R for bioinformatics, data visualisation

HUST Bioinformatics course series

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section 1: TOC

前情提要

iterations 与并行计算

- for loop
- apply functions
- dplyr 的本质是遍历
- map functions in purrr package
- 遍历与并行计算

相关包

- purrr
- parallel
- foreach
- iterators

本次提要

- basic plot functions
- basic ggplot2
- special letters
- equations
- advanced ggplot2

section 2: basic plot functions using R

R basic plot functions

过去几节课我们已经使用了 R basic plot 和 ggplot2 的一些绘画功能，比如讲 factor 时。今次我们进行系统的介绍。

基础做图由 plot 提供。先看示例。这里我们使用系统自带的 swiss 数据，它包含了 47 个法语地区的一些社会经济指标。

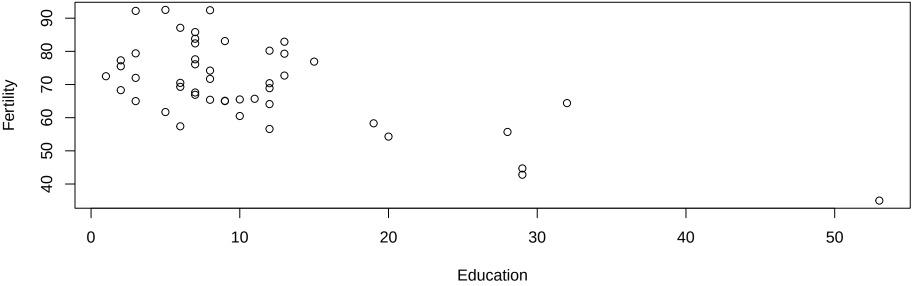
```r
head(swiss);
```

```
##              Fertility Agriculture Examination Education Catholic
## Courtelary        80.2        17.0          15        12     9.96
## Delemont          83.1        45.1           6         9    84.84
## Franches-Mnt      92.5        39.7           5         5    93.40
## Moutier           85.8        36.5          12         7    33.77
## Neuveville        76.9        43.5          17        15     5.16
## Porrentruy        76.1        35.3           9         7    90.57
##              Infant.Mortality
## Courtelary               22.2
## Delemont                 22.2
## Franches-Mnt             20.2
## Moutier                  20.3
## Neuveville               20.6
## Porrentruy               26.6
```

散点图（dot plot）

我们看一下教育与生育率的关系：

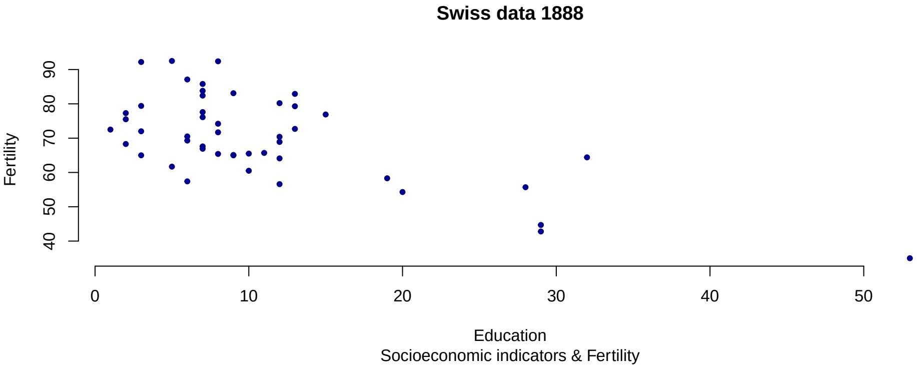
```
with( swiss, plot( Education, Fertility ) );
```



注意 `with` 的作用是什么??

plot 的参数初探：先看示例

```
with( swiss, plot(Education, Fertility, type = "p", main = "Swiss data 1888",
                  sub = "Socioeconomic indicators & Fertility",
                  xlab = "Education", ylab = "Fertility", col = "darkblue",
                  xlim = range( Education ), ylim = range( Fertility ),
                  pch = 20, frame.plot = F) );
```



plot 参数，an annotated example

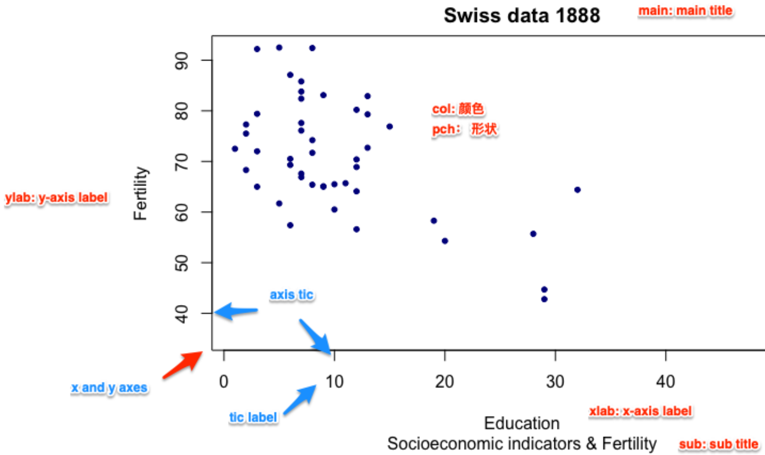
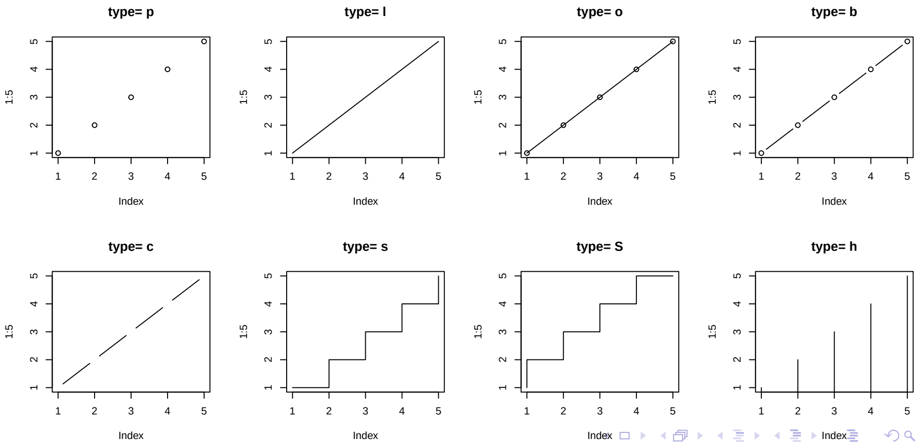


Figure 1: an annotated example

plot 支持的画图类型，参数 p = '?' 的取值

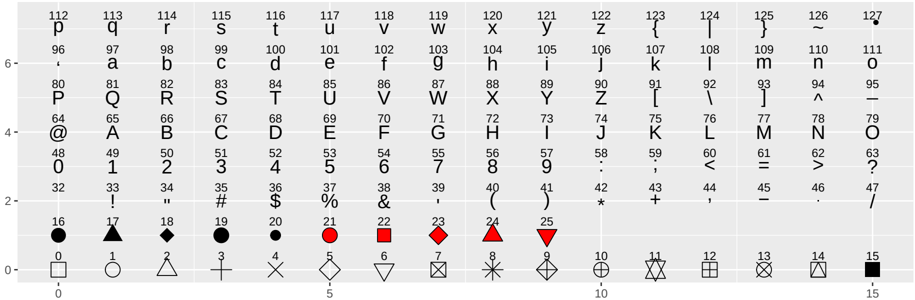
```
par( mfrow = c(2,4) ); ### 在一张图上画 2 x 4 个 panel
opts <- c( "p", "l", "o", "b", "c", "s", "S", "h" );
for( o in opts ){
  plot(1:5, type = o, main = paste( "type=", o ) );
}
```



pch 是什么？

决定了数据点的形状，注意它的取值范围

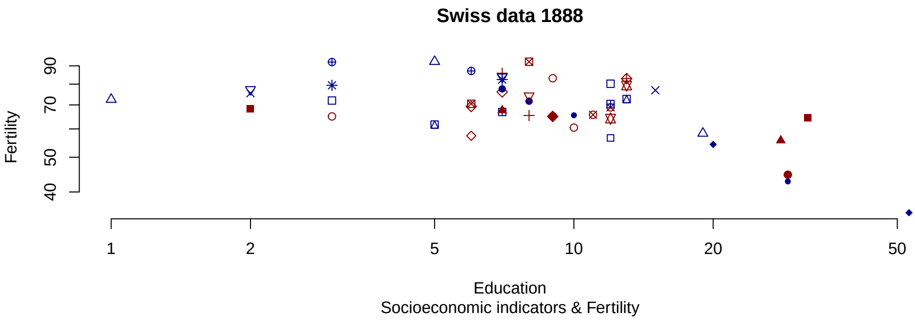
```r
library(tidyverse); library(extrafont);
ggplot( data.frame( p = c(0:25, 32:127) ) ) +
  scale_y_continuous( name = "" ) + scale_x_continuous( name = "" ) +
  scale_shape_identity() +
  geom_point( aes( x = p%%16, y = p%/%16, shape = p ), size = 5, fill = "red" ) +
  geom_text( aes( x = p %% 16, y = p%/%16 + 0.4, label = p  ), size = 3 );
```



log transform aexes

plot 还有一些其它有用的参数，详见：？plot.default

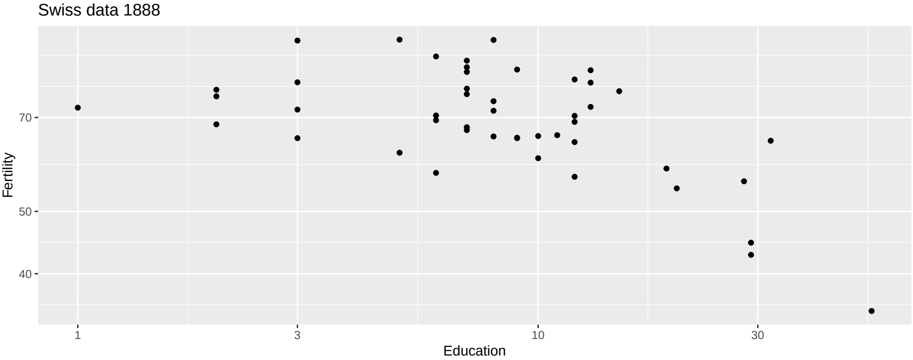
```
with( swiss, plot(Education, Fertility, type = "p", main = "Swiss data 1888",
                  sub = "Socioeconomic indicators & Fertility",
                  xlab = "Education", ylab = "Fertility", col = c("darkblue", "darkred"),
                  xlim = range( Education ), ylim = range( Fertility ),
                  pch = 0:25, frame.plot = F, log = "xy") );
```



```
## 注：也可以用 log='x' 或 log='y' 只对一个 axis 进行 log 处理
```

ggplot 版本

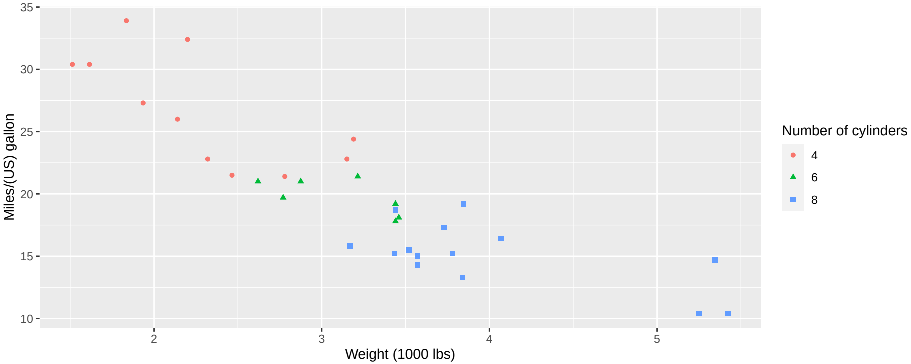
```
ggplot( swiss, aes( x = Education, y = Fertility ) ) +
  geom_point(  ) + scale_x_log10() + scale_y_log10() +
  xlab( "Education" ) + ylab( "Fertility" ) +
  ggtitle( "Swiss data 1888" );
```



ggplot 更多散点示例

以 mtcars 为例

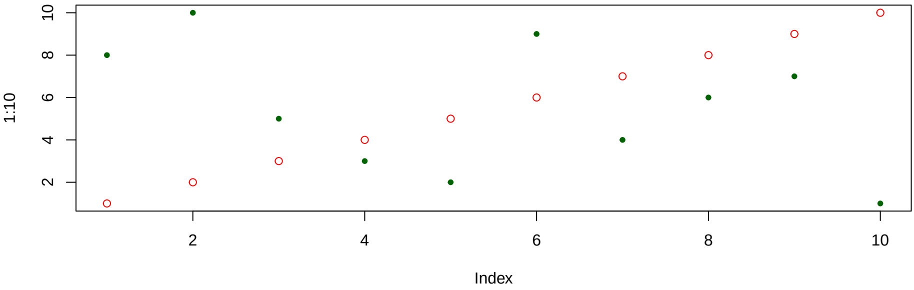
```
ggplot( mtcars, aes( x = wt, y = mpg, colour = factor( cyl ), shape = factor(cyl) ) ) +
  geom_point() + xlab( "Weight (1000 lbs)" ) + ylab( "Miles/(US) gallon" ) +
  labs( colour = "Number of cylinders", shape = "Number of cylinders" ) ;
```



plot: high-level vs. low-level plots

- **high level**: plotting functions create a new plot on the graphics device
- **low level**: plotting functions add more information to an existing plot

```r
plot( 1:10, col = "red" ); ## high level
points( sample(1:10, 10), col = "darkgreen", pch = 20 ); ## low level
```



low level plots 列表

- `points`：点图
- `lines`：线图
- `abline`：直线
- `polygon`：多边形
- `legend`：图例
- `title`： 标题
- `axis`：轴 ...

high level plots 列表

- `plot`：通用画图函数
- `pairs`
- `coplot`
- `qqnorm`
- `hist`
- `dotchart`
- `image`
- `contour` ...

