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 wil see;

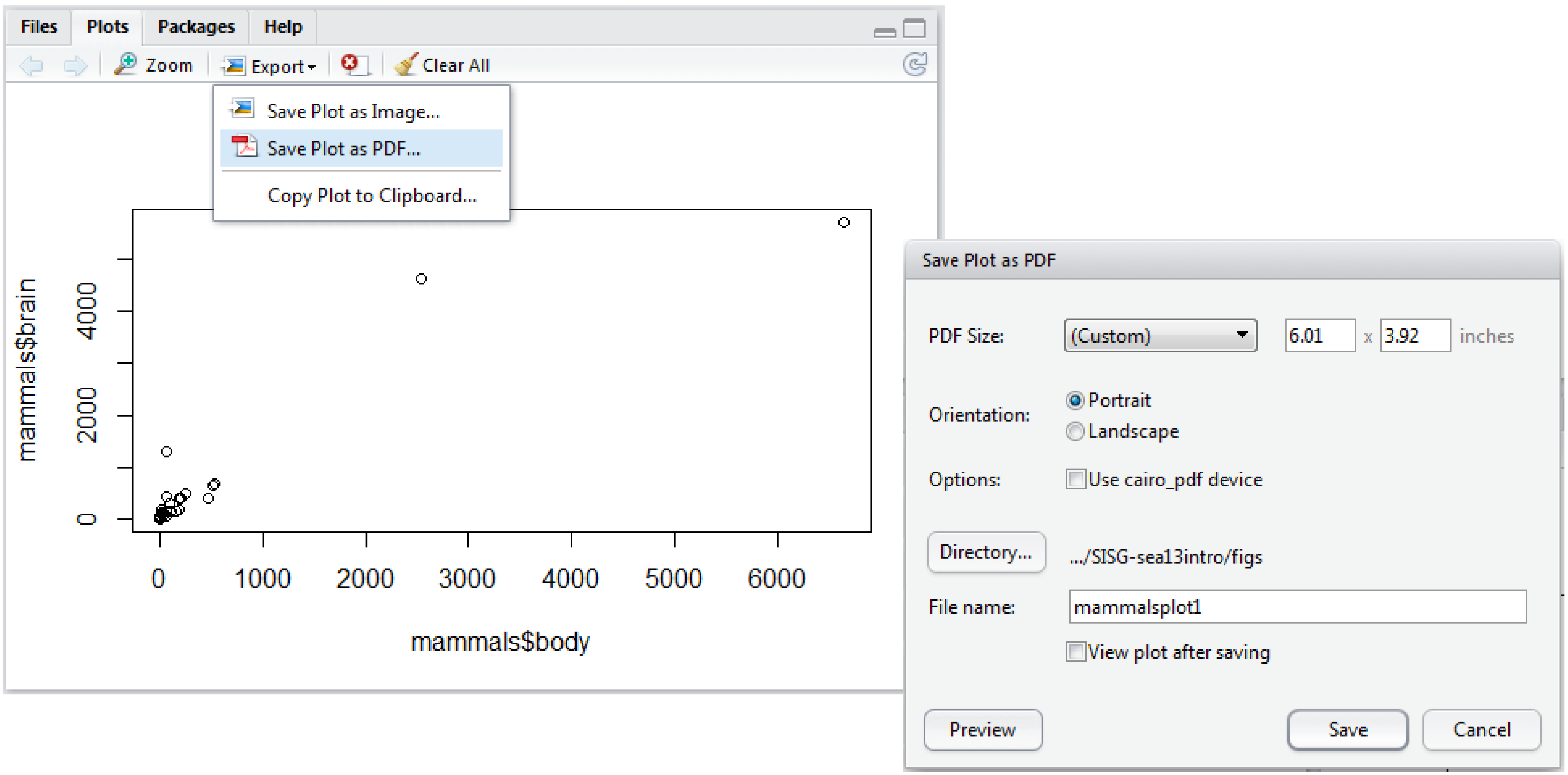
- Some *generic* plotting commands
- Making graphics files
- Fine-tuning your plots (and why not to do too much of this)
- The formula syntax

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;

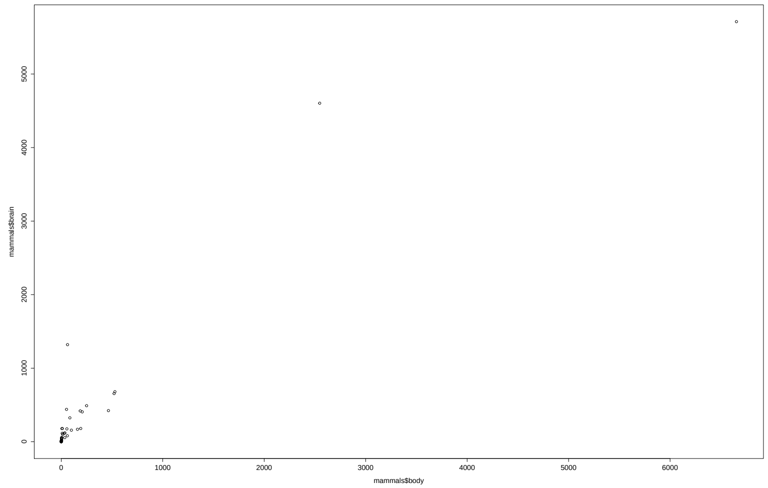
- Copy directly to clipboard as a bitmap or editable (Windows) metafile - then paste into e.g. your Powerpoint slides
- With 'Save Plot as Image', PNG is a (good) bitmap format, suitable for line art, i.e. graphs. JPEG is good for photos, not so good for graphs
- For PNG/JPEG, previews disappear if they 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()`

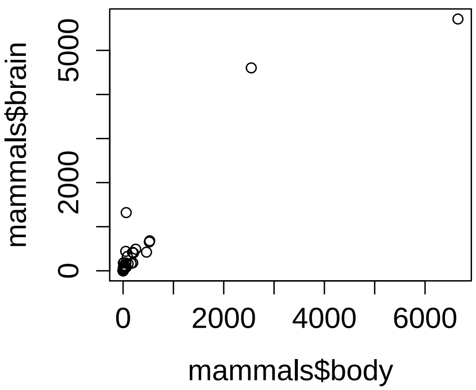
A golden rule for exporting;

> 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 $\times$ 16 inches



The same plot, saved at 4 $\times$ 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.frame`*s,* `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`...

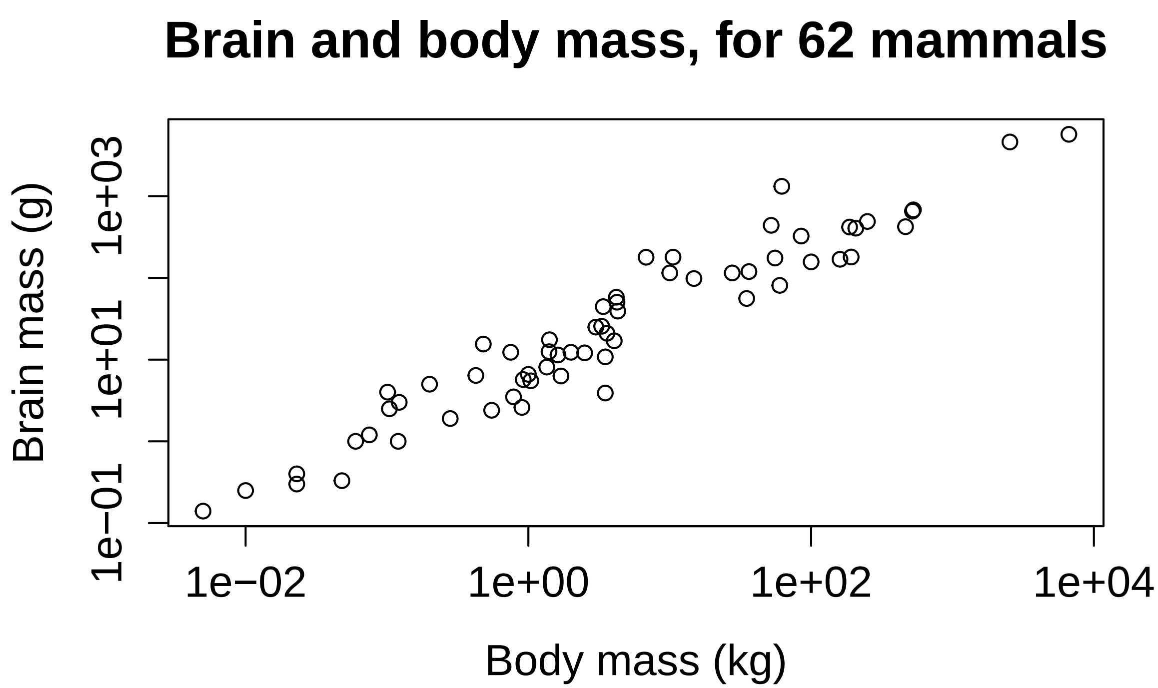
```
plot(x, y = NULL, type = "p",  xlim = NULL, ylim = NULL,
     log = "", main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
     ann = par("ann"), axes = TRUE, frame.plot = axes,
     panel.first = NULL, panel.last = NULL, asp = NA, ...)
```

