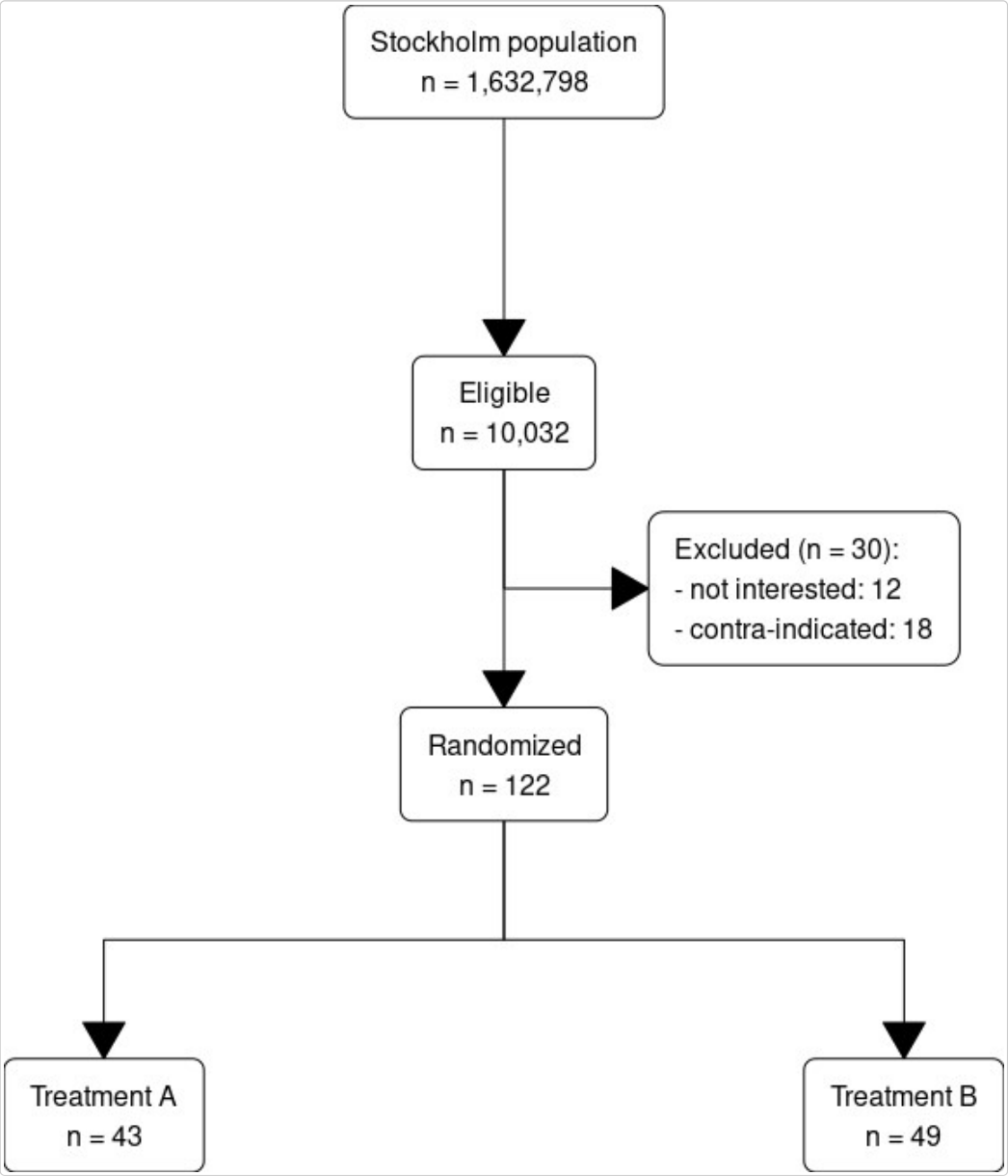
Flowchart

A flowchart is a type of diagram that represents a workflow or process. In research we often want to explain how we recruited our patients, how many that were available from the start, how many that were excluded and how many were left at the final analysis. The **Gmisc** package provides a convenient set of functions for doing this using the R's built-in `grid` package with some bells and whistles. Below is a simple example that illustrates what we're aiming for.

```
library(Gmisc, quietly = TRUE)
library(glue)
library(htmlTable)
library(grid)
library(magrittr)

org_cohort <- boxGrob(glue("Stockholm population",
                           "n = {pop}",
                           pop = txtInt(1632798),
                           .sep = "\n"))
eligible <- boxGrob(glue("Eligible",
                         "n = {pop}",
                          pop = txtInt(10032),
                          .sep = "\n"))
included <- boxGrob(glue("Randomized",
                         "n = {incl}",
                         incl = txtInt(122),
                         .sep = "\n"))
grp_a <- boxGrob(glue("Treatment A",
                      "n = {recr}",
                      recr = txtInt(43),
                      .sep = "\n"))

grp_b <- boxGrob(glue("Treatment B",
                      "n = {recr}",
                      recr = txtInt(122 - 43 - 30),
                      .sep = "\n"))

excluded <- boxGrob(glue("Excluded (n = {tot}):",
                         " - not interested: {uninterested}",
                         " - contra-indicated: {contra}",
                         tot = 30,
                         uninterested = 12,
                         contra = 30 - 12,
                         .sep = "\n"),
                    just = "left")

grid.newpage()
vert <- spreadVertical(org_cohort,
                       eligible = eligible,
                       included = included,
                       grps = grp_a)
grps <- alignVertical(reference = vert$grps,
                      grp_a, grp_b) %>%
  spreadHorizontal()
vert$grps <- NULL

excluded <- moveBox(excluded,
                    x = .8,
```

```
                    y = coords(vert$included)$top + distance(vert$eligible, vert$included, half = TRUE,
          center = FALSE))

for (i in 1:(length(vert) - 1)) {
  connectGrob(vert[[i]], vert[[i + 1]], type = "vert") %>%
    print
}
connectGrob(vert$included, grps[[1]], type = "N")
connectGrob(vert$included, grps[[2]], type = "N")

connectGrob(vert$eligible, excluded, type = "L")

# Print boxes
vert
grps
excluded
```



Basic components explained

There is a basic set of components that are used for generating flowcharts:

- Boxes, these are generated through the `boxGrob` and `boxPropGrob` functions.
- Arrows between boxes, these are generated through the `connectGrob` function.

