Tutorial 2

Data Vizualization in R.

ggplot2: statistics, coordinate system, facets.

Victoria Mironova

Associate Professor, Department of Plant Systems Physiology

Course structure

Week 1-2:

Lecture 1. Principles of figure design.

Quiz 1.

Week 3-4:

Tutorial 1. ggplot2: plots and charts.

Quiz 2.

Week 5-6:

Tutorial 2. ggplot2: statistics, coordinate system, facets.

Tutorial 3. ggplot2: themes and styles.

Practice 1.

Quiz 3.

Week 7-8:

Practice 2. Project.

Practice 3. Project.

Practice 4. Project.

Assignment.

Course structure

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Lecture 1. Principles of figure design.
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Practice 1.
Quiz 3.

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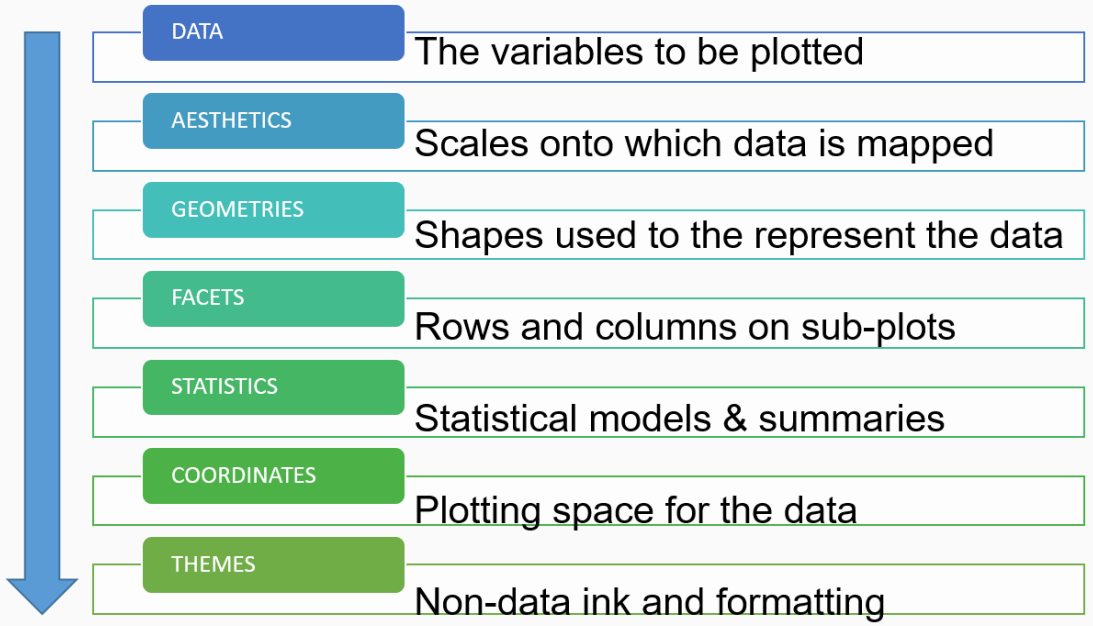
Practice 2. Project.
Practice 3. Project.
Practice 4. Project.
Assignment.

Learning goals

- Understand the basic principles behind effective data visualization
- **Create data visualizations in R using ggplot2**
- Craft elegant visual presentations of data

Grammar of graphics

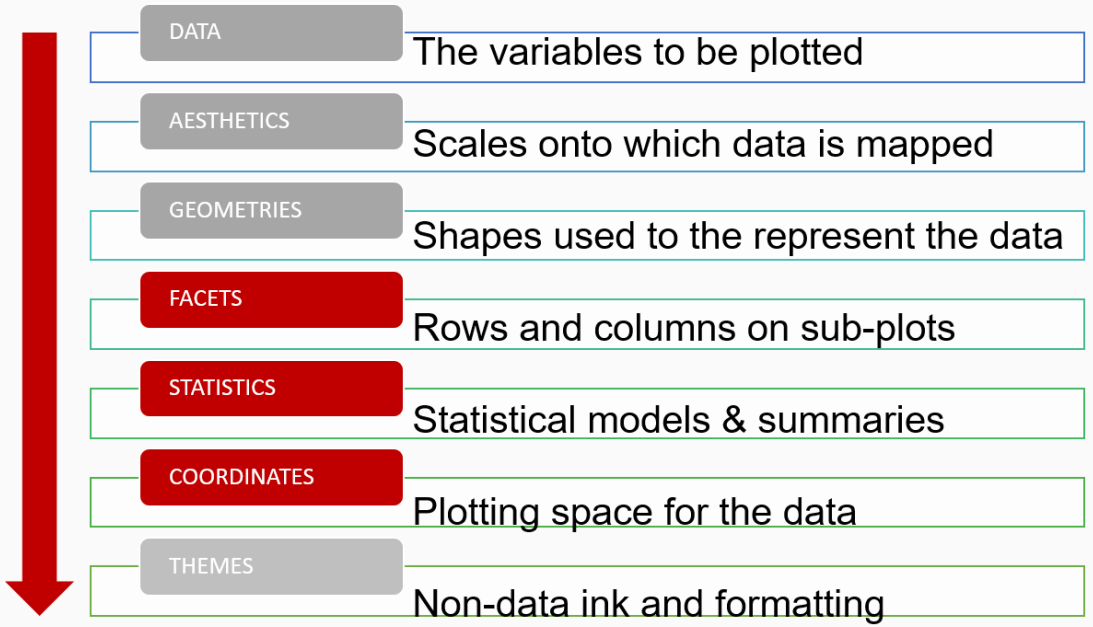


Layers in grammar of graphics

There are two important principles behind *grammar of graphics*:

- Graphics are made of distinct layers of grammatical elements
- Plots are built with appropriate aesthetic mappings to make these plots meaningful

Grammar of graphics



Layers in grammar of graphics

Coordinate system: What kind of a coordinate system should the visualization be based on — should it be cartesian or polar?

Facets: Do we need to create subplots based on specific data dimensions?

Statistics: Do we need to show some statistical measures in the visualization like measures of central tendency, spread, confidence intervals?

Plan of the tutorial

- Extended graphing template
- Coordinate system
- Faceting
- Statistics
- Save visualizations

Data

We keep working with the data on: Number of deaths in the population of the Netherlands by main underlying cause of death, by age and sex, 1996-2021.