Making a scatterplot with `plot()`

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

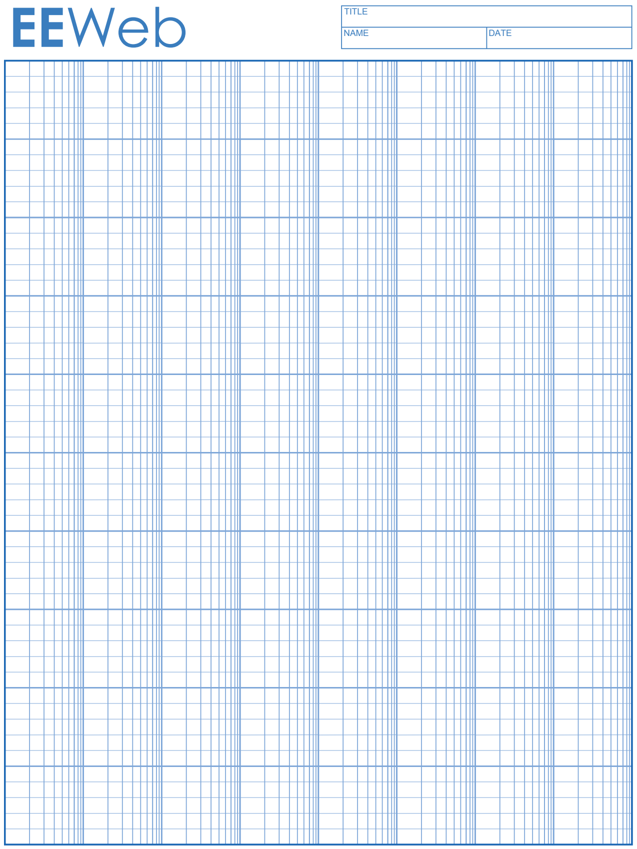
- `xlab`, `ylab` for the axis labels
- `main` for the main title
- `log` to log the axes – `log="xy"`, to log them both

```
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")
```

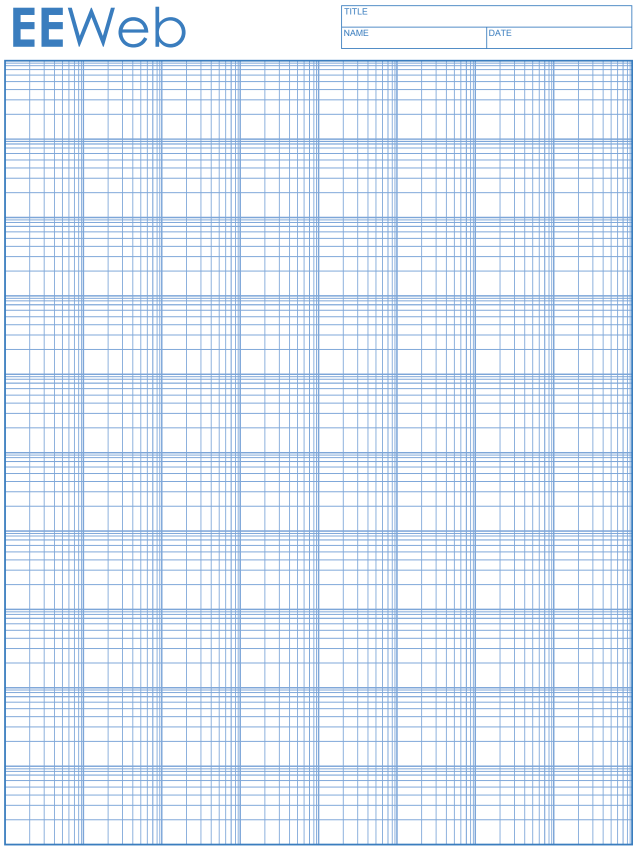


Making a scatterplot with `plot()`

For those with historical interests (or long memories);