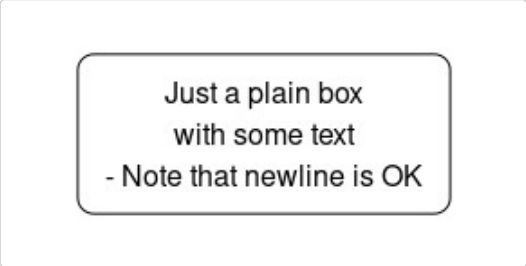
These can be positioned directly or preferably manipulated according to the following principles:

- Spread - we want to use the full plot and either we position each element or we automatically spread them in a vertical or horizontal direction, `spreadHorizontal` and `spreadVertical` functions.
- Alignment of boxes - before or after spreading we may want to align boxes: `alignHorizontal` and `alignVertical` functions.

A basic box

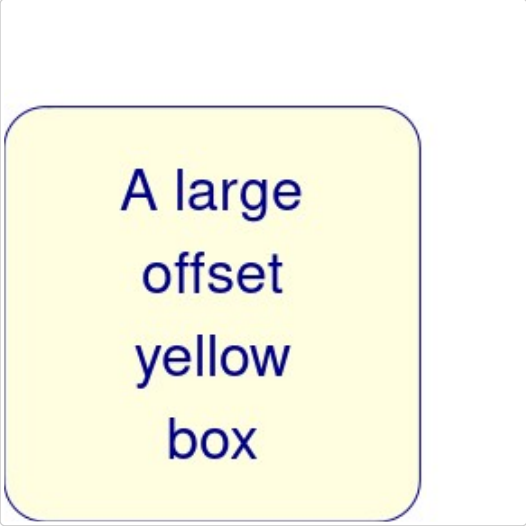
We can start with outputting a single box:

```
grid.newpage()
txt <-
"Just a plain box
with some text
- Note that newline is OK"
boxGrob(txt)
```



We can position and style this box as any element:

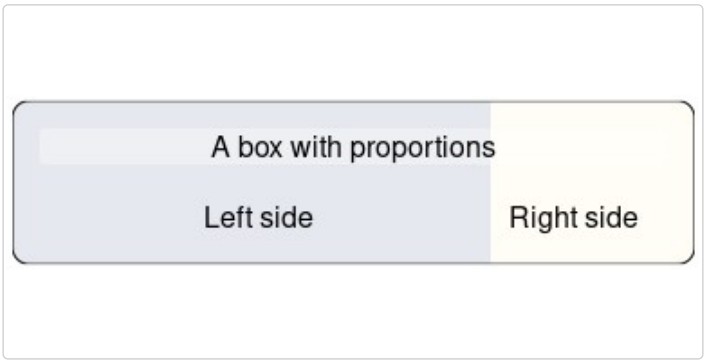
```
grid.newpage()
boxGrob("A large\noffset\nyellow\nbox",
        width = .8, height = .8,
        x = 0, y = 0,
        bjust = c("left", "bottom"),
        txt_gp = gpar(col = "darkblue", cex = 2),
        box_gp = gpar(fill = "lightyellow", col = "darkblue"))
```



A box with proportiions

The `boxPropGrob` is for displaying proportions as the name indicates.

```
grid.newpage()
boxPropGrob("A box with proportions",
            "Left side", "Right side",
            prop = .7)
```

