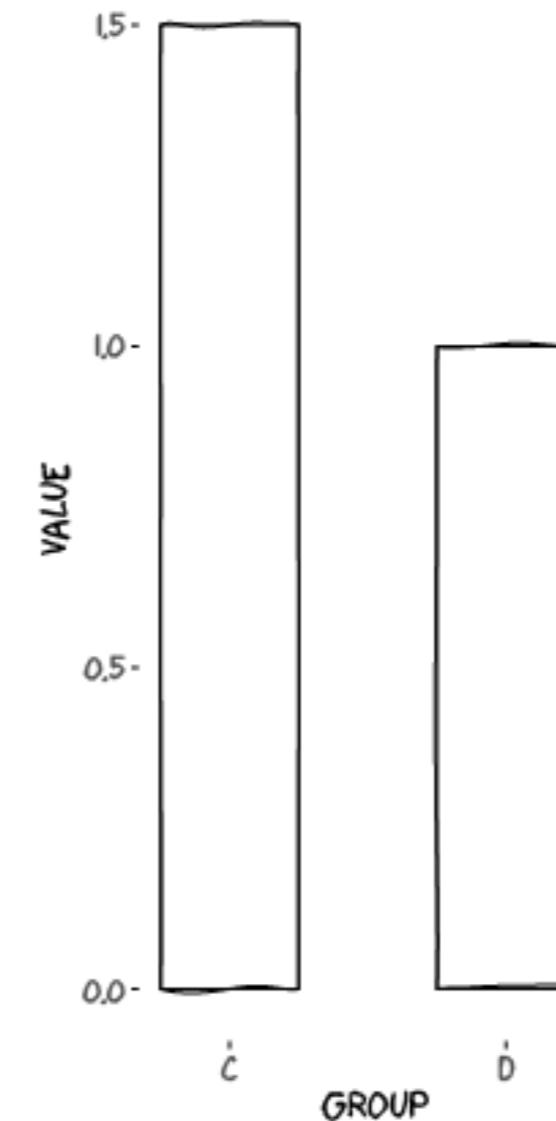
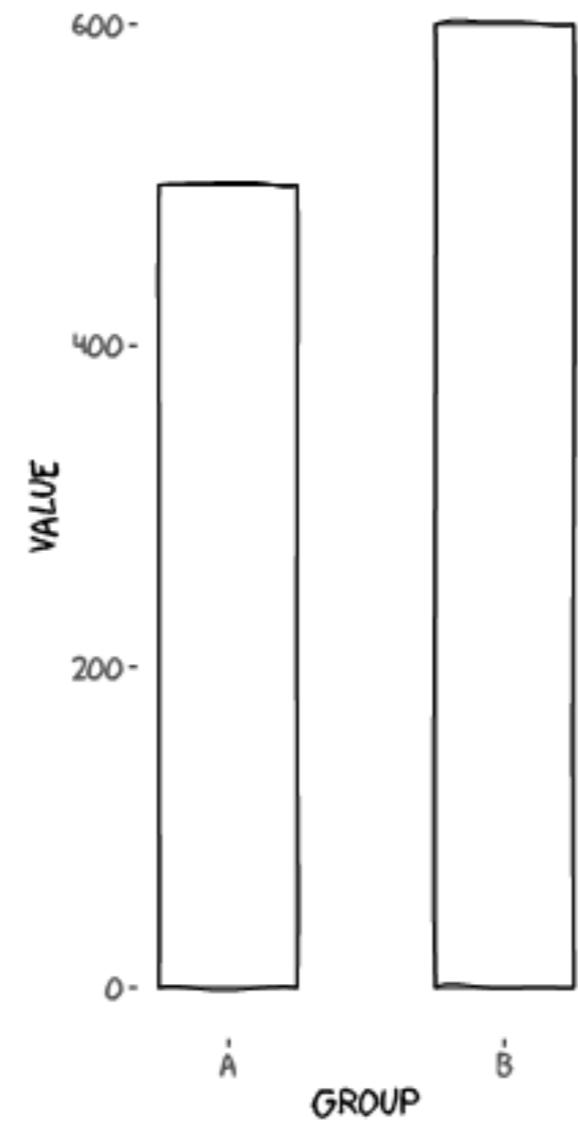
Broken y-axes



