**Instituto Juan March · Curso Metodológico**

# Introduction to R

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# Welcome

# Goals

This R prefresher is intended to help you get started with R

R is the most widely used statistical language, with likely 1 million users worldwide

In many fields, including statistics, R is the default package

We will focus on using R for graphics

R has very powerful graphics tools

You could port your results from Stata (or another package) just to do graphics in R

But R is well worth learning

- Powerful and growing in capabilities
- Now the main package we teach in US political science Ph.D. programs

# Why R?

Real question: Why programming?

Non-programmers are stuck with package defaults

For your substantive problem, these default settings may be

- inappropriate (not quite the right model, but "close")
- unintelligible (reams of non-linear coefficients and stars)

Programming allows you to match the methods to the data & question

Get better, more easily explained results.

# Why R?

Many side benefits:

1. Never forget what you did: The code can be re-run.

2. Repeating an analysis $n$ times? Write a loop!

3. Programming makes data processing/reshaping easy.

4. Programming makes replication easy.

# Why R?

R is

- free
- open source
- growing fast
- widely used
- the future for most fields

But once you learn one language, the others are much easier

# Introduction to R

R is a calculator that can store lots of information in memory

R stores information as "objects"

```
> x <- 2
> print(x)
[1] 2

> y <- "hello"
> print(y)
[1] "hello"

> z <- c(15, -3, 8.2)
> print(z)
[1] 15.0 -3.0  8.2
```

# Introduction to R

```
> w <- c("gdp", "pop", "income")
> print(w)
[1] "gdp"    "pop"    "income"
>
```

Note the assignment operator, <-, not =

An object in memory can be called to make new objects

```
> a <- x^2
> print(x)
[1] 2
> print(a)
[1] 4
```

```
> b <- z + 10
> print(z)
[1] 15.0 -3.0  8.2
> print(b)
[1] 25.0  7.0 18.2
```

# Introduction to R

```
> c <- c(w,y)
> print(w)
[1] "gdp"    "pop"    "income"
> print(y)
[1] "hello"
> print(c)
[1] "gdp"    "pop"    "income" "hello"
```

Commands (or "functions") in R are always written `command()`

The usual way to use a command is:

```
output <- command(input)
```

We've already seen that `c()` pastes together variables.

A simple example:

```
> z <- c(15, -3, 8.2)
> mz <- mean(z)
> print(mz)
[1] 6.733333
```

# Introduction to R

Some commands have multiple inputs. Separate them by commas:

`plot(var1,var2)` plots var1 against var2

Some commands have optional inputs. If omitted, they have default values.

`plot(var1)` plots var1 against the sequence {1,2,3,. . . }

Inputs can be identified by their position or by name.

`plot(x=var1,y=var2)` plots var2 against var1

# Entering code

You can enter code by typing at the prompt, by cutting or pasting, or from a file

If you haven't closed the parenthesis, and hit enter,
`R` let's you continue with this prompt `+`

You can copy and paste multiple commands at once

You can run a text file containing a program using `source()`,
with the name of the file as the input: `source("mycode.R")`

I prefer the `source()` approach. Leads to good habits of retaining code.

# Data types

R has three important data types to learn now

| | |
|---|---|
| Numeric | `y <- 4.3` |
| Character | `y <- "hello"` |
| Logical | `y <- TRUE` |

We can always check a variable's type, and sometimes change it:

```
population <- c("1276", "562", "8903")
print(population)
is.numeric(population)
is.character(population)
```

Oops! The data have been read in as characters, or "strings."
R does not know they are numbers.

```
population <- as.numeric(population)
```

# Some special values

| | |
|---|---|
| Missing data | `NA` |
| A "blank" | `NULL` |
| Infinity | `Inf` |
| Not a number | `NaN` |

# Data structures

All R objects have a data type *and* a data structure

Data structures can contain numeric, character, or logical entries

Important structures:

Vector

Matrix

Dataframe

List (to be covered later)

# Vectors in R

Vectors in R are simply 1-dimensional lists of numbers or strings

Let's make a vector of random numbers:

```
x <- rnorm(1000)
```

x contains 1000 random normal variates drawn from a Normal distribution with mean 0 and standard deviation 1.

What if we wanted the mean of this vector?

```
mean(x)
```

What if we wanted the standard deviation?

```
sd(x)
```

# Vectors in R

What if we wanted just the first element?

```
x[1]
```

or the 10th through 20th elements?

```
x[10:20]
```

what if we wanted the 10th percentile?

```
sort(x)[100]
```

Indexing a vector can be very powerful. Can apply to any vector object.

What if we want a histogram?

```
hist(x)
```

# Vectors in R

Useful commands for vectors:

| | |
|---|---|
| `seq(from, to, by)` | generates a sequence |
| `rep(x,times)` | repeats `x` |
| `sort()` | sorts a vector from least to greatest |
| `rev()` | reverses the order of a vector |
| `rev(sort())` | sorts a vector from greatest to least |

# Matrices in R

Vector are the standard way to store and manipulate variables in R

But usually our datasets have several variables measured on the same observations

Several variables collected together form a matrix
with one row for each observation and one column for each variable

# Matrices in R

Many ways to make a matrix in R

```
a <- matrix(data=NA, nrow, ncol, byrow=FALSE)
```

This makes a matrix of `nrow` $\times$ `ncol`, and fills it with missing values.

To fill it with data, substitute a vector of data for NA in the command.
It will fill up the matrix column by column.

We could also paste together vectors, binding them by column or by row:

```
b <- cbind(var1, var2, var3)
c <- rbind(obs1, obs2)
```

# Matrices in R

Optionally, R can remember names of the rows and columns of a matrix

To assign names, use the commands:

```
colnames(a) <- c("Var1", "Var2")
rownames(a) <- c("Case1", "Case2")
```

Substituting the actual names of your variables and observations
(and making sure there is one name for each variable & observation)

# Matrices in R

Matrices are indexed by row and column.

We can subset matrices into vectors or smaller matrices

| | |
|---|---|
| `a[1,1]` | Gets the first element of a |
| `a[1:10,1]` | Gets the first ten rows of the first column |
| `a[,5]` | Gets every row of the fifth column |
| `a[4:6,]` | Gets every column of the 4th through 6th rows |

To make a vector into a matrix, use `as.matrix()`

R defaults to treating one-dimensional arrays as vectors, not matrices

Useful matrix commands:

| | |
|---|---|
| `nrow()` | Gives the number of rows of the matrix |
| `ncol()` | Gives the number of columns |
| `t()` | Transposes the matrix |

# Dataframes in R

Dataframes are a special kind of matrix used to store datasets

To turn a matrix into a dataframe (note the extra .):

```
a <- as.data.frame(a)
```

Dataframes always have columns names, and these are set or retrieved using the `names()` command

```
names(a) <- c("Var1","Var2")
```

You can access a variable from a dataframe directly using `$`:

```
a$Var1
```

Dataframes can also be "attached,"
which makes each column into a vector with the appropriate name

```
attach(a)
```

# Loading data

There are many ways to load data to R.

I prefer using comma-separated variable files, which can be loaded with `read.csv()`

You can also check the `foreign` library for other data file types

Suppose you load a dataset using

```
data <- read.csv("mydata.csv")
```

You can check out the names of the variables using `names(data)`

And access any variables, such as `gdp`, using `data$gdp`

# Benefits and dangers of `attach()`

If your data have variable names, you can also "attach" the dataset like so:

```
data <- read.csv("mydata.csv")
attach(data)
```

to access all the variables directly through newly created vectors.

*Be careful!* `attach()` is tricky.

1. If you attach a variable `data$x` in `data` and then modify `x`, the original `data$x` is unchanged.

2. If you have more than one dataset with the same variable names, `attach()` is a bad idea: only one dataset can be attached!

Sometimes `attach()` is handy, but be careful!

# Missing data

When loading a dataset, you can often tell R what symbol that file uses for missing data using the option `na.strings=`

So if your dataset codes missings as ., set `na.strings="."`

If your dataset codes missings as a blank, set `na.strings=""`

If your dataset codes missings in multiple ways, you could set, e.g., `na.strings=c(".","","NA")`

# Missing data

Many R commands will not work properly on vectors, matrices, or dataframes containing missing data (NAs)

To check if a variables contains missings, use `is.na(x)`

To create a new variable with missings listwise deleted, use `na.omit`

If we have a dataset `data` with NAs at data[15,5] and data[17,3]

```
dataomitted <- na.omit(data)
```

will create a new dataset with the 15th and 17th rows left out

Be careful! If you have a variable with lots of NAs you are not using in your analysis, remove it from the dataset *before* using `na.omit()`

# Mathematical Operations

R can do all the basic math you need

Binary operators:

```
+ - * / ^
```

Binary comparisions:

```
< <= > >= == !=
```

Logical operators (and, or, and not; use parentheses!):

```
&& || !
```

Math/stat fns:

```
log exp mean median min max sd var cov cor
```

Set functions (see `help(sets)`), Trigonometry (see `help(Trig)`),

R follows the usual order of operations; if it doubt, use parentheses

# Example 1: US Economic growth

Let's investigate an old question in political economy:

Are there partisan cycles, or tendencies, in economic performance?

Does one party tend to produce higher growth on average?

(Theory: Left cares more about growth vis-a-vis inflation than the Right

If there is partisan control of the economy,
then Left should have higher growth ceteris paribus)

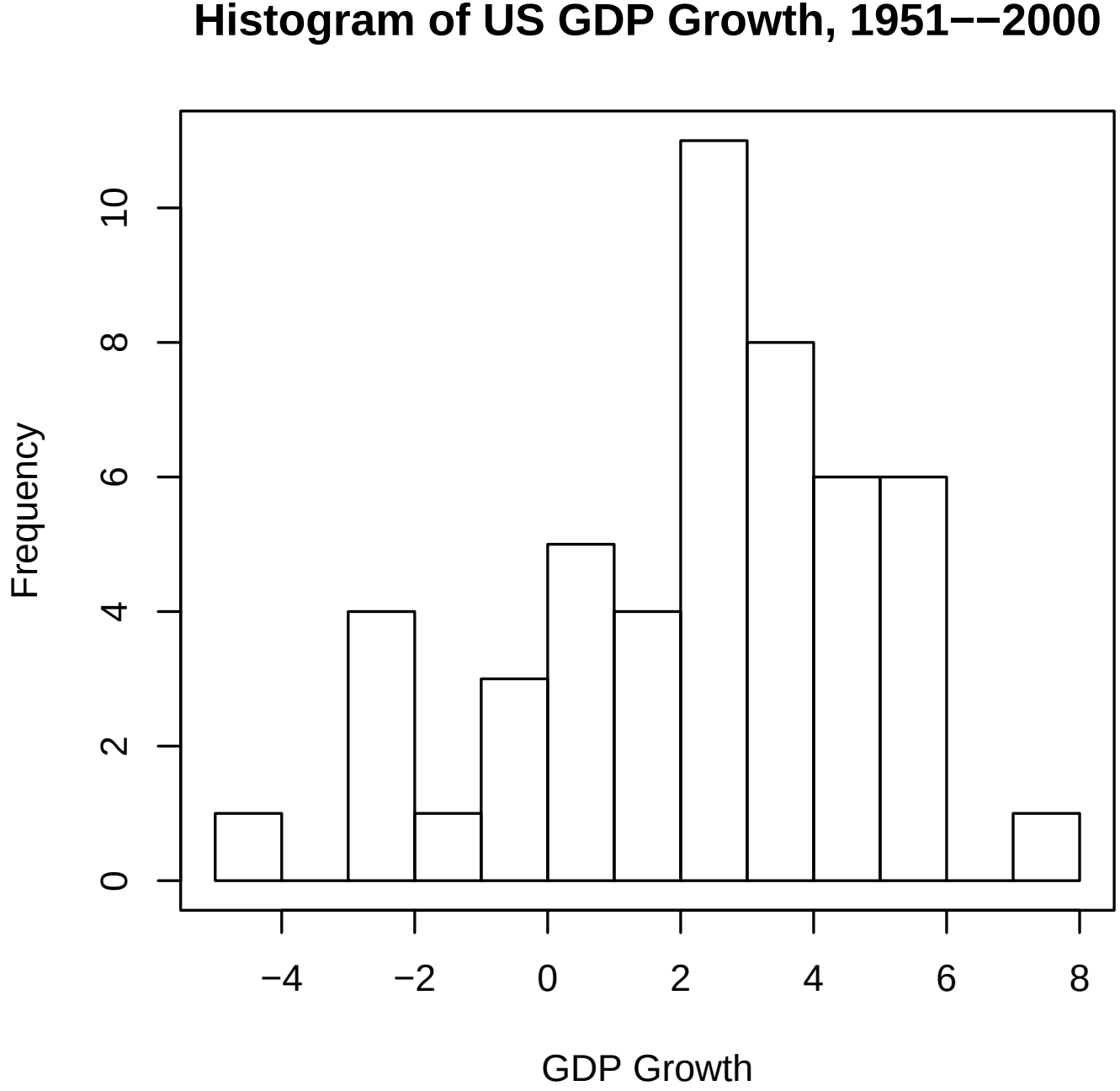
Data from the Penn World Tables (Annual growth rate of GDP in percent)

