

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Data Visualization (2)

Intermediate

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POLI3148 Data Science in PPA (The University of Hong Kong)

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Objectives

Data Visualization
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Master data visualization methods with `ggplot`.

- ▶ Housekeeping
 - ▶ `ggplot` syntax
 - ▶ Variable types
- ▶ How to visualize everything

Reading Materials on Data Visualization

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- ▶ [Kabacoff] Kabacoff, Rob. Data Visualization with R. 2020. E-book: rkabacoff.github.io/datavis
- ▶ [Healy] Healy, Kieran. Data visualization: a practical introduction. Princeton University Press, 2018. E-book: socviz.co

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Load Data

Housekeeping

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```
library(tidyverse)
theme_set(theme_bw()) # Set my default theme for the whole document

d <- readRDS("Lec_07/data/wealth_and_health.rds")
d |> print(n = 3)

## # A tibble: 23,593 x 9
##   country_text_id    year  region life_expectancy gdppc population democracy_binary
##   <chr>           <dbl>   <dbl>            <dbl>   <dbl>        <dbl>             <dbl>
## 1 MEX              1800     17            26.9   1.35       5100            NA
## 2 MEX              1801     17            26.9   1.34       5174.           NA
## 3 MEX              1802     17            26.9   1.32       5249.           NA
## # i 23,590 more rows
## # i 2 more variables: democracy_lexical <dbl>, democracy_polity5 <dbl>
```

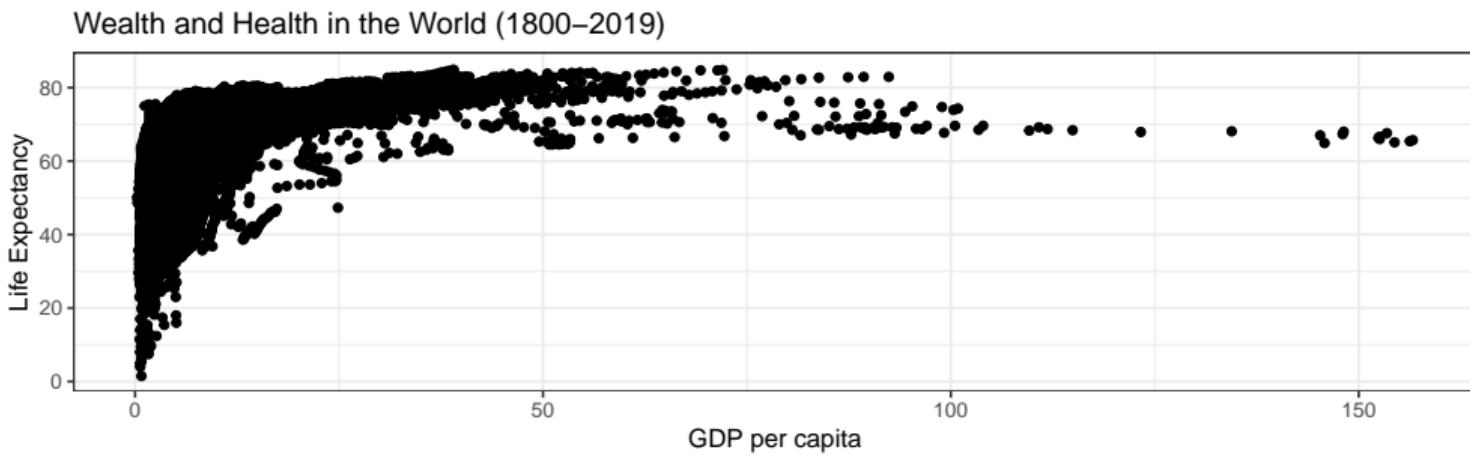
ggplot syntax

- ▶ Consider: “Painting” your data on a canvas, layer by layer
- ▶ Steps
 - ▶ Specify the data you want to visualize
 - ▶ Specify the type(s) of visualization tools
 - ▶ Label the figure (titles of the figure, axes, and legends)
- ▶ Command: Use + to connect layers (ATTENTION: not |>)

Note: **Always** properly label your figures!

ggplot syntax: example

```
d |> # Specify the data frame to plot
  ggplot(aes(x = gdppc, y = life_expectancy)) + # Specify the variables to plot
    geom_point() + # Choose the visualization tool: point
    labs(x = "GDP per capita", y = "Life Expectancy", # set up the axes' titles
         title = "Wealth and Health in the World (1800-2019)", # set up the figure's title
         caption = "By Haohan Chen. Data source: V-Dem v.13") # set up footnote
```



Variable Types

Visualization tools to use largely depends on variable types

- ▶ “Quantitative” (Continuous, Count)
 - ▶ GDP per capita
 - ▶ Life expectancy
 - ▶ Population
 - ▶ (Maybe) Polity V index
- ▶ Categorical
 - ▶ Binary: Binary “democracy” indicator
 - ▶ Nominal: Region
 - ▶ Ordinal: Lexical Index of Electoral Democracy

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Quant. X 1

Viaulize One Quantitative Variable

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- ▶ Summary Statistics

- ▶ Min, max, median, mean, standard deviation, variance,
- ▶ Quantiles, quintiles

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- ▶ Visualization

- ▶ Histogram
- ▶ Density Plot

- ▶ Advanced

- ▶ Skewed distribution
- ▶ Annotate cases

Summary Statistics

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```
summary(d$gdppc) # Quick summary

##      Min. 1st Qu. Median      Mean 3rd Qu.      Max.    NA's
##  0.286   1.599   2.774   7.194   7.606 156.628    4571

length(d$gdppc) # Number of observations
```

```
## [1] 23593

is.na(d$gdppc) |> sum() # Number of missing values
```

```
## [1] 4571
```

Summary Statistics (con'd)

```
mean(d$gdppc, na.rm = TRUE) # Mean  
  
## [1] 7.193588  
  
var(d$gdppc, na.rm = TRUE) # Variance  
  
## [1] 131.029  
  
sd(d$gdppc, na.rm = TRUE) # Standard deviation  
  
## [1] 11.44679  
  
quantile(d$gdppc, na.rm = TRUE) # Quantile  
  
##      0%      25%      50%      75%     100%  
## 0.28600 1.59900 2.77400 7.60575 156.62800  
  
quantile(d$gdppc, seq(0, 1, 0.1), na.rm = TRUE) # Quintile  
  
##      0%     10%    20%    30%    40%    50%    60%    70%  
## 0.2860 1.0451 1.4340 1.7760 2.1624 2.7740 4.0246 6.0687  
##     80%    90%   100%  
## 9.4364 18.7600 156.6280
```

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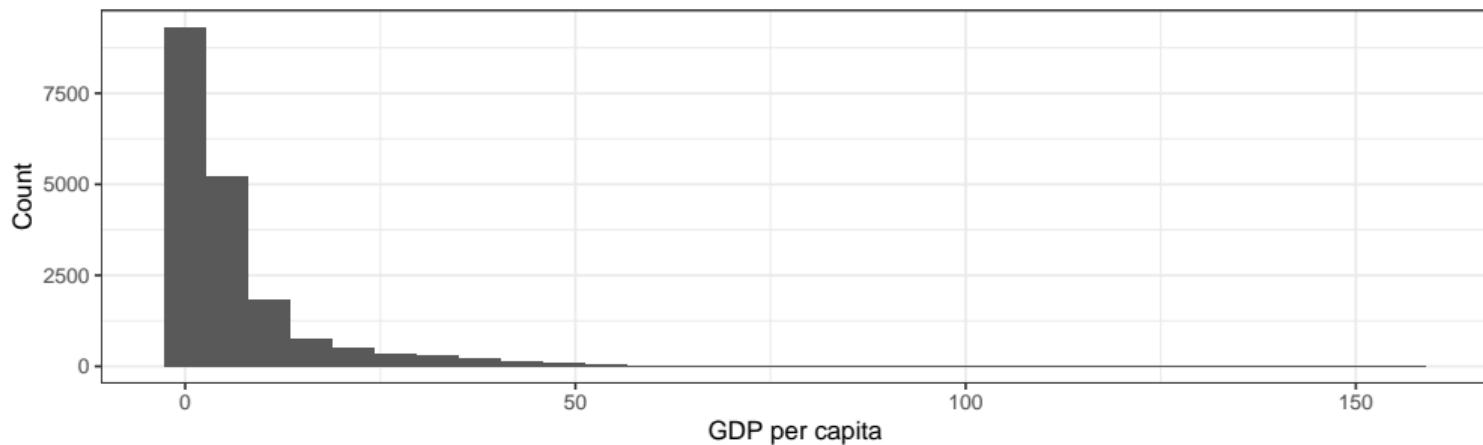
Histogram

```
d |>
  ggplot(aes(x = gdppc)) +
  geom_histogram() + # Draw a histogram
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

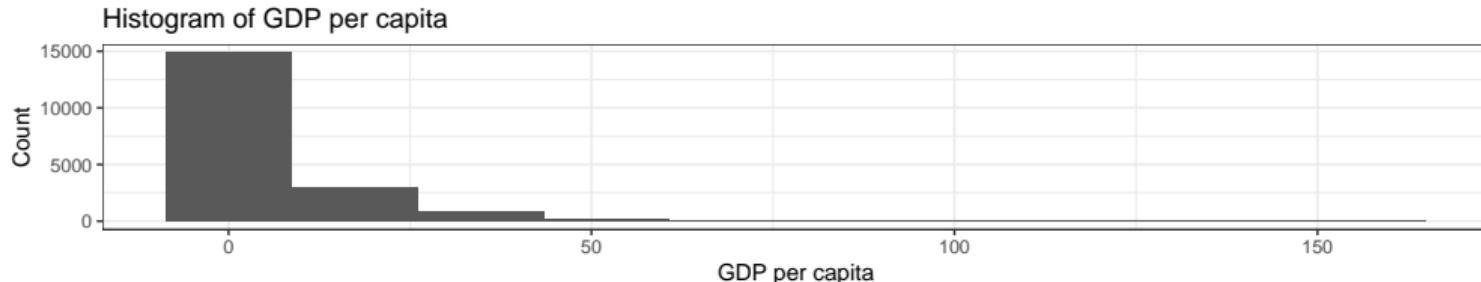
```
## Warning: Removed 4571 rows containing non-finite values (stat_bin).
```

Histogram of GDP per capita



Histogram (customized)

```
d |> ggplot(aes(x = gdppc)) + geom_histogram(bins = 10) +
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



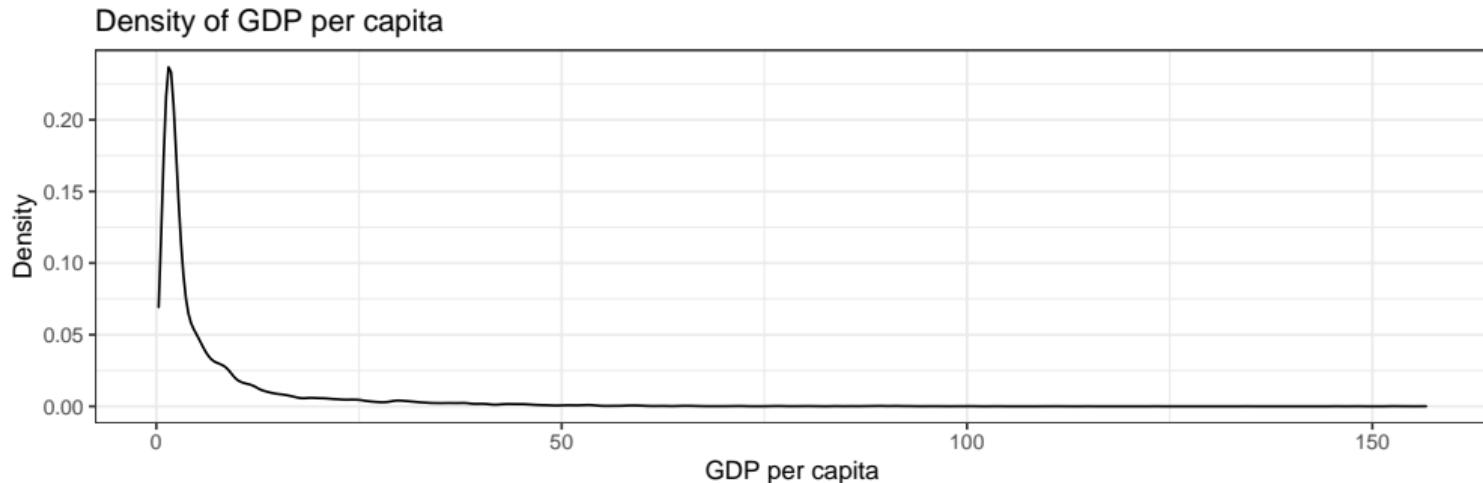
```
d |> ggplot(aes(x = gdppc)) + geom_histogram(bins = 50, fill = "blue", color = "red") +
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



Density

d |>