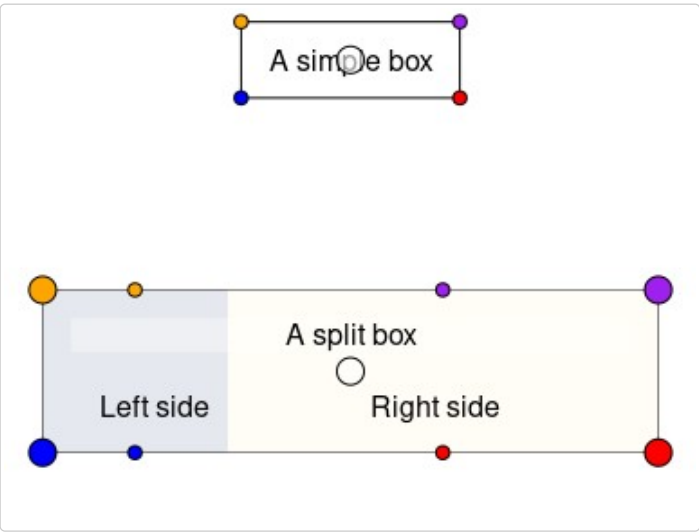


The box coordinates

The boxes have coordinates that allow you to easily draw lines to and from it. The coordinates are stored in the `coords` attribute. Below is an illustration of the coordinates for the two boxes:

```
grid.newpage()
smpl_bx <- boxGrob(
  label = "A simple box",
  x = .5,
  y = .9,
  just = "center")

prop_bx <- boxPropGrob(
  label = "A split box",
  label_left = "Left side",
  label_right = "Right side",
  x = .5,
  y = .3,
  prop = .3,
  just = "center")

plot(smpl_bx)
plot(prop_bx)

smpl_bx_coords <- coords(smpl_bx)
grid.circle(y = smpl_bx_coords$y,
            x = smpl_bx_coords$x,
            r = unit(2, "mm"),
            gp = gpar(fill = "#FFFFFF99", col = "black"))
grid.circle(y = smpl_bx_coords$bottom,
            x = smpl_bx_coords$right,
            r = unit(1, "mm"),
            gp = gpar(fill = "red"))
grid.circle(y = smpl_bx_coords$top,
            x = smpl_bx_coords$right,
            r = unit(1, "mm"),
            gp = gpar(fill = "purple"))
grid.circle(y = smpl_bx_coords$bottom,
            x = smpl_bx_coords$left,
            r = unit(1, "mm"),
            gp = gpar(fill = "blue"))
```

```
grid.circle(y = smpl_bx_coords$top,
            x = smpl_bx_coords$left,
            r = unit(1, "mm"),
            gp = gpar(fill = "orange"))

prop_bx_coords <- coords(prop_bx)
grid.circle(y = prop_bx_coords$y,
            x = prop_bx_coords$x,
            r = unit(2, "mm"),
            gp = gpar(fill = "#FFFFFF99", col = "black"))
grid.circle(y = prop_bx_coords$bottom,
            x = prop_bx_coords$right_x,
            r = unit(1, "mm"),
            gp = gpar(fill = "red"))
grid.circle(y = prop_bx_coords$top,
            x = prop_bx_coords$right_x,
            r = unit(1, "mm"),
            gp = gpar(fill = "purple"))
grid.circle(y = prop_bx_coords$bottom,
            x = prop_bx_coords$left_x,
            r = unit(1, "mm"),
            gp = gpar(fill = "blue"))
grid.circle(y = prop_bx_coords$top,
            x = prop_bx_coords$left_x,
            r = unit(1, "mm"),
            gp = gpar(fill = "orange"))

grid.circle(y = prop_bx_coords$bottom,
            x = prop_bx_coords$right,
            r = unit(2, "mm"),
            gp = gpar(fill = "red"))
grid.circle(y = prop_bx_coords$top,
            x = prop_bx_coords$right,
            r = unit(2, "mm"),
            gp = gpar(fill = "purple"))
grid.circle(y = prop_bx_coords$bottom,
            x = prop_bx_coords$left,
            r = unit(2, "mm"),
            gp = gpar(fill = "blue"))
grid.circle(y = prop_bx_coords$top,
            x = prop_bx_coords$left,
            r = unit(2, "mm"),
            gp = gpar(fill = "orange"))
```

