A BRIEF INTRODUCTION TO R

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WHY R?

Why use a complicated, command-line driven stats package like R?

- It's free!
- Widely used by statisticians for new statistical methods
- If something doesn't work the way you like, you can change it
- R is a programming language — you can write your own functions
- R scripts, Sweave, & knitr for reproducible research
- Works everywhere (Windows, OS X, Linux, ...)
- R was designed for expressive data analysis

R BASICS

R BASICS

Start RStudio — take a look around

R will be running in either your home directory or where is was installed

Set the working directory to folder containing your analysis

GETTING HELP

R comes with a lot of documentation

To get help on functions or concepts within R, use the **"?"** operator

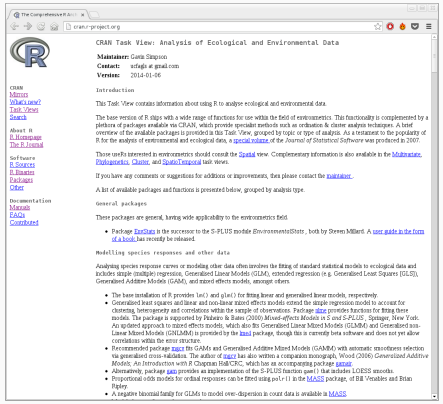
For help on the `getwd()` function use: `?getwd`

Function `help.search("foo")` will search through all packages installed for help pages with `foo` in them

R-Help mailing list: `http://www.r-project.org/mail.html`

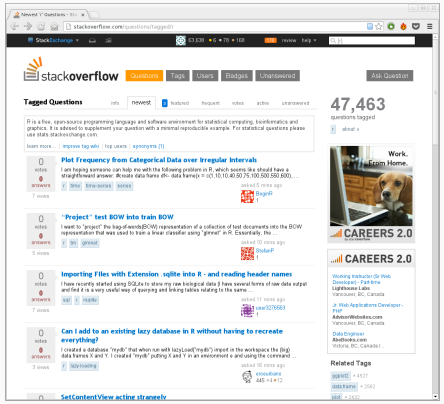
GETTING HELP: TASK VIEWS

`cran.r-project.org/web/views/`



GETTING HELP: STACK OVERFLOW

`stackoverflow.com/questions/tagged/r`



WORKING WITH R

Type commands at the prompt **>** — R evaluates them when you hit **`Return`**

If a line is *not* syntactically complete, the prompt changes to **+**

Create an object by assigning something to it

```
radius <- 5
pi * radius^2
```

```
[1] 78.53982
```

If we don't assign, R prints a *representation* of the object

PACKAGES

R comes with a basic set of functionality plus some recommended packages

Additional functionality added via packages from **CRAN**, **github**, **Bioconductor**, **drat** repos

```
install.packages(c("gapminder", "ggplot2"))
library("gapminder")
library("ggplot2")
```

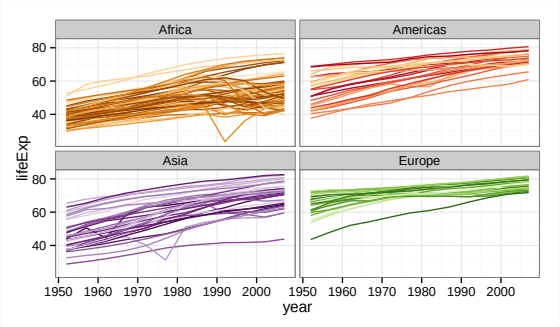

READING DATA INTO R

```
gap <- system.file("gapminder.tsv", package = "gapminder")
gapminder <- read.delim(gap)
head(gapminder)
```

```
      country continent year lifeExp      pop gdpPercap
1 Afghanistan      Asia 1952  28.801  8425333  779.4453
2 Afghanistan      Asia 1957  30.332  9240934  820.8530
3 Afghanistan      Asia 1962  31.997 10267083  853.1007
4 Afghanistan      Asia 1967  34.020 11537966  836.1971
5 Afghanistan      Asia 1972  36.088 13079460  739.9811
6 Afghanistan      Asia 1977  38.438 14880372  786.1134
```


