Plotting with ggplot2: Part 2

Biostatistics 140.776

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**

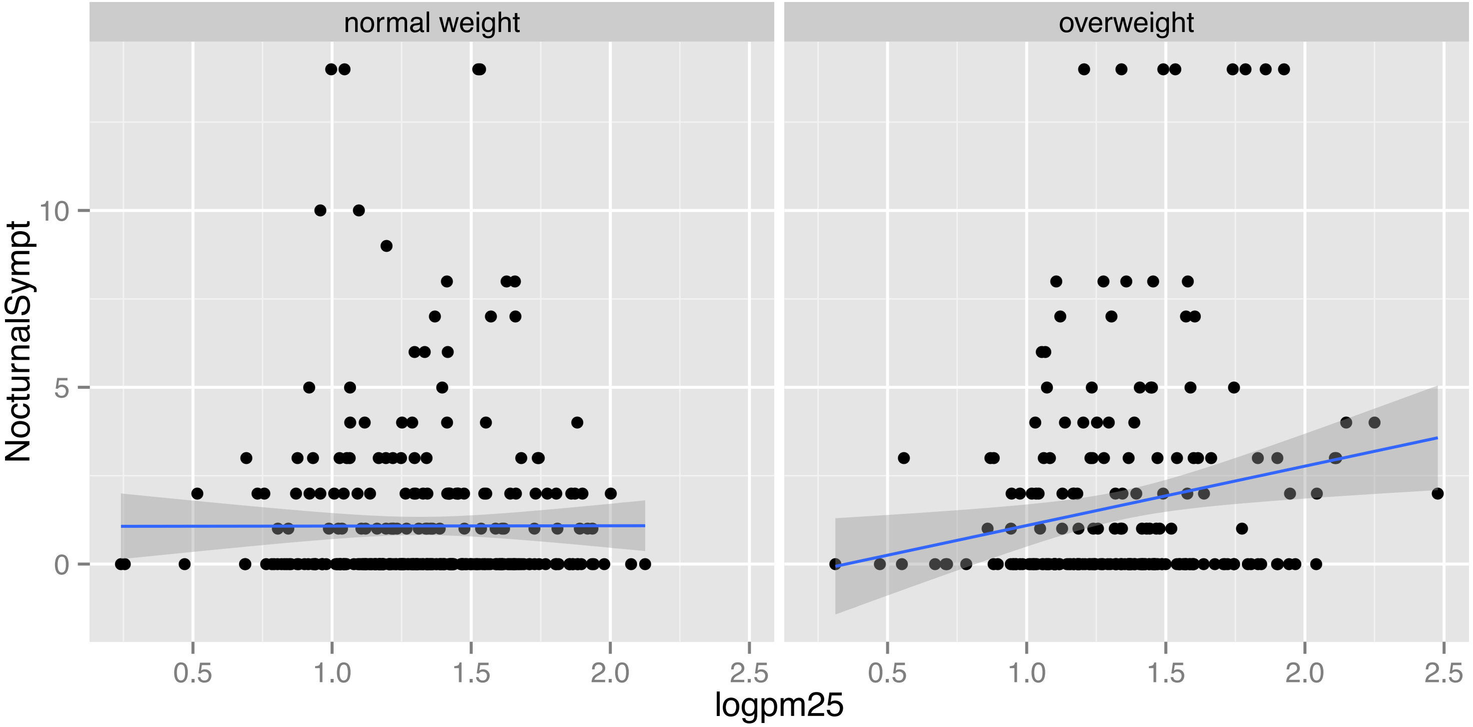
Building Plots with ggplot2

- 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, $PM_{2.5}$, 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 $PM_{2.5}$ and asthma symptoms?

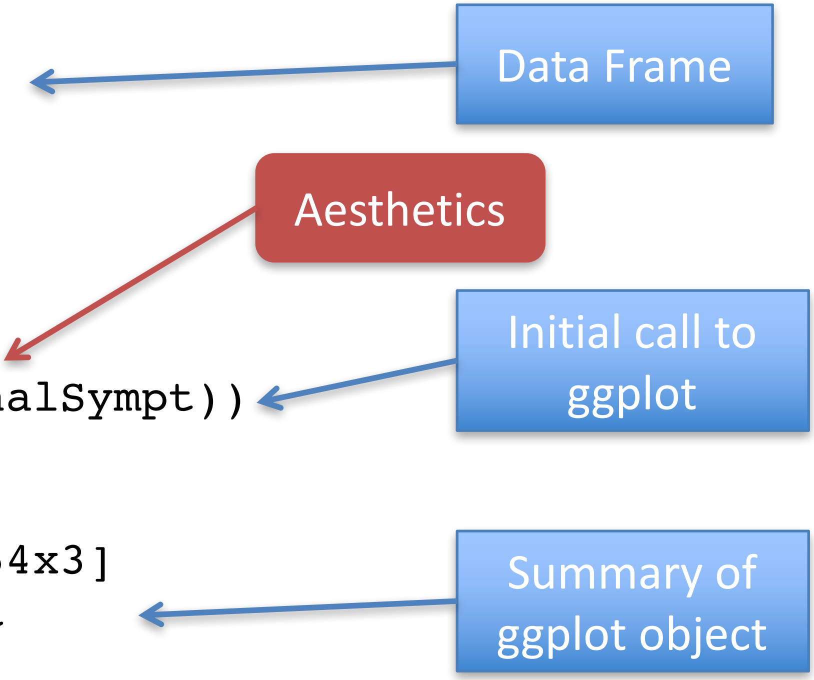
Basic Plot



```
qplot(logpm25, NocturnalSympt, data = maacs, facets = . ~ bmicat) +
geom_smooth(method = “lm”)
```