`log="x"`
Semi-log graph paper

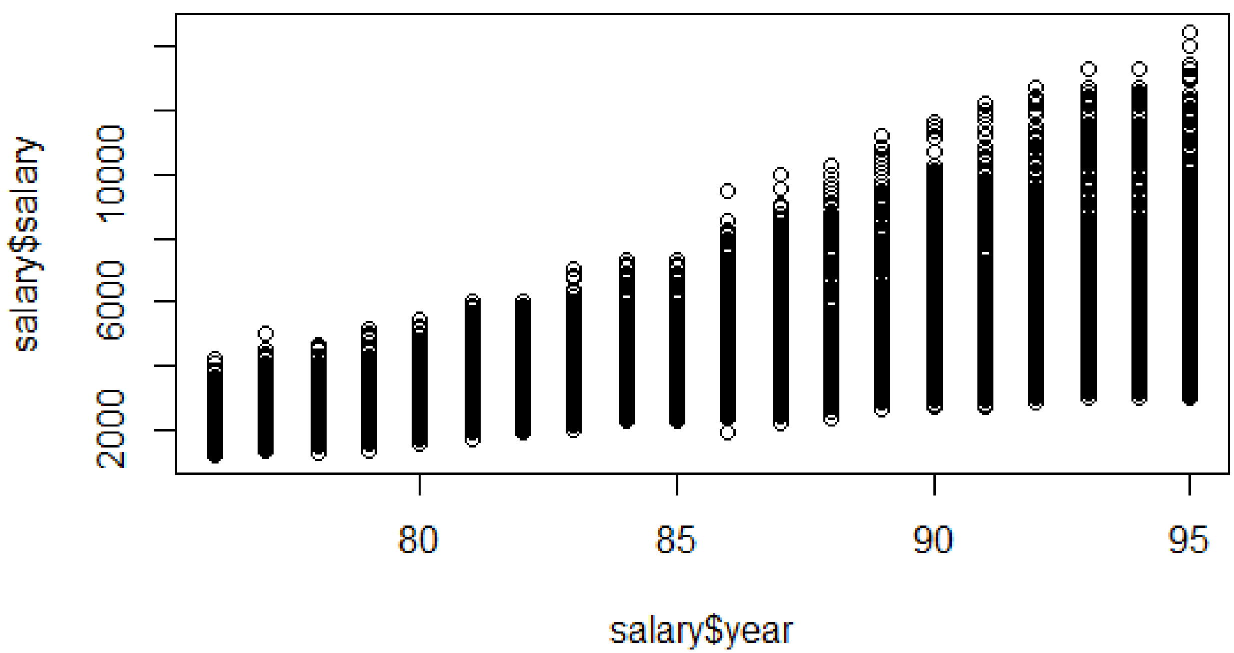


`log="xy"`
Log-log graph paper

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)
```

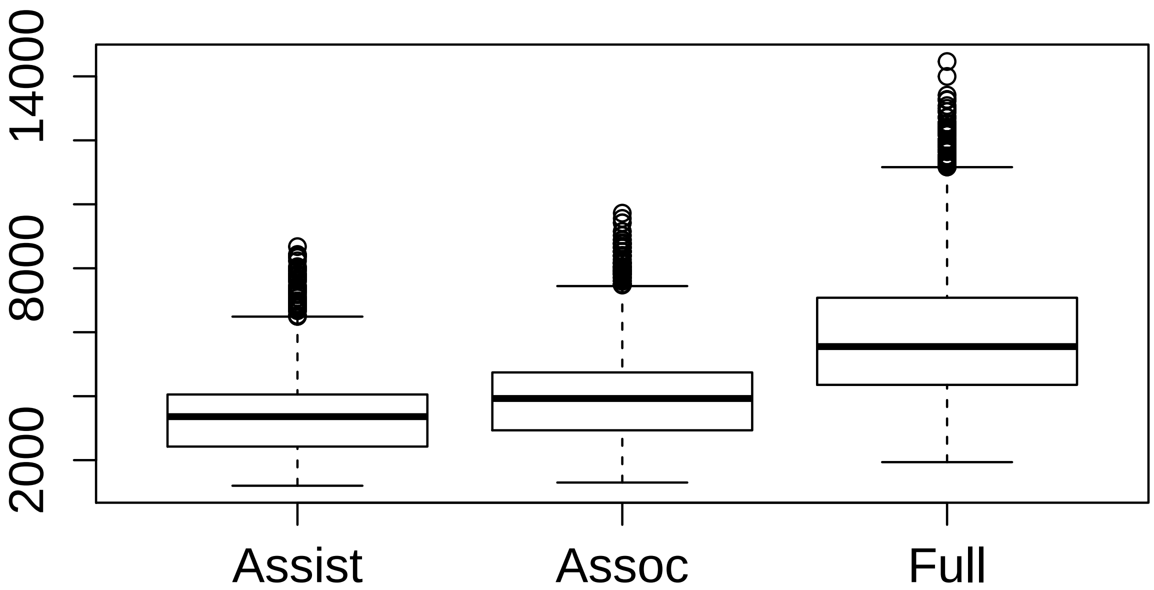


Tip: export graphs of large datasets as PNG, not PDF or JPEG.

Other plots made with `plot()`

Plotting one numeric variable against a factor;

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

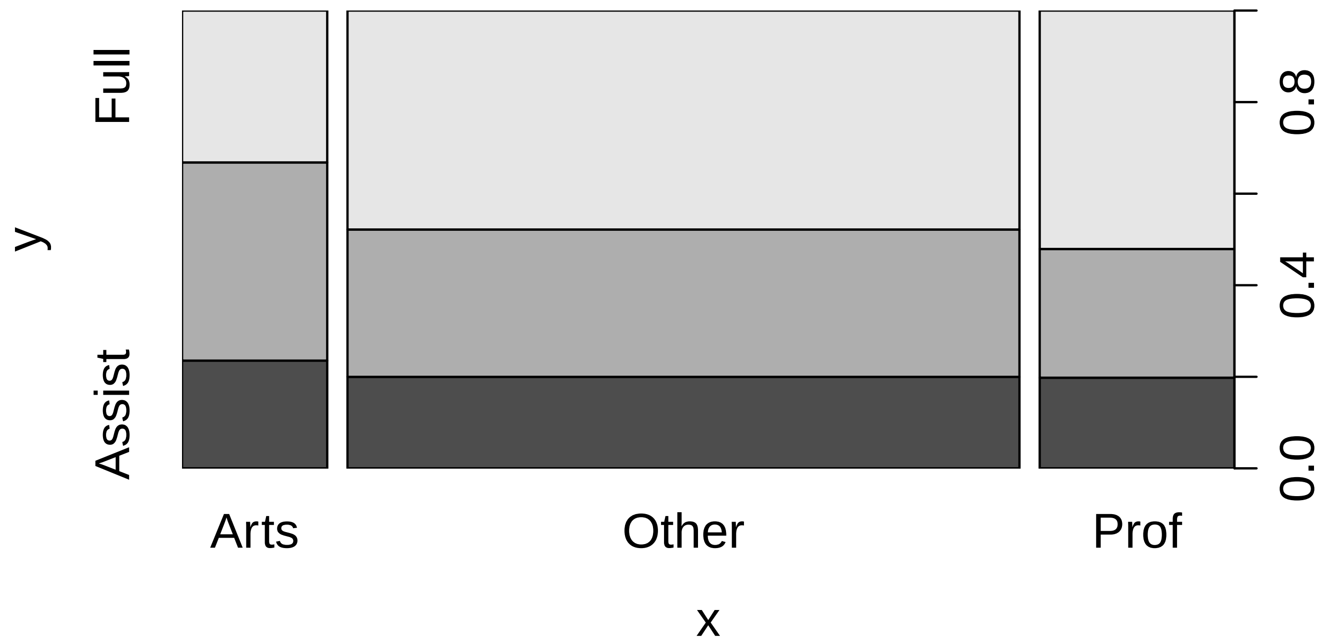


There is also a `boxplot()` function.

Other plots made with `plot()`

Plotting one factor variable against another;

