Review of R and RStudio

EES 4891-06/5891-01

Bayesian Statistical Methods

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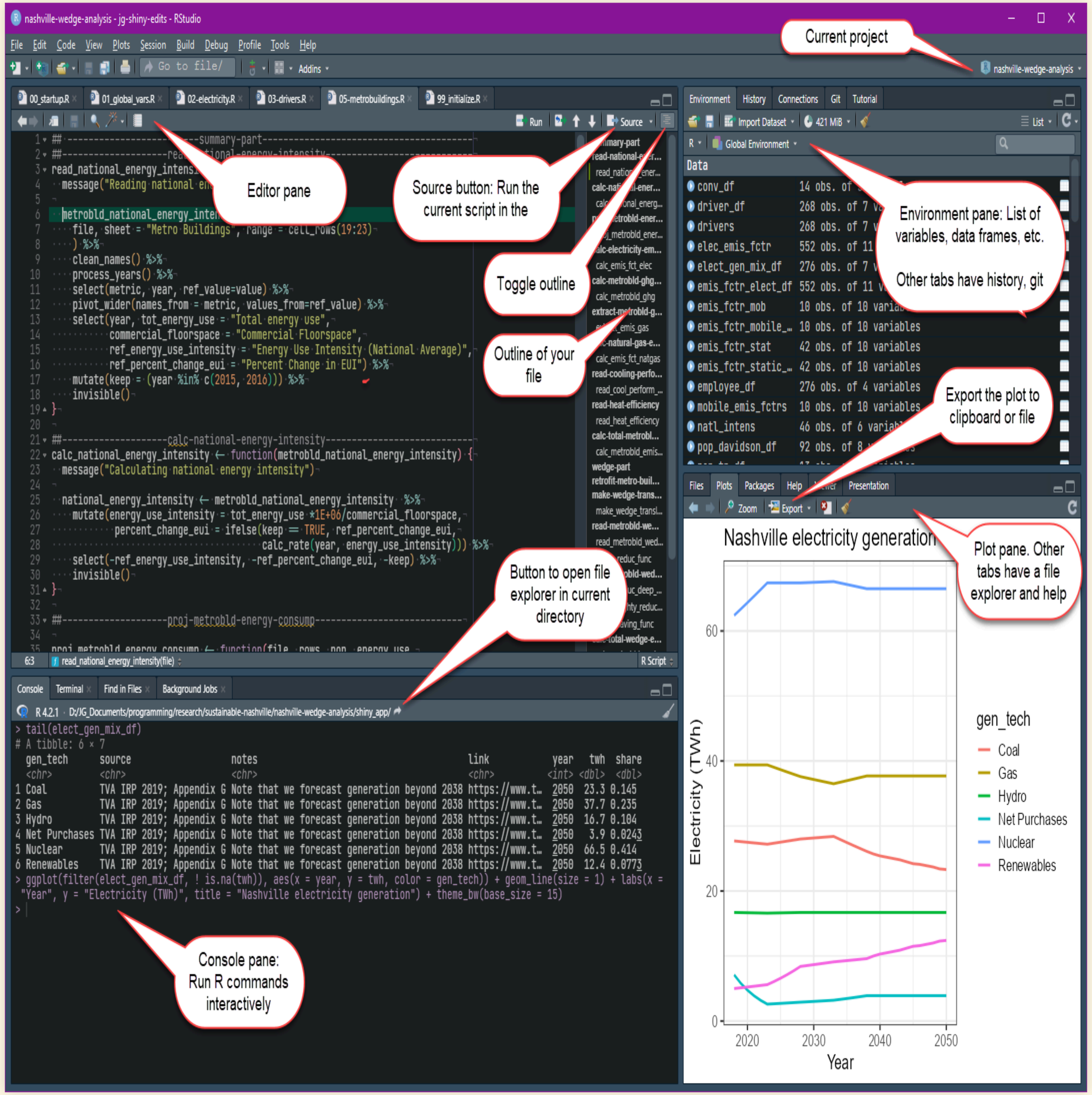
Class #4: Wednesday, January 14 2026

Overview of Rstudio

RStudio Window layout

- Project oriented
  - A project is a directory with a group of related files (R, data, etc.)
  - A project can be managed with `git` for revision control
  - Create a new project:
    - Create a new directory for a project
    - Create a project in an existing directory
    - Download a project from GitHub or another external source, using `git`
- Online help and cheat-sheets
- Window layout
  - Four panes:
    1. Editor pane (edit R scripts, text files, etc.)
    2. Console and Terminal pane (interactively run R commands, etc.)
    3. Files, Plots, Packages, Help, etc.
       - You can export plots to the clipboard or files.
    4. Environment, History, Git, etc.



Current project

Editor pane

Source button: Run the current script in the

Toggle outline

Outline of your file

Environment pane: List of variables, data frames, etc.