Building Up in Layers

```
> head(maacs[, 1:3])
    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!

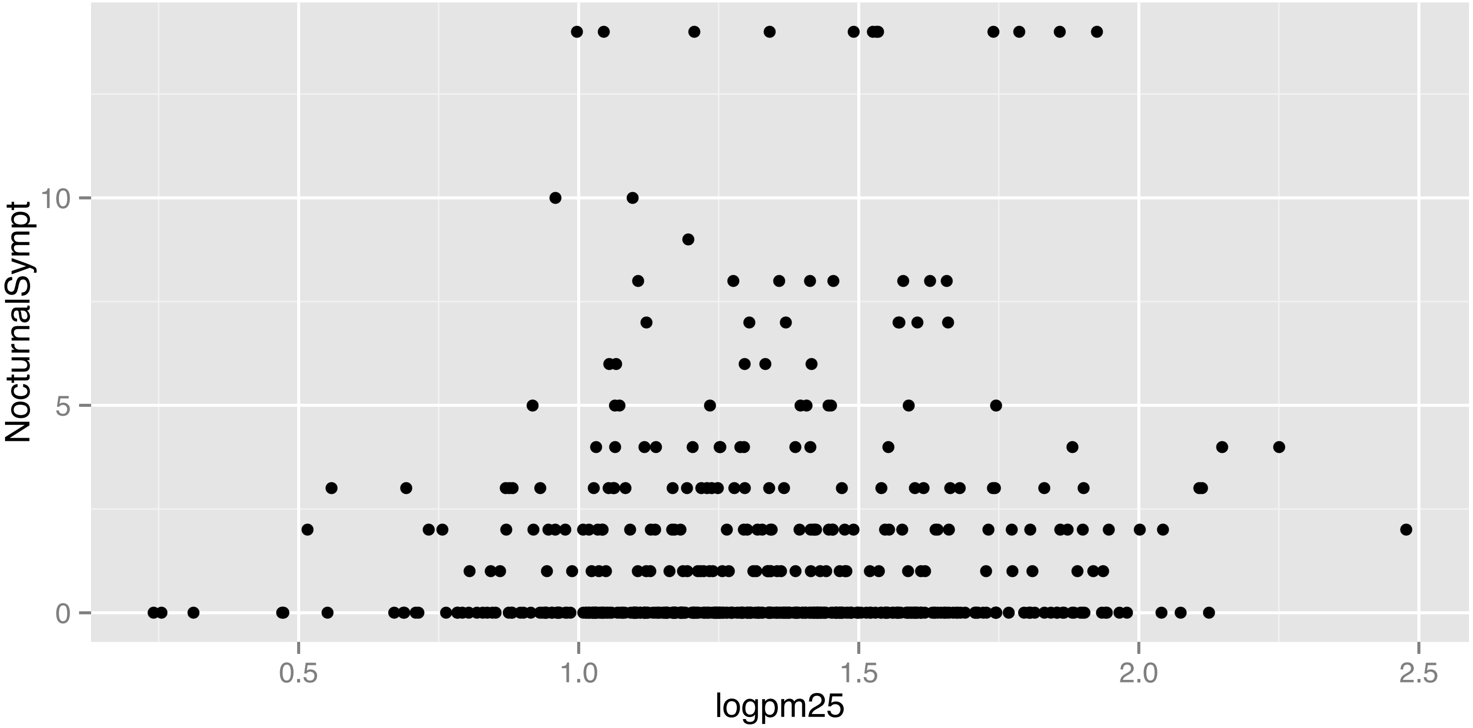
```
> g <- ggplot(maacs, aes(logpm25, NocturnalSympt))
> print(g)
Error: No layers in plot