ID	Sex	Age	CausesOfDeath	Year	Deaths
2957560	Female	85-89	Perinatal	2004	0
1424313	Male	30-34	Perinatal	2003	0
1457025	Male	35-39	CirculatorySystem	2007	110
1377865	Male	25-29	Perinatal	2017	0
2327624	Female	20-24	Neoplasms	1996	27

- **ID**: Numeric, continuous;
- **Sex**: Categorical, unordered;
- **Age**: Categorical, ordered;
- **CausesOfDeath**: categorical, unordered;
- **Year**: Numeric, discreet;
- **Deaths**: Numeric, continuous.

Updated graphing template

On the last tutorial you saw an incomplete template highlighted in yellow. Below is a complete one.

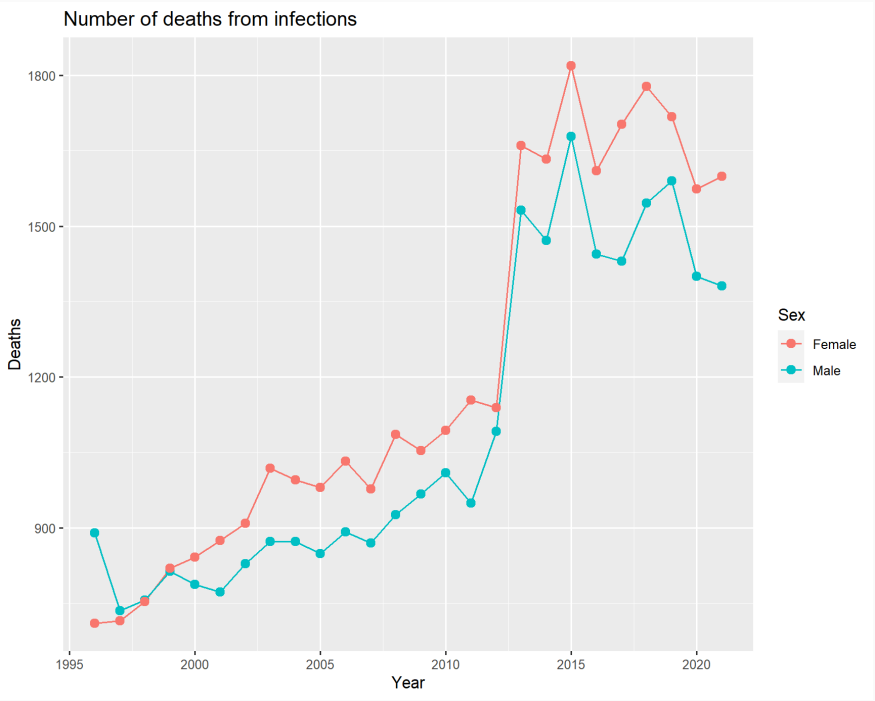
```
ggplot(data = <DATA>)+
  <GEOM_FUNCTION>(
    mapping = aes(<MAPPINGs>),
    method = <STAT>,
    position = <POSITION>) +
  <STAT_FUNCTION>()+
  <COORDINATE_FUNCTION>()+
  <FACET_FUNCTION>()+
  <THEME>()
```

Coordinate systems

Cartesian Coordinates

When we plot a chart using ggplot2, Cartesian Coordinates is the default coordinate system.

```
Death_in_NL %>%
  filter(Age == "Total", CausesOfDeath == "Infections")%>%
  ggplot(mapping = aes(x = Year, y = Deaths, color = Sex))+
  geom_path()+
  geom_point(size = 2.5)+
  ggtitle("Number of deaths from infections")
```

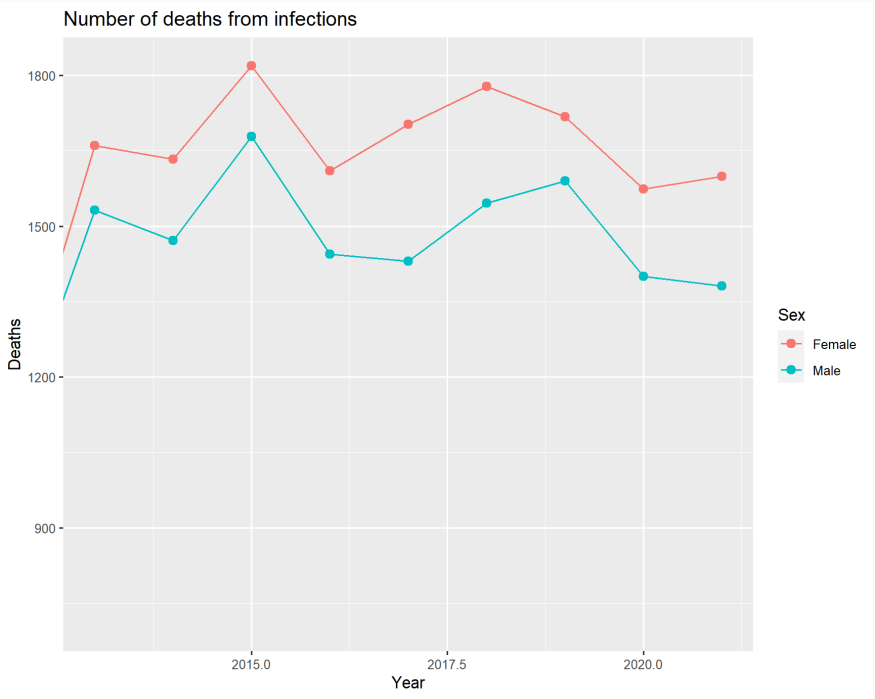


Cartesian coordinates: zooming in

When we plot a chart using ggplot2, Cartesian Coordinates is the default coordinate system.

```
Death_in_NL %>%
  filter(Age == "Total", CausesOfDeath == "Infections")%>%
  ggplot(aes(x = Year, y = Deaths, color = Sex))+
  geom_path()+
  geom_point(size = 2.5)+
  coord_cartesian(xlim = c(2013, 2021))+
  ggtitle("Number of deaths from infections")
```

