

# Plotting with ggplot2

## Exploratory Data Analysis

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# What is ggplot2?

- An implementation of the *Grammar of Graphics* by Leland Wilkinson
- Written by Hadley Wickham (while he was a graduate student at Iowa State)
- A “third” graphics system for R (along with **base** and **lattice**)
- Available from CRAN via `install.packages( )`
- Web site: <http://ggplot2.org> (better documentation)

# What is ggplot2?

- Grammar of graphics represents and abstraction of graphics ideas/objects
- Think “verb”, “noun”, “adjective” for graphics
- Allows for a “theory” of graphics on which to build new graphics and graphics objects
- “Shorten the distance from mind to page”

# Grammar of Graphics

“In brief, the grammar tells us that a statistical graphic is a **mapping** from data to **aesthetic** attributes (colour, shape, size) of **geometric** objects (points, lines, bars). The plot may also contain statistical transformations of the data and is drawn on a specific coordinate system”

from *ggplot2* book

## The Basics: `qplot()`

- Works much like the `plot` function in base graphics system
- Looks for data in a data frame, similar to `lattice`, or in the parent environment
- Plots are made up of *aesthetics* (size, shape, color) and *geoms* (points, lines)

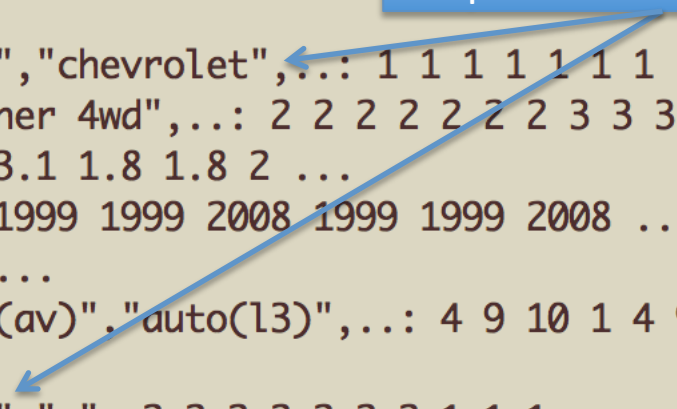
## The Basics: `qplot()`

- Factors are important for indicating subsets of the data (if they are to have different properties); they should be **labeled**
- The `qplot()` hides what goes on underneath, which is okay for most operations
- `ggplot()` is the core function and very flexible for doing things `qplot()` cannot do

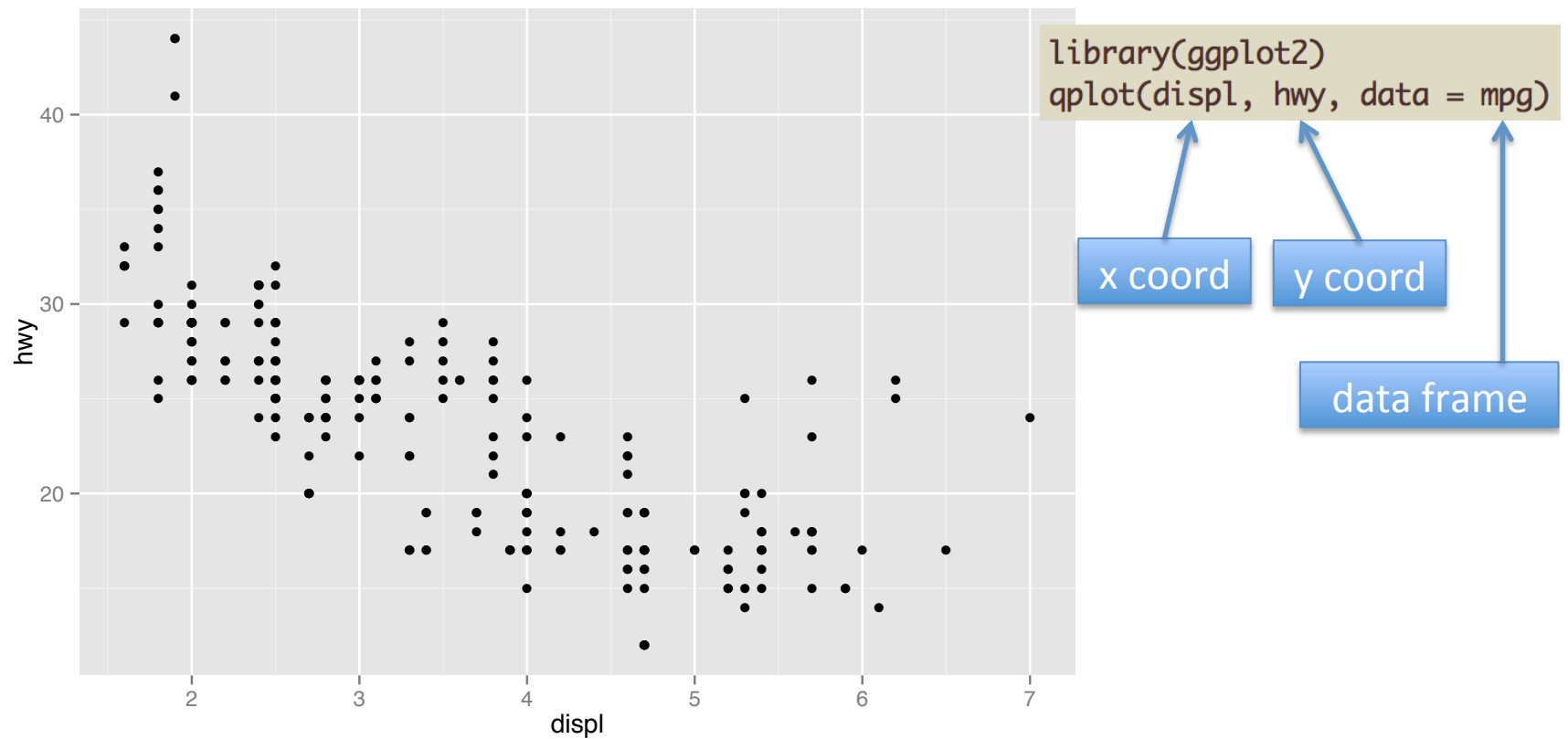
# Example Dataset

```
> library(ggplot2)
> str(mpg)
'data.frame':  234 obs. of  11 variables:
 $ manufacturer: Factor w/ 15 levels "audi","chevrolet",...: 1 1 1 1 1 1 1 1 1 1 ...
 $ model       : Factor w/ 38 levels "4runner 4wd",...: 2 2 2 2 2 2 2 3 3 3 ...
 $ displ      : num  1.8 1.8 2 2 2.8 2.8 3.1 1.8 1.8 2 ...
 $ year       : int  1999 1999 2008 2008 1999 1999 2008 1999 1999 2008 ...
 $ cyl        : int   4 4 4 4 6 6 6 4 4 4 ...
 $ trans      : Factor w/ 10 levels "auto(av)","auto(l3)",...: 4 9 10 1 4 9 1 9 4 10
...
 $ drv        : Factor w/ 3 levels "4","f","r": 2 2 2 2 2 2 2 1 1 1 ...
 $ cty        : int   18 21 20 21 16 18 18 18 16 20 ...
 $ hwy        : int   29 29 31 30 26 26 27 26 25 28 ...
 $ fl         : Factor w/ 5 levels "c","d","e","p",...: 4 4 4 4 4 4 4 4 4 4 ...
 $ class      : Factor w/ 7 levels "2seater","compact",...: 2 2 2 2 2 2 2 2 2 2 ...
```