```
ggplot(aes(x = gdppc)) +  
  geom_density() # Draw a density plot  
  labs(x = "GDP per capita", y = "Density", title = "Density of GDP per capita")
```



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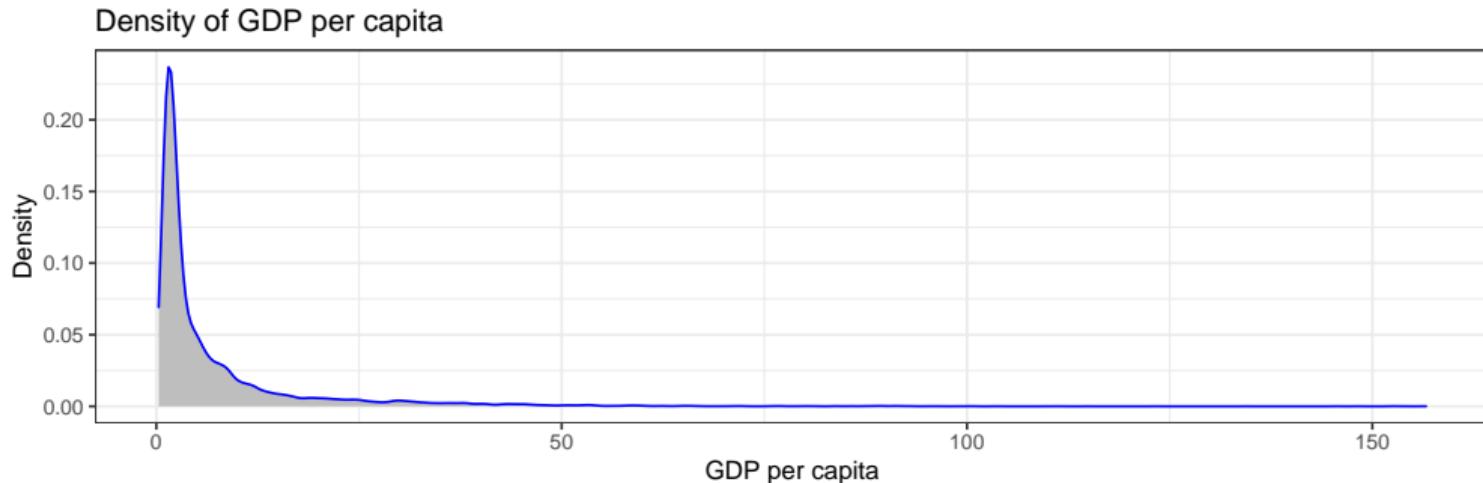
Quant. X 2

Quant. X 3

Quant. X 4+?

Density (customized)

```
d |>
ggplot(aes(x = gdppc)) +
  geom_density(fill = "gray", color = "blue") + # Draw a density plot
  labs(x = "GDP per capita", y = "Density", title = "Density of GDP per capita")
```



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Skewed Distribution

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Quant. X 4+?

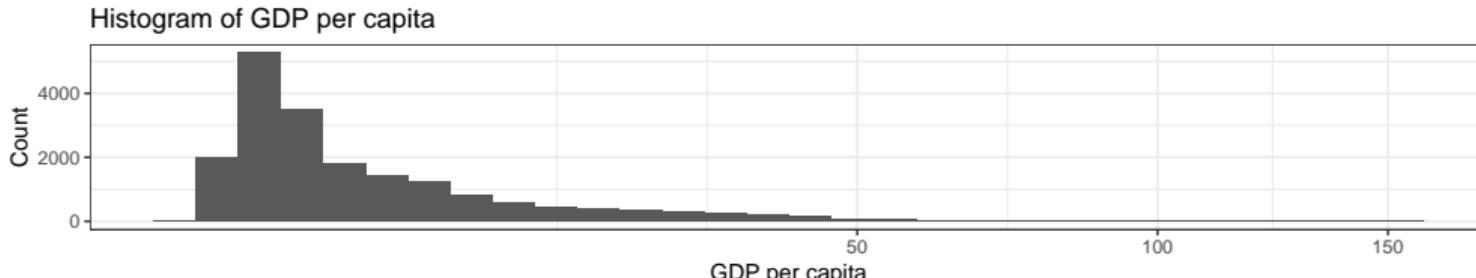
► **Challenge:** Quantitative data may have skewed distributions, which can make the visualization uninformative.

► **Solution:**

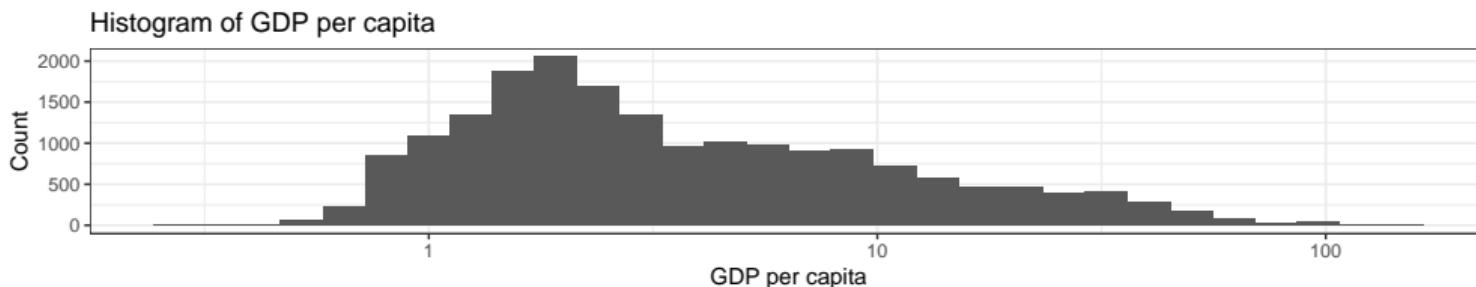
- Re-scale the axes
- Transform the variable(s)

Skewed Distribution: Re-scale Axes

```
d |> ggplot(aes(x = gdppc)) + geom_histogram() +  
  scale_x_sqrt() + # Scale the x axis to make distribution easy to read  
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



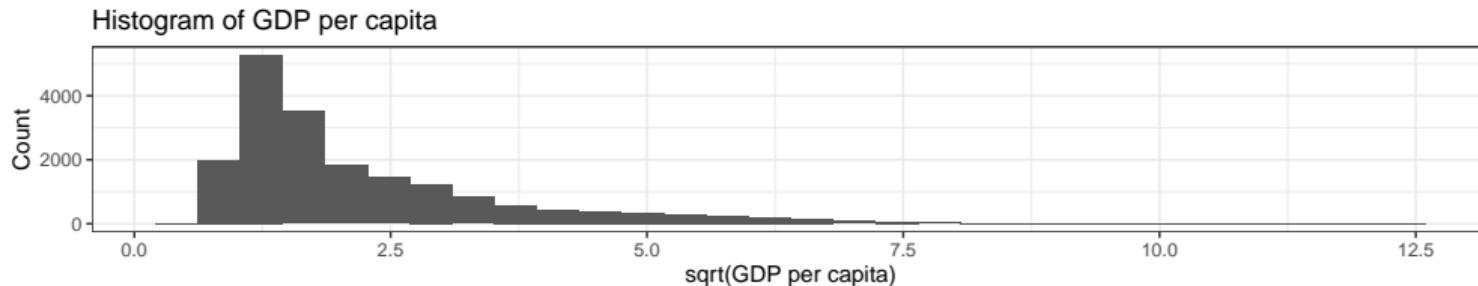
```
d |> ggplot(aes(x = gdppc)) + geom_histogram() +  
  scale_x_log10() + # Scale the x axis to make distribution easy to read  
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



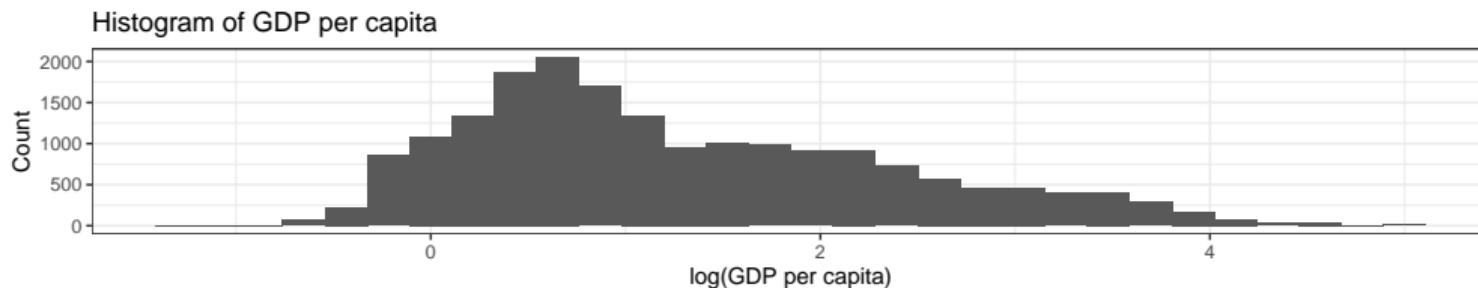
Skewed Distribution: Transform Variables

Alternatively you can first transform the variable before your visualization

```
d |> mutate(gdppc_sqrt = sqrt(gdppc)) |> # Transform the variable before visualization
  ggplot(aes(x = gdppc_sqrt)) + 
  labs(x = "sqrt(GDP per capita)", y = "Count", title = "Histogram of GDP per capita")
```



```
d |> mutate(gdppc_log = log(gdppc)) |> # Transform the variable before visualization
  ggplot(aes(x = gdppc_log)) + 
  labs(x = "log(GDP per capita)", y = "Count", title = "Histogram of GDP per capita")
```



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Skewed Distribution: Note

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Quant. X 4+?

```
summary(d$gdppc)
```

```
##      Min. 1st Qu. Median      Mean 3rd Qu.    Max.    NA's
## 0.286   1.599   2.774   7.194   7.606 156.628   4571
```

**The method only work when your variable contains
NON-NEGATIVE values only.**

Housekeeping

Quant. X 1

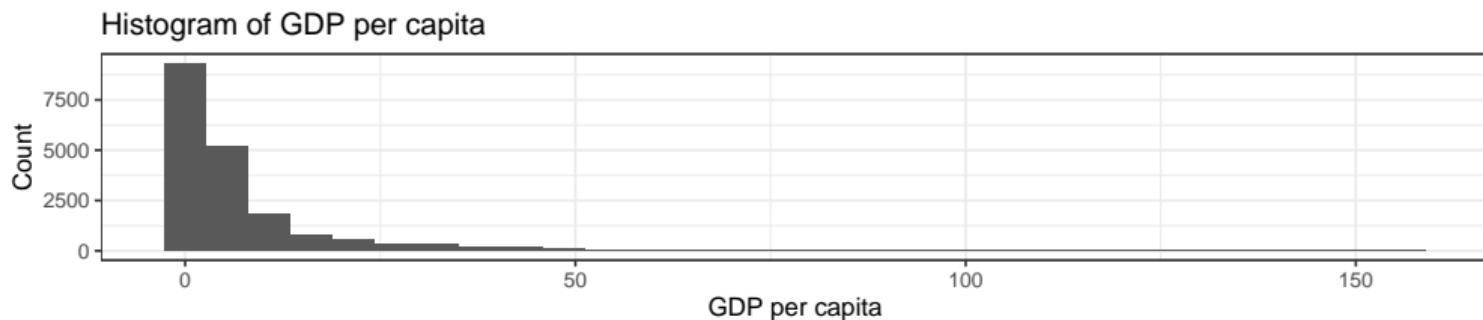
Quant. X 2

Quant. X 3

Quant. X 4+?

Annotate Case(s) of Interest

```
d |> ggplot(aes(x = gdppc)) + geom_histogram() +  
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```