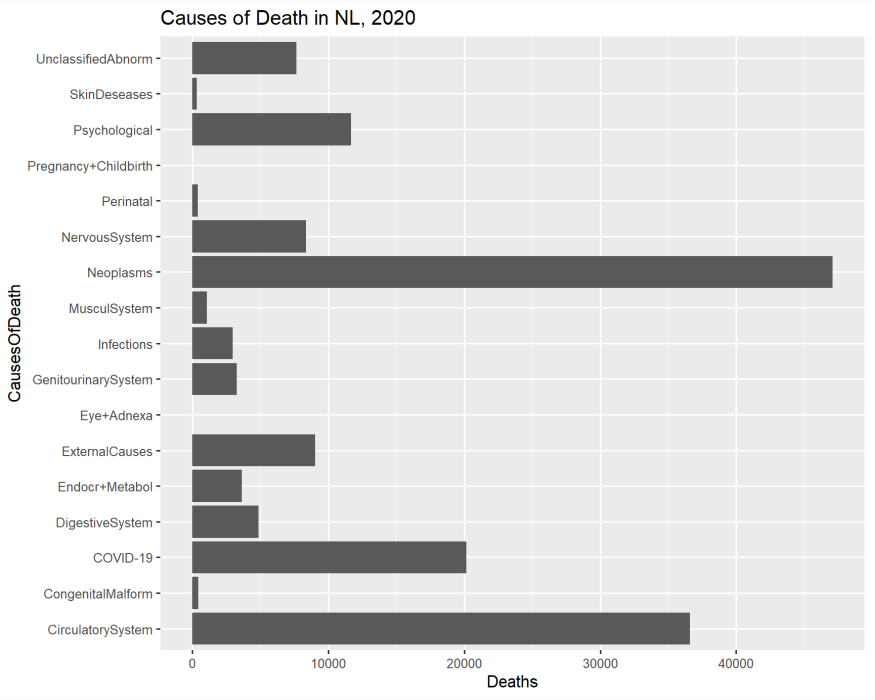
But you can still set it specifying parameters, for example, to zoom in the plot display.



Flipped cartesian coordinates

It is convenient to flip the axes when the name of the groups on the x axis is long.

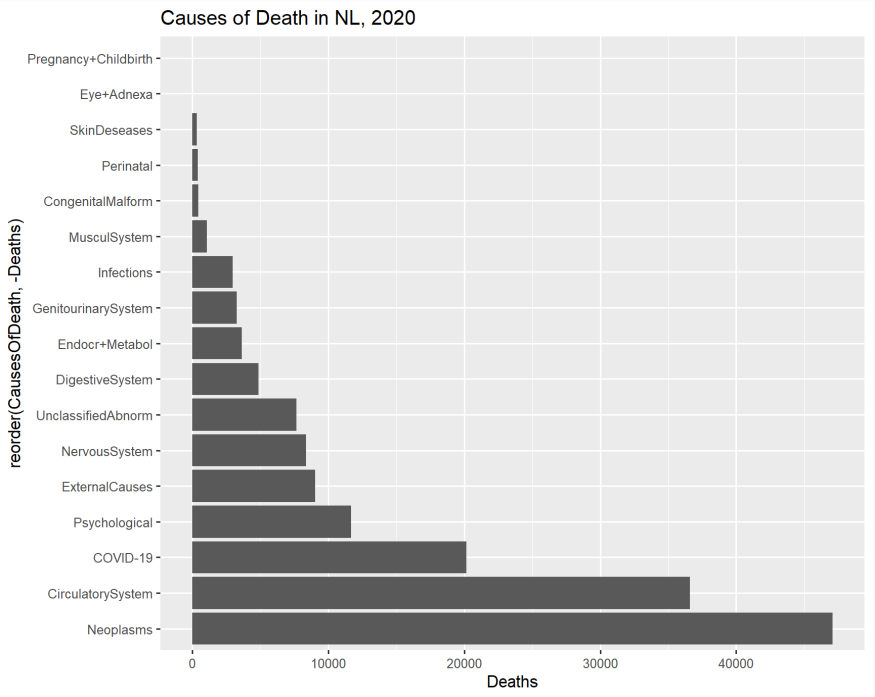
```
Death_in_NL%>%
  filter(Year == 2020, Age == "Total")%>%
  ggplot(aes(x = CausesOfDeath, y = Deaths))+
  geom_col()+
  coord_flip()+
  ggtitle("Causes of Death in NL, 2020")
```



Change the order of the groups on the axis

You might also need to change the order of unordered categorical data on the axis.

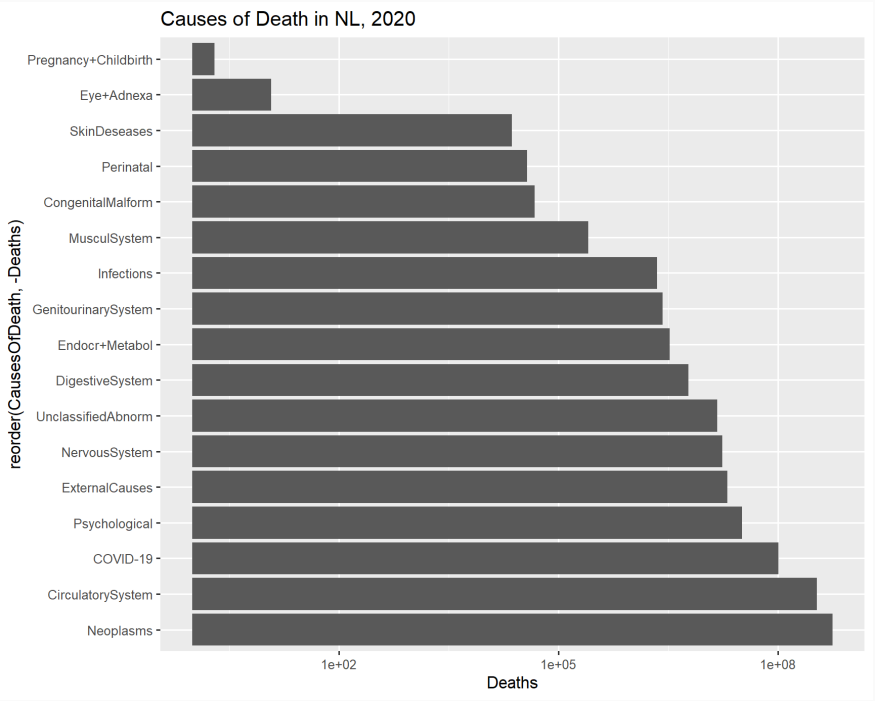
```
Death_in_NL%>%
  filter(Year == 2020, Age == "Total")%>%
  ggplot(aes(x = reorder(CausesOfDeath, -Deaths), y = Deaths))+
  geom_col()+
  coord_flip()+
  ggtitle("Causes of Death in NL, 2020")
```