THIS IS WHERE WE ARE HEADING

```
ggplot(subset(gapminder, continent != "Oceania"),
       aes(x = year, y = lifeExp, group = country, color = country)) +
  geom_line(show_guide = FALSE) + facet_wrap(~ continent) +
  scale_color_manual(values = country_colors) +
  theme_bw()
```



R OBJECTS

What kind of object is `gapminder`?

```
str(gapminder)
```

```
'data.frame':   1704 obs. of  6 variables:
 $ country  : Factor w/ 142 levels "Afghanistan",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ continent: Factor w/ 5 levels "Africa","Americas",..: 3 3 3 3 3 3 3 3 3 3 ...
 $ year     : int  1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 ...
 $ lifeExp  : num  28.8 30.3 32 34 36.1 ...
 $ pop      : num  8425333 9240934 10267083 11537966 13079460 ...
 $ gdpPercap: num  779 821 853 836 740 ...
```

```
class(gapminder)
```

```
[1] "data.frame"
```

DATA FRAMES

A data frame is R's version of an Excel spreadsheet

Columns are variables

Rows are observations

Different **types** of data in columns

Each column (component) is of the same length

Is a special case of a list

SUBSETTING

Access the columns of a data frame using `[`, `[[` or `$`

`$` is simple:

Access just a single variable

```
head(gapminder$country)
```

```
[1] Afghanistan Afghanistan Afghanistan Afghanistan Afghanistan Afghanistan
142 Levels: Afghanistan Albania Algeria Angola Argentina ... Zimbabwe
```

Uses the name of required variable

Partial matching

```
head(gapminder$cou)
```

```
[1] Afghanistan Afghanistan Afghanistan Afghanistan Afghanistan Afghanistan
142 Levels: Afghanistan Albania Algeria Angola Argentina ... Zimbabwe
```


SUBSETTING

`[[` is a little more flexible:

Access just a single variable

Use the name of required variable

```
head(gapminder[["continent"]])
```

```
[1] Asia Asia Asia Asia Asia Asia
Levels: Africa Americas Asia Europe Oceania
```

Or select the *n*th component

```
head(gapminder[[2]])
```

```
[1] Asia Asia Asia Asia Asia Asia
Levels: Africa Americas Asia Europe Oceania
```

Partial matching optional — `gapminder[["cont", exact = FALSE]]`

SUBSETTING

`[` is a even more flexible:

Access one or more variables

Use the name(s) of required variable

```
head(gapminder[c("country", "continent")])
```

```
      country continent
1 Afghanistan      Asia
2 Afghanistan      Asia
3 Afghanistan      Asia
4 Afghanistan      Asia
5 Afghanistan      Asia
6 Afghanistan      Asia
```

SUBSETTING

Or select the *n*th component(s)

```
head(gapminder[1:2])
```

```
      country continent
1 Afghanistan      Asia
2 Afghanistan      Asia
3 Afghanistan      Asia
4 Afghanistan      Asia
5 Afghanistan      Asia
6 Afghanistan      Asia
```


SUBSETTING

Or we can index by rows and columns: `[rows, cols, other_args]`

```
head(gapminder[1:4, c(1,3)])
```

```
      country year
1 Afghanistan 1952
2 Afghanistan 1957
3 Afghanistan 1962
4 Afghanistan 1967
```


SUBSETTING

Leaving the row or column identifier *blank* means **"give me all of the rows (columns)"**

```
head(gapminder[1:4, ])                # all columns, rows 1--4
```

```
      country continent year lifeExp      pop gdpPercap
1 Afghanistan      Asia 1952  28.801  8425333  779.4453
2 Afghanistan      Asia 1957  30.332  9240934  820.8530
3 Afghanistan      Asia 1962  31.997 10267083  853.1007
4 Afghanistan      Asia 1967  34.020 11537966  836.1971
```

```
head(gapminder[, 1:3], 3)             # all rows, columns 1--3
```

```
      country continent year
1 Afghanistan      Asia 1952
2 Afghanistan      Asia 1957
3 Afghanistan      Asia 1962
```


SUBSETTING

Empty dimensions get **dropped** if you select a single column

```
head(gapminder[, 2], 3)               # just column 2
```

```
[1] Asia Asia Asia
Levels: Africa Americas Asia Europe Oceania
```