注：可以用 `add = TRUE` 参数（如果可用）将 high level 函数强制转换为 low level

图形相关参数（系统函数）

par() 函数：显示或修改当前图形设备的参数。用以下命令查看支持的内容：

```
par( c( "mar", "bg" ) ); ## 显示指定参数的值
```

```
## $mar
## [1] 5.1 4.1 4.1 2.1
##
## $bg
## [1] "transparent"
```

```
## 显示所有参数
par();
```

```
## $xlog
## [1] FALSE
##
## $ylog
## [1] FALSE
##
## $adj
## [1] 0.5
##
## $ann
## [1] TRUE
```

调整 par() 参数前请备份

par() 用于指定全局参数，因此在改变前尽量备份

```
oldpar <- par(); ## 备份

do some changes here ...

## 恢复
par( oldpar );
```

常用图形参数及调整：margin

图形边距（figure margins ）

```
par( mar = c( 5.1, 4.1, 4.1, 2.1 )); ## 设置新 martin
```

分别指定下 -> 左 -> 上 -> 右的边距，即从下面开始，顺时针移动。

单位是：text lines

或：

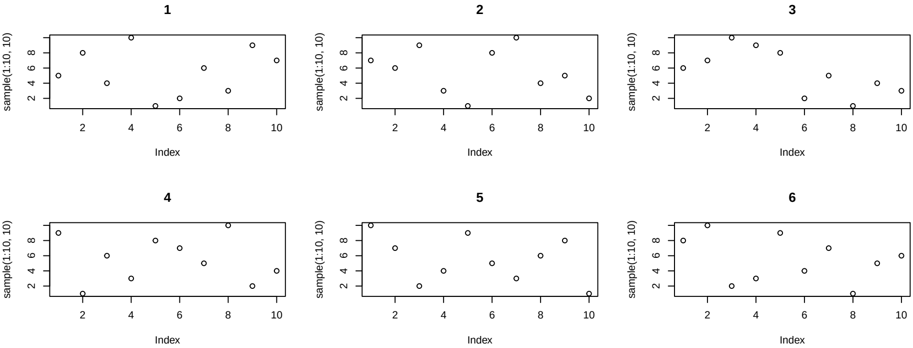
```
par( mai = c( 5.1, 4.1, 4.1, 2.1 )); ## 设置新 martin
```

单位是：inch

常用图形参数及调整：多 panel

画 2x3 共 6 个 panel，从左到右。（2 行 3 列）

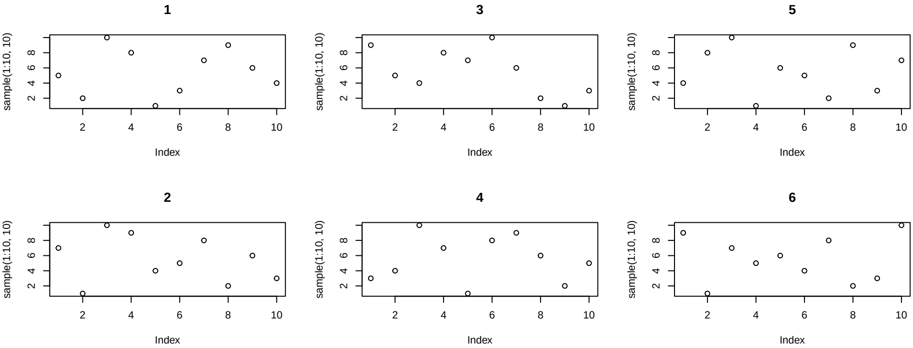
```
par( mfrow=c(2,3) );
for( i in 1:6 )
  plot( sample( 1:10, 10 ), main = i );
```



常用图形参数及调整：多 panel ，cont.

画 2x3 共 6 个 panel，从上到下。（2 行 3 列）

```
par( mfcol=c(2,3) );
for( i in 1:6 )
  plot( sample( 1:10, 10 ), main = i );
```



重要概念：图形设备

图形设备是指图形输出的设备，可以将**图形设备理解为保存格式**。

默认设备是：

- X11()：*nix
- windows()：windows
- quartz()：OS X

图形显示在**显示器上**。

图形设备： cont.

常用其它设备有:

- pdf()
- png()
- jpeg()

分别对应输出文件格式。

常用图形设备：pdf()

使用方法如下：

```
pdf( file = "/path/to/dir/<file_name>.pdf", height = 5, width = 5 ); ## 创建一个新设备/ pdf 文件
plot(1:10); ## 作图;
dev.off(); ## 关闭设备
```

说明

1. 默认文件名为 Rplots.pdf ，
2. dev.off() 必须关闭。关闭后，返回到最近使用的图形设备
3. height 和 width 参数的单位是 inch
4. 如果运行多个 high level 作图命令，则会产生多页 **pdf**

请尽量使用 pdf 作为文件输出格式

1. 生信图片大多是点线图，适合保存为矢量格式（如 pdf, ps 等）；
2. 矢量图可无限放大而不失真（变成像素）；
3. 可由 Adobe Illustrator 等矢量图软件进行编辑

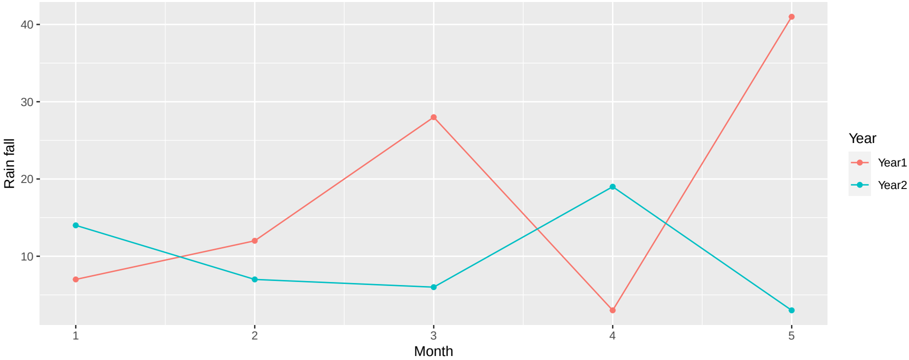
section 3: ggplot2 基础

一个简单的示例

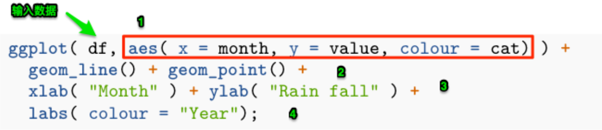
```r
## 准备数据
year1 <- c(7, 12, 28, 3, 41);
year2 <- c(14, 7, 6, 19, 3);

df <- rbind( tibble( month = 1:length( year1 ), value = year1, cat = "Year1" ),
             tibble( month = 1:length( year2 ), value = year2, cat = "Year2 ") );

plot1 <-  ## 将图保存在变量中;
  ggplot( df, aes( x = month, y = value, colour = cat) ) +
  geom_line() + geom_point() +
  xlab( "Month" ) + ylab( "Rain fall" ) +
  labs( colour = "Year");
```

画图

```
plot1;  ## 画图
```



ggplot2 基础概念详解



```
ggplot( df, aes( x = month, y = value, colour = cat) ) +
  geom_line() + geom_point() +
  xlab( "Month" ) + ylab( "Rain fall" ) +
  labs( colour = "Year");
```

Figure 2: ggplot2 参数简介

1. **aes** (aesthetics) 美学：控制全局参数，包括：x,y 轴使用的数据，颜色（ colour, fill），形状（ shape ），大小（ size ），分组（ group ）等等；
2. **图层**：`geom_<layer_name>`；每张图可有多个图层（此处有两个）；图层可使用全局数据 (df) 和参数 (aes)，也可以使用自己的 aes 和数据；
3. 其它控制函数

ggplot2 优缺点

ggplot2 优点：

1. 强大又专业
2. 复杂又好看
3. canvas 大小，坐标会根据数据、图层自动调整，让用户专注于作图本身；

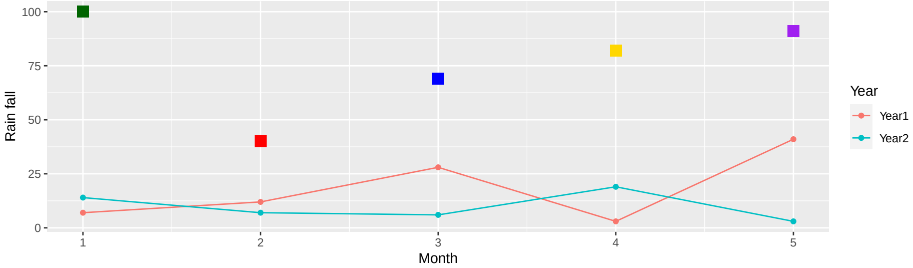
缺点：

太难学！

图层使用自己的数据，示例

图层可从 ggplot 继承**数据**和其它参数，包括 aes，但也可使用自己的

```
plot1 +
  geom_point( data = data.frame( x2 = 1:5, y2 = sample(30:100, 5) ),  ## 注意： data = 是必须的
              aes( x = x2, y = y2 ),  ## 使用自己的 aes ...
              colour =  c("darkgreen", "red", "blue", "gold", "purple") , shape = 15, size = 4 )
```



要点

1. 如上所见，xy -axes 会随数据自动调整
2. ggplot2 作图结果可以保存在变量中，并可累加更多图层
3. 图层使用自己的数据时，需要用 data = 指定；而全局数据则不用 ggplot (data.frame(...))

section 4: ggplot2 作图的四个基本组成部分详解

1. 图层

geom_< 图层名 >

- geom_point，geom_line: 点线图，用于揭示两组数据间的关系；
- geom_smooth：常与 geom_point 联合使用，揭示数据走势
- geom_bar ： bar 图
- geom_boxplot：箱线图，用于比较 N 组数据，揭示区别
- geom_path：与 geom_line 相似，但也可以画其它复杂图形
- geom_histogram, “ geom_density “‘：数据的分布，也可用于多组间的比较
- 其它十余种，请见 “ggplot2：elegant graphics for data analysis” 一书!!

2. scale 显示控制

基本规则

- scale_< 控制内容 >_< 控制手段 >, e.g. scale_color_manual(): **以手选方式控制 颜色**

四种控制类型

- scale_color_...
- scale_fill_...
- scale_shape_...
- scale_size_...

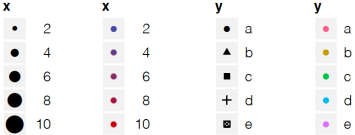
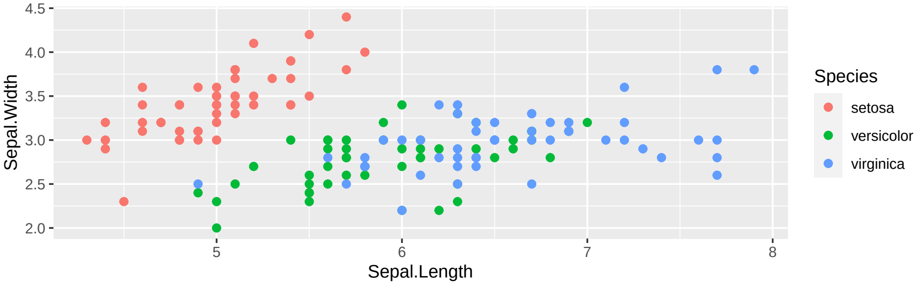


Figure 3: 数据的 4 种 scale 方法

2.1 改变颜色

```r
library(ggplot2);
ggplot(iris, aes(x=Sepal.Length, y=Sepal.Width, color=Species)) +
  geom_point(size=2);
```



解释：

- 使用 iris 里 萼片大小数据；
- colour = Species： 根据 Species 列决定颜色；
- 共需要 3 种颜色；
- 由默认色板决定；

默认的色板

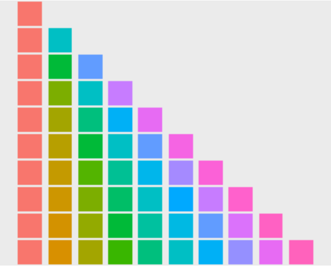
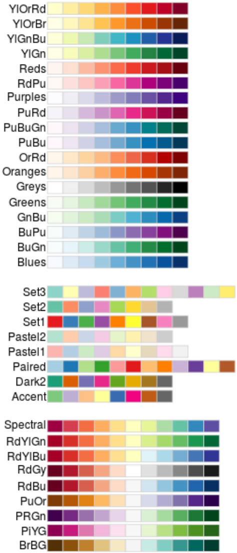


Figure 4: default discrete colour palette

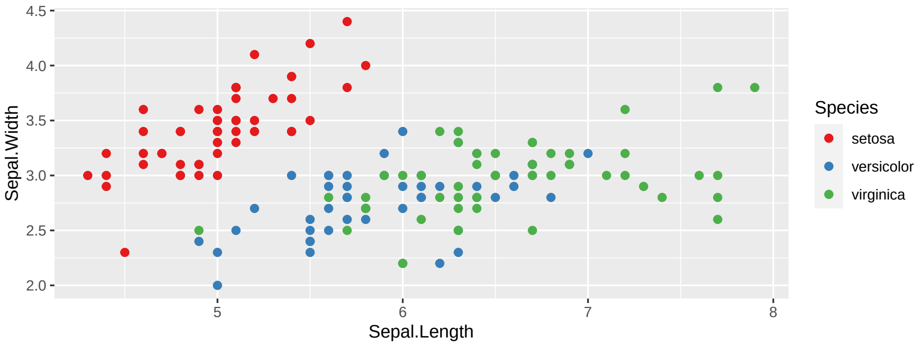
- 根据需要的颜色数量，取相应的行

使用其它色板，比如 scale_colour_brewer()



scale_colour_brewer()，使用示例

```
ggplot(iris, aes(x=Sepal.Length, y=Sepal.Width, color=Species)) + geom_point(size=2) +
  scale_color_brewer( palette = "Set1" );
```



- 使用方法：`scale_color_brewer( palette = "<palette name>" );`
- 取前 N 个颜色

scale_color_brewer 提供的其它色板

Diverging

BrBG, PiYG, PRGn, PuOr, RdBu, RdGy, RdYlBu, RdYlGn, Spectral

Qualitative

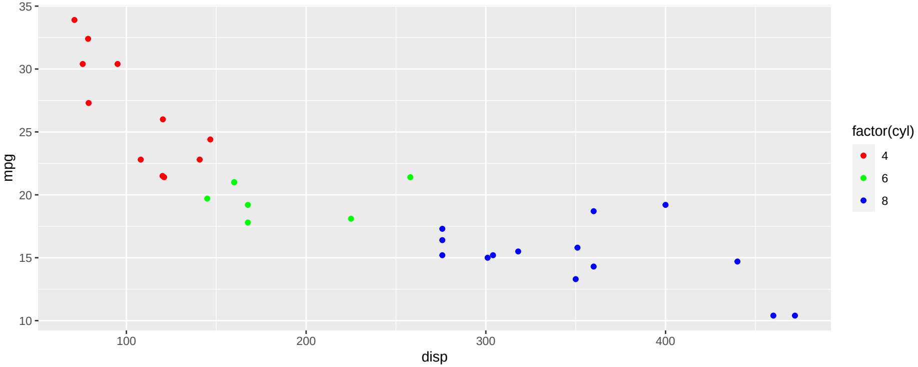
Accent, Dark2, Paired, Pastel1, Pastel2, **Set1**, Set2, Set3

Sequential

Blues, BuGn, BuPu, GnBu, Greens, Greys, Oranges, OrRd, PuBu, PuBuGn, PuRd, Purples, RdPu, Reds, YlGn, YlGnBu, YlOrBr, YlOrRd

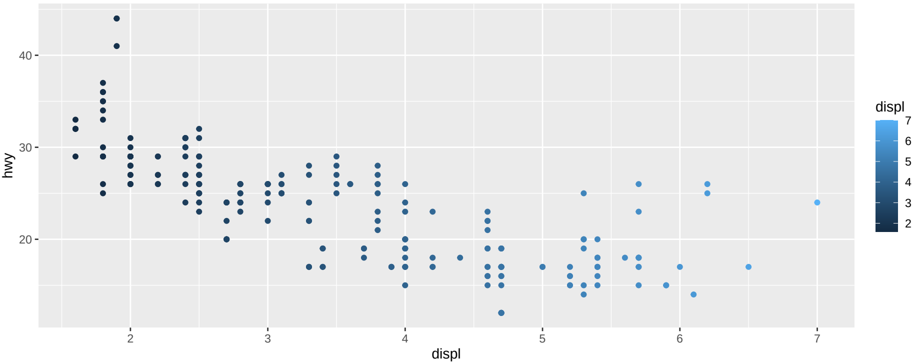
手动设置颜色：scale_colour_manual()

```
mtcars %>% ggplot( aes(disp, mpg) ) + geom_point( aes( color = factor(cyl) ) ) +
  scale_color_manual( breaks = c("4","6","8"), values = c("red","green","blue") );
```