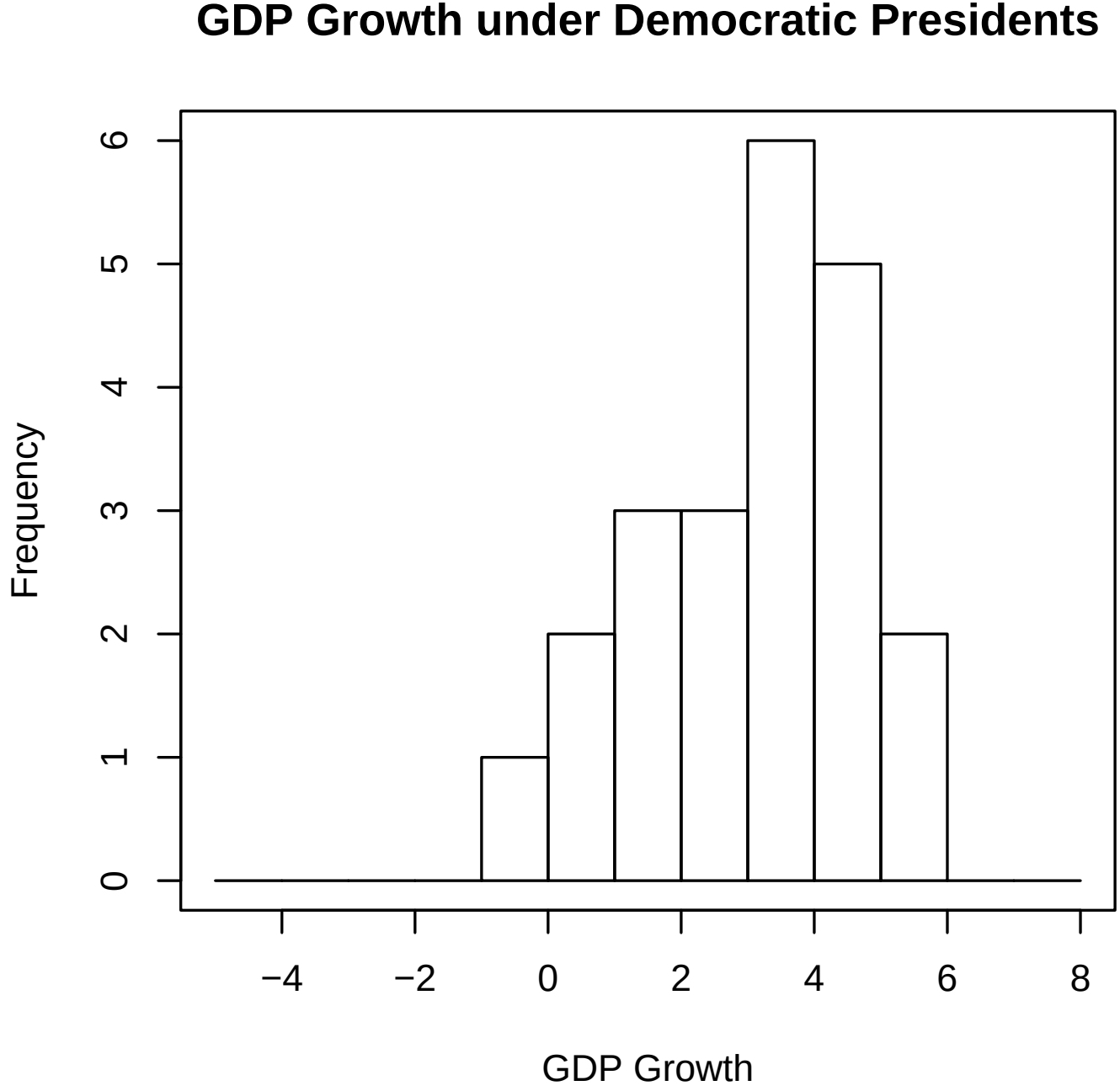
Two variables:

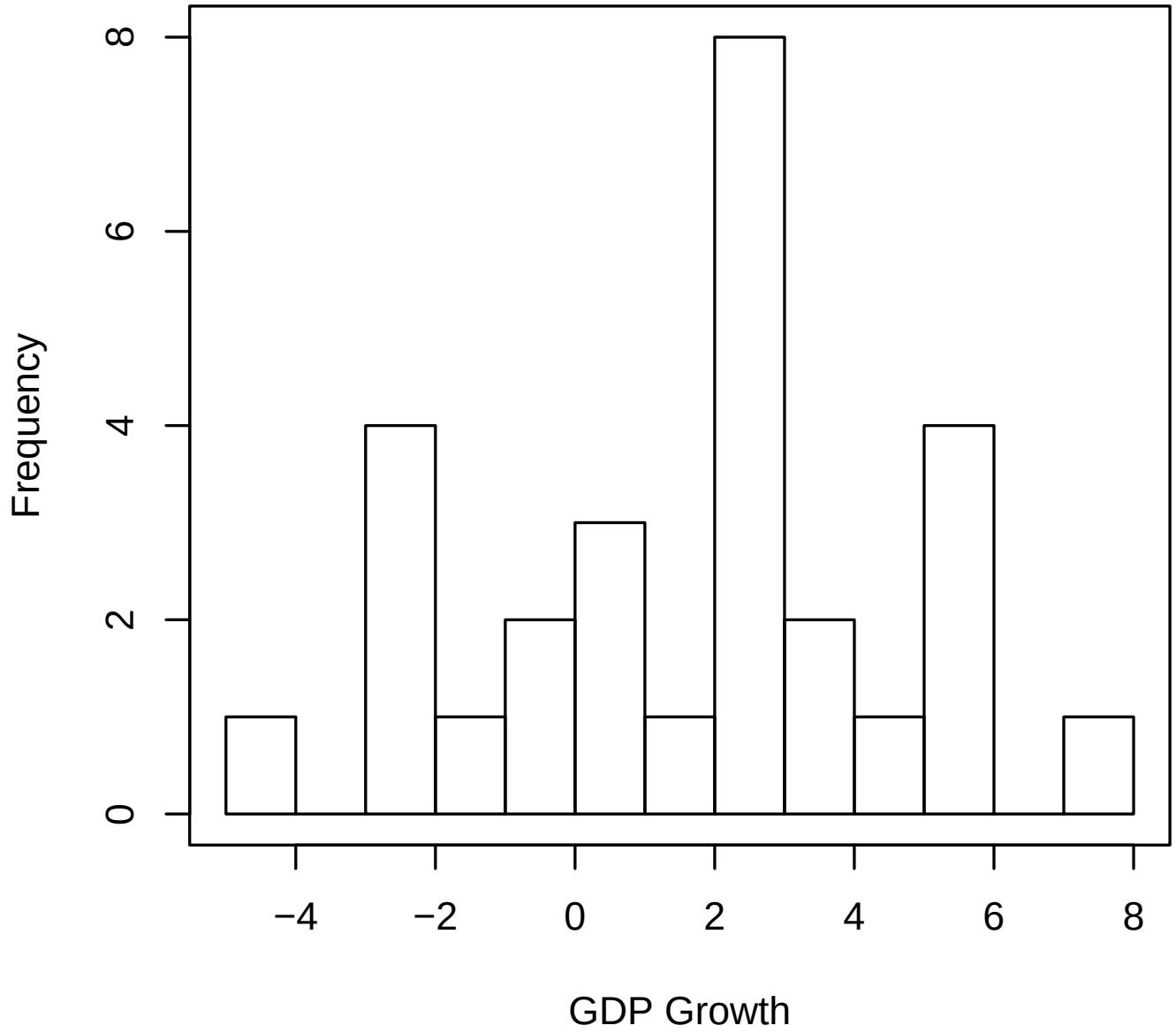
| | |
|---|---|
| `grgdpch` | The per capita GDP growth rate |
| `party` | The party of the president (Dem = -1, Rep = 1) |

# Example 1: US Economic growth

```
# Load data
data <- read.csv("gdp.csv",na.strings="")
attach(data)

# Construct party specific variables
gdp.dem <- grgdpch[party==-1]
gdp.rep <- grgdpch[party==1]

# Make the histogram
hist(grgdpch,
     breaks=seq(-5,8,1),
     main="Histogram of US GDP Growth, 1951--2000",
     xlab="GDP Growth")
```


Histogram of US GDP Growth, 1951−−2000
Frequency
0
2
4
6
8
10
−4
−2
0
2
4
6
8
GDP Growth


GDP Growth under Democratic Presidents
Frequency
0
1
2
3
4
5
6
−4
−2
0
2
4
6
8
GDP Growth


GDP Growth under Republican Presidents
Frequency
0
2
4
6
8
−4
−2
0
2
4
6
8
GDP Growth

```
# Make a box plot
boxplot(grgdpch~as.factor(party),
        boxwex=0.3,
        range=0.5,
        names=c("Democratic\n Presidents",
          "Republican\n Presidents"),
        ylab="GDP growth",
        main="Economic performance of partisan governments")
```

Note the unusual first input: this is an R formula

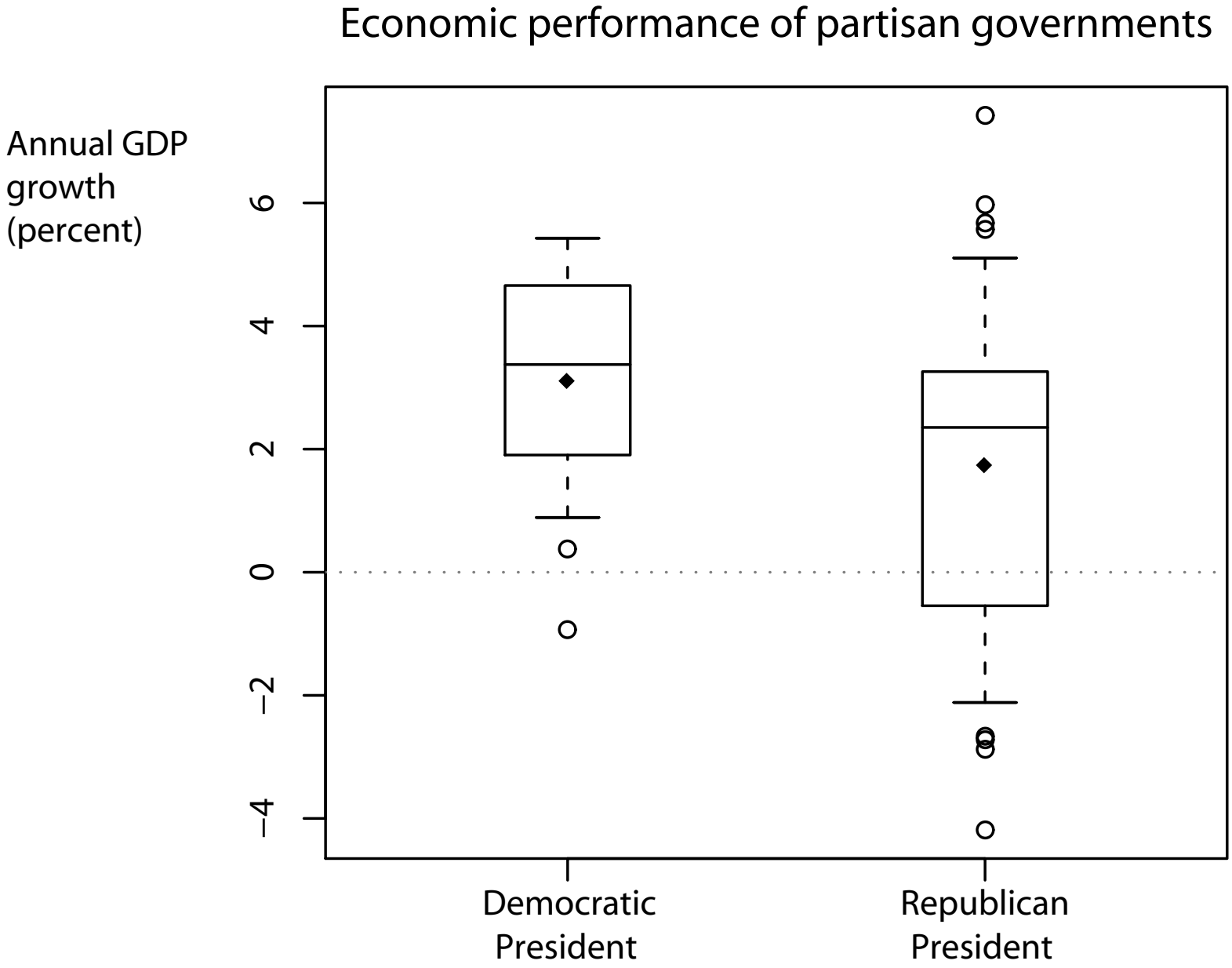
`y~x1+x2+x3`

In this case, `grgdpch` is being "modeled" as a function of `party`

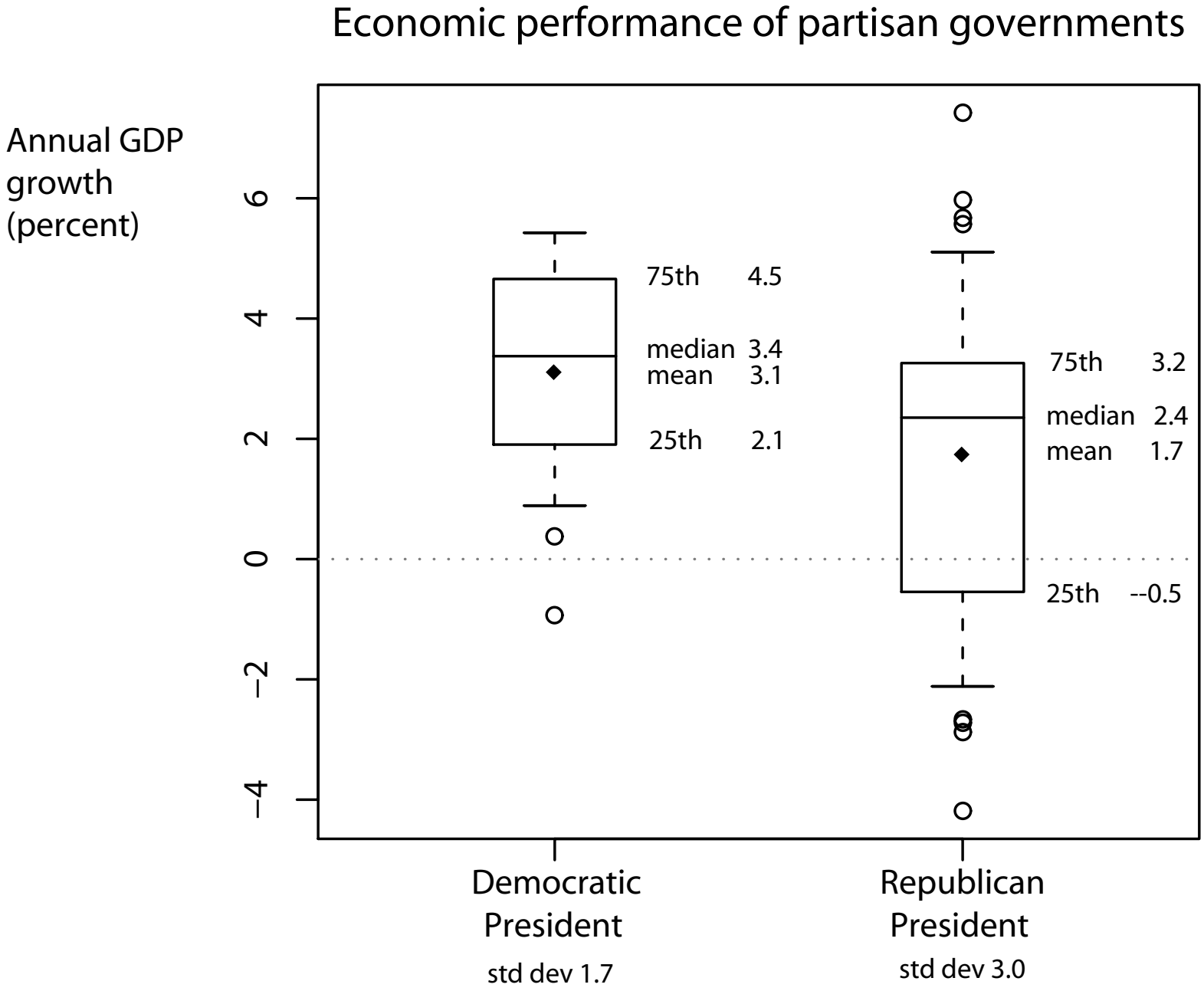
`boxplot()` needs party to be a "factor" or an explicitly categorical variable