Preserve dimensions using `drop = FALSE`

```
head(gapminder[, 2, drop = FALSE], 3)   # all rows, columns 1--3
```

```
  continent
1      Asia
2      Asia
3      Asia
```

SUBSETTING

Can use a range of index types

- Numeric values select the nth elements
- Negative numeric values select all but those elements
- Character values select elements by name (possibly with partial matching)
- Logical values select (TRUE) & deselect (FALSE) elements
- Logical indices are recycled to the correct length

```
(1:10)[c(FALSE, TRUE)]
```

```
[1]  2  4  6  8 10
```

```
(1:9)[c(FALSE, TRUE)]                # no warning
```

```
[1] 2 4 6 8
```


VECTORS

What are the columns of `gapminder`?

```
str(gapminder)
```

```
'data.frame':   1704 obs. of  6 variables:
 $ country  : Factor w/ 142 levels "Afghanistan",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ continent: Factor w/ 5 levels "Africa","Americas",..: 3 3 3 3 3 3 3 3 3 3 ...
 $ year     : int  1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 ...
 $ lifeExp  : num  28.8 30.3 32 34 36.1 ...
 $ pop      : num  8425333 9240934 10267083 11537966 13079460 ...
 $ gdpPercap: num  779 821 853 836 740 ...
```

Each component is a vector, of which there are several types: `numeric`, `character`, `logical`, `factor`, `integer`

VECTORS — NUMERIC & INTEGER

R normally stores numeric data as *doubles* (decimal values)

There is an *integer* type too

```
class(gapminder$lifeExp)
```

```
[1] "numeric"
```

```
class(gapminder$year)
```

```
[1] "integer"
```


VECTORS — NUMERIC & INTEGER

Create numeric vectors using `c()` or `:`

```
c(1,3,5,7,9)
```

```
[1] 1 3 5 7 9
```

```
1:10
```

```
 [1]  1  2  3  4  5  6  7  8  9 10
```

`x:y` is shorthand for `seq(from = x, to = y, by = 1)`

VECTORS — CHARACTER

Character vectors contain text (strings)

```
c("foo","bar")
```

```
[1] "foo" "bar"
```

Quote each string using single or double quotes

VECTORS — LOGICAL

Logical vectors are vectors of TRUE or FALSE values

```
c(TRUE, TRUE, FALSE)
```

```
[1]  TRUE  TRUE FALSE
```

- FALSE is 0
- TRUE is anything else, but is coerced to 1

```
as.numeric(c(TRUE, TRUE, FALSE))
```

```
[1] 1 1 0
```


VECTORS — FACTORS

Factors are a special kind of vector

- stored internally as a vector of *codes*
- the codes index a set of levels or categories, which can be numeric of character

```
f <- factor(c("Male","Female","Male"))
levels(f)
```

```
[1] "Female" "Male"
```

```
f <- factor(c(1,2,5,5,2,1))
as.numeric(f)                          # WRONG! Gets internal codes
```

```
[1] 1 2 3 3 2 1
```

```
as.numeric(as.character(f))            # RIGHT! correct coercion
```

```
[1] 1 2 5 5 2 1
```


SEQUENCES & PATTERNED VECTORS

Sequences and patterned vectors are very useful in some circumstances

```
seq(from = 1, to = 10, by = 2)
```

```
[1] 1 3 5 7 9
```

```
1:5
```

```
[1] 1 2 3 4 5
```

```
rep(1:3, each = 2)
```

```
[1] 1 1 2 2 3 3
```

```
rep(1:3, times = 3:1)
```

```
[1] 1 1 1 2 2 3
```

FUNCTIONS

FUNCTIONS

Pretty much everything in R is either a function or the result of a call to one

Called with following format: `fun_name(arg1 = value1, arg2 = value2)`

```
rnorm(10)
```

```
 [1]  0.26225849 -0.44882572  0.01023055 -0.52419573 -0.93363066
 [6] -0.63689938 -0.87347879 -0.63486581 -0.79731712 -1.68350867
```

```
args(rnorm)
```

```
function (n, mean = 0, sd = 1)
NULL
```

```
rnorm(10, mean = 2, sd = 4)
```

```
 [1] -2.038808  4.445248  4.609071  6.462982 10.390252 -2.320591  4.360110
 [8]  5.049838  1.887431 -3.856392
```