Factor label information  
important for annotation

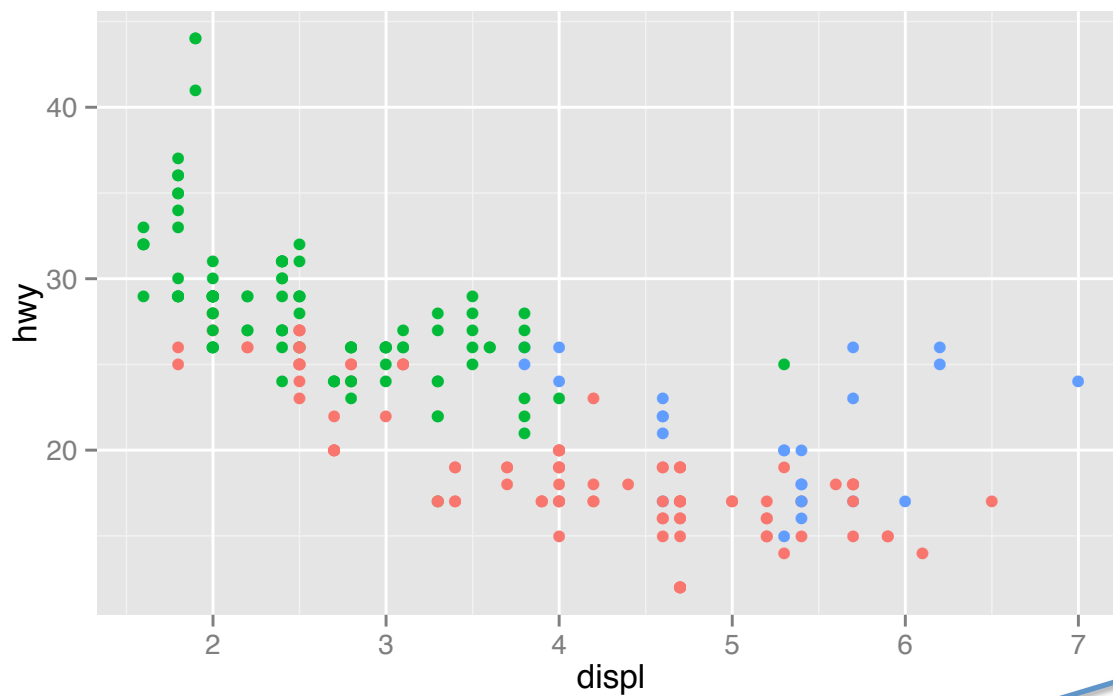


# ggplot2 “Hello, world!”





# Modifying aesthetics

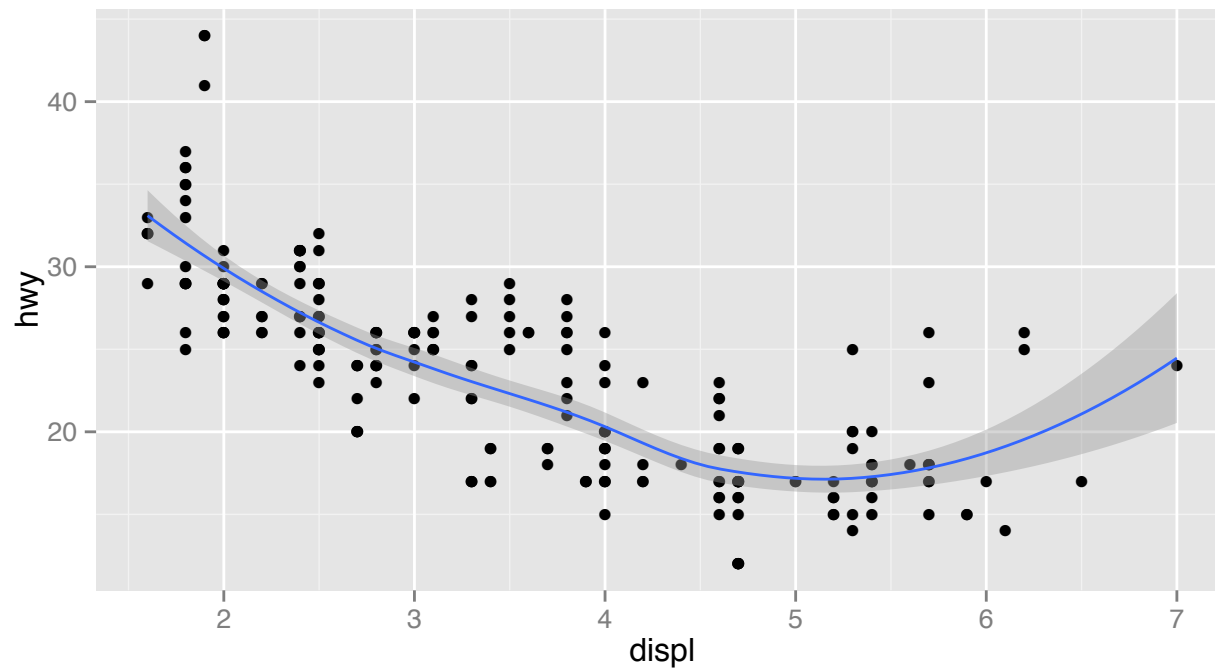


auto legend  
placement

color aesthetic

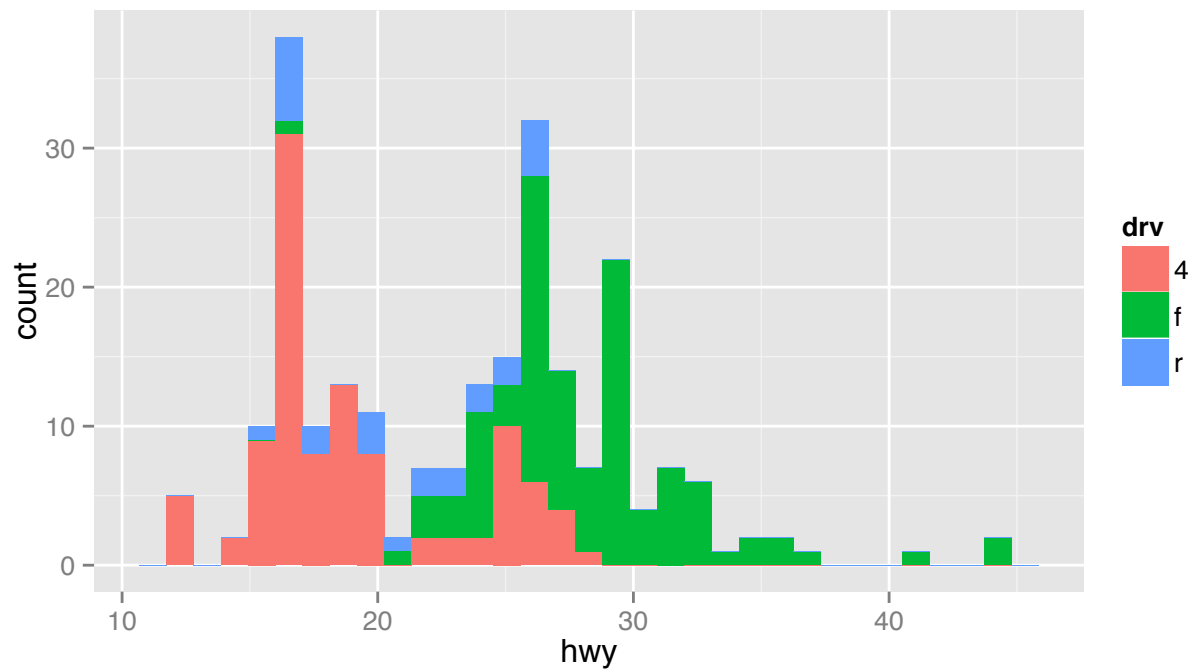
```
qplot(displ, hwy, data = mpg, color = drv)
```

# Adding a geom



```
qplot(displ, hwy, data = mpg, geom = c("point", "smooth"))
```

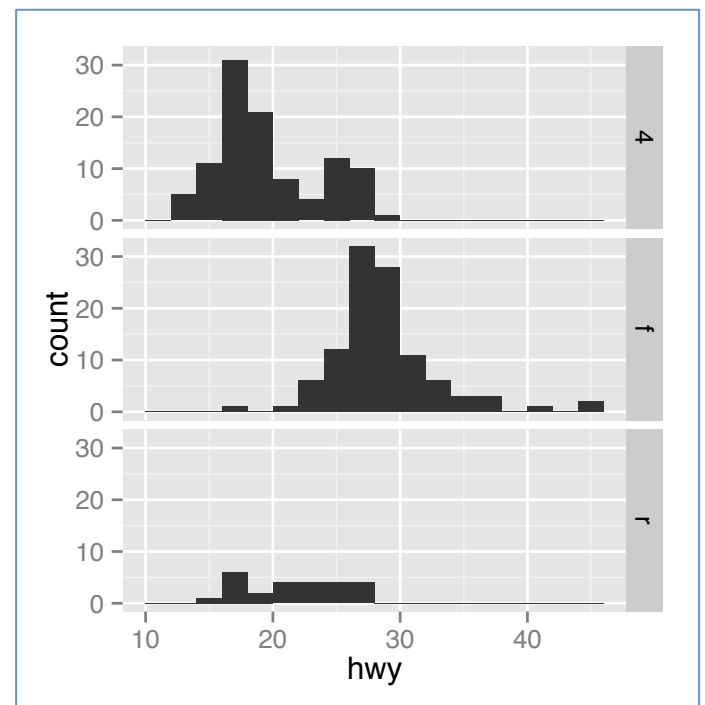
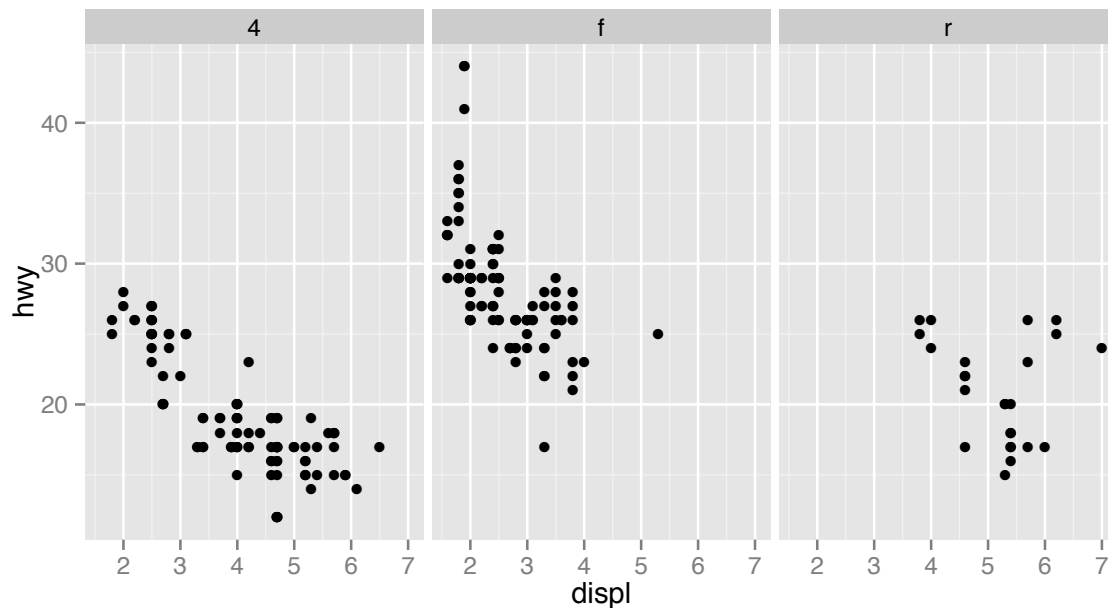
# Histograms



```
qplot(hwy, data = mpg, fill = drv)
```

# Facets

```
qplot(displ, hwy, data = mpg, facets = . ~ drv)
```



```
qplot(hwy, data = mpg, facets = drv ~ ., binwidth = 2)
```

# MAACS Cohort

- Mouse Allergen and Asthma Cohort Study
- Baltimore children (aged 5—17)
- Persistent asthma, exacerbation in past year
- Study indoor environment and its relationship with asthma morbidity
- Recent publication: <http://goo.gl/WqE9j8>

