



3. Plotting functions and formulas

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In this session

R is known for having good graphics – good for data exploration and summary, as well as illustrating analyses. Here, we will see;

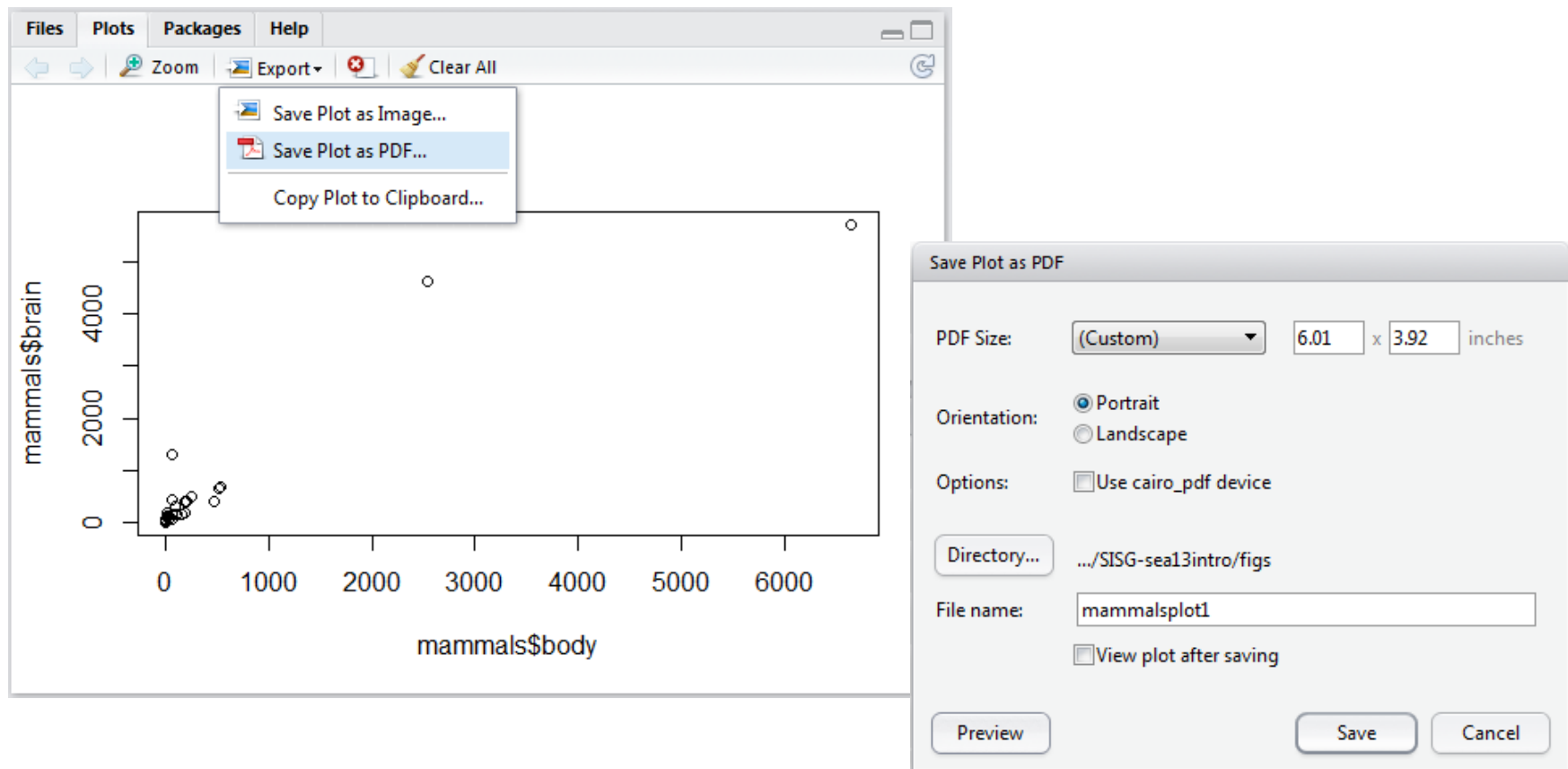
- Some *generic* plotting commands
- Making graphics files
- Fine-tuning your plots (and why not to do too much of this)
- The formula syntax

NB more graphics commands will follow, in the next session.

Making a scatterplot with `plot()`

A first example, using the `mammals` dataset – and its output in the Plot window; (The preview button is recommended)

```
plot(x=mammals$body, y=mammals$brain)
```



Making a scatterplot with `plot()`

Some other options for exporting;

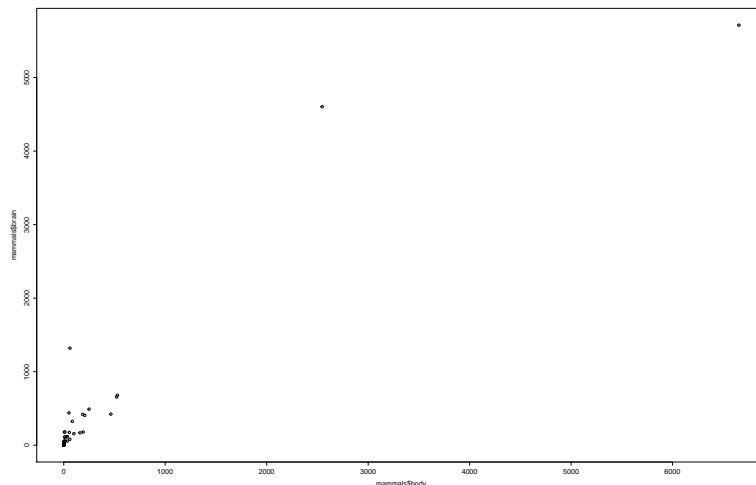
- Copy directly to clipboard as a bitmap or editable (Windows) metafile - then paste into e.g. your Powerpoint slides
- With 'Save Plot as Image', PNG is a (good) bitmap format, suitable for line art, i.e. graphs. JPEG is good for photos, not so good for graphs
- For PNG/JPEG, previews disappear if they get too large!
- Many of the options (TIFF, EPS) are seldom used, today
- Handy hint; if too much re-sizing confuses your graphics device (i.e. the Plot window) enter `dev.off()` and just start over

Making a scatterplot with `plot()`

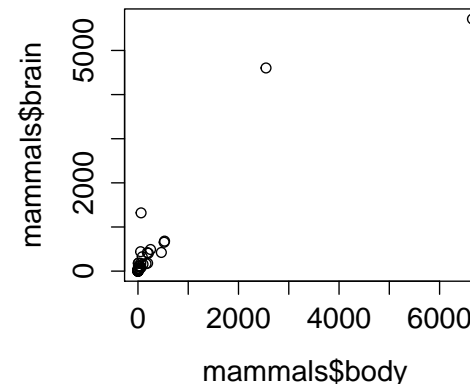
A golden rule for exporting;

Make the file the size it will be in the final document –
because R is good at choosing font sizes

A 6:4 plot, saved
at 24 × 16 inches



The same plot,
saved at 4 × 2.67 inches



- Not the same plot ‘blown up’ – note e.g. axes labels
- R likes to add white space around the edges – good in documents, less good in slides, depending on your software

Making a scatterplot with `plot()`

Better axes, better axis labels and a title would make the scatterplot better. But on looking up `?plot...`

“For simple scatter plots, `plot.default` will be used. However, there are `plot` methods for many R objects, including functions, `data.frames`, density objects, etc. Use `methods(plot)` and the documentation for these.”