如何对应数量与颜色？使用渐变颜色！

```
mpg %>% ggplot( aes(displ, hwy) ) + geom_point( aes( color = displ ) );
```



- 根据 displ 排气量的值显色;
- 默认使用 2 色;

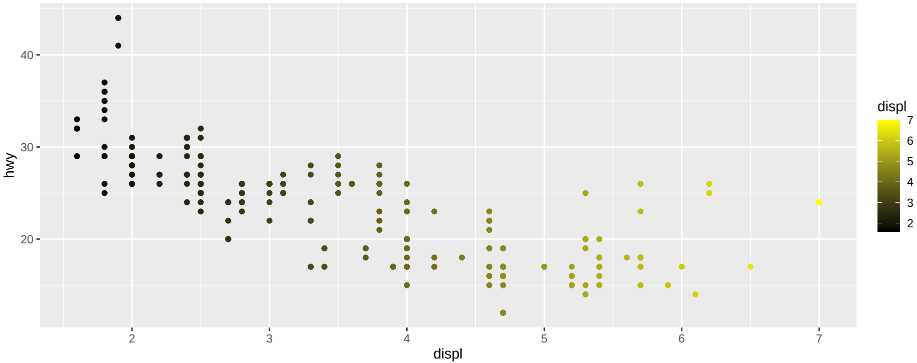
用 scale_color_gradient() 改变渐变颜色

```
scale_colour_gradient(
  ...,
  low = "#132B43",
  high = "#56B1F7",
  space = "Lab",
  na.value = "grey50",
  guide = "colourbar",
  aesthetics = "colour"
)
```

改变 low 和 high 的值即可;

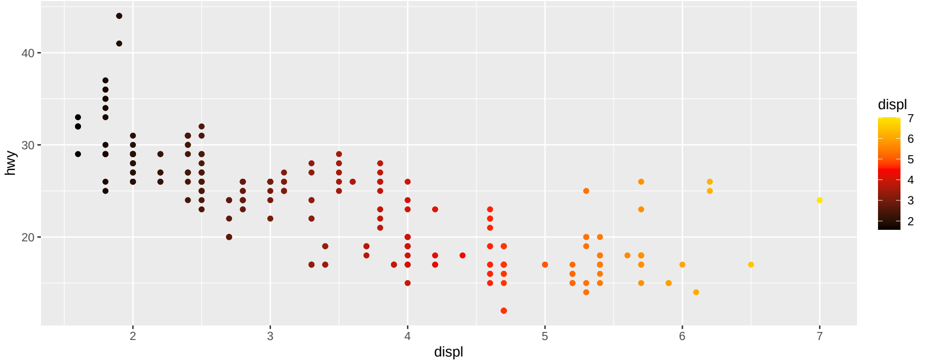
scale_color_gradient() 举例

```
mpg %>% ggplot( aes(displ, hwy) ) + geom_point( aes( color = displ ) ) +
  scale_color_gradient( low = "black", high = "yellow" );
```



使用 3 个渐变色？用 scale_color_gradient2()

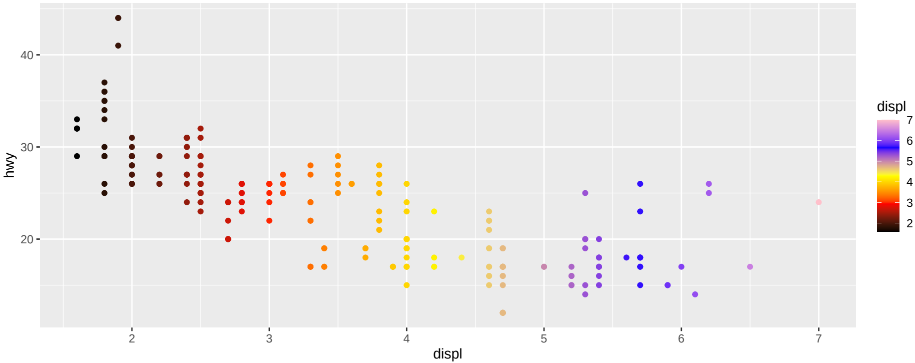
```
mpg %>% ggplot( aes(displ, hwy) ) + geom_point( aes( color = displ ) ) +
  scale_colour_gradient2( low = "black", mid = "red", high = "yellow", midpoint = 4.5 );
```



- 三个颜色： low mid high
- **注意** midpoint 参数!!

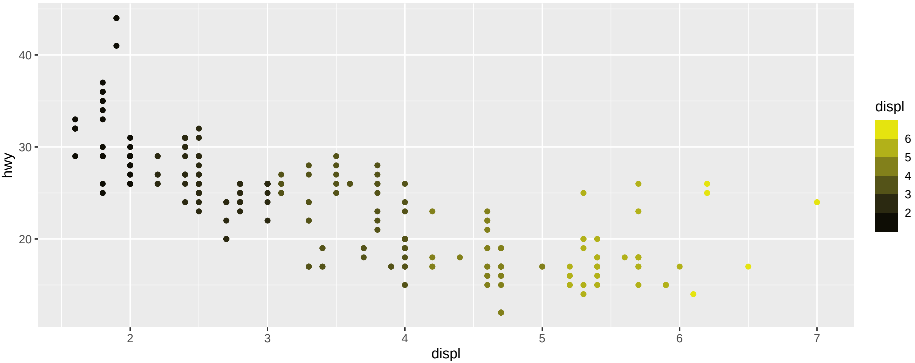
更多颜色？使用 scale_colour_gradientn

```
mpg %>% ggplot( aes(displ, hwy) ) + geom_point( aes( color = displ ) ) +
  scale_colour_gradientn( colors = c("black","red", "yellow", "blue", "pink") );
```



一种有趣的渐变色显示方法：scale_colour_binned

```
mpg %>% ggplot( aes(displ, hwy) ) + geom_point( aes( color = displ ) ) +
  scale_color_binned( low = "black", high = "yellow" );
```



- 渐变色，但分组显示

2.2 fill 颜色

fill 与 colour 有什么区别 ???

- colour defines the colour with which a geom is **outlined** (the shape's “stroke”)
- filldefines the colour with which a geom is **filled**

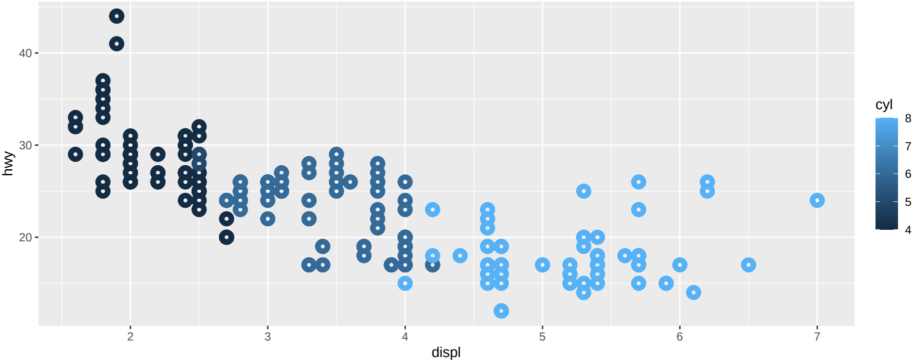
哪些 pch 们有 fill ??

- Points generally only have a colour and **no fill**
- However, point shapes **21–25** that include **both** a colour and a fill.

fill 与 colour 有啥区别 ??? (again)

找一个有两种属性的 point (pch = 21)，先看 fill 的效果；

```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( colour = cyl ), shape = 21, stroke = 3);
```



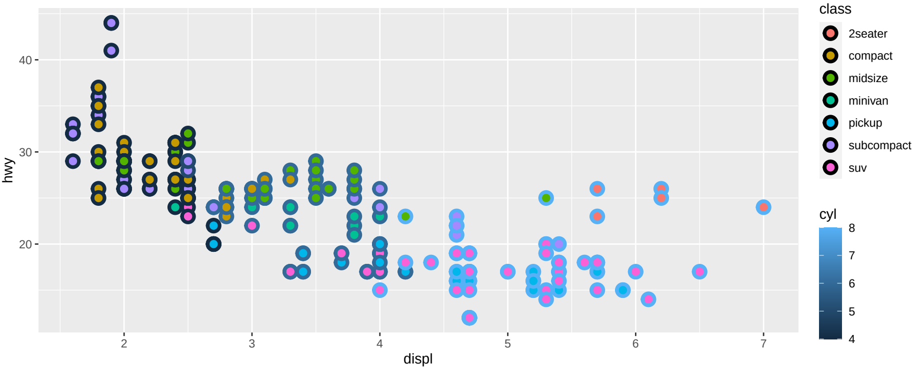
说明

- colour 在 shape = 21 时，为描边 (stroke) 色；
- 可用 stroke 控制线条粗细；

fill 与 colour 有啥区别 ???, cont.

同时有 fill 和 colour

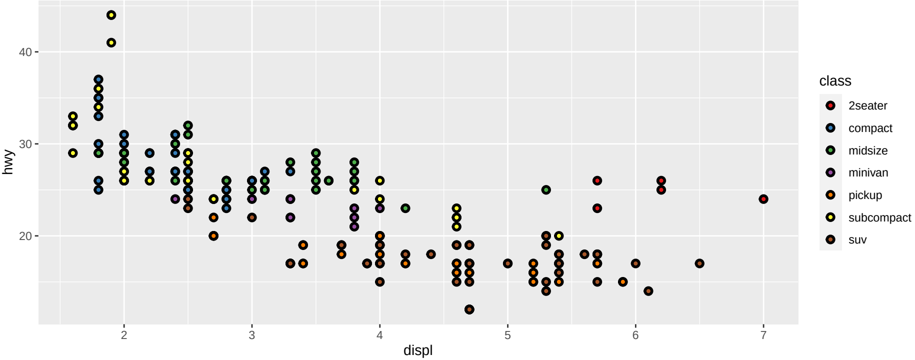
```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( colour = cyl, fill = class ),
              shape = 21, size = 3,
              stroke = 2);
```



fill 的调色板与 colour 一样！

先看看离散值的色板

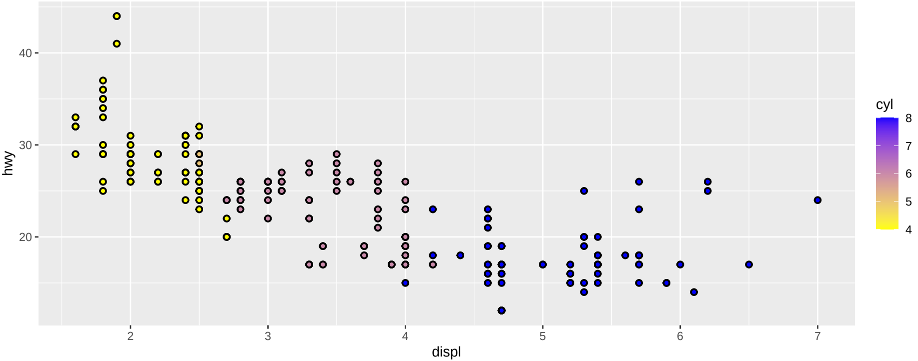
```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( fill = class ), shape = 21, stroke = 1.5) +
  scale_fill_brewer( palette = "Set1" )
```



注：默认的 stroke 颜色为 black；

fill 的 gradient 色板

```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( fill = cyl ), shape = 21, stroke = 1) +
  scale_fill_gradient( low = "yellow", high = "blue" ) ;
```

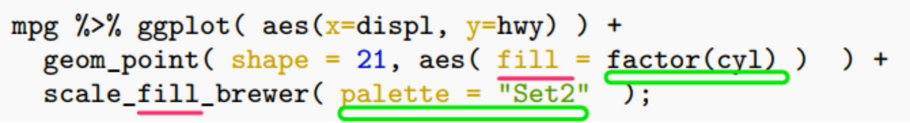


注：默认的 stroke 颜色为 black；

fill 与 colour 小结

1. 做到两个匹配，即：

a) aes 参数 (如 fill =) 与函数 (如 scale_fill_xxx) 匹配；colour 也是如此；
b) 数据类型与色板类型匹配：数量配渐变，离散配离散；



```
mpg %>% ggplot( aes(x=displ, y=hwy) ) +
  geom_point( shape = 21, aes( fill = factor(cyl) )  ) +
  scale_fill_brewer( palette = "Set2"  );
```

2. 两者色板是通用的；函数也是，比如 scale_fill_xx 对应 scale_colour_xx；
3. 有些 shape / pch 只有 colour (stroke)，有些则两者都有；

其它颜色相关函数

- scale_fill_continuous, scale_colour_continuous
- scale_fill_manual, scale_colour_manual

...

其它包中的调色板和相应函数

included in ggplot2

`scale_color_hue`, `scale_color_manual`, `scale_color_grey`, `scale_colour_viridis_d`, `scale_color_brewer` ...

from the `RColorBrewer` package

`scale_color_brewer(palette = "<palette name>")` ... note: 函数属于 ggplot2

from the `viridis` package

`scale_color_viridis( discrete=TRUE, option="<palette name>" )` note: 提供了函数和 palette

other packages ...

- `paletteer` package: `scale_color_paletteer_xx` functions
- `ggsci` package

ggsci: 论文发表用的色板!!!

install

```
install.packages("ggsci"); # Install ggsci from CRAN:
devtools::install_github("nanxstats/ggsci"); # or from github
```

contents

scale_color_<journal> 和 scale_fill_<journal> functions and color palettes

supported journals

- NPG scale_color_npg(), scale_fill_npg()
- AAAS, NEJM, Lancet, JAMA ...

ggsci 举例

```r
library("ggsci")
library("ggplot2")
library("gridExtra")
data("diamonds")
p1 <- ggplot(
  subset(diamonds, carat >= 2.2),
  aes(x = table, y = price, colour = cut)
) +
  geom_point(alpha = 0.7) +
  geom_smooth(method = "loess", alpha = 0.05, size = 1, span = 1) +
  theme_bw() + labs( tag = "A" )

p2 <- ggplot(
  subset(diamonds, carat > 2.2 & depth > 55 & depth < 70),
  aes(x = depth, fill = cut)
) +
  geom_histogram(colour = "black", binwidth = 1, position = "dodge") +
  theme_bw() + labs( tag = "B" )
```

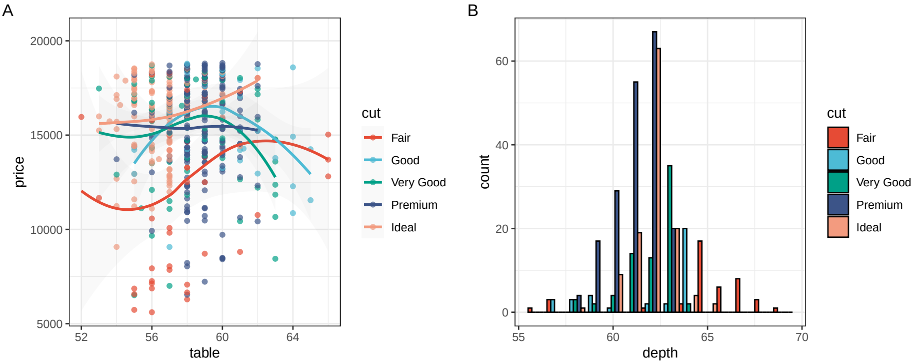
要点

- library(gridExtra)

ggsci 结果，Nature Style !!