# Example: MAACS

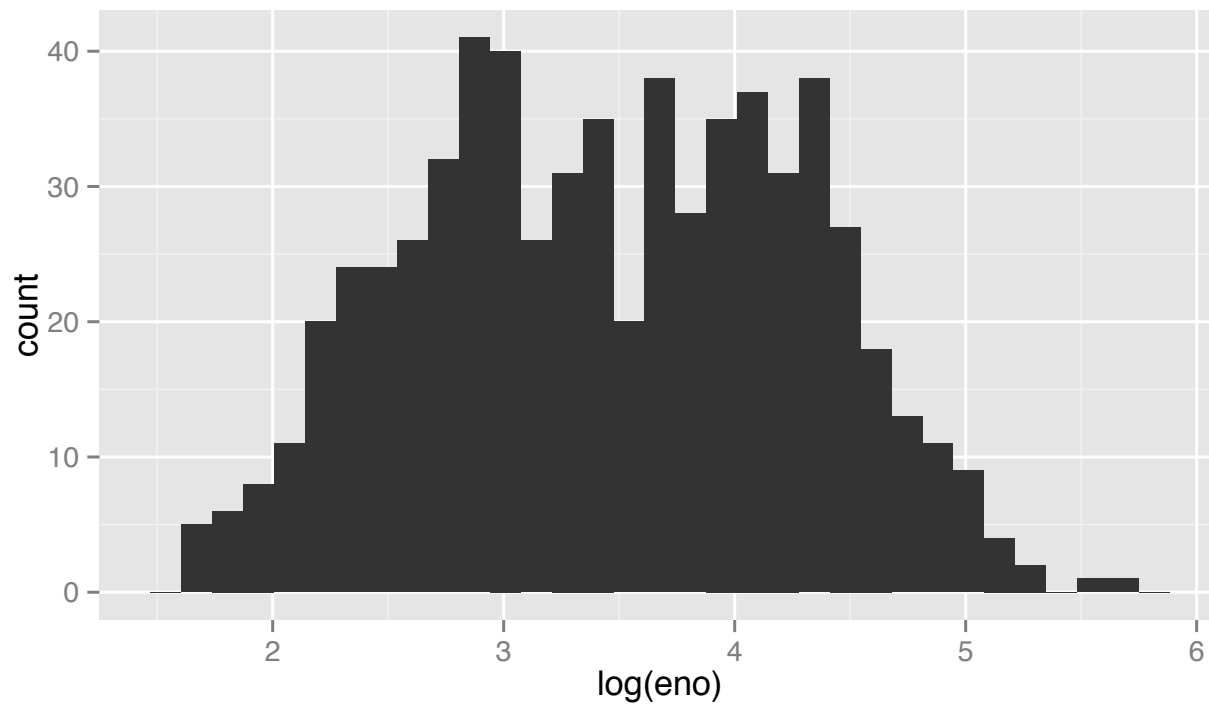
Exhaled nitric  
oxide

```
> str(maacs)
'data.frame':   750 obs. of  5 variables:
 $ id      : int  1 2 3 4 5 6 7 8 9 10 ...
 $ eno     : num  141 124 126 164 99 68 41 50 12 30 ...
 $ duBedMusM: num  2423 2793 3055 775 1634 ...
 $ pm25    : num  15.6 34.4 39 33.2 27.1 ...
 $ _mopos  : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
```

Fine particulate  
matter

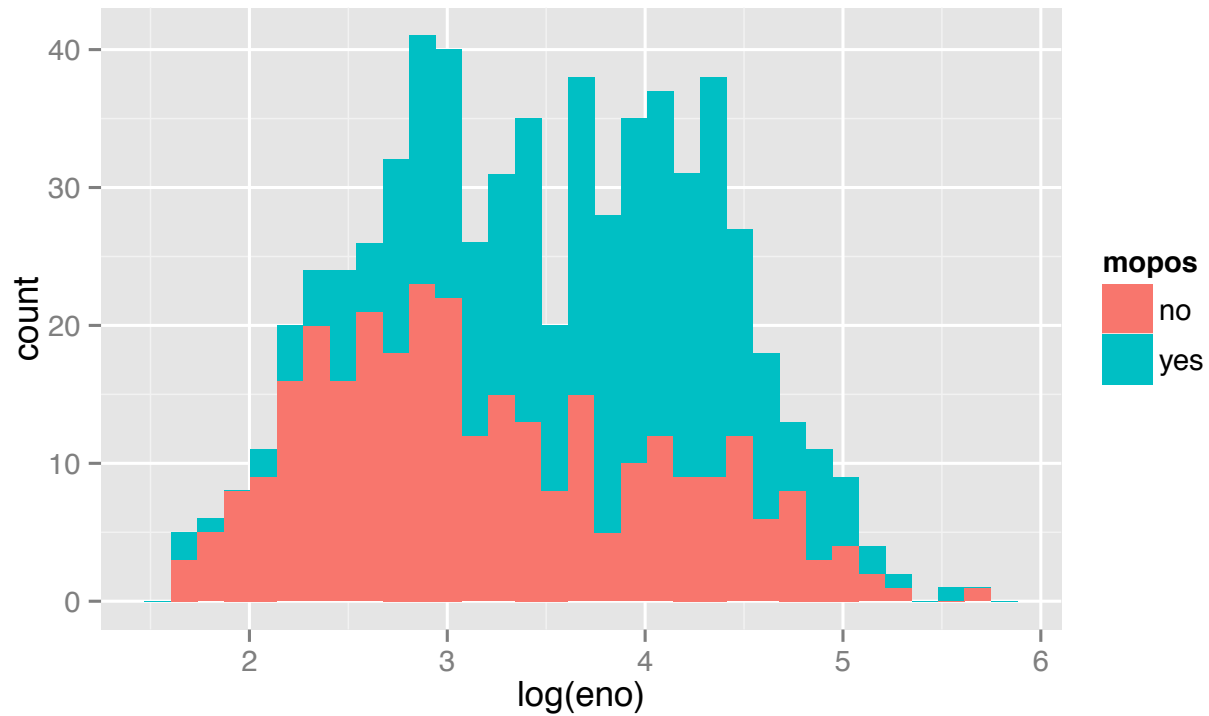
Sensitized to  
mouse allergen

# Histogram of eNO



`qplot(log(enno), data = maacs)`

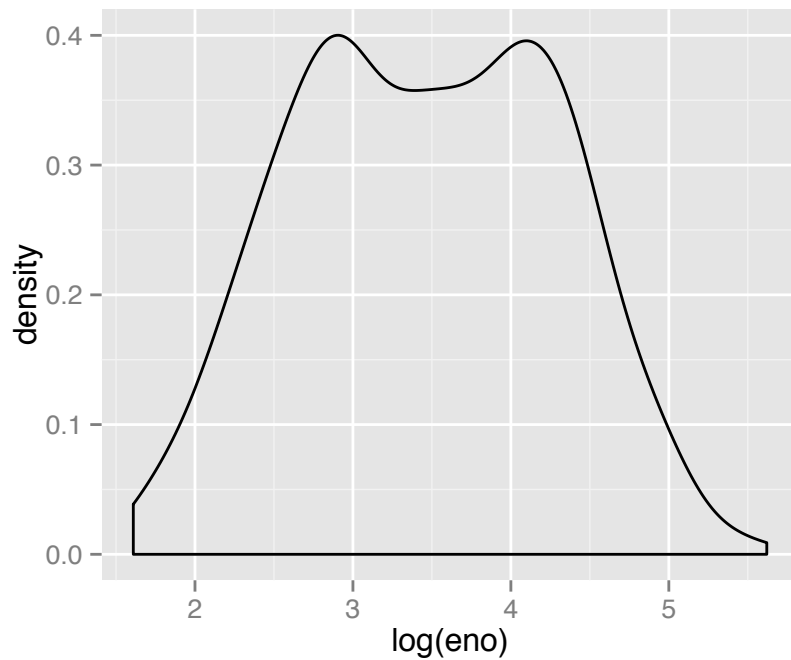
# Histogram by Group



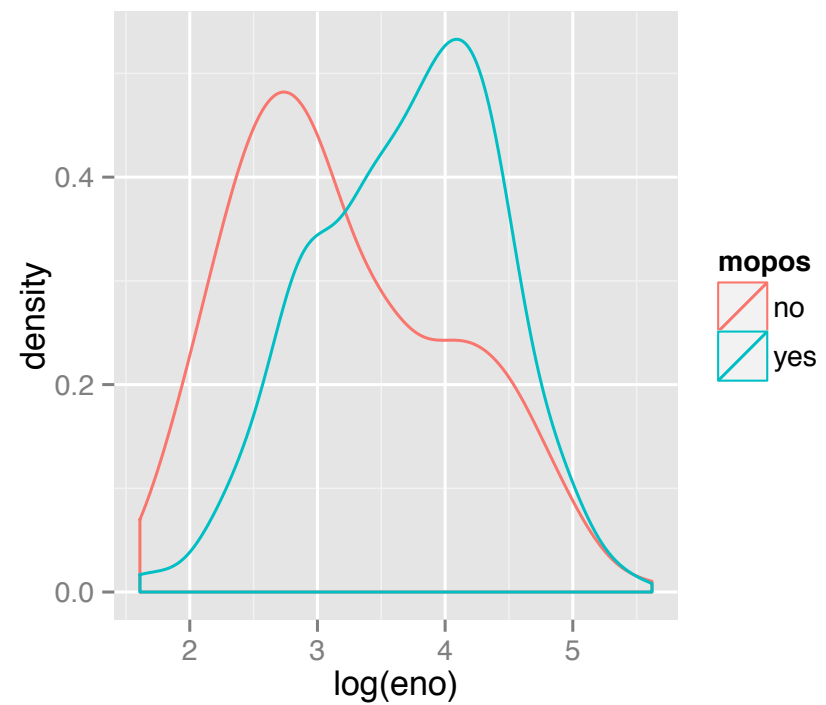
`qplot(log(eno), data = maacs, fill = mopos)`



# Density Smooth

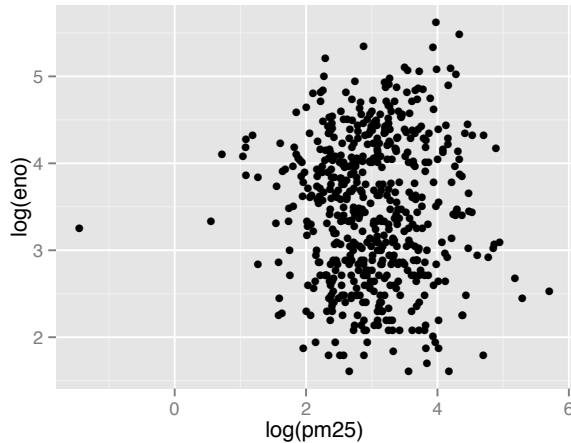


```
qplot(log(eno), data = maacs, geom = "density")
```

