5. Advanced Plots

Grouped bar charts, dumbbell plots, data labels, and building a custom theme step by step

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```r
for (pkg in c("tidyverse", "gapminder", "showtext", "ggtext")) {
  if (!require(pkg, character.only = TRUE)) install.packages(pkg)
}

showtext::showtext_opts(dpi = 300)
```

In the previous chapters we learned the individual building blocks of ggplot2: axes, colors, themes, and export. Now it is time to combine them into complete, publication-ready graphics. To do this, we switch from the small `PlantGrowth` dataset to the {gapminder} dataset - a much richer dataset tracking life expectancy, population, and GDP per capita for 142 countries from 1952 to 2007.

Along the way, we will encounter several practical challenges that arise when building real-world plots: how to control the order of categories, how to add data labels that align correctly with grouped bars, and how to build a custom theme function step by step - inspired by the clean design of Nature graphics.

Data preparation

We start by filtering the gapminder data to compare two time points - 1952 and 2007 - for seven selected countries that span a range of development patterns. The `year` column needs to be converted to a factor because ggplot2 treats numeric values as continuous by default, and we want distinct groups rather than a continuous scale.

```r
dat <- gapminder::gapminder %>%
  filter(year == 1952 | year == 2007) %>%
  filter(country %in% c(
    "Canada", "Germany", "Japan",
    "Netherlands", "Nigeria", "Vietnam", "Zimbabwe"
  )) %>%
  mutate(year = as.factor(year)) %>%
  droplevels()

dat
```

```
# A tibble: 14 × 6
   country     continent year  lifeExp       pop gdpPercap
   <fct>       <fct>     <fct>   <dbl>     <int>     <dbl>
 1 Canada      Americas  1952     68.8  14785584    11367.
 2 Canada      Americas  2007     80.7  33390141    36319.
 3 Germany     Europe    1952     67.5  69145952     7144.
 4 Germany     Europe    2007     79.4  82400996    32170.
 5 Japan       Asia      1952     63.0  86459025     3217.
 6 Japan       Asia      2007     82.6 127467972    31656.
 7 Netherlands Europe    1952     72.1  10381988     8942.
 8 Netherlands Europe    2007     79.8  16570613    36798.
 9 Nigeria     Africa    1952     36.3  33119096     1077.
10 Nigeria     Africa    2007     46.9 135031164     2014.
11 Vietnam     Asia      1952     40.4  26246839      605.
```

```
12 Vietnam     Asia       2007      74.2  85262356      2442.
13 Zimbabwe    Africa     1952      48.5   3080907       407.
14 Zimbabwe    Africa     2007      43.5  12311143       470.
```

Factor level reordering

By default, ggplot2 sorts factor levels alphabetically and applies this order from bottom to top on the y-axis (and left to right on the x-axis). For our plot this would mean Canada at the bottom and Zimbabwe at the top - a purely arbitrary order that makes it harder for the reader to spot patterns. It makes much more sense to sort countries by a meaningful variable, such as their 2007 life expectancy.

The {forcats} package (loaded with tidyverse) provides convenient functions for reordering factor levels. Here we use `fct_relevel()` with a pre-sorted vector of country names:

```
sorted_countries <- dat %>%
  filter(year == "2007") %>%
  arrange(lifeExp) %>%
  pull(country) %>%
  as.character()

dat <- dat %>%
  mutate(country = fct_relevel(country, sorted_countries))
```

Alternative approaches to reordering

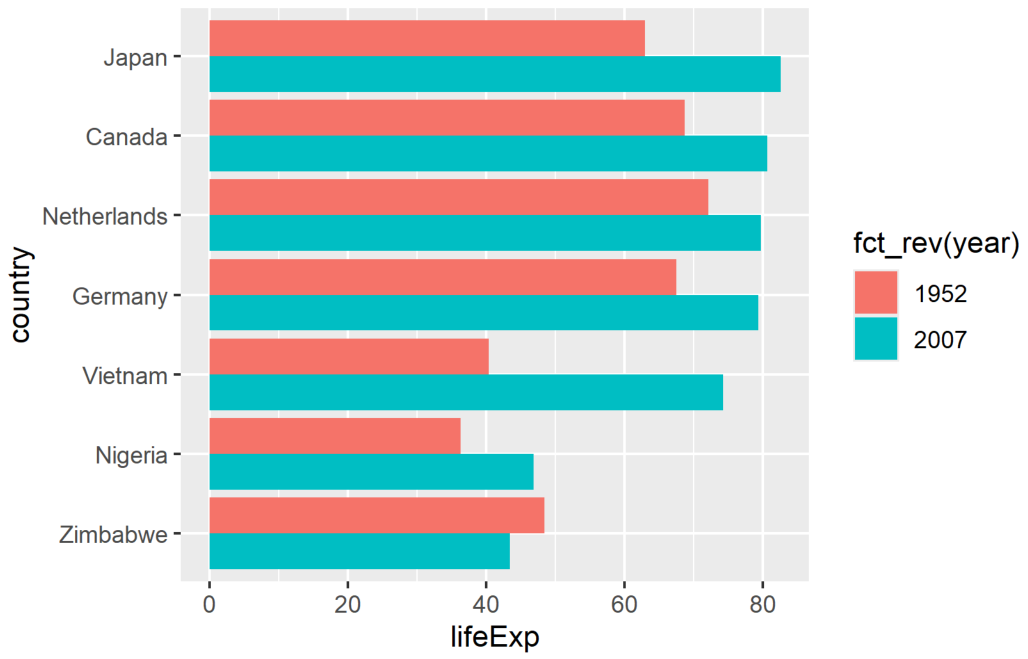
Instead of creating a sorted vector and using `fct_relevel()`, there are other options:

- **`fct_rev()` directly in `aes()`**: `aes(y = fct_rev(country))` reverses the current order without changing the data. This is quick but only reverses - it does not sort by a variable.
- **`limits` in the scale**: `scale_y_discrete(limits = c("Zimbabwe", "Nigeria", ...))` manually specifies the order. This works but is fragile - if a country name changes or a level is missing, the plot silently drops it.
- **`fct_reorder()`**: `mutate(country = fct_reorder(country, lifeExp))` sorts by another variable. This is the most concise approach for simple cases but requires care when the sorting variable exists for multiple years.

Grouped bar chart

A classic way to visualize paired comparisons is a grouped bar chart. `geom_col()` creates bars from the data, and `position_dodge()` places bars for different groups side by side rather than stacking them:

```
ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_discrete(limits = c("1952", "2007"))
```



There are two details worth noting here. First, `fct_rev(year)` reverses the year factor so that 2007 bars appear above 1952 bars within each country group - matching the intuitive "newer on top" expectation. Second, `limits = c("1952", "2007")` in the scale ensures the legend shows 1952 before 2007 (chronological order), regardless of how the factor levels are internally ordered.

Alternative for legend order: guides()

Instead of using `limits` in the scale, one can also reverse the legend order with `guides(fill = guide_legend(reverse = TRUE))`. This is sometimes more convenient when the scale already has other settings configured.

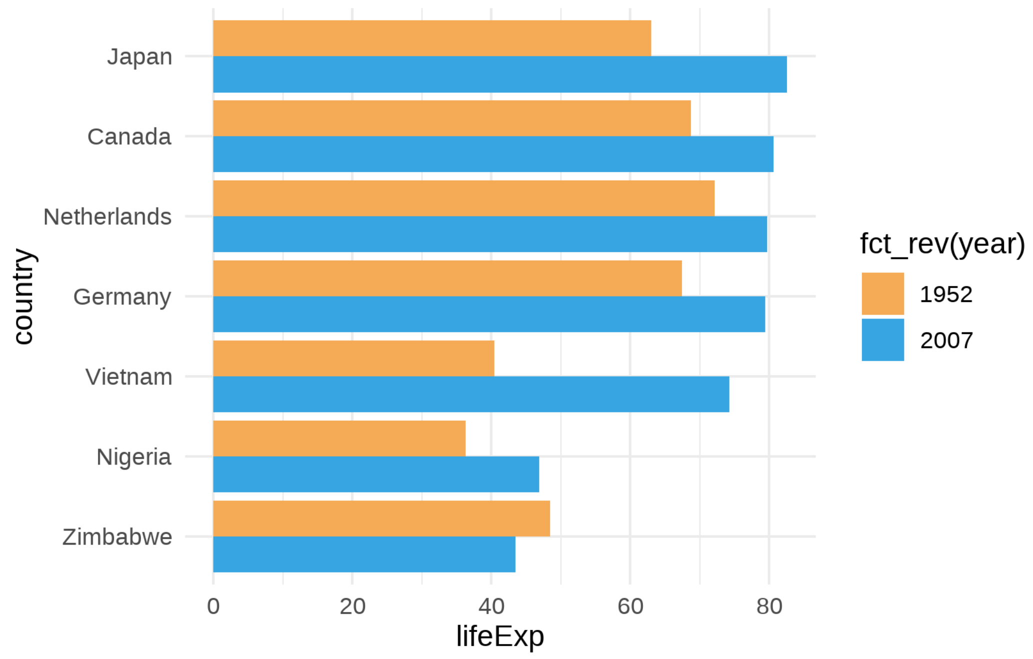
Building a custom theme step by step

Instead of applying a ready-made theme, we will build one from scratch - inspired by the clean, minimalist style of Nature graphics. This step-by-step approach makes it easy to understand what each theme element does, and the result is a reusable `theme_nature()` function.

Starting point

We begin with `theme_minimal()` and a custom color palette for the two years:

```r
sysfonts::font_add_google("Kanit", "kanit")
showtext::showtext_auto()

year_colors <- c("1952" = "#F7AA59", "2007" = "#37A9E1")

ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_manual(limits = names(year_colors), values = year_colors) +
  theme_minimal()
```

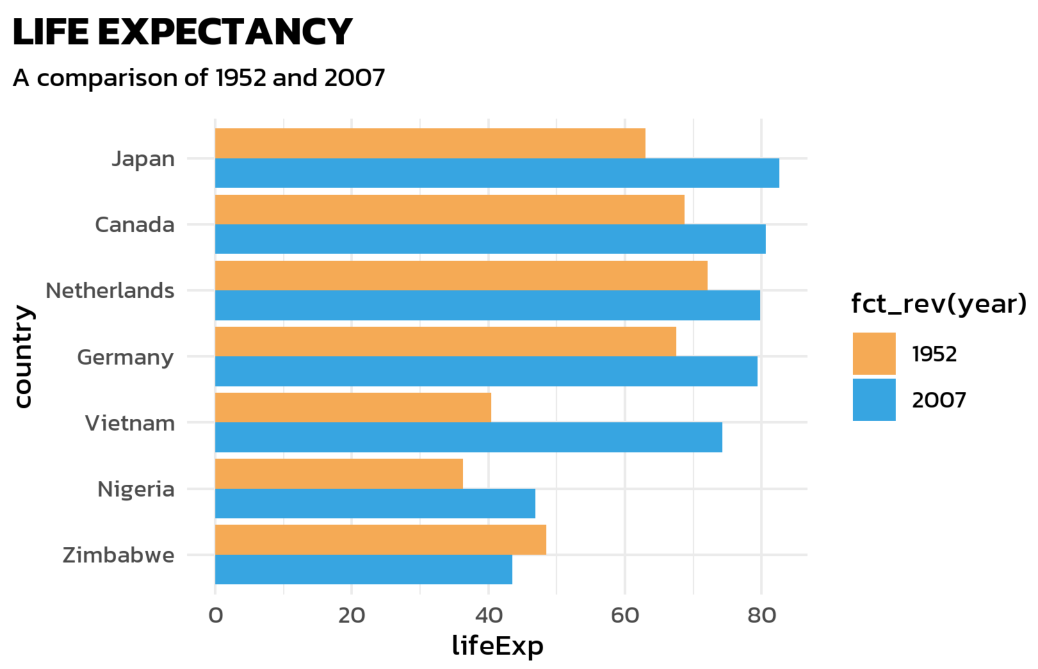


This already looks cleaner than the default theme, but the font is still generic, the title is missing, and several elements need refinement.

Font, title, and subtitle

Next, we apply the Kanit font, add a bold title, and use `element_textbox_simple()` from {ggtext} for a subtitle that supports HTML formatting - this will be useful later for color-coded text:

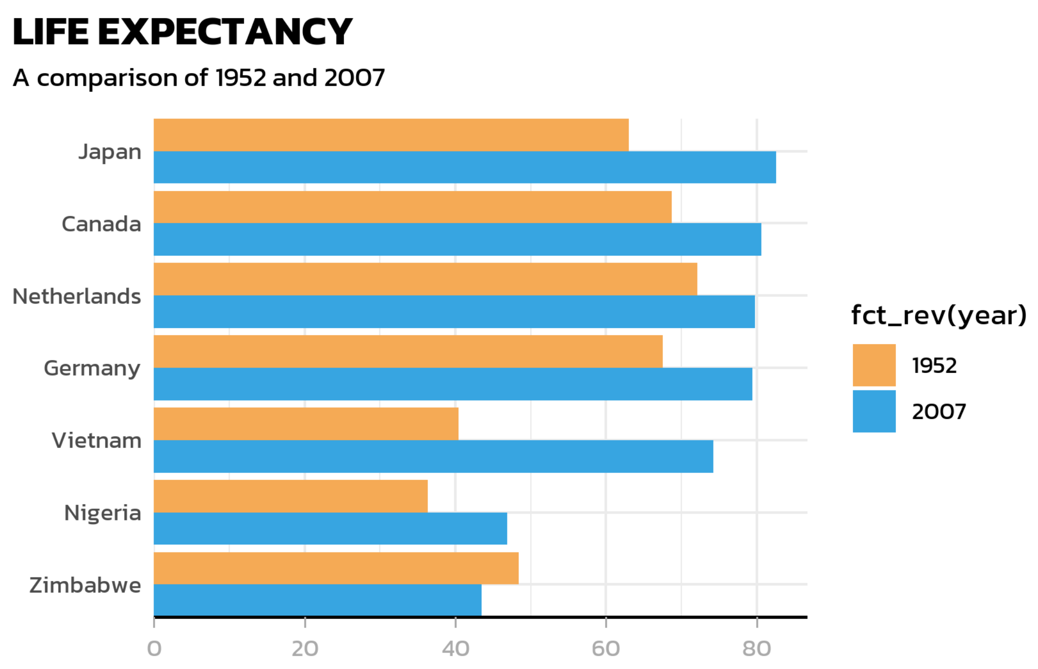
```r
ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_manual(limits = names(year_colors), values = year_colors) +
  labs(title = "LIFE EXPECTANCY", subtitle = "A comparison of 1952 and 2007") +
  theme_minimal() +
  theme(
    text = element_text(family = "kanit"),
    plot.title.position = "plot",
    plot.title = element_text(size = 15, face = "bold"),
    plot.subtitle = ggtext::element_textbox_simple(
      size = 10, margin = margin(0, 0, 10, 0)
    )
  )
```



Axis customization

The y-axis line is unnecessary for a horizontal bar chart (the bars themselves define the categories). The x-axis gets a clean black line with subtle grey tick marks:

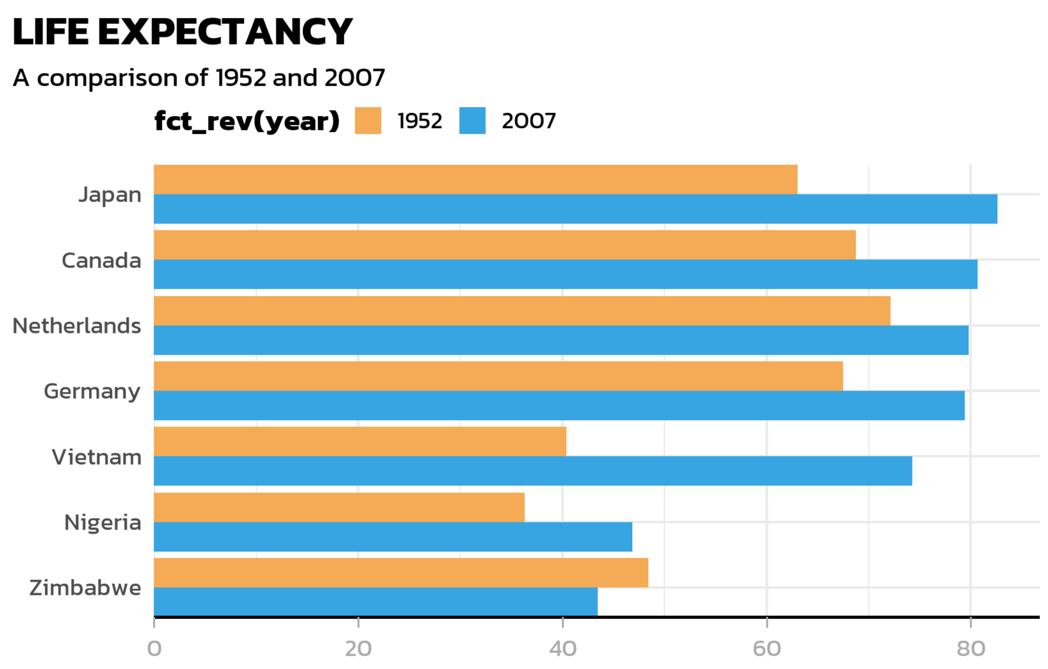
```r
ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_manual(limits = names(year_colors), values = year_colors) +
  scale_y_discrete(name = NULL, expand = c(0, 0)) +
  scale_x_continuous(name = NULL, expand = expansion(mult = c(0, 0.05))) +
  labs(title = "LIFE EXPECTANCY", subtitle = "A comparison of 1952 and 2007") +
  theme_minimal() +
  theme(
    text = element_text(family = "kanit"),
    plot.title.position = "plot",
    plot.title = element_text(size = 15, face = "bold"),
    plot.subtitle = ggtext::element_textbox_simple(
      size = 10, margin = margin(0, 0, 10, 0)
    ),
    axis.line.y = element_blank(),
    axis.text.x = element_text(color = "#AAAAAA"),
    axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
    axis.ticks.length.x = unit(4, "pt"),
    axis.line.x = element_line(color = "black", linewidth = 0.6)
  )
```



Legend positioning

The legend moves to the top-left corner. A subtle but important detail: `legend.margin` with a negative top margin pulls the legend closer to the subtitle, reducing wasted white space:

```r
ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_manual(limits = names(year_colors), values = year_colors) +
  scale_y_discrete(name = NULL, expand = c(0, 0)) +
  scale_x_continuous(name = NULL, expand = expansion(mult = c(0, 0.05))) +
  labs(title = "LIFE EXPECTANCY", subtitle = "A comparison of 1952 and 2007") +
  theme_minimal() +
  theme(
    text = element_text(family = "kanit"),
    plot.title.position = "plot",
    plot.title = element_text(size = 15, face = "bold"),
    plot.subtitle = ggtext::element_textbox_simple(
      size = 10, margin = margin(0, 0, 10, 0)
    ),
    axis.line.y = element_blank(),
    axis.text.x = element_text(color = "#AAAAAA"),
    axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
    axis.ticks.length.x = unit(4, "pt"),
    axis.line.x = element_line(color = "black", linewidth = 0.6),
    legend.position = "top",
    legend.box.just = "left",
    legend.justification = "left",
    legend.title = element_text(face = "bold"),
    legend.key.size = unit(0.4, "cm"),
    legend.margin = margin(-5, 0, 0, 0)
  )
```



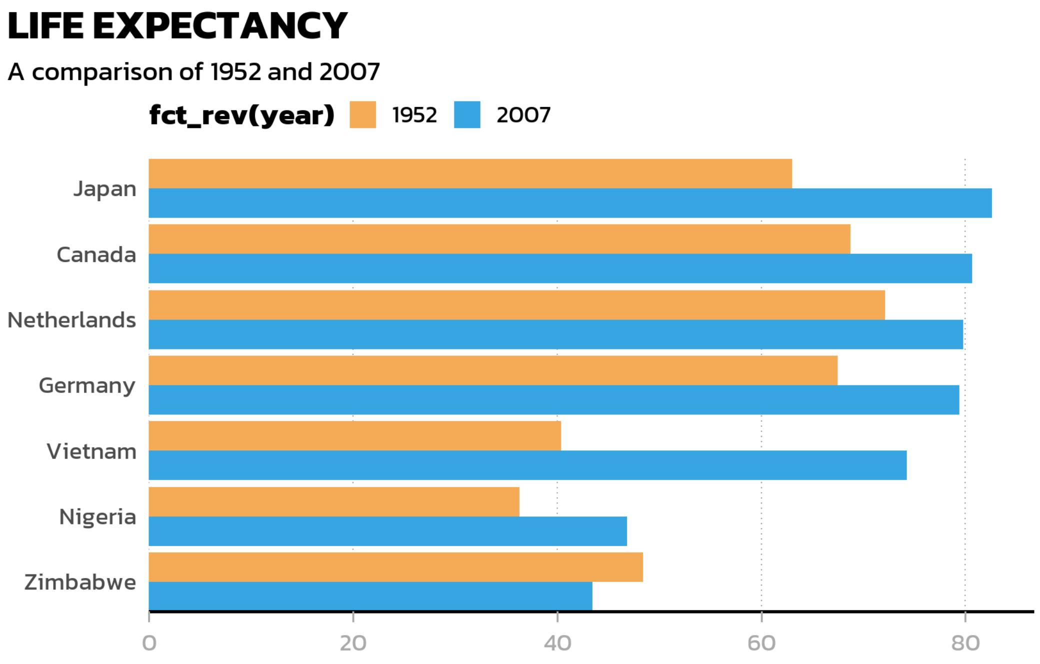
i The negative margin trick

`legend.margin = margin(-5, 0, 0, 0)` uses a negative top margin to pull the legend upward, closer to the subtitle. This is a common trick to tighten the layout when the legend sits at the top. The value needs to be tuned by eye - too large a negative margin and the legend overlaps the subtitle.

Grid lines

Finally, we remove the minor grid and horizontal major gridlines (they add clutter to a bar chart), keeping only vertical dotted gridlines as subtle reference marks:

```r
ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  scale_fill_manual(limits = names(year_colors), values = year_colors) +
  scale_y_discrete(name = NULL, expand = c(0, 0)) +
  scale_x_continuous(name = NULL, expand = expansion(mult = c(0, 0.05))) +
  labs(title = "LIFE EXPECTANCY", subtitle = "A comparison of 1952 and 2007") +
  theme_minimal() +
  theme(
    text = element_text(family = "kanit"),
    plot.title.position = "plot",
    plot.title = element_text(size = 15, face = "bold"),
    plot.subtitle = ggtext::element_textbox_simple(
      size = 10, margin = margin(0, 0, 10, 0)
    ),
    axis.line.y = element_blank(),
    axis.text.x = element_text(color = "#AAAAAA"),
    axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
    axis.ticks.length.x = unit(4, "pt"),
    axis.line.x = element_line(color = "black", linewidth = 0.6),
    legend.position = "top",
    legend.box.just = "left",
    legend.justification = "left",
    legend.title = element_text(face = "bold"),
    legend.key.size = unit(0.4, "cm"),
    legend.margin = margin(-5, 0, 0, 0),
    panel.grid.minor = element_blank(),
    panel.grid.major.y = element_blank(),
    panel.grid.major.x = element_line(
      linetype = "dotted", color = "#AAAAAA", linewidth = 0.3
    )
  )
```



Wrapping it in a function

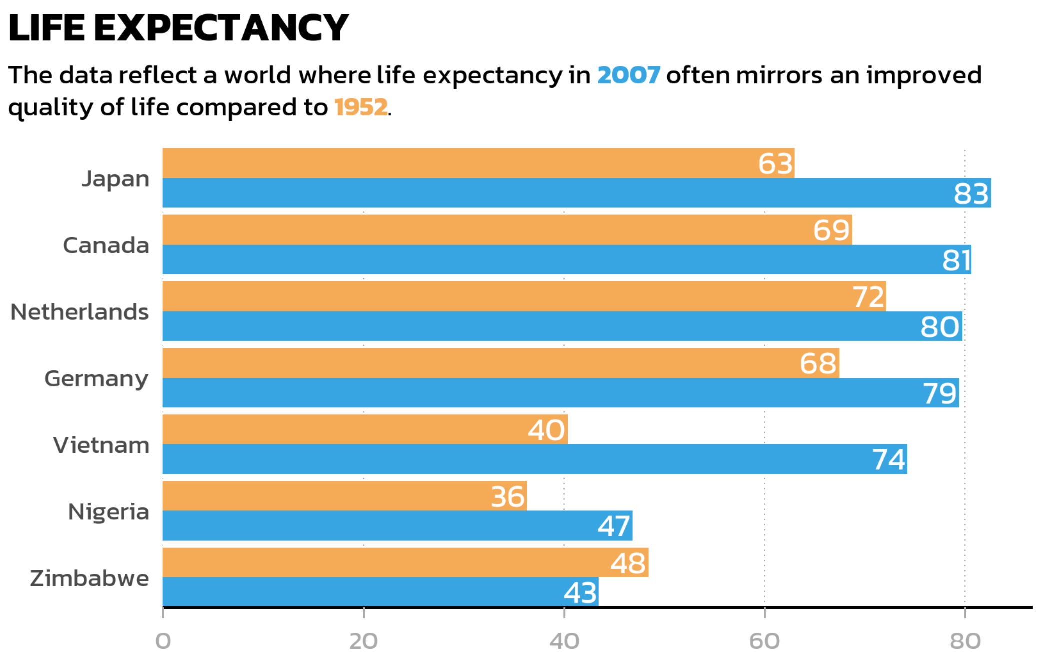
Now that we are happy with every element, we wrap the entire `theme()` call into a reusable function. This way, applying the theme to any plot is a single line of code:

```
theme_nature <- function(base_size = 12) {
  theme_minimal(base_size = base_size) +
    theme(
      text = element_text(family = "kanit"),
      plot.title.position = "plot",
      plot.title = element_text(size = 15, face = "bold"),
      plot.subtitle = ggtext::element_textbox_simple(
        size = 10, margin = margin(0, 0, 10, 0)
      ),
      axis.line.y = element_blank(),
      axis.text.x = element_text(color = "#AAAAAA"),
      axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
      axis.ticks.length.x = unit(4, "pt"),
      axis.line.x = element_line(color = "black", linewidth = 0.6),
      legend.position = "top",
      legend.box.just = "left",
      legend.justification = "left",
      legend.title = element_text(face = "bold"),
      legend.key.size = unit(0.4, "cm"),
      legend.margin = margin(-5, 0, 0, 0),
      panel.grid.minor = element_blank(),
      panel.grid.major.y = element_blank(),
      panel.grid.major.x = element_line(
        linetype = "dotted", color = "#AAAAAA", linewidth = 0.3
      )
    )
}
```

Styled bar chart with data labels

Now we combine everything: the grouped bar chart, the custom theme, data labels inside the bars, and an HTML-formatted subtitle where the color coding is explained directly in the text - replacing the need for a separate legend:

```r
long_subtitle <- "The data reflect a world where life expectancy in <b
style='color:#37A9E1;'>2007</b> often mirrors an improved quality of life compared
to <b style='color:#F7AA59;'>1952</b>."

p <- ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
  geom_col(position = position_dodge()) +
  geom_text(
    mapping = aes(label = round(lifeExp), group = fct_rev(year)),
    position = position_dodge(width = 0.9),
    hjust = 1.1,
    color = "white",
    family = "kanit"
  ) +
  scale_y_discrete(name = NULL, expand = c(0, 0)) +
  scale_x_continuous(
    name = NULL,
    expand = expansion(mult = c(0, 0.05))
  ) +
  scale_fill_manual(
    guide = "none",
    name = "Year",
    limits = names(year_colors),
    values = year_colors
  ) +
  labs(
    title = "LIFE EXPECTANCY",
    subtitle = long_subtitle
  ) +
  theme_nature()

p
```



Several details in this code deserve explanation:

- **`group = fct_rev(year)` in `geom_text()`**: Without an explicit `group` aesthetic, `geom_text()` does not know which bar each label belongs to and cannot dodge the labels correctly. The `group` must match the fill aesthetic (including the `fct_rev()`) so that labels and bars are dodged in exactly the same way.
- **`position_dodge(width = 0.9)`**: The default dodge width for `geom_col()` is 0.9. When adding labels or other layers on top of dodged bars, one must specify this width explicitly - otherwise the labels dodge at a different width than the bars, causing misalignment.
- **`family = "kanit"` in `geom_text()`**: Unlike most theme elements, text inside geoms is *not* affected by the `theme()` settings. If the plot uses a custom font, it must be specified explicitly in every `geom_text()` or `geom_label()` call.
- **`guide = "none"`**: This removes the legend since the color-coded subtitle already explains the meaning of each color - a cleaner design that reduces visual clutter.

! Geoms do not inherit font family from the theme

This is a common source of confusion: `theme(text = element_text(family = "kanit"))` sets the font for *theme elements* (titles, axis labels, legend text), but **not** for text drawn by geoms like `geom_text()` or `geom_label()`. These geoms use the default font unless `family` is set explicitly. Forgetting this leads to plots where the title uses one font but the data labels use another.

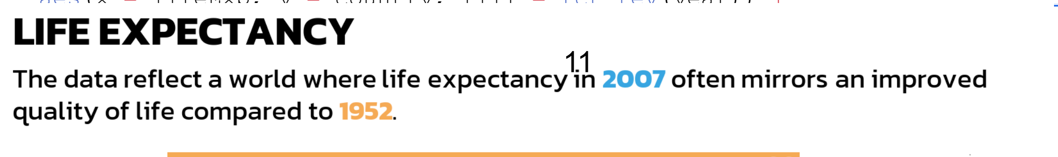
Legend alternative: color-coded subtitle

Instead of a traditional legend, the styled subtitle uses HTML `<b style='color:...'>` tags to color the year labels directly in the text. This only works when the subtitle uses `element_textbox_simple()` from ggtext (which our `theme_nature()` does). The advantage is a cleaner design - the reader sees the color coding in context rather than having to match legend entries to plot elements.

i Checkpoint: Grouped bar chart

This standalone code block reproduces the styled bar chart from scratch:

```r
library(tidyverse)
library(gapminder)
library(showtext)
library(ggtext)

showtext_opts(dpi = 300)
font_add_google("Kanit", "kanit")
showtext_auto()

dat <- gapminder %>%
  filter(year %in% c(1952, 2007)) %>%
  filter(country %in% c(
    "Canada", "Germany", "Japan",
    "Netherlands", "Nigeria", "Vietnam", "Zimbabwe"
  )) %>%
  mutate(year = as.factor(year)) %>%
  droplevels()

sorted_countries <- dat %>%
  filter(year == "2007") %>%
  arrange(lifeExp) %>%
  pull(country) %>%
  as.character()

dat <- dat %>%
  mutate(country = fct_relevel(country, sorted_countries))

year_colors <- c("1952" = "#F7AA59", "2007" = "#37A9E1")

theme_nature <- function(base_size = 12) {
  theme_minimal(base_size = base_size) +
    theme(
      text = element_text(family = "kanit"),
      plot.title.position = "plot",
      plot.title = element_text(size = 15, face = "bold"),
      plot.subtitle = element_textbox_simple(
        size = 10, margin = margin(0, 0, 10, 0)
      ),
      axis.line.y = element_blank(),
      axis.text.x = element_text(color = "#AAAAAA"),
      axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
      axis.ticks.length.x = unit(4, "pt"),
      axis.line.x = element_line(color = "black", linewidth = 0.6),
      legend.position = "top",
      legend.box.just = "left",
      legend.justification = "left",
      legend.title = element_text(face = "bold"),
      legend.key.size = unit(0.4, "cm"),
      legend.margin = margin(-5, 0, 0, 0),
      panel.grid.minor = element_blank(),
      panel.grid.major.y = element_blank(),
      panel.grid.major.x = element_line(
        linetype = "dotted", color = "#AAAAAA", linewidth = 0.3
      )
    )
}

long_subtitle <- "The data reflect a world where life expectancy in <b
style='color:#37A9E1;'>2007</b> often mirrors an improved quality of life
compared to <b style='color:#F7AA59;'>1952</b>."

ggplot(data = dat) +
  aes(x = lifeExp, y = country, fill = fct_rev(year)) +
```



Dumbbell plot

A grouped bar chart works well for comparing absolute values, but when the focus is on the *change* between two time points, a dumbbell plot often tells the story more clearly. It connects two data points with a line segment, making the direction and magnitude of change immediately visible - especially when some countries improved dramatically while others barely changed.

We first need a wide-format version of the data, with one column per year, so that `geom_segment()` can draw lines from the 1952 value to the 2007 value:

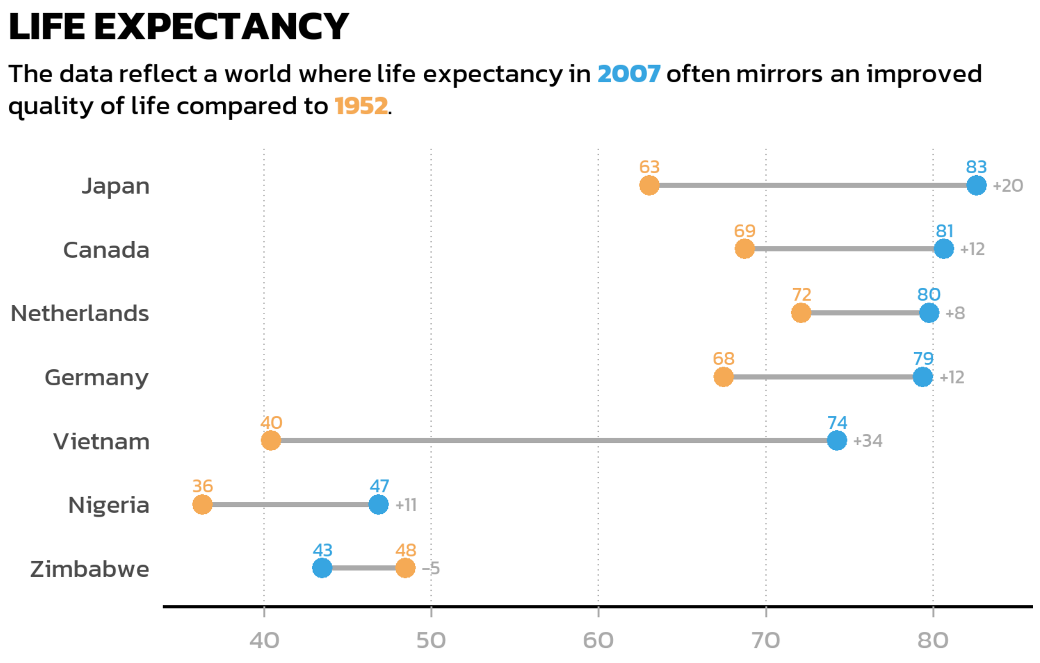
```r
dat_wide <- dat %>%
  select(country, year, lifeExp) %>%
  pivot_wider(
    names_from = year,
    values_from = lifeExp,
    names_prefix = "year_"
  ) %>%
  mutate(
    max_x = pmax(year_2007, year_1952),
    diff = year_2007 - year_1952,
    diff_lab = sprintf("%+d", round(diff))
  )