`plot()` is a *generic* function – it does different things given different input; see `methods(plot)` for a full list. For our plot of `y` vs `x`, the details we need are in `?plot.default...`

```
plot(x, y = NULL, type = "p", xlim = NULL, ylim = NULL,  
     log = "", main = NULL, sub = NULL, xlab = NULL, ylab = NULL,  
     ann = par("ann"), axes = TRUE, frame.plot = axes,  
     panel.first = NULL, panel.last = NULL, asp = NA, ...)
```

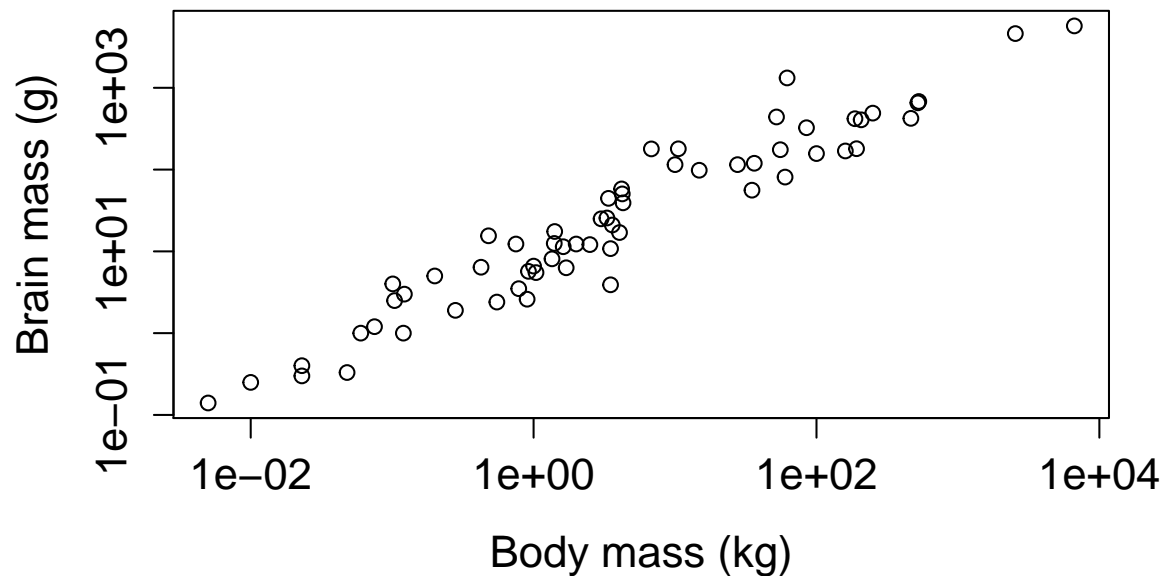
Making a scatterplot with `plot()`

After checking the help page to see what these mean, we use;

- `xlab`, `ylab` for the axis labels
- `main` for the main title
- `log` to log the axes – `log="xy"`, to log them both

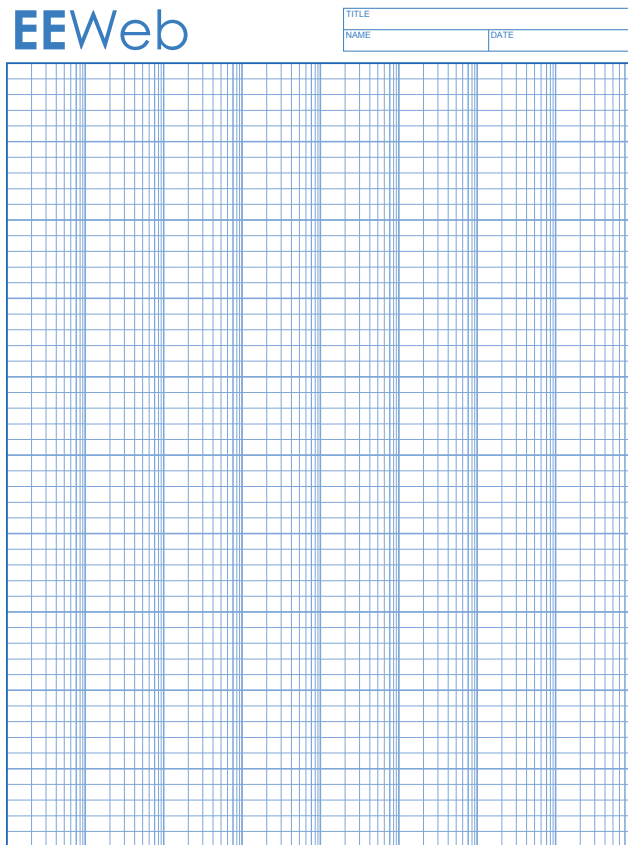
```
plot(x=mammals$body, y=mammals$brain, xlab="Body mass (kg)",  
     ylab="Brain mass (g)", main="Brain and body mass, for 62 mammals",  
     log="xy")
```

Brain and body mass, for 62 mammals

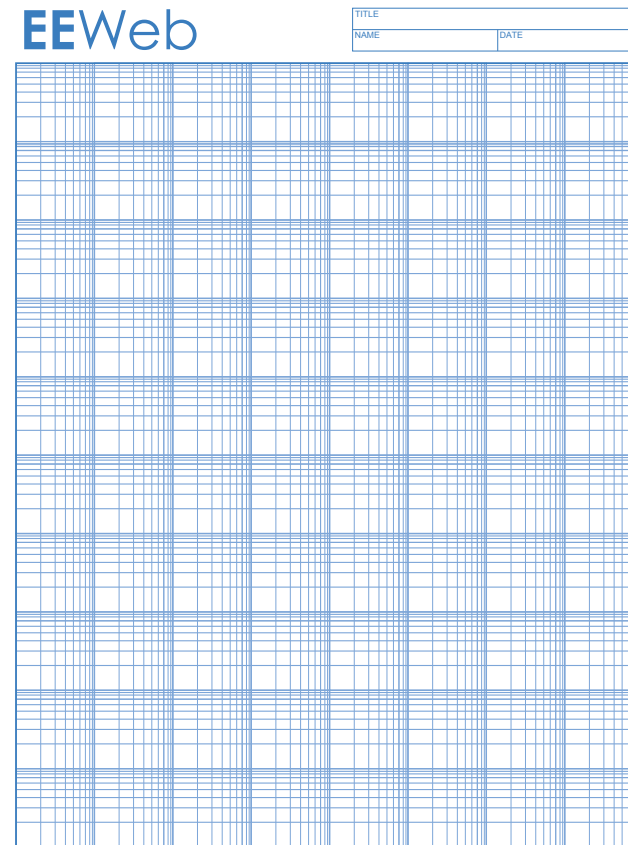


Making a scatterplot with `plot()`

For those with historical interests (or long memories);



$\log="x"$
Semi-log graph paper

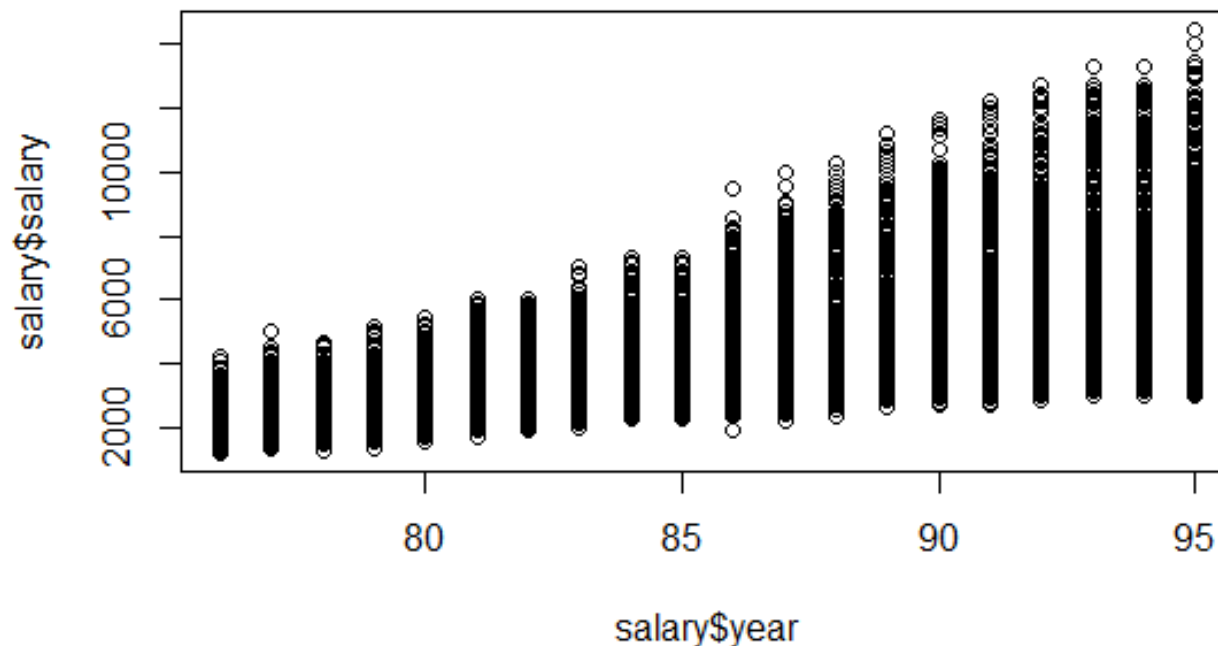


$\log="xy"$
Log-log graph paper

Other plots made with `plot()`

As the help file suggests, `plot()` gives different output for different types of input. First, another scatterplot;

```
plot(x=salary$year, y=salary$salary)
```



Tip: export graphs of large datasets as PNG, not PDF or JPEG.