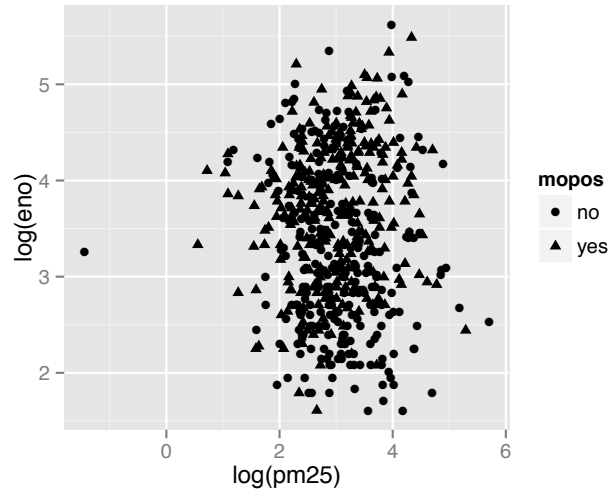


```
qplot(log(eno), data = maacs, geom = "density", color = mopos)
```

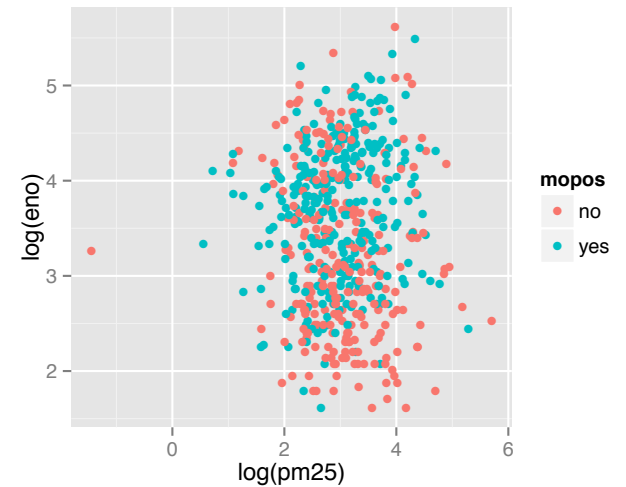
# Scatterplots: eNO vs. PM<sub>2.5</sub>



```
qplot(log(pm25), log(eno), data =  
maacs)
```

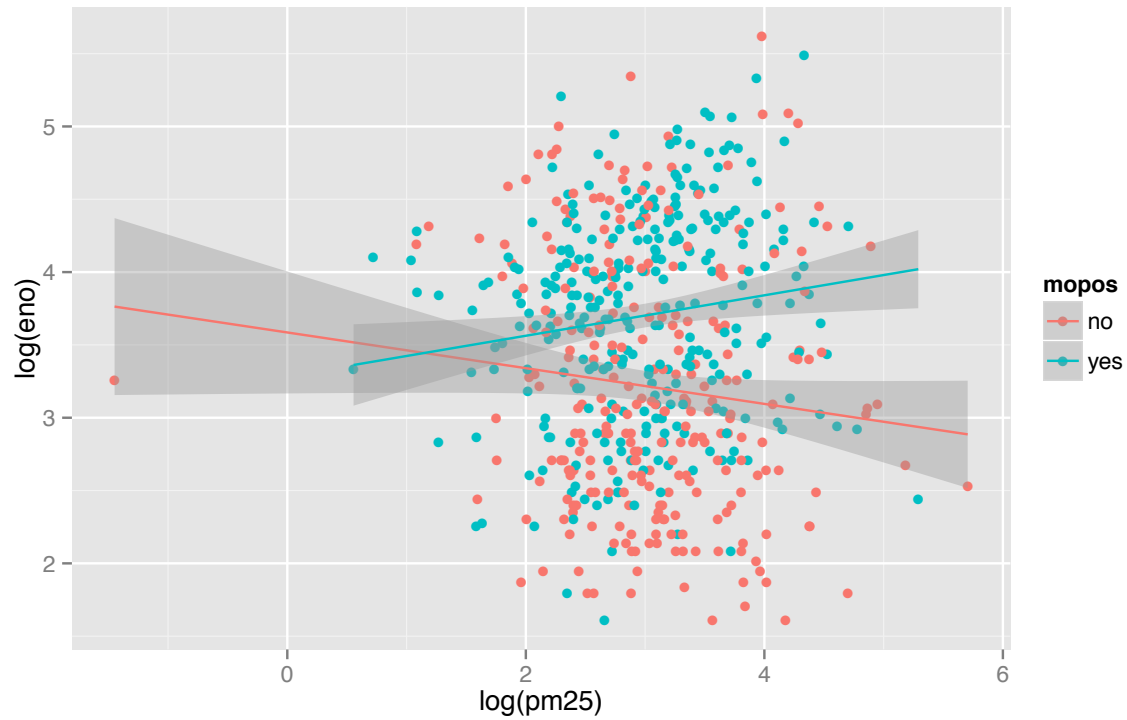


```
qplot(log(pm25), log(eno), data =  
maacs, shape = mopos)
```



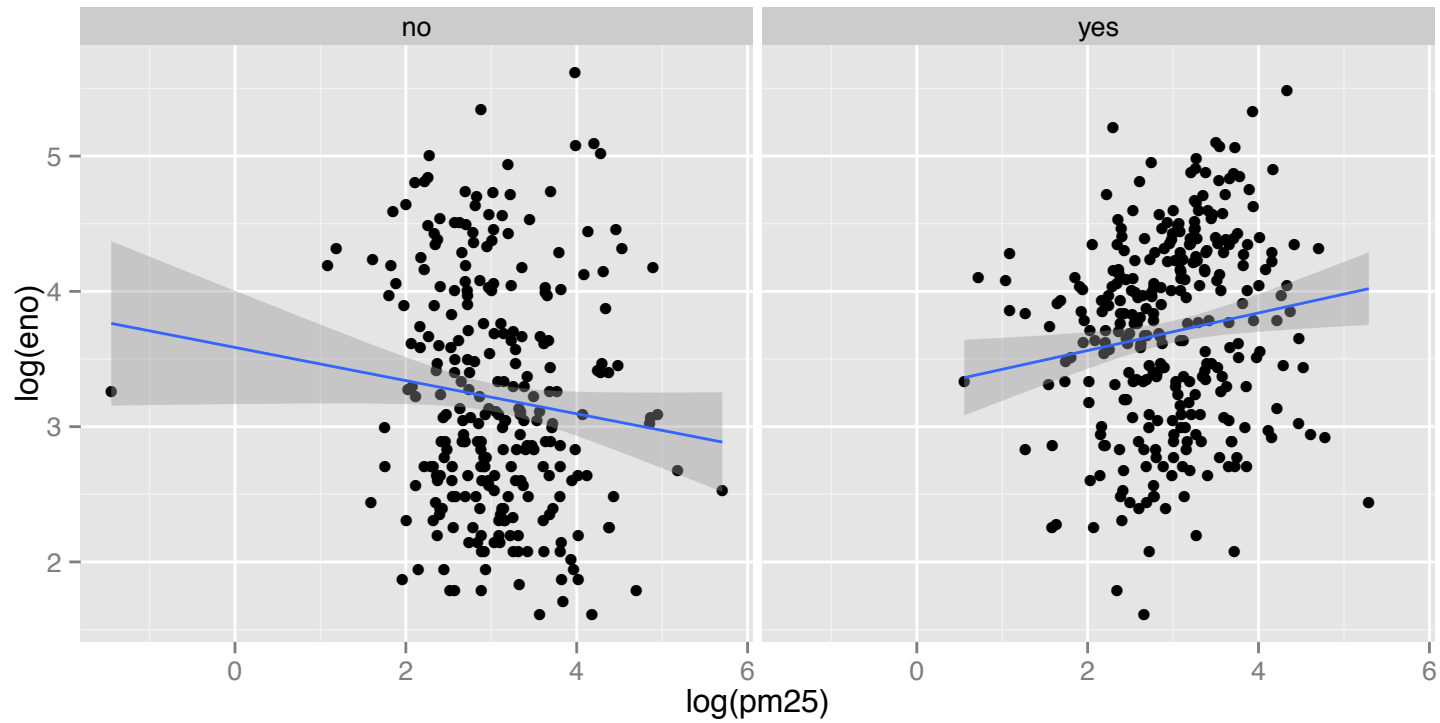
```
qplot(log(pm25), log(eno), data =  
maacs, color = mopos)
```

# Scatterplots: eNO vs. PM<sub>2.5</sub>



```
qplot(log(pm25), log(enno), data = maacs, color = mopos, geom = c("point", "smooth"), method = "lm")
```

# Scatterplots: eNO vs. PM<sub>2.5</sub>



```
qplot(log(pm25), log(enox), data = maacs, geom = c("point", "smooth"), method = "lm", facets = . ~ mopos)
```

# Summary of `qplot()`

- The `qplot()` function is the analog to `plot()` but with many built-in features
- Syntax somewhere in between base/lattice
- Produces very nice graphics, essentially publication ready (if you like the design)
- Difficult to go against the grain/customize (don't bother; use full `ggplot2` power in that case)

# Resources

- The *ggplot2* book by Hadley Wickham
- The *R Graphics Cookbook* by Winston Chang (examples in base plots and in ggplot2)
- ggplot2 web site (<http://ggplot2.org>)
- ggplot2 mailing list (<http://goo.gl/OdW3uB>), primarily for developers

# What is ggplot2?

- An implementation of the *Grammar of Graphics* by Leland Wilkinson
- Grammar of graphics represents and abstraction of graphics ideas/objects
- Think “verb”, “noun”, “adjective” for graphics
- Allows for a “theory” of graphics on which to build new graphics and graphics objects