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

Explicitly save and print ggplot object

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

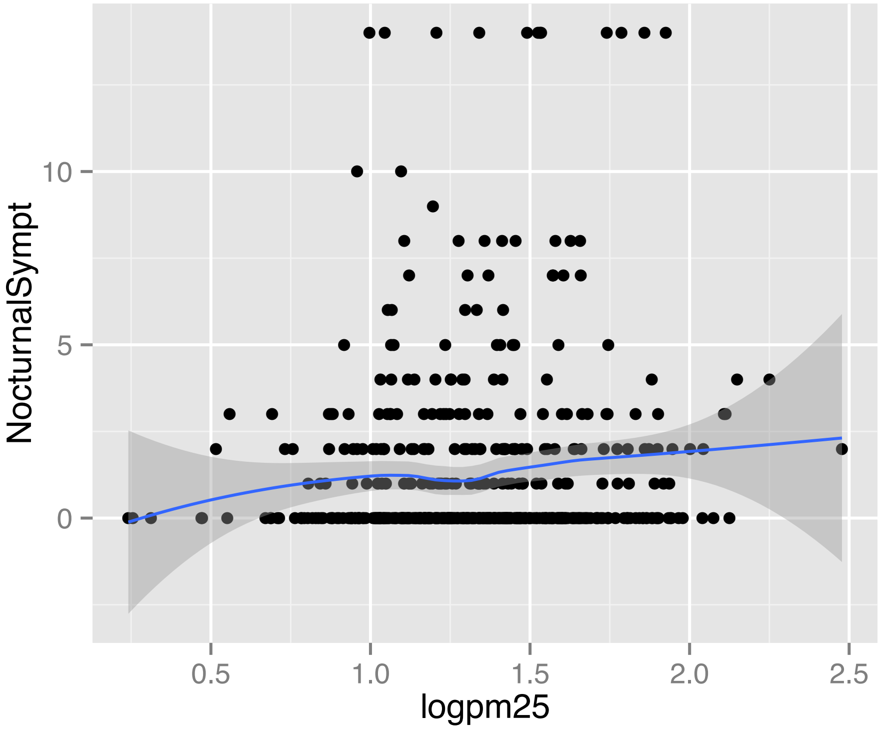
Auto-print plot object without saving

First Plot with Point Layer

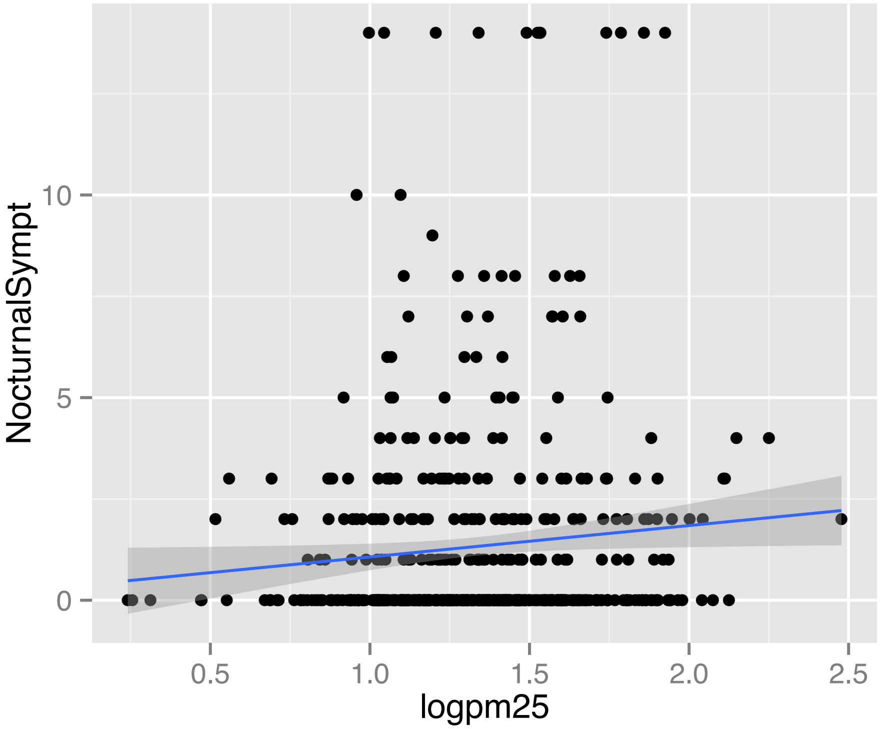


```
g <- ggplot(maacs, aes(logpm25, NocturnalSympt))
g + geom_point()
```

Adding More Layers: Smooth

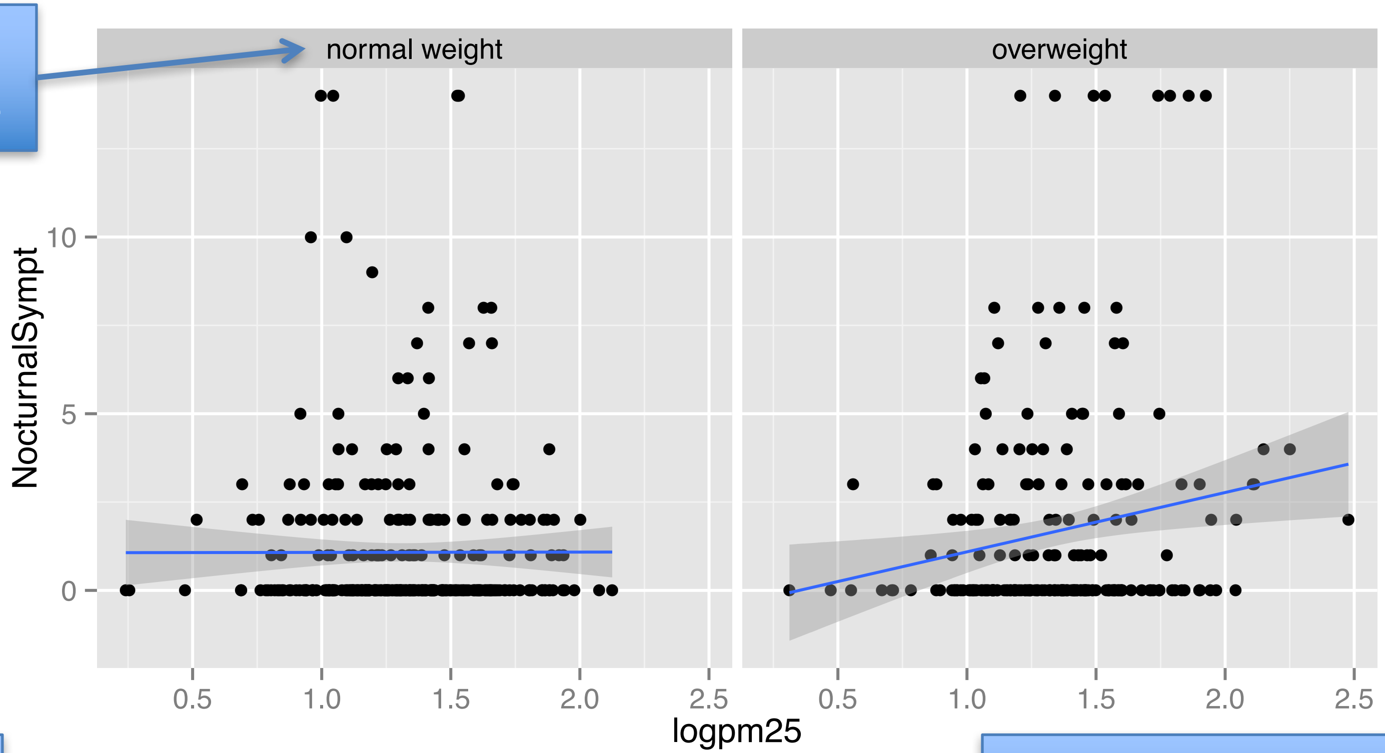


```
g + geom_point() + geom_smooth()
```