Other tabs have history, git

Export the plot to clipboard or file

Plot pane. Other tabs have a file explorer and help

Button to open file explorer in current directory

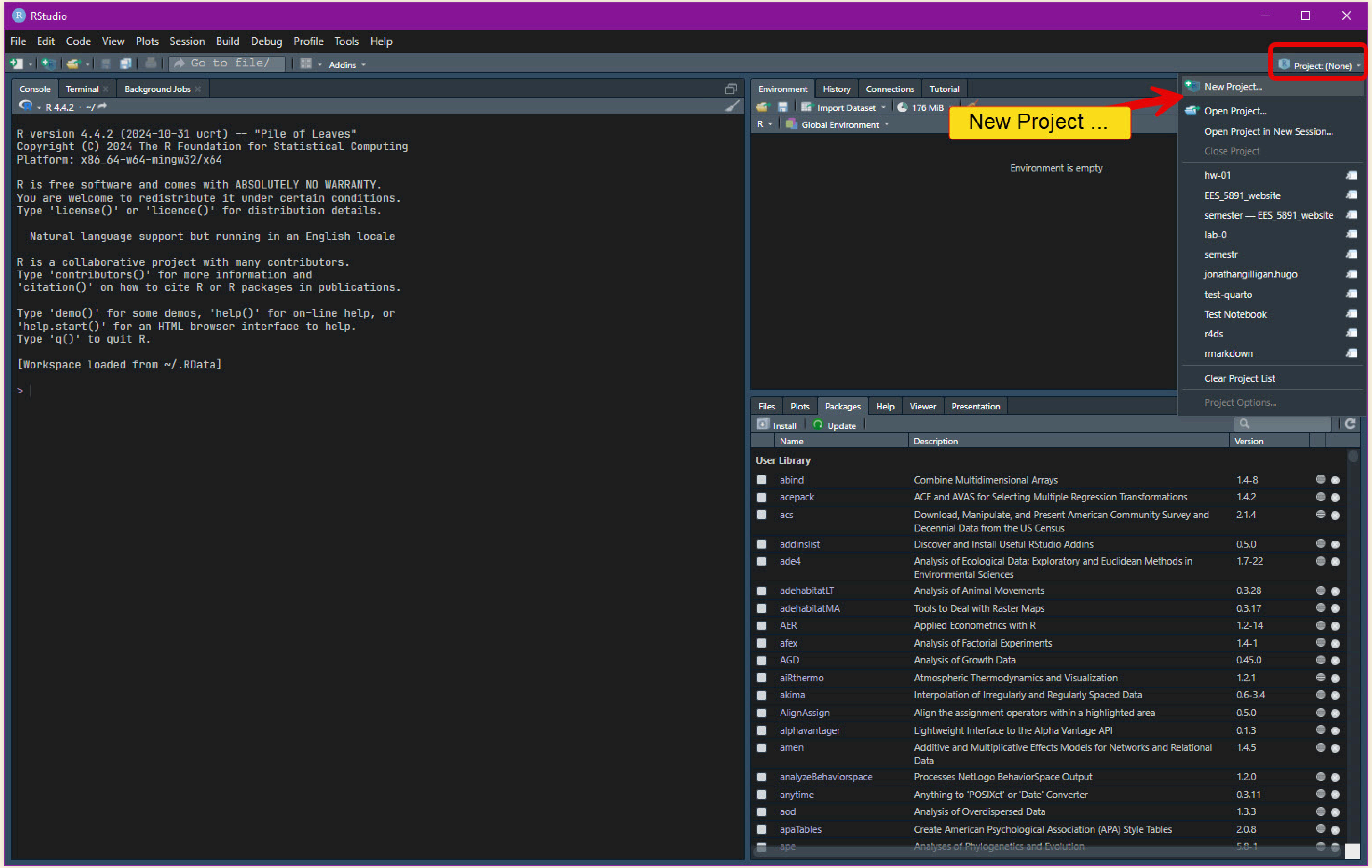
Console pane: Run R commands interactively

```r
## ----------------------summary-part----------------------------------
##-------------------rea    tional-energy-intensity------------------------
read_national_energy_intens
  message("Reading national en

  metrobld_national_energy_inten
    file, sheet = "Metro Buildings", range = cell_rows(19:23)
    ) %>%
    clean_names() %>%
    process_years() %>%
    select(metric, year, ref_value=value) %>%
    pivot_wider(names_from = metric, values_from=ref_value) %>%
    select(year, tot_energy_use = "Total energy use",
           commercial_floorspace = "Commercial Floorspace",
           ref_energy_use_intensity = "Energy Use Intensity (National Average)",
           ref_percent_change_eui = "Percent Change in EUI") %>%
    mutate(keep = (year %in% c(2015, 2016))) %>%
    invisible()
}

##-------------------calc-national-energy-intensity------------------------
calc_national_energy_intensity ← function(metrobld_national_energy_intensity) {
  message("Calculating national energy intensity")

  national_energy_intensity ← metrobld_national_energy_intensity  %>%
    mutate(energy_use_intensity = tot_energy_use *1E+06/commercial_floorspace,
           percent_change_eui = ifelse(keep == TRUE, ref_percent_change_eui,
                                       calc_rate(year, energy_use_intensity))) %>%
    select(-ref_energy_use_intensity, -ref_percent_change_eui, -keep) %>%
    invisible()
}

##-------------------proj-metrobld-energy-consump---------------------------

proj_metrobld_energy_consump ← function(file, rows, pop, energy_use,
```

```
Data
conv_df            14 obs. of
driver_df          268 obs. of 7 va
drivers            268 obs. of 7 v
elec_emis_fctr     552 obs. of 11
elect_gen_mix_df   276 obs. of 7 v
emis_fctr_elect_df 552 obs. of 11 v
emis_fctr_mob      10 obs. of 10 varia
emis_fctr_mobile_… 10 obs. of 10 variables
emis_fctr_stat     42 obs. of 10 variables
emis_fctr_static_… 42 obs. of 10 variables
employee_df        276 obs. of 4 variables
mobile_emis_fctrs  10 obs. of 10 variables
natl_intens        46 obs. of 6 variab
pop_davidson_df    92 obs. of 8
```

```
R 4.2.1 · D:/JG_Documents/programming/research/sustainable-nashville/nashville-wedge-analysis/shiny_app/
> tail(elect_gen_mix_df)
# A tibble: 6 × 7
  gen_tech      source                notes                                link                 year   twh  share
  <chr>         <chr>                 <chr>                                <chr>               <int> <dbl>  <dbl>
1 Coal          TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050  23.3 0.145
2 Gas           TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050  37.7 0.235
3 Hydro         TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050  16.7 0.104
4 Net Purchases TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050   3.9 0.0243
5 Nuclear       TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050  66.5 0.414
6 Renewables    TVA IRP 2019; Appendix G Note that we forecast generation beyond 2038 https://www.t…  2050  12.4 0.0773
> ggplot(filter(elect_gen_mix_df, ! is.na(twh)), aes(x = year, y = twh, color = gen_tech)) + geom_line(size = 1) + labs(x =
 "Year", y = "Electricity (TWh)", title = "Nashville electricity generation") + theme_bw(base_size = 15)
>
```