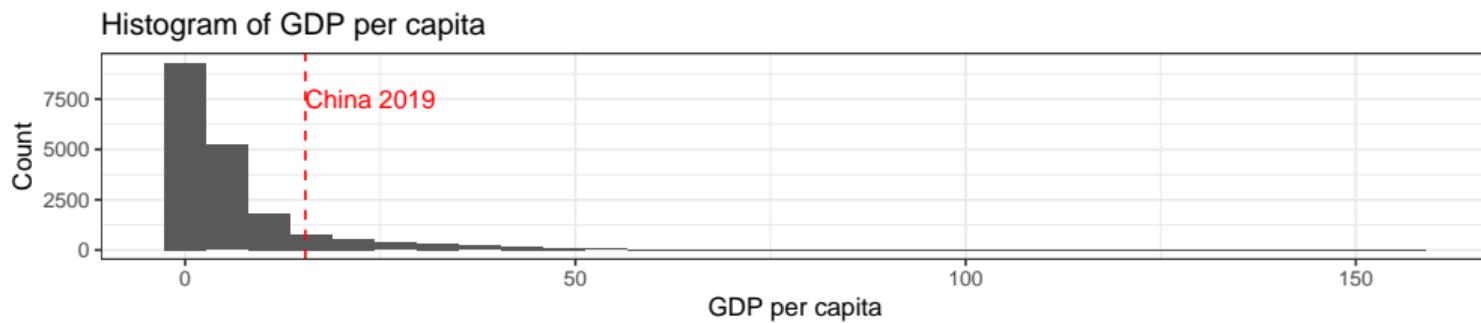


Annotate Case(s) of Interest (con'd)

```
d_anno <- d |> filter(country_text_id == "CHN", year == 2019) |> mutate(anno = paste(country_text_id, year), .after = year) Haohan Chen
print(d_anno)

## # A tibble: 1 x 10
##   country_text_id  year anno      region life_expectancy gdppc population
##   <chr>           <dbl> <chr>     <dbl>        <dbl>    <dbl>       <dbl>
## 1 CHN             2019 CHN 2019     12         77.6    15.4     1407745
## # i 3 more variables: democracy_binary <dbl>, democracy_lexical <dbl>,
## #   democracy_polity5 <dbl>

# A "manual" approach
d |> ggplot(aes(x = gdppc)) + geom_histogram() +
  geom_vline(aes(xintercept = 15.4), linetype = "dashed", color = "red") +
  annotate("text", x = 15.4, y = 7500, hjust = 0, label = "China 2019", color = "red") +
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



```
# How do I get y = 7500? Observe the y-axis in the previous figure.
```

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Quant. X 1

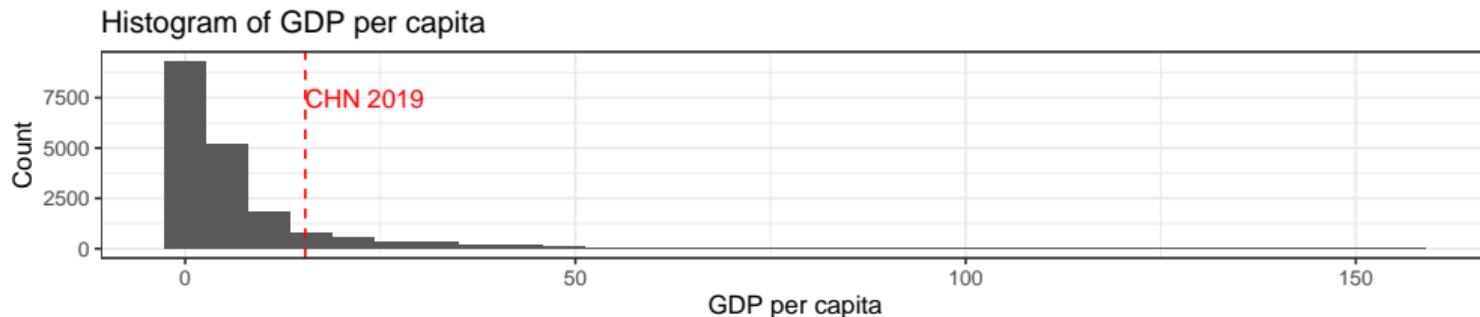
Quant. X 2

Quant. X 3

Quant. X 4+?

Annotate Case(s) of Interest (con'd)

```
# An automated approach
d |> ggplot(aes(x = gdppc)) + geom_histogram() +
  geom_vline(data = d_anno, aes(xintercept = gdppc), linetype = "dashed", color = "red") +
  geom_text(data = d_anno, aes(x = gdppc, y = 7500, label = anno), hjust = 0, color = "red") +
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



Why bother with the automated approach? It helps when you want to annotate multiple cases.

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Quant. X 1

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Quant. X 1

Quant. X 2

Quant. X 3

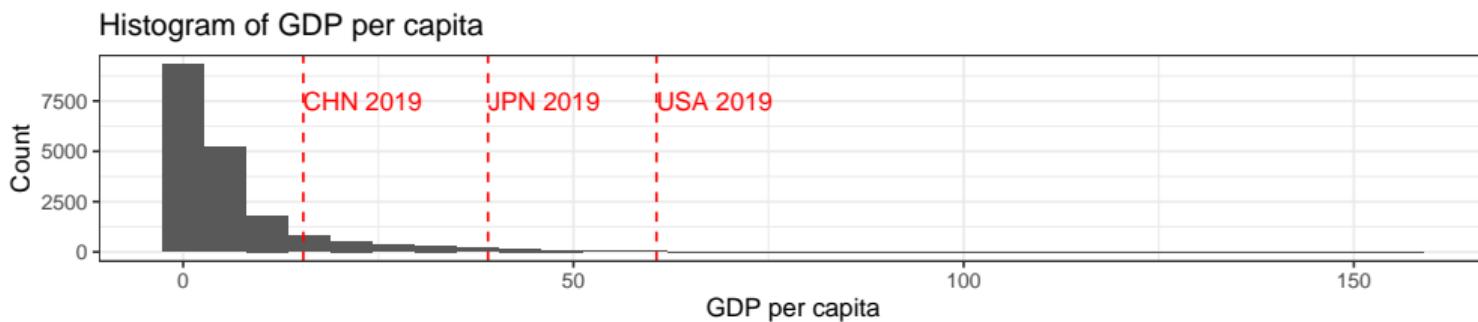
Quant. X 4+?

Annotate Case(s) of Interest (con'd)

```
d_anno <- d |> filter(country_text_id %in% c("CHN", "JPN", "USA"), year == 2019) |>  
  mutate(anno = paste(country_text_id, year), .after = year)  
print(d_anno)
```

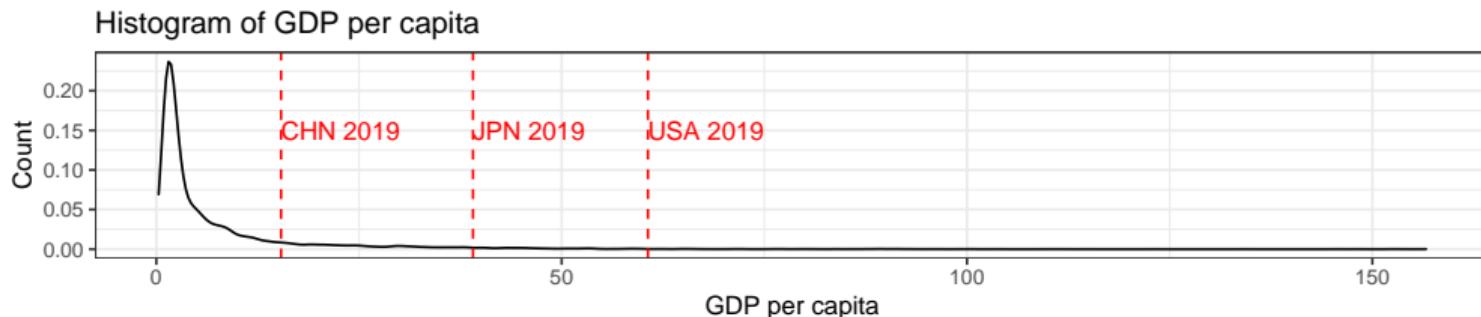
```
## # A tibble: 3 x 10  
##   country_text_id  year anno      region life_expectancy gdppc population  
##   <chr>           <dbl> <chr>     <dbl>        <dbl>    <dbl>       <dbl>  
## 1 JPN              2019 JPN 2019     12         84.8   39.1     126633  
## 2 USA              2019 USA 2019     16         78.9   60.6     328330.  
## 3 CHN              2019 CHN 2019     12         77.6   15.4     1407745  
## # i 3 more variables: democracy_binary <dbl>, democracy_lexical <dbl>,  
## #   democracy_polity5 <dbl>
```

```
d |> ggplot(aes(x = gdppc)) + geom_histogram() +  
  geom_vline(data = d_anno, aes(xintercept = gdppc), linetype = "dashed", color = "red") +  
  geom_text(data = d_anno, aes(x = gdppc, y = 7500, label = anno), hjust = 0, color = "red") +  
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



Annotate Case(s) of Interest (con'd)