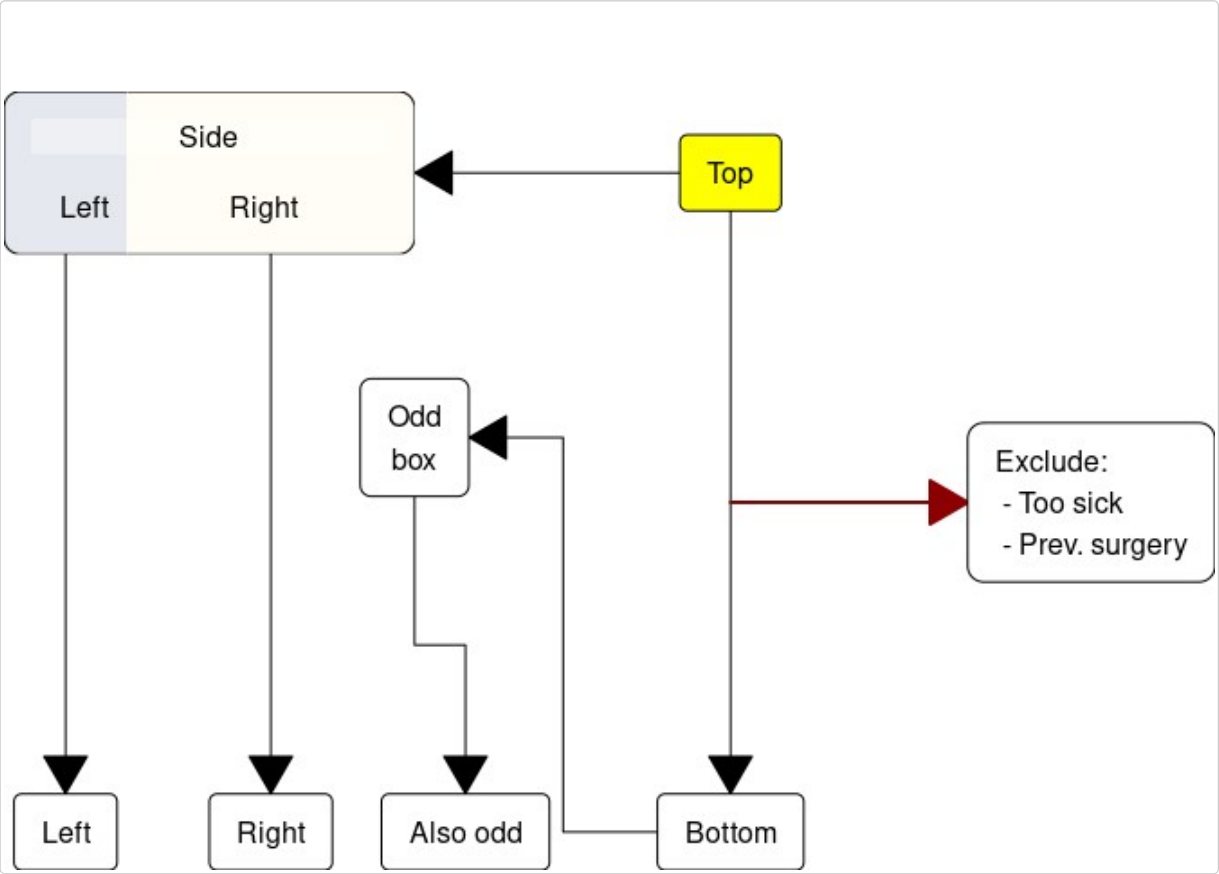


Connecting the boxes

In order to make connecting boxes with an arrow there is the `connectGrob` function. Here's an example of how you can use it for connecting a set of boxes:

```
grid.newpage()
# Initiate the boxes that we want to connect
side <- boxPropGrob("Side", "Left", "Right",
                    prop = .3,
                    x = 0, y = .9,
                    bjust = c(0,1))
start <- boxGrob("Top",
                 x = .6, y = coords(side)$y,
                 box_gp = gpar(fill = "yellow"))
bottom <- boxGrob("Bottom",
                  x = .6, y = 0,
                  bjust = "bottom")


sub_side_left <- boxGrob("Left",
                         x = coords(side)$left_x,
                         y = 0,
                         bjust = "bottom")
sub_side_right <- boxGrob("Right",
                          x = coords(side)$right_x,
                          y = 0,
                          bjust = "bottom")

odd <- boxGrob("Odd\nbox",
               x = coords(side)$right,
               y = .5)

odd2 <- boxGrob("Also odd",
               x = coords(odd)$right +
                 distance(bottom, odd, type = "h", half = TRUE) -
                 unit(2, "mm"),
               y = 0,
               bjust = c(1,0))

exclude <- boxGrob("Exclude:\n - Too sick\n - Prev. surgery",
                   x = 1,
                   y = coords(bottom)$top +
                     distance(start, bottom, type = "v", half = TRUE),
                   just = "left", bjust = "right")

# Connect the boxes and print/plot them
connectGrob(start, bottom, "vertical")
connectGrob(start, side, "horizontal")
connectGrob(bottom, odd, "Z", "l")
connectGrob(odd, odd2, "N", "l")
connectGrob(side, sub_side_left, "v", "l")
connectGrob(side, sub_side_right, "v", "r")
connectGrob(start, exclude, "-",
            lty_gp = gpar(lwd = 2, col = "darkred", fill = "darkred"))

# Print the grobs
start
bottom
```

```
side
exclude
sub_side_left
sub_side_right
odd
odd2
```



Alignment

We frequently want to align boxes in either a horizontal or a vertical row. For this there are two functions, `alignHorizontal()` and `alignVertical()`.

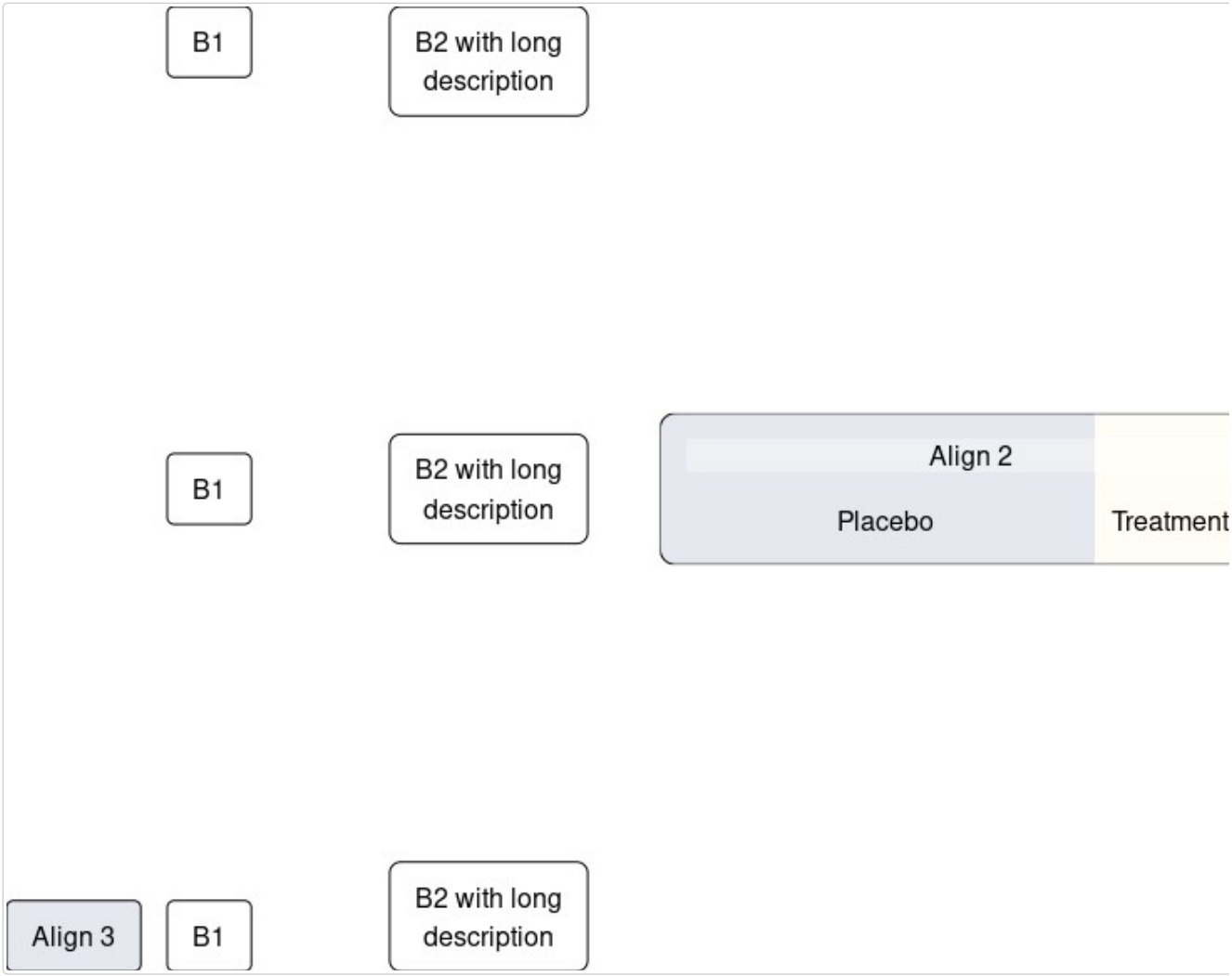
```
align_1 <- boxGrob("Align 1",
                   y = .9,
                   x = 0,
                   bjust = c(0),
                   box_gp = gpar(fill = "#E6E8EF"))

align_2 <- boxPropGrob("Align 2",
                       "Placebo",
                       "Treatment",
                       prop = .7,
                       y = .8,
                       x = .5)

align_3 <- boxGrob("Align 3\nvertical\ntext",
                   y = 1,
                   x = 1,
                   bjust = c(1, 1),
                   box_gp = gpar(fill = "#E6E8EF"))

b1 <- boxGrob("B1",
```

```
              y = .3,
              x = .1,
              bjust = c(0))
b2 <- boxGrob("B2 with long\ndescription",
              y = .6,
              x = .5)
b3 <- boxGrob("B3",
              y = .2,
              x = .8,
              bjust = c(0, 1))

grid.newpage()
align_1
alignHorizontal(reference = align_1,
                b1, b2, b3,
                .position = "left")

align_2
alignHorizontal(reference = align_2,
                b1, b2, b3,
                .position = "center",
                .sub_position = "left")
alignHorizontal(reference = align_2,
                b1, b2, b3,
                .position = "left",
                .sub_position = "right")

align_3
alignHorizontal(reference = align_3,
                b1, b2, b3,
                .position = "right")
```