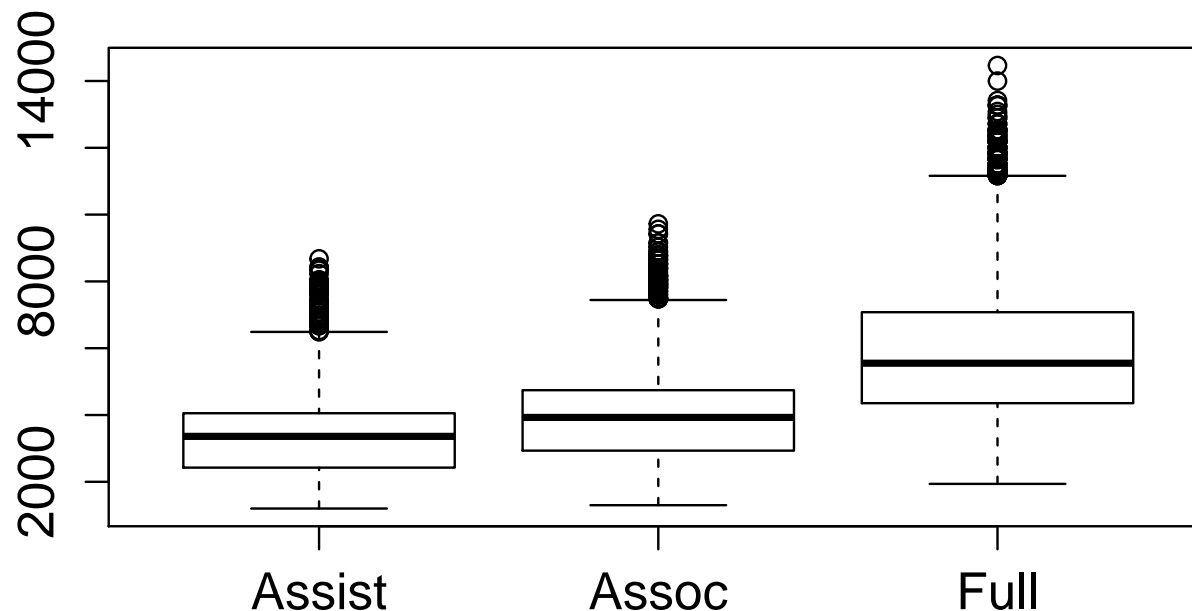
Other plots made with `plot()`

Plotting a numeric variable against a character gives an error;

```
> plot(x=salary$rank, y=salary$salary)
Error in plot.window(...) : need finite 'xlim' values
```

Could use `x=as.factor(salary$rank)`, but gets tiresome. Instead:

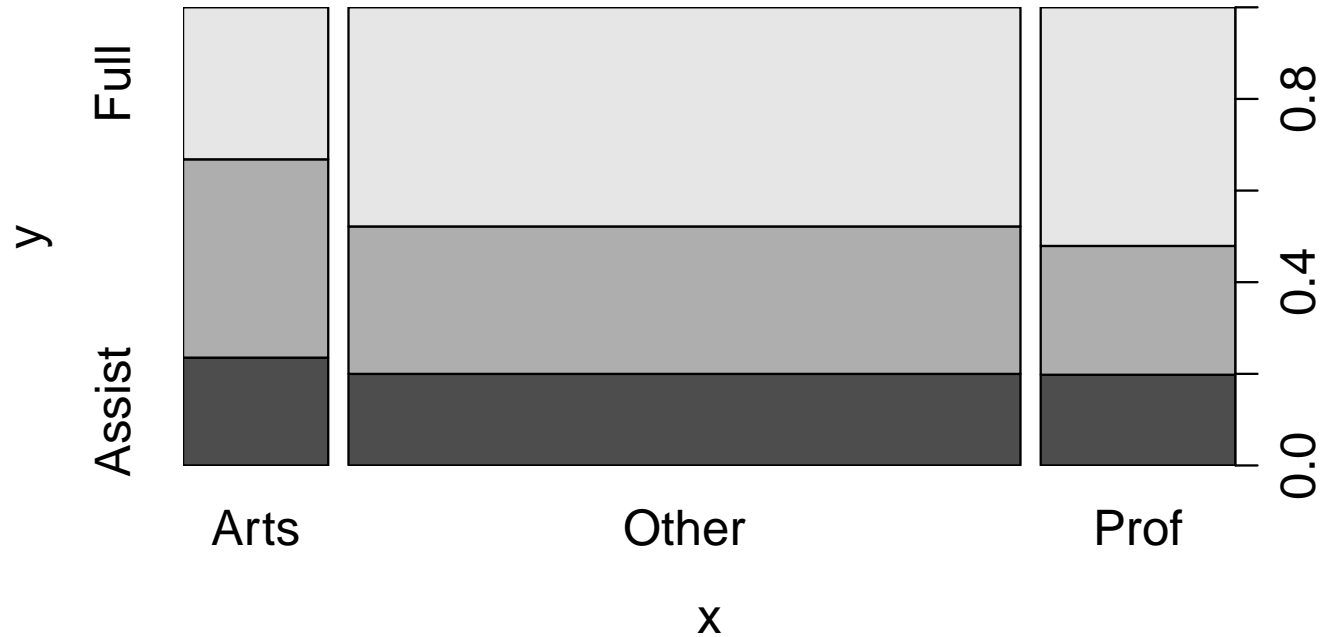
```
salary <- read.csv("http://faculty.washington.edu/kenrice/rintro/salary.csv",
                  stringsAsFactors = TRUE)
plot(x=salary$rank, y=salary$salary)
```



There is also a `boxplot()` function.

Other plots made with `plot()`

Plotting one factor variable against another;
`plot(x=salary$field, y=salary$rank)`

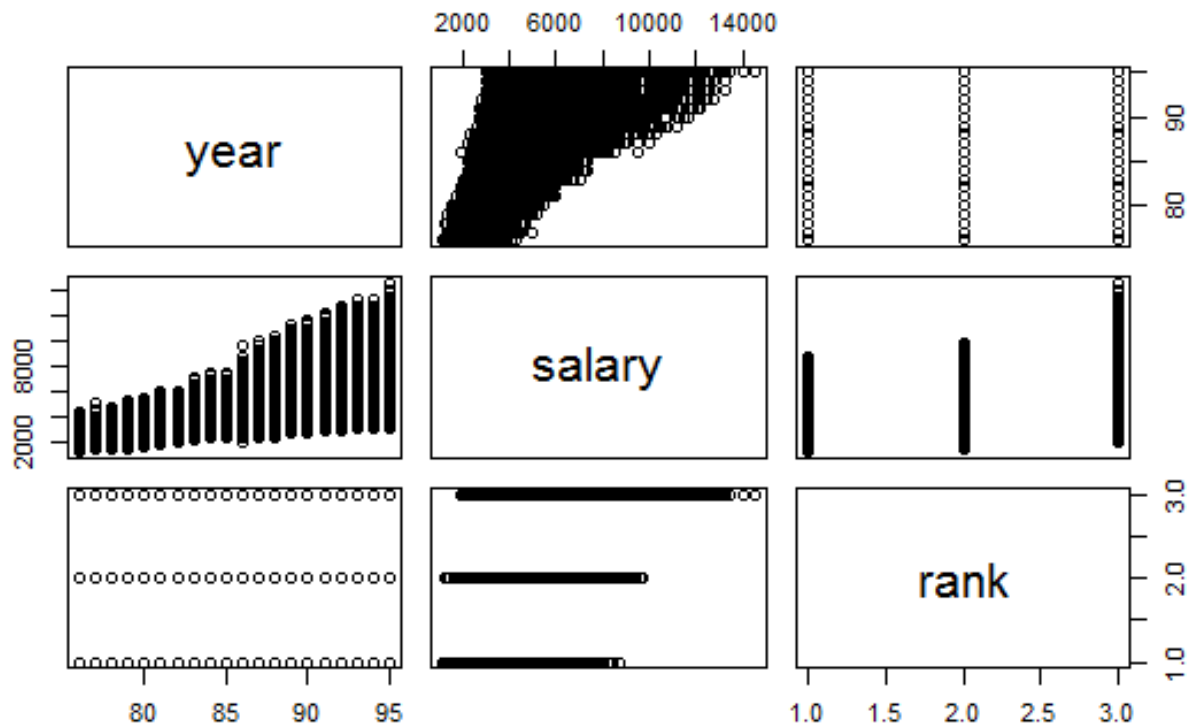


This is a *stacked barplot* – see also the `barplot()` function

Other plots made with `plot()`

Plotting an entire data frame (not too many columns)

```
smallsalary <- salary[,c("year", "salary", "rank")]  
plot(smallsalary)
```



Not so clever! But quick, & okay if all numeric – see also `pairs()`.
NB Plotting functions for large datasets are in later sessions.