```
plot(x=salary$field, y=salary$rank)
```

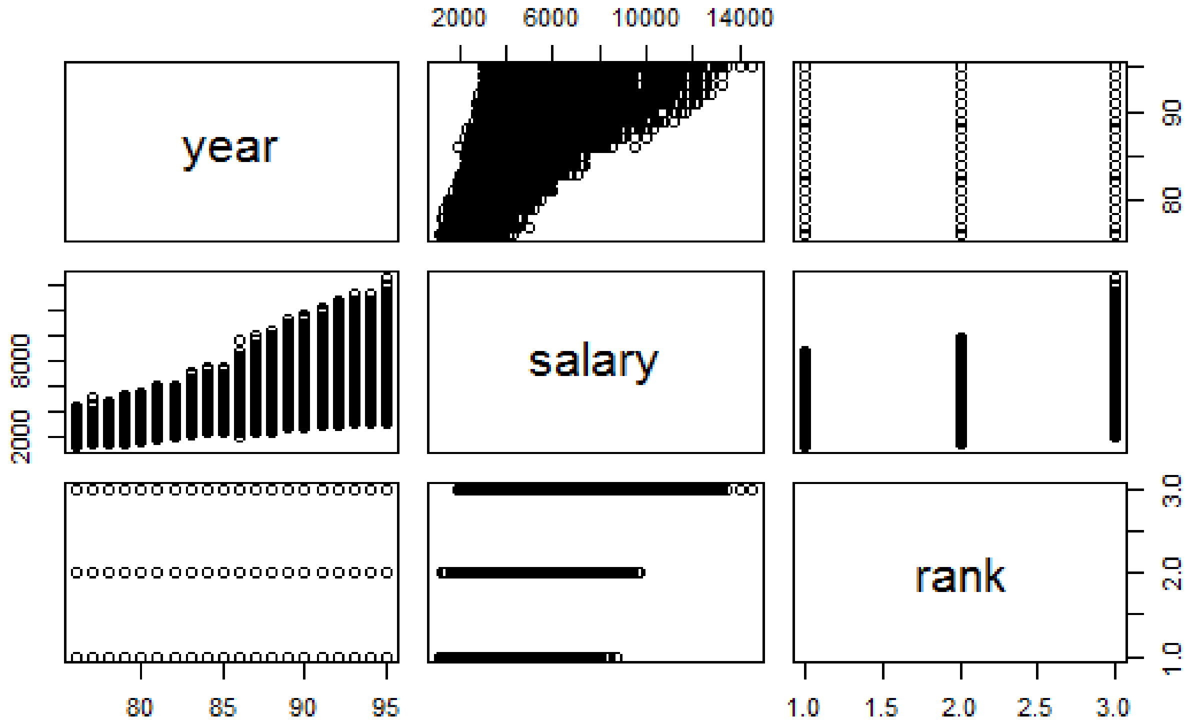


This is a *stacked barplot* – see also the **`barplot()`** function

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()`;

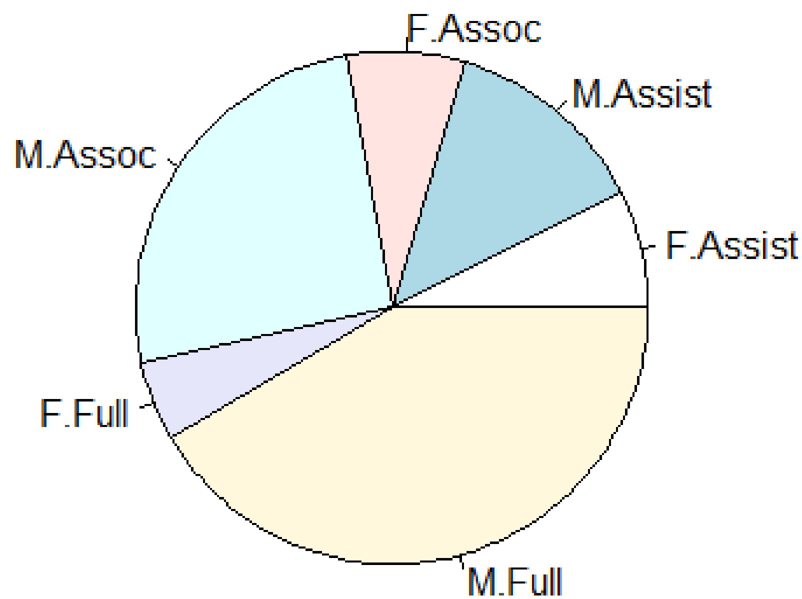
```
hist(salary$salary, main="Monthly salary", xlab="salary")
```

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;

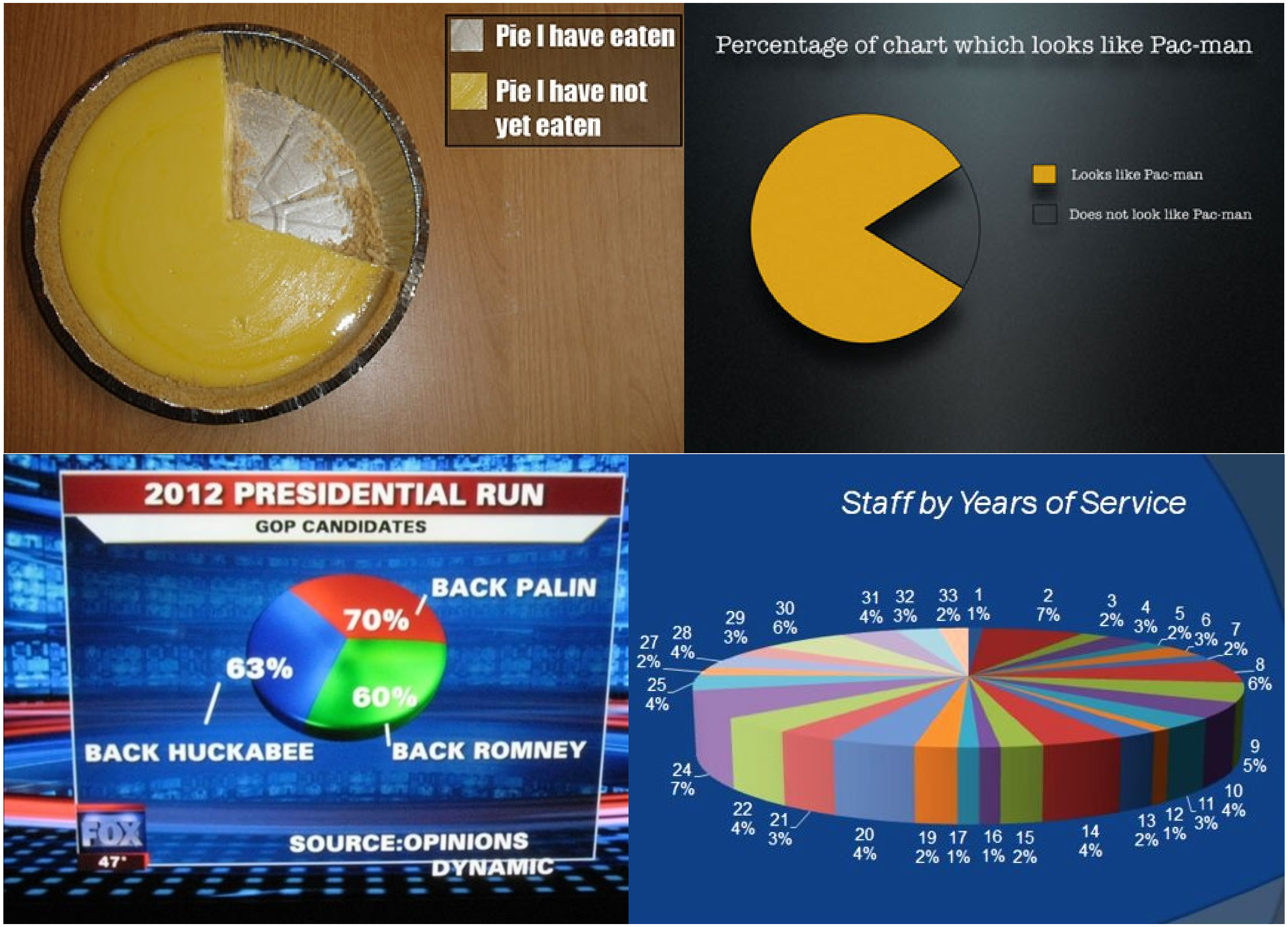
```
> table( interaction(salary$gender, salary$rank) )
F.Assist M.Assist  F.Assoc  M.Assoc   F.Full   M.Full
    1460     2588     1465     5064     1001     8210
> pie( table( interaction(salary$gender, salary$rank) ) )
```



Why do statisticians hate pie charts with such passion?