Creating an RStudio Project

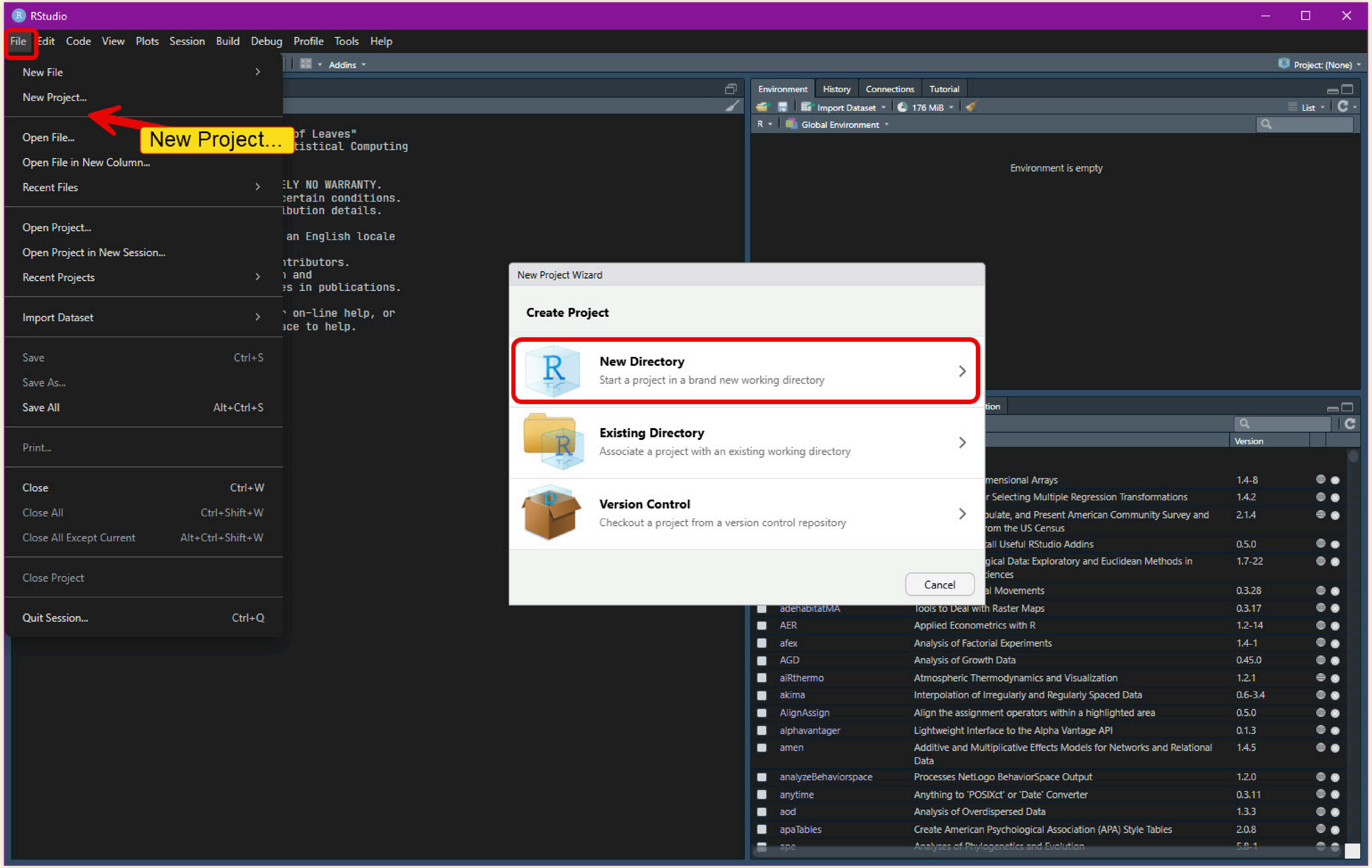


New Project ...

```
R version 4.4.2 (2024-10-31 ucrt) -- "Pile of Leaves"
Copyright (C) 2024 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Workspace loaded from ~/.RData]

>
```

	Name	Description	Version
User Library			
□	abind	Combine Multidimensional Arrays	1.4-8
□	acepack	ACE and AVAS for Selecting Multiple Regression Transformations	1.4.2
□	acs	Download, Manipulate, and Present American Community Survey and Decennial Data from the US Census	2.1.4
□	addinslist	Discover and Install Useful RStudio Addins	0.5.0
□	ade4	Analysis of Ecological Data: Exploratory and Euclidean Methods in Environmental Sciences	1.7-22
□	adehabitatLT	Analysis of Animal Movements	0.3.28
□	adehabitatMA	Tools to Deal with Raster Maps	0.3.17
□	AER	Applied Econometrics with R	1.2-14
□	afex	Analysis of Factorial Experiments	1.4-1
□	AGD	Analysis of Growth Data	0.45.0
□	aiRthermo	Atmospheric Thermodynamics and Visualization	1.2.1
□	akima	Interpolation of Irregularly and Regularly Spaced Data	0.6-3.4
□	AlignAssign	Align the assignment operators within a highlighted area	0.5.0
□	alphavantager	Lightweight Interface to the Alpha Vantage API	0.1.3
□	amen	Additive and Multiplicative Effects Models for Networks and Relational Data	1.4.5
□	analyzeBehaviorspace	Processes NetLogo BehaviorSpace Output	1.2.0
□	anytime	Anything to 'POSIXct' or 'Date' Converter	0.3.11
□	aod	Analysis of Overdispersed Data	1.3.3
□	apaTables	Create American Psychological Association (APA) Style Tables	2.0.8
□	ape	Analyses of Phylogenetics and Evolution	5.8-1

Creating an RStudio Project



```
of Leaves"
tistical Computing

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ntributors.
n and
es in publications.

 on-line help, or
ace to help.
```

		Version
	mensional Arrays	1.4-8
	r Selecting Multiple Regression Transformations	1.4.2
	pulate, and Present American Community Survey and rom the US Census	2.1.4
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apaTables	Create American Psychological Association (APA) Style Tables	2.0.8
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R Language

R Language

- R is flexible
- Two approaches
  - Base R
    - Very flexible and powerful
    - Sometimes confusing and verbose
    - Nothing special about data frames (`data.frame`)
  - Tidyverse (`library(tidyverse)`)
    - Unified philosophy of data analysis
      - Canonical reference: R for Data Science
      - Oriented toward `data.frames` (and `tibbles`)
      - Principles of “Tidy Data”
      - Consistent approach makes it easy to figure out how to do what you want to do.
      - Download extensive cheat-sheets via RStudio help menu.

Working with Data

- R data types:
  - `integer`, `numeric` (real), `character`, `logical`, `factor`, …
- R data structures:
  - 1-dim: `vector`, `list`
  - 2-dim: `matrix`, `data.frame`, …
  - *n*-dim: `array`
  - Data types:
    - `vector`, `array`, `matrix`: elements must be the same type
    - `list`: elements can be different types
  - `data.frame`, `tibble`:
    - Like a spreadsheet or database table.
      - A `list` of `vectors`:
      - Each column is a `vector` representing a variable:
        - height, weight, …
        - Each column can be a different type.
      - Each row is a set of related measurements for a given person (height, weight, …).

- Anthropometric data: !Kung San people

```
library(tidyverse)
library(tidybayes)
library(rethinking)
library(tidybayes.rethinking)

data(Howell1)
d <- tibble(Howell1)
head(d)
```

```
## # A tibble: 6 × 4
##   height weight   age  male
##    <dbl>  <dbl> <dbl> <int>
## 1   152.   47.8    63     1
## 2   140.   36.5    63     0
## 3   137.   31.9    65     0
## 4   157.   53.0    41     1
## 5   145.   41.3    51     0
## 6   164.   63.0    35     1
```