FUNCTIONS

Can use positional matching for argument names, but don't except for the first

```
rnorm(10, 2, 4)                         # What the heck does this do?
```

```
 [1]  7.9504510  2.5050757  1.3142966 -2.6856997 -2.0826316 -0.8252653
 [7] 10.5205840  7.8822262  4.4565896  3.4448368
```

If you name arguments can be in any order (can be partial names)

```
rnorm(sd = 4, mean = 2, n = 10)
```

```
 [1] -0.1235672 -0.2620203  2.5597837  3.9062834 -3.5814213 -0.1317407
 [7]  1.4856301  7.5251081  0.7260785  3.2503350
```


FUNCTIONS

You can write your own functions using the `function()` function

```
foo <- function(x) {                    # foo() squares it's input
    x * x                               # last statement determines return value
}
class(foo)
```

```
[1] "function"
```

```
foo(10)
```

```
[1] 100
```

SPLIT-APPLY-COMBINE

SPLIT-APPLY-COMBINE

The split-apply-combine model is a common type of data analysis

- split data into chunks based on one or more factors
- apply a function to each chunk
- combine the outputs of applying the function to each chunk

Several R packages provide consistent and efficient implementations of the split-apply-combine model

- **plyr**, **dply**, **data.table**

But base R has useful functions too

- `aggregate()`, `split()` + `apply()`-family + `c|rbind()`

SPLIT-APPLY-COMBINE

`aggregate` applies `FUN` to a vector, split up by one or more factors:

```
aggregate(pop ~ continent, data = gapminder, FUN = median)
```

```
  continent      pop
1    Africa  4579311
2  Americas  6227510
3      Asia 14530830
4    Europe  8551125
5   Oceania  6403492
```


SPLIT-APPLY-COMBINE

Can do this by hand too

```
with(gapminder, sapply(split(pop, f = continent), FUN = median))
```

```
  Africa Americas     Asia   Europe  Oceania
 4579311  6227510 14530830  8551125  6403492
```

SPLIT-APPLY-COMBINE — APPLY FAMILY

The `apply` family provides very general approaches to applying function to aspects of data

- `apply` applies a function to the `MARGIN`s of a matrix, array, or data frame
- `sapply` applies the function to components of a list or data frame & **simplifies** if possible
- `lapply` applies the function to components of a list or data frame & returns a list
- `tapply` applies the function to chunks of data created by splitting on a factor
- `mapply`, `vapply()`, `rapply()` are specialist alternatives

SPLIT-APPLY-COMBINE — APPLY FAMILY

```
apply(gapminder[, 4:5], 2, FUN = median)
```

```
     lifeExp          pop
     60.7125 7023595.5000
```

```
tapply(gapminder$pop, gapminder$continent, FUN = median)
```

```
  Africa Americas     Asia   Europe  Oceania
 4579311  6227510 14530830  8551125  6403492
```


SPLIT-APPLY-COMBINE — APPLY FAMILY

```
with(gapminder, lapply(split(pop, f = continent), FUN = median))
```

```
$Africa
[1] 4579311

$Americas
[1] 6227510

$Asia
[1] 14530830

$Europe
[1] 8551125

$Oceania
[1] 6403492
```


MODELLING

PLOTTING

PLOTTING

Your R installation comes with two main plotting toolboxes

- base graphics
- grid graphics

Grid graphics is extremely flexible but that comes at a cost of complexity

Two high-level interfaces to grid provides extensive plotting capabilities

- **lattice**, which comes with R
- **ggplot2**, which needs to be installed from CRAN

BASE GRAPHICS

These are the standard types of plots available in & produced by R & add-on packages