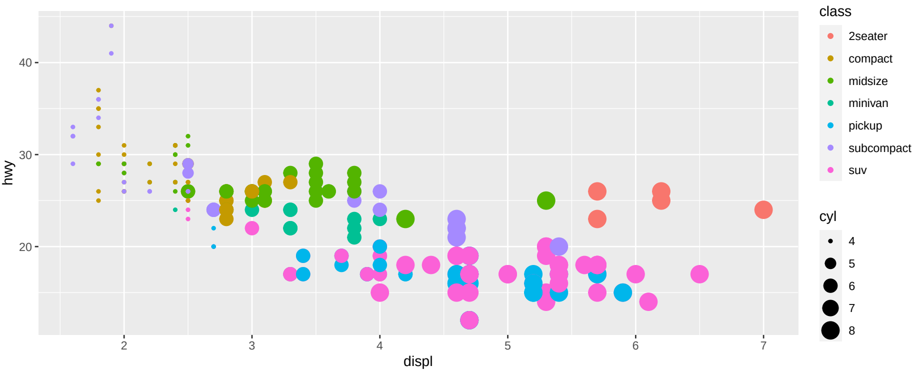
```
p1_npg <- p1 + scale_color_npg()
p2_npg <- p2 + scale_fill_npg()
grid.arrange(p1_npg, p2_npg, ncol = 2)
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



2.3 size

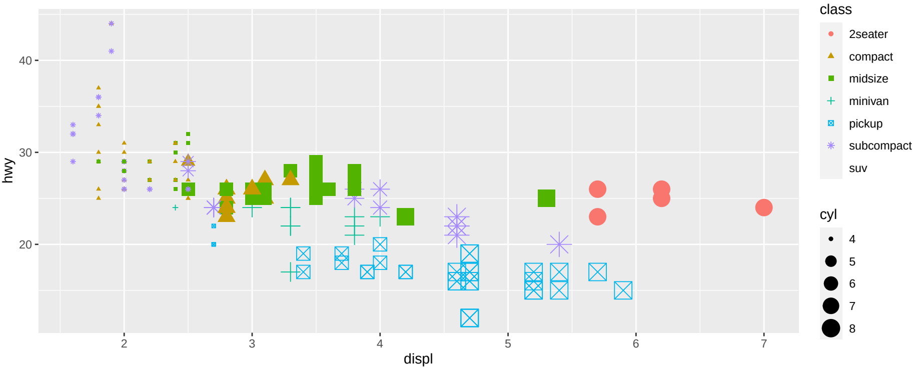
```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( size = cyl, colour = class  ) );
```



- size : 用 cyl 列的值确定大小

2.4 shape

```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( size = cyl, colour = class, shape = class  ) );
```



问题：size, colour 等参数可在 aes() 内部，也可在外部，有什么区别 ???

在内部时，以指定列的值确定**大小**，或按 factor 的数量确定颜色、形状的**数量**：

```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( aes( size = cyl, colour = class, shape = class  ) );
```

在外部时，则以**指定值**为准：

```
mpg %>% ggplot( aes(displ, hwy) ) +
  geom_point( size = 2, colour = "green", shape = 21 );
```

注：size 等接受的值，长度要么为 1，要么与行数等长；

ggplot2 要素 3：坐标系统

线性坐标系统

- coord_cartesian(),
- coord_flip(),
- coord_fixed()

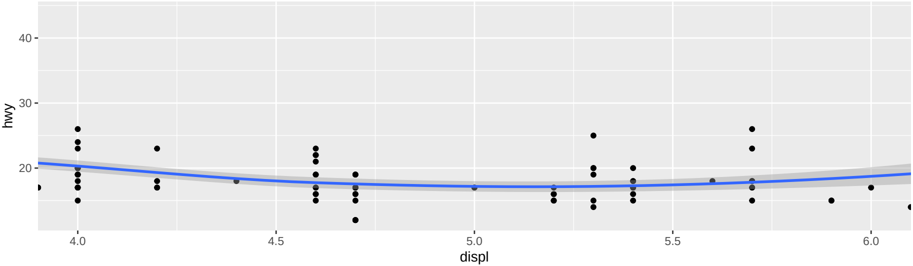
非线性坐标系统

- coord_trans()
- coord_polar()
- coord_map()

3.1 线性坐标系统，coord_cartesian()

默认的坐标系统，可使用 xlim, ylim 等参数，**实现缩放局部**

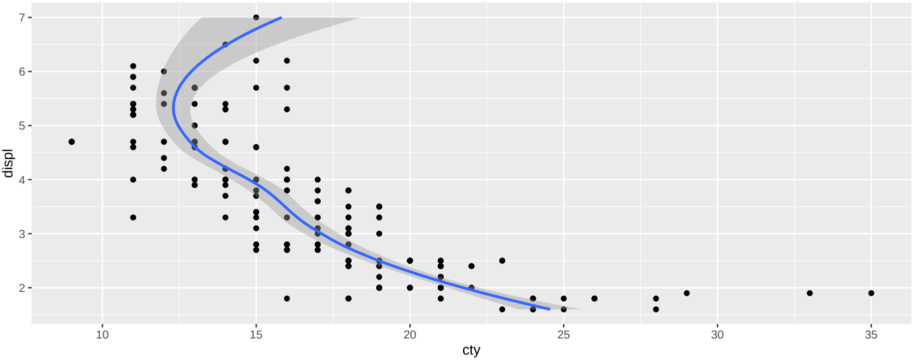
```
p1 <- ggplot(mpg, aes(displ, hwy)) +
  geom_point() + geom_smooth()

p1 + coord_cartesian(xlim = c(4, 6))
```



3.1 线性坐标系统，coord_flip()

exchange the x and y axes

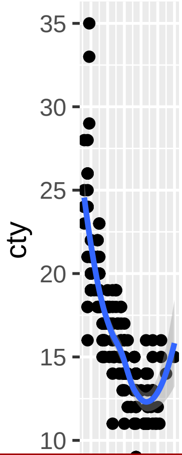
```
ggplot(mpg, aes(displ, cty)) +
  geom_point() + geom_smooth() +
  coord_flip()
```



3.1 线性坐标系统，coord_fixed()

用特定的长宽比例 (aspect ratio) 作图，如下图所示：

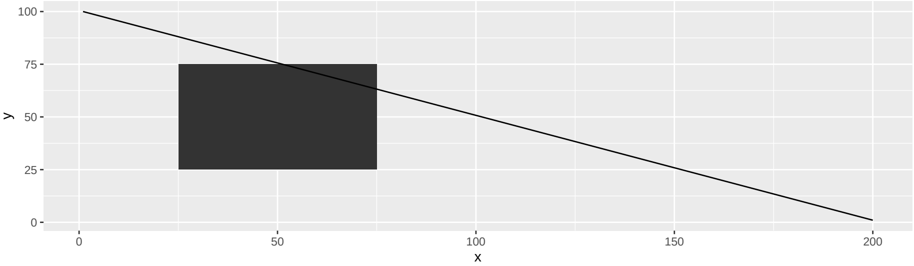
```
ggplot(mpg, aes(displ, cty)) +
  geom_point() + geom_smooth() +
  coord_fixed(ratio = 1) ## ratio = y/x
```



3.2 非线性，coord_trans()

x, y 轴的转换；先生成原图

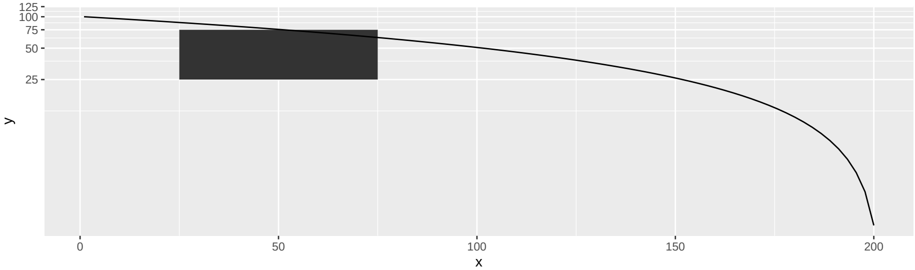
```
rect <- data.frame(x = 50, y = 50)
line <- data.frame(x = c(1, 200), y = c(100, 1))
base <- ggplot(mapping = aes(x, y)) +
  geom_tile(data = rect, aes(width = 50, height = 50)) +
  geom_line(data = line)

base ; ## 画出来
```



3.2 非线性，coord_trans(), cont.

log10(y):

```r
base + coord_trans(y = "log10");
```

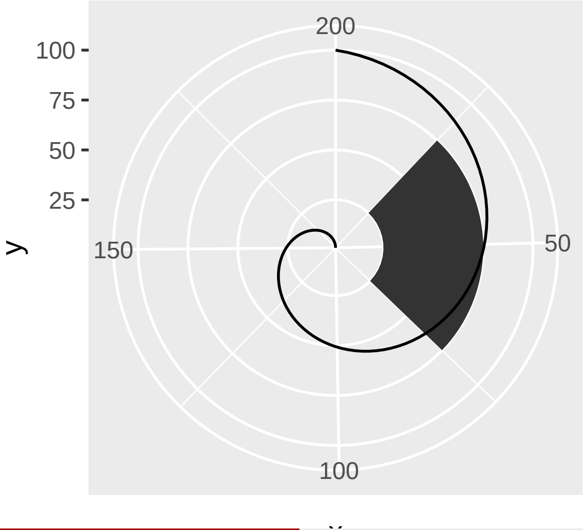


coord_trans() 的其它参数：

- limx, limy: 限制 xy 的显示范围

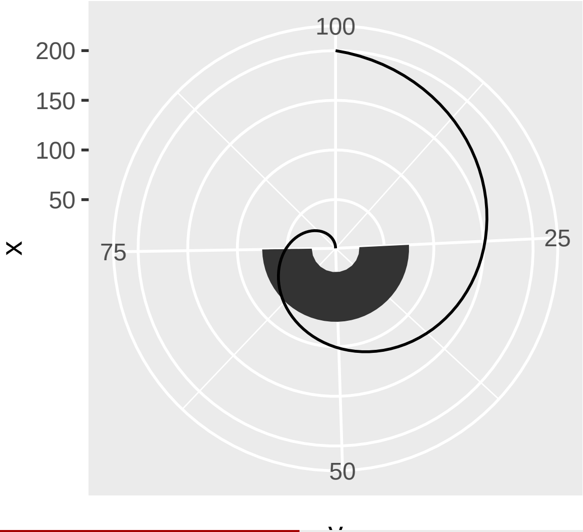
3.2 非线性，coord_polar()

```
base + coord_polar(); ## 默认为 coord_polar("x")
```



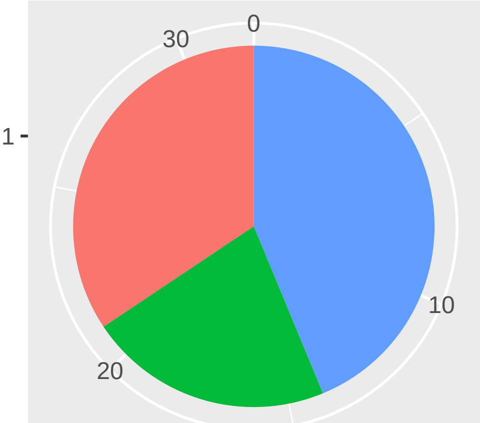
3.2 非线性，coord_polar()，cont.

```
base + coord_polar("y");
```



3.2 非线性，coord_polar()，柱图变饼图

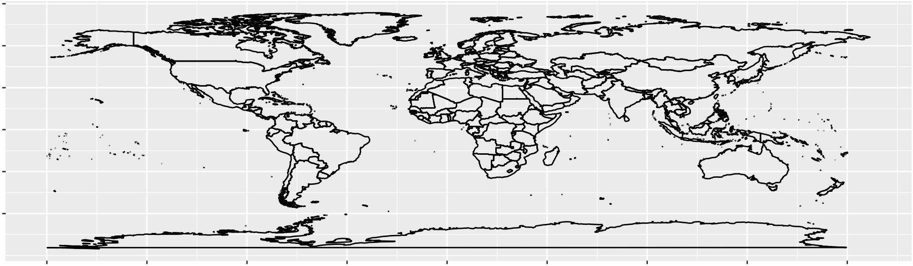
```
base <- ggplot(mtcars, aes(factor(1), fill = factor(cyl))) +
  geom_bar(width = 1) + theme(legend.position = "none") +
  scale_x_discrete(NULL, expand = c(0, 0)) +
  scale_y_continuous(NULL, expand = c(0, 0))

base + coord_polar(theta = "y") ## 变饼图
```



3.2 非线性，coord_map()

世界地图

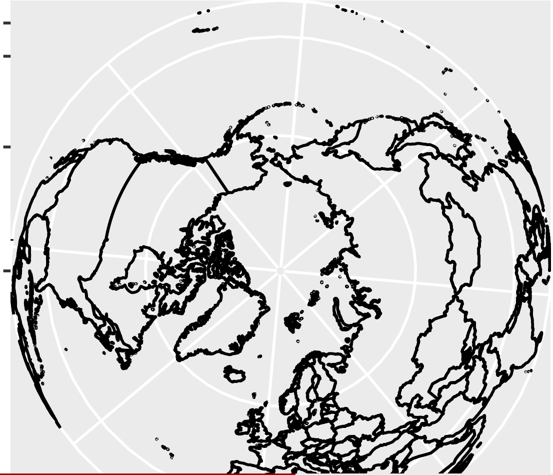
```
world <- map_data("world")
worldmap <- ggplot(world, aes(long, lat, group = group)) +
  geom_path() +
  scale_y_continuous(NULL, breaks = (-2:3) * 30, labels = NULL) +
  scale_x_continuous(NULL, breaks = (-4:4) * 45, labels = NULL)

worldmap; ## 画出来
```



3.2 非线性，coord_map(), cont.

球形图

```
library(mapproj);
worldmap + coord_map("ortho");
```

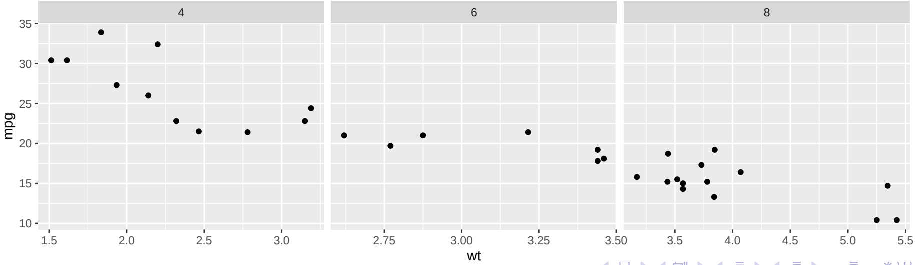


ggplot2 要素 4：faceting ...

Faceting generates small multiples each showing a different subset of the data.

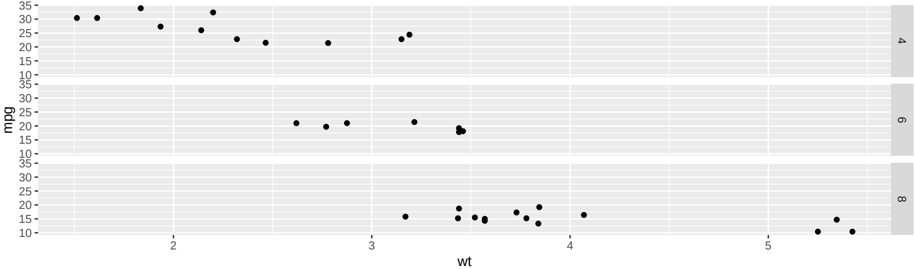
facet_grid(<by_row> ~ <by_col>) 汽缸、车重与燃油效率间的关系

```
ggplot( mtcars, aes( x = wt, y = mpg ) ) +
  geom_point() +
  facet_grid( . ~ cyl, scales = "free" );
```



faceting , cont.