Other graphics commands

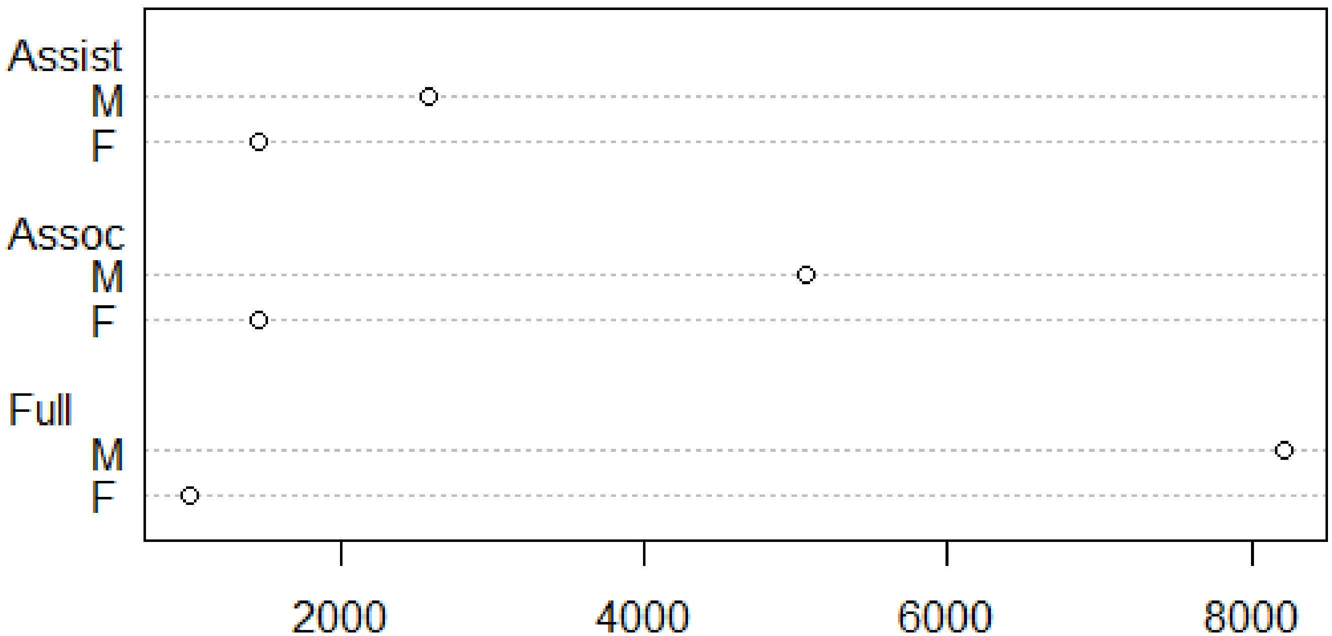
... they really do!



Other graphics commands

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

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

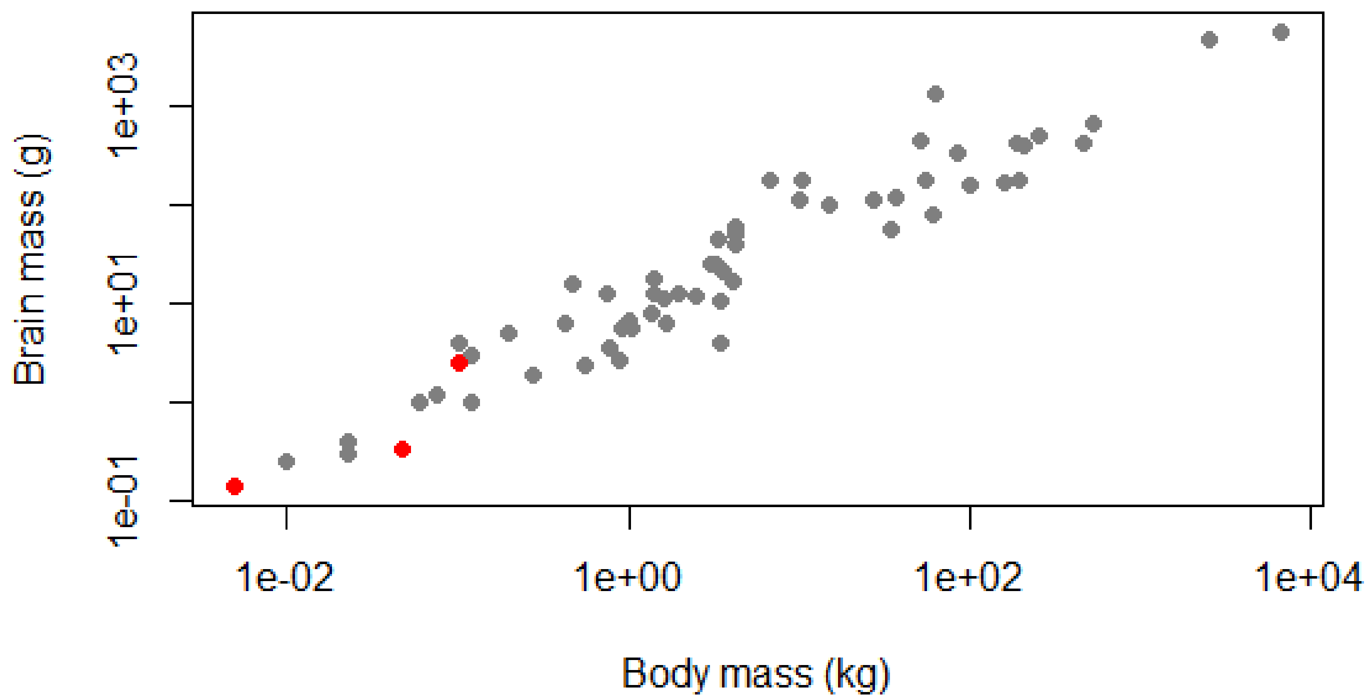


See also `stripchart()`; with multiple symbols per line, these are a good alternative to boxplots, for small samples.

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", row.names(mammals)) # 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 `red`s and 59 `gray50`s.

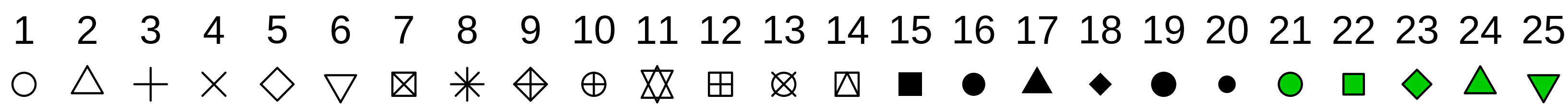
- If we supply fewer colors than datapoints, what we supplied is recycled