Here are similar examples of vertical alignment:

```
align_1 <- boxGrob("Align 1\nvertical\ntext",
                   y = 1,
                   x = 1,
                   bjust = c(1, 1),
                   box_gp = gpar(fill = "#E6E8EF"))

align_2 <- boxPropGrob("Align 2",
                       "Placebo",
                       "Treatment",
                       prop = .7,
                       y = .5,
                       x = .6)

align_3 <- boxGrob("Align 3",
                   y = 0,
                   x = 0,
                   bjust = c(0, 0),
                   box_gp = gpar(fill = "#E6E8EF"))


b1 <- boxGrob("B1",
              y = .3,
              x = 0.1,
              bjust = c(0, 0))
b2 <- boxGrob("B2 with long\ndescription",
              y = .6,
```

```
              x = .3)
b3 <- boxGrob("B3",
              y = .2,
              x = .85,
              bjust = c(0, 1))

grid.newpage()
align_1
alignVertical(reference = align_1,
              b1, b2, b3,
              .position = "top")

align_2
alignVertical(reference = align_2,
              b1, b2, b3,
              .position = "center")

align_3
alignVertical(reference = align_3,
              b1, b2, b3,
              .position = "bottom")
```

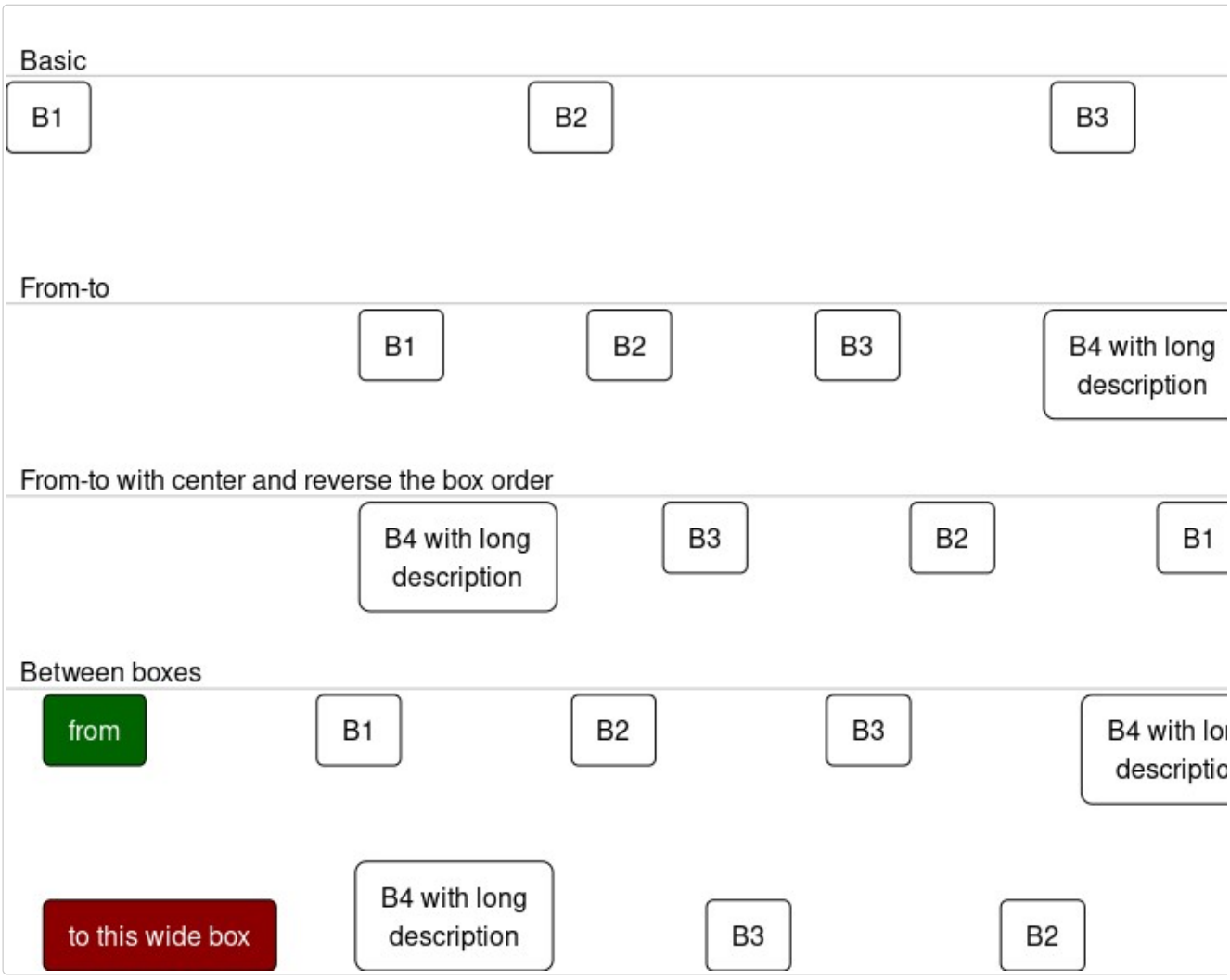


Spreading

Similarly to alignment we often want to spread our boxes within a space so that we use all the available space in the `viewport`. This can be done through the `spreadHorizontal()` and `spreadVertical()`. You can both spread the entire span or only between a subspan that is defined using the `.to` and `.from` arguments.

```
b1 <- boxGrob("B1",
              y = .85,
              x = 0.1,
              bjust = c(0, 0))
b2 <- boxGrob("B2",
              y = .65,
              x = .6)
b3 <- boxGrob("B3",
              y = .45,
              x = .6)
b4 <- boxGrob("B4 with long\ndescription",
              y = .7,
              x = .8)

from <- boxGrob("from",