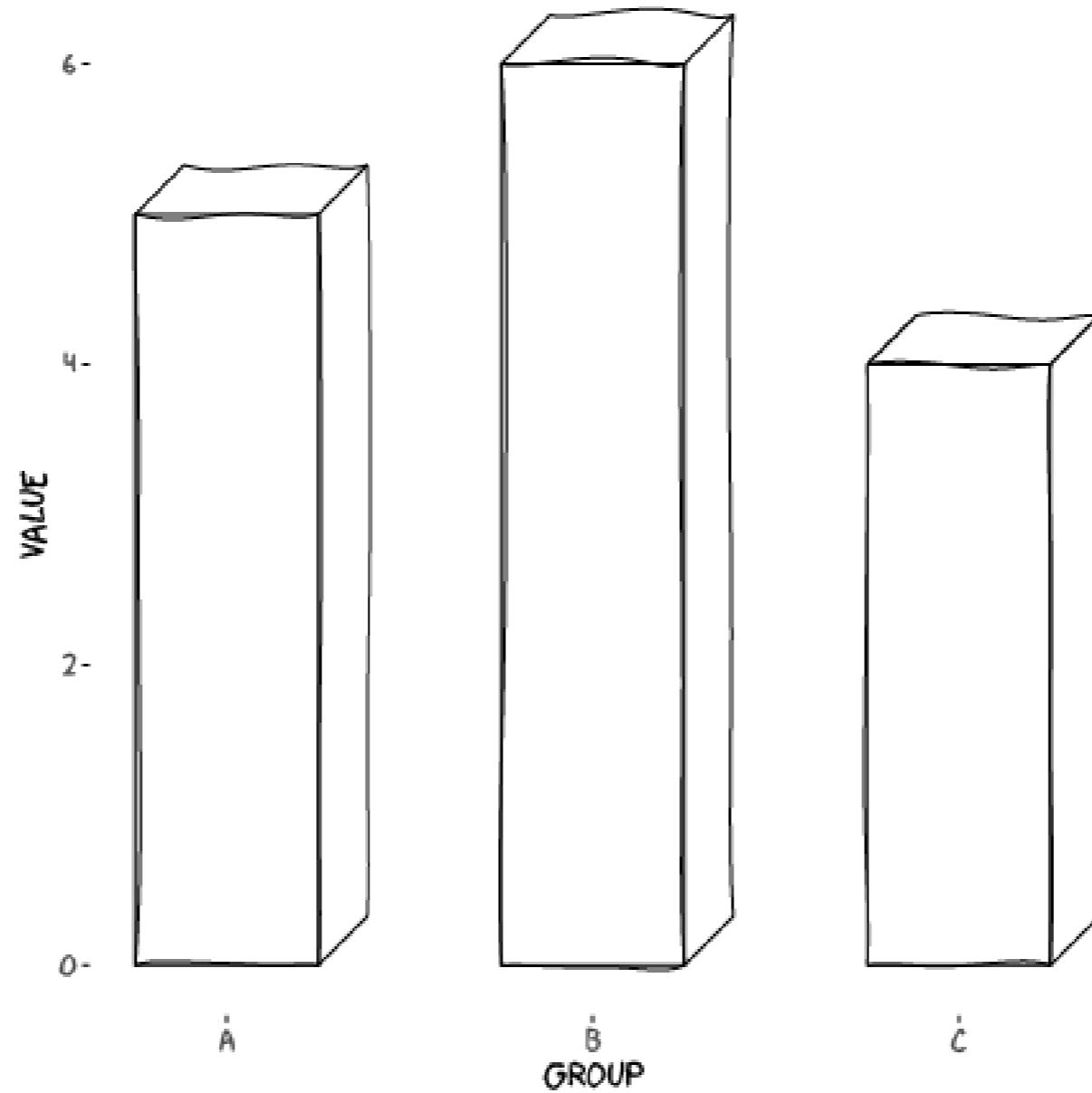
Broken y-axes, replace with transformed data