Other graphics commands

For histograms, use `hist()`;

```
hist(salary$salary, main="Monthly salary", xlab="salary")
```

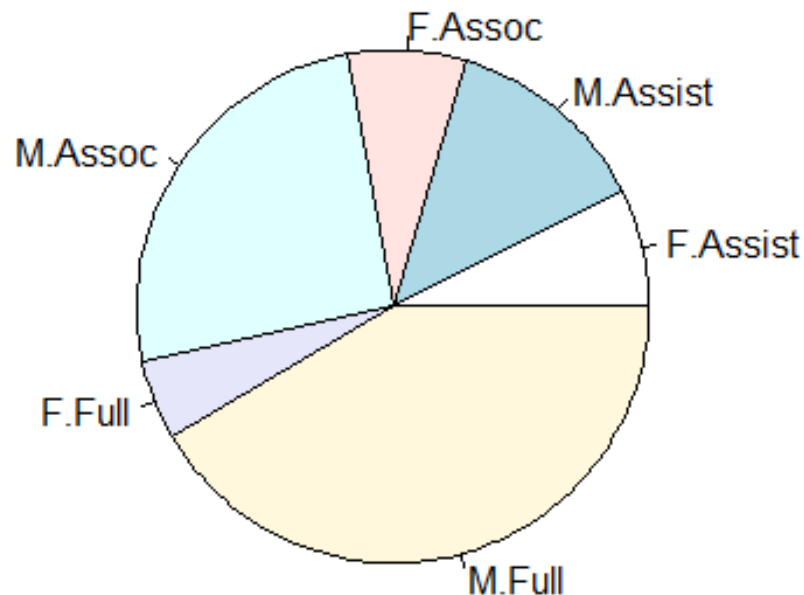


For more control, set argument `breaks` to *either* a number, or a vector of the breakpoints.

Other graphics commands

Please tell no-one I told you this one;

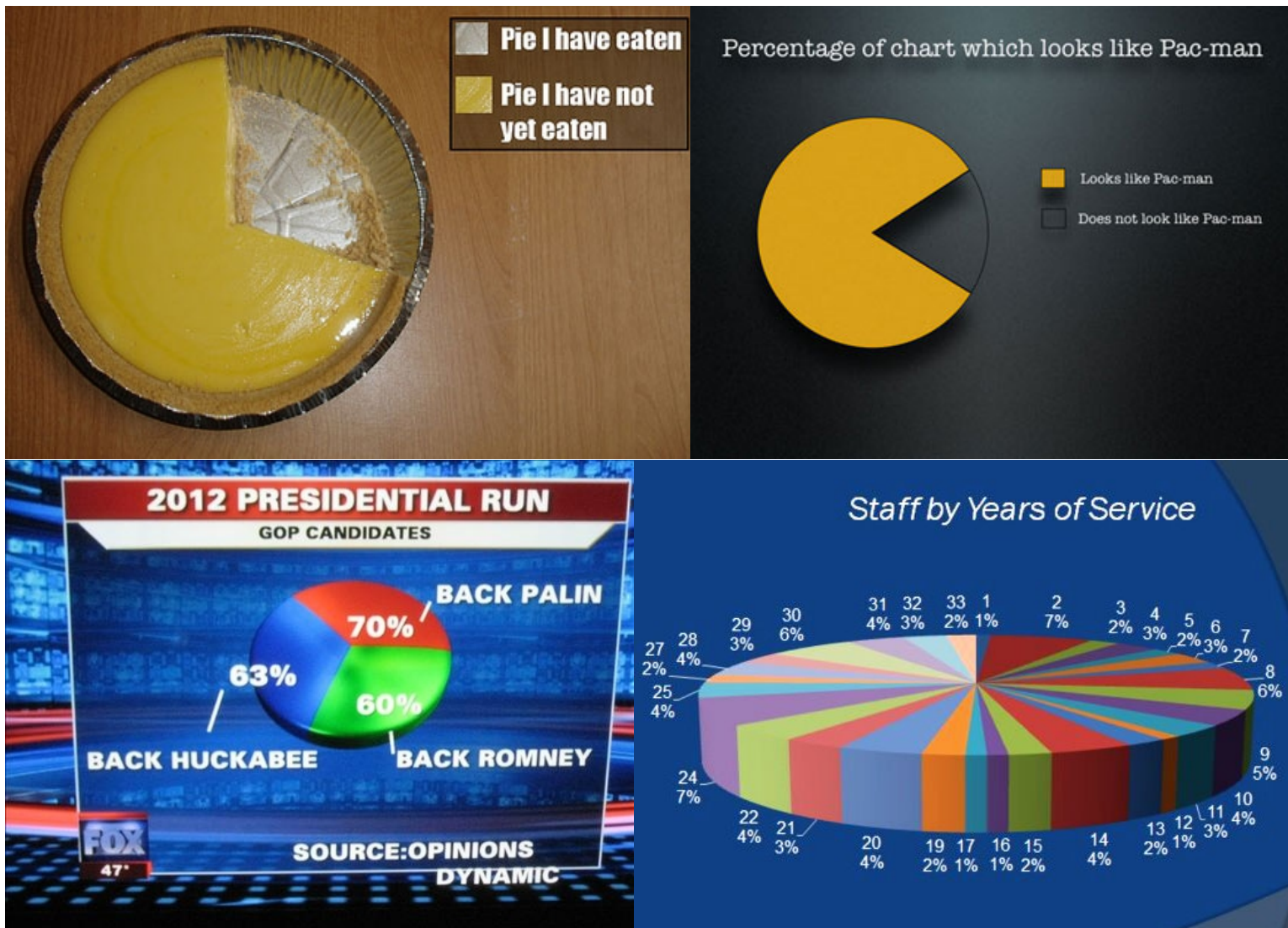
```
> table( interaction(salary$gender, salary$rank) )  
F.Assist M.Assist F.Assoc M.Assoc F.Full M.Full  
  1460    2588   1465   5064   1001   8210  
> pie( table( interaction(salary$gender, salary$rank) ) )
```



Why do statisticians hate pie charts with such passion?

Other graphics commands

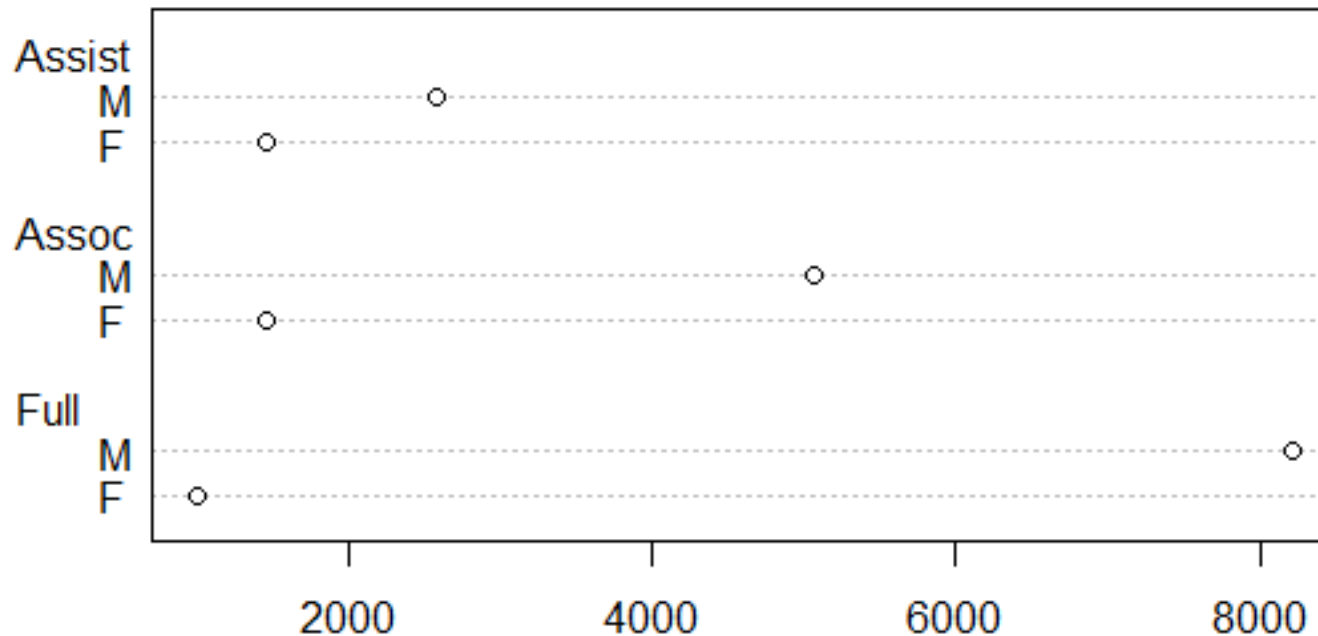
... they really do!