Change an axis scale

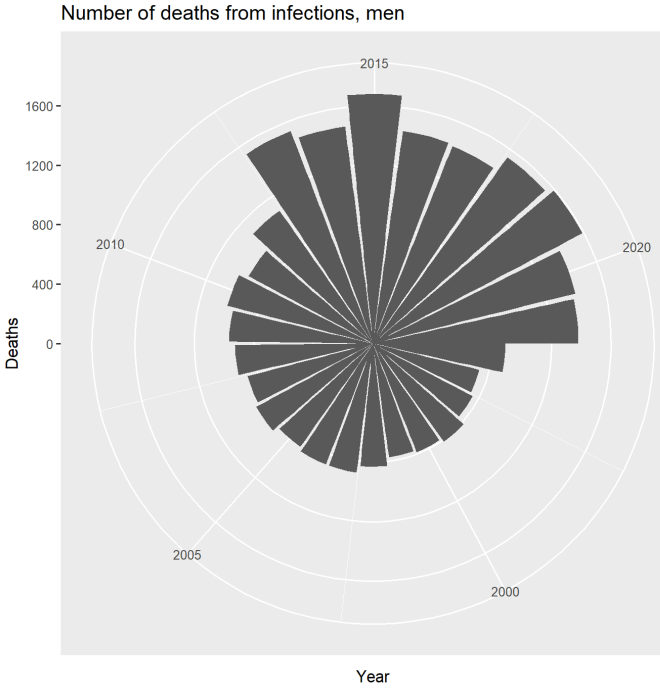
```
Death_in_NL%>%
  filter(Year == 2020, Age == "Total")%>%
  ggplot(aes(x = reorder(CausesOfDeath, -Deaths), y = Deaths))+
  geom_col()+
  coord_flip()+
  scale_y_log10()+
  ggtitle("Causes of Death in NL, 2020")
```

You can learn more about specifying the axes here



Polar coordinates

```
Death_in_NL %>%
  filter(Age == "Total", Sex == "Male", CausesOfDeath == "Infections")%>%
  ggplot(aes(x = Year, y = Deaths))+
  geom_col()+
  coord_polar(start = pi/2)+
  ggtitle("Number of deaths from infections, men")
```

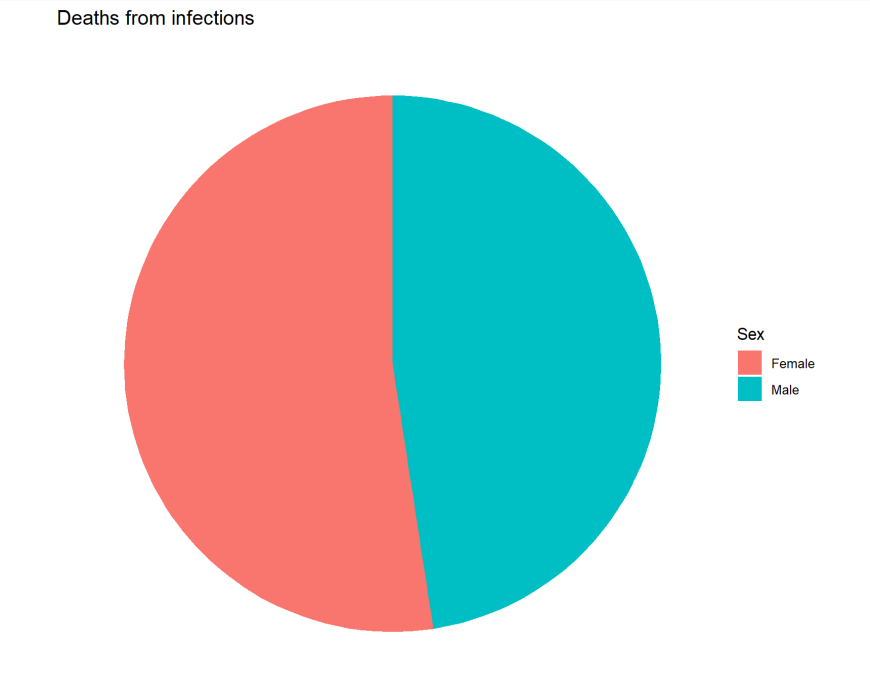


Polar coordinate system: pie chart

We use polar coordinate system to build pie charts

```
Death_in_NL %>%
  filter(Age == "Total", CausesOfDeath == "Infections")%>%
  ggplot(aes(x = "", y = Deaths, fill = Sex))+
  geom_col()+
  coord_polar("y", start = 0)+
  ggtitle("Deaths from infections")+
  theme_void() # remove background, grid, numeric labels
```

Here you can learn how to add the labels on the pie chart.