Hence we pass boxplot `as.factor(party)`,
which turns the numeric variable into a factor

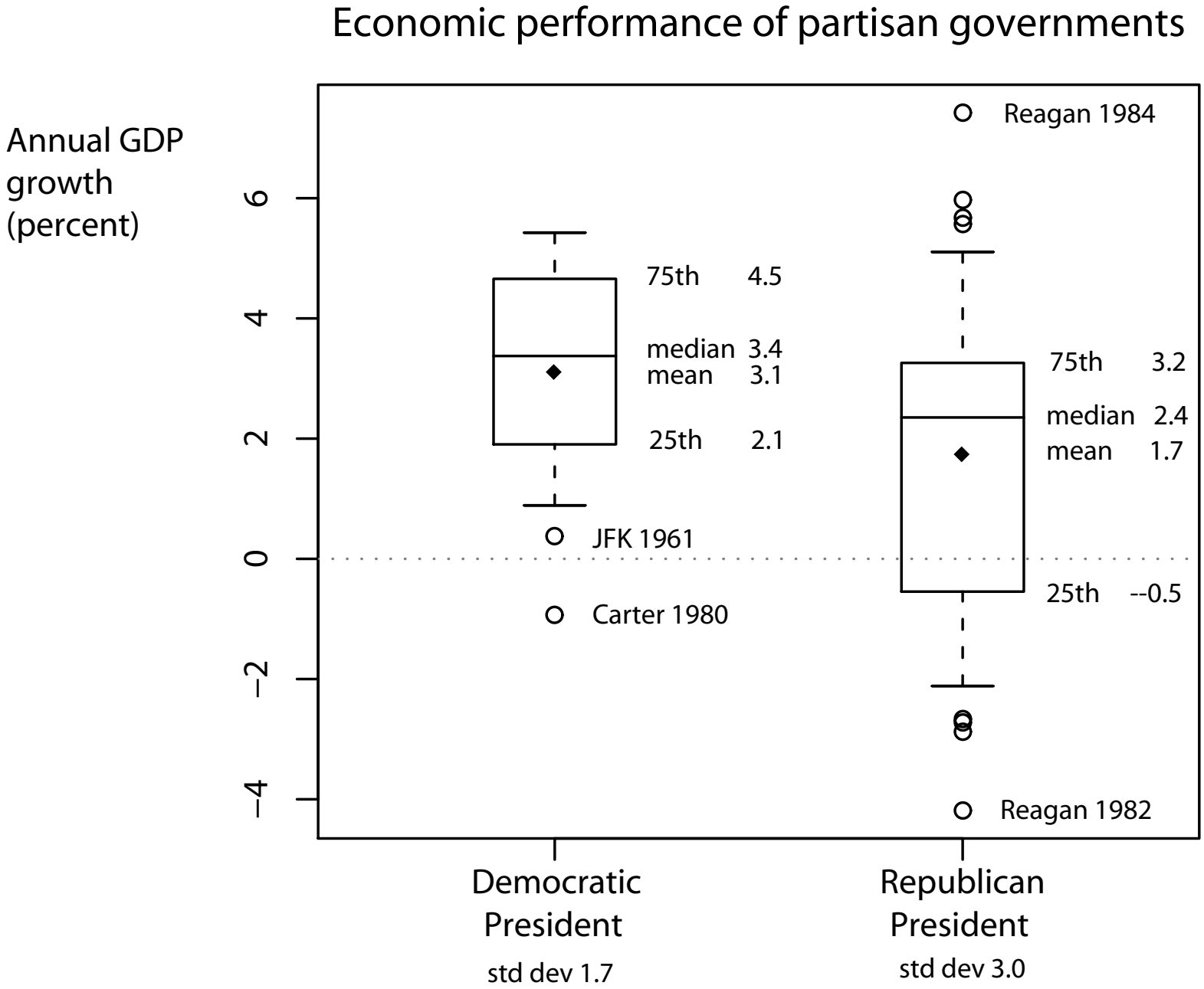
# Box plots: Annual US GDP growth, 1951–2000



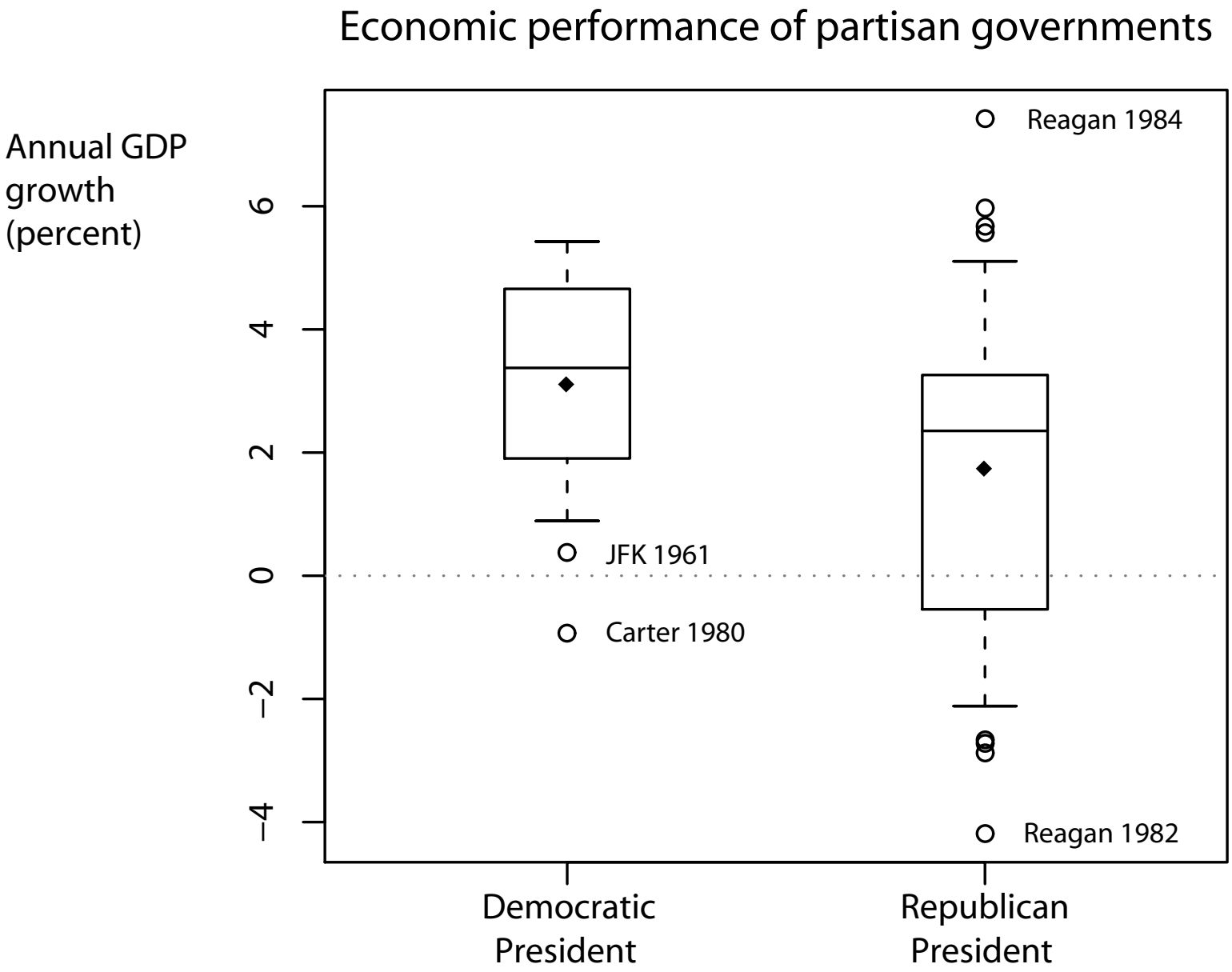
# Box plots: Annual US GDP growth, 1951–2000



# Box plots: Annual US GDP growth, 1951–2000



# Box plots: Annual US GDP growth, 1951–2000



# Help!

To get help on a known command `x`, type `help(x)` or `?x`

To search the help files using a keyword string `s`, type `help.search(s)`

Note that this implies to search on the word regression, you should type `help.search("regression")`

but to get help for the command `lm`, you should type `help(lm)`

Hard to use Google directly for R help ("r" is kind of a common letter)

Easiest way to get help from the web: `rseek.org`

Rseek tries to limit results to R topics (not wholly successful)

# Installing R on a PC

- Go to the Comprehensive R Archive Network (CRAN)
  `http://cran.r-project.org/`

- Under the heading "Download and Install R", click on "Download R for Windows"

- Click on "base"

- Download and run the R setup program.
  The name changes as R gets updated;
  the current version is "R-2.15.2-win.exe"

- Once you have R running on your computer,
  you can add new libraries from inside R by selecting
  "Install packages" from the Packages menu

# Installing R on a Mac

- Go to the Comprehensive R Archive Network (CRAN)
  `http://cran.r-project.org/`

- Under the heading "Download and Install R", click on "Download R for MacOS X"

- Download and run the R setup program.
  The name changes as R gets updated;
  the current version is "R-2.15.2.pkg"

- Once you have R running on your computer,
  you can add new libraries from inside R by selecting
  "Install packages" from the Packages menu

# Editing scripts

Don't use Microsoft Word to edit R code!

Word adds lots of "stuff" to text; R needs the script in a plain text file.

Some text editors:

- Notepad: Free, and comes with Windows (under Start → Programs → Accessories). Gets the job done; not powerful.
- TextEdit: Free, and comes with Mac OS X. Gets the job done; not powerful.
- TINN-R: Free and powerful. Windows only. `http://www.sciviews.org/Tinn-R/`
- **Emacs:** Free and *very* powerful (my preference). Can use for R, Latex, and any other language. Available for Mac, PC, and Linux.

  For Mac (easy installation): `http://aquamacs.org/`

  For Windows (see the README): `http://ftp.gnu.org/gnu/emacs/windows/`

# Editing data

R can load many other packages' data files

See the `foreign` library for commands

For simplicity & universality, I prefer Comma-Separated Variable (CSV) files

Microsoft Excel can edit and export CSV files (under Save As)

R can read them using `read.csv()`

OpenOffice free alternative to Excel (for Windows and Unix):
`http://www.openoffice.org/`

My detailed guide to installing social science software on the Mac:
`http://thewastebook.com/?post=social-science-computing-for-mac`

Focus on steps 1.1 and 1.3 for now; come back later for Latex in step 1.2

# Example 2: A simple linear regression

Let's investigate a bivariate relationship

Cross-national data on fertility (children born per adult female)
and the percentage of women practicing contraception.

Data are from 50 developing countries.

Source: Robey, B., Shea, M. A., Rutstein, O. and Morris, L. (1992) "The reproductive revolution: New survey findings." *Population Reports.* Technical Report M-11.