                y = .25,
                x = .05,
                box_gp = gpar(fill = "darkgreen"),
                txt_gp = gpar(col = "white"))
to <- boxGrob("to this wide box",
              y = coords(from)$y,
              x = .95,
              bjust = "right",
              box_gp = gpar(fill = "darkred"),
              txt_gp = gpar(col = "white"))


txtOut <- function(txt, refBx) {
  grid.text(txt,
            x = unit(2, "mm"),
            y = coords(refBx)$top + unit(2, "mm"),
            just = c("left", "bottom"))
  grid.lines(y = coords(refBx)$top + unit(1, "mm"),
             gp = gpar(col = "grey"))
}
grid.newpage()
txtOut("Basic", b1)
alignVertical(reference = b1,
              b1, b2, b3, b4,
              .position = "top") %>%
  spreadHorizontal()

txtOut("From-to", b2)
alignVertical(reference = b2,
              b1, b2, b3, b4,
              .position = "top") %>%
  spreadHorizontal(.from = .2,
                   .to = .7)

txtOut("From-to with center and reverse the box order", b3)
alignVertical(reference = b3,
              b1, b2, b3, b4,
              .position = "top") %>%
  spreadHorizontal(.from = .7,
                   .to = .2,
                   .type = "center")

txtOut("Between boxes", from)
from
```

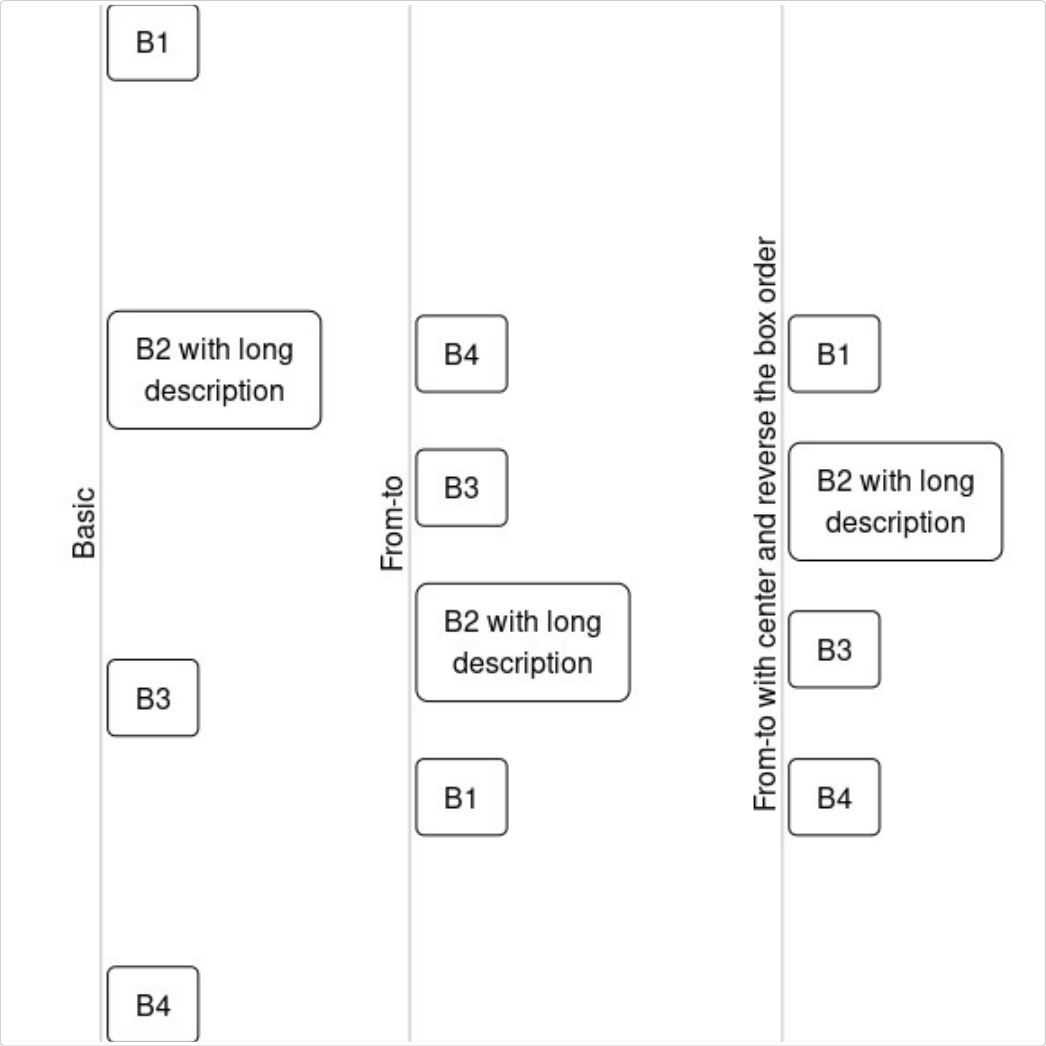
```
to
alignVertical(reference = from,
              b1, b2, b3, b4,
              .position = "top") %>%
  spreadHorizontal(.from = from,
                   .to = to)

# Now we switch the order and set the type to center the distance between the boxes
bottom_from <- moveBox(from, x = coords(to)$right, y = 0, just = c(1, 0))
bottom_to <- moveBox(to, x = coords(from)$left, y = 0, just = c(0, 0))
bottom_from
bottom_to
alignVertical(reference = bottom_from,
              b1, b2, b3, b4,
              .position = "bottom") %>%
  spreadHorizontal(.from = bottom_from,
                   .to = bottom_to,
                   .type = "center")
```