# Basic Components of a ggplot2 Plot

- **A data frame**
- **aesthetic mappings:** how data are mapped to color, size
- **geoms:** geometric objects like points, lines, shapes.
- **facets:** for conditional plots.
- **stats:** statistical transformations like binning, quantiles, smoothing.
- **scales:** what scale an aesthetic map uses (example: male = red, female = blue).
- **coordinate system**



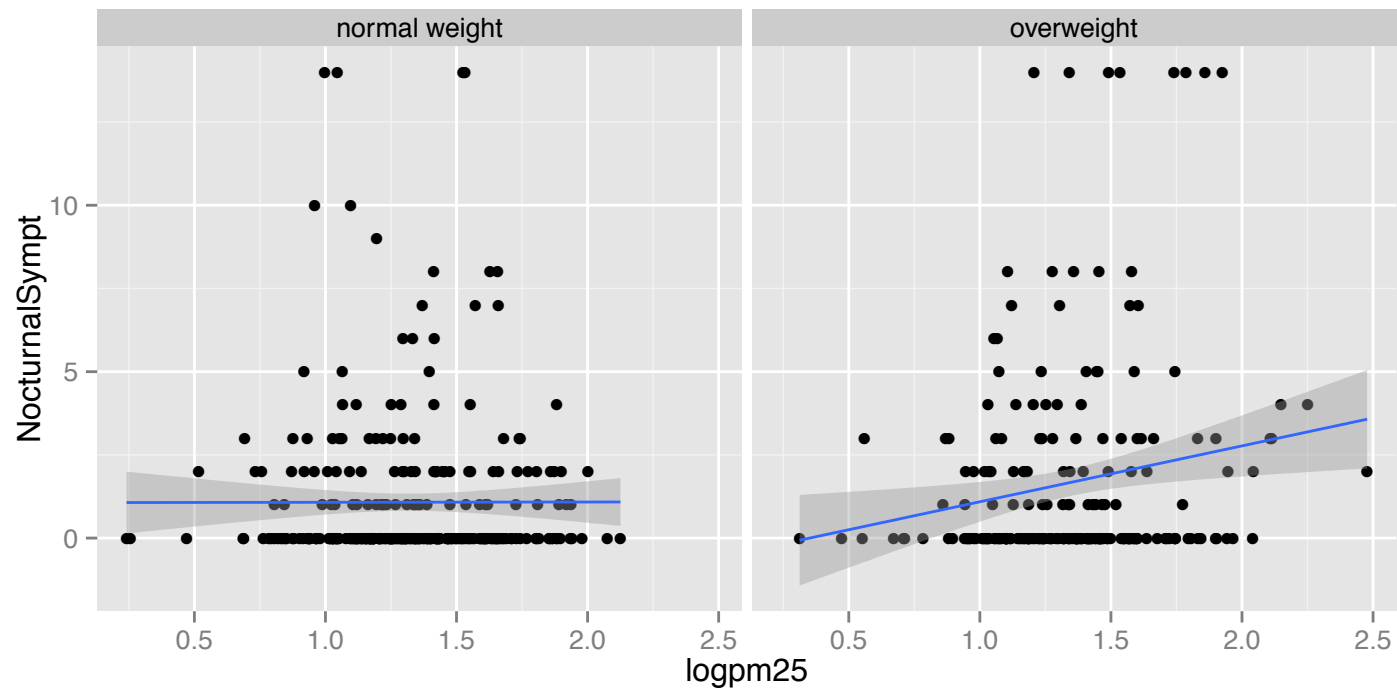
# Building Plots with ggplot2

- When building plots in ggplot2 (rather than using qplot) the “artist’s palette” model may be the closest analogy
- Plots are built up in layers
  - Plot the data
  - Overlay a summary
  - Metadata and annotation

## Example: BMI, PM<sub>2.5</sub>, Asthma

- Mouse Allergen and Asthma Cohort Study
- Baltimore children (age 5-17)
- Persistent asthma, exacerbation in past year
- Does BMI (normal vs. overweight) modify the relationship between PM<sub>2.5</sub> and asthma symptoms?

# Basic Plot



```
qplot(logpm25, NocturnalSympt, data = maacs, facets = . ~ bmicat, geom =  
c("point", "smooth"), method = "lm")
```

# Building Up in Layers

```
> head(maacs)
      logpm25      bmicat NocturnalSympt
2 1.5361795 normal weight           1
3 1.5905409 normal weight           0
4 1.5217786 normal weight           0
5 1.4323277 normal weight           0
6 1.2762320  overweight           8
8 0.7139103  overweight           0
```

```
> g <- ggplot(maacs, aes(logpm25, NocturnalSympt))
```

```
> summary(g)
data: logpm25, bmicat, NocturnalSympt [554x3]
mapping: x = logpm25, y = NocturnalSympt
faceting: facet_null()
```

Data Frame

Aesthetics

Initial call to  
ggplot

Summary of  
ggplot object

# No Plot Yet!

```
> g <- ggplot(maacs, aes(logpm25, NocturnalSympt))  
> print(g)  
Error: No layers in plot
```

```
> p <- g + geom_point()  
> print(p)
```