Other graphics commands

Because pie charts are usually a terrible way to present data. Dotcharts can be *much* better – and are also easy to code;

```
dotchart(table( salary$gender, salary$rank ) )
```

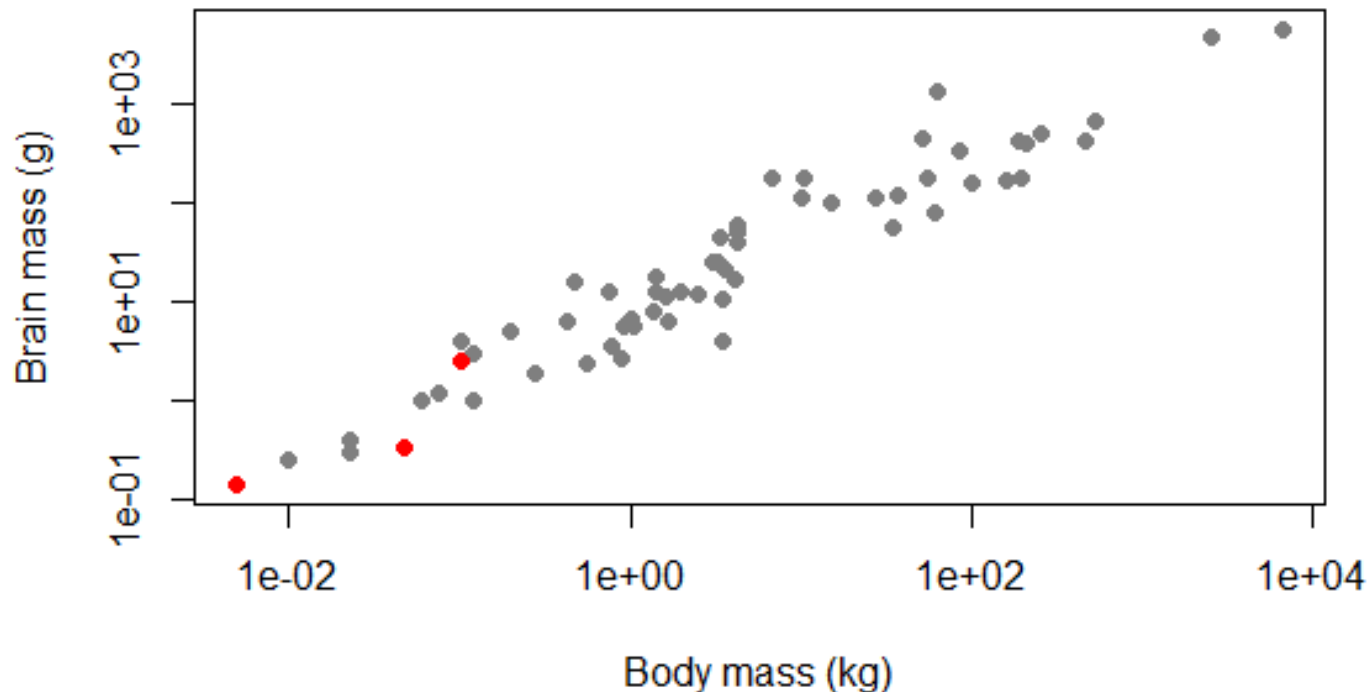


See also `stripchart()`; with multiple symbols per line, these are a good alternative to boxplots, for small samples.

Changing plotting symbols

Suppose you want to highlight certain points on a scatterplot; other options to the `plot()` command change point style & color;

```
> grep("shrew", mammals$species) # or just look in Data viewer
[1] 14 55 61
> is.shrew <- 1:62 %in% c(14,55,61) # 3 TRUEs and 59 FALSEs
> plot(x=mammals$body, y=mammals$brain, xlab="Body mass (kg)",
+      ylab="Brain mass (g)", log="xy",
+      col=ifelse(is.shrew, "red", "gray50"), pch=19)
```



Changing plotting symbols

We used `col=ifelse(is.shrew, "red", "gray50")` – a vector of 3 reds and 59 gray50s.

- If we supply fewer colors than datapoints, what we supplied is recycled
- You could probably guess "red", "green", "purple" etc, but not "gray50". To find out the names of the (many) available R colors, use the `colors()` command – no arguments needed
- Can also specify colors by numbers; 1=black, 2=red, 3=green up to 8, then it repeats
- Or consult [this online chart](#) – or many others like it
- Can also supply colors by hexadecimal coding; #RRGGBB for red/green/blue – with #RRGGBBTT for transparency – or `useadjustcolor()`

NB legends will follow, in the next session.

Changing plotting symbols

We also used `pch=19` – to obtain the same non-default plotting symbol, a filled circle. (`pch`: plot character)

The full range;

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
○ △ + × ◇ ▽ ☒ * ⋈ ⊕ ⊗ ⊞ ⊠ ⊡ ⊢ ⊣ ⊤ ⊥ ⊦ ⊧ ⊨ ⊩ ⊪ ⊫ ⊬ ⊭ ⊮ ⊯ ⊰ ⊱ ⊲ ⊳ ⊴ ⊵ ⊶ ⊷ ⊸ ⊹ ⊺ ⊻ ⊼ ⊽ ⊾ ⊿ ⊿

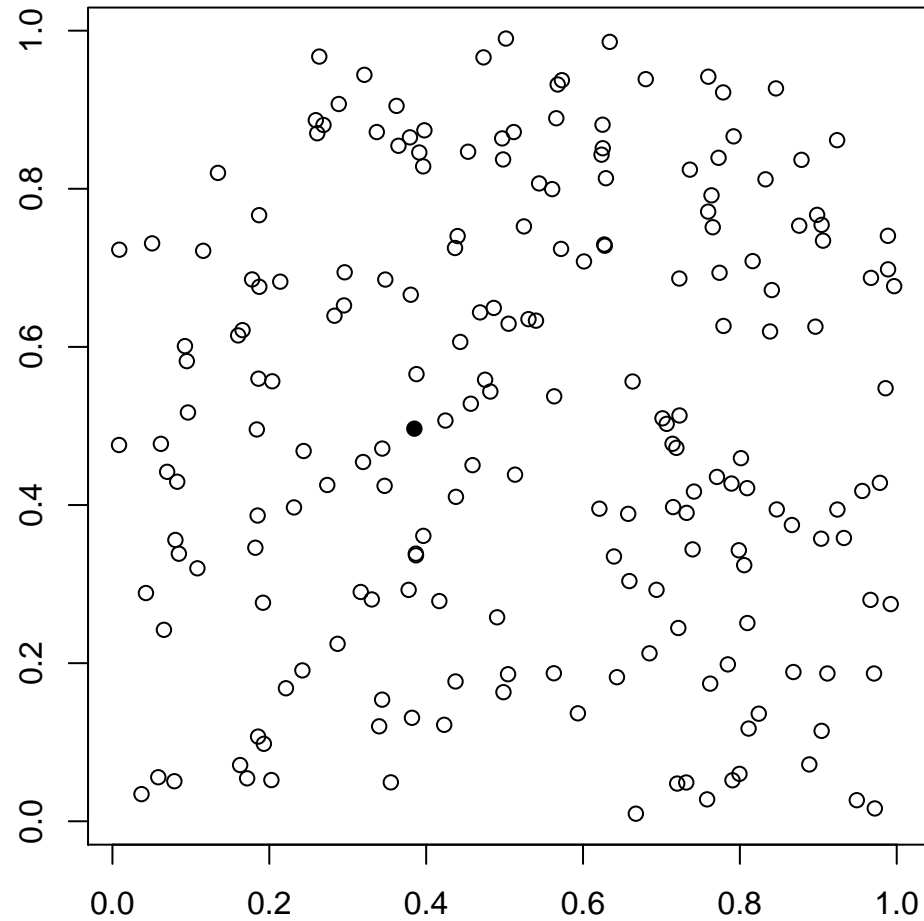
- Set the fill color for 21:25 with the `bg` argument
- The open circle (`pch=1`) is the default – because it makes it easiest to see points that nearly overlap. Change it only if you have a good reason to
- Filled symbols 15:20 work well with transparent colors, e.g. `col="#FF000033"` for translucent pink