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

Adding More Layers: Facets



Labels from facet variable

Add facets

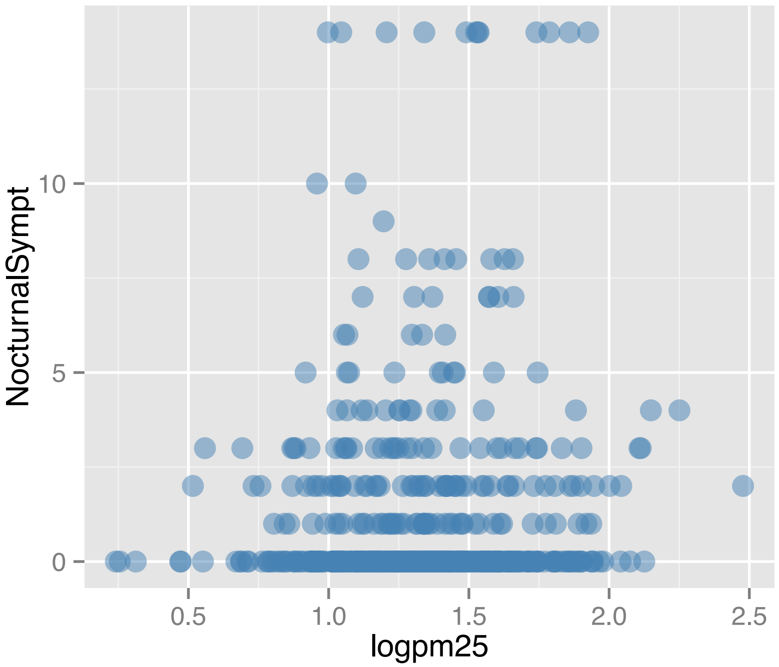
Faceting (factor) variable

```
g + geom_point() + facet_grid(. ~ bmicat) + geom_smooth(method = "lm")
```

Annotation

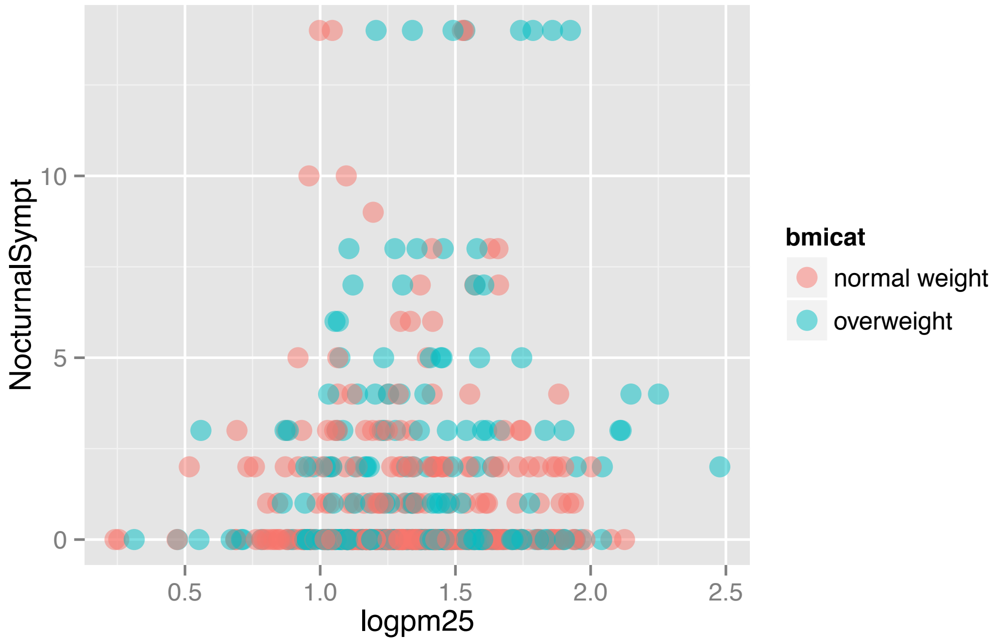
- Labels: xlab(), ylab(), labs(), ggtitle()
- Each of the “geom” functions has options to modify
- For things that only make sense globally, use theme()
  - Example: theme(legend.position = "none")
- Two standard appearance themes are included
  - theme_gray(): The default theme (gray background)
  -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