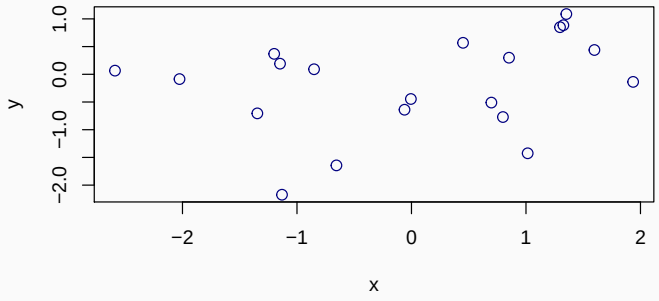
The main function is `plot()`, with `points()`, `lines()`, `text()`, `segments()`, `polygons()`, etc acting as lower-level elements

The look and feel of the plots is essentially controlled via graphical parameters — `?par`

Other high-level functions provide to access to the main plot types — `boxplot()`, `hist()`, `stripchart()`, `barchart()`

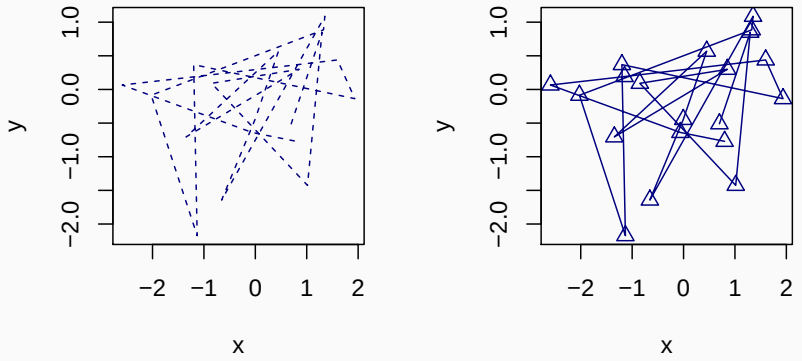
BASE GRAPHICS

```
x <- rnorm(20)
y <- rnorm(20)
plot(x, y, pch = 1, col = "navyblue", cex = 1.2, type = "p")
```



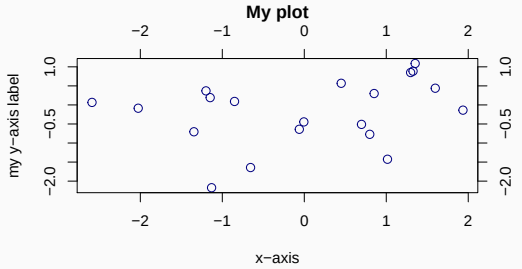
BASE GRAPHICS

```
plot(x, y, lty = "dashed", col = "navyblue", cex = 1.2, type = "l")
plot(x, y, pch = 2, col = "navyblue", cex = 1.2, type = "o")
```



BASE GRAPHICS

```
op <- par(mar = c(5,4,5,4) + 0.1)       # alter margins
plot(x, y, pch = 1, col = "navyblue", cex = 1.2, type = "p", ann = FALSE, axes = FALSE)
axis(side = 1); axis(side = 2)          # add axis, can be customised
axis(side = 3); axis(side = 4)
box()                                   # draw the box round the plot
title(main = "My plot", xlab = "x-axis", ylab = "my y-axis label")
par(op)                                 # reset plotting parameters
```



GGPLOT

Base graphics are serviceable but require a lot of cruft code to go beyond basic plots — encoding size, colour, etc using data

This is where **lattice** and **ggplot2** graphics come in

These are high-level plotting toolboxes that provide interfaces espousing Trellis Graphics and The Grammar of Graphics ideas, both built on top of **grid**

These are *not* general purpose graphics toolkits — need to follow the ideas & theory behind the respective paradigm

If you want general-purpose, you need to use base graphics or grid

Can't (easily) mix base and grid graphics

GGPLOT

ggplot2 is an implementation of Leland Wilkinson's Grammar of Graphics (hence **gg** in the name)