# Example 2: A simple linear regression

```
# Load data
data <- read.csv("robeymore.csv",header=T,na.strings="")
completedata <- na.omit(data)
attach(completedata)

# Transform variables
contraceptors <- contraceptors/100

# Run linear regression
res.lm <- lm(tfr~contraceptors)
print(summary(res.lm))

# Get predicted values
pred.lm <- predict(res.lm)
```

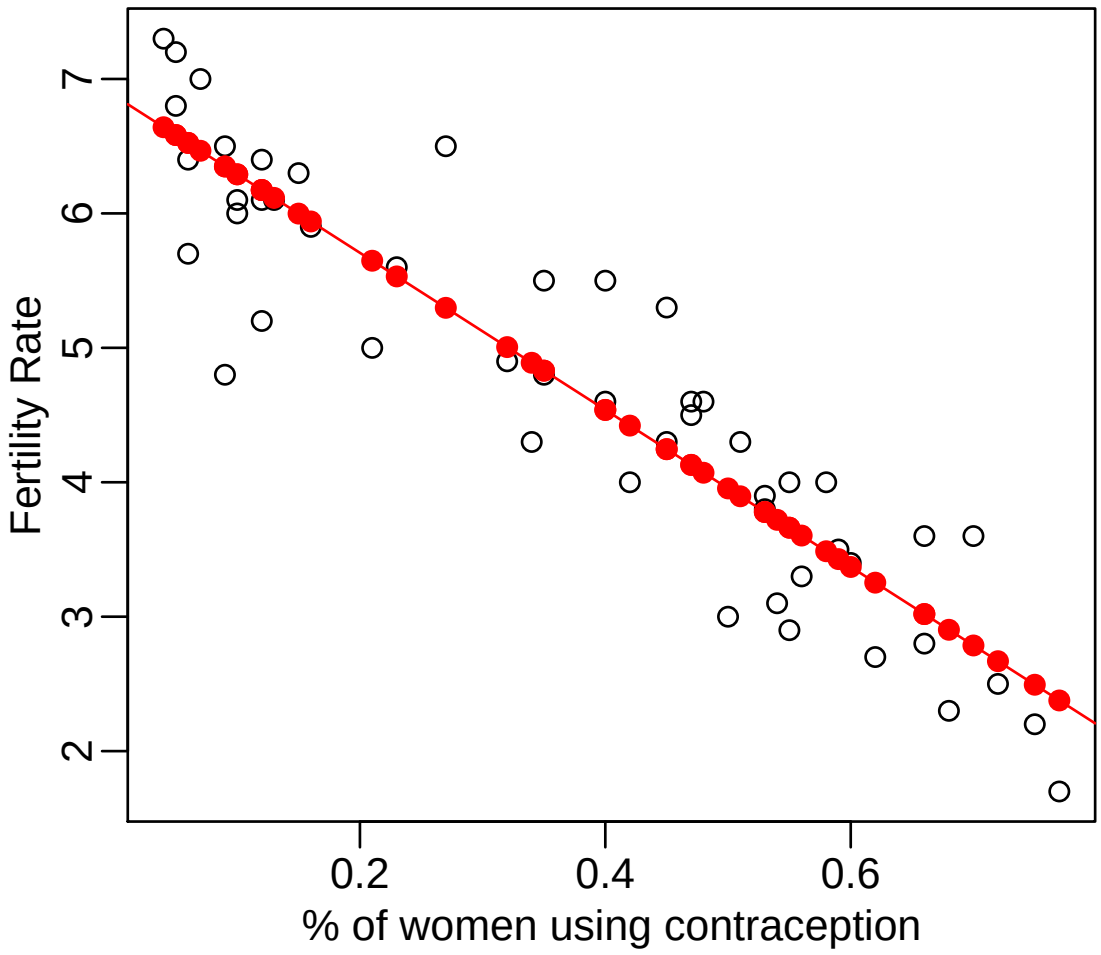
# Example 2: A simple linear regression

```
# Make a plot of the data
plot(x=contraceptors,
     y=tfr,
     ylab="Fertility Rate",
     xlab="% of women using contraception",
     main="Average fertility rates & contraception; \n
           50 developing countries",
     xaxp=c(0,1,5)
     )

# Add predicted values to the plot
points(x=contraceptors,y=pred.lm,pch=16,col="red")
```

# Example 2: A simple linear regression

```
> summary(res.lm)

Call:
lm(formula = tfr ~ contraceptors)

Residuals:
     Min       1Q   Median       3Q      Max
-1.54934 -0.30133  0.02540  0.39570  1.20214

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)    6.8751     0.1569   43.83   <2e-16 ***
contraceptors -5.8416     0.3584  -16.30   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5745 on 48 degrees of freedom
Multiple R-Squared: 0.847,      Adjusted R-squared: 0.8438
F-statistic: 265.7 on 1 and 48 DF,  p-value: < 2.2e-16
```

# Data and Prediction



# Matrix Algebra in R

| | |
|---|---|
| `det(a)` | Computes the determinant of matrix `a` |
| `solve(a)` | Computes the inverse of matrix `a` |
| `t(a)` | Takes the transpose of `a` |
| `a%*%b` | Matrix multiplication of `a` by `b` |
| `a*b` | Element by element multiplication |

# An R list is a basket containing many other variables

```
> x <- list(a=1, b=c(2,15), giraffe="hello")

> x$a
[1] 1

> x$b
[1]  2 15

> x$b[2]
[1] 15

> x$giraffe
[1] "hello"

> x[3]
$giraffe
[1] "hello"

> x[["giraffe"]]
[1] "hello"
```

# R lists

Things to remember about lists

- Lists can contain any number of variables of any type
- Lists can contain other lists
- Contents of a list can be accessed by name or by position
- Allow us to move lots of variables in and out of functions
- Functions often return lists (only way to have multiple outputs)

# `lm()` basics

```
# To run a regression
res <- lm(y~x1+x2+x3,
          data,                    # A dataframe containing
                                   # y, x1, x2, etc.
          na.action="")

# To print a summary
summary(res)

# To get the coefficients
res$coefficients

# or
coef(res)

#To get residuals
res$residuals

#or

resid(res)
```

# `lm()` basics

```
# To get the variance-covariance matrix of the regressors
vcov(res)

# To get the standard errors
sqrt(diag(vcov(res)))

# To get the fitted values
predict(res)

# To get expected values for a new observation or dataset
predict(res,
        newdata,                    # a dataframe with same x vars
                                    # as data, but new values
        interval = "confidence",    # alternative: "prediction"
        level = 0.95
        )
```

# R lists & Object Oriented Programming

A list object in R can be given a special "class" using the `class()` function

This is just a metatag telling other R functions that this list object conforms to a certain format

So when we run a linear regression like this:

```
res <- lm(y~x1+x2+x3, data, na.action="")
```

The result `res` is a list object of class ``'lm'''

Other functions like `plot()` and `predict()` will react to `res` in a special way because of this class designation

Specifically, they will run functions called `plot.lm()` and `predict.lm()`

Object-oriented programming:
a function does different things depending on class of input object

# Example 3: Party systems & Redistribution

Cross sectional data on industrial democracies:

| | |
|---|---|
| povred | Percent of citizens lifted out of poverty by taxes and transfers |
| lnenp | Natural log of effective number of parties |
| maj | Majoritarian election system dummy |
| pr | Proportional representation dummy |
| unam | Unanimity government dummy (Switz) |

Source of data & plot: Torben Iversen and David Soskice, 2002, "Why do some democracies redistribute more than others?" Harvard University.

# Example 3: Party systems & Redistribution

```
# Clear memory of all objects
rm(list=ls())

# Load data
file <- "iver.csv";
data <- read.csv(file,header=TRUE);
attach(data)

lm.result <- lm(povred~lnenp)
print(summary(lm.result))
```

# Example 3: Party systems & Redistribution

```
Call:
lm(formula = povred ~ lnenp)

Residuals:
    Min      1Q  Median      3Q     Max
-48.907  -4.115   8.377  11.873  18.101

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)    21.80      16.15   1.349   0.2021
lnenp          24.17      12.75   1.896   0.0823 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 19.34 on 12 degrees of freedom
Multiple R-Squared: 0.2305,     Adjusted R-squared: 0.1664
F-statistic: 3.595 on 1 and 12 DF,  p-value: 0.08229
```

# Example 3: Party systems & Redistribution

```
# A new model with multiple regressors
lm.result2 <- lm(povred~lnenp+maj+pr)
print(summary(lm.result2))
```

# Example 3: Party systems & Redistribution

```
Call:
lm(formula = povred ~ lnenp + maj + pr)

Residuals:
     Min       1Q   Median       3Q      Max
-23.3843  -1.4903   0.6783   6.2687  13.9376

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   -31.29      26.55  -1.179  0.26588
lnenp          26.69      14.15   1.886  0.08867 .
maj            48.95      17.86   2.740  0.02082 *
pr             58.17      13.52   4.302  0.00156 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12.37 on 10 degrees of freedom
Multiple R-Squared: 0.7378,     Adjusted R-squared: 0.6592
F-statistic: 9.381 on 3 and 10 DF,  p-value: 0.002964
```

# Example 3: Party systems & Redistribution

```
# A new model with multiple regressors and no constant
lm.result3 <- lm(povred~lnenp+maj+pr+unam-1)
print(summary(lm.result3))
```

# Example 3: Party systems & Redistribution

```
Call:
lm(formula = povred ~ lnenp + maj + pr + unam - 1)

Residuals:
     Min       1Q   Median       3Q      Max
-23.3843  -1.4903   0.6783   6.2687  13.9376

Coefficients:
      Estimate Std. Error t value Pr(>|t|)
lnenp    26.69      14.15   1.886   0.0887 .
maj      17.66      12.69   1.392   0.1941
pr       26.88      21.18   1.269   0.2331
unam    -31.29      26.55  -1.179   0.2659
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12.37 on 10 degrees of freedom
Multiple R-Squared: 0.9636,     Adjusted R-squared: 0.949
F-statistic: 66.13 on 4 and 10 DF,  p-value: 3.731e-07
```

# Example 3: Party systems & Redistribution

```
# A model with an interaction term added
lm.result4 <- lm(povred~lnenp+maj+pr+lnenp:maj)
print(summary(lm.result4))
```

# Example 3: Party systems & Redistribution

```
Call:
lm(formula = povred ~ lnenp + maj + pr + lnenp:maj)

Residuals:
      Min        1Q    Median        3Q       Max
-22.25124   0.06679   2.85314   4.73179  12.99480

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   -14.83      31.42  -0.472  0.64813
lnenp          16.78      17.39   0.965  0.35994
maj            16.34      37.65   0.434  0.67445
pr             56.18      13.70   4.102  0.00267 **
lnenp:maj      29.55      30.02   0.984  0.35065
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12.39 on 9 degrees of freedom
Multiple R-Squared: 0.7633,     Adjusted R-squared: 0.6581
F-statistic: 7.256 on 4 and 9 DF,  p-value: 0.006772
```

# Example 3: Party systems & Redistribution

```
# A quicker way to add interactions
lm.result5 <- lm(povred~pr+lnenp*maj)
print(summary(lm.result5))
```

# Example 3: Party systems & Redistribution

```
Call:
lm(formula = povred ~ pr + lnenp * maj)

Residuals:
      Min        1Q    Median        3Q       Max
-22.25124   0.06679   2.85314   4.73179  12.99480

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   -14.83      31.42  -0.472  0.64813
pr             56.18      13.70   4.102  0.00267 **
lnenp          16.78      17.39   0.965  0.35994
maj            16.34      37.65   0.434  0.67445
lnenp:maj      29.55      30.02   0.984  0.35065
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12.39 on 9 degrees of freedom
Multiple R-Squared: 0.7633,     Adjusted R-squared: 0.6581
F-statistic: 7.256 on 4 and 9 DF,  p-value: 0.006772
```

# R Graphics

R has several graphics systems.

The `base` system

The `grid` system

(`grid` is more powerful, but has a steeper learning curve.
See Paul Murrel's book on R Graphics for an introduction.)

Focus here on `base`

# R Graphics: Devices

Everything you draw in R must be drawn on a canvas

Must create the canvas before you draw anything

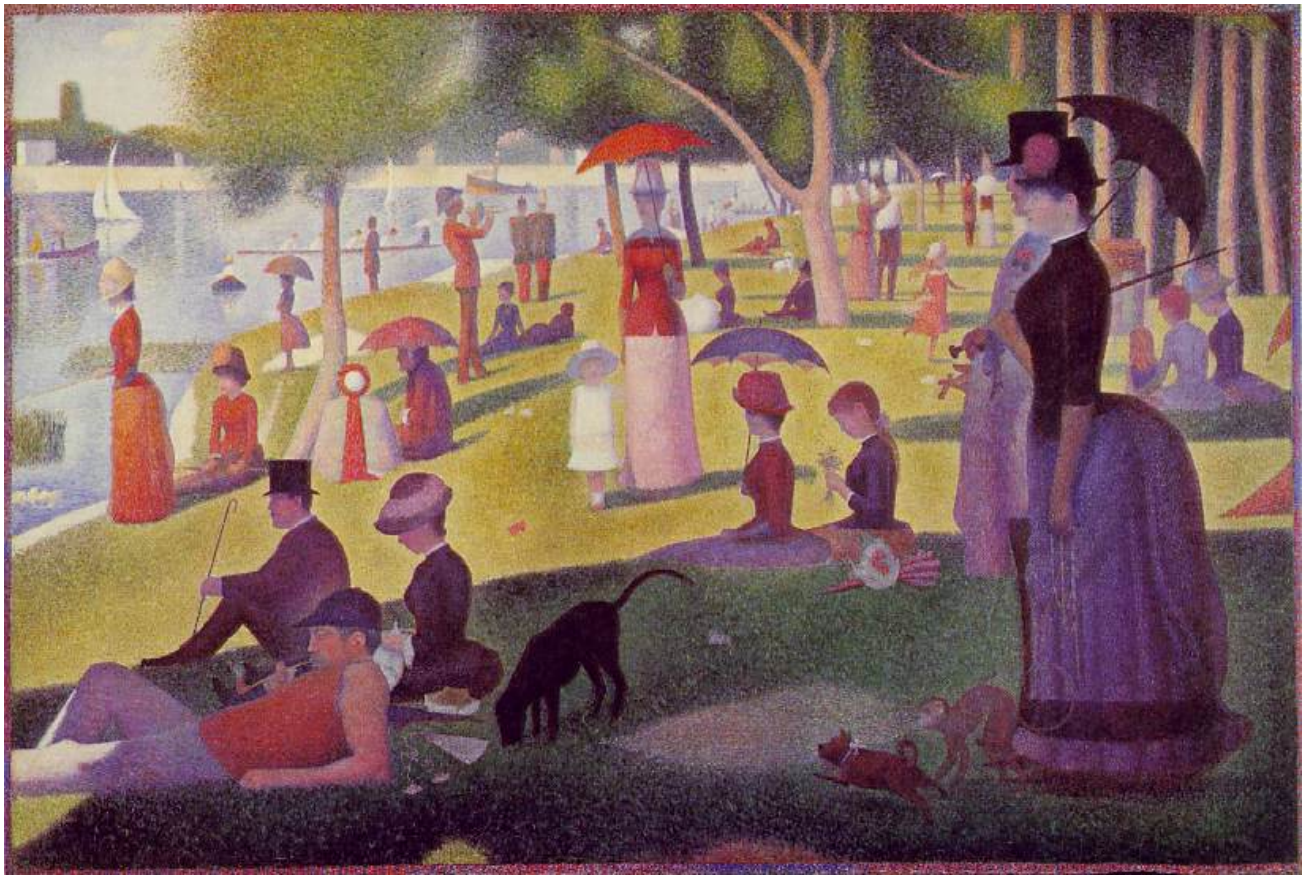
Computer canvasses are **devices** you draw to

Devices save graphical input in different ways

Sometimes to the disk, sometimes to the screen

Most important distinction: raster vs. vector devices

# Vector vs. raster



Pointalism = raster graphics. Plot each pixel on an $n$ by $m$ grid.