```
d |> ggplot(aes(x = gdppc)) +  
  geom_density() +  
  geom_vline(data = d_anno, aes(xintercept = gdppc), linetype = "dashed", color = "red") +  
  geom_text(data = d_anno, aes(x = gdppc, y = 0.15, label = anno), hjust = 0, color = "red") +  
  labs(x = "GDP per capita", y = "Count", title = "Histogram of GDP per capita")
```



Why do I change y to 0.15? Through observation again...

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Quant. X 1

Quant. X 2

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Quant. X 4+?

Quant. X 2

Visualize Two Quantitative Variables

Data Visualization
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- ▶ Plots

- ▶ Scatter plot
- ▶ Scatter plot with a trend line

Housekeeping

Quant. X 1

Quant. X 2

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Quant. X 4+?

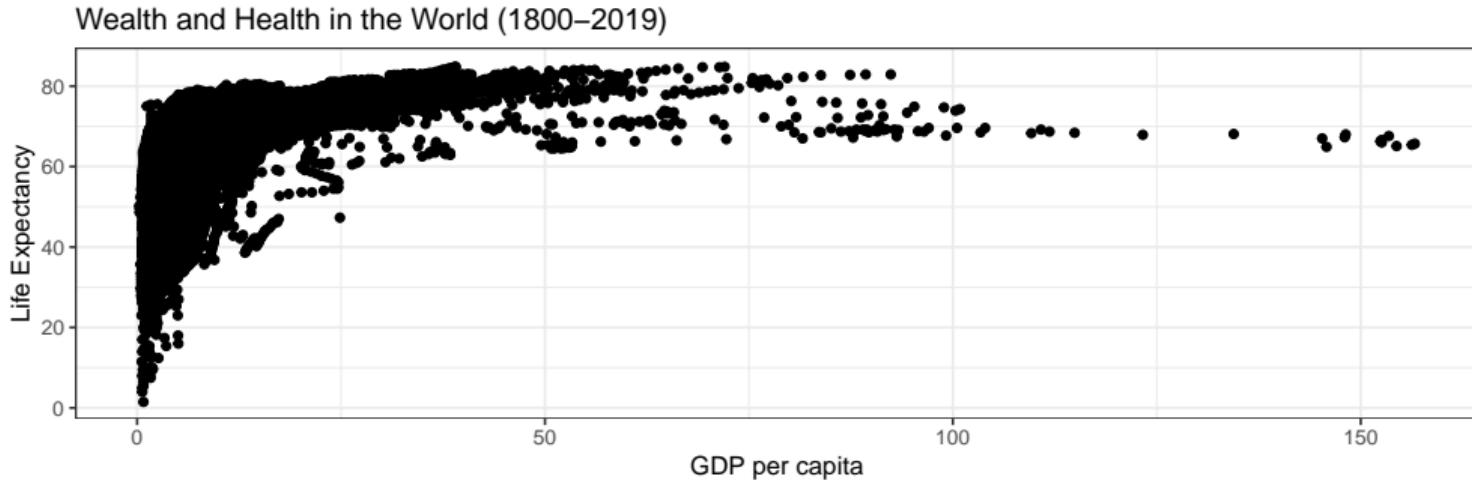
- ▶ Advanced

- ▶ Skewed distribution
- ▶ Annotate data points
- ▶ 2D “Histogram”

- ▶ Summary Statistics: Correlation

Scatter Plot

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



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Quant. X 1

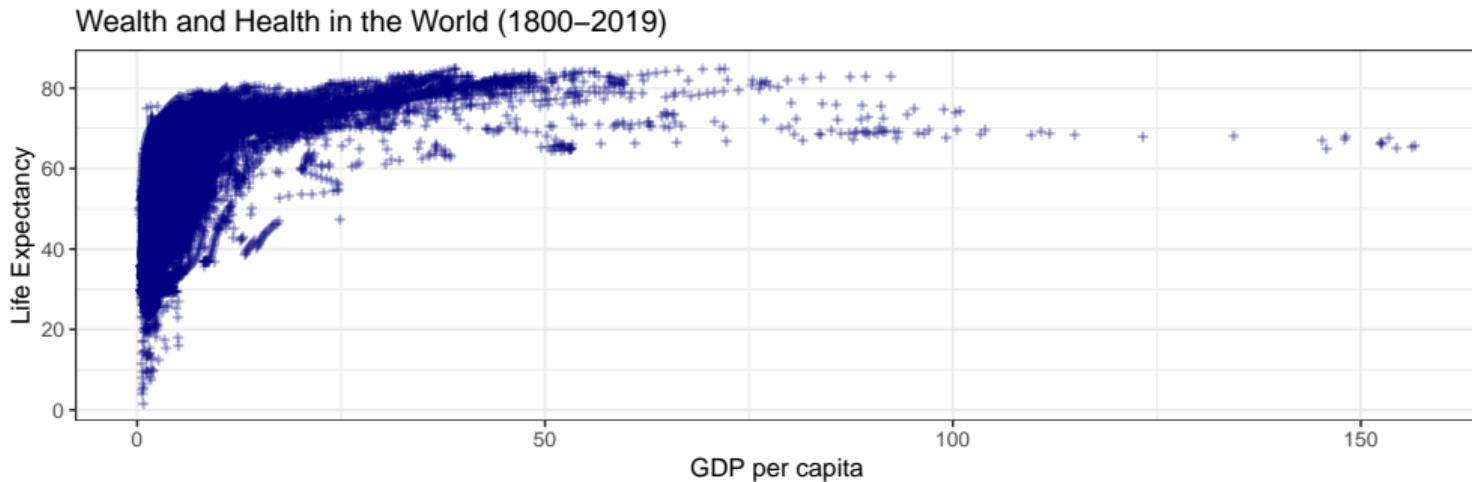
Quant. X 2

Quant. X 3

Quant. X 4+?

Scatter Plot (customized)

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, color = "navy", shape = 3, size = 0.5, stroke = 1) +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

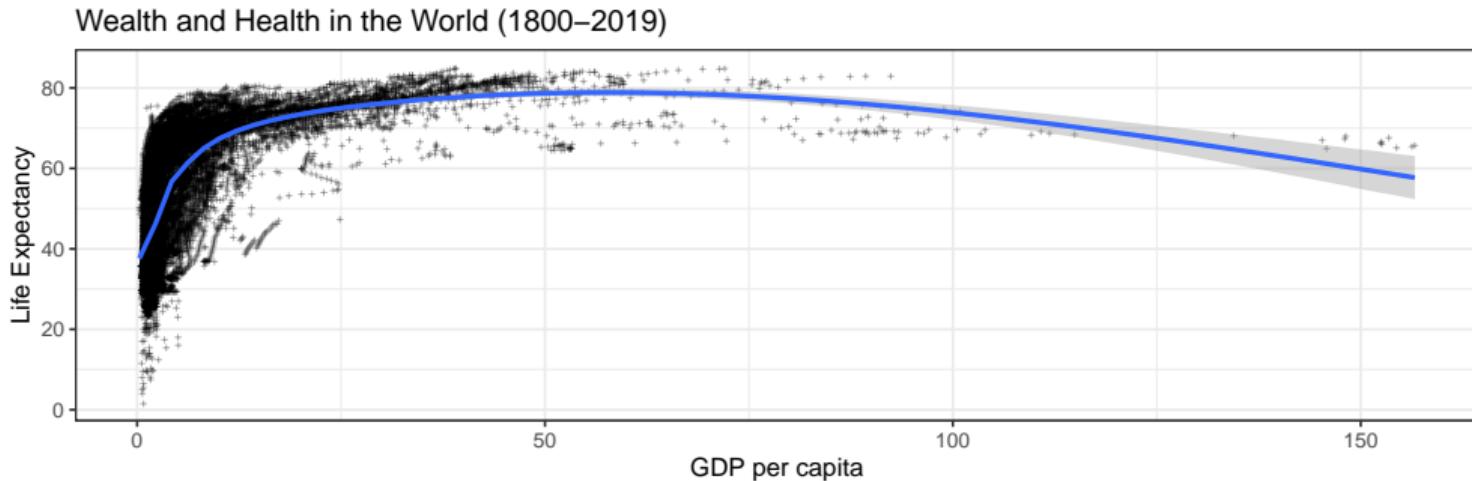
Quant. X 2

Quant. X 3

Quant. X 4+?

Scatter Plot with a Trend Line

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  geom_smooth() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

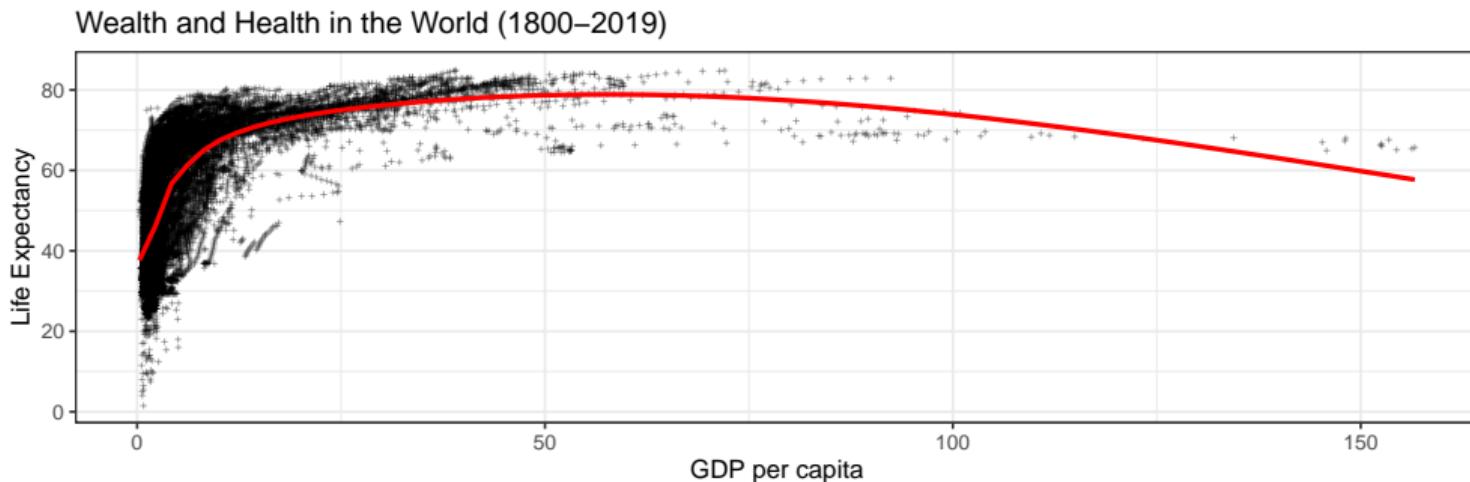
Quant. X 2

Quant. X 3

Quant. X 4+?

Scatter Plot with a Trend Line (customized aesthetic)

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  geom_smooth(se = FALSE, color = "red") +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

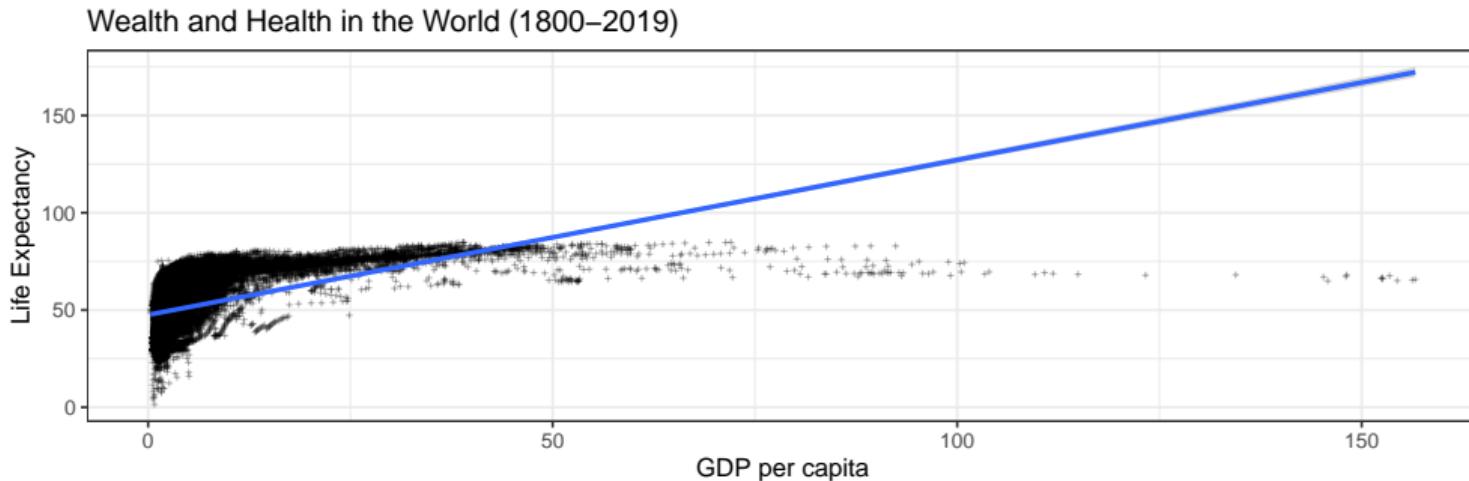
Quant. X 2

Quant. X 3

Quant. X 4+?

Scatter Plot with a Trend Line (customized model)

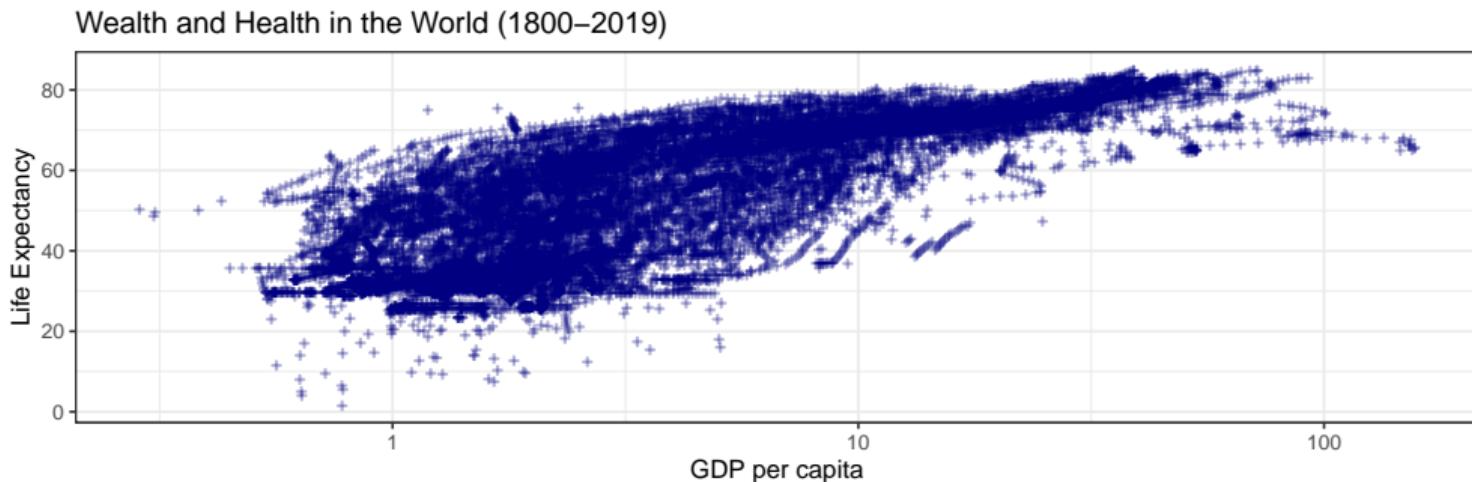
```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  geom_smooth(method = "lm") +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



This is a **BAD** example, because the relationship between the two variables is clearly not linear!

Skewed Distribution: Re-scale Axes

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, color = "navy", shape = 3, size = 0.5, stroke = 1) +  
  scale_x_log10() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