dat_wide
```

```
# A tibble: 7 × 6
  country     year_1952 year_2007 max_x  diff diff_lab
  <fct>           <dbl>     <dbl> <dbl> <dbl> <chr>
1 Canada           68.8      80.7  80.7 11.9  +12
2 Germany          67.5      79.4  79.4 11.9  +12
3 Japan            63.0      82.6  82.6 19.6  +20
4 Netherlands      72.1      79.8  79.8  7.63 +8
5 Nigeria          36.3      46.9  46.9 10.5  +11
6 Vietnam          40.4      74.2  74.2 33.8  +34
7 Zimbabwe         48.5      43.5  48.5 -4.96 -5
```

The `pmax()` function finds the larger of the two years for each country - we need this later to position the difference labels to the right of each dumbbell. The `sprintf("%+d", ...)` formatting ensures that positive changes display a `+` sign (like “+38”) for immediate visual clarity.

The dumbbell plot uses three layers: `geom_segment()` for the connecting lines, `geom_point()` for the colored endpoints, and two `geom_text()` layers for the value labels and difference labels:

```r
p2 <- ggplot(data = dat) +
  aes(x = lifeExp, y = country, color = fct_rev(year)) +
  geom_segment(
    data = dat_wide,
    aes(x = year_1952, xend = year_2007, y = country, yend = country),
    color = "#AAAAAA",
    linewidth = 1
  ) +
  geom_point(size = 3) +
  geom_text(
    mapping = aes(label = round(lifeExp)),
    size = 2.5,
    vjust = -1,
    family = "kanit"
  ) +
  geom_text(
    data = dat_wide,
    mapping = aes(x = max_x, label = diff_lab),
    size = 2.5,
    hjust = 0,
    position = position_nudge(x = 1),
    color = "#AAAAAA",
    family = "kanit"
  ) +
  scale_color_manual(
    name = "Year",
    limits = c("1952", "2007"),
    values = year_colors,
    guide = "none"
  ) +
  scale_y_discrete(name = NULL) +
  scale_x_continuous(name = NULL) +
  labs(
    title = "LIFE EXPECTANCY",
    subtitle = long_subtitle
  ) +
  theme_nature()

p2
```



The first `geom_text()` adds the actual values above each colored point. The second `geom_text()` uses the wide-format data to place difference labels (like "+38" or "+3") to the right of each dumbbell - `position_nudge(x = 1)` shifts the label slightly so it does not overlap with the rightmost point.

Notice that the segment layer uses a separate `data` argument (`data = dat_wide`) while the point layer uses the original long-format `dat`. This is a common pattern in ggplot2: different layers can draw from different data sources, as long as the aesthetics match up.

Checkpoint: Dumbbell plot

This standalone code block reproduces the dumbbell plot from scratch:

```r
library(tidyverse)
library(gapminder)
library(showtext)
library(ggtext)

showtext_opts(dpi = 300)
font_add_google("Kanit", "kanit")
showtext_auto()

dat <- gapminder %>%
  filter(year %in% c(1952, 2007)) %>%
  filter(country %in% c(
    "Canada", "Germany", "Japan",
    "Netherlands", "Nigeria", "Vietnam", "Zimbabwe"
  )) %>%
  mutate(year = as.factor(year)) %>%
  droplevels()

sorted_countries <- dat %>%
  filter(year == "2007") %>%
  arrange(lifeExp) %>%
  pull(country) %>%
  as.character()

dat <- dat %>%
  mutate(country = fct_relevel(country, sorted_countries))

year_colors <- c("1952" = "#F7AA59", "2007" = "#37A9E1")

theme_nature <- function(base_size = 12) {
  theme_minimal(base_size = base_size) +
    theme(
      text = element_text(family = "kanit"),
      plot.title.position = "plot",
      plot.title = element_text(size = 15, face = "bold"),
      plot.subtitle = element_textbox_simple(
        size = 10, margin = margin(0, 0, 10, 0)
      ),
      axis.line.y = element_blank(),
      axis.text.x = element_text(color = "#AAAAAA"),
      axis.ticks.x = element_line(color = "#AAAAAA", linewidth = 0.4),
      axis.ticks.length.x = unit(4, "pt"),
      axis.line.x = element_line(color = "black", linewidth = 0.6),
      legend.position = "top",
      legend.box.just = "left",
      legend.justification = "left",
      legend.title = element_text(face = "bold"),
      legend.key.size = unit(0.4, "cm"),
      legend.margin = margin(-5, 0, 0, 0),
      panel.grid.minor = element_blank(),
      panel.grid.major.y = element_blank(),
      panel.grid.major.x = element_line(
        linetype = "dotted", color = "#AAAAAA", linewidth = 0.3
      )
    )
}

long_subtitle <- "The data reflect a world where life expectancy in <b
style='color:#37A9E1;'>2007</b> often mirrors an improved quality of life
compared to <b style='color:#F7AA59;'>1952</b>."

dat_wide <- dat %>%
  select(country, year, lifeExp) %>%
```

LIFE EXPECTANCY
The data reflect a world where life expectancy in 2007 often mirrors an improved quality of life compared to 1952.

Bibliography

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