Explicitly save and print  
ggplot object

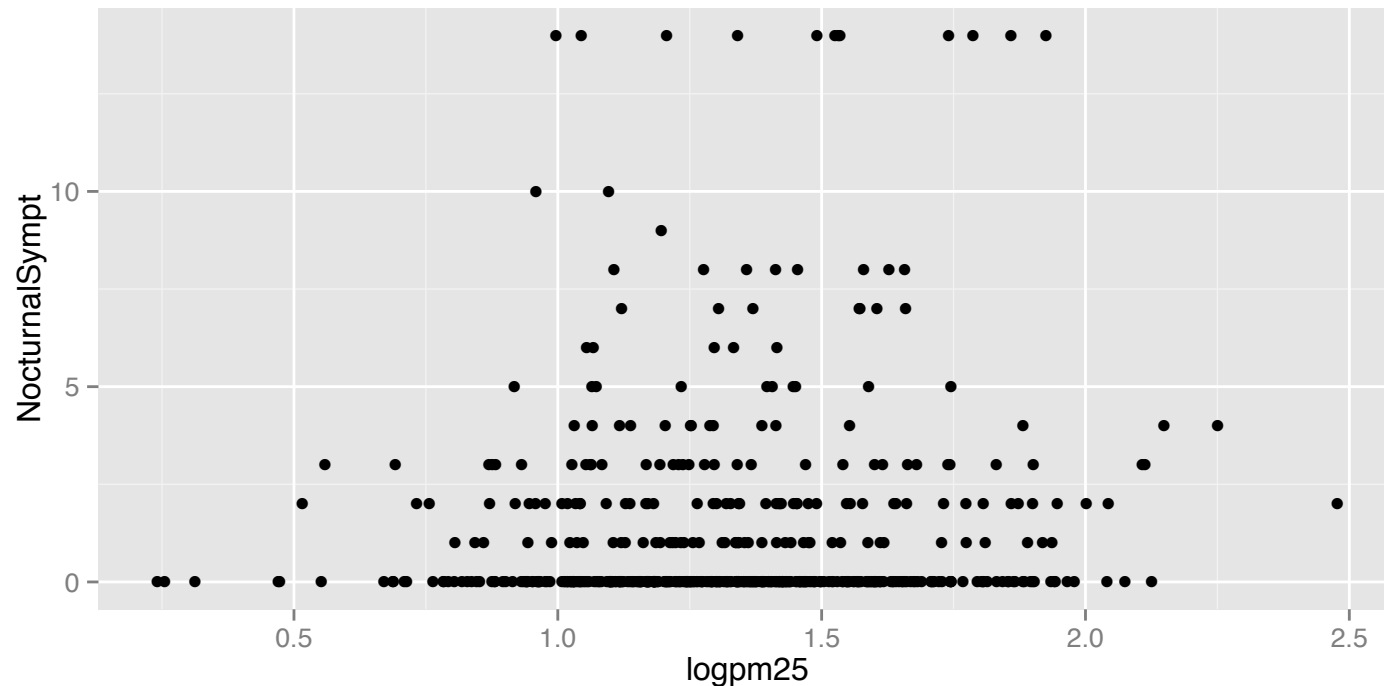


```
> g + geom_point()
```

Auto-print plot object  
without saving

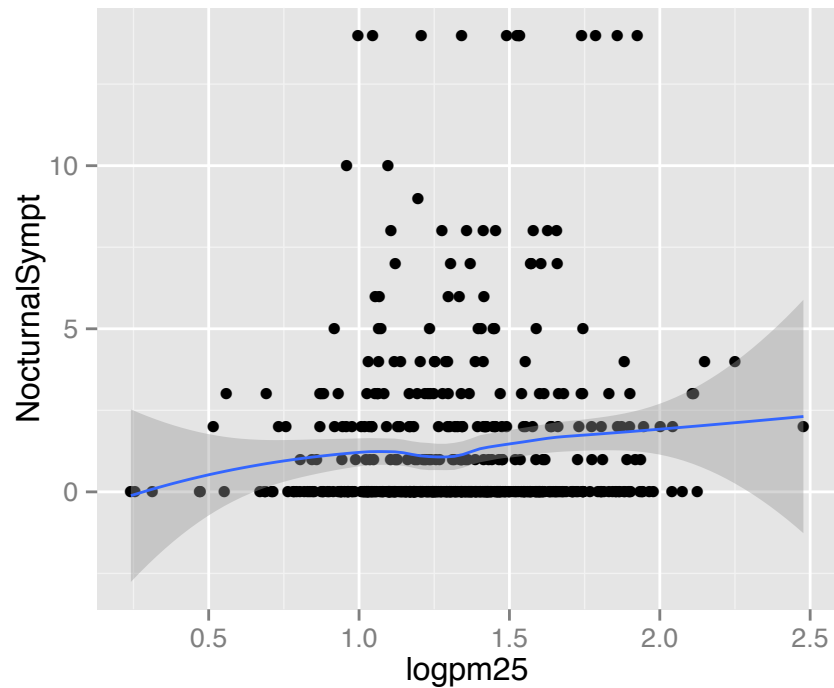


# First Plot with Point Layer

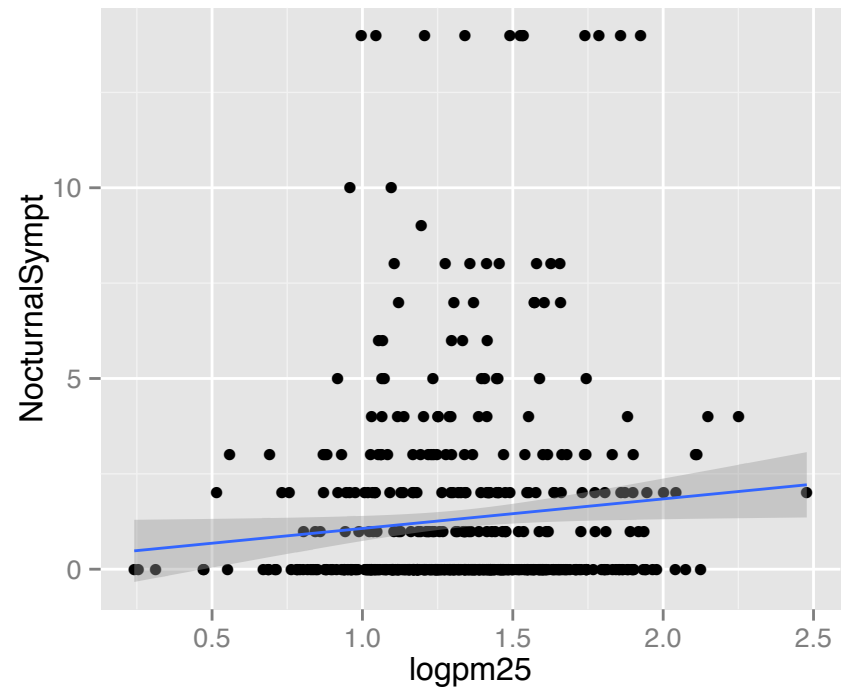


```
g <- ggplot(maacs, aes(logpm25, NocturnalSympt))  
g + geom_point()
```

# Adding More Layers: Smooth

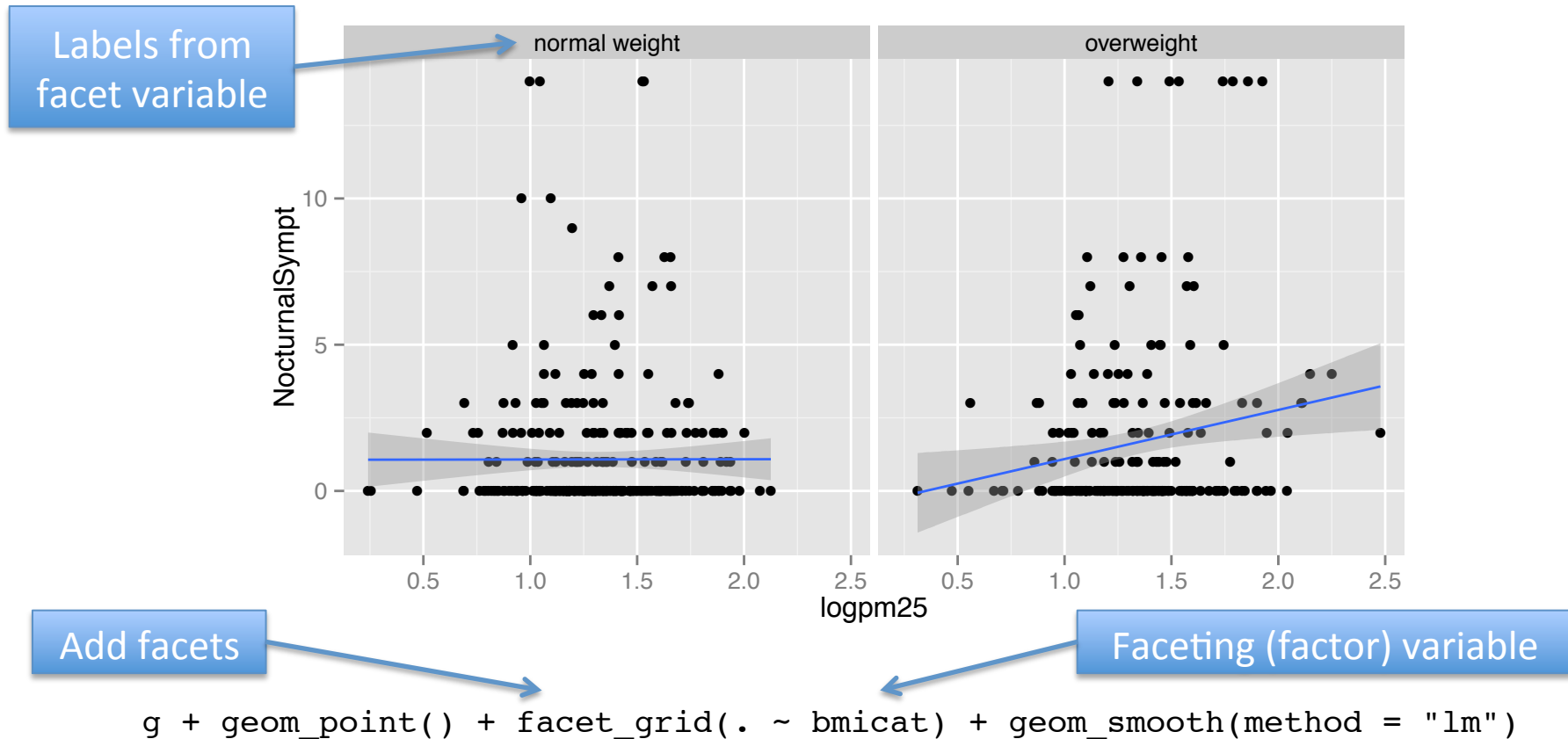


```
g + geom_point() + geom_smooth()
```



```
g + geom_point() + geom_smooth(method = "lm")
```

# Adding More Layers: Facets

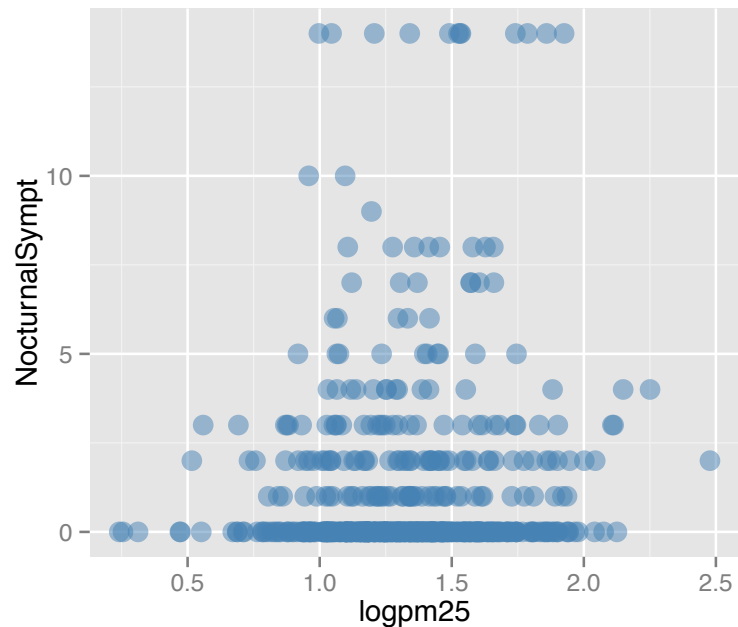




# Annotation

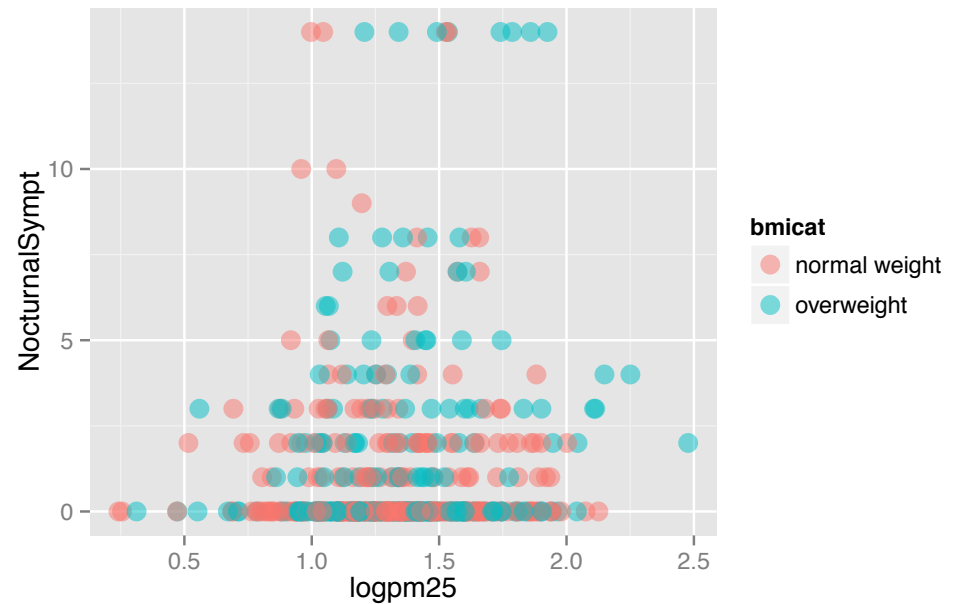
- Labels: `xlab()`, `ylab()`, `labs()`, `ggtitle()`
- Each of the “geom” functions has options to modify
- For things that only make sense globally, use `theme()`
  - Example: `theme(legend.position = "none")`
- Two standard appearance themes are included
  - `theme_gray()`: The default theme (gray background)
  - `theme_bw()`: More stark/plain