Facetted graphs

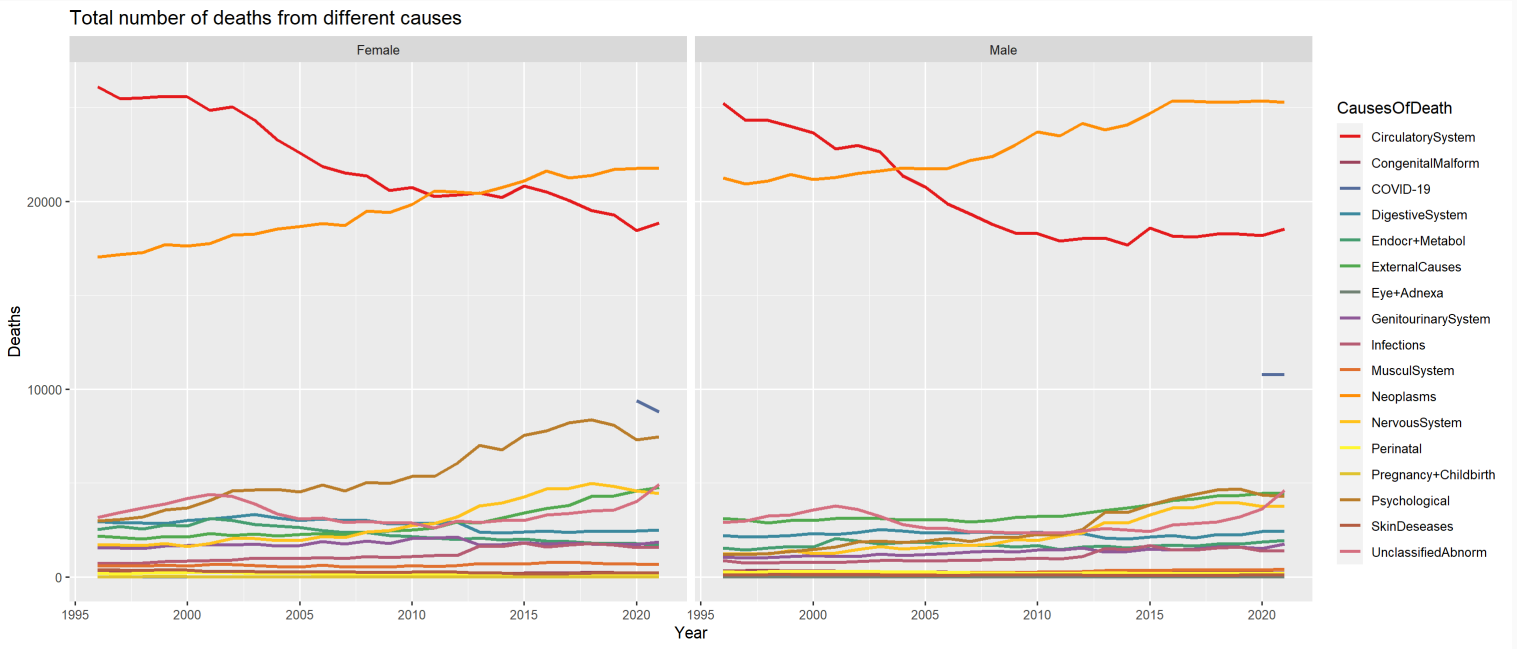
Vizualizing data slices, line plot

Code | Output

```
nb.cols ← 18
mycolors ← colorRampPalette(brewer.pal(8, "Set1"))(nb.cols)

Death_in_NL %>%
  filter(Age == "Total")%>%
  ggplot(aes(x = Year, y = Deaths, color = CausesOfDeath))+
  geom_path(linewidth = 1)+
  scale_colour_manual(values = mycolors)+
  ggtitle("Total number of deaths from different causes")+
  facet_wrap( ~ Sex)
```

Vizualizing data slices, line plot

Code | Output



Vizualizing data slices, heatmap

Code | Output

```
Death_in_NL %>%
  filter(CausesOfDeath == "Infections", Age =/= "Total") %>%
  ggplot(mapping = aes(x = Year, y = Age, fill = Deaths))+
  geom_tile()+
  scale_fill_viridis(discrete = FALSE)+
  ggtitle("Number of deaths from infections")+
  facet_wrap(~Sex)
```

Vizualizing data slices, heatmap

Code | Output

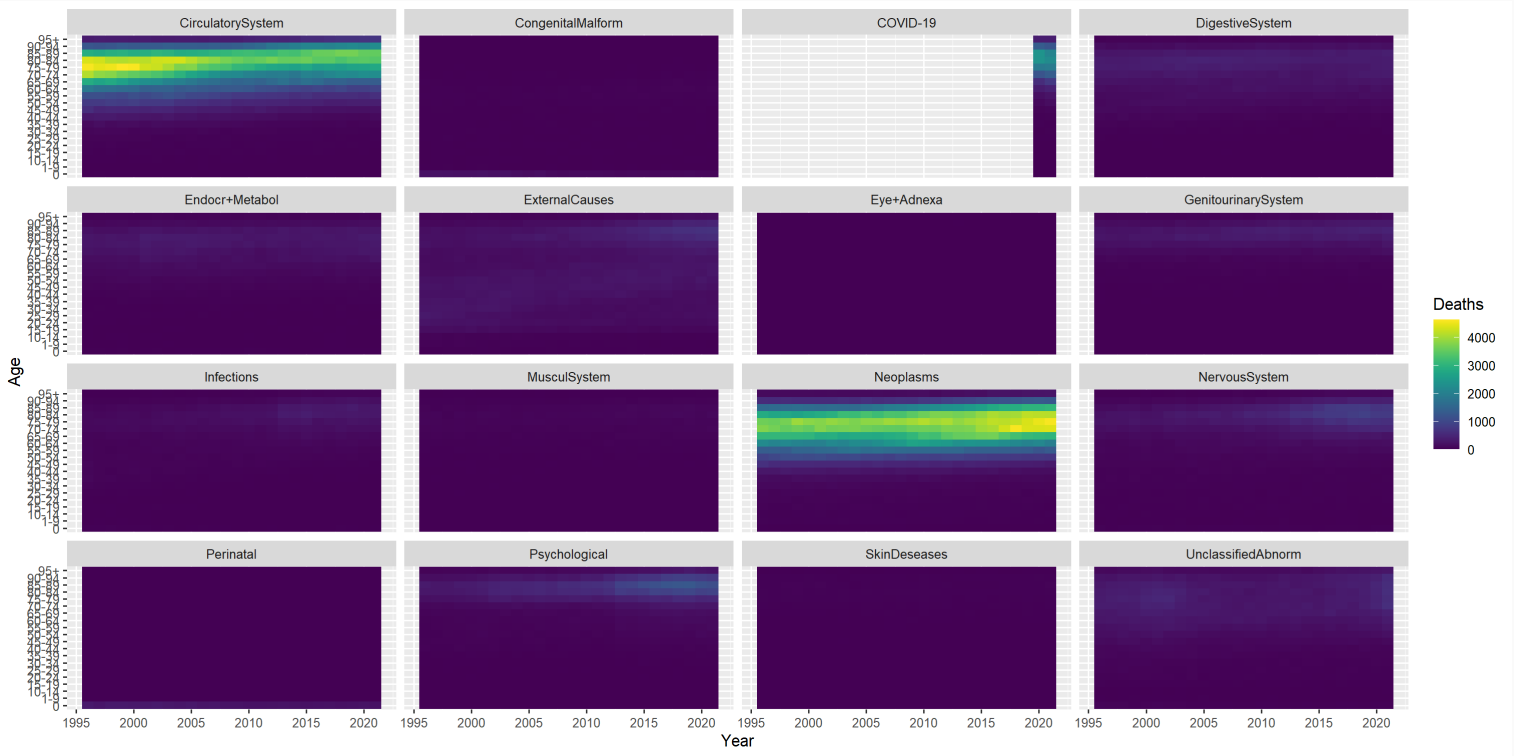
One can generate many facets of data

Code | Output

```
Death_in_NL %>%
  filter(Sex == "Male", Age =/= "Total") %>%
  ggplot(mapping = aes(x = Year, y = Age, fill = Deaths))+
  geom_tile()+
  scale_fill_viridis(discrete = FALSE)+
  facet_wrap(~CausesOfDeath)
```