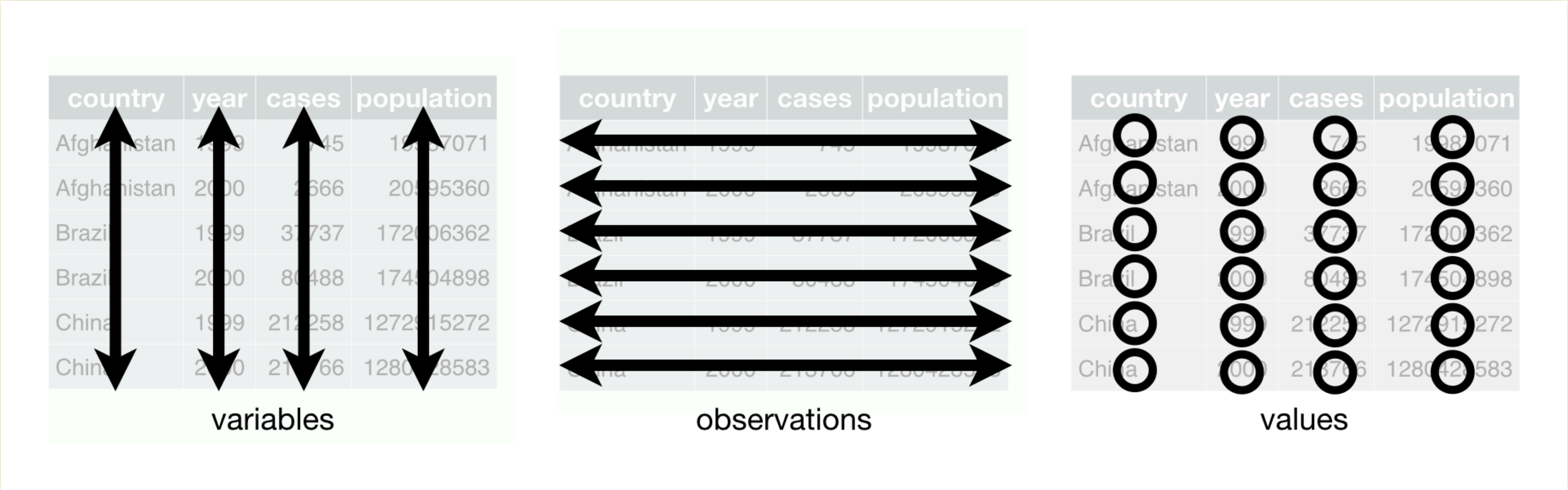
```
precis(d)
```

```
##               mean         sd      5.5%
94.5%
## height 138.2635963 27.6024476 81.108550
165.73500
## weight  35.6106176 14.7191782  9.360721
54.50289
## age     29.3443934 20.7468882  1.000000
66.13500
## male     0.4724265  0.4996986  0.000000
1.00000
##              histogram
## height ▁▁▁▁▁▁▁▂▁▇▇▅▁
## weight ▁▂▃▂▂▂▂▅▇▇▃▂▁
## age        ▇▅▅▃▅▂▂▁▁
## male      ▇▁▁▁▁▁▁▁▁▇
```

Data Structures

Data Structures

- **Data** is represented as a `data.frame`, or a special kind of data frame called a `tibble` (for “Tidy Table”)
  - A `data.frame` is like a spreadsheet.
  - Each column represents a different variable (year, month, temperature, rainfall, humidity, etc.)
  - Each row represents a different measurement of all the variables.



- Columns can be different data types (integer, numeric, character, logical, factor, ...)
- All rows of a column are the same type

Data

- Base R
  - Separate 1-dimensional lists or vectors of data
  - 2D (or higher) arrays: `data.frame`, `matrix`, `array`
  - Index rows and columns:
    - Indexing starts at 1
      - Like Matlab, unlike Python, which starts at 0
    - `Howell1[107,]` for all columns of the row
    - `Howell1[,"height"]` for all rows of the "height" column
    - `Howell1[10:15, c(1, 3, 4)]` to get rows 10–15 of columns 1, 3, and 4.
    - `Howell1["age" >= 18, c("height", "weight")]`

- Tidyverse (`library(tidyverse)`)
  - `data.frame` or `tibble`
  - Select columns:

```
select(Howell1, height, weight, age)
select(Howell1, -male, -age)
```

    - Select all columns that start with "`foo_`" but don't end with "`bar`"

```
select(my_data, starts_with("foo_"),
       -ends_with("bar"))
```

  - Select rows:

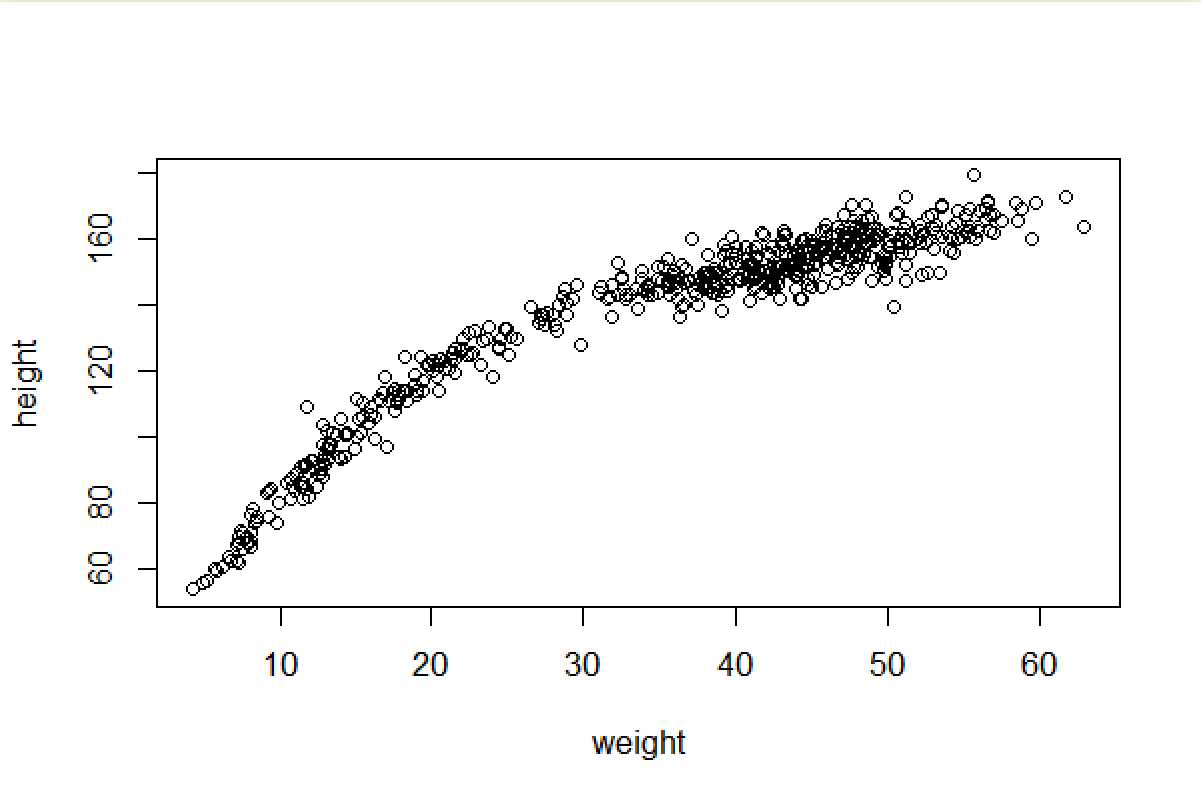
```
filter(Howell1, age >= 18, male)
```

Graphics

- Base R
  - plot command

```
plot(x, y) # plot y vs. x with points
plot(x, y, type = "l") # plot with a line
```