# Modifying Aesthetics



```
g + geom_point(color = "steelblue",  
size = 4, alpha = 1/2)
```

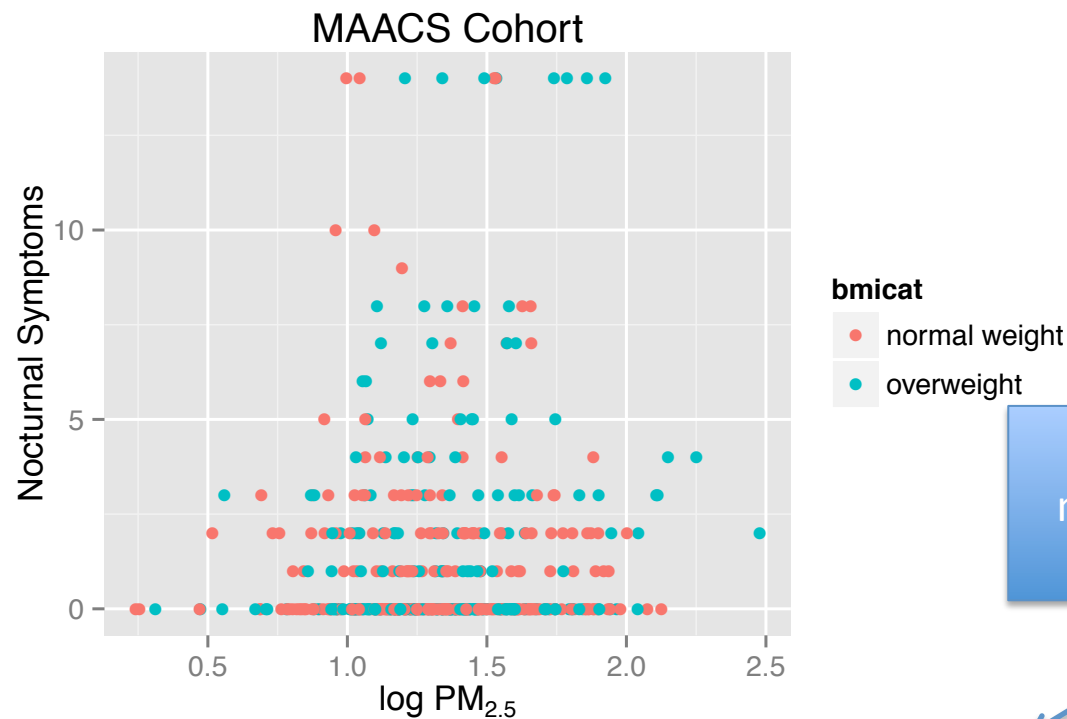
Constant values



```
g + geom_point(aes(color = bmicat),  
size = 4, alpha = 1/2)
```

Data variable

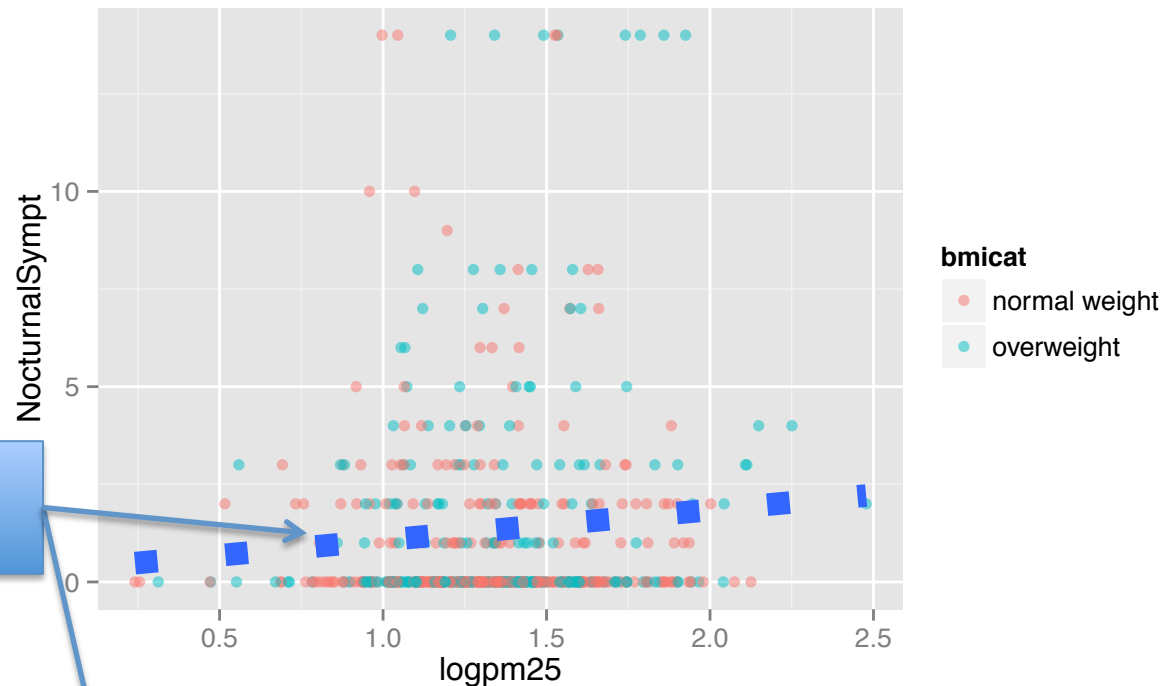
# Modifying Labels



labs() function for  
modifying titles and  
x-, y-axis labels

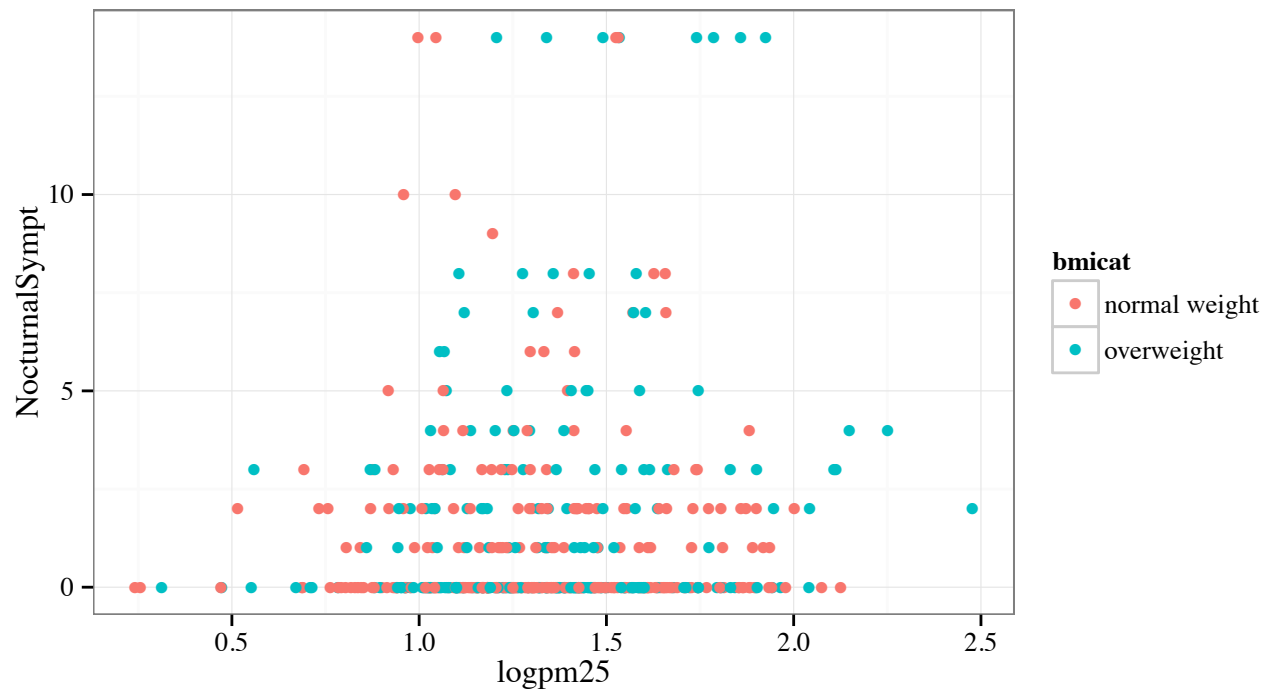
```
g + geom_point(aes(color = bmicat)) + labs(title = "MAACS Cohort") + labs(x = expression("log "
* PM[2.5]), y = "Nocturnal Symptoms")
```

# Customizing the Smooth



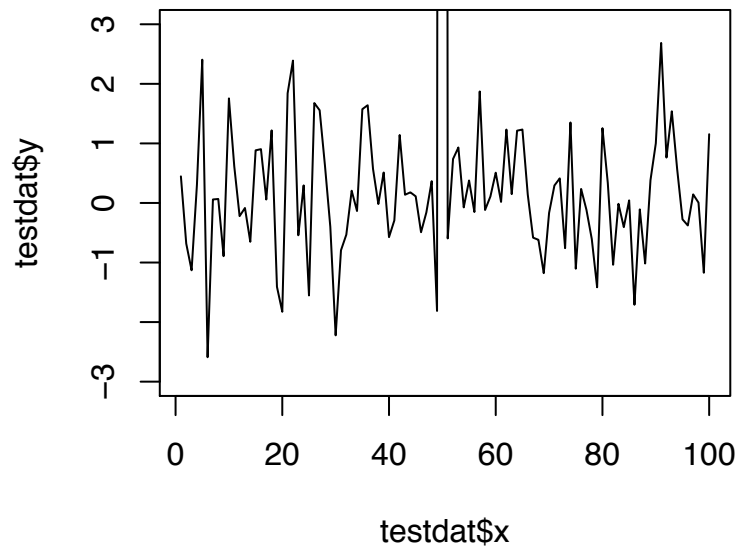
```
g + geom_point(aes(color = bmicat), size = 2, alpha = 1/2) +  
  geom_smooth(size = 4, linetype = 3, method = "lm", se = FALSE)
```