```
ggplot( mtcars, aes( x = wt, y = mpg ) ) +
  geom_point() +
  facet_grid( cyl ~ . );
```



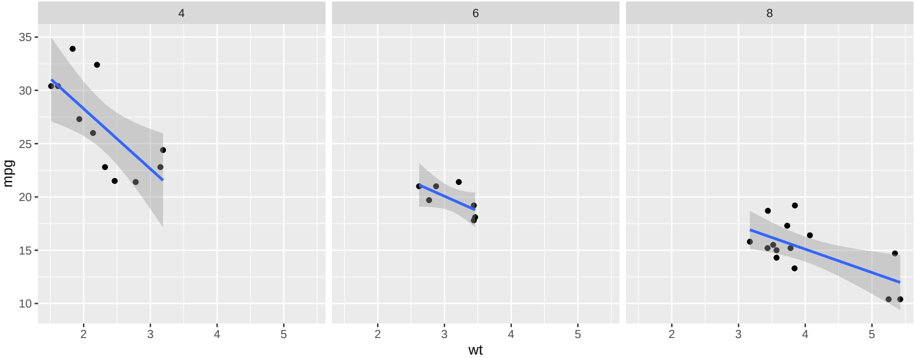
** 注意 **

作图相关概念：panel, strip, axis, tick, tick label, axis label

facet_grid , cont.

```
ggplot( mtcars, aes( x = wt, y = mpg ) ) +
  geom_point() + geom_smooth( method = "lm" ) +
  facet_grid( . ~ cyl );
```

```
## `geom_smooth()` using formula = 'y ~ x'
```

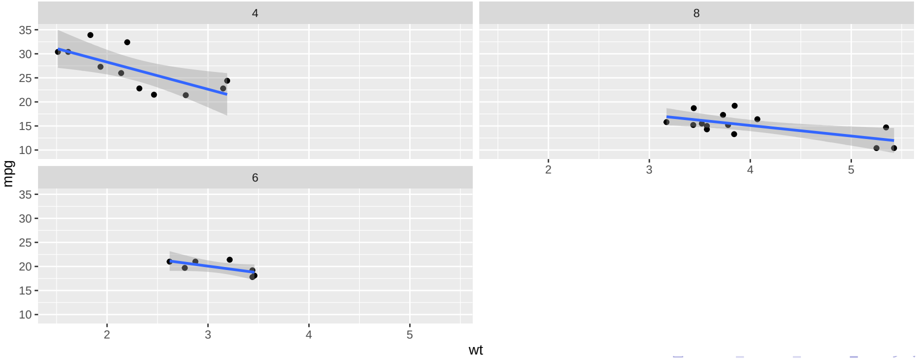


facet_wrap

指定行、列数和方向

```
ggplot( mtcars, aes( x = wt, y = mpg ) ) +
  geom_point() + geom_smooth( method = "lm" ) +
  facet_wrap( . ~ cyl , ncol = 2, dir = "v" );
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



parameters of facet_wrap

```r
facet_wrap(
  facets,
  nrow = NULL,
  ncol = NULL,
  scales = "fixed",
  shrink = TRUE,
  labeller = "label_value",
  as.table = TRUE,
  switch = NULL,
  drop = TRUE,
  dir = "h",
  strip.position = "top"
)
```

ggplot2 小结

layered grammer（图层语法）的成分

- 图层（ geom_xxx ）
- scale（ scale_xxx ）
- 坐标系统
- faceting（ facet_xxx ）

ggplot2 进阶 1 ： 如何在一张图中画多个 panel ？

key requirements for multi-panel plots

- order / position
- labeling
- layout

combine multiple plots

Useful packages:

- gridExtra
- cowplot
- grid
- lattice

install or load packages

```
if (!require("gridExtra")){
  install.packages("gridExtra");
}

if (!require("cowplot")){
  install.packages("cowplot");
}
```

```
## Loading required package: cowplot

##
## Attaching package: 'cowplot'

## The following object is masked from 'package:lubridate':
##
```

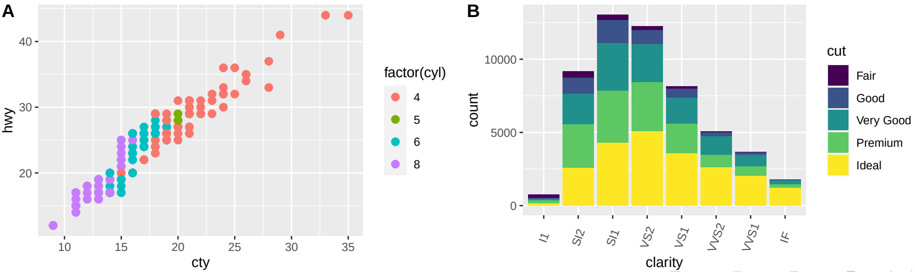
arranging multiple graphs using cowplot

Prepare two plots

```
sp <- ggplot(mpg, aes(x = cty, y = hwy, colour = factor(cyl)))+
  geom_point(size=2.5)
# Bar plot
bp <- ggplot(diamonds, aes(clarity, fill = cut)) +
  geom_bar() +
  theme(axis.text.x = element_text(angle=70, vjust=0.5))
```

Combine the two plots (the scatter plot and the bar plot):

```
cowplot::plot_grid(sp, bp, labels=c("A", "B"), ncol = 2, nrow = 1)
```



plot_grid parameters

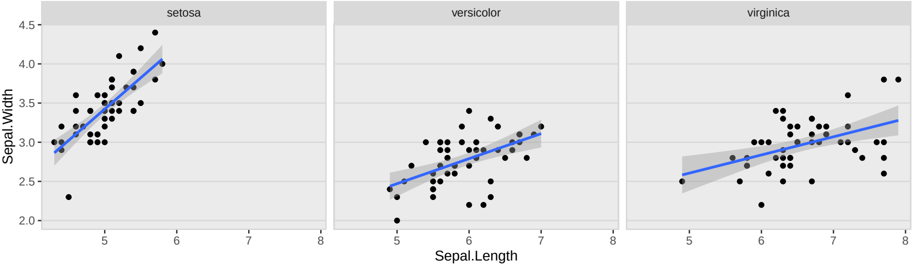
```
plot_grid(
  ...,
  plotlist = NULL,
  align = c("none", "h", "v", "hv"),
  axis = c("none", "l", "r", "t", "b", "lr", "tb", "tblr"),
  nrow = NULL,
  ncol = NULL,
  rel_widths = 1,
  rel_heights = 1,
  labels = NULL,
  label_size = 14,
  label_fontfamily = NULL,
  label_fontface = "bold",
  label_colour = NULL,
  label_x = 0,
  label_y = 1,
  hjust = -0.5,
  vjust = 1.5,
  scale = 1,
  greedy = TRUE,
  byrow = TRUE,
  cols = NULL,
  rows = NULL
)
```

用 draw_plot 调整 graph 的相对大小

先生成一个新的 panel

```
plot.iris <- ggplot(iris, aes(Sepal.Length, Sepal.Width)) +
  geom_point() + facet_grid(. ~ Species) + stat_smooth(method = "lm") +
  background_grid(major = 'y', minor = "none") + # add thin horizontal lines
  panel_border();
plot.iris;
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



用 draw_plot 将三个 panel 画在一起

```
plot <-
  ggdraw() +
  draw_plot(plot.iris, x=0, y=.5, width=1, height=.5) +
  draw_plot(sp, 0, 0, .5, .5) +
  draw_plot(bp, .5, 0, .5, .5) +
  draw_plot_label(c("A", "B", "C"), c(0, 0, 0.5), c(1, 0.5, 0.5), size = 15);
```

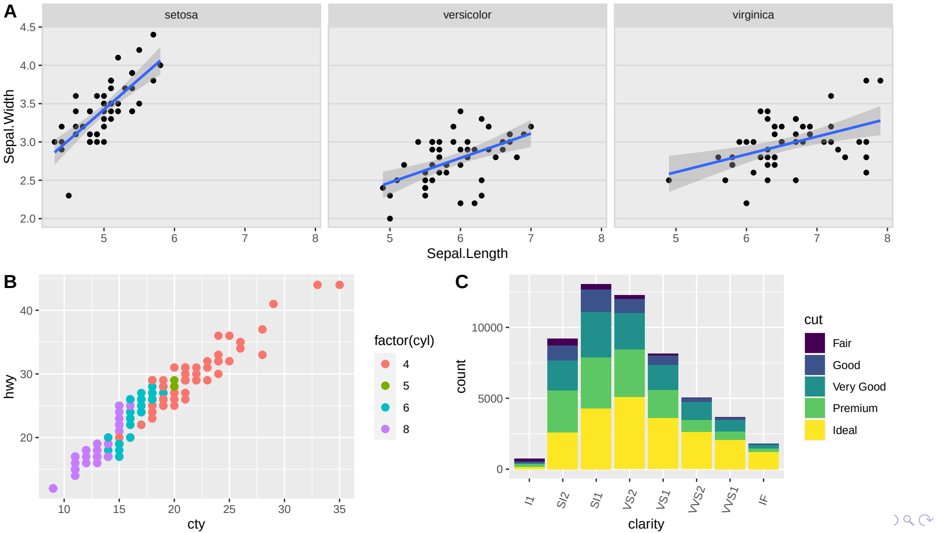
```
## `geom_smooth()` using formula = 'y ~ x'
```

draw_plot(plot, x = 0, y = 0, width = 1, height = 1) 详解：

- plot: the plot to place (ggplot2 or a gtable)
- x: The x location of the lower left corner of the plot.
- y: The y location of the lower left corner of the plot.
- width, height: the width and the height of the plot

draw_plot results

```
plot
```



draw_plot_label parameters

Use draw_plot_label to add the labels

```
draw_plot_label(c("A", "B", "C"), c(0, 0, 0.5), c(1, 0.5, 0.5), size = 15);

draw_plot_label(
  label,
  x = 0,
  y = 1,
  hjust = -0.5,
  vjust = 1.5,
  size = 16,
  fontface = "bold",
  family = NULL,
  color = NULL,
  colour,
  ...
)
```

use gridExtra::grid.arrange to arrange multiple graphs

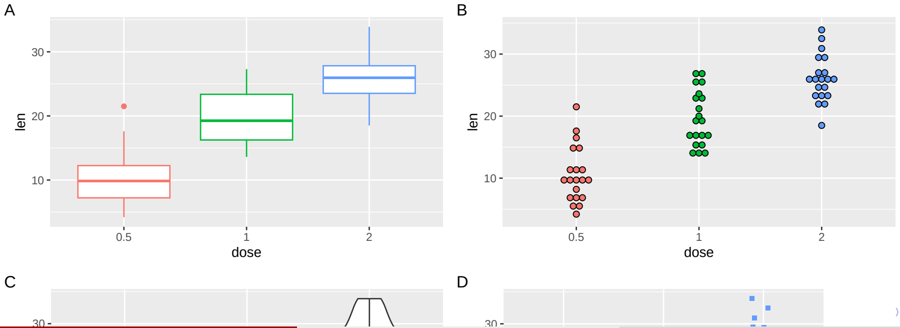
Create four plots

```
library(ggplot2); library("gridExtra");
df <- ToothGrowth
df$dose <- as.factor(df$dose)

bp <- ggplot(df, aes(x=dose, y=len, color=dose)) +
  geom_boxplot() +
  theme(legend.position = "none") + labs( tag = "A");
dp <- ggplot(df, aes(x=dose, y=len, fill=dose)) +
  geom_dotplot(binaxis='y', stackdir='center')+
  stat_summary(fun.data=mean_sdl, mult=1,
               geom="pointrange", color="red")+
   theme(legend.position = "none") + labs( tag = "B")
vp <- ggplot(df, aes(x=factor(dose), y=len)) +
  geom_violin()+
  geom_boxplot(width=0.1) + labs( tag = "C")
sc <- ggplot(df, aes(x=dose, y=len, color=dose, shape=dose)) +
  geom_jitter(position=position_jitter(0.2))+
  theme(legend.position = "none") +
  theme_gray() + labs( tag = "D")
```

use gridExtra::grid.arrange to arrange multiple graphs, cont.

```
grid.arrange(bp, dp, vp, sc, ncol=2, nrow =2);
```

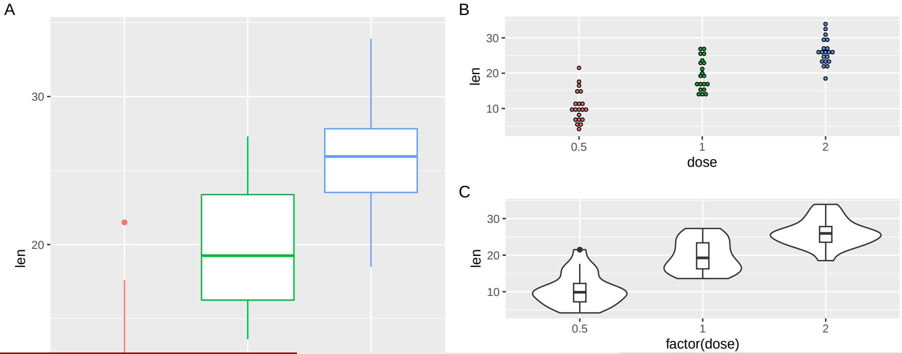
```
## Bin width defaults to 1/30 of the range of the data. Pick better value with
## `binwidth`.

## Warning: Computation failed in `stat_summary()`
## Caused by error in `fun.data()`:
## ! The package "Hmisc" is required.
```



use layout_matrix parameter in grid.arrange

```
grid.arrange(bp, dp, vp, sc, ncol = 2,
             layout_matrix = cbind(c(1,1,1), c(2,3,4)));
```

```
## Bin width defaults to 1/30 of the range of the data. Pick better value with
## `binwidth`.

## Warning: Computation failed in `stat_summary()`
## Caused by error in `fun.data()`:
## ! The package "Hmisc" is required.
```



explain layout_matrix

```
grid.arrange(bp, dp, vp, sc,
             ncol = 2,   ## two columns
             layout_matrix = cbind(c(1,1,1), c(2,3,4)) ## specify the layout
             );
```

How the layout look like??

```
cbind(c(1,1,1), c(2,3,4));
```

```
##      [,1] [,2]
## [1,]    1    2
## [2,]    1    3
## [3,]    1    4
```

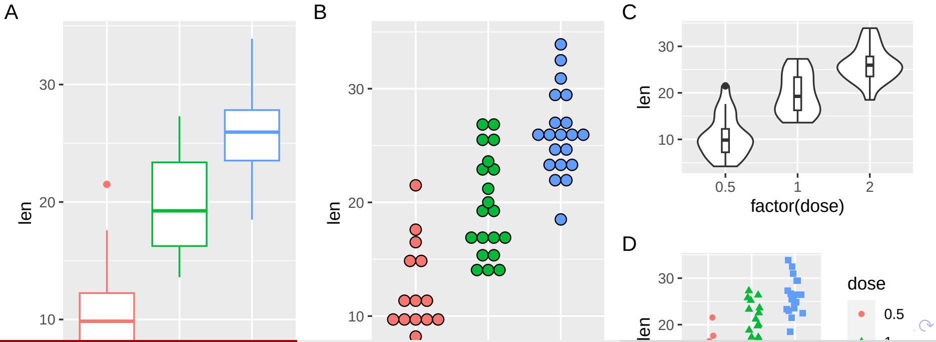
make a different layout???

three columns, A and B take the first two, C and D take the third one.