For different size symbols, there is a `cex` option (`cex`: character expansion); `cex=1` is standard size, `cex=1.5` is 50% bigger, etc.

But beware! These options should be used *sparingly*...

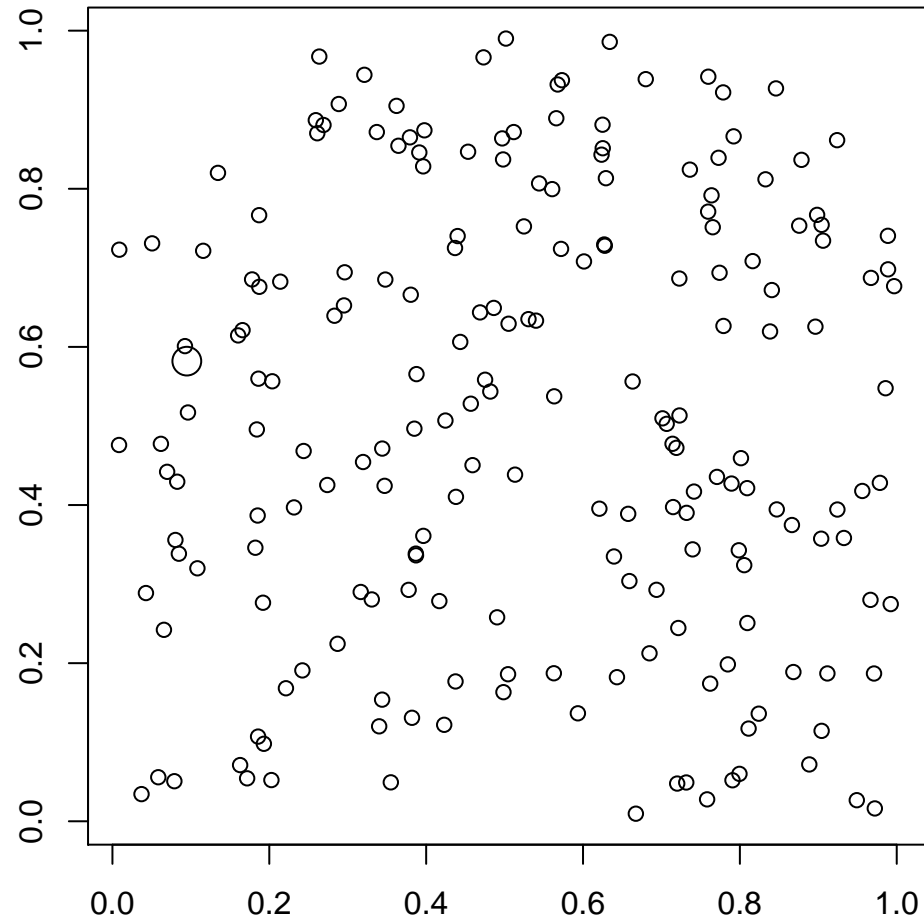
Changing plotting symbols

One of these points is not like the others...



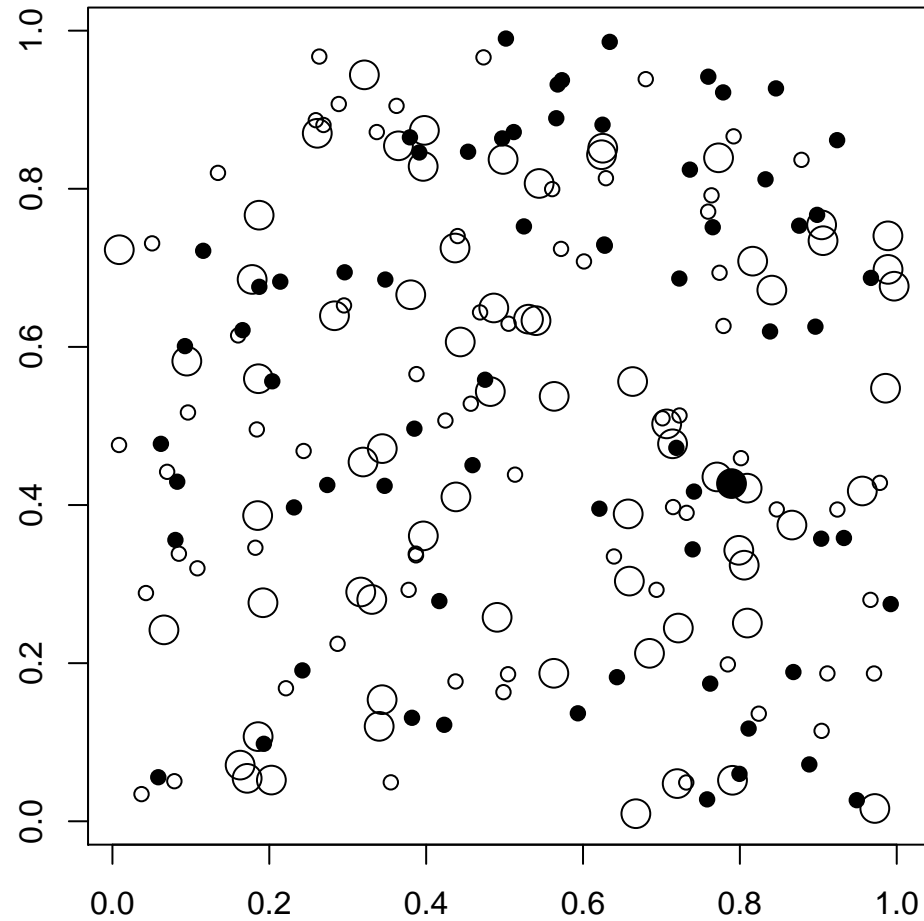
Changing plotting symbols

One of these points is not like the others...



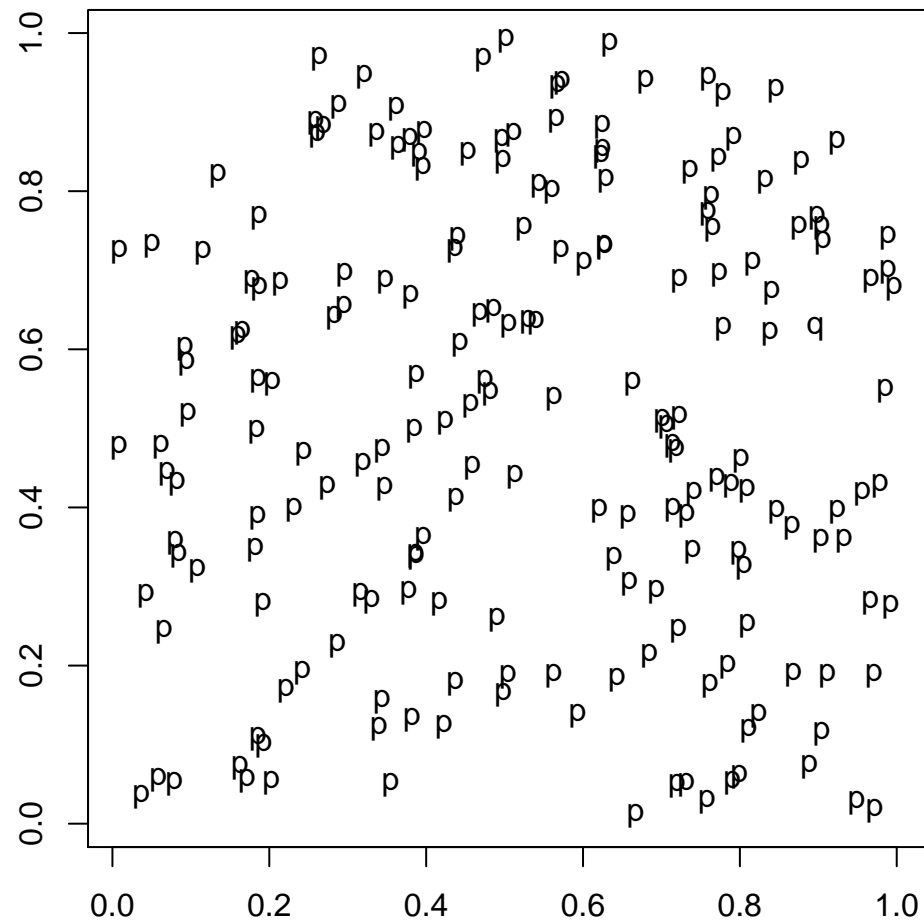
Changing plotting symbols

One of these points is not like the others...