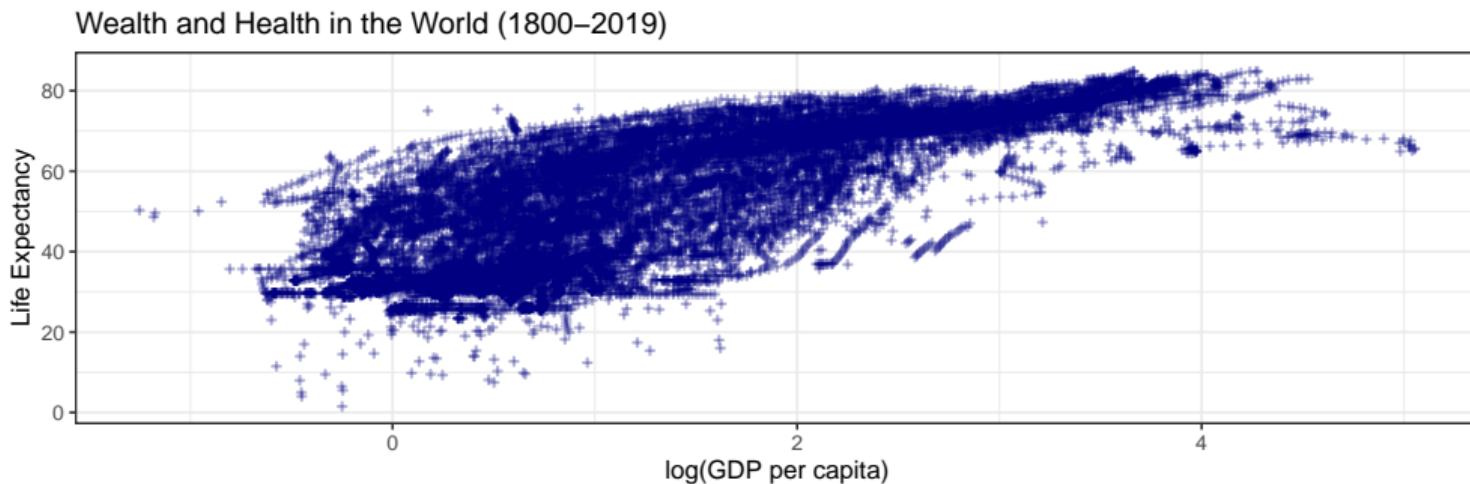
Quant. X 2

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Skewed Distribution: Transform variables

```
d |>
  mutate(gdppc_log = log(gdppc)) |>
  ggplot(aes(x = gdppc_log, y = life_expectancy)) +
  geom_point(alpha = 0.3, color = "navy", shape = 3, size = 0.5, stroke = 1) +
  labs(x = "log(GDP per capita)", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



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Quant. X 1

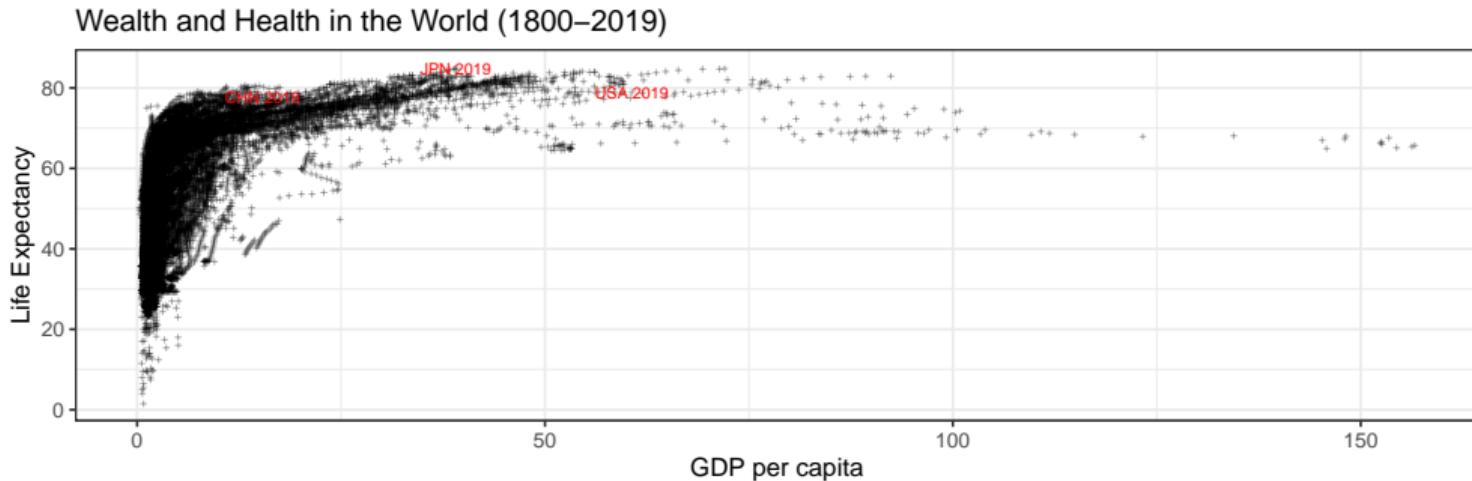
Quant. X 2

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Quant. X 4+?

Annotate Data Points: geom_text

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  geom_text(data = d_anno, aes(x = gdppc, y = life_expectancy, label = anno), color = "red", size = 2.5) +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

Quant. X 2

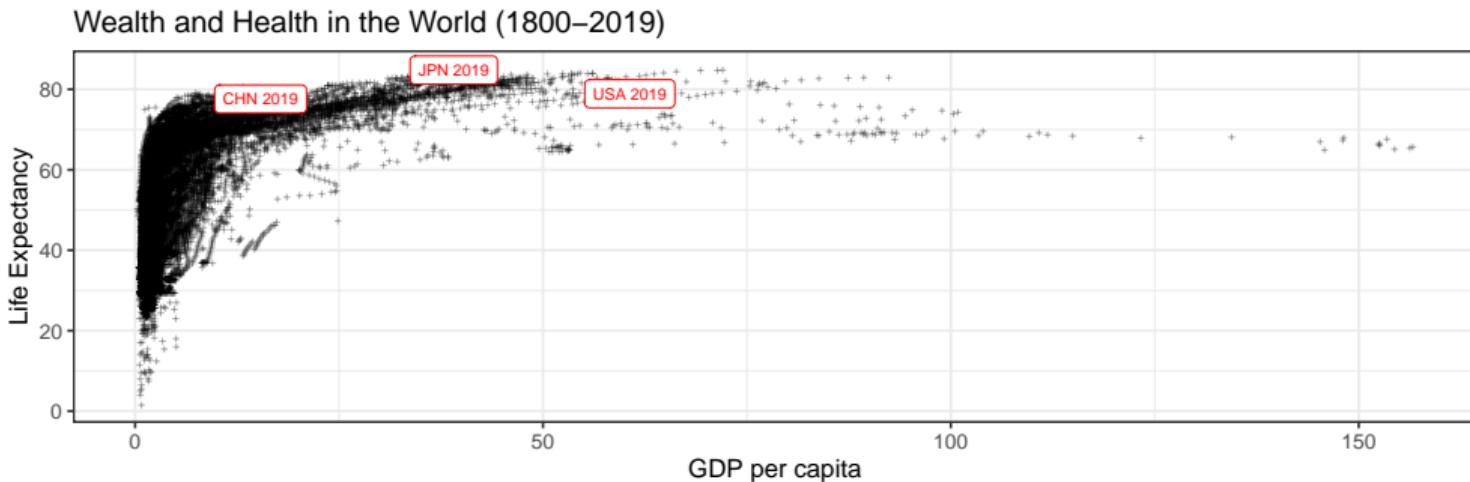
Quant. X 3

Quant. X 4+?

Annotate Data Points: geom_label

geom_text might not be able to highlight your data points enough (especially when your scatter plot has a lot of data points). geom_label may help.

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  geom_label(data = d_anno, aes(x = gdppc, y = life_expectancy, label = anno), color = "red", size = 2.5) +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



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Quant. X 1

Quant. X 2

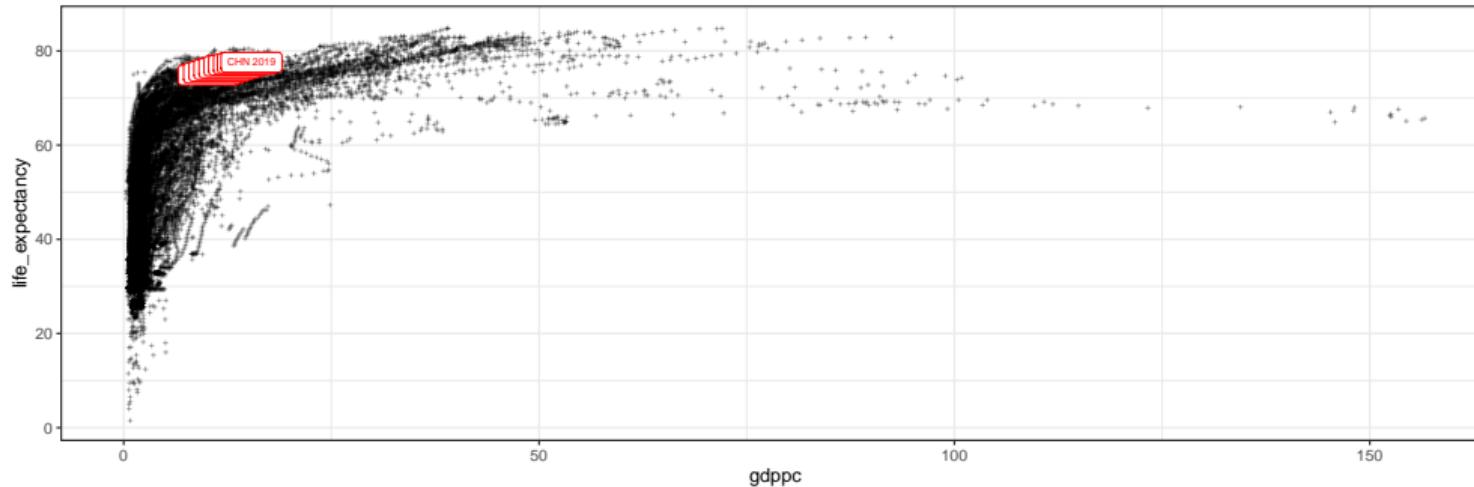
Quant. X 3

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Annotate MANY Data Points: Problem

`geom_label` and `geom_text` may get you uninformative annotation if the points you want to annotate cluster in a small area of your figure.

```
d_anno_2 <- d |> filter(year >= 2010, country_text_id == "CHN") |>  
  mutate(anno = paste(country_text_id, year), .after = year)  
  
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +  
  # geom_point(data = d_anno_2, aes(x = gdppc, y = life_expectancy), color = "red", size = 0.5) +  
  geom_label(data = d_anno_2, aes(x = gdppc, y = life_expectancy, label = anno), color = "red", size = 2)
```



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Quant. X 1

Quant. X 2

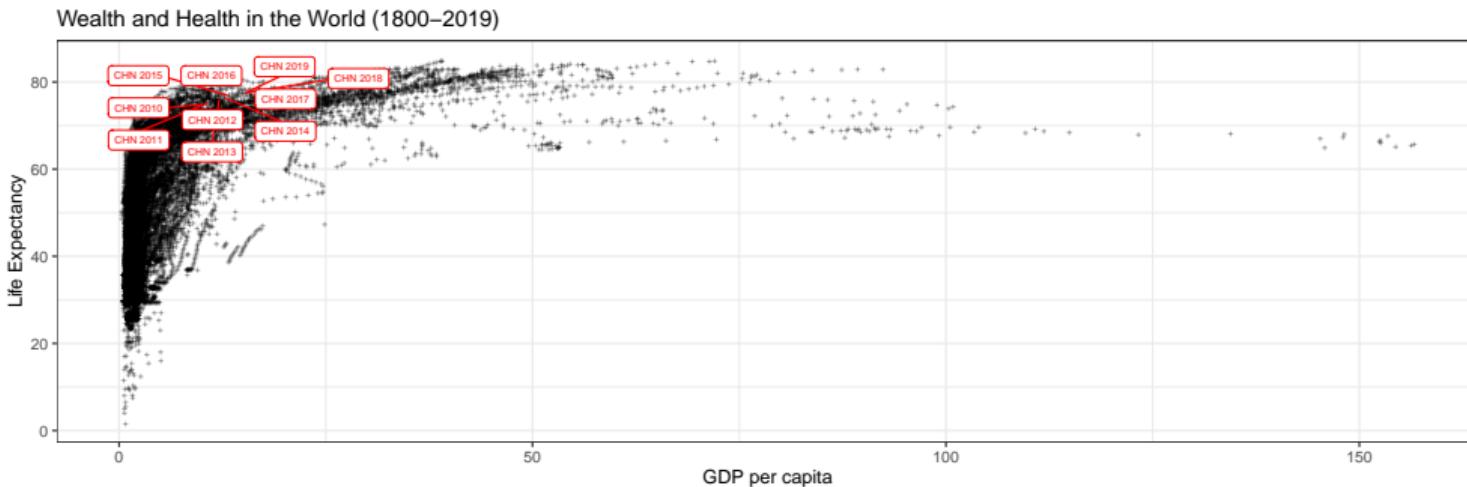
Quant. X 3

Quant. X 4+?

Annotate MANY Data Points: geom_label_repel

When you need to annotate a few points that may cluster in a small area of your figure, `geom_label_repel` can adjust the labels' locations to avoid overlaps.