Vertical spreading follows the same pattern:

```
b1 <- boxGrob("B1",
              y = .8,
              x = 0.1,
              bjust = c(0, 0))
b2 <- boxGrob("B2 with long\ndescription",
              y = .5,
              x = .5)
```

```
b3 <- boxGrob("B3",
              y = .2,
              x = .8)
b4 <- boxGrob("B4",
              y = .7,
              x = .8)


txtOut <- function(txt, refBx) {
  grid.text(txt,
            x = coords(refBx)$left - unit(2, "mm"),
            y = .5,
            just = c("center", "bottom"),
            rot = 90)
  grid.lines(x = coords(refBx)$left - unit(1, "mm"),
             gp = gpar(col = "grey"))
}

grid.newpage()
txtOut("Basic", b1)
alignHorizontal(reference = b1,
                b1, b2, b3, b4,
                .position = "left") %>%
  spreadVertical()

txtOut("From-to", b2)
alignHorizontal(reference = b2,
                b1, b2, b3, b4,
                .position = "left") %>%
  spreadVertical(.from = .2,
                 .to = .7)

txtOut("From-to with center and reverse the box order", b3)
alignHorizontal(reference = b3,
                b1, b2, b3, b4,
                .position = "left") %>%
  spreadVertical(.from = .7,
                 .to = .2,
                 .type = "center")
```



Math expressions in boxes

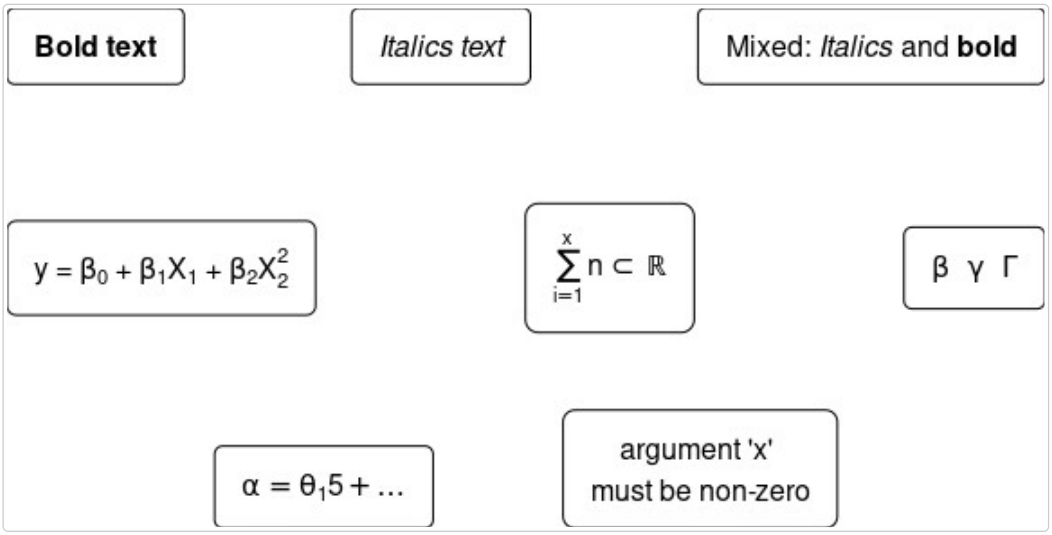
It is possible to use the R `expression` or the `bquote` functions to produce bold or italics text, or even formulas.

A few pointers on `expression`...

- expressions with multiple elements should be combined using `paste`. E.g. `expression(paste(beta, "1"))` would produce $\beta 1$
- the behavior of `paste` when used in expression is more like the normal behavior or `paste0` (i.e. no separating space)
- Greek letters can be entered outside of quotes by typing the name e.g. `expression(beta)` will become β and `expression(Gamma)` will become Γ (note the case, not all Greek letters are available in upper case)
- superscripts are done via `expression(x^2)` and subscripts via `expression(x[2])`

```
grid.newpage()
###############
# Expressions #
###############
# Font style
alignVertical(
  reference = 1,
  .position = "top",
  boxGrob(expression(bold("Bold text"))),
  boxGrob(expression(italic("Italics text"))),
  boxGrob(expression(paste("Mixed: ", italic("Italics"), " and ", bold("bold"))))) %>%
  spreadHorizontal

# Math
```

```
alignVertical(
  reference = .5,
  boxGrob(expression(paste("y = ", beta[0], " + ", beta[1], X[1], " + ", beta[2], X[2]^2))),
  boxGrob(expression(sum(n, i == 1, x) %subset% " \u211D")),
  boxGrob(expression(beta ~~ gamma ~~ Gamma))) %>%
  spreadHorizontal

##########
# Quotes #
##########
a = 5
alignVertical(
  reference = 0,
  .position = "bottom",
  bquote(alpha == theta[1] * .(a) + ldots) %>% boxGrob,
  paste("argument", sQuote("x"), "\nmust be non-zero") %>% boxGrob) %>%
  spreadHorizontal(.from = .2, .to = .8)
```



See the `plotmath` help file for more details.