- You could probably guess `"red","green","purple"` etc, but not `"gray50"`. To find out the names of the (many) available R colors, use the `colors()` command – no arguments needed
- Can also specify colors by numbers; 1=black, 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 use`adjustcolor()`

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.

The full range;



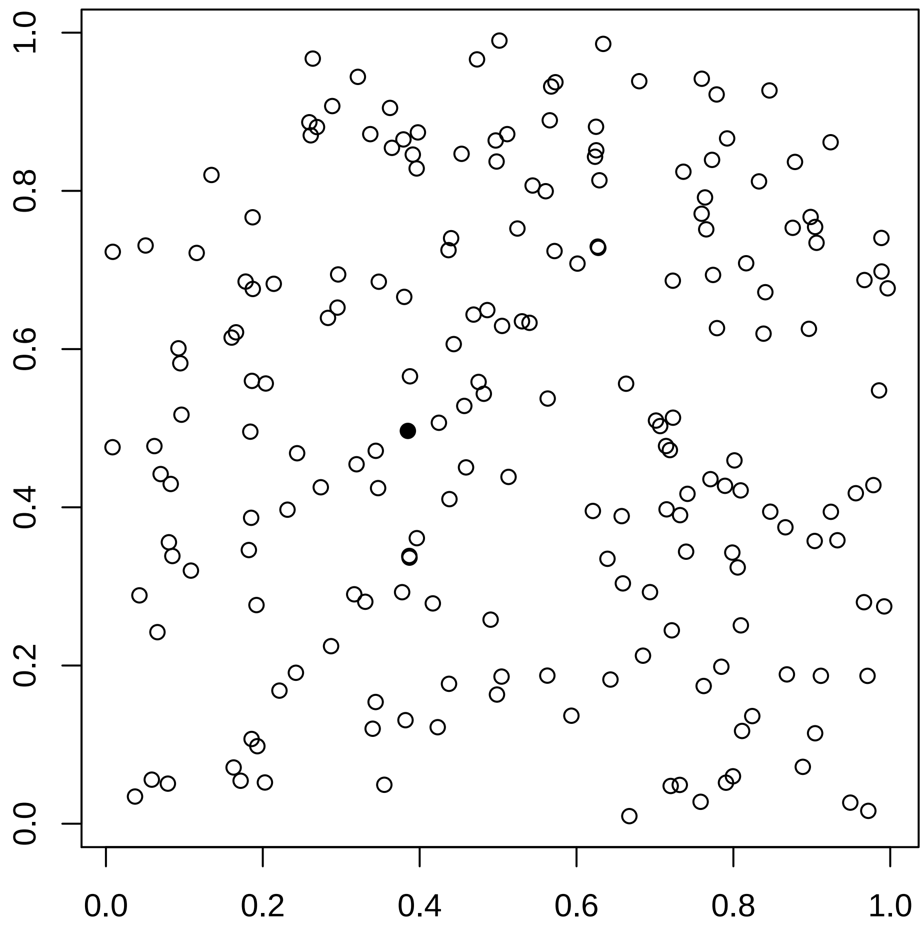
- Set the fill color for `21:25` with the `bg` argument
- The open circle (`pch=1`) is the default – because it makes it easiest to see points that nearly overlap. Change it only if you have a good reason to
- Filled symbols `15:20` work well with transparent colors, e.g. `col="#FF000033"` for translucent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