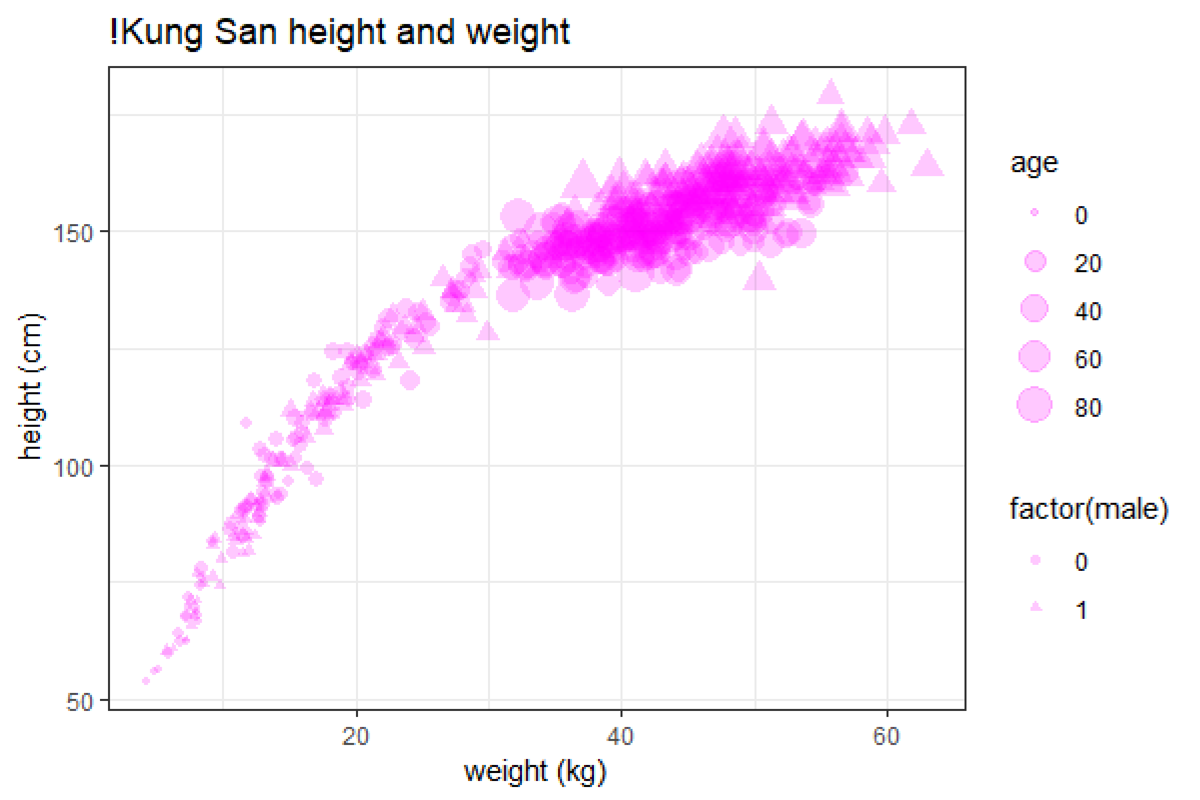
```
plot(height ~ weight, data = Howell1) # with a data.frame
```



- Tidyverse
  - ggplot command

```
ggplot(Howell1, aes(x = weight, y = height)) +
  geom_point() +
  labs(x = "weight (kg)", y = "height (cm)",
    title = "!Kung San height and weight")
```

```
ggplot(Howell1, aes(x = weight, y = height)) +
  geom_point(aes(shape = factor(male), size = age),
             color = "magenta", alpha=0.2) +
  labs(x = "weight (kg)", y = "height (cm)",
    title = "!Kung San height and weight") +
  theme_bw()
```

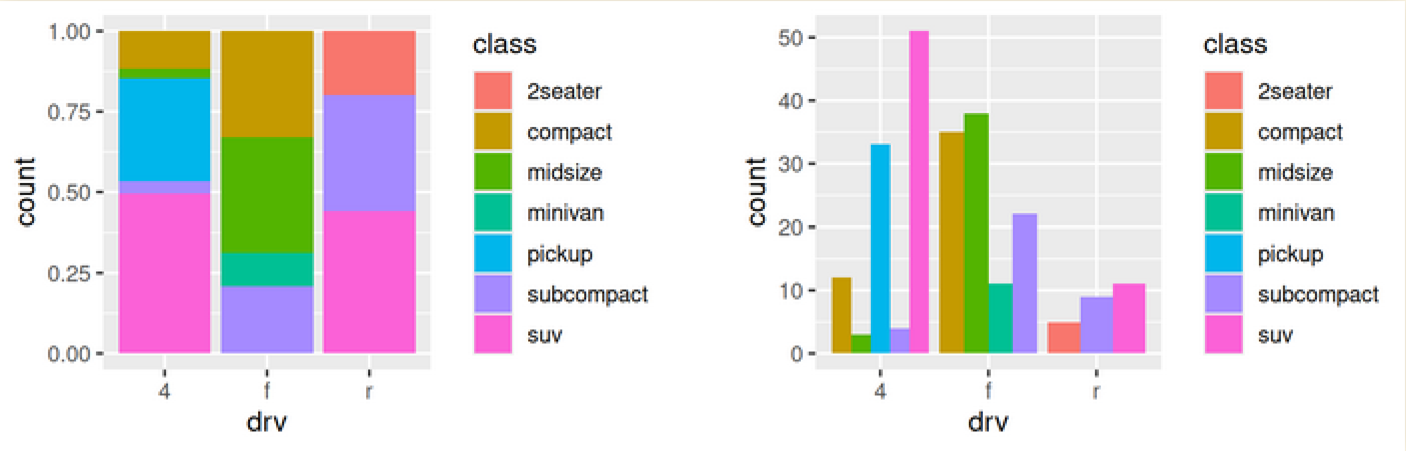


Grammar of Graphics

Grammar of Graphics

- The heart of data visualization in the Tidyverse is the `ggplot2` package.
  - `gg` from Leland Wilkinson, *The Grammar of Graphics*
- A graph has a grammar, which can be expressed in terms of 7 layers

1. **Data**
2. **Geometries:** How to draw the data (Lines, points, etc.)
3. **Aesthetics:** How to mapping different dimensions of the data to visual attributes (x & y coordinates, colors, shape, etc.)
4. **Statistical transformations:** histograms, smoothing, box-plots, etc.
5. **Position adjustments:** e.g., side-by-side versus stacked bar charts



6. **Coordinate systems:** Cartesian vs. polar, pie charts, etc.
7. **Facets:** Breaking a graph into sub-plots.