Modifying Aesthetics



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

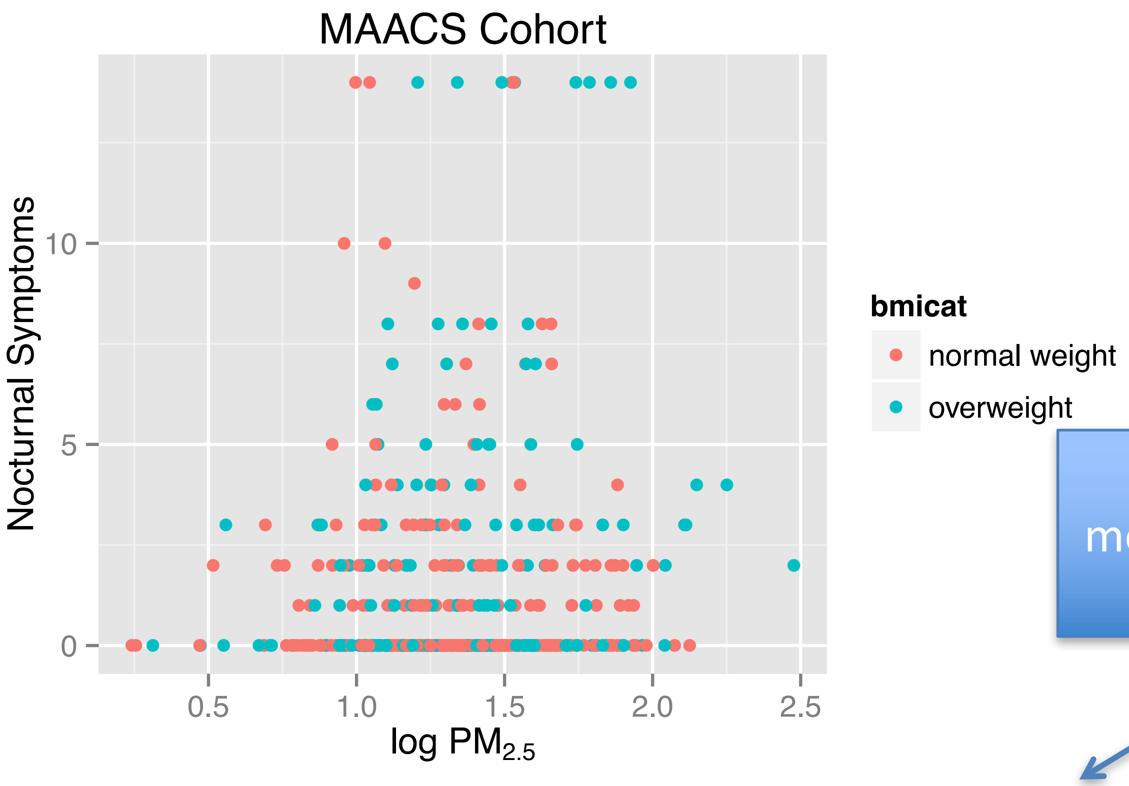
Constant values



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

Data variable

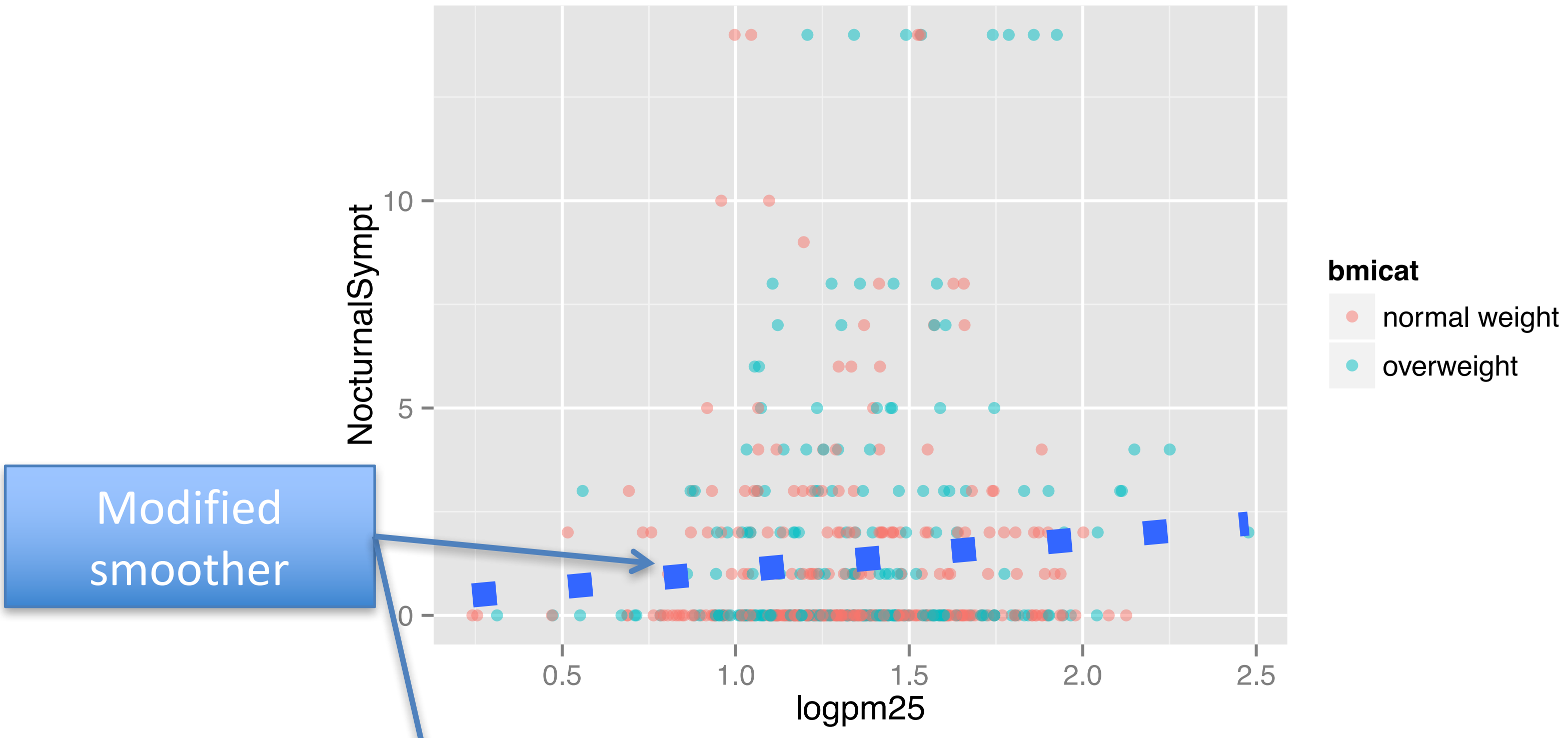
Modifying Labels



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

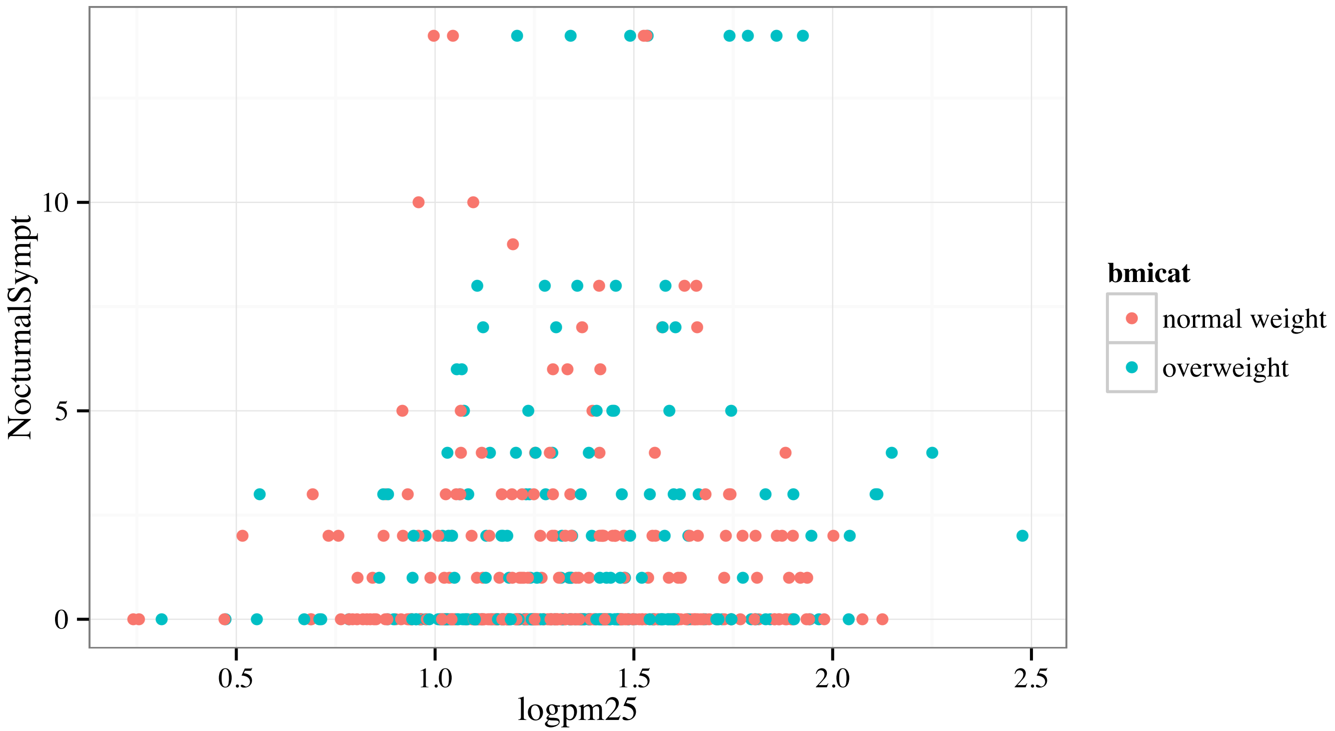