```
( laymat = cbind(c(1,1), c(2,2), c(3,4)) );
```

```
##      [,1] [,2] [,3]
## [1,]    1    2    3
## [2,]    1    2    4
```

```
grid.arrange(bp, dp, vp, sc,
             ncol = 3, layout_matrix = laymat);
```



Add a common legend for multiple ggplot2 graphs

Prepare a function to extract legend from a plot. Note **the legend should exist**.

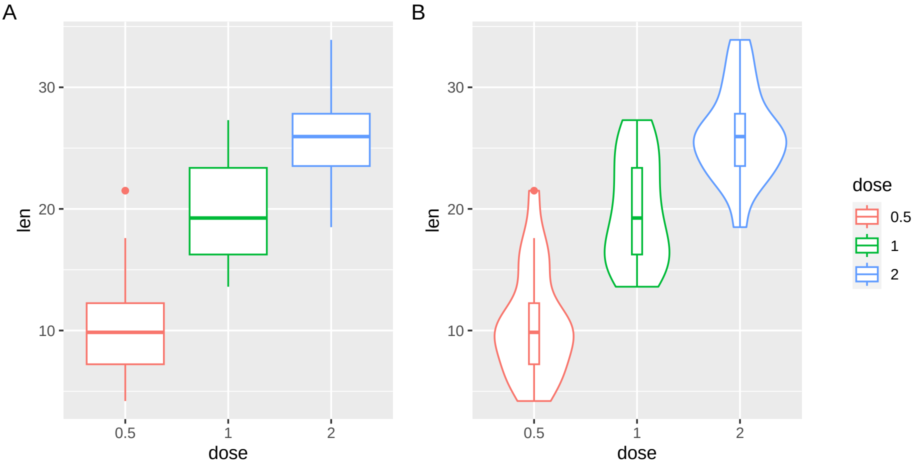
```r
library(gridExtra)
get_legend<-function(myggplot){
  tmp <- ggplot_gtable(ggplot_build(myggplot))
  leg <- which(sapply(tmp$grobs, function(x) x$name) == "guide-box")
  legend <- tmp$grobs[[leg]]
  return(legend)
}
```

Prepare the graphs and a legend

```
## 1. Create a box plot WITH legend
bp <- ggplot(df, aes(x=dose, y=len, color=dose)) +
  geom_boxplot() + labs(tag = "A");
## 2. Create a violin plot WITHOUT legend
vp <- ggplot(df, aes(x=dose, y=len, color=dose)) +
  geom_violin()+ geom_boxplot(width=0.1) + labs( tag = "B") +
  theme(legend.position="none") ## no legend
## 3. extract the legend from the first plot
legend <- get_legend(bp);
## 4. remove the legend from the first plot
bp2 <- bp + theme(legend.position="none");
```

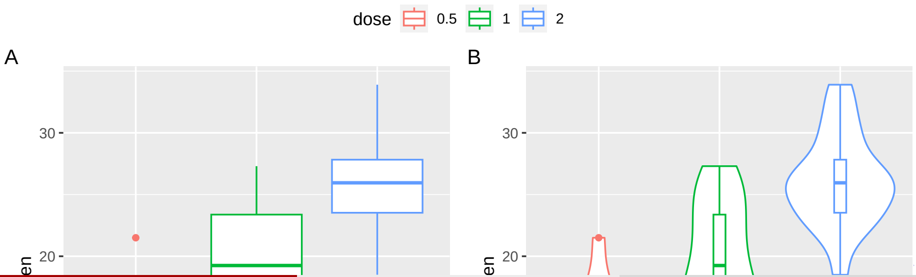
plot the common legned to the right

```
grid.arrange(bp2, vp, legend, ## three objects to plot
             ncol=3, ## plot by column
             widths=c(2.3, 2.3, 0.8)); ## set the width of each graph
```



SOLUTION: place the legend at top and align to the center

```
## 1. re-make bp WITH legend, place the legend at top
bp <- ggplot(df, aes(x=dose, y=len, color=dose)) +
  geom_boxplot() + labs(tag = "A") + theme(legend.position = "top");
## 2. extract the legend
legend <- get_legend(bp);
## 3. remove teh legend from the plot
bp2 <- bp + theme(legend.position = "none")
## 4. plot
grid.arrange(legend, bp2, vp,  ncol=2, nrow = 2,
             layout_matrix = rbind(c(1,1), c(2,3)),
             widths = c(2.7, 2.7), heights = c(0.2, 2.5));
```



Explain

```
grid.arrange(legend, bp2, vp,
             ncol=2, nrow = 2,
             layout_matrix = rbind(c(1,1), c(2,3)),
             widths = c(2.7, 2.7), heights = c(0.2, 2.5));
```

```
rbind(c(1,1), c(2,3));
```

```
##      [,1] [,2]
## [1,]    1    1
## [2,]    2    3
```

- legend takes the first row, and has a height of 0.2
- the other two graphs take the second row and has a height of 2.5

Practise on your own

To place the legend at:

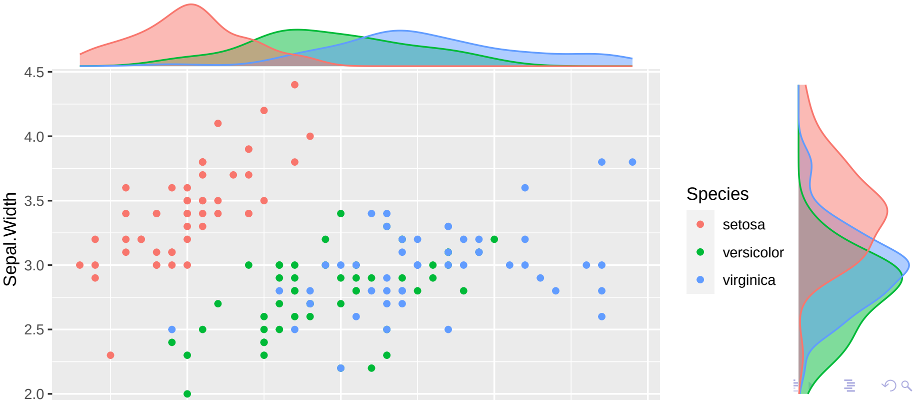
- the bottom, centered at the middle
- top-left
- top-right
- bottom-left
- bottom-right

ggExtra - Add marginal histograms to ggplot2

please install the package if not exists …

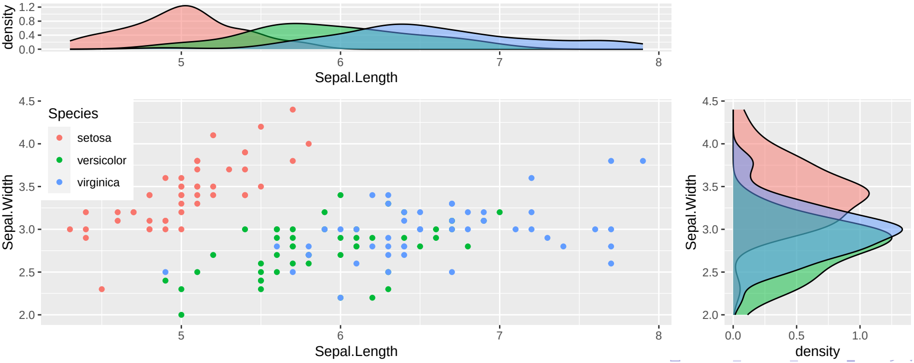
```
install.packages("ggExtra")
```

```
library(ggExtra);
piris <- ggplot(iris, aes(Sepal.Length, Sepal.Width, colour = Species)) +
  geom_point()
ggMarginal(piris, groupColour = TRUE, groupFill = TRUE)
```



也可自己写代码实现

```
piris <- ggplot(iris, aes(Sepal.Length, Sepal.Width, colour = Species)) +
  geom_point() + theme(legend.position=c(0,1), legend.justification=c(0,1))
xdensity <- ggplot(iris, aes(Sepal.Length, fill = Species)) +
  geom_density(alpha=.5) + theme(legend.position = "none")
ydensity <- ggplot(iris, aes(Sepal.Width, fill=Species)) +
  geom_density(alpha=.5) + theme(legend.position = "none") + coord_flip()
grid.arrange(xdensity, NULL, piris, ydensity,
        ncol=2, nrow=2, widths=c(4, 1.4), heights=c(1.4, 4));
```



Extended reading

Other ggplot2 extensions

See the gallery at `https://exts.ggplot2.tidyverse.org/gallery/`. Or Google `ggplot2 extensions gallery`.

Explore the `grid` package

- create graphical objects (grobs)
- arrange multiple grobs using `arrangeGrob` function

Explore the `gridExtra` package

- plot table
- ...

小结

Essentials for combining multiple graphs in one:

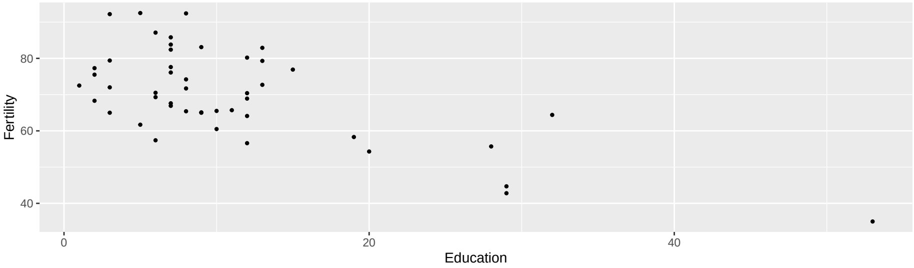
- ordering
- layout

ggplot2 进阶 2：如何写公式？

散点图的进一步分析

显示两组数据间的相关性：

```
## 作图
ggplot( swiss, aes( x = Education, y = Fertility ) ) +
  geom_point( shape = 20 );
```

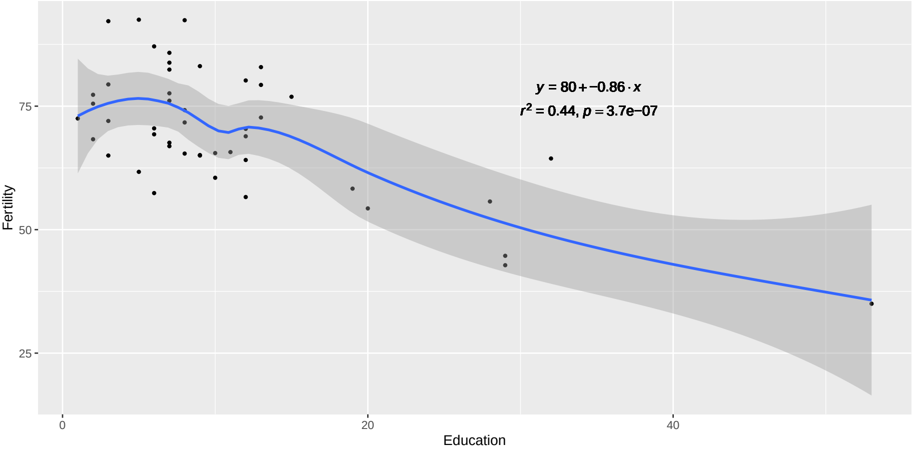


```
## 分析
with( swiss, cor.test( Education, Fertility  )$estimate );
```

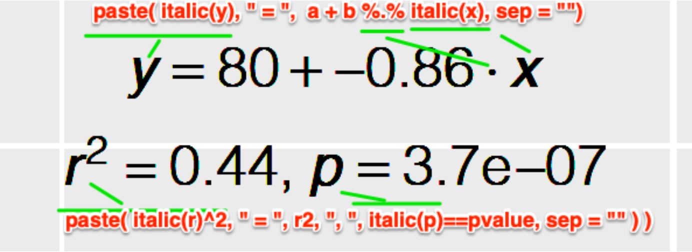
```
##        cor
## -0.6637889
```

在图中加入公式和统计信息

先展示一下结果



公式详解



```
paste( italic(y), " = ",  a + b %.% italic(x), sep = "")
paste( italic(r)^2, " = ", r2, ", ", italic(p)==pvalue, sep = "" ) )
```

Figure 5: equation explained!

公式详解，cont.

以下代码实现两个任务：

1. 将两个公式上下放置 `atop ( <equation_1> , <equation_2> );`
2. 将公式中的某些值替换为数值 `substitute( <equation>, list( ... ) )`

```
## 计算 ...
m = lm(Fertility ~ Education, swiss);
c = cor.test( swiss$Fertility, swiss$Education );

## 生成公式
eq <- substitute( atop( paste( italic(y), " = ",  a + b %.% italic(x), sep = ""),
                        paste( italic(r)^2, " = ", r2, ", ", italic(p)==pvalue, sep = "" ) ),
                      list(a = as.vector( format(coef(m)[1], digits = 2) ),
                           b =  as.vector(  format(coef(m)[2], digits = 2) ),
                           r2 =  as.vector( format(summary(m)$r.squared, digits = 2) ),
                           pvalue =  as.vector( format( c$p.value , digits = 2) ) )
    );

## 用 as.expression 对公式进行转化
eq <- as.character(as.expression(eq));
```

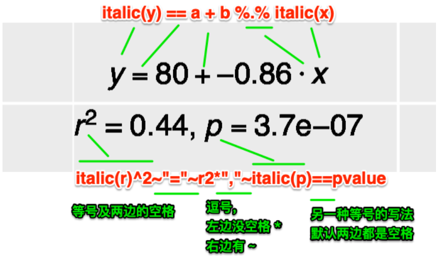
完整代码

```
## 计算 ...
m = lm(Fertility ~ Education, swiss);
c = cor.test( swiss$Fertility, swiss$Education );

## 生成公式
eq <- substitute( atop( paste( italic(y), " = ",  a + b %.% italic(x), sep = ""),
                        paste( italic(r)^2, " = ", r2, ", ", italic(p)==pvalue, sep = "" ) ),
                      list(a = as.vector( format(coef(m)[1], digits = 2) ),
                           b =  as.vector(  format(coef(m)[2], digits = 2) ),
                           r2 =  as.vector( format(summary(m)$r.squared, digits = 2) ),
                           pvalue =  as.vector( format( c$p.value , digits = 2) ) )
    );

## 用 as.expression 对公式进行转化  !!!!
eq <- as.character(as.expression(eq));

## 作图，三个图层；特别是 geom_text 使用自己的 data 和 aes ...
ggplot(swiss, aes( x = Education,  y = Fertility ) ) +
        geom_point( shape = 20 ) +
        geom_smooth( se = T ) + ## smooth line ...
        geom_text( data = NULL,
                   aes( x = 30, y = 80, label= eq, hjust = 0, vjust = 1), ## hjust, vjust ???
                   size = 4, parse = TRUE, inherit.aes=FALSE); ## 注意： parse = TRUE !!!
```

equation 的其它写法（更复杂难懂）

```
## 计算 ...
m = lm(Fertility ~ Education, swiss);
c = cor.test( swiss$Fertility, swiss$Education );