```
library(ggrepel)
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(alpha = 0.3, shape = 3, size = 0.5) +
  # geom_point(data = d_anno_2, aes(x = gdppc, y = life_expectancy), color = "red", size = 0.5) +
  geom_label_repel(data = d_anno_2, aes(x = gdppc, y = life_expectancy, label = anno),
                   color = "red", size = 2, max.overlaps = 20) +
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



Housekeeping

Quant. X 1

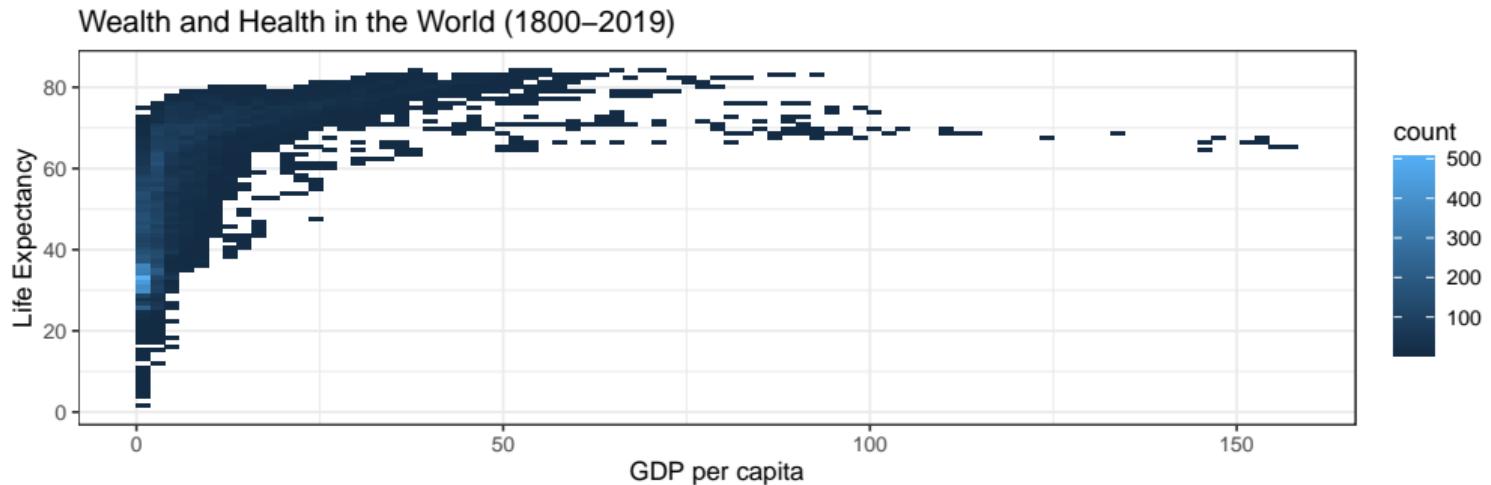
Quant. X 2

Quant. X 3

Quant. X 4+?

2D "Histogram"

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_bin_2d(bins = 80) +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800–2019)")
```



Housekeeping

Quant. X 1

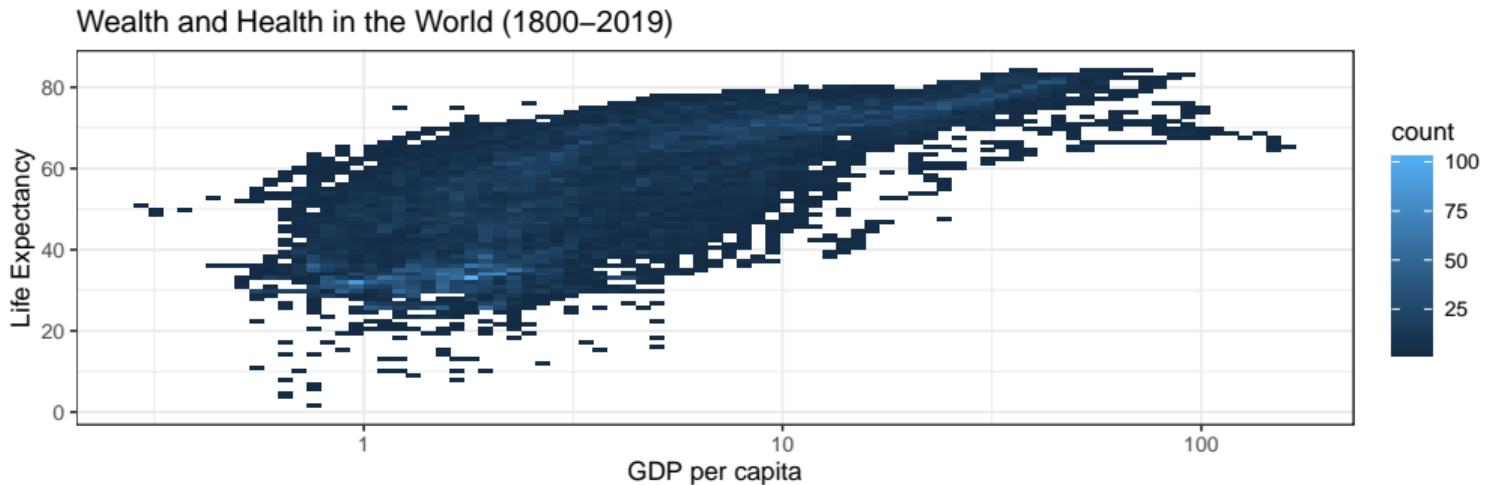
Quant. X 2

Quant. X 3

Quant. X 4+?

2D “Histogram”

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_bin_2d(bins = 80) + scale_x_log10() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800–2019)")
```



Housekeeping

Quant. X 1

Quant. X 2

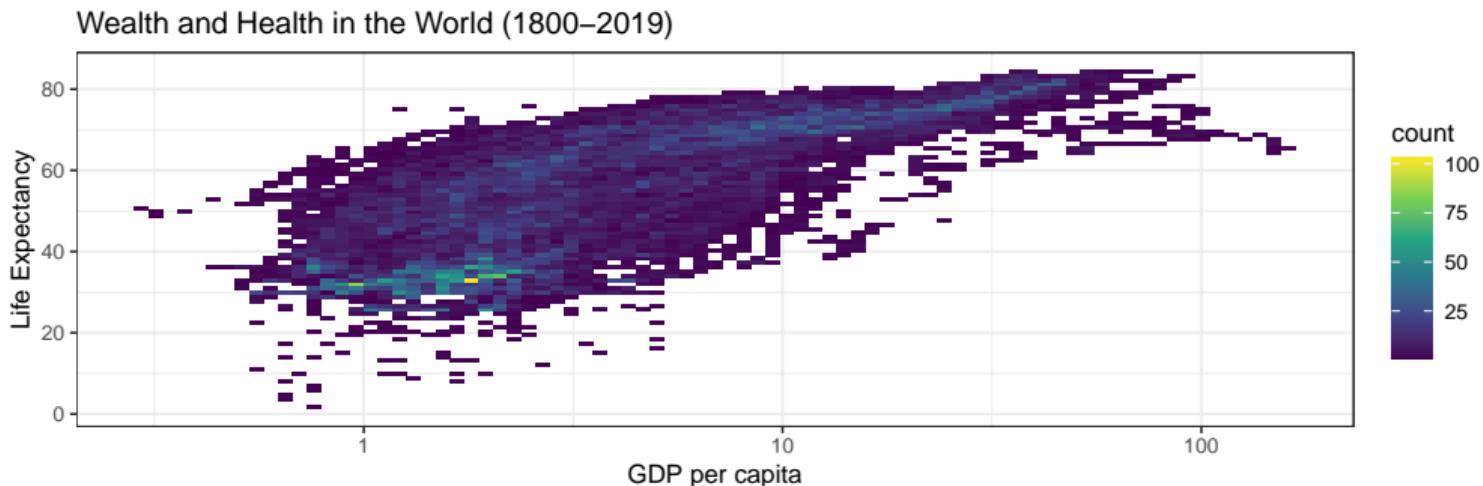
Quant. X 3

Quant. X 4+?

2D “Histogram”

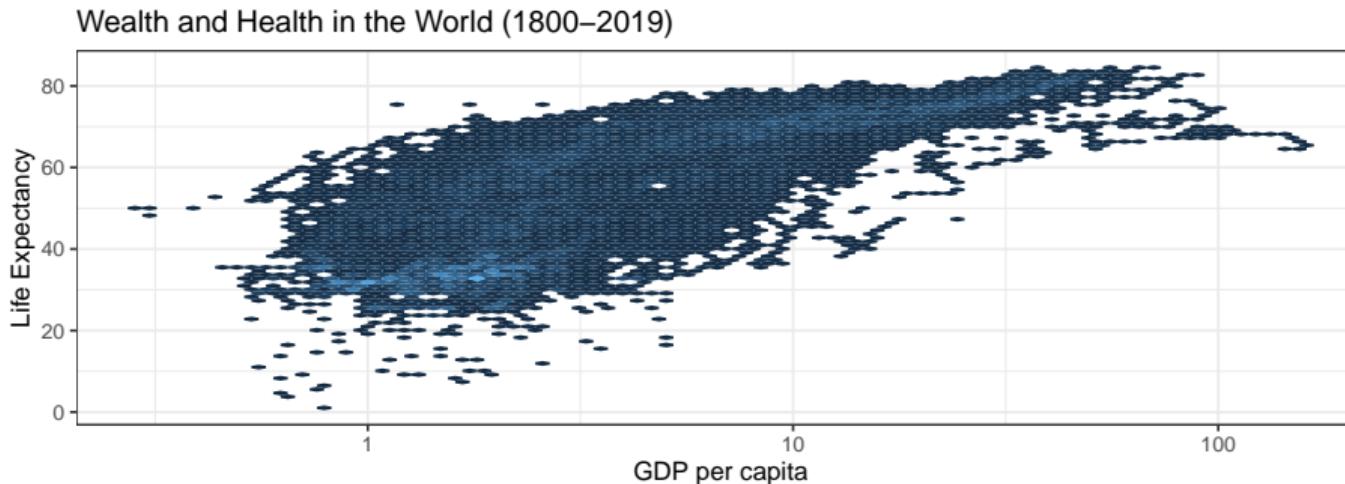
If you find the default color scheme (dark to light blue) to no adequately visualize the different frequencies, you may use a different scheme that offers higher “contrast” between low and high values. `scale_fill_viridis_c` is one of my favorite.

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_bin_2d(bins = 80) + scale_x_log10() +  
  scale_fill_viridis_c() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800-2019)")
```



2D “Histogram”

```
d |> ggplot(aes(x = gdppc, y = life_expectancy)) +  
  geom_hex(bins = 80) + scale_x_log10() +  
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (1800–2019)")
```



Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Summary Statistics: Pearson Correlation

Pearson correlation (aka. Pearson's r), ranging from -1 to 1, is our typical indicator of the correlation between two quantitative variables.

```
cor(d$life_expectancy, d$gdppc, use = "complete.obs", method = "pearson")
```

```
## [1] 0.5600421
```

```
cor.test(d$life_expectancy, d$gdppc, use = "complete.obs", method = "pearson")
```

```
##  
## Pearson's product-moment correlation  
##  
## data: d$life_expectancy and d$gdppc  
## t = 92.412, df = 18688, p-value < 2.2e-16  
## alternative hypothesis: true correlation is not equal to 0  
## 95 percent confidence interval:  
## 0.5501224 0.5698037  
## sample estimates:  
## cor  
## 0.5600421
```

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Summary Statistics: Pearson Correlation

Data Visualization
(2)

Haohan Chen

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

To use Pearson correlation, the two variables should meet the following assumptions:

- ▶ Continuous
- ▶ Linear relationship
- ▶ No outlier
- ▶ Normally distributed

Summary Statistics: Spearman Correlation

If the data seem to break at least one of the assumptions for Pearson correlation, you may use Spearman correlation (aka. Spearman's ρ).

```
cor(d$life_expectancy, d$gdppc, use = "complete.obs", method = "spearman")
```

```
## [1] 0.767604
```

```
cor.test(d$life_expectancy, d$gdppc, use = "complete.obs", method = "spearman")
```

```
## Warning in cor.test.default(d$life_expectancy, d$gdppc, use = "complete.obs", :  
## Cannot compute exact p-value with ties
```