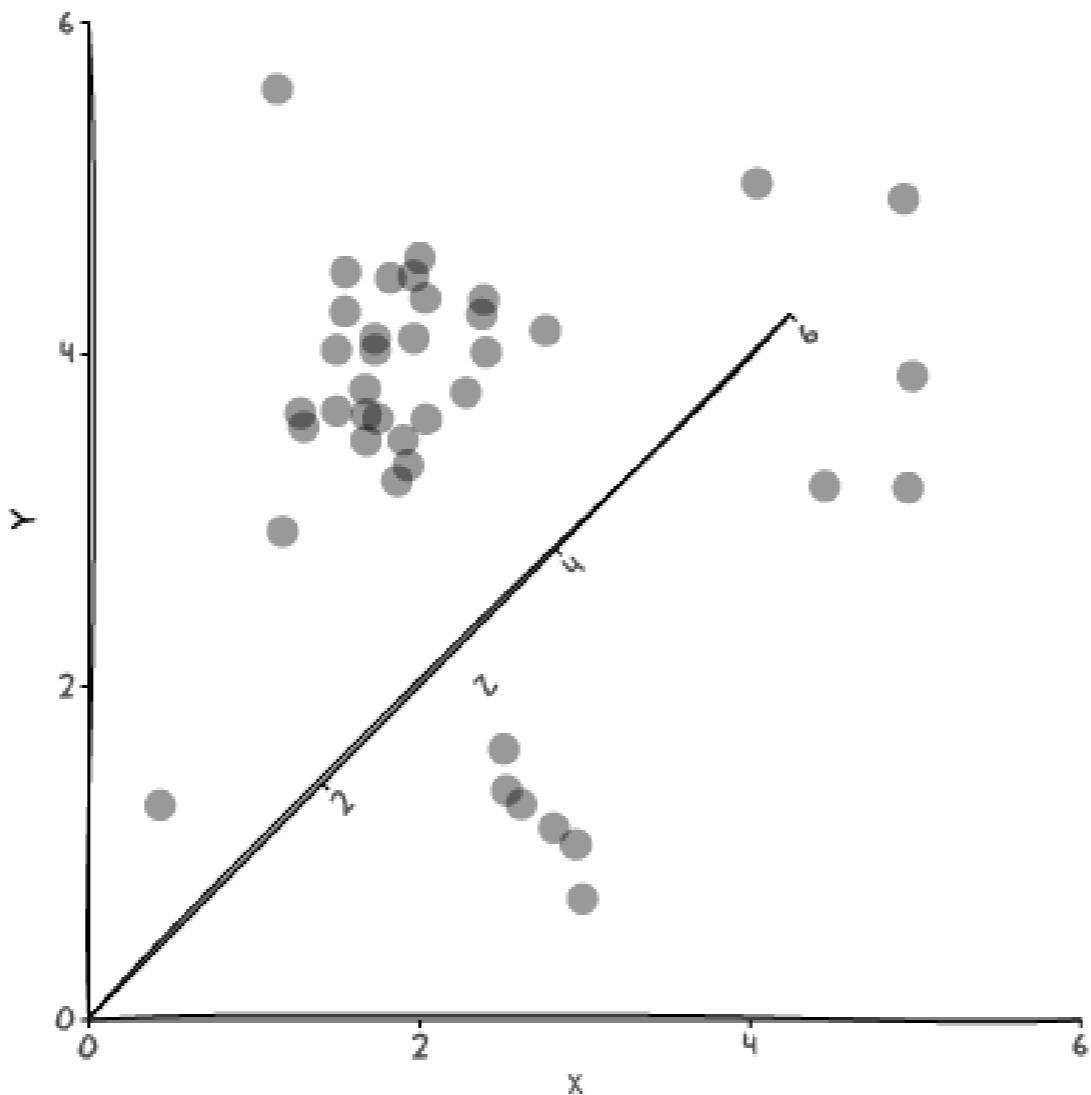
Broken y-axes, use facets



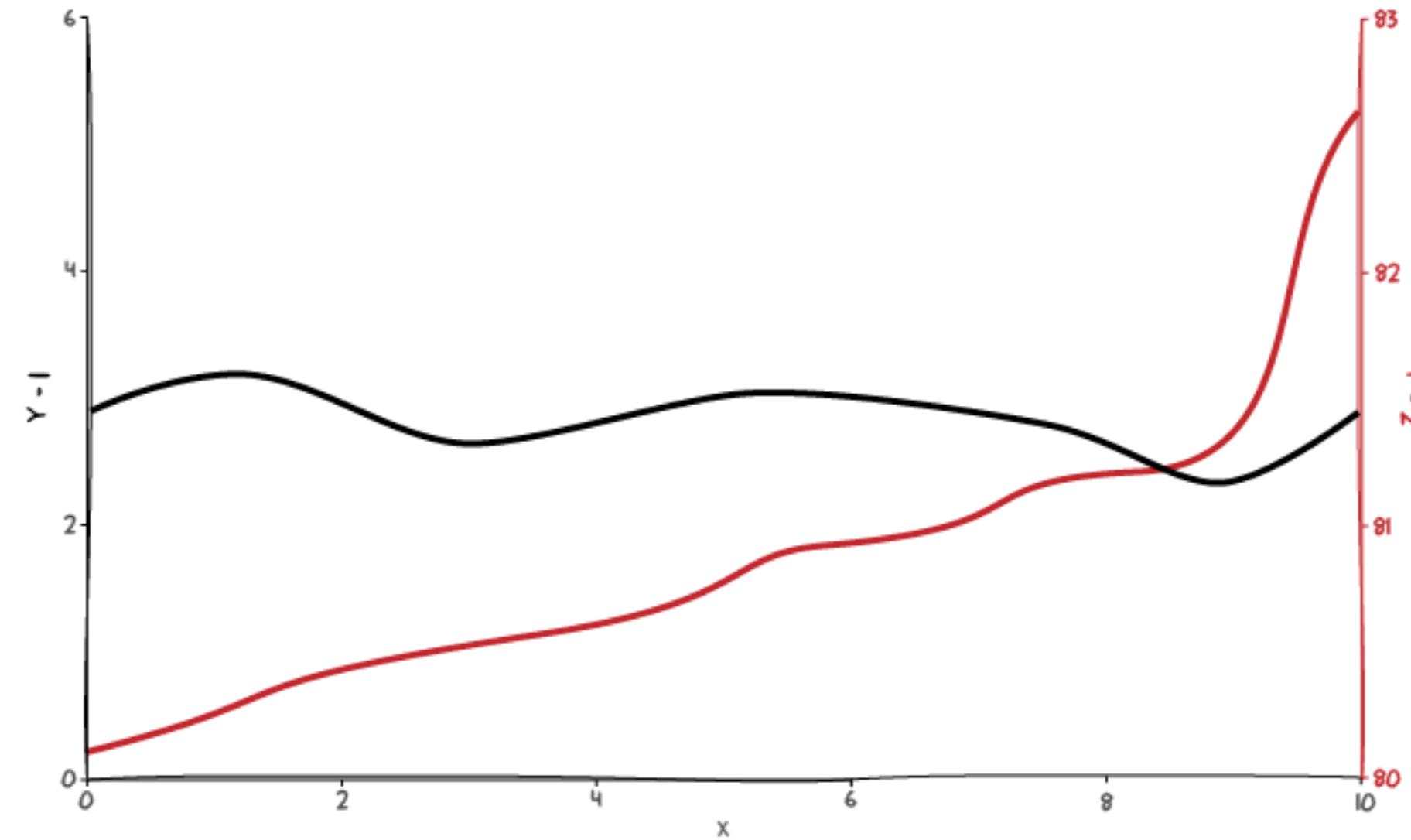
3D plots, without data on the 3rd axis



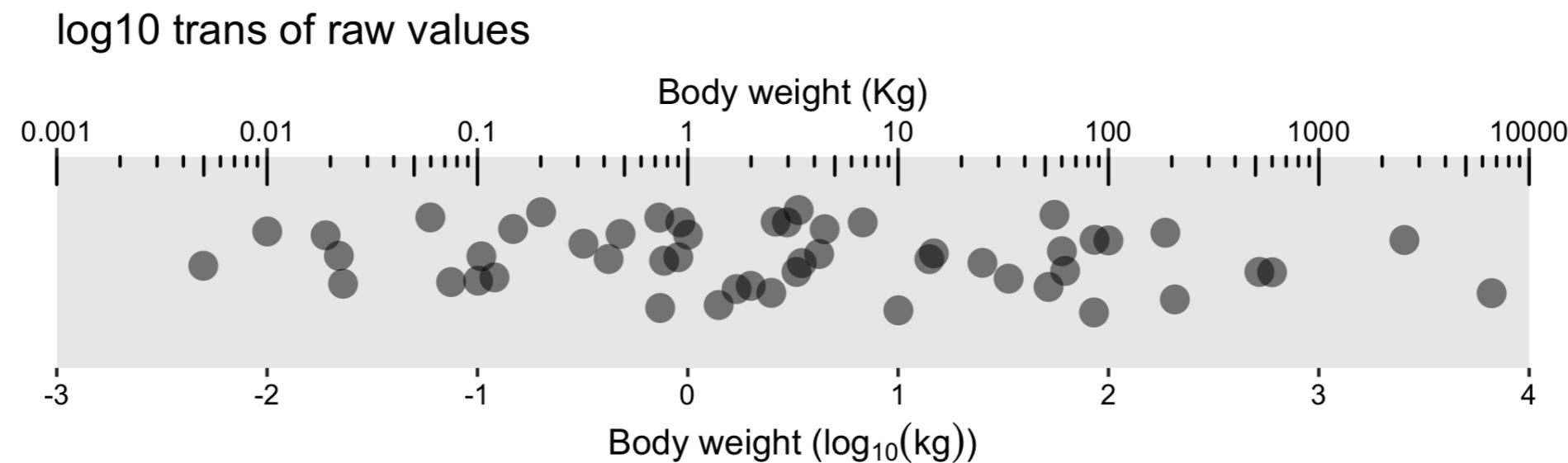
3D plots, with data on the 3rd axis



Double y-axes



Double y-axis for transformations



Guidelines not rules

- Use your common sense:
 - Is there anything on my plot that obscure a clear reading of the data or the take-home message?

Let's practice!

INTERMEDIATE DATA VISUALIZATION WITH GGPLOT2