## 生成公式
eq <- substitute( atop( italic(y) == a + b %.% italic(x),
                            italic(r)^2~"="~r2*","~italic(p)==pvalue ),
                      list(a = as.vector( format(coef(m)[1], digits = 2) ),
                           b =  as.vector(  format(coef(m)[2], digits = 2) ),
                           r2 =  as.vector( format(summary(m)$r.squared, digits = 2) ),
                           pvalue =  as.vector( format( c$p.value , digits = 2) ) )
    );
## 用 as.expression 对公式进行转化  !!!!
eq <- as.character(as.expression(eq));

## 作图，三个图层；特别是 geom_text 使用自己的 data 和 aes ...
ggplot(swiss, aes( x = Education,  y = Fertility ) ) +
        geom_point( shape = 20 ) +
        geom_smooth( se = T ) + ## smooth line ...
        geom_text( data = NULL,
                   aes( x = 30, y = 80, label= eq, hjust = 0, vjust = 1), ## hjust, vjust ???
                   size = 4, parse = TRUE, inherit.aes=FALSE); ## 注意:  parse = TRUE !!!
```

公式详解



```
italic(y) == a + b %.% italic(x)
italic(r)^2~"="~r2*","~italic(p)==pvalue
```

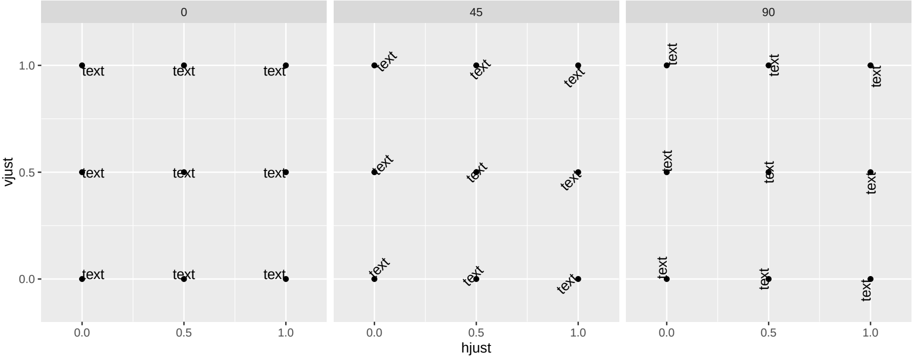
Figure 6: equation explained!

注

- 引号两边必须有 * 或 ~ 字符，~ 表示空格，* 表示什么都没有。~~ 表示两个空格。如果公式中需要 ~ 字符怎么办 ?? 见下面 “公式示例 3”。

hjust 和 vjust

geom_text(aes(angle, hjust, vjust)) 三参数详解



公式中的写法之代数符号

分类	R 的表达式	显示结果
代数符号	`expression(x + y)`	$x + y$
	`expression(x - y)`	$x - y$
	`expression(x * y)`	xy
	`expression(x / y)`	x/y
	`expression(x %+-% y)`	$x \pm y$
	`expression(x %/% y)`	$x \div y$
	`expression(x %*% y)`	$x \times y$
	`expression(x %.% y)`	$x \cdot y$
	`expression(x[i])`	x_i
	`expression(x^2)`	x^2
	`expression(sqrt(x))`	$\sqrt{x}$
	`expression(sqrt(x,y))`	$\sqrt[y]{x}$
	`expression(list(x,yz))`	x, y, z

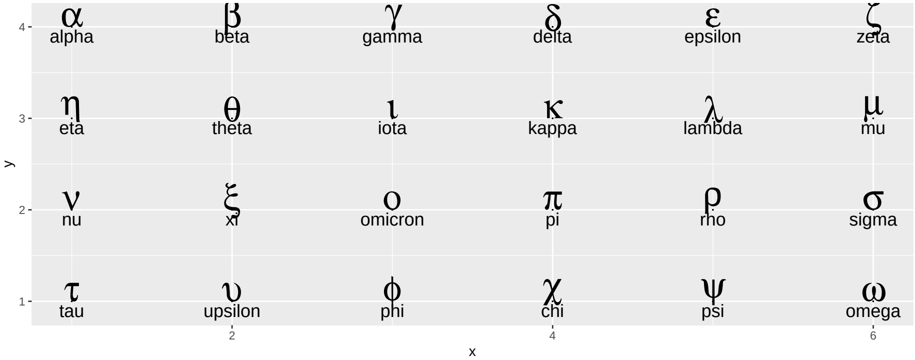
… 更多，不在这里介绍了。

希腊字符

代码

```r
library(ggplot2);
greeks <- c("Alpha", "Beta", "Gamma", "Delta", "Epsilon", "Zeta",
            "Eta", "Theta", "Iota", "Kappa", "Lambda", "Mu",
            "Nu", "Xi", "Omicron", "Pi", "Rho", "Sigma",
            "Tau", "Upsilon", "Phi", "Chi", "Psi", "Omega");

dat <- data.frame( x = rep( 1:6, 4 ), y = rep( 4:1, each = 6), greek = greeks );

plot2 <-
  ggplot( dat, aes(x=x,y=y) ) + geom_point(size = 0) +
    # 画希腊字符，注意下面两行代码的区别
    geom_text( aes( x, y + 0.1, label = tolower( greek ) ), size = 10, parse = T ) +
    geom_text( aes( x, y - 0.1, label = tolower( greek ) ), size = 5  );
```

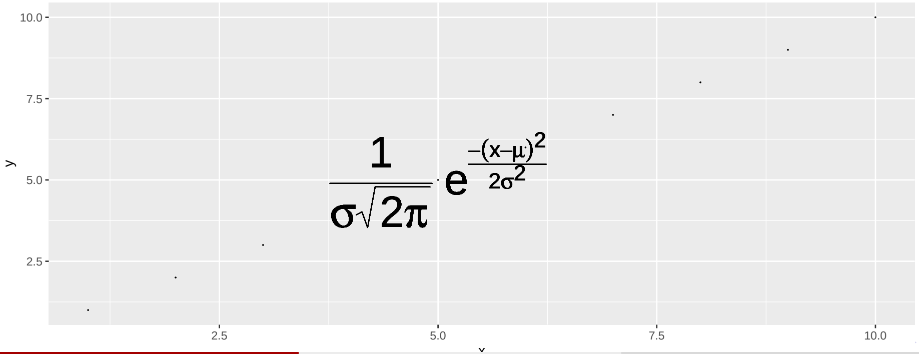
希腊字符，cont.


α
alpha
β
beta
γ
gamma
δ
delta
ε
epsilon
ζ
zeta
η
eta
θ
theta
ι
iota
κ
kappa
λ
lambda
μ
mu
ν
nu
ξ
xi
ο
omicron
π
pi
ρ
rho
σ
sigma
τ
tau
υ
upsilon
ϕ
phi
χ
chi
ψ
psi
ω
omega
4
3
2
1
y
2
4
6
x

公式示例

注写公式的方式很多

```
eq <- expression(paste(frac(1, sigma*sqrt(2*pi)), " ",
                       plain(e)^{frac(-(x-mu)^2, 2*sigma^2)}));

ggplot( data.frame(x=1:10, y=1:10), aes( x,y ) ) +
    geom_point( size = 0 ) +
    geom_text(data = NULL, x = 5, y = 5, size = 12,
              label = as.character(eq), parse = TRUE );
```

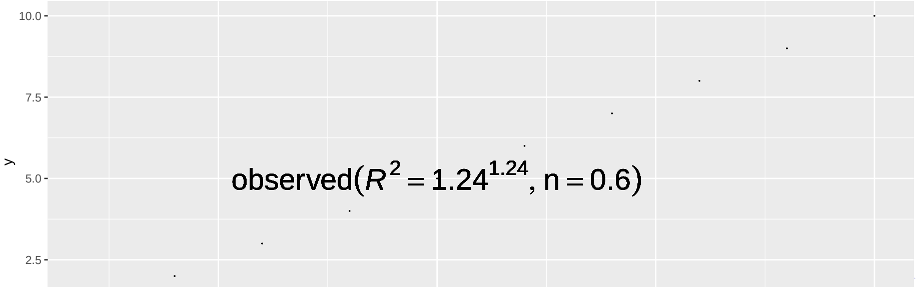


$$\frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

公式示例 2

另一种代入变量值的方法：

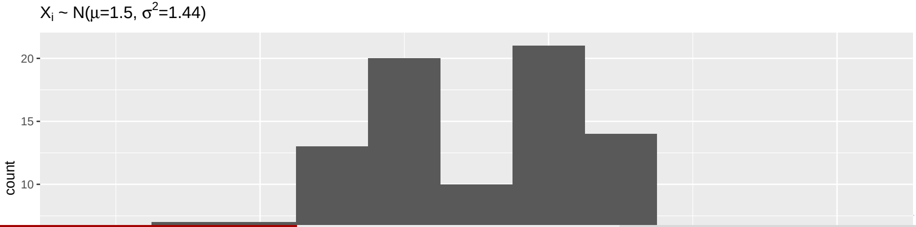
```
x <- 1.24;
y <- 0.6;

ex <- bquote(.(parse(text=paste( "observed (", "italic(R)^2==",
                               x,   "^bold(", x, "), n == ", y, ")",
                               sep = "  " ))) );

ggplot( data.frame(x=1:10, y=1:10), aes( x,y ) ) + geom_point( size = 0 ) +
    geom_text(data = NULL, x = 5, y = 5, size = 8,
              label = as.character(ex), parse = TRUE );
```



公式示例 3

使用 paste 和 substitute：

```
x_mean <- 1.5;
x_sd <- 1.2;

# 表达式
ex <- substitute(
    paste(X[i], " ~ N(", mu, "=", m, ", ", sigma^2, "=", s2, ")"),
    list(m = x_mean, s2 = x_sd^2)
);

# histogram
ggplot( data.frame( x = rnorm(100, x_mean, x_sd) ), aes( x ) ) +
    geom_histogram( binwidth=0.5 ) +
    ggtitle(ex); ## 为什么不需要 parse = TURE ????
```



ggplot2 进阶 3：核心在于先计算再做图

举例说明

先看数据（来自 talk05）：

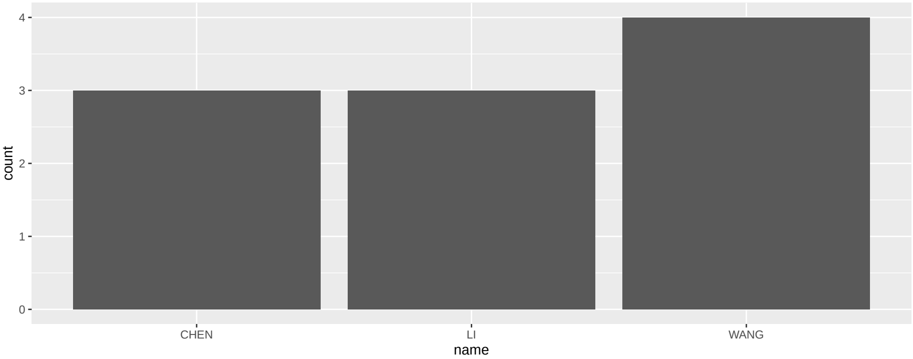
```
grades2 <- read_delim( file = "data/talk05/grades2.txt", delim = "\t",
                       quote = "", col_names = T);
knitr::kable( grades2 );
```

name	class	course	grade
CHEN	1	bioinformatics	90
CHEN	1	chemistry	92
CHEN	2	chinese	35
CHEN	3	german	62
LI	1	bioinformatics	44
LI	2	chinese	68
LI	3	microbiology	95
LI	3	japanese	90
WANG	1	bioinformatics	35
WANG	1	chemistry	76
WANG	1	mathmatics	82
WANG	3	german	100
WANG	3	spanish	78

geom_bar

任务：画出每位学生及格的课程数

```
ggplot( grades2 %>% filter( grade >= 60 ), aes( name ) ) +
  geom_bar();
```

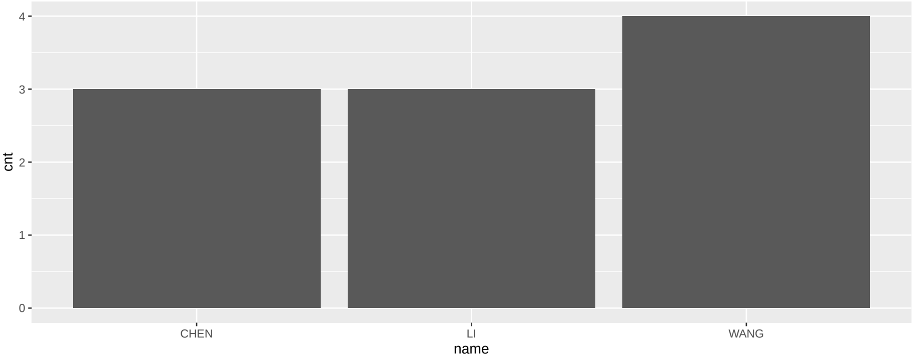


为什么会这样呢？因为 geom_bar(stat = "count") 的默认参数是 count ，即数一下每个 factor 的出现次数。

geom_bar，cont.

以上命令，实际上等于：

```
## 先做统计
cnt <- grades2 %>% group_by( name ) %>% summarise( cnt = sum( grade >= 60 )  );
ggplot( cnt, aes( x = name, y = cnt ) ) +
  geom_bar( stat = "identity" );
```



default stat behaviors (默认计算方法)

- geom_bar : count
- geom_boxplot : boxplot
- geom_count : sum
- geom_density : density
- geom_histogram : bin
- geom_quantile : quantile ...

stacked bars

应用场景：宏基因组多样本物种丰度图

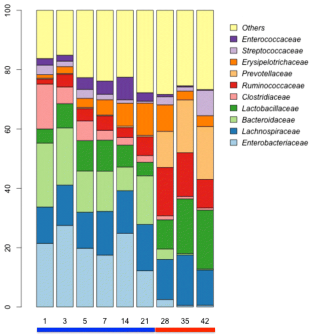


Figure 7: Microbiome 3, 28 2015

stacked bars , cont.

load data

```
speabu <-read_tsv( file = "data/talk09/mock_species_abundance.txt"  );
```

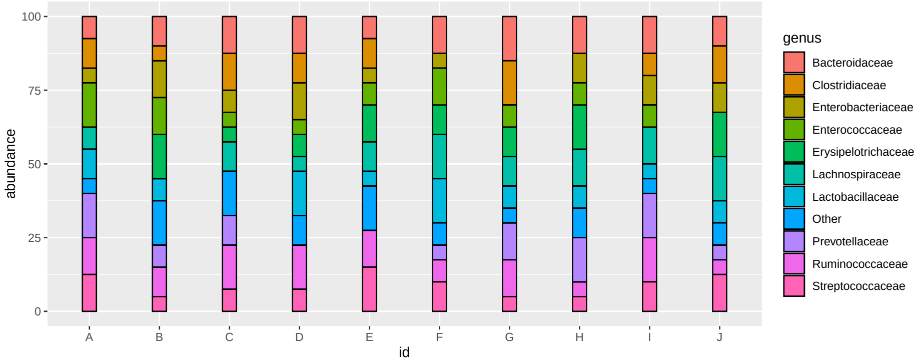
```
## Rows: 110 Columns: 3
## -- Column specification --------------------------------------------------------
## Delimiter: "\t"
## chr (2): id, genus
## dbl (1): abundance
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
head( speabu );
```