# Vector vs. raster

Pixel = Point = Raster

Good for pictures. Bad for drawings/graphics/cartoons.

(Puzzle: isn't everything raster? In display, yes. Not in storage)

Advantages of vector:

- Easily manipulable/modifiable groupings of objects
- Easy to scale objects larger or smaller/ Arbitrary precision
- Much smaller file sizes
- Can always convert to raster (but not the other way round, at least not well)

Disadvantages:

- A photograph would be really hard to show (and huge file size)
- Not web accessible. Convert to PNG or PDF.

# Some common graphics file formats

| | Lossy | Lossless |
|---|---|---|
| Raster | .gif, .jpeg | .wmf, .png, .bmp |
| Vector | – | .ps, .eps, .pdf, .ai, .wmf |

Lossy means during file compression, some data is (intentionally) lost

Avoid lossy formats whenever possible

# Some common graphics file formats

In `R`, have access to several formats:

| | |
|---|---|
| win.metafile() | wmf, Windows media file |
| pdf() | pdf, Adobe portable data file |
| postscript() | postscript file (printer language) |
| | |
| quartz() | opens a screen; Mac only |
| windows() | opens a screen; PC only |
| x11() | opens a screen; works on all machines |

Latex, Mac or Unix users can't use wmf

`windows(record=TRUE)` let's you cycle thru old graphs with arrow keys

# High-level graphics commands

In R, High level graphics commands:

- produce a standard graphic type
- fill in lots of details (axes, titles, annotation)
- have many configurable parameters
- have varied flexibility

You don't need to use HLCs to make R graphics.

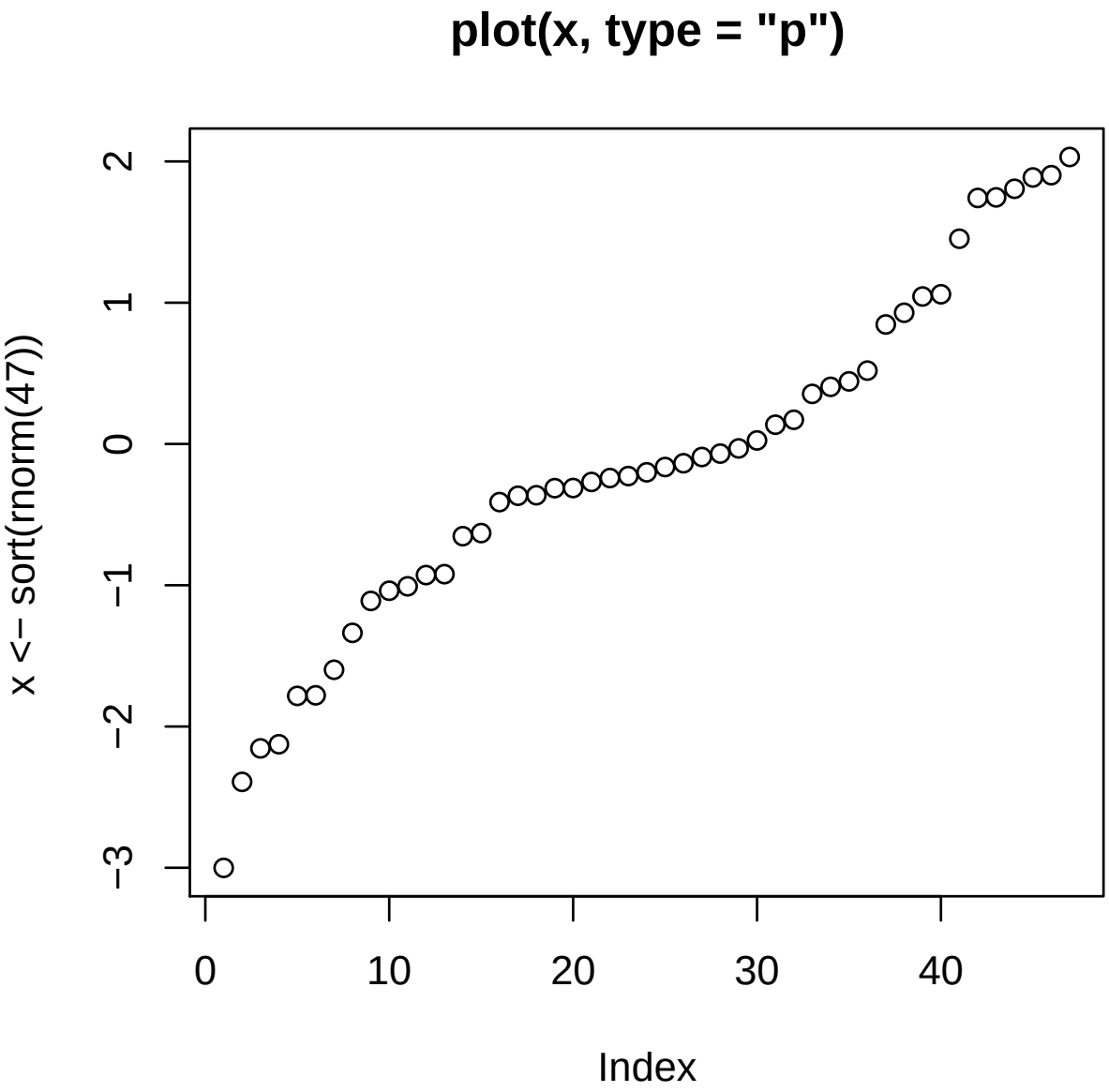
Could use primitive commands to do each task above

Using low levels commands gives more control but takes more time

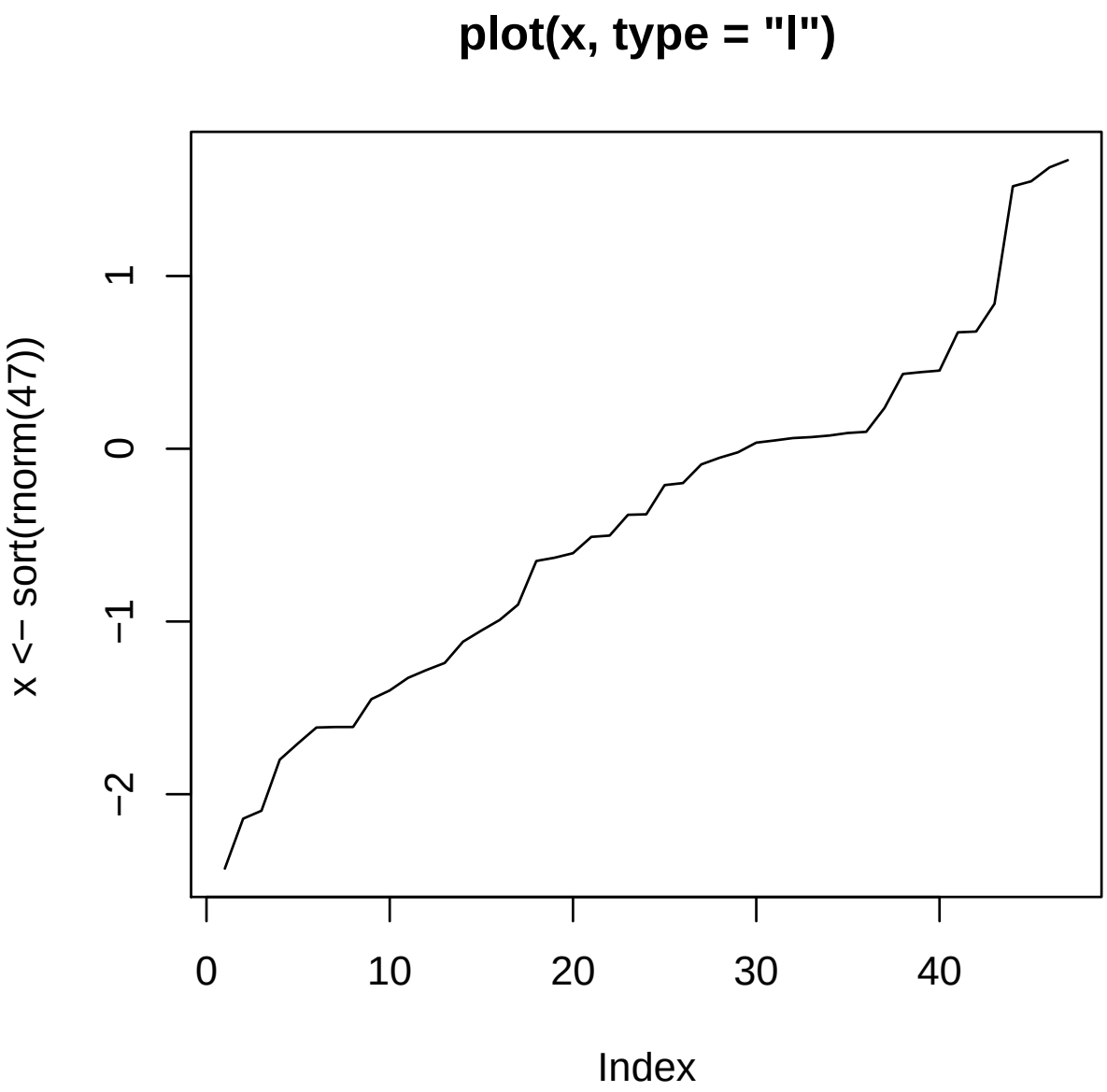
# Some major high-level graphics commands

| Graphic | Base command | Lattice command |
|---|---|---|
| scatterplot | plot() | xyplot() |
| line plot | plot(. . . ,type="l") | xyplot(. . . ,type="l") |
| Bar chart | barplot() | barchart() |
| Histogram | hist() | histogram() |
| Smoothed histograms | plot() after density() | densityplot() |
| boxplot | boxplot() | bwplot() |
| Dot plot | dotchart() | dotplot() |
| Contour plots | contour() | contourplot() |
| image plot | image() | levelplot() |
| 3D surface | persp() | wireframe() |
| 3D scatter | scatterplot3d()* | cloud() |
| conditional plots | coplot() | xyplot() |
| Scatterplot matrix | | splom() |
| Parallel coordinates | | parallel() |
| Star plot | stars() | |
| Stem-and-leaf plots | stem() | |
| ternary plot | ternaryplot() in vcd | |
| Fourfold plot | fourfoldplot() in vcd | |
| Mosaic plots | mosaicplot() in vcd | |