One can generate many facets of data

Code | Output



Arrange multiple plots in a grid

You can use other packages to organize individual plots altogether. E.g `plot_grid` from `cowplot` package.

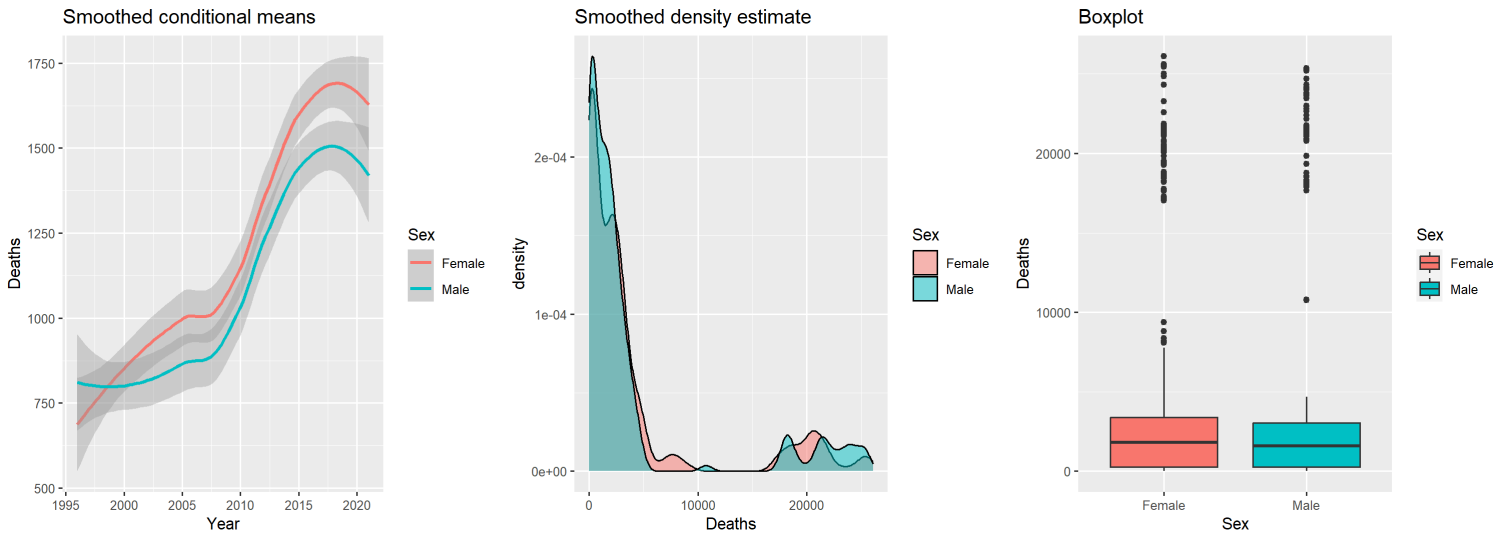
Code | Output

```
smoothp ← Death_in_NL %>%
  filter(CausesOfDeath == "Infections", Age == "Total") %>%
  ggplot(mapping = aes(x = Year, y = Deaths, color = Sex))+
  geom_smooth()+
  ggtitle("Smoothed conditional means")

boxp ← Death_in_NL %>%
  filter(Age == "Total") %>%
  ggplot(mapping = aes(x = Sex, y = Deaths, fill = Sex))+
  geom_boxplot()+
  ggtitle("Boxplot")

denp ← Death_in_NL %>%
  filter(Age == "Total") %>%
  ggplot(aes(x = Deaths, fill = Sex))+
  geom_density(alpha = 0.5)+
  ggtitle("Smoothed density estimate")

plot_grid(smoothp, denp, boxp, ncol = 3, label_size = 12)
```

Arrange multiple plots in a grid

You can use other packages to organize individual plots altogether. E.g `plot_grid` from `cowplot` package.

Code | Output



Statistics layer

Two categories of functions:

- called from within a geom
- called independently

Statistics layer

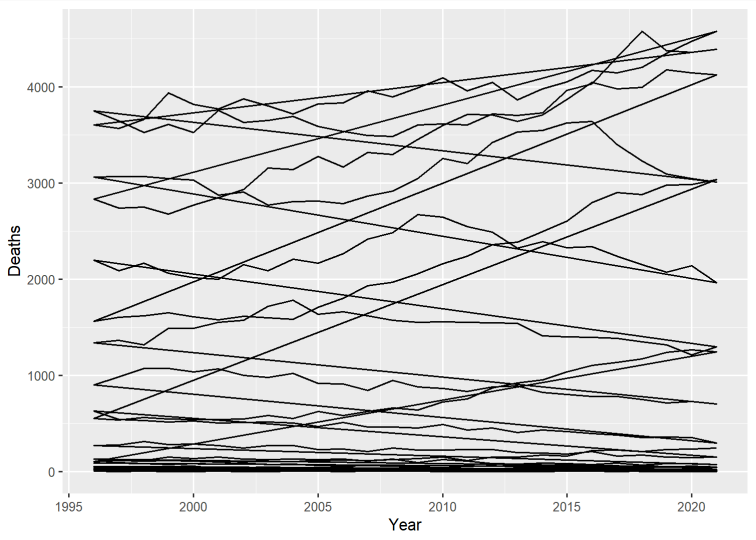
Two categories of functions:

- called from within a geom
- called independently

All the statistics functions called independently starts with *stat_*

Some geoms have built-in statistical methods

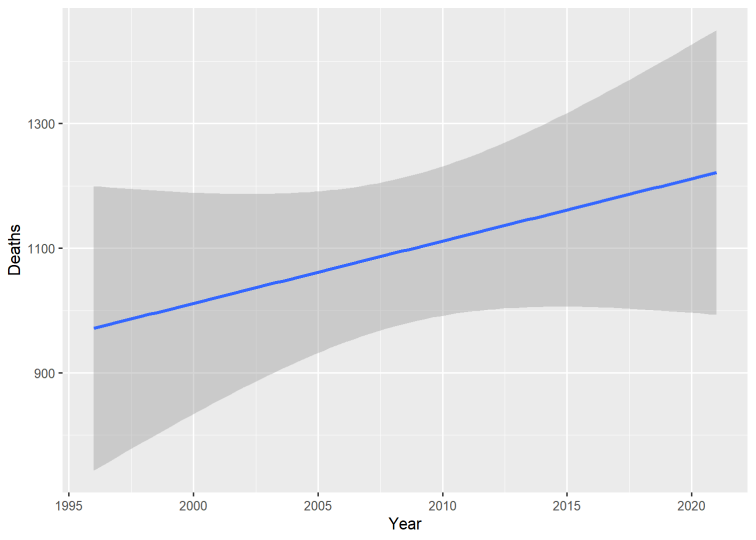
```
Death_in_NL%>%
  filter(CausesOfDeath == "Neoplasms", Sex == "Male", Age != "Total")%>%
  ggplot(aes(x = Year, y = Deaths))+
    geom_path()
```



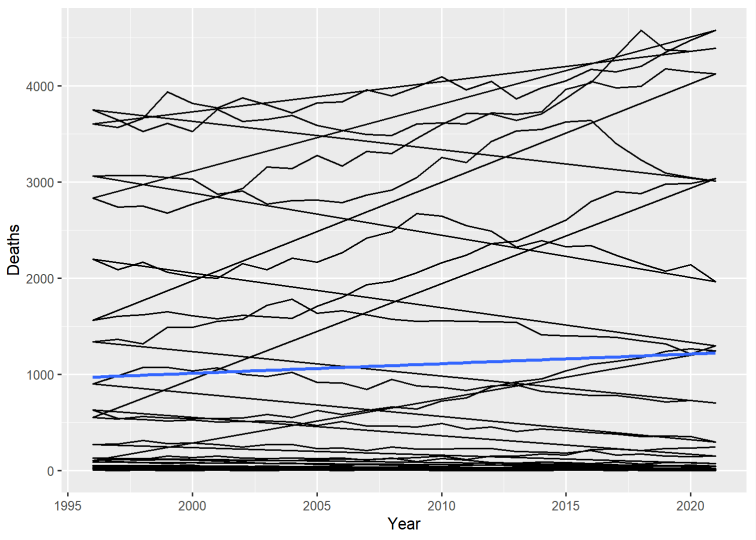

```
Death_in_NL%>%
  filter(CausesOfDeath == "Neoplasms", Sex == "Male", Age != "Total")%>%
  ggplot(aes(x = Year, y = Deaths))+
    geom_smooth()
```

Adjusting statistical methods in geom

```
Death_in_NL%>%
  filter(CausesOfDeath == "Neoplasms", Sex == "Male", Age != "Total")%>%
  ggplot(aes(x = Year, y = Deaths))+
    geom_smooth(method = "lm",
                formula = y ~ x)
```




```
Death_in_NL%>%
  filter(CausesOfDeath == "Neoplasms", Sex == "Male", Age != "Total")%>%
  ggplot(aes(x = Year, y = Deaths))+
    geom_path()+
    geom_smooth(method = "lm", se = FALSE)
```



Showing statistical estimates on a plot

Lets draw a bar plot with error bars using `geom_errorbar()` function. Lets use the annual data as independent observations.

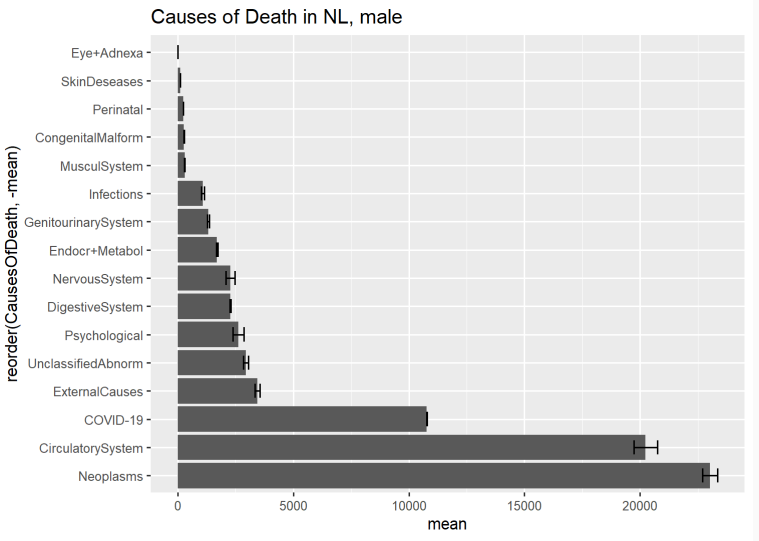
Note: the lower and upper limits of your error bars must be computed before building the chart, and available in a column of the input data.

```
data_stat ← Death_in_NL%>%
  filter(Sex == "Male", Age == "Total")%>%
    group_by(CausesOfDeath)%>%
    summarize(mean = mean(Deaths),
              se = sd(Deaths)/sqrt(n()),
              max = mean + se,
              min = mean - se,
              N = n())
```

CausesOfDeath	mean	se	max	min	N
COVID-19	10772.500000	8.500000	10781.00000	10764.000000	2
CirculatorySystem	20239.038462	502.475639	20741.51410	19736.562823	26
CongenitalMalform	266.538461	8.748139	275.28660	257.790322	26
DigestiveSystem	2284.076923	24.724570	2308.80149	2259.352353	26
Endocr+Metabol	1702.923077	29.283649	1732.20673	1673.639428	26
ExternalCauses	3440.961539	105.080445	3546.04198	3335.881093	26
Eye+Adnexa	2.538461	0.509089	3.04755	2.029373	26
GenitourinarySystem	1324.153846	39.444048	1363.59789	1284.709798	26
Infections	1090.884615	61.835970	1152.72059	1029.048646	26
MusculSystem	297.923077	11.546151	309.46923	286.376926	26
Neoplasms	23028.653846	325.132593	23353.78644	22703.521253	26
NervousSystem	2282.615385	197.962095	2480.57748	2084.653290	26
Perinatal	239.423077	8.353935	247.77701	231.069142	26
Psychological	2620.461539	235.839275	2856.30081	2384.622263	26
SkinDeseases	108.384615	3.596185	111.98080	104.788431	26
UnclassifiedAbnorm	2941.307692	110.288486	3051.59618	2831.019207	26