```
##  
## Spearman's rank correlation rho  
##  
## data: d$life_expectancy and d$gdppc  
## S = 2.5287e+11, p-value < 2.2e-16  
## alternative hypothesis: true rho is not equal to 0  
## sample estimates:  
##      rho  
## 0.767604
```

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Quant. X 3

Visualize 3 Quantitative Variables

Data Visualization
(2)

Haohan Chen

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

- ▶ Correlation Matrix
- ▶ Bubble Plot: 3rd variable visualized with size
- ▶ Make it colorful: 3rd variable visualized with color

Housekeeping

Quant. X 1

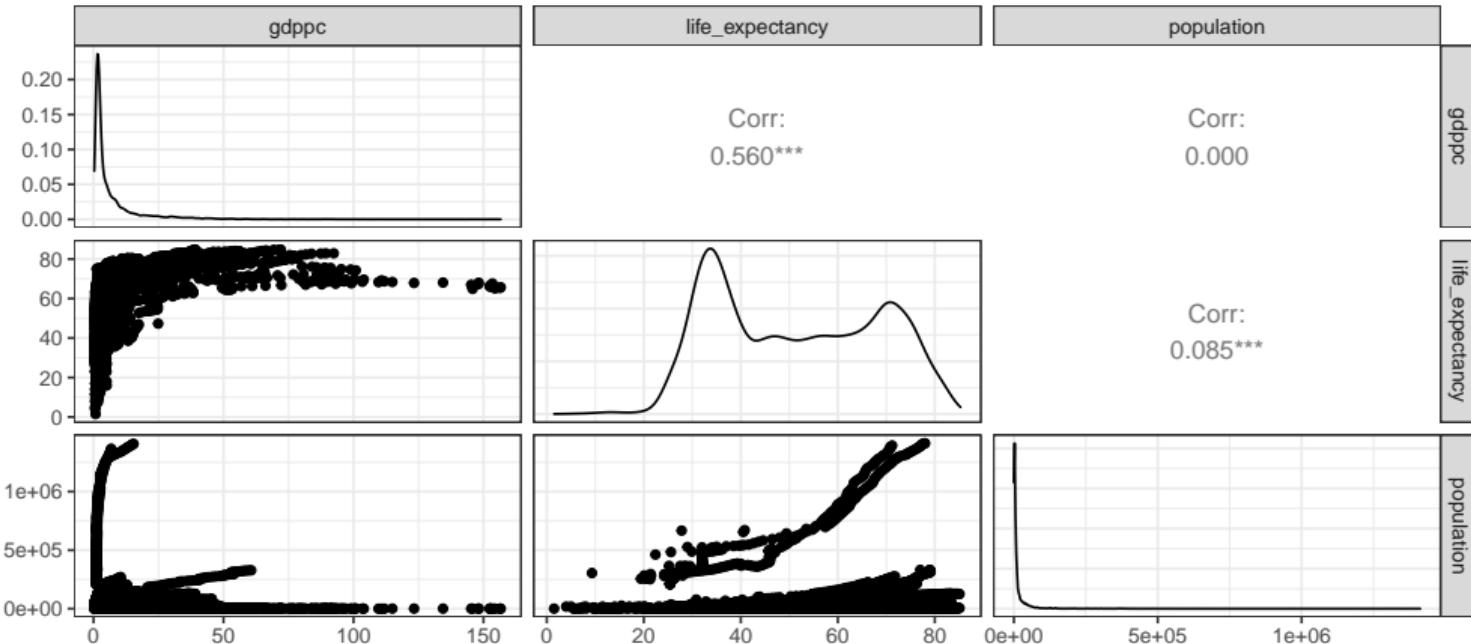
Quant. X 2

Quant. X 3

Quant. X 4+?

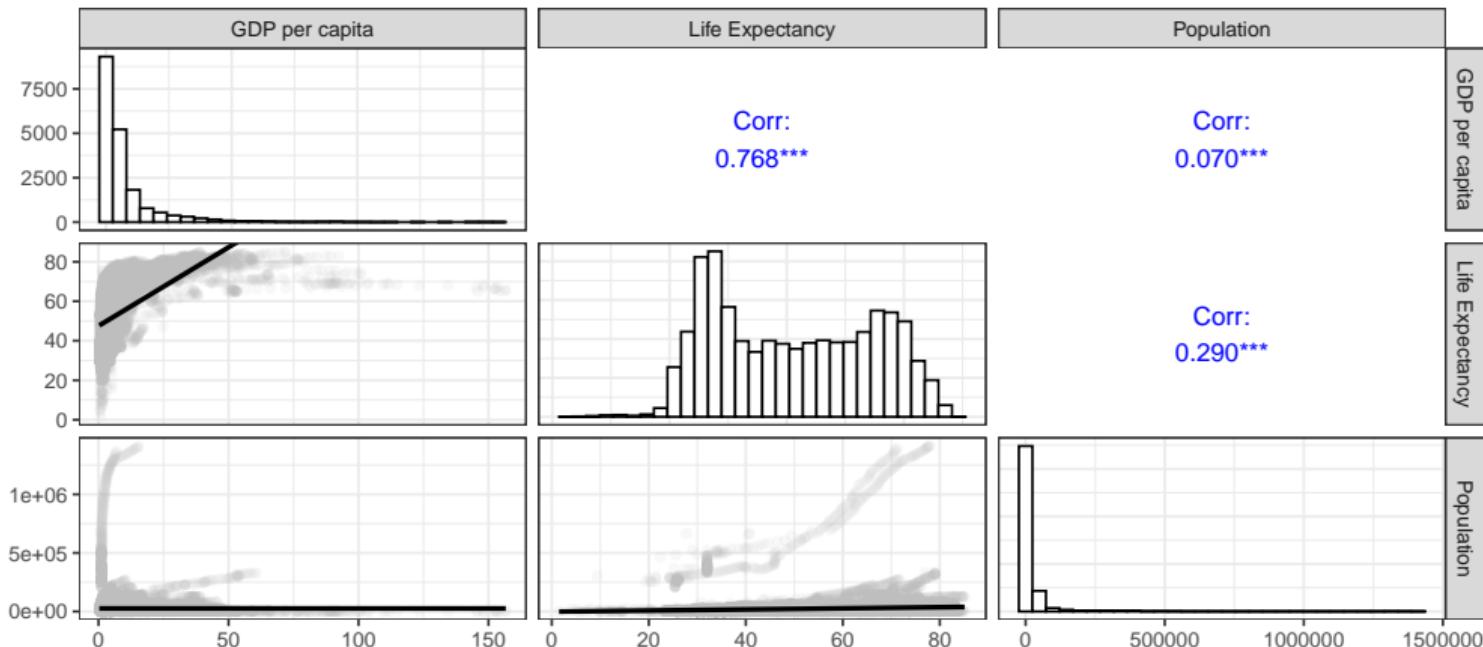
Correlation Matrix

```
# install.packages("GGally")
library(GGally)
d |>
  select(gdppc, life_expectancy, population) |>
  ggpairs()
```



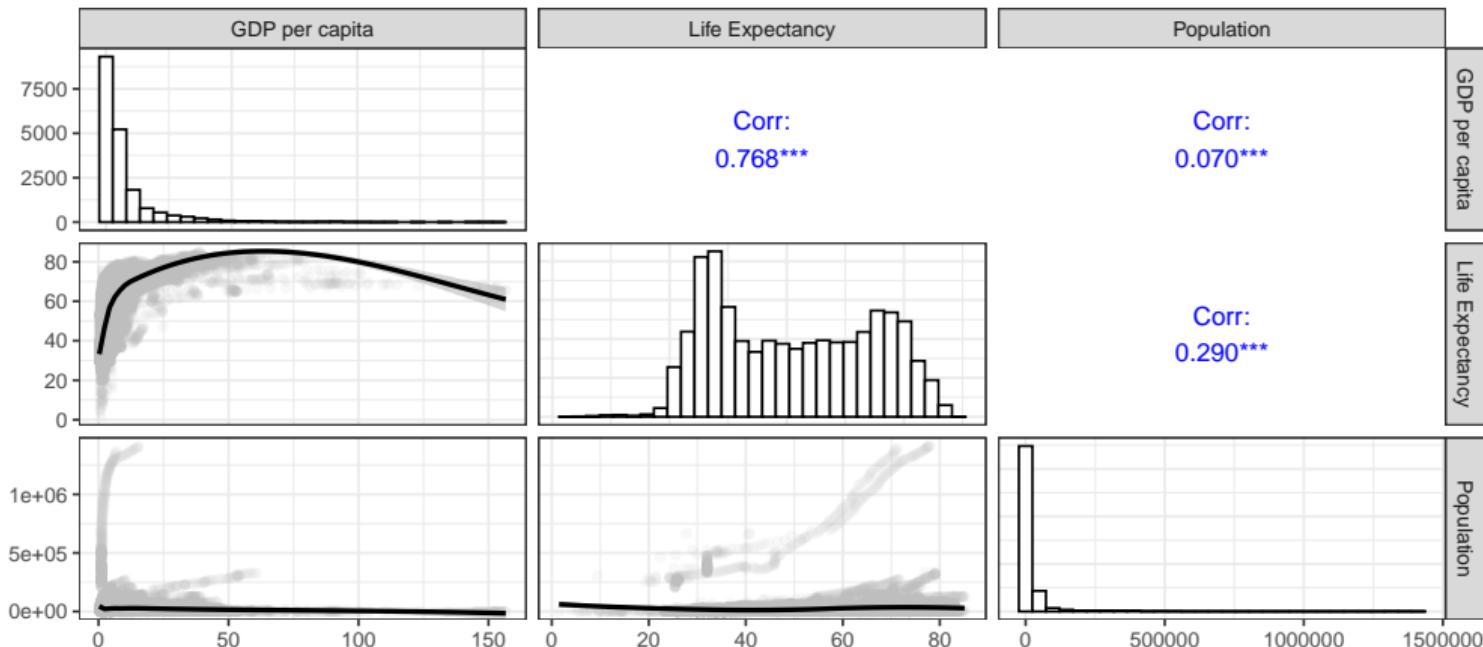
Correlation Matrix

```
d |> select(gdppc, life_expectancy, population) |>  
  ggpairs(  
    columnLabels = c("GDP per capita", "Life Expectancy", "Population"), # Label variables  
    upper = list(continuous = wrap("cor", method = "spearman", color = "blue")), # Upper triangle: Spearman correlation  
    diag = list(continuous = wrap("barDiag", bins = 30, fill = "white", color = "black")), # Diagonal: histogram  
    lower = list(continuous = wrap("smooth", alpha = 0.1, color = "gray")))) # Lower triag: + linear trend line
```



Correlation Matrix

```
d |> select(gdppc, life_expectancy, population) |>  
  ggpairs(  
    columnLabels = c("GDP per capita", "Life Expectancy", "Population"), # Label variables  
    upper = list(continuous = wrap("cor", method = "spearman", color = "blue")), # Upper triangle: Spearman correlation  
    diag = list(continuous = wrap("barDiag", bins = 30, fill = "white", color = "black")), # Diagonal: histogram  
    lower = list(continuous = wrap("smooth_loess", alpha = 0.1, color = "gray")))) # Lower triag: + loess trend line
```

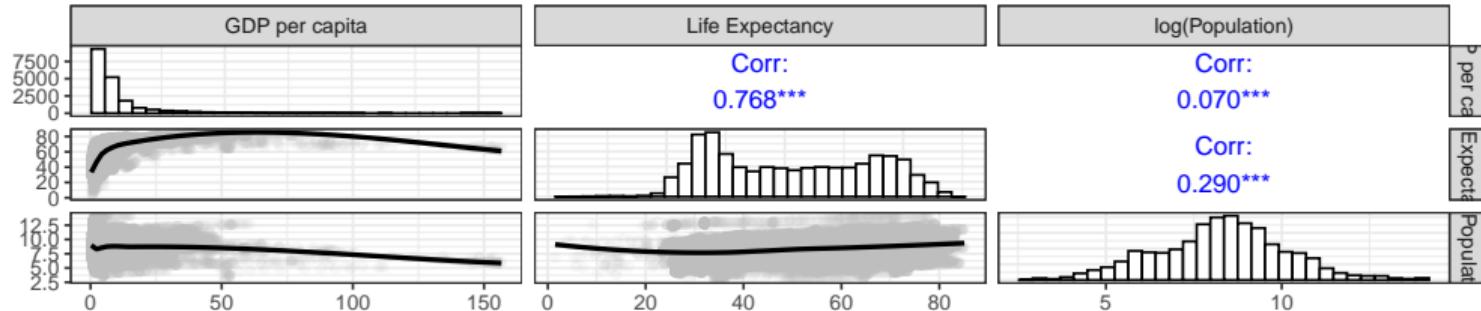


Correlation Matrix

```
summary(d$population) # The population variable is skewed. Consider transformation
```

```
##      Min.    1st Qu.     Median      Mean    3rd Qu.      Max.    NA's
##    17.9    1246.3    4234.3   23083.3   11914.2  1412360.0    2981
```