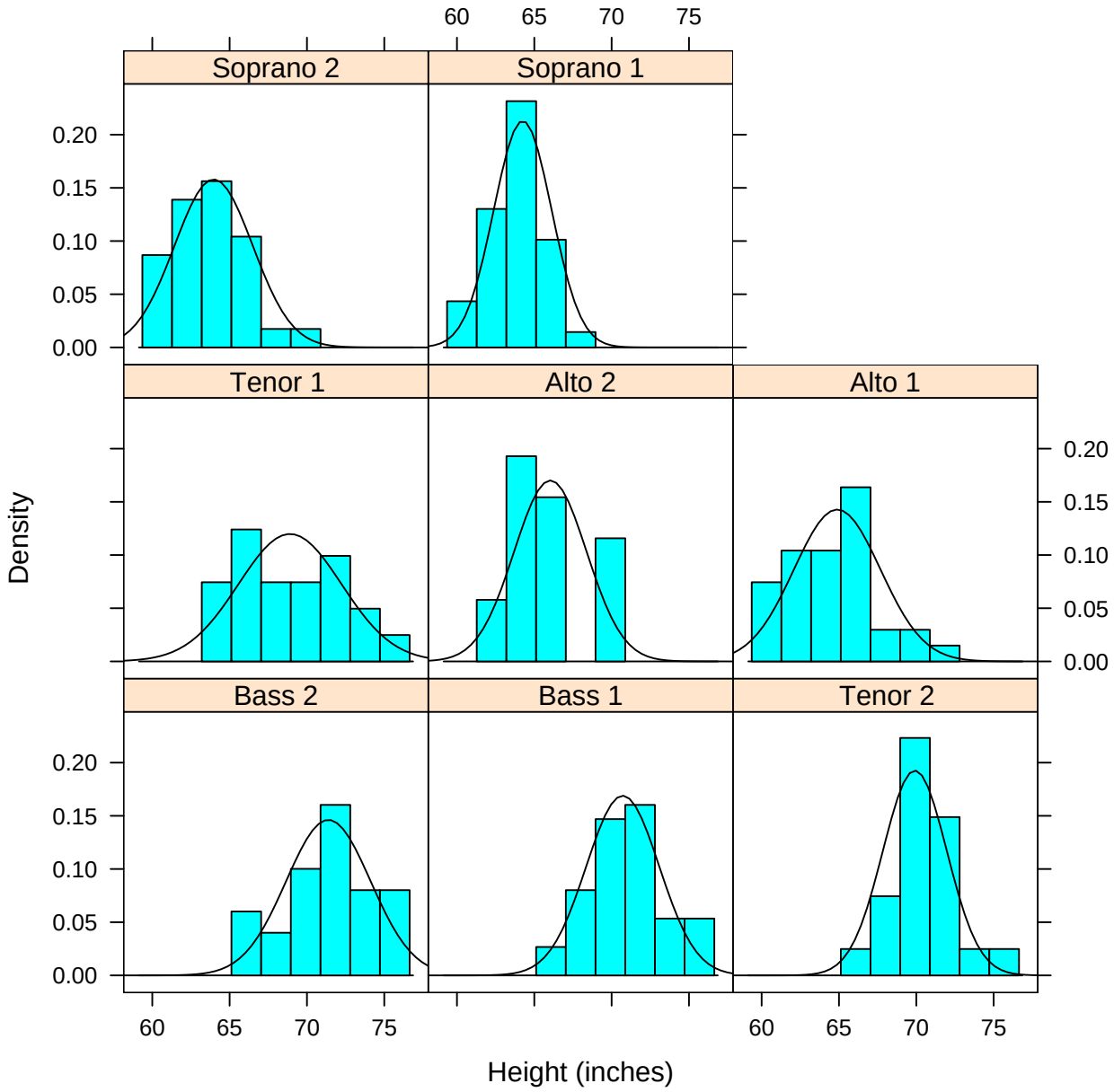
# Scatterplot: `plot()`



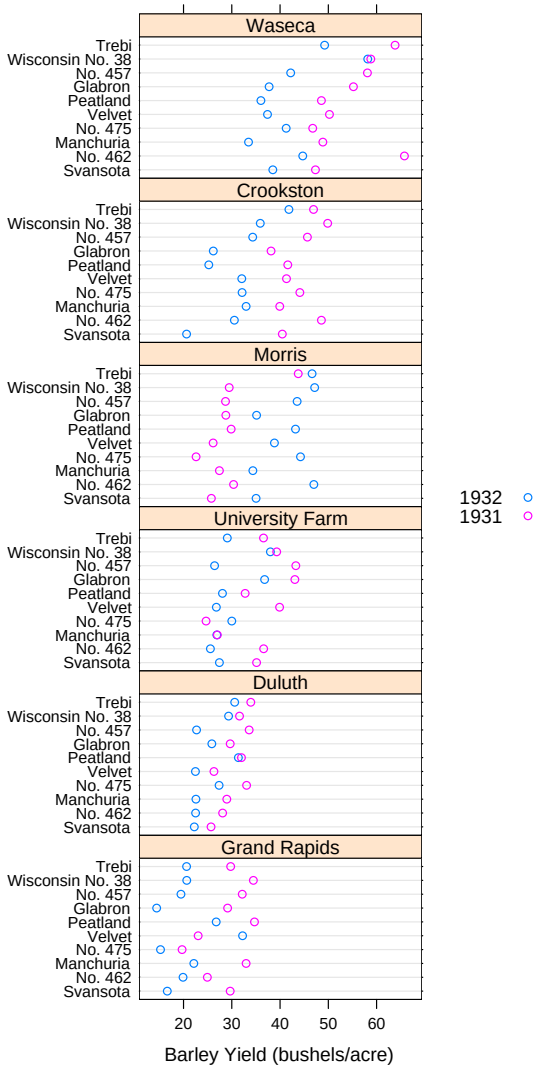
# **Line plot:** `plot(...,type="l")`



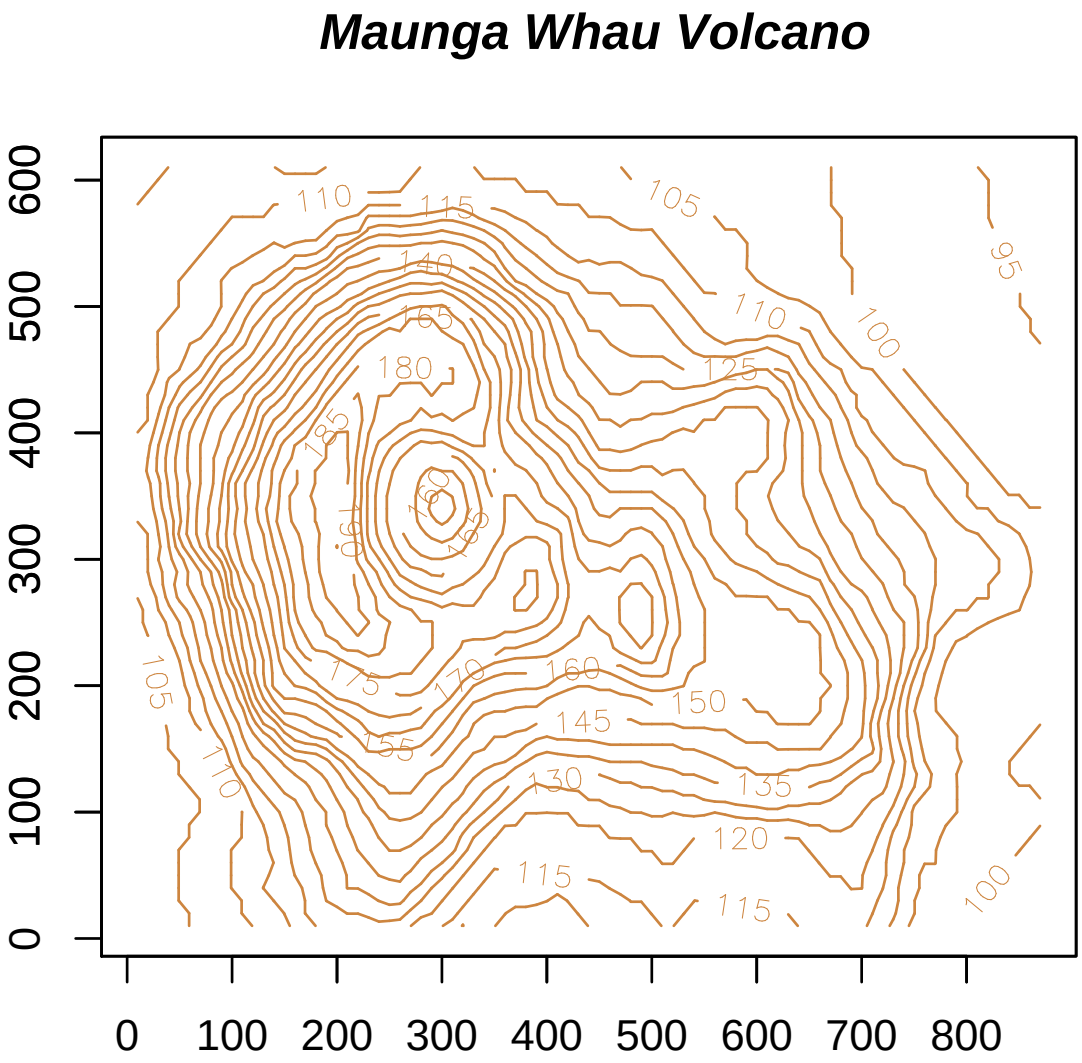
# (Smoothed) Histograms: `densityplot()` & others