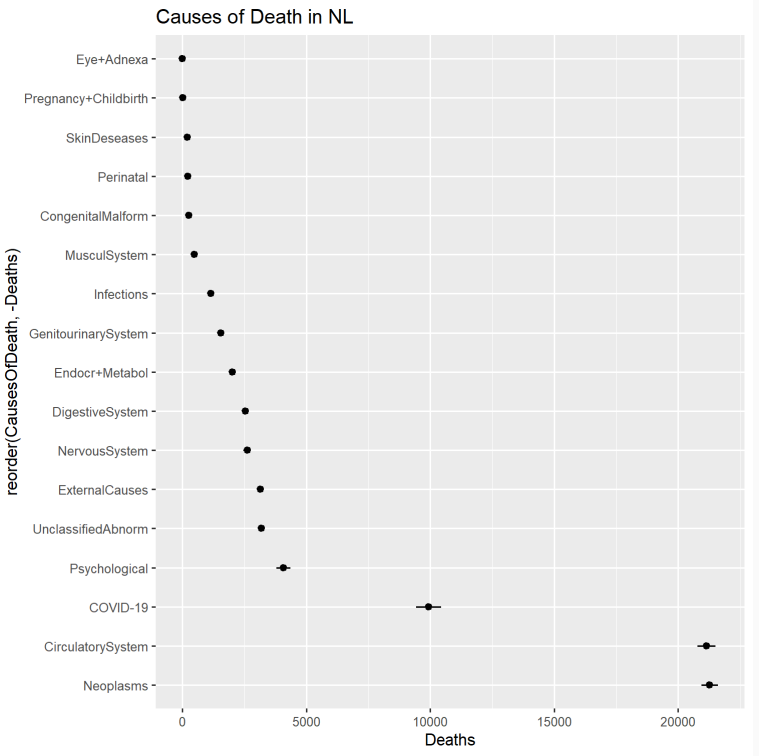
Bar Plot with error bars

```
data_stat%>%
  ggplot(aes(x = reorder(CausesOfDeath, -mean), y = mean, ymin = min, ymax
  geom_col()+
  coord_flip()+
  geom_errorbar(width =0.5)+
  ggtitle("Causes of Death in NL, male")
```



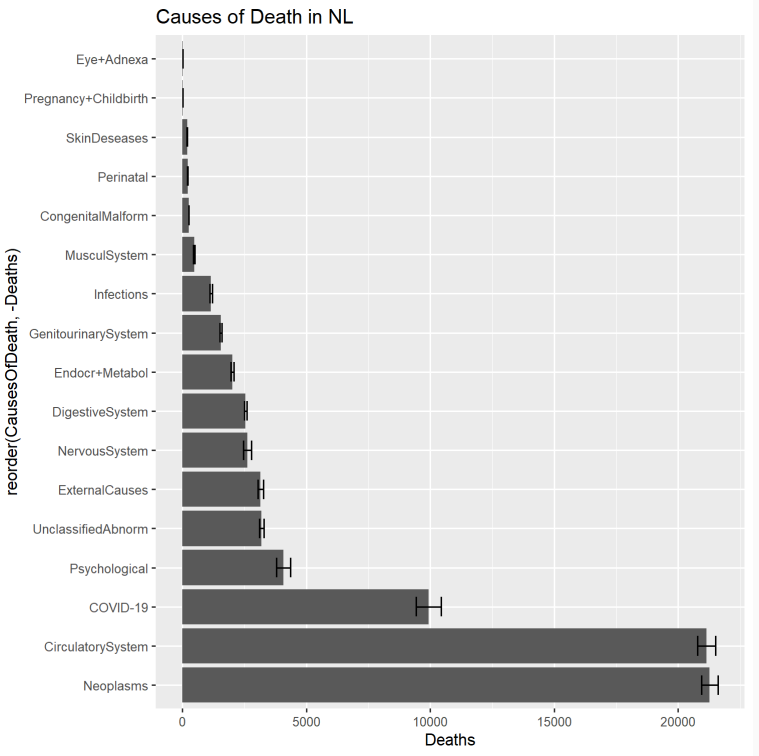
Use of statistical functions in ggplot2

```
Death_in_NL%>%
  filter(Age == "Total")%>%
  ggplot(aes(x = reorder(CausesOfDeath, -Deaths), y = Deaths))+
  stat_summary(size = 0.3)+
  coord_flip()+
  ggtitle("Causes of Death in NL")
```



Use of *stat_summary* in ggplot2

```
Death_in_NL%>%
  filter(Age == "Total")%>%
  ggplot(aes(x = reorder(CausesOfDeath, -Deaths), y = Deaths))+
  stat_summary(fun.data = "mean_se", geom = "bar")+
  stat_summary(fun.data = "mean_se", geom = "errorbar", width = 0.5)+
  coord_flip()+
  ggtitle("Causes of Death in NL")
```



Saving the plot

You can use `ggsave()` to save the vizualization in the format and resolution you wish.

```
?ggsave
```

```
ggsave(
  filename,
  plot = last_plot(),
  device = NULL,
  path = NULL,
  scale = 1,
  width = NA,
  height = NA,
  units = c("in", "cm", "mm", "px"),
  dpi = 300,
  limitsize = TRUE,
  bg = NULL,
  ...
)
```

```
ggsave(filename= "figs/BarPlotSD.png", device = png, width = 10, height = 10, units = "cm")
```

Your turn

Using the `Death_in_NL` dataset, build the following two visualizations:

1) What is the age profile of the number of deaths from external causes (not a disease) in NL? Is there any difference between men and women?

2) How has the number of perinatal deaths in the Netherlands changed over time?

You will need this information to complete the quiz in the brightspace (to be done after Tutorial 3).