Three key components of a **ggplot2** plot

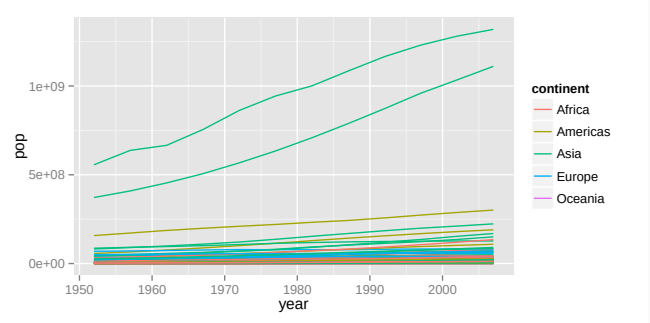
- **data** — the data must be in the form of a data frame
- **aesthetics** — how should data be represented on the plot
  - essentially **mappings** from variables to coordinates, size, colour, shape, transparency
- **geometries** — how to physically draw the data & mappings

ggplot graphics consist of zero or more layers

Additionally, **stats** transform variables, **scales** control axis scaling & legends, **themes** control overall look & feel, **facets** split data into panels

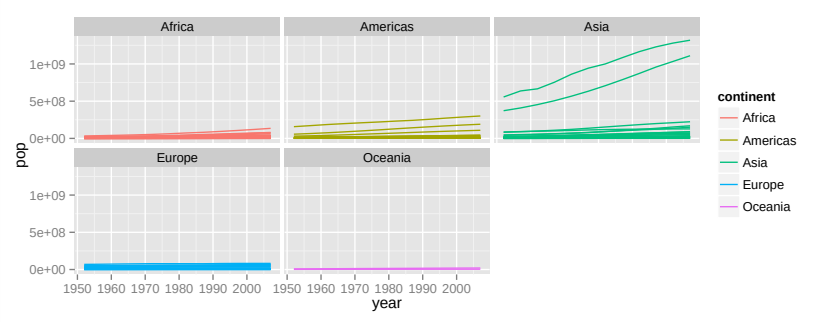
GGPLOT — A BASIC PLOT

```
library("ggplot2")            # load the package
plt <- ggplot(gapminder, mapping = aes(x = year, y = pop, colour = continent, group = country)) +
        geom_line()           # add a layer with a line geometry
plt                           # Have to print the object to draw plot
```



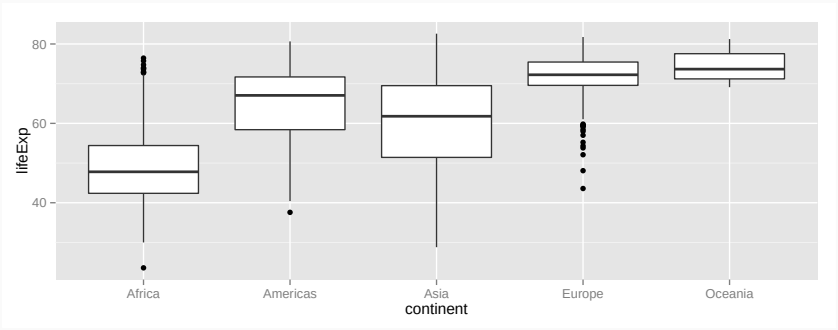
GGPLOT — FACETING

```
plt + facet_wrap(~ continent)  # facet by continent
```



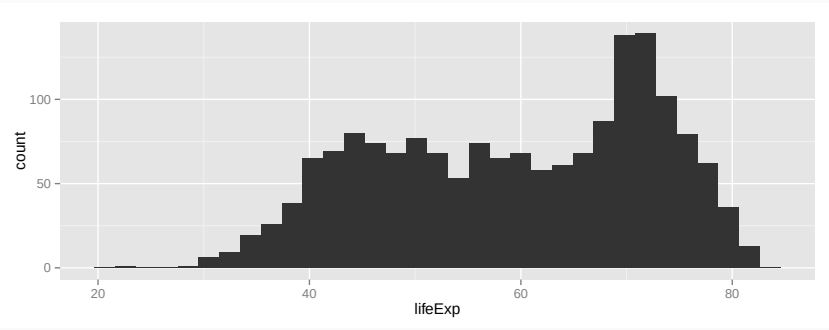
GGPLOT — STATS

```
ggplot(gapminder, mapping = aes(x = continent, y = lifeExp)) +
    geom_boxplot()                    # has a default stat "boxplot"
```