For different size symbols, there is a `cex` option; `cex=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

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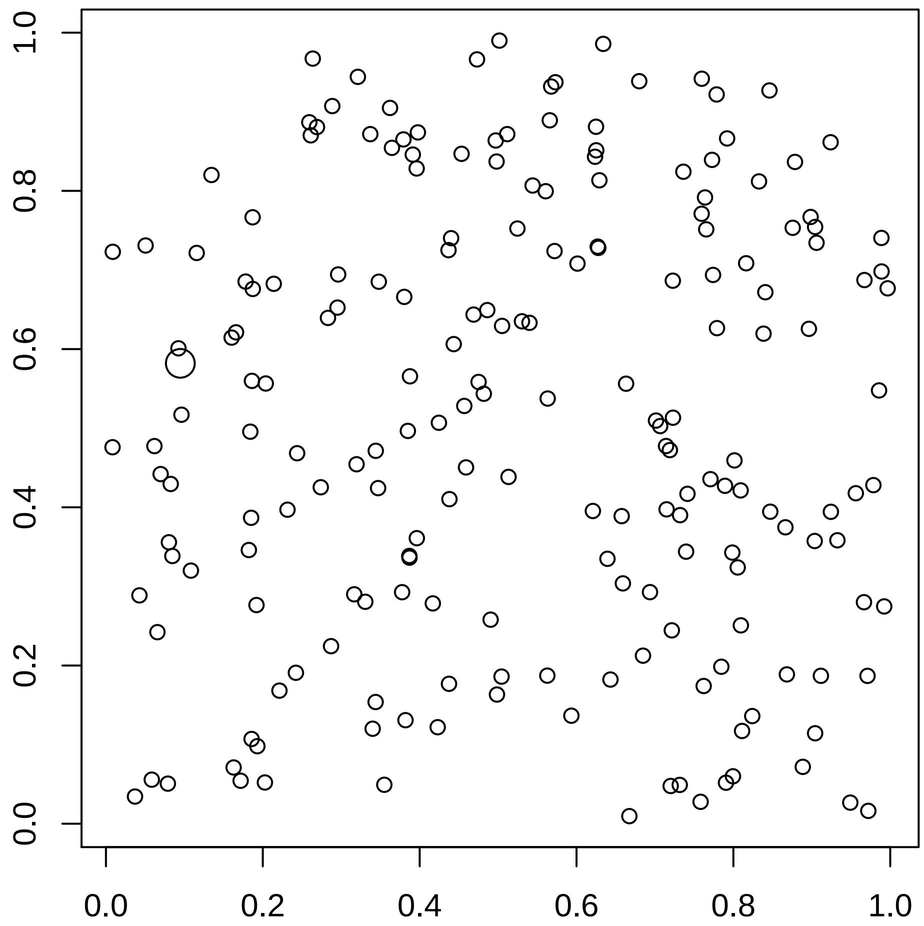

Changing plotting symbols

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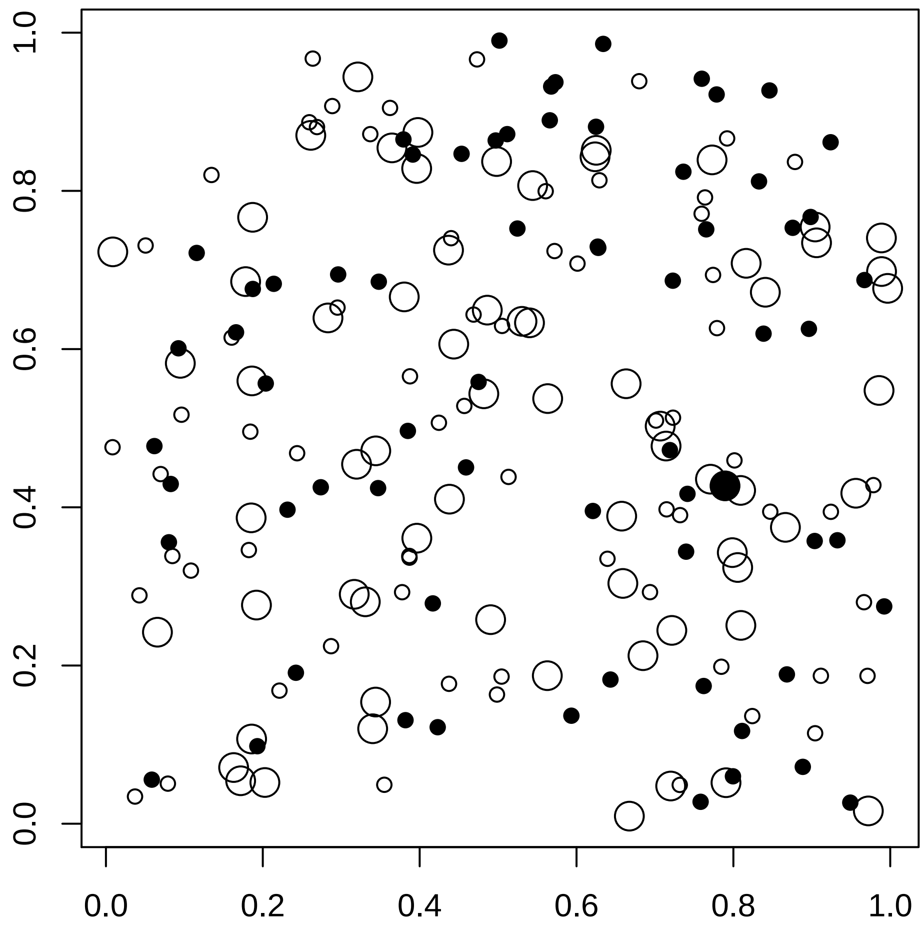
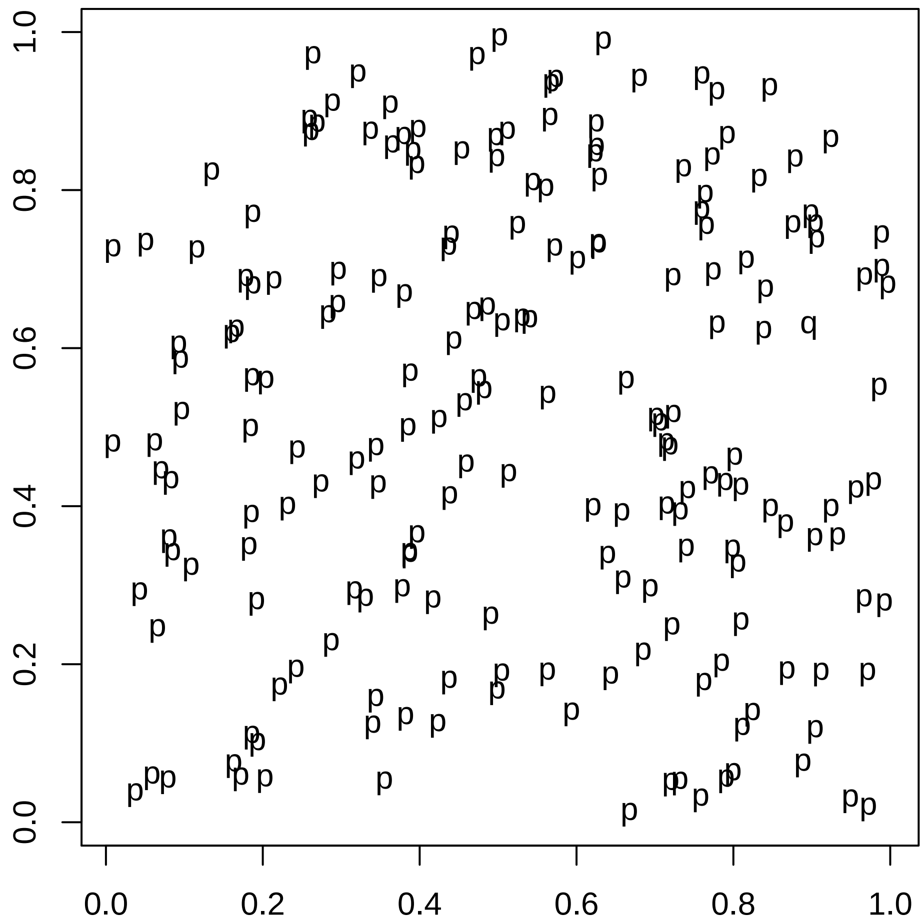


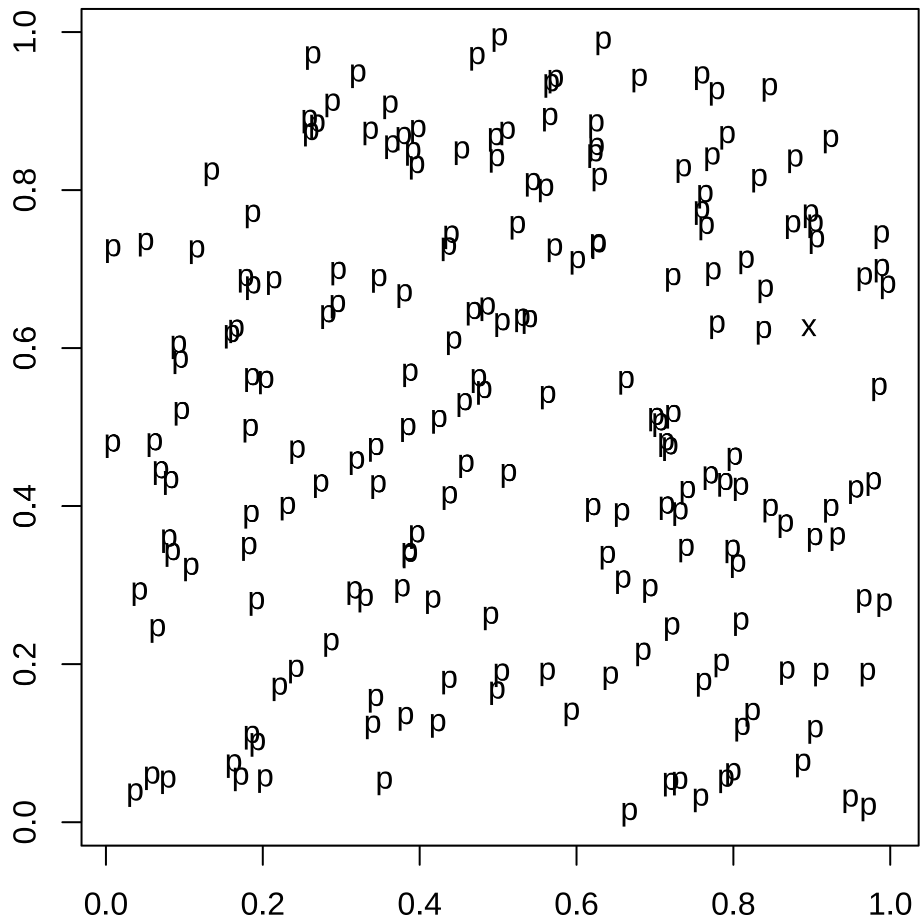
Changing plotting symbols

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



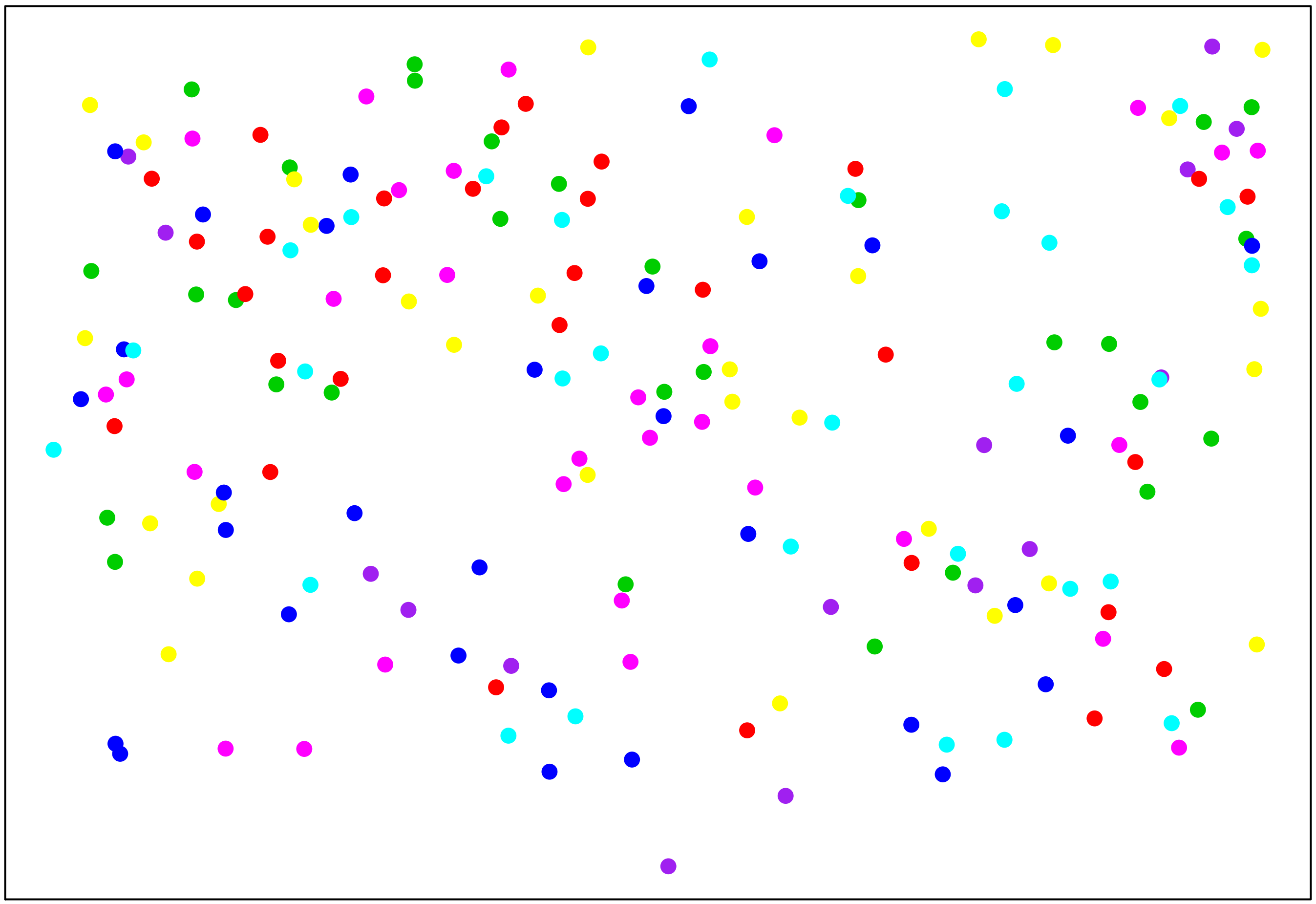
Changing plotting symbols

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



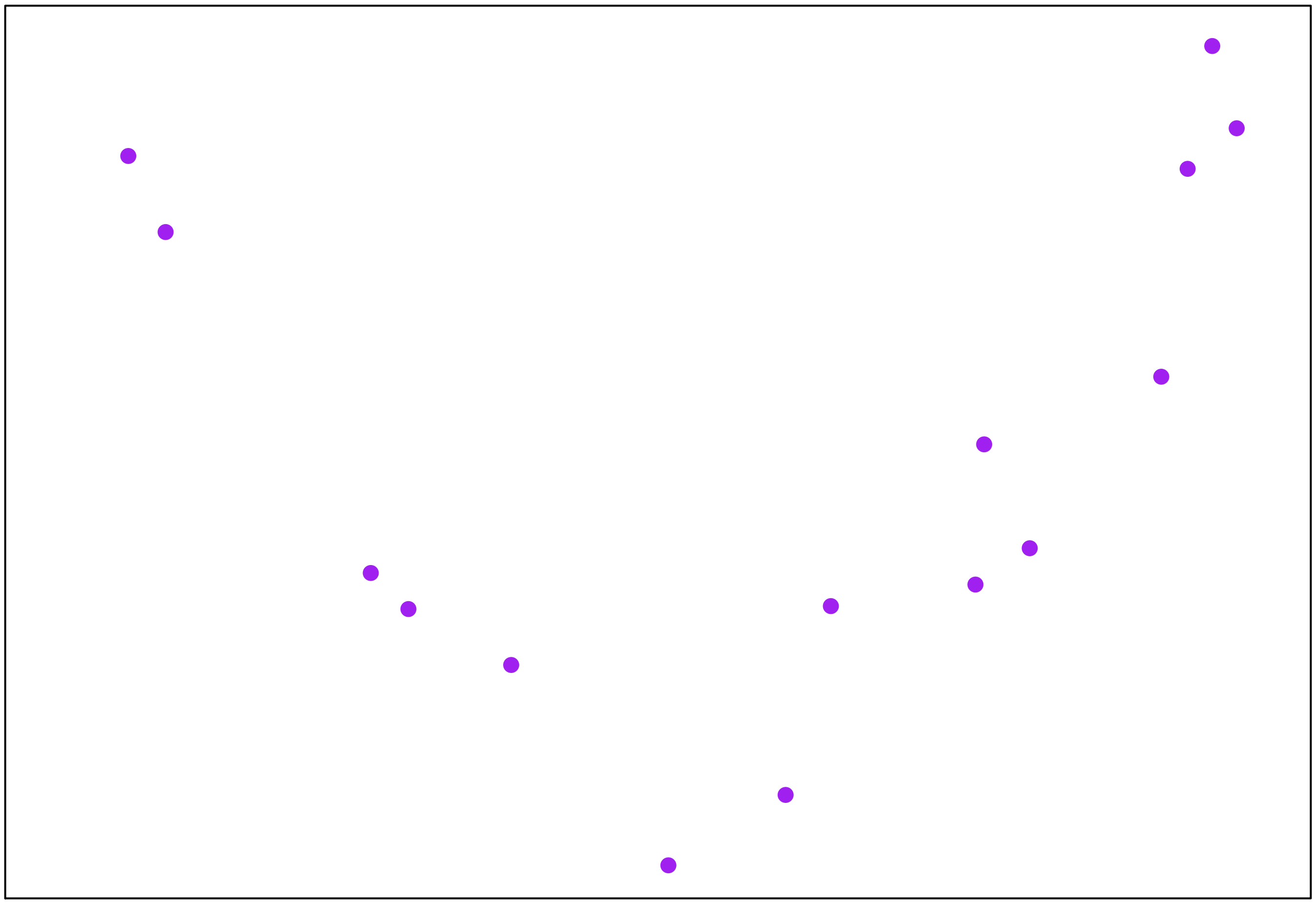
Changing plotting symbols