```
## # A tibble: 6 x 3
##   id    genus              abundance
##   <chr> <chr>                  <dbl>
## 1 A     Enterobacteriaceae       5
## 2 A     Lachnospiraceae          7.5
## 3 A     Bacteroidaceae           7.5
## 4 A     Lactobacillaceae        10
## 5 A     Clostridiaceae          10
## 6 A     Ruminococcaceae         12.5
```

stacked bars , cont.

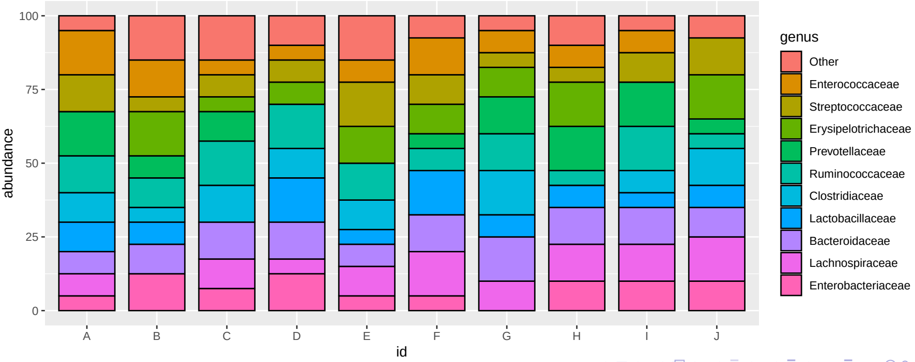
```
ggplot( speabu, aes( x = id, y = abundance, fill = genus ) ) +
  geom_bar( stat = "identity", position = "stack", color = "black", width = 0.2 );
```



指定 Genus 展示顺序

factor 的操纵详见第 4 章。

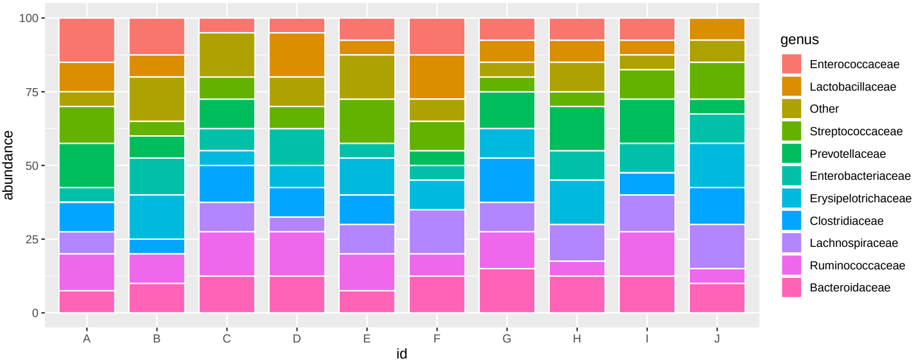
```
speabu$genus <- factor( speabu$genus, levels = rev( c( "Enterobacteriaceae", "Lachnospiraceae",
       "Clostridiaceae", "Ruminococcaceae", "Prevotellaceae", "Erysipelotrichaceae", "Streptoco
ggplot( speabu, aes( x = id, y = abundance, fill = genus ) ) +
  geom_bar( stat = "identity", position = "stack", color = "black", width = 0.8 );
```



按丰度排序

按丰度中值大小排序

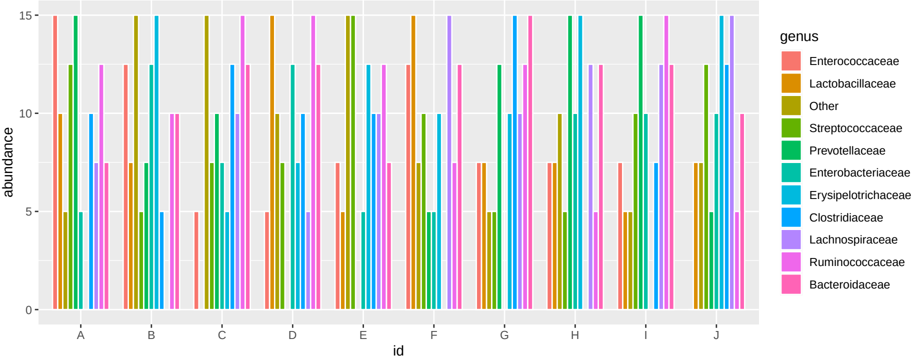
```
speabu$genus <- reorder( speabu$genus, speabu$abundance, median );
ggplot( speabu, aes( x = id, y = abundance, fill = genus ) ) +
  geom_bar( stat = "identity", position = "stack", color = "white", width = 0.8 );
```



position = "stack" 又是什么 ??

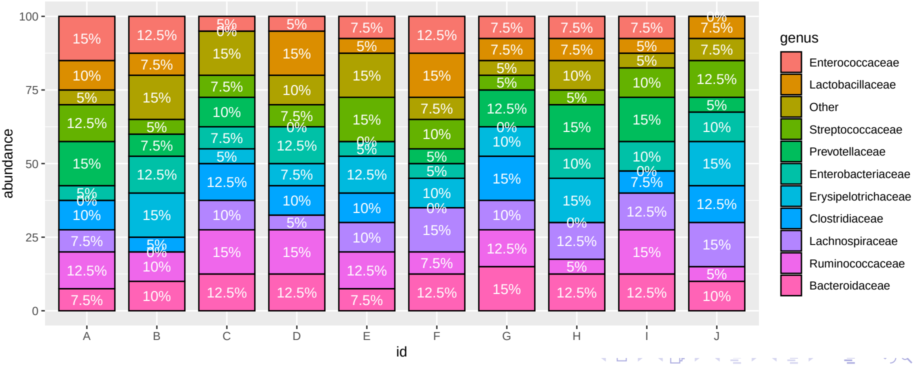
position = "dodge" : plot bars next to each other ...

```
ggplot( speabu, aes( x = id, y = abundance, fill = genus ) ) +
  geom_bar( stat = "identity", position = "dodge", color = "white", width = 0.8 );
```



显示数值 ...

```
## 先计算显示位置
speabu <- speabu %>% arrange( id, desc( factor( genus ) ) ) %>%
  group_by( id ) %>% mutate( ypos = cumsum( abundance ) - abundance / 2 );
## 画图
ggplot( speabu, aes( x = id, y = abundance, fill = genus ) ) +
  geom_bar( stat = "identity", position = "stack", color = "black", width = 0.8 ) +
  geom_text( aes( y = ypos, label = paste( abundance, "%", sep = "" ) ), color = "white" );
```



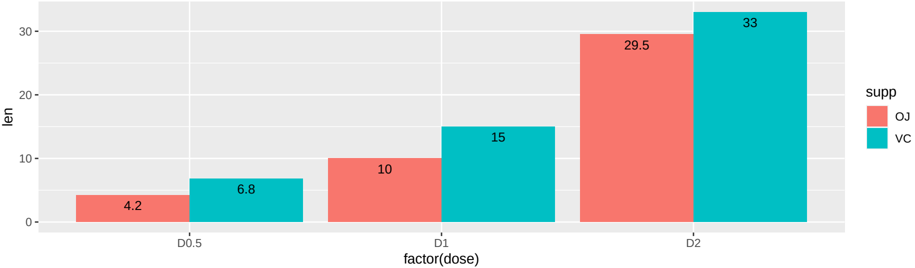
显示数值 ... , cont.

要点

- 使用 ddplyr 的 cumsum() 函数 ...
- 计算位置：当前累加值 - 自身值/2，使数字显示在当前值的中间
- 累加前，要对数据按 factors 进行排序；通过 arrange 函数实现；

在 position = "dodge" 的情况下添加 label

```
df2 <- data.frame(supp=rep(c("VC", "OJ"), each=3),
                  dose=rep(c("D0.5", "D1", "D2"),2),
                 len=c(6.8, 15, 33, 4.2, 10, 29.5))
ggplot( df2, aes(x=factor(dose), y=len, fill=supp)) +
  geom_bar(stat="identity", position=position_dodge())+
  geom_text(aes(label=len), vjust=1.6, color="black",
            position = position_dodge(0.9), size=3.5)
```



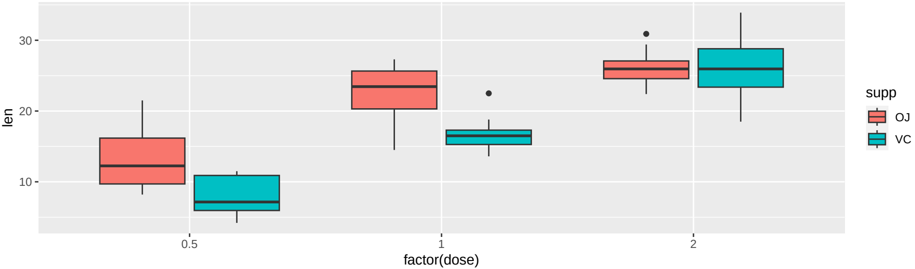
position 的其它取值

除了 “dodge”, “stack” 之外，position 还可以：

- position = position_stack(reverse = TRUE)
- position = position_dodge(reverse = TRUE)
- position = position_identity()
- position = position_jitter() ：jitter points to avoid overplotting …
- position = position_nudge() ：is generally useful for adjusting the position of items on discrete scales by a small amount

不同的图层有不同默认值

```
ggplot(ToothGrowth, aes(x=factor( dose ), y=len, fill=supp)) +
  geom_boxplot()
```



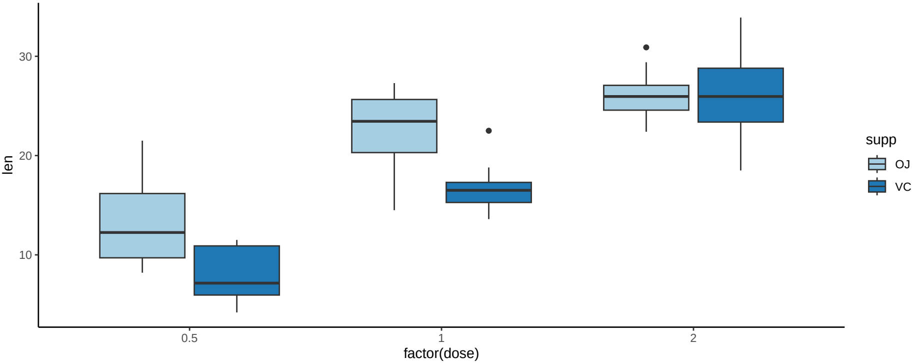
geom_boxplot()：默认为 dodge

改变 theme()

theme 调整包括 theme() 函数，用于调整各个 elements

和 theme_xxx() 函数，直接使用已经定制好的内容；

```
ggplot(ToothGrowth, aes(x=factor( dose ), y=len, fill=supp)) +
  geom_boxplot() + scale_fill_brewer( palette = "Paired" ) + theme_classic();
```



ggplot2 中的主题

- theme_gray：系统默认主题
- theme_bw，theme_linedraw, theme_light, theme_dark, theme_minimal，theme_classic, theme_void()

see here for a complete list:
https://ggplot2.tidyverse.org/reference/ggtheme.html

theme() 函数

除了 theme_ 用于调整整体视觉效果外，ggplot2 还提供了 theme() 函数用于细调。

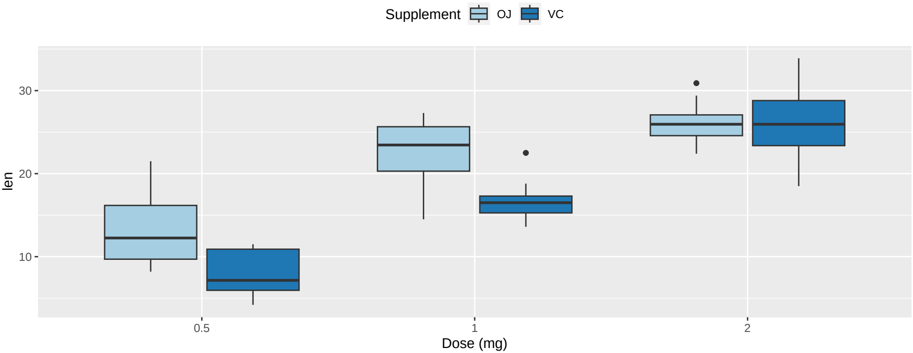
- line, rect, text, title ： 整体框架
- axis.<component> ： 调整坐标轴
- legend.<parameter> ： 调整图例
- plot.<> ： 控制 title, subtitle 等细节
- panel.<...> ： 调整 facet 情况下的 panel （facet 下面会介绍）
- strip.<...> ： 调整 facet 的标题细节 ...

更多详见：

官方： https://ggplot2.tidyverse.org/reference/theme.html

legend 细调

```
ggplot(ToothGrowth, aes(x=factor( dose ), y=len, fill=supp)) +
  geom_boxplot() + scale_fill_brewer( palette = "Paired" ) +
  labs( fill = "Supplement", x = "Dose (mg)" ) +
  theme( legend.position = "top" )
```

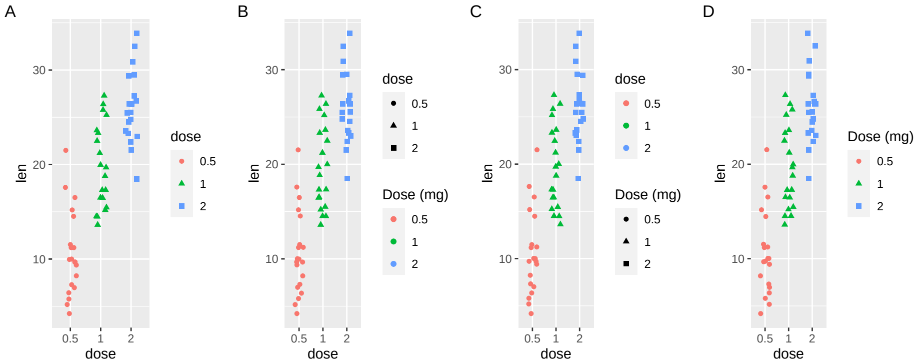


labs() function: Modify axis, legend, and plot labels

```r
labs(
  ...,
  x = "<x label>",
  y = "<y label>",
  colour = "<legend title>", # 与 aes 里的 colour 配合使用
  fill = "<legend title>", # 与 aes 里的 fill 配合使用
  shape = "<legend title>", # 与 aes 里的 shape 配合使用
  title = waiver(),
  subtitle = waiver(),
  caption = waiver(),
  tag = waiver(),
  alt = waiver(),
  alt_insight = waiver()
)
```

labs() with examples

```
grid.arrange(sc + labs(tag = "A"),
             sc + labs( colour = "Dose (mg)" , tag = "B"),
             sc + labs( shape = "Dose (mg)" , tag = "C"),
             sc + labs( colour = "Dose (mg)", shape = "Dose (mg)", tag = "D"  ),
             ncol=4, nrow =1);
```



more to read

ggplot2 的在线书

`https://ggplot2-book.org/themes`

Exercise and home work

总结，本节内容

ggplot2 基础

- 优缺点
- 用法
- 基本组成

ggplot2 进阶

- 颜色和色板
- 复杂 layout 的实现
- 公式
- ggplot2 的数据统计逻辑

更多阅读

- Ggplot2: Elegant Graphics for Data Analysis, Book by Hadley Wickham
- ggplot2 gallery provided by RStudio on Github

写在后面

1. ggplot2 博大精深，需要一门课去讲
2. 上手容易，精通难
3. 太多记忆点
4. 本节内容只涉及了基础中的基础，更多内容，包括进阶技巧和生信相关的扩展包，更多的需要同学们自行探索
5. 遇到不会的图，先百度/Google，找包和代码

下次预告

data summary and modeling

作业

- Exercises and homework 目录下 talk09-homework.Rmd 文件；
- 完成时间：见钉群的要求