Grammar of Graphics in R

- To start a graph, specify the data and aesthetics:

```
ggplot(Howell1, aes(x = weight, y = height))
```

- Next, we add geometries

```
ggplot(Howell1, aes(x = weight, y = height)) +
geom_point(alpha = 0.2)
```

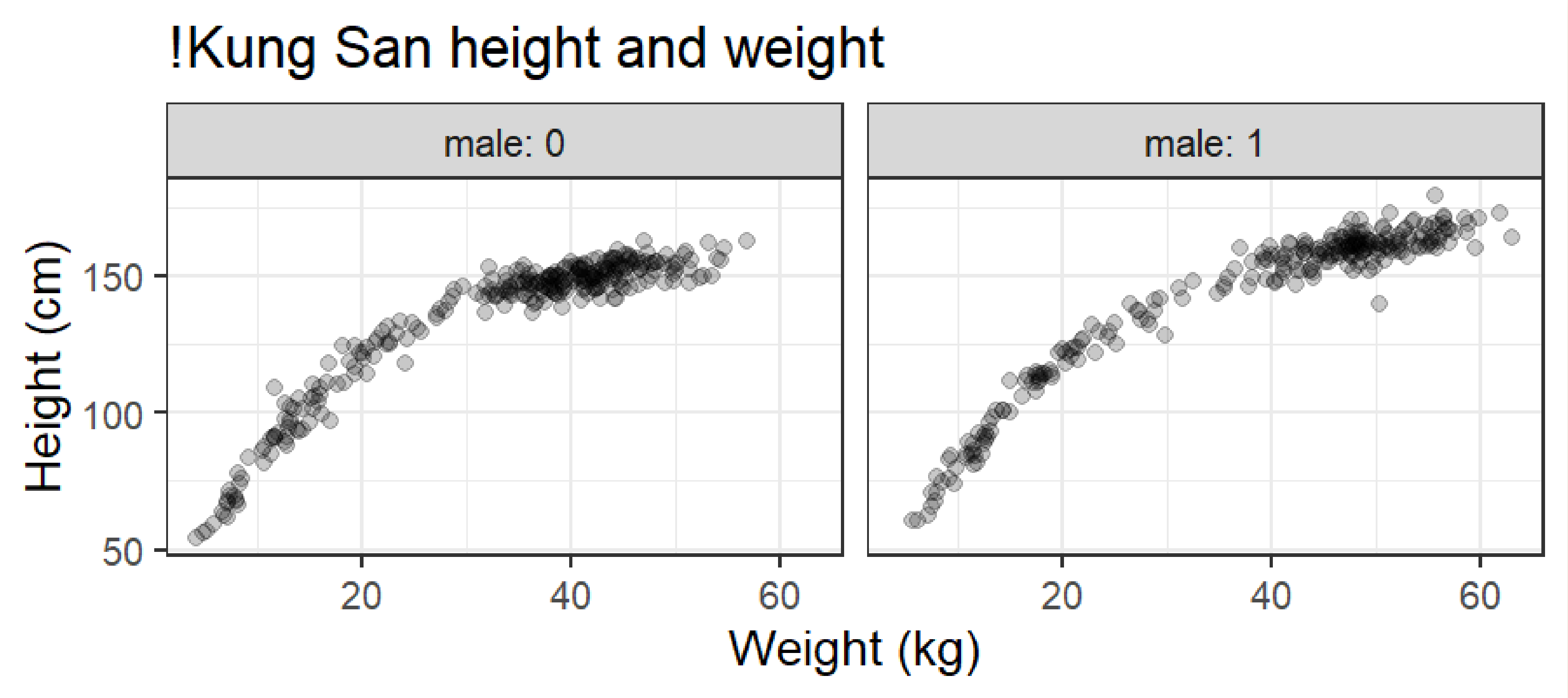
`alpha` makes the points semi-transparent

- Label coordinates

```
ggplot(Howell1, aes(x = weight, y = height)) +
geom_point(alpha = 0.2) +
labs(x = "Weight (kg)", y = "Height (cm)",
     title = "!Kung San height and weight")
```

- Use facets to separate males and females

```
ggplot(Howell1, aes(x = weight, y = height)) +
geom_point(alpha = 0.2) +
labs(x = "Weight (kg)", y = "Height (cm)",
     title = "!Kung San height and weight") +
facet_wrap(~male, labeller = "label_both")
```



Jura Data Set

Jura Data Set

Transforming Rows

- Survey of soil contamination in the Swiss Jura
  - O. Attela, J.-P. Dubois, & R. Webster. 1994. *Environ. Pollution* **86**, 315.
- The data set contains measurements of cadmium, cobalt, chromium, copper, nickel, lead, and zinc concentrations from 100 soil samples.

```
library(tidyverse)
library(gstat)
data(jura)
jura <- as_tibble(jura.val) |> select(-(Xloc:Yloc))
```

- You may need to run `install.packages("gstat")` in the RStudio console.

```
head(jura)
```

```
## # A tibble: 6 × 11
##    long   lat Landuse Rock           Cd    Co    Cr    Cu    Ni    Pb    Zn
##   <dbl> <dbl> <fct>   <fct>       <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1  6.85  47.1 Meadow  Quaternary  1.57   8.28  37.1 18.6   18.6  38.2  65.2
## 2  6.87  47.2 Meadow  Argovian    2.04  10.8   40.8 11.5   21.5  33.4 113.
## 3  6.87  47.2 Pasture Argovian    1.20  12     53.2 13.0   23.9  26.6  91.6
## 4  6.86  47.1 Pasture Quaternary  0.49  10.9   23.4  5.64  14.6  25.9  41.2
## 5  6.84  47.1 Meadow  Sequanian   0.692  8.12  27.2 10.3   14.6  31.2  50.4
## 6  6.87  47.1 Forest  Kimmeridgian 1.75   9.12  35.5  8.36  26.4  37.7  63.2
```

```
glimpse(jura)
```

```
## Rows: 100
## Columns: 11
## $ long    <dbl> 6.854080, 6.865951, 6.871425, 6.857691, 6.837664, 6.871310,
6.…
## $ lat     <dbl> 47.14342, 47.15141, 47.15390, 47.13966, 47.13603, 47.13773,
47.…
## $ Landuse <fct> Meadow, Meadow, Pasture, Pasture, Meadow, Forest, Forest,
Past…
## $ Rock    <fct> Quaternary, Argovian, Argovian, Quaternary, Sequanian,
Kimmeri…
## $ Cd      <dbl> 1.570, 2.045, 1.203, 0.490, 0.692, 1.750, 0.415, 0.685,
0.920,…
## $ Co      <dbl> 8.280, 10.800, 12.000, 10.920, 8.120, 9.120, 9.120, 11.720,
10…
## $ Cr      <dbl> 37.12, 40.80, 53.20, 23.40, 27.16, 35.48, 30.32, 31.92,
49.04,…
## $ Cu      <dbl> 18.600, 11.480, 13.040, 5.640, 10.320, 8.360, 4.440, 10.920,
3…
## $ Ni      <dbl> 18.60, 21.52, 23.92, 14.60, 14.64, 26.40, 24.24, 13.12,
31.52,…
## $ Pb      <dbl> 38.20, 33.36, 26.56, 25.88, 31.16, 37.72, 41.00, 30.84,
68.12,…
## $ Zn      <dbl> 65.20, 112.80, 91.60, 41.20, 50.40, 63.20, 53.16, 49.28,
102.7…
```