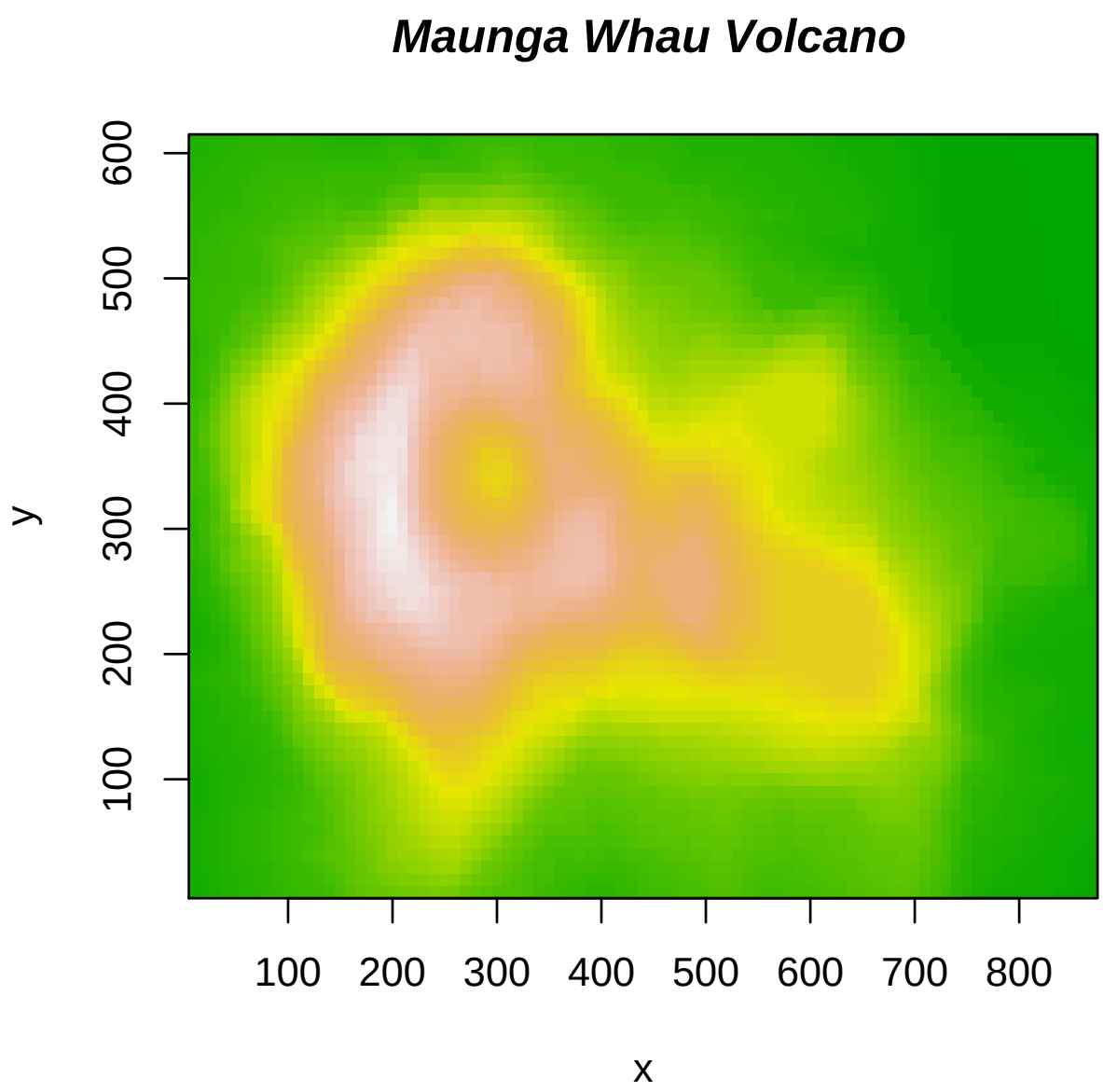
# Dot plot: `dotplot()`



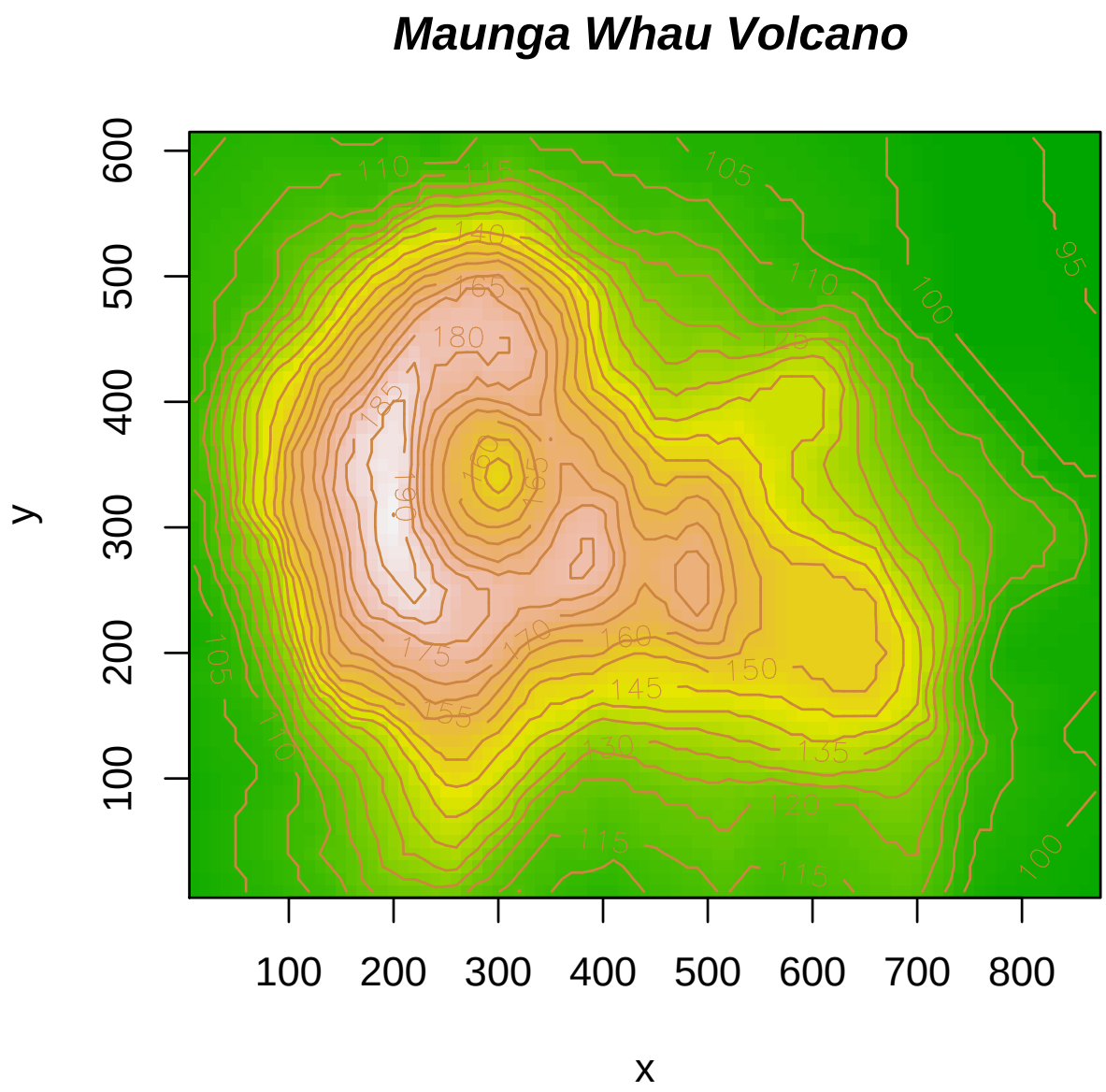
# Contour plot: `contour()`



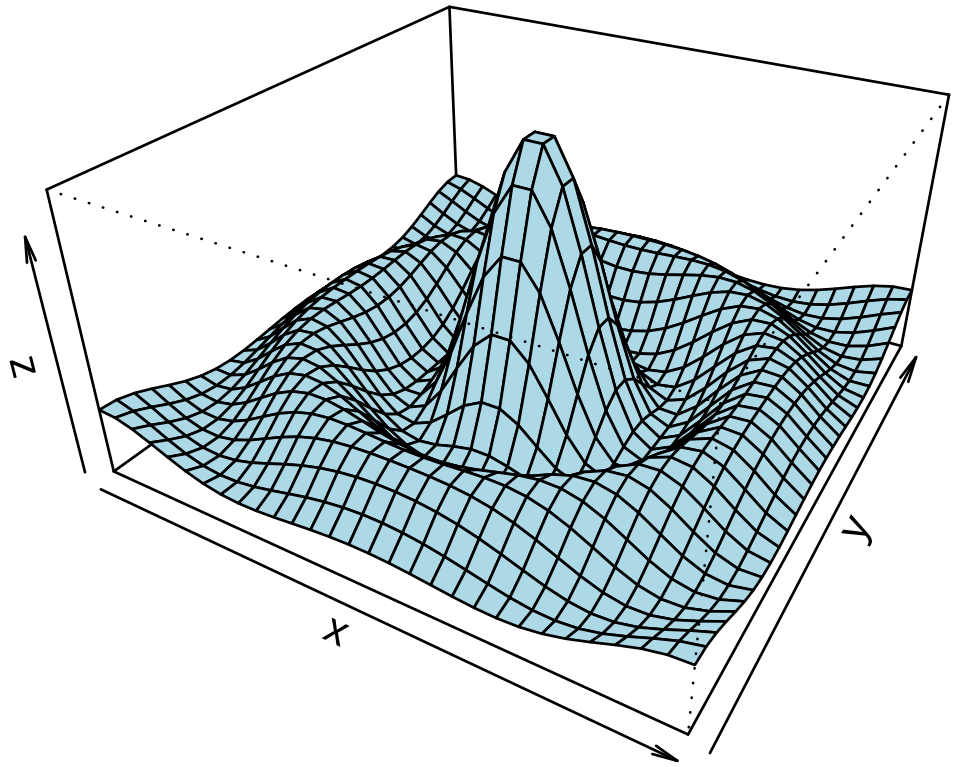
# Image plot: `image()`



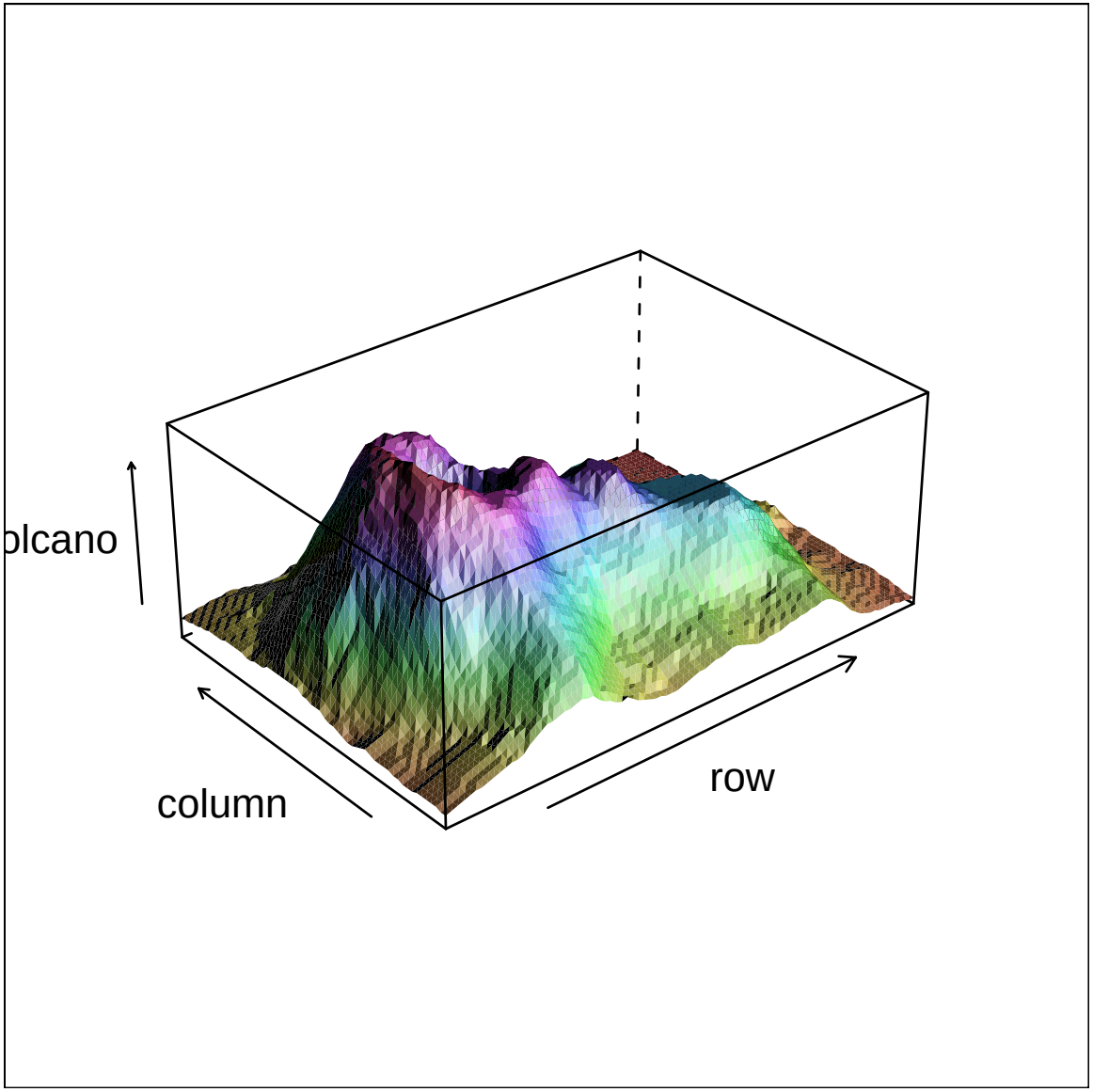
# Image plot with contours: `contour(...,add=TRUE)`