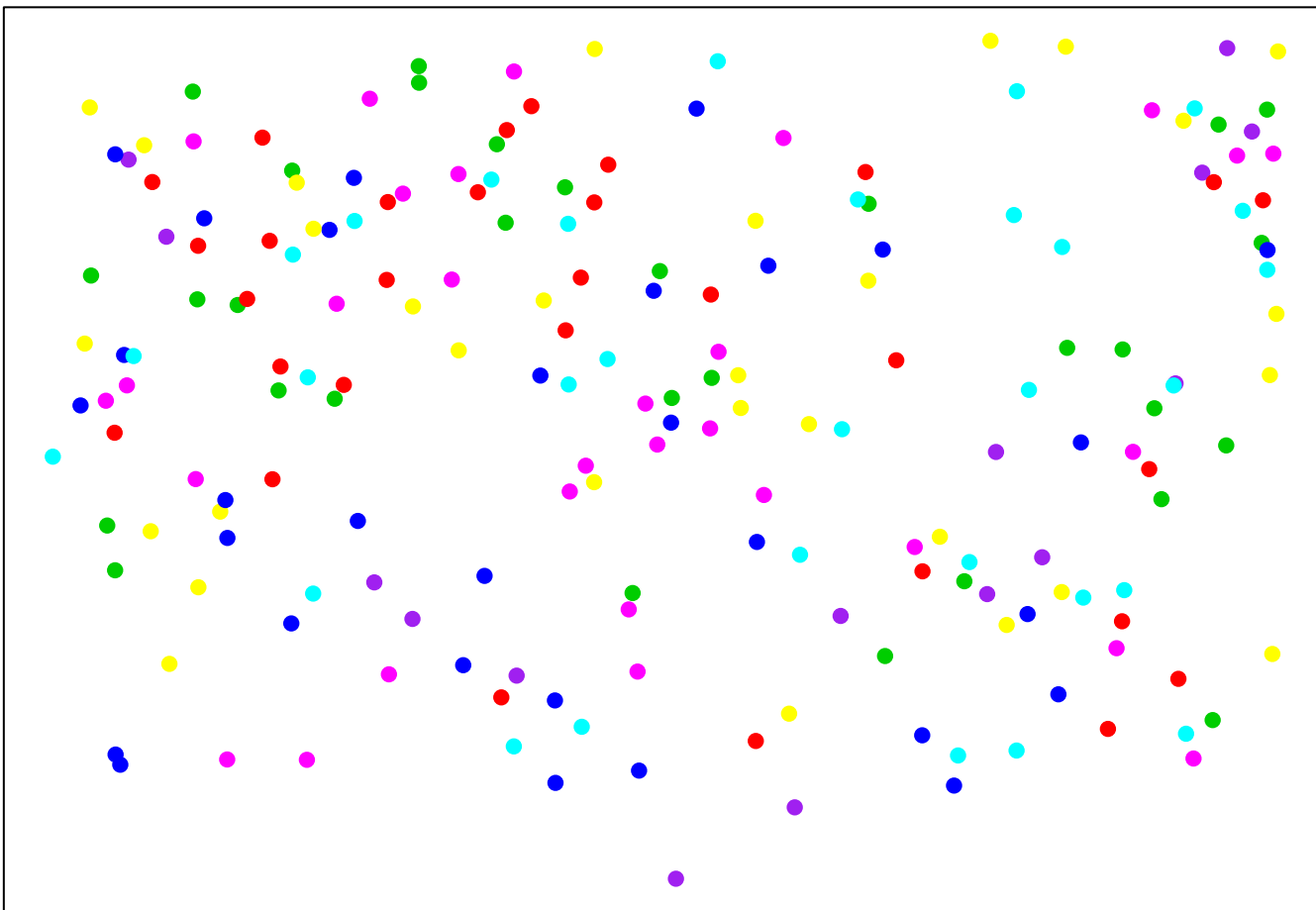
Changing plotting symbols

One of these points is not like the others... (`pch="p"`)



Changing plotting symbols

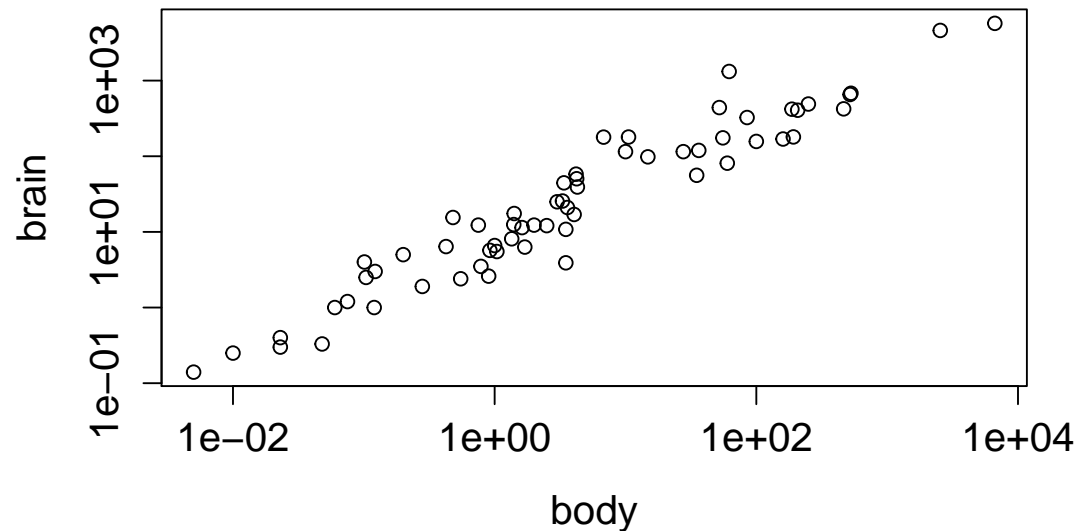
Too many colors (> 4 , say) requires too much attention; what pattern is illustrated here?



Plots via the formula syntax

To make plots, we've used arguments `x` (on the X-axis) and `y` (on the Y-axis). But another method makes a stronger connection to *why* we're making the plot;

```
plot(brain~body, data=mammals, log="xy")
```



“Plot how brain *depends on* body, using the mammals dataset, with logarithmic x and y axes”

Plots via the formula syntax

A few more examples, using the salary dataset;

```
plot(salary~year, data=salary) # scatterplot
plot(salary~rank, data=salary) # boxplot
plot(rank~field, data=salary) # stacked barplot
```

In all of these, $Y \sim X$ can be interpreted as Y depends on X – the ‘tilde’ symbol is R’s shorthand for ‘depends on’.