Transforming Rows

- Selecting:

```
  filter(jura, Landuse == "Meadow") |> head()
```

```
## # A tibble: 6 × 11
##    long   lat Landuse Rock            Cd    Co    Cr    Cu    Ni    Pb
Zn
##   <dbl> <dbl> <fct>   <fct>        <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
<dbl>
## 1  6.85  47.1 Meadow  Quaternary   1.57   8.28  37.1  18.6  18.6  38.2
65.2
## 2  6.87  47.2 Meadow  Argovian     2.04  10.8   40.8  11.5  21.5  33.4
113.
## 3  6.84  47.1 Meadow  Sequanian    0.692  8.12  27.2  10.3  14.6  31.2
50.4
## 4  6.85  47.1 Meadow  Kimmeridgian 0.92  10.6   49.0  30.3  31.5  68.1
103.
## 5  6.85  47.1 Meadow  Argovian     0.495  8.52  31.4  17.1  16.1  46.8
57.6
## 6  6.84  47.1 Meadow  Sequanian    1.19   9.68  37.4  31.4  22.4  72.4
108.
```

- Sorting:

```
filter(jura, Landuse == "Meadow") |>
  arrange(Rock, long, lat) |>
  head()
```

```
## # A tibble: 6 × 11
##    long   lat Landuse Rock        Cd    Co    Cr    Cu    Ni    Pb    Zn
##   <dbl> <dbl> <fct>   <fct>    <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1  6.83  47.1 Meadow  Argovian 0.475  3.96  22.2  22.7  7.92  55.2  46.8
## 2  6.84  47.1 Meadow  Argovian 3.78   9.68  42.8  32.8 23.5   94.4 175.
## 3  6.84  47.1 Meadow  Argovian 0.585  5.8   39.9  15.2 13.2   56.4  51.2
## 4  6.84  47.1 Meadow  Argovian 0.57   4.08  24.9  21.4  9.68  67.2  56.8
```

Transforming Rows

- Selecting on multiple criteria:

```
filter(jura, Landuse == "Meadow", Rock == "Quaternary", Cd > 1.3) |>
  head()
```

```
## # A tibble: 5 × 11
##     long   lat Landuse Rock          Cd    Co    Cr    Cu    Ni    Pb
Zn
##   <dbl> <dbl> <fct>   <fct>      <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
<dbl>
## 1  6.85  47.1 Meadow  Quaternary  1.57  8.28  37.1  18.6  18.6  38.2
65.2
## 2  6.86  47.2 Meadow  Quaternary  1.58  5.8   40.4  56.4  22.5  93.6 109.
## 3  6.88  47.1 Meadow  Quaternary  1.42 11.1   27.5  18.8  20.6  36.5
63.2
## 4  6.86  47.1 Meadow  Quaternary  2.08 13.2   45.9  39    26.4  52.4 104
## 5  6.88  47.1 Meadow  Quaternary  2.61 20.6   37.2  24    29.4  47.2
86.4
```

Transforming Columns

Transforming Columns

```
mutate(jura, CuNi = Cu / Ni, PbZn = Pb/Zn) |>
rename(longitude = long, latitude = lat) |>
  head()
```

```
## # A tibble: 6 × 13
##   longitude latitude Landuse Rock            Cd    Co    Cr    Cu    Ni    Pb    Zn  CuNi
PbZn
##       <dbl>    <dbl> <fct>   <fct>        <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
<dbl>
## 1      6.85     47.1 Meadow  Quaternary   1.57   8.28  37.1 18.6   18.6  38.2  65.2 1
0.586
## 2      6.87     47.2 Meadow  Argovian     2.04  10.8   40.8 11.5   21.5  33.4 113.  0.533
0.296
## 3      6.87     47.2 Pasture Argovian     1.20  12     53.2 13.0   23.9  26.6  91.6 0.545
0.290
## 4      6.86     47.1 Pasture Quaternary   0.49  10.9   23.4  5.64  14.6  25.9  41.2 0.386
0.628
## 5      6.84     47.1 Meadow  Sequanian    0.692  8.12  27.2 10.3   14.6  31.2  50.4 0.705
0.618
## 6      6.87     47.1 Forest  Kimmeridgian 1.75   9.12  35.5  8.36  26.4  37.7  63.2 0.317
0.597
```

```
mutate(jura, CuNi = Cu / Ni, PbZn = Pb/Zn) |>
rename(longitude = long, latitude = lat) |>
relocate(CuNi:PbZn, .before = Cd) |>
  head()
```

```
## # A tibble: 6 × 13
##   longitude latitude Landuse Rock          CuNi  PbZn    Cd    Co    Cr    Cu    Ni    Pb
Zn
##       <dbl>    <dbl> <fct>   <fct>        <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
<dbl>
```

```
## 1      6.85     47.1 Meadow  Quaternary   1     0.586 1.57   8.28  37.1 18.6   18.6  38.2
65.2
## 2      6.87     47.2 Meadow  Argovian     0.533 0.296 2.04  10.8   40.8 11.5   21.5  33.4
113.
## 3      6.87     47.2 Pasture Argovian     0.545 0.290 1.20  12     53.2 13.0   23.9  26.6
91.6
## 4      6.86     47.1 Pasture Quaternary   0.386 0.628 0.49  10.9   23.4  5.64  14.6  25.9
41.2
## 5      6.84     47.1 Meadow  Sequanian    0.705 0.618 0.692  8.12  27.2 10.3   14.6  31.2
50.4
## 6      6.87     47.1 Forest  Kimmeridgian 0.317 0.597 1.75   9.12  35.5  8.36  26.4  37.7
63.2
```

Pipes

Pipes

- The pipe %>% or |> sends the output from one function into another.
- This code is hard to read:

```
relocate( rename( mutate( jura,
                          CuNi = Cu / Ni,
                          PbZn = Pb/Zn),
                  longitude = long,
                  latitude = lat),
          CuNi:PbZn, .before = Cd)
```

- This code is much easier to read

```
jura |>
  mutate(CuNi = Cu / Ni, PbZn = Pb/Zn) |>
  rename(longitude = long, latitude = lat) |>
  relocate(CuNi:PbZn, .before = Cd)
```

- We could also write

```
tmp <- mutate(jura, CuNi = Cu / Ni, PbZn = Pb/Zn)
tmp <- rename(tmp, longitude = long,
              latitude = lat)
relocate(tmp, CuNi:PbZn, .before = Cd)
```

Summarizing and Grouping

Summarizing and Grouping

- Average lead content:

```
jura |> summarize(mean_Pb = mean(Pb),
                  sd_Pb = sd(Pb),
                  count = n())
```

```
## # A tibble: 1 × 3
##   mean_Pb sd_Pb count
##     <dbl> <dbl> <int>
## 1    56.5  40.5   100
```