# Changing the Theme

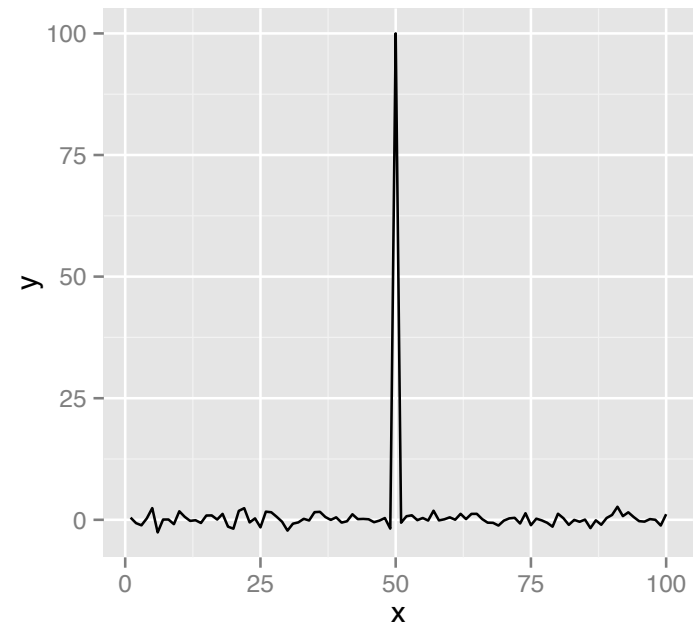


```
g + geom_point(aes(color = bmicat)) + theme_bw(base_family = "Times")
```

# A Notes about Axis Limits



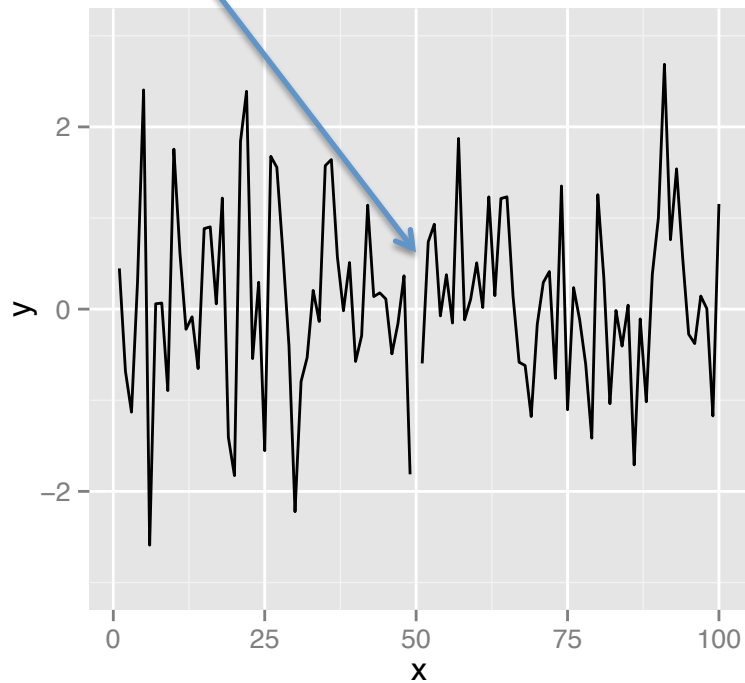
```
testdat <- data.frame(x = 1:100, y = rnorm(100))
testdat[50,2] <- 100 ## Outlier!
plot(testdat$x, testdat$y, type = "l", ylim = c(-3,3))
```



```
g <- ggplot(testdat, aes(x = x, y = y))
g + geom_line()
```

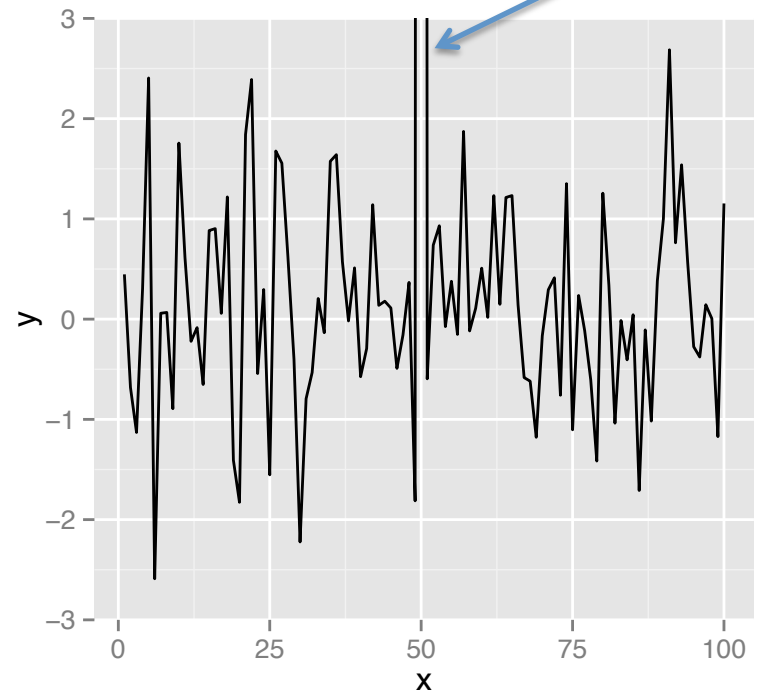
# Axis Limits

Outlier missing



```
g + geom_line() + ylim(-3, 3)
```

Outlier included



```
g + geom_line() + coord_cartesian(ylim = c(-3, 3))
```

# More Complex Example

- How does the relationship between  $PM_{2.5}$  and nocturnal symptoms vary by BMI and  $NO_2$ ?
- Unlike our previous BMI variable,  $NO_2$  is continuous
- We need to make  $NO_2$  categorical so we can condition on it in the plotting
  - Use the `cut()` function for this



# Making NO<sub>2</sub> Deciles

```
## Calculate the deciles of the data
> cutpoints <- quantile(maacs$logno2_new, seq(0, 1, length = 11), na.rm = TRUE)

## Cut the data at the deciles and create a new factor variable
> maacs$no2dec <- cut(maacs$logno2_new, cutpoints)

## See the levels of the newly created factor variable
> levels(maacs$no2dec)
[1] "(0.378,0.969]" "(0.969,1.1]"   "(1.1,1.17]"   "(1.17,1.26]"
[5] "(1.26,1.32]"   "(1.32,1.38]"   "(1.38,1.44]"   "(1.44,1.54]"
[9] "(1.54,1.69]"   "(1.69,2.55]"
```

# Final Plot

Non-default font

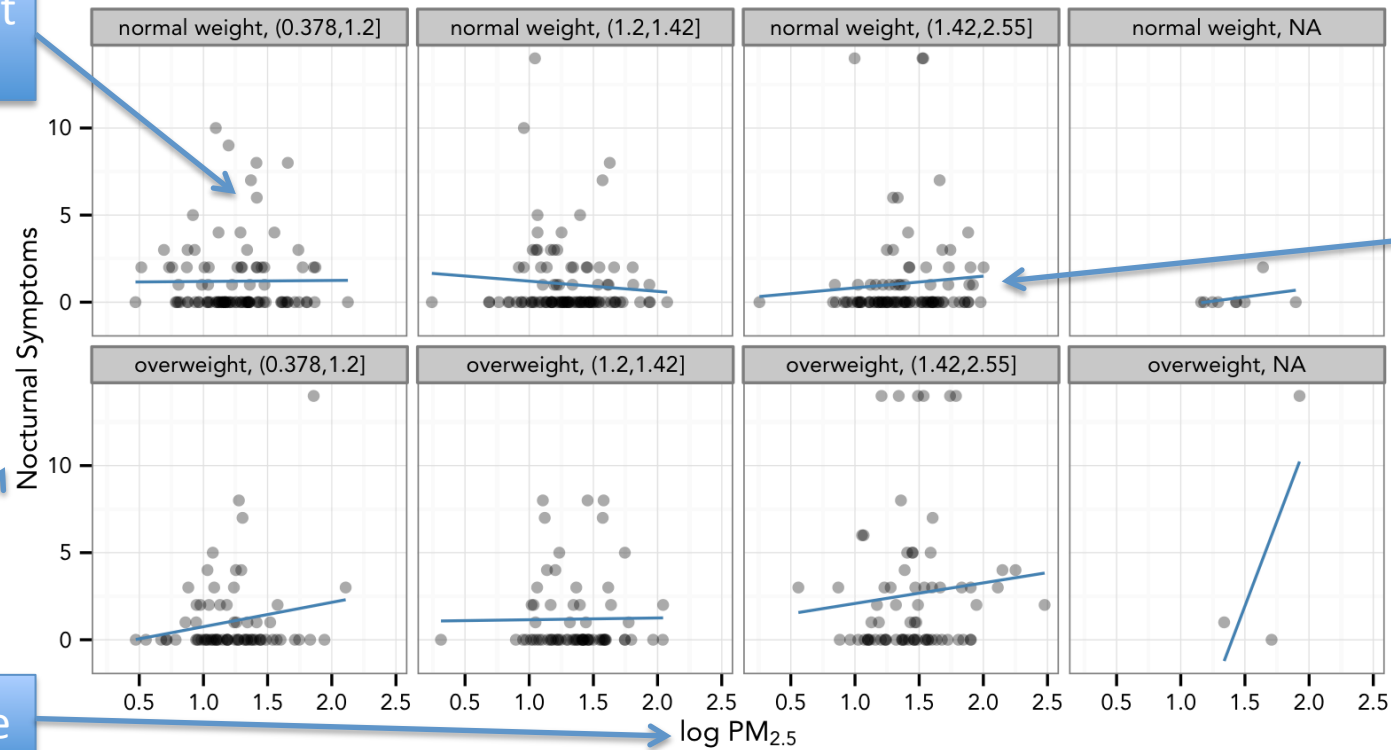
Multiple panels

Transparent points

MAACS Cohort

Smoother

Labels/Title



# Code for Final Plot

```
## Setup ggplot with data frame
g <- ggplot(maacs, aes(logpm25, NocturnalSympt))

## Add layers
g + geom_point(alpha = 1/3)
  + facet_wrap(bmicat ~ no2dec, nrow = 2, ncol = 4)
  + geom_smooth(method="lm", se=FALSE, col="steelblue")
  + theme_bw(base_family = "Avenir", base_size = 10)
  + labs(x = expression("log " * PM[2.5]))
  + labs(y = "Nocturnal Symptoms")
  + labs(title = "MAACS Cohort")
```

Add points

Make panels

Add smoother

Change theme

Add labels

# Summary

- ggplot2 is very powerful and flexible if you learn the “grammar” and the various elements that can be tuned/modified
- Many more types of plots can be made; explore and mess around with the package (references mentioned in Part 1 are useful)