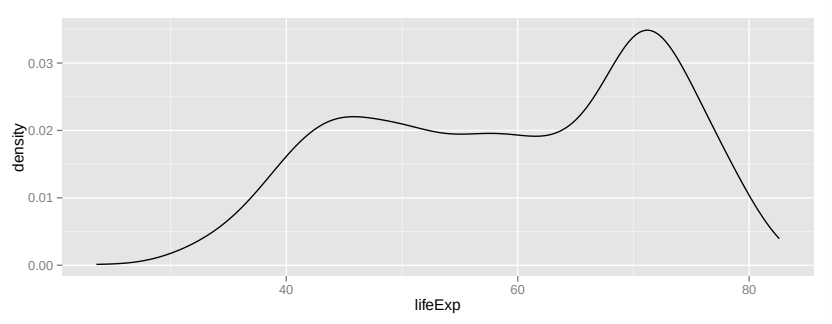
GGPLOT — STATS

```
ggplot(gapminder, mapping = aes(x = lifeExp)) +
    geom_histogram()                  # has a default stat "bin"
```



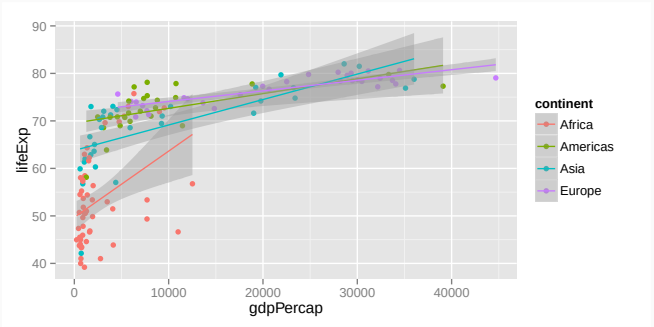
GGPLOT — STATS

```
ggplot(gapminder, mapping = aes(x = lifeExp)) +
    geom_line(stat = "density")         # change the stat
```



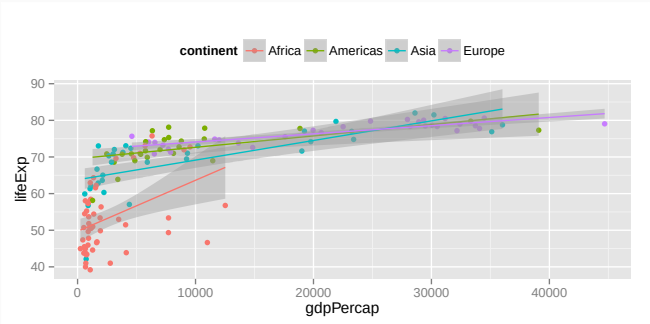
GGPLOT — GROUPING & SMOOTHS

```
(p2 <- ggplot(subset(gapminder, year == 2002 & continent != "Oceania"),
              aes(x = gdpPercap, y = lifeExp, colour = continent, group = continent)) +
       geom_point() + geom_smooth(method = "lm"))
```



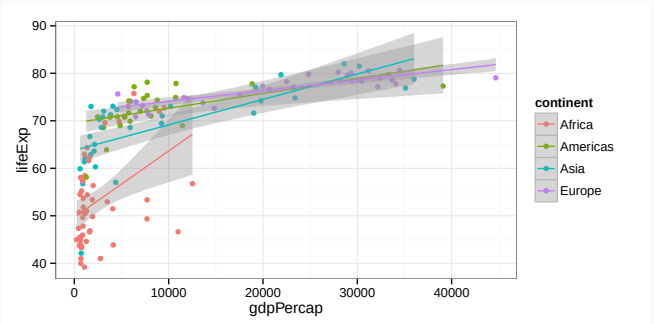
GGPLOT — THEMES

```
p2 + theme(legend.position = "top")     # move the legend, see ?theme
```



GGPLOT — PRESENT THEMES

```
p2 + theme_bw()                         # a simple theme
```



GGPLOT — EXPORTING PLOTS

ggplot plots can be exported to disk using `ggsave()`

- If the image is on screen (last plot)

```
ggsave(file = "filename.pdf")
```

- If the plot is saved as an object

```
ggsave(p2, file = "filename.pdf")
```

- Specify the size

```
ggsave(file = "filename.pdf", width = 6, height = 4)
```

- Change the file type by modifying the extension

```
ggsave(file = "filename.png")
```


RE-USE