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



Changing plotting symbols

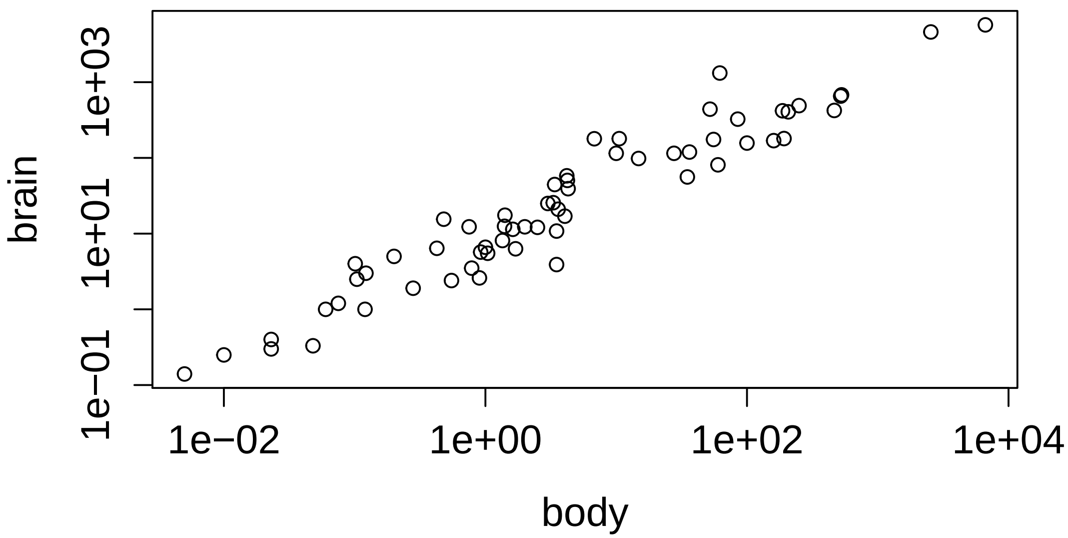
Too many colors (>4, say) requires too much attention; what pattern is illustrated here?



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;

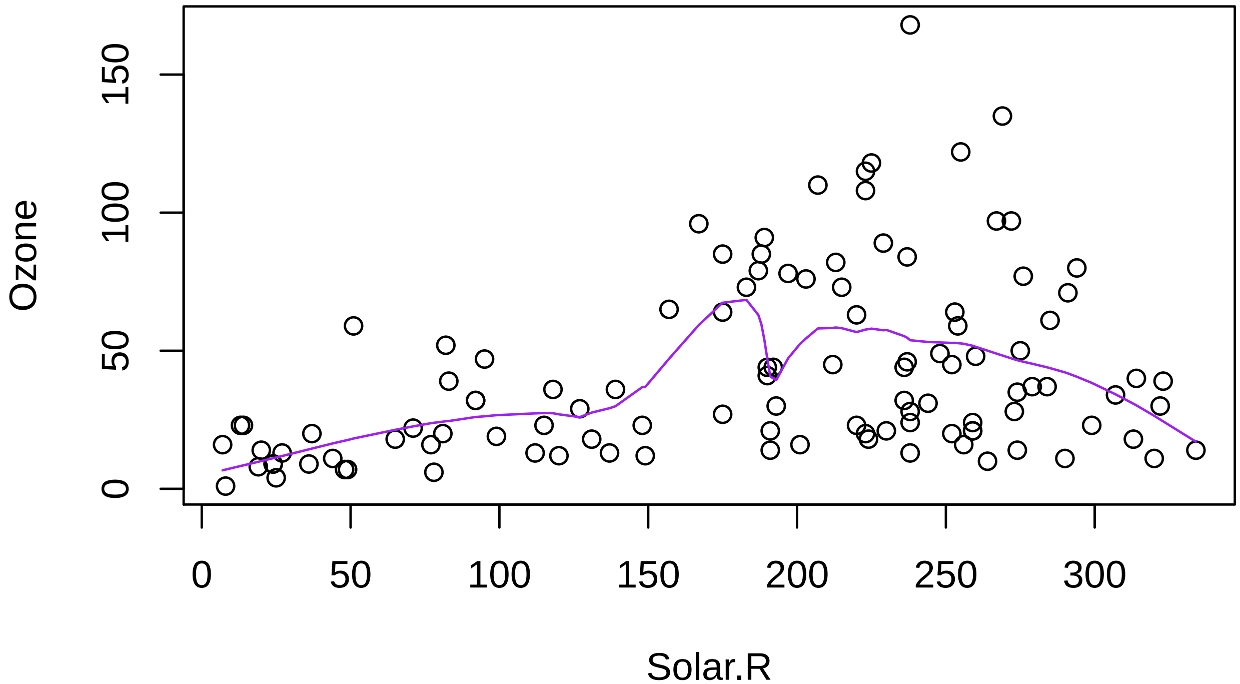
- How does some outcome (Y) depend on a covariate (X)? (a.k.a. a predictor)
- How does a dependent variable (Y) depend on an independent variable (X)?

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 atmostpheric 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) ...



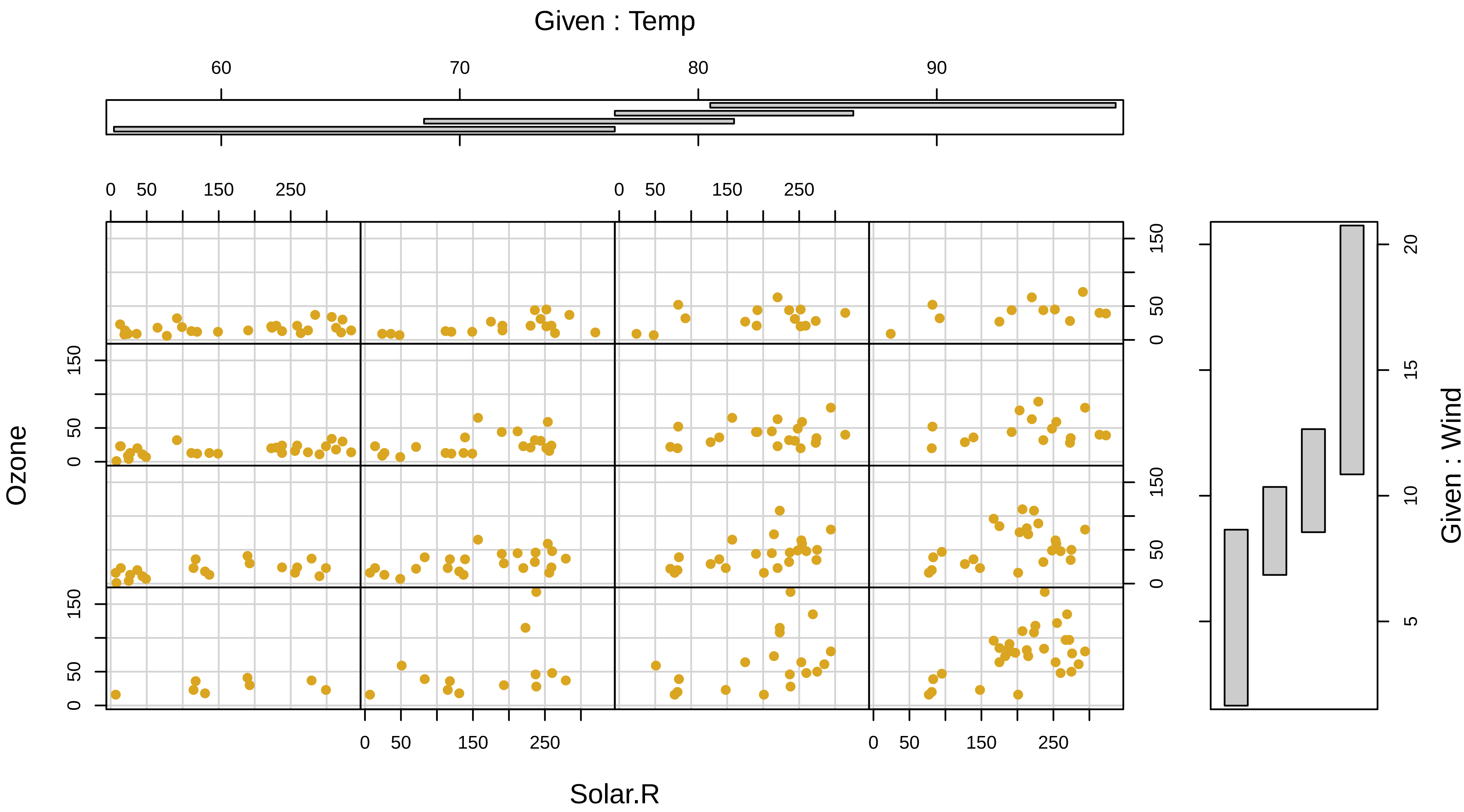
Plots via the formula syntax

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