```
g + geom_point(aes(color = bmicat)) + labs(title = "MAACS Cohort") + labs(x = expression("log
" * PM[2.5]), y = "Nocturnal Symptoms")
```

Customizing the Smooth



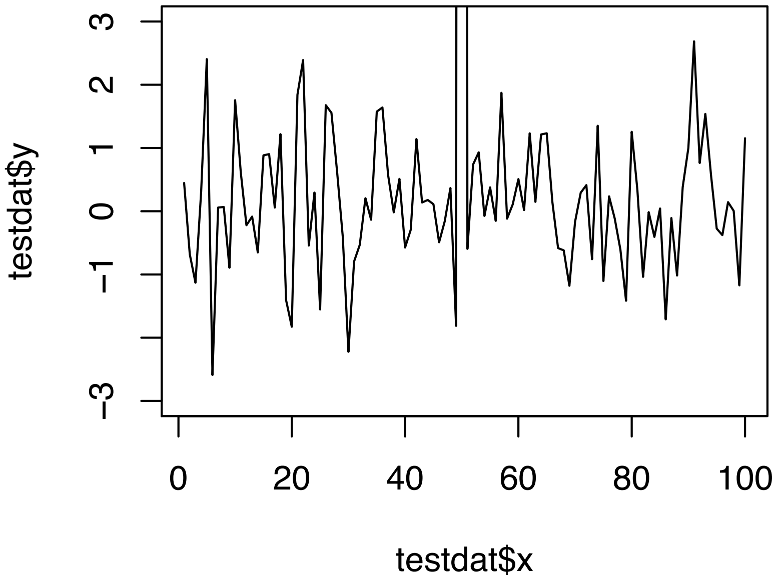
```
g + geom_point(aes(color = bmicat), size = 2, alpha = 1/2) +
geom_smooth(size = 4, linetype = 3, method = "lm", se = FALSE)
```