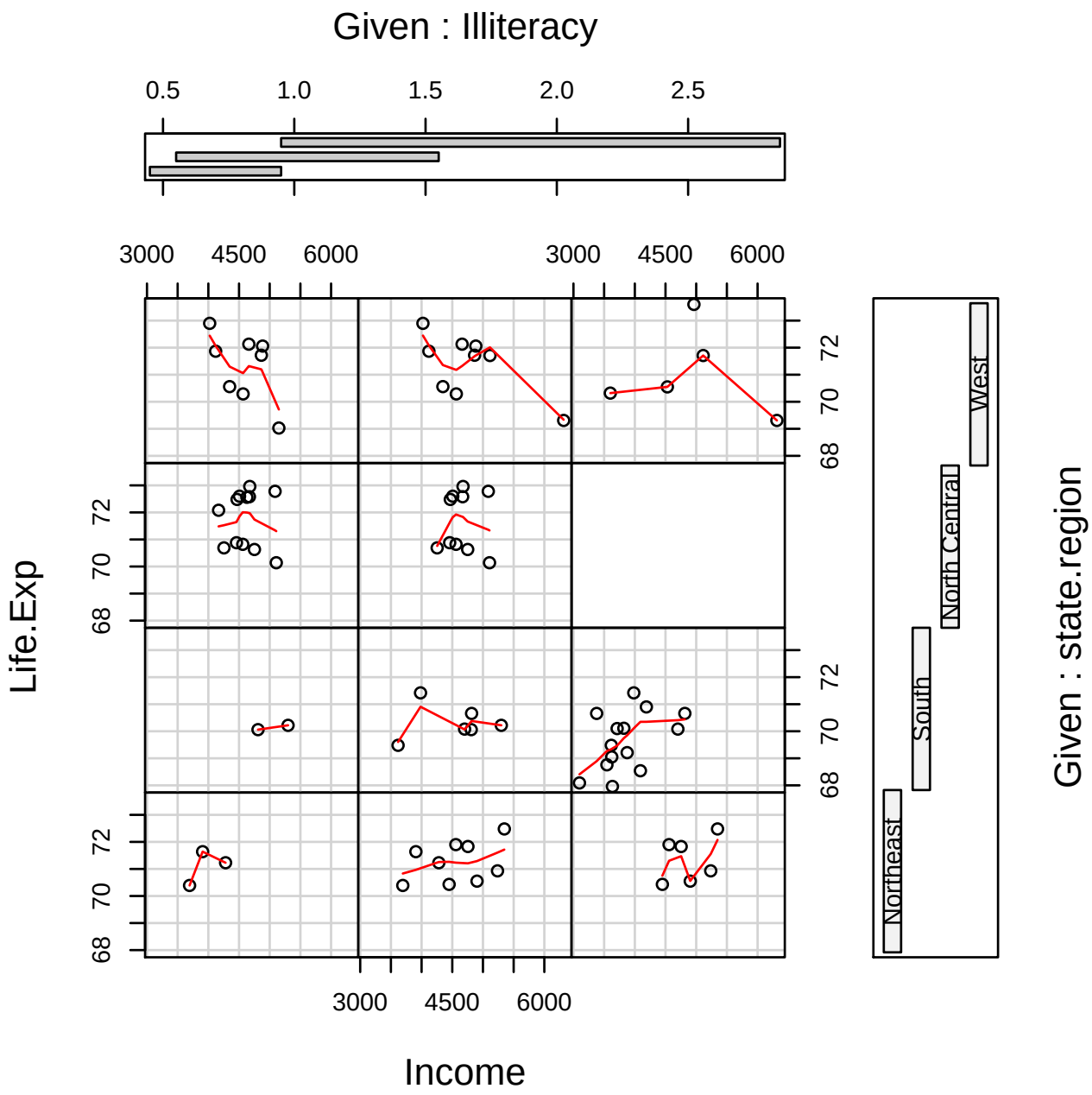
# 3D surface: `persp()`



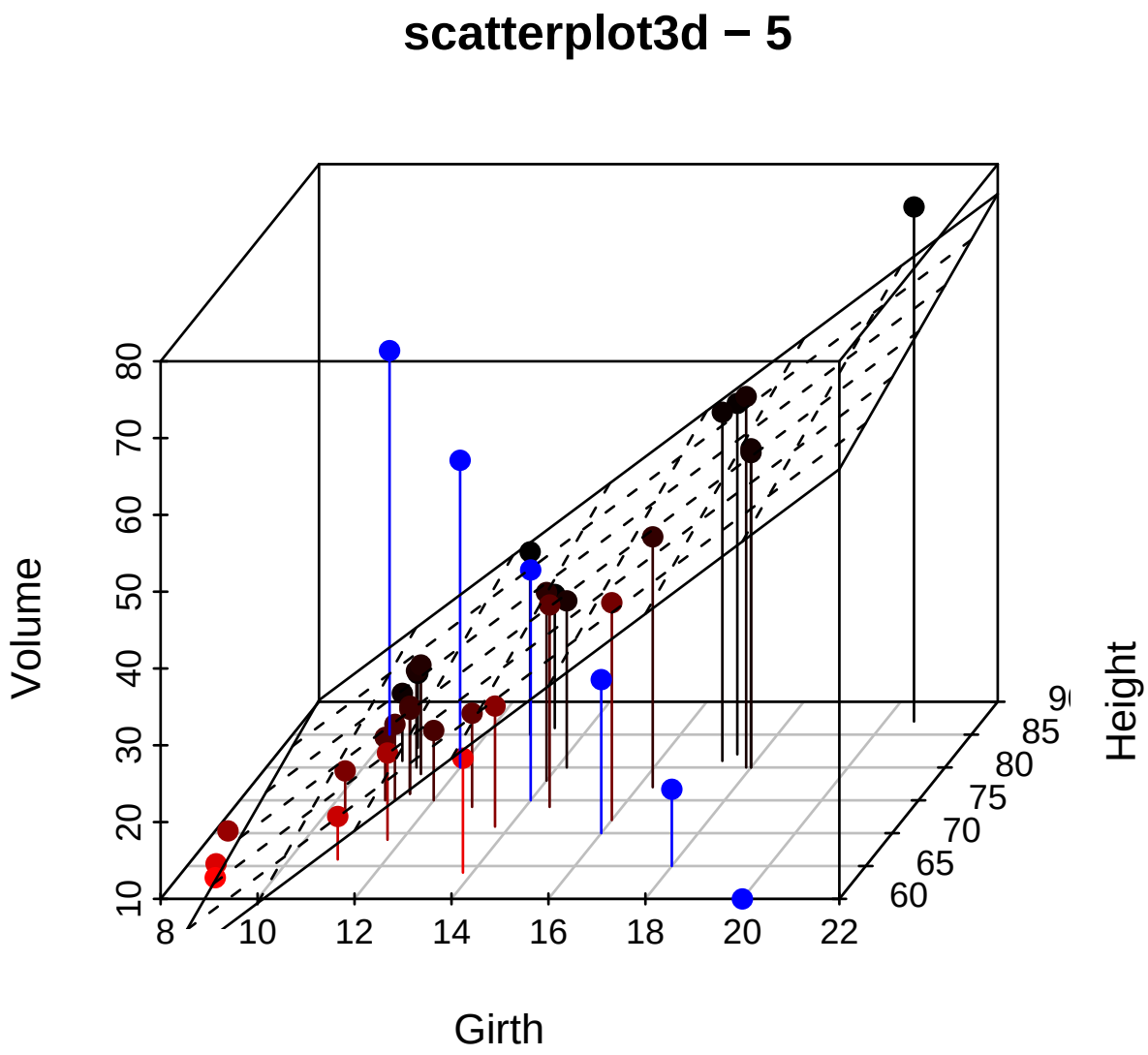
# 3D surface: `wireframe()`



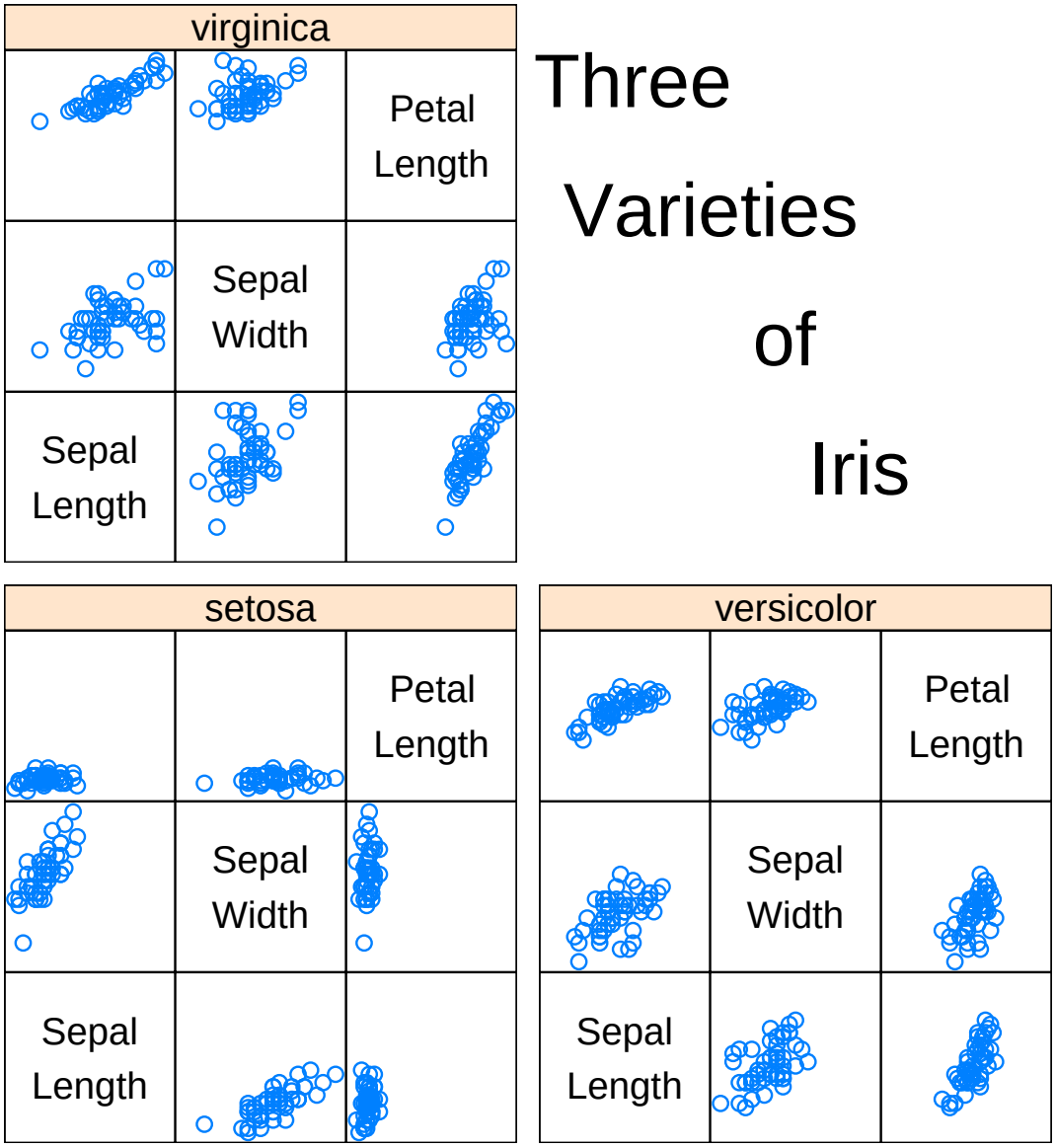
# Conditional plots: `coplot()`



# 3D scatter: `scatterplot3d()` in own library



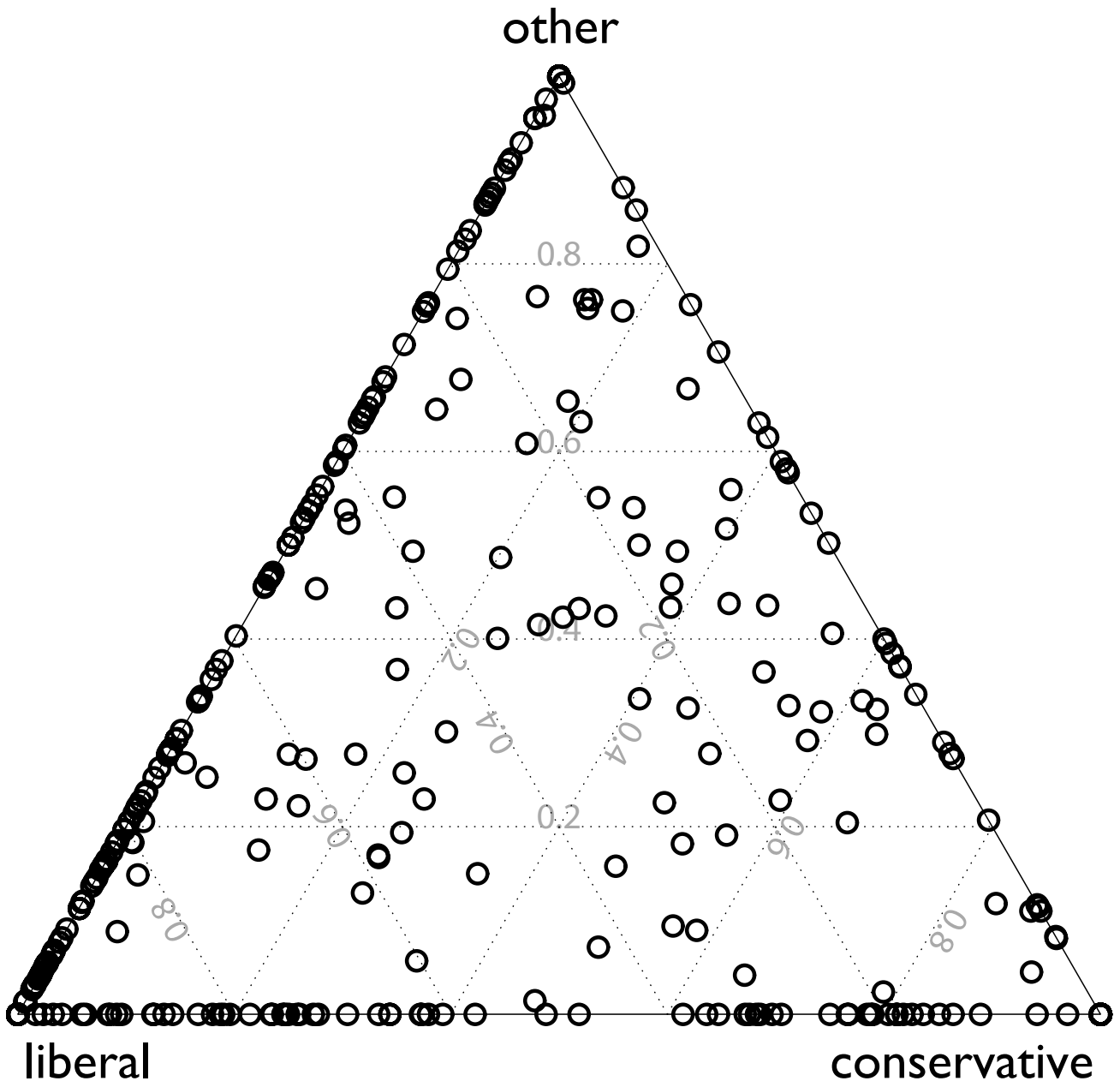
# Scatterplot matrix: `splom()`




Three Varieties of Iris

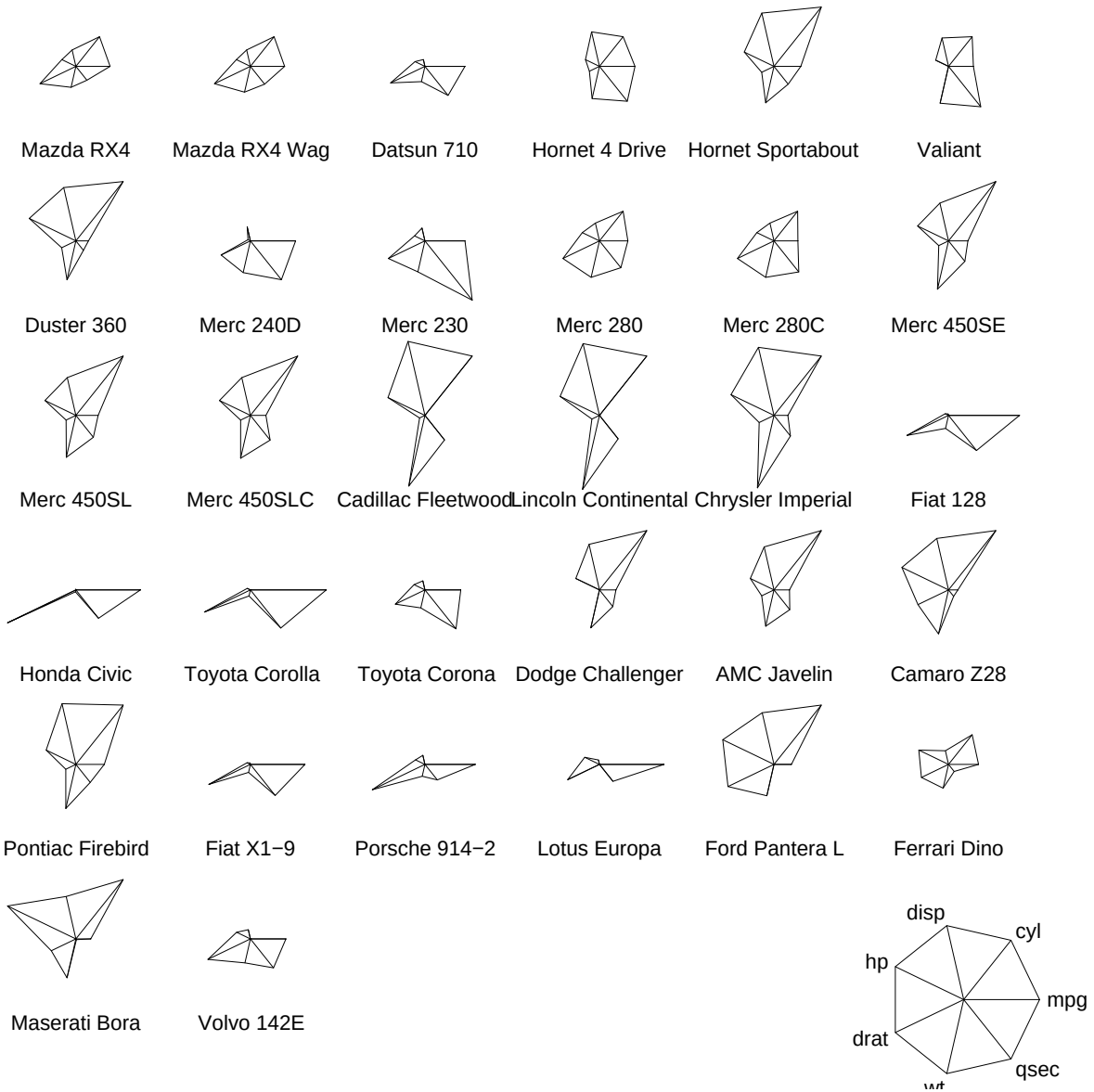
Scatter Plot Matrix

# **Ternary plot:** `ternaryplot()` **in** `vcd`



# Star plot: `stars()`

**Motor Trend Cars : full stars()**



# Stem-and-leaf plot

```
stem> stem(log10(islands))

  The decimal point is at the |

  1 | 1111112222233444
  1 | 5555556666667899999
  2 | 3344
  2 | 59
  3 |
  3 | 5678
  4 | 012
```

# Basic customization

For any given high-level plotting command, there are many options listed in help

```
barplot(height, width = 1, space = NULL,
        names.arg = NULL, legend.text = NULL, beside = FALSE,
        horiz = FALSE, density = NULL, angle = 45,
        col = NULL, border = par("fg"),
        main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
        xlim = NULL, ylim = NULL, xpd = TRUE,
        axes = TRUE, axisnames = TRUE,
        cex.axis = par("cex.axis"), cex.names = par("cex.axis"),
        inside = TRUE, plot = TRUE, axis.lty = 0, offset = 0, ...)
```

Just the tip of the iceberg: notice the `...`

This means you can pass other, unspecified commands throough `barplot`

# Basic customization

The most important (semi-) documented parameters to send through `...` are settings to `par()`

Most base (traditional) graphics options are set through `par()`

`par()` has no effect on lattice or grid graphics

Consult `help(par)` for the full list of options

Some key examples, grouped functionally

# `par()` settings

Customizing text size:

| | |
|---|---|
| cex | Text size (a multiplier) |
| cex.axis | Text size of tick numbers |
| cex.lab | Text size of axes labels |
| cex.main | Text size of plot title |
| cex.sub | Text size of plot subtitle |

note the latter will multiply off the basic `cex`

# `par()` settings

More text specific formatting

| | |
|---|---|
| font | Font face (bold, italic) |
| font.axis | etc |
| | |
| srt | Rotation of text in plot (degrees) |
| las | Rotation of text in margin (degrees) |

Note the distinction between text in the plot and outside.

Text in the plot is plotted with `text()`

Text outside the plot is plotted with `mtext()`, which was designed to put on titles, etc.

# `par()` settings

Formatting for most any object

| | |
|---|---|
| bg | background color |
| col | Color of lines, symbols in plot |
| col.axis | Color of tick numbers, etc |

The above expect colors (see `colors()` for a list of names

# `par()` settings

Formatting for lines and symbols

| | |
|---|---|
| lty | Line type (solid, dashed, etc) |
| lwd | Line width (default too large; try really small, e.g., 0) |
| pch | Data symbol type; see `example(points)` |

You will very often need to set the above

# More `par()` settings

Formatting for axes

| | |
|---|---|
| lab | Number of ticks |
| xaxp | Number of ticks for xaxis |
| tck,tcl | Length of ticks relative to plot/text |
| mgp | Axis spacing: axis title, tick labels, axis line |

These may seem trivial, but affect the aesthetics of the plot & effective use of space

`R` defaults to excessive mgp, which looks ugly & wastes space

# `par()` settings

More formating for axes

The following commands are special:
they are primitives in `par()` that can't be set inside the `...` of high-level commands

You must set them with `par()` first

| | |
|---|---|
| usr | Ranges of axes, (xmin, xmax, ymin, ymax) |
| xlog | Log scale for x axis? |
| ylog | Log scale for y axis? |

You can also make a logged axis by hand, by changing the labels argument of `axis()`