Statisticians (and scientists) like to think this way;

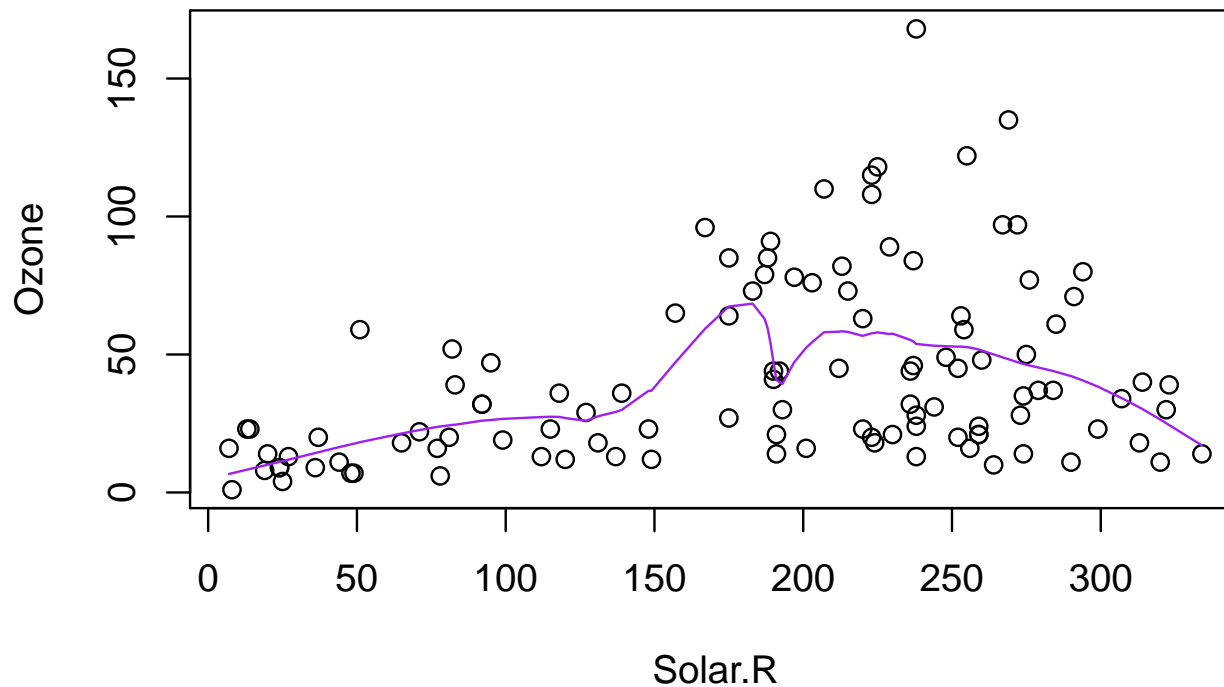
- How does some outcome (Y) depend on a covariate (X)? (a.k.a. a predictor)
- How does a dependent variable (Y) depend on an independent variable (X)?

And how does Y depend on X in observations with the same Z ?

Plots via the formula syntax

To help us illustrate how scientists think, a bit of science;

Ozone is a *secondary pollutant*, produced from organic compounds and atmospheric oxygen, in reactions catalyzed by nitrogen oxides and powered by sunlight. But for ozone concentrations in NY in summer (Y) a smoother (code later) shows a non-monotone relationship with sunlight (X) ...



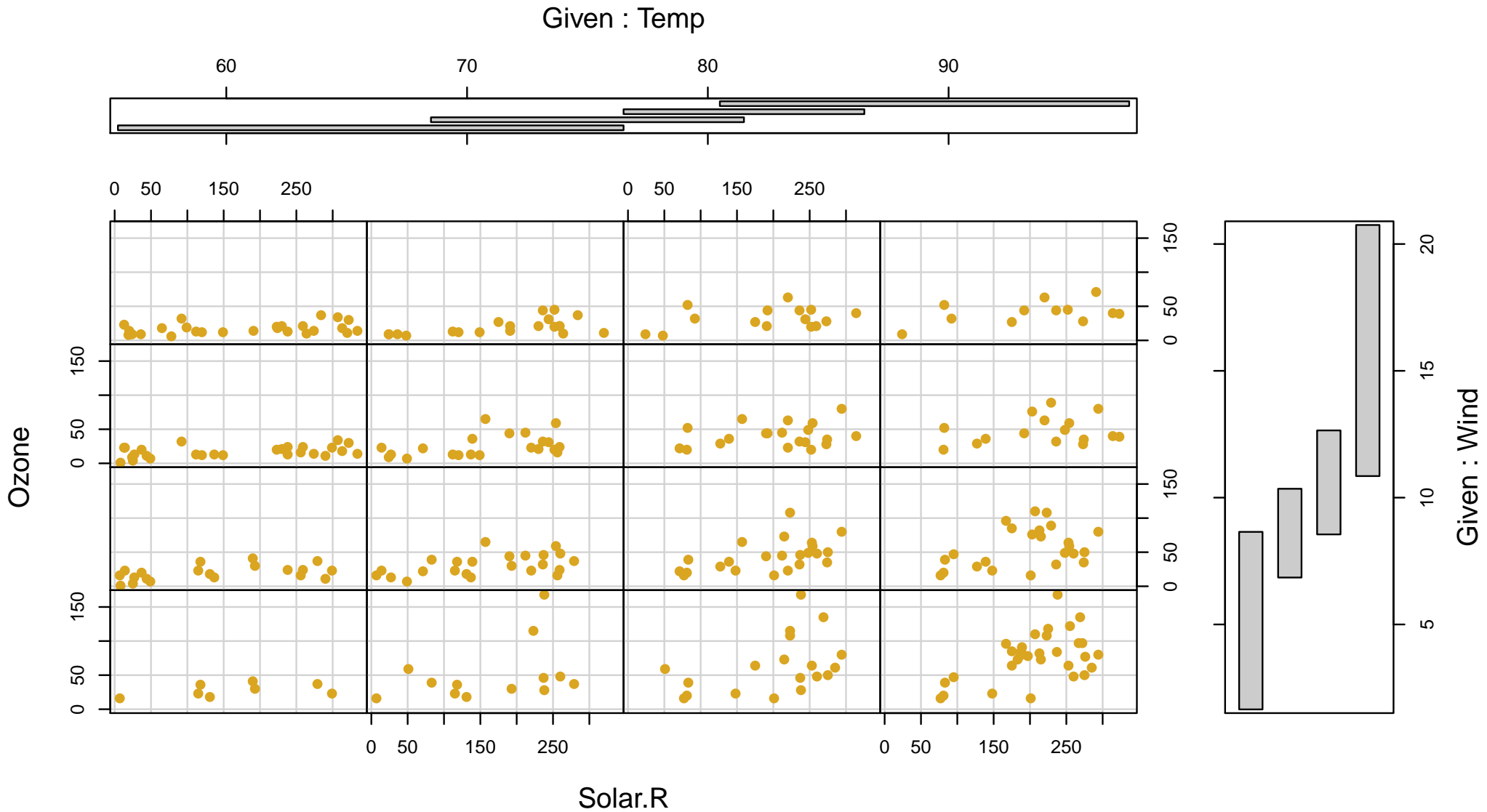
Plots via the formula syntax

Now draw a scatterplot of `Ozone` vs `Solar.R` for various subranges of `Temp` and `Wind`.

```
data("airquality") # using a dataset supplied with R
coplot(Ozone ~ Solar.R | Temp + Wind, number = c(4, 4),
       data = airquality,
       pch = 21, col = "goldenrod", bg = "goldenrod")
```

- The vertical dash ("`|`") means 'given particular values of', i.e. 'conditional on'
- Here, "`+`" means 'and', not 'plus' – see `?formula`, and later sessions
- How does Ozone depend on Solar Radiation, on days with (roughly) the same Temperature *and* Wind Speed?
- ...using the `airquality` data, with a 4×4 layout, with solid dark yellow circular symbols

Plots via the formula syntax



Plots via the formula syntax

What does this show?

- A 4-D relationship is illustrated; the Ozone/sunlight relationship changes in strength depending on both the Temperature and Wind
- The horizontal/vertical 'shingles' tell you which data appear in which plot. The overlap can be set to zero, if preferred
- `coplot()`'s default layout is a bit odd; try setting `rows`, `columns` to different values
- Almost any form of plot can be 'conditioned' in this way – but the commands are in the non-default `lattice` package

NB it is possible to produce 'fake 3D' plots in R – but (on 2D paper) conditioning plots work better!

Summary

- R makes publication-quality graphics, as well as graphics for data exploration and summary
- `plot()` is generic, and adapts to what you give it. There are (necessarily) lots of arguments to consider; colors, plotting symbols, labels, etc
- `hist()`, `boxplot()`, `dotplot()` and `coplot()` offer more functionality
- The formula syntax is a (more) natural way from translate scientific aims to choice of what to plot
- Much more to come! In the next section we'll build up more complex plots