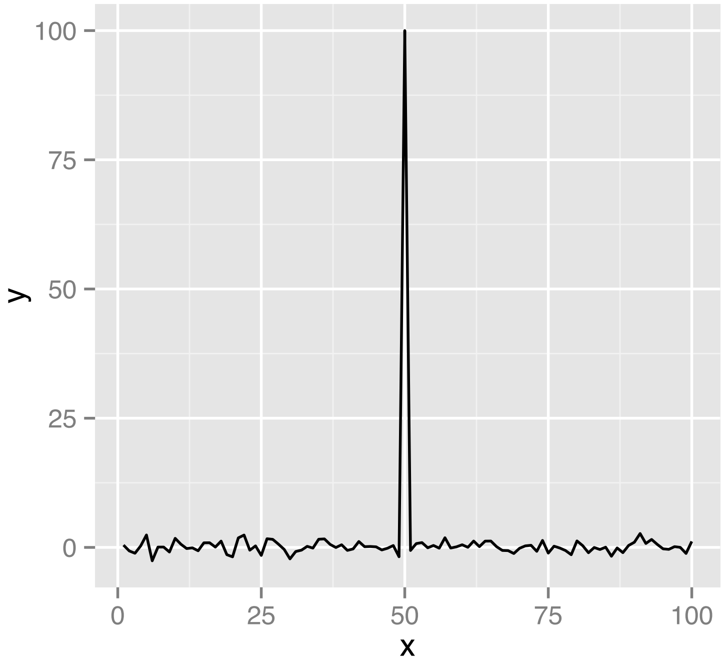
Changing the Theme



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

A Notes about Axis Limits



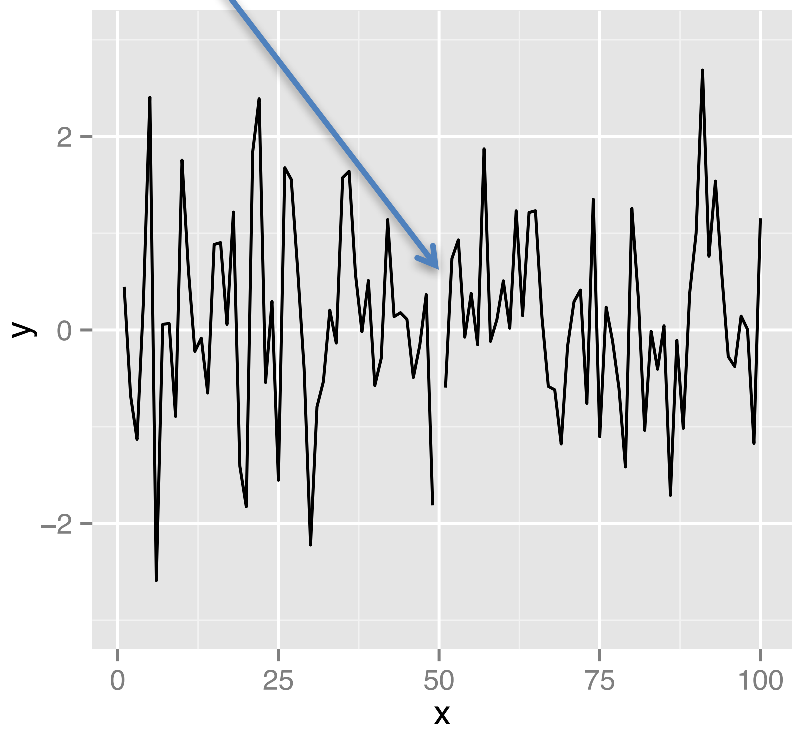


```
testdat <- data.frame(x = 1:100, y = rnorm(100))
testdat[50,2] <- 100  ## Outlier!
plot(testdat$x, testdat$y, type = "l", ylim = c(-3,3))
```