```
d |> select(gdppc, life_expectancy, population) |>
  mutate(population = log(population)) |> # log transformation
  ggpairs(
    columnLabels = c("GDP per capita", "Life Expectancy", "log(Population)"), # Label variables
    upper = list(continuous = wrap("cor", method = "spearman", color = "blue")), # Upper triangle: Spearman correlation
    diag = list(continuous = wrap("barDiag", bins = 30, fill = "white", color = "black")), # Diagonal: histogram
    lower = list(continuous = wrap("smooth_loess", alpha = 0.1, color = "gray"))) # Lower triag: + loess trend line
```



Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Play with ggpairs

Data Visualization
(2)

Haohan Chen

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

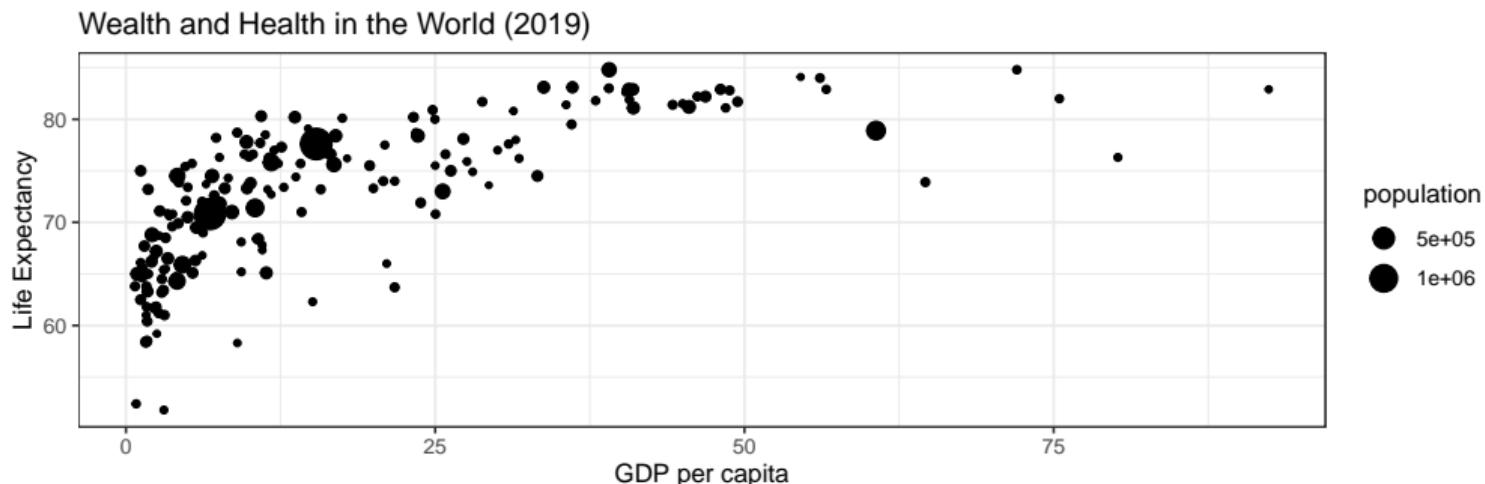
Check out its documentation: https:

//www.rdocumentation.org/packages/GGally/versions/1.5.0/topics/ggpairs

Bubble Plot

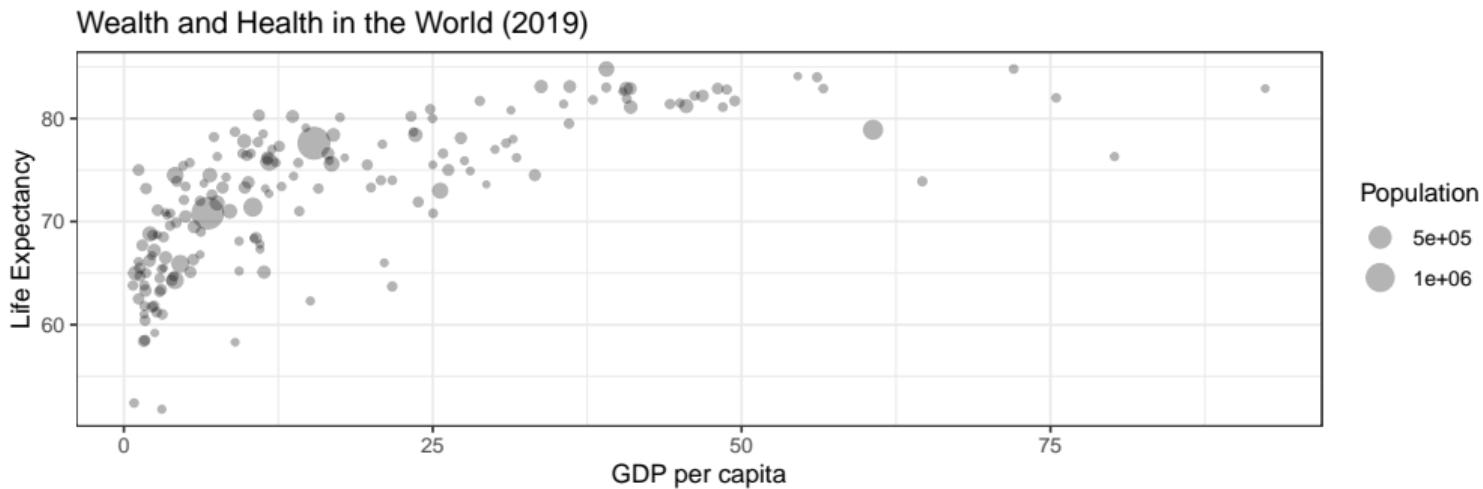
```
d |>
  filter(year == 2019) |>
  ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(aes(size = population)) +
  labs(x = "GDP per capita", y = "Life Expectancy", title = "Wealth and Health in the World (2019)")
```

Warning: Removed 8 rows containing missing values (geom_point).



Bubble Plot (customized)

```
d |>
  filter(year == 2019) |>
  ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(aes(size = population), alpha = 0.3) +
  labs(x = "GDP per capita", y = "Life Expectancy", size = "Population",
       title = "Wealth and Health in the World (2019)")
```



Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

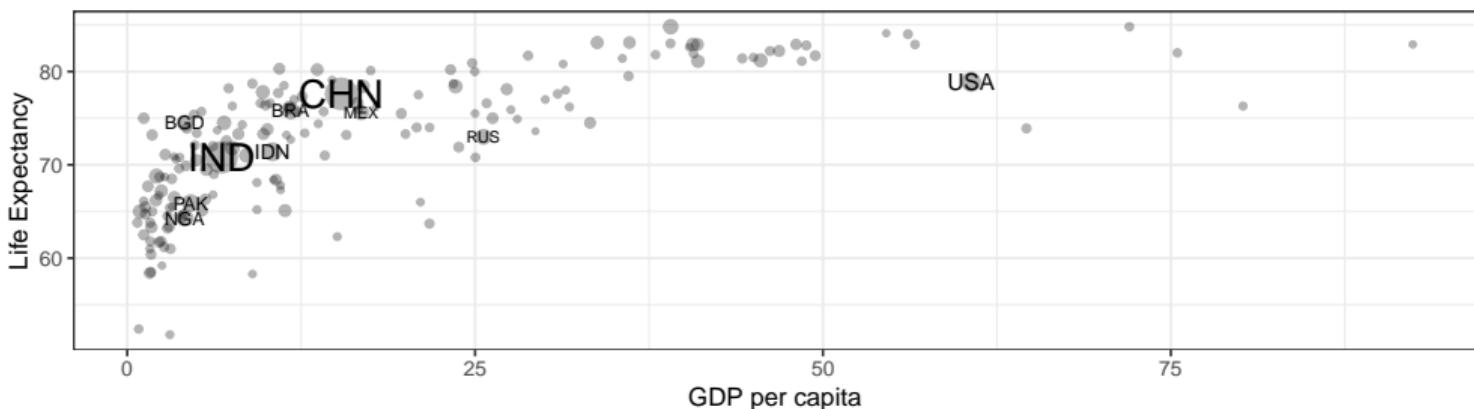
Quant. X 4+?

Bubble Plot (annotated)

```
d_anno_pop <- d |> filter(year == 2019) |> slice_max(order_by = population, n = 10)

d |>
  filter(year == 2019) |>
  ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(aes(size = population), alpha = 0.3) +
  geom_text(data = d_anno_pop, aes(x = gdppc, y = life_expectancy, label = country_text_id, size = population)) +
  labs(x = "GDP per capita", y = "Life Expectancy", size = "Population",
       title = "Wealth and Health in the World (2019)",
       caption = "Note: World's top 10 most populated countries are annotated.") +
  theme(legend.position = "none") # Remove the legend
```

Wealth and Health in the World (2019)

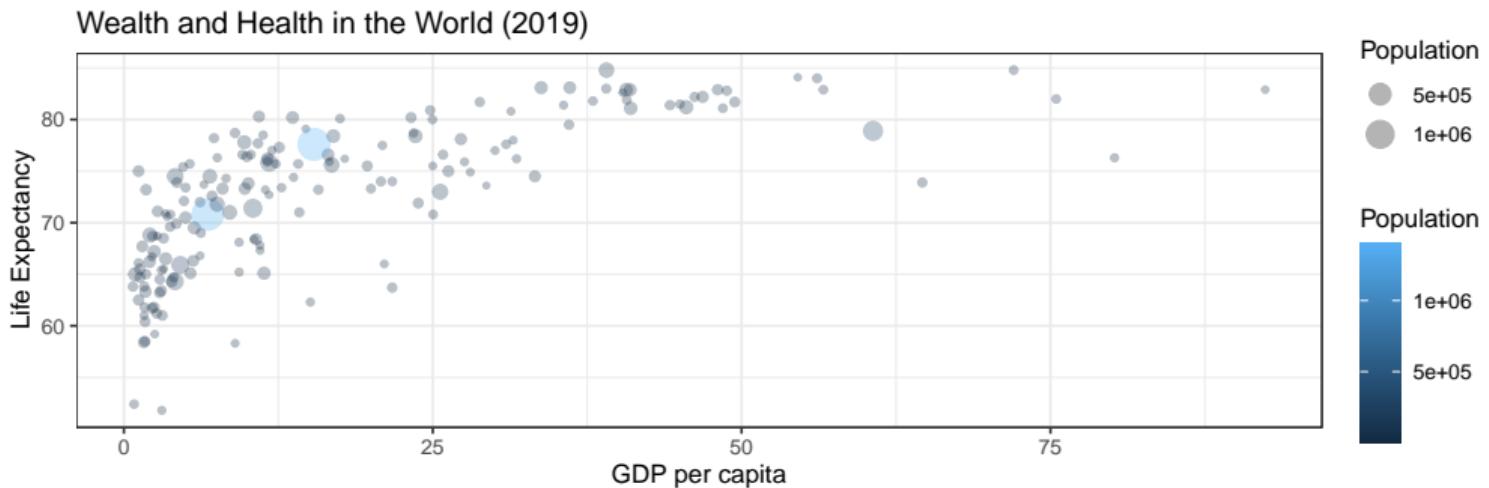


Note: World's top 10 most populated countries are annotated.

Make it Colorful

Strengthen the visual message from the third variable

```
d |>
  filter(year == 2019) |>
  ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(aes(size = population, color = population), alpha = 0.3) +
  labs(x = "GDP per capita", y = "Life Expectancy",
       size = "Population", color = "Population", fill = "Population",
       title = "Wealth and Health in the World (2019)")
```



Housekeeping

Quant. X 1

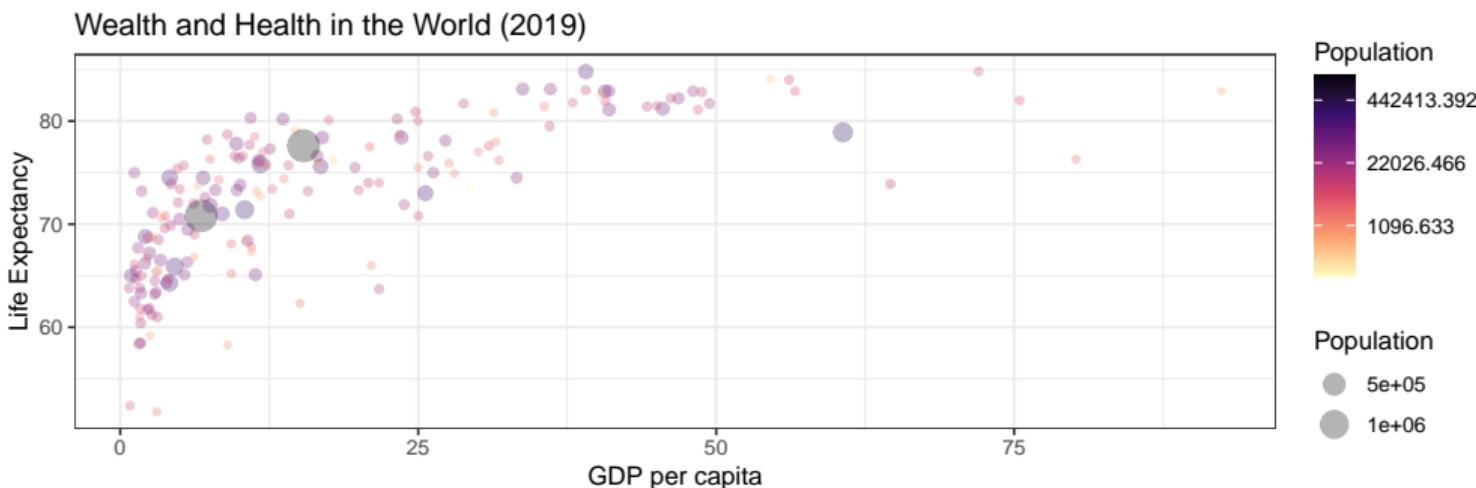
Quant. X 2

Quant. X 3

Quant. X 4+?

Make it Colorful (customized)

```
d |>
  filter(year == 2019) |>
  ggplot(aes(x = gdppc, y = life_expectancy)) +
  geom_point(aes(size = population, color = population), alpha = 0.3) +
  scale_color_viridis_c(option = "A", trans = "log", direction = -1) +
  labs(x = "GDP per capita", y = "Life Expectancy",
       size = "Population", color = "Population", fill = "Population",
       title = "Wealth and Health in the World (2019)")
```



Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Quant. X 4+?

Housekeeping

Quant. X 1

Quant. X 2

Quant. X 3

Quant. X 4+?

Warning

It is *technically* feasible to plot more than 3 variables in the same figure, but...

- ▶ You don't want your figure to be too "busy"
- ▶ "Less is more"