Grid & some background info

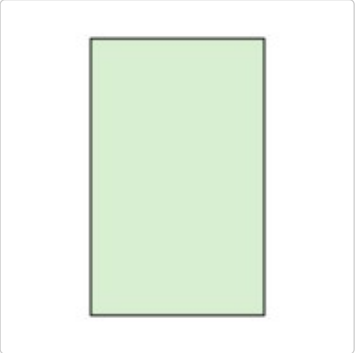
The `grid` package is what makes R graphics great. All the popular tools with awesome graphics use the `grid` as the back-end, e.g. `ggplot2` and `lattice`. When I started working on the `forestplot` package I first encountered the `grid` and it was instant love. In this vignette I'll show how you can use the flowchart-functions in this package together with `grid` in order to generate a flowchart.

Basics

The grid package splits the plot into views. You can define a `viewport` and it will work as an isolated part of the plot, ignorant of the world around it. You do this via `viewport()`, below I create a plot and add a rectangle to it:

```
# Load the grid library
# part of standard R libraries so no need installing
library(grid)

# Create a new graph
grid.newpage()

pushViewport(viewport(width = .5, height = .8))
```

```
grid.rect(gp = gpar(fill = "#D8F0D1"))

popViewport()
```



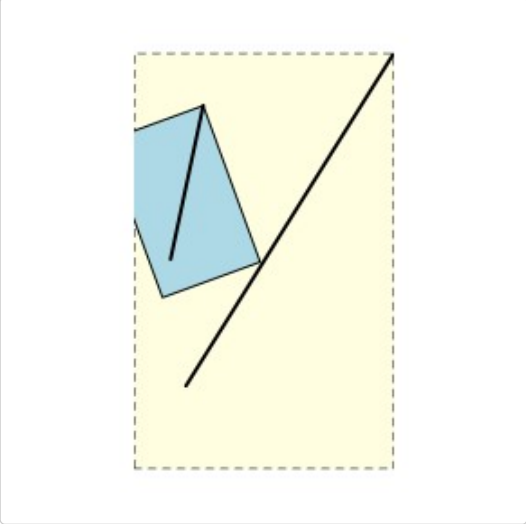
Important to note is that the grid allows you to define precise units or relative units.

Relative units

- `npc` - ranges from 0-1 where 1 is 100% of the `viewport` width.
- `snpc` - similar to `npc` but is the same length in height/width.
- `lines` - the height of a line. The go-to method if you want to know the height of a few lines of text. It's relative to the `viewport`'s `fontsize` and `lineheight`.
- `char` - the `lines` without the `lineheight` part.

Below we draw a line with relative units in two nested viewports. Note that the to lines are generated from the exact same `grob` object but appear different depending on the `viewport` they are in:

```
grid.newpage()
pushViewport(viewport(width = .5, height = .8, clip = "on"))
grid.rect(gp = gpar(lty = 2, fill = "lightyellow"))
lg <- linesGrob(x = unit(c(.2, 1), "npc"),
                y = unit(c(.2, 1), "npc"),
                gp = gpar(lwd = 2))
grid.draw(lg)
pushViewport(viewport(x = 0, y = .6, just = "left", width = .4, height = .4, angle = 20))
grid.rect(gp = gpar(fill = "lightblue")) # A translucent box to indicate the new viewport
grid.draw(lg)
popViewport()
```

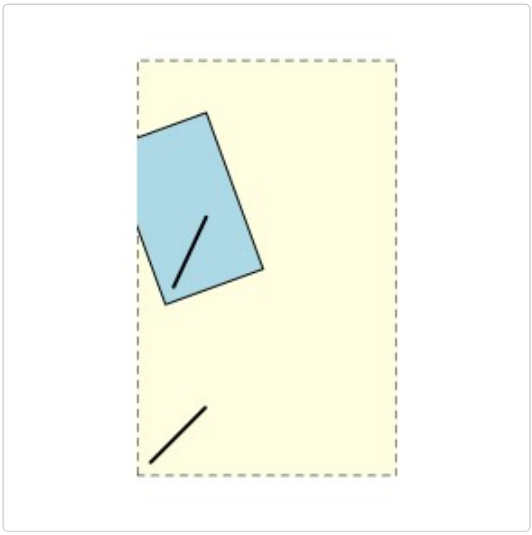


Absolute units

- `mm` - probably my go-to unit when I want something absolute.
- `inch` - if you prefer inches I guess this is the go-to choice.

Below we draw a line with absolute units in two nested `viewports`. Note that the lines have the exact same length:

```
grid.newpage()
pushViewport(viewport(width = .5, height = .8, clip = "on"))
grid.rect(gp = gpar(lty = 2, fill = "lightyellow"))
lg <- linesGrob(x = unit(c(2, 10), "mm"),
                y = unit(c(2, 10), "mm"),
                gp = gpar(lwd = 2))
grid.draw(lg)
pushViewport(viewport(x = 0, y = .6, just = "left", width = .4, height = .4, angle = 20))
grid.rect(gp = gpar(fill = "lightblue")) # A translucent box to indicate the new viewport
grid.draw(lg)
popViewport()
```



Tips for debugging

If you find that your elements don't look as expected make sure that your not changing `viewport`/device. While most coordinates are relative some of them need to be fixed and therefore changing the `viewport` may impact where elements are rendered.