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

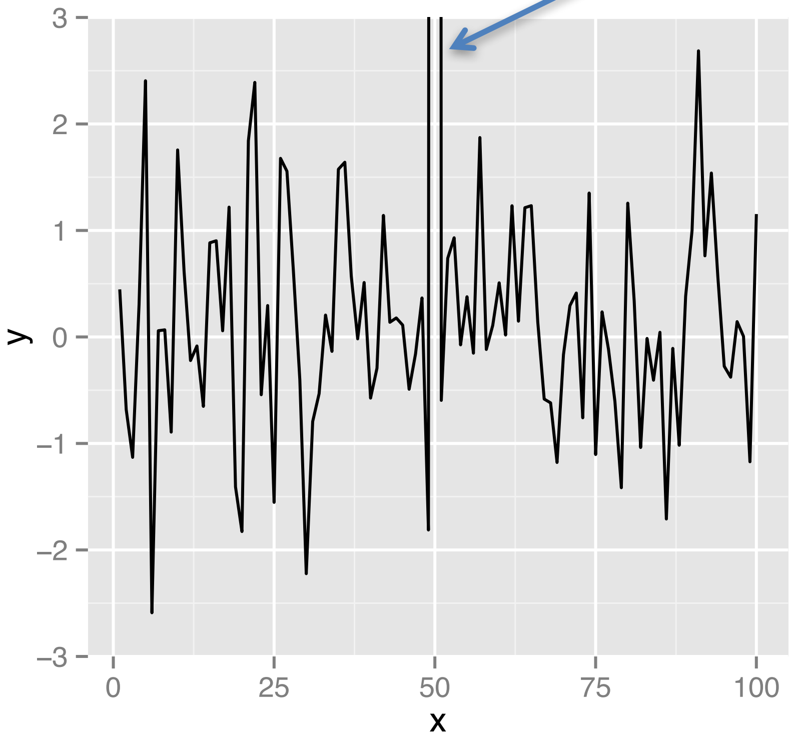
Axis Limits

Outlier missing



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

Outlier included



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

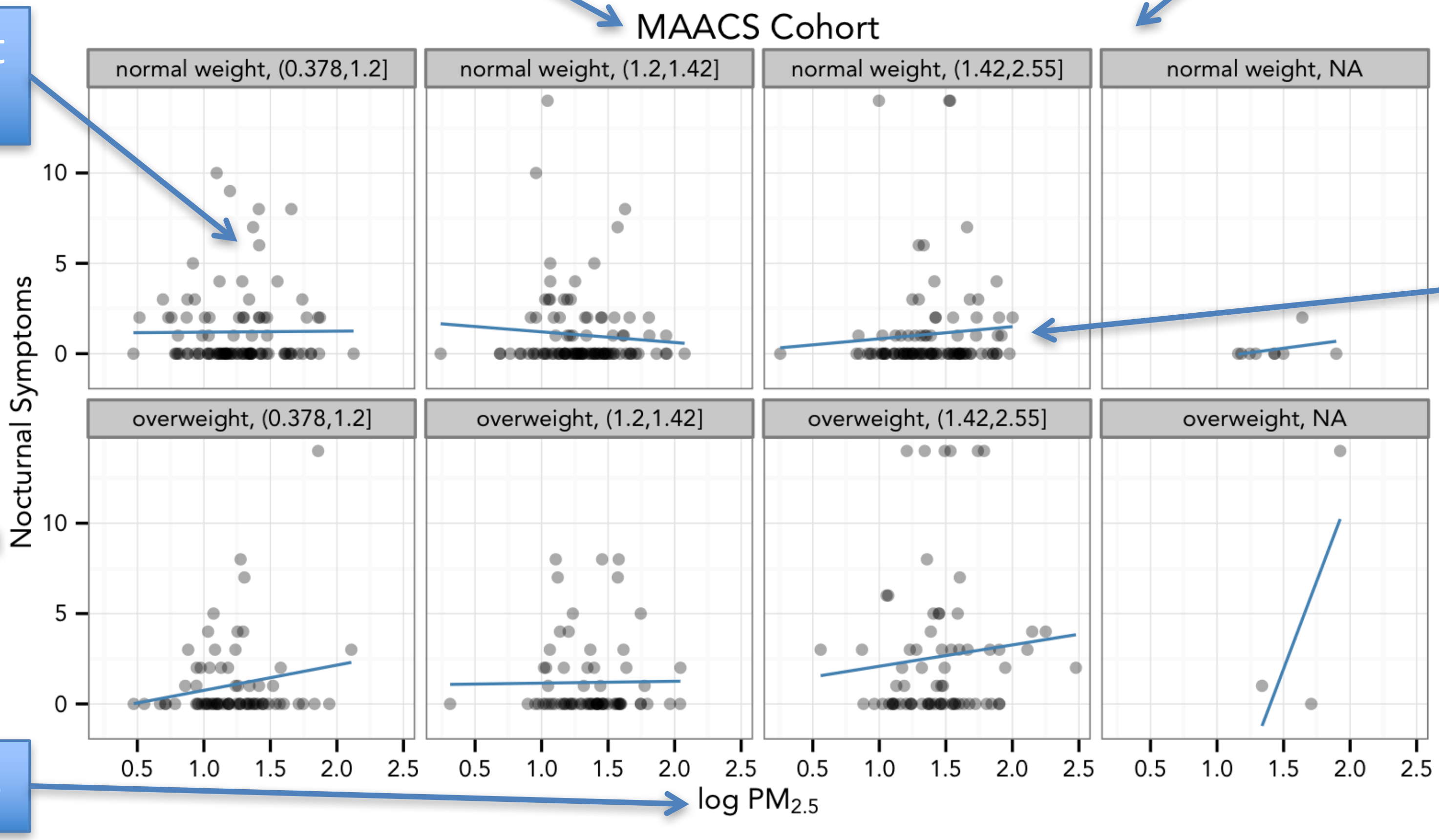
More Complex Example

- 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 NO2 categorical so we can condition on it in the plotting
  - Use the cut() function for this

Making NO$_2$ Tertiles

```
## Calculate the deciles of the data
> cutpoints <- quantile(maacs$logno2_new, seq(0, 1, length = 4), 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] "(0.378,1.2]" "(1.2,1.42]"  "(1.42,2.55]”
```

Final Plot



Non-default font

Multiple panels

Transparent points

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

Add smoother

Make panels

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)