- Grouped Summaries:

```
jura |> group_by(Landuse, Rock) |>
  summarize(mean_Pb = mean(Pb),
            sd_Pb = sd(Pb), count = n()) |>
  ungroup()
```

```
## # A tibble: 15 × 5
##    Landuse Rock         mean_Pb sd_Pb count
##    <fct>   <fct>          <dbl> <dbl> <int>
##  1 Forest  Argovian        33.9  3.21     4
##  2 Forest  Kimmeridgian    53.6 15.3     10
##  3 Forest  Sequanian       57.9 13.4      2
##  4 Forest  Portlandian     42.0  9.56     2
##  5 Pasture Argovian        28.5 11.4      4
##  6 Pasture Kimmeridgian    60.9 69.4     14
##  7 Pasture Sequanian       42.1 11.5      6
##  8 Pasture Quaternary      37.1 15.9      2
##  9 Meadow  Argovian        53.1 25.3     14
## 10 Meadow  Kimmeridgian    50.1 11.9     13
## 11 Meadow  Sequanian       73.1 54.1     18
## 12 Meadow  Portlandian    109.  NA        1
## 13 Meadow  Quaternary      60.8 41.5      7
## 14 Tillage Argovian       153.  NA        1
## 15 Tillage Kimmeridgian    42.3  5.77     2
```

More Grouping

- Counting combinations:

```
jura |> count(Landuse, Rock)
```

```
## # A tibble: 15 × 3
##    Landuse Rock             n
##    <fct>   <fct>        <int>
##  1 Forest  Argovian         4
##  2 Forest  Kimmeridgian    10
##  3 Forest  Sequanian        2
##  4 Forest  Portlandian      2
##  5 Pasture Argovian         4
##  6 Pasture Kimmeridgian    14
##  7 Pasture Sequanian        6
##  8 Pasture Quaternary       2
##  9 Meadow  Argovian        14
## 10 Meadow  Kimmeridgian    13
## 11 Meadow  Sequanian       18
## 12 Meadow  Portlandian      1
## 13 Meadow  Quaternary       7
## 14 Tillage Argovian         1
## 15 Tillage Kimmeridgian     2
```

- Alternate Grouping:

```
jura |> summarize(mean_Pb = mean(Pb),
                  sd_Pb = sd(Pb),
                  count = n(),
                  .by = c("Landuse", "Rock"))
```

```
## # A tibble: 15 × 5
##    Landuse Rock         mean_Pb sd_Pb count
##    <fct>   <fct>          <dbl> <dbl> <int>
##  1 Meadow  Quaternary      60.8 41.5      7
##  2 Meadow  Argovian        53.1 25.3     14
##  3 Pasture Argovian        28.5 11.4      4
##  4 Pasture Quaternary      37.1 15.9      2
##  5 Meadow  Sequanian       73.1 54.1     18
##  6 Forest  Kimmeridgian    53.6 15.3     10
##  7 Pasture Sequanian       42.1 11.5      6
##  8 Meadow  Kimmeridgian    50.1 11.9     13
##  9 Pasture Kimmeridgian    60.9 69.4     14
## 10 Forest  Portlandian     42.0  9.56     2
## 11 Forest  Argovian        33.9  3.21     4
## 12 Meadow  Portlandian    109.  NA        1
## 13 Tillage Kimmeridgian    42.3  5.77     2
## 14 Forest  Sequanian       57.9 13.4      2
## 15 Tillage Argovian       153.  NA        1
```

Slicing

- Selecting:

```
jura |> group_by(Landuse, Rock) |>
  slice_max(Pb, n = 1)
```

```
## # A tibble: 15 × 11
## # Groups:   Landuse, Rock [15]
##     long   lat Landuse Rock            Cd    Co    Cr     Cu    Ni
Pb    Zn
##    <dbl> <dbl> <fct>   <fct>        <dbl> <dbl> <dbl>  <dbl> <dbl>
<dbl> <dbl>
##  1  6.86  47.2 Forest  Argovian     1.32   3.74  27.6   5.4  14.4
37.5  46.4
##  2  6.86  47.1 Forest  Kimmeridgian 1.25   8.08  39.6  13.1  18.6   88
86.8
##  3  6.85  47.1 Forest  Sequanian    1.01   9.96  28.7   5.96 17.4
67.4  52.5
##  4  6.87  47.1 Forest  Portlandian  1.22   5.24  27.0   5.52 21.0
48.8  46.4
##  5  6.85  47.1 Pasture Argovian     0.375 12.0   34.1  19.4  16.4
45.2  70
##  6  6.86  47.1 Pasture Kimmeridgian 1.76  10.3   40.5 127    30.8  300
192
##  7  6.83  47.1 Pasture Sequanian    2.54  12.6   70      8.72 26.2
55.6  71.6
##  8  6.88  47.1 Pasture Quaternary   1.31  12.7   34.8  17.7  19.6
48.4  80.4
##  9  6.85  47.1 Meadow  Argovian     0.394  4.44  21.6  39.6   8.92 106.
72.4
## 10  6.85  47.1 Meadow  Kimmeridgian 0.825 15.3   36.5  31.2  25.4
70.4  75.4
## 11  6.86  47.1 Meadow  Sequanian    1.78  11.4   41   155.   24.5  240.
260.
## 12  6.88  47.1 Meadow  Portlandian  1.62  12.0   34.6  91.2  30.2  109.
157.
## 13  6.85  47.1 Meadow  Quaternary   0.75  15.6   29.8  73.1  20.2  139.
95.7
## 14  6.85  47.1 Tillage Argovian     1.31   8.44  41.6 118.   20.4  153.
145.
## 15  6.87  47.1 Tillage Kimmeridgian 1.93  13.8   45    19.3  35.7
46.4  90
```

- Random Sampling

```
jura |> slice_sample(n = 5)
```

```
## # A tibble: 5 × 11
##    long   lat Landuse Rock            Cd    Co    Cr    Cu    Ni    Pb
Zn
##   <dbl> <dbl> <fct>   <fct>        <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
<dbl>
## 1  6.83  47.1 Meadow  Argovian     0.475  3.96  22.2 22.7   7.92  55.2
46.8
## 2  6.84  47.1 Meadow  Argovian     3.78   9.68  42.8 32.8  23.5   94.4
175.
## 3  6.86  47.1 Meadow  Argovian     0.745  3.95  26.6  8.52 15.4   30.3
52.4
## 4  6.86  47.1 Meadow  Kimmeridgian 1.68  14.4   46.3 22.9  43.7   61.4
111.
## 5  6.85  47.1 Meadow  Quaternary   1.57   8.28  37.1 18.6  18.6   38.2
65.2
```

Sampling from models

- Base R

```
library(rethinking)

data(Howell1)
adults <- filter(Howell1, age >= 18)

mdl <- quap(alist(
  height ~ dnorm(mu, sigma),
  mu <- a + b * weight,
  a ~ dnorm(178,20),
  b ~ dlnorm(0,1),
  sigma ~ dunif(0,50)
  ), data = adults)

w_lst <- data.frame(weight = seq(30, 70, by = 5))
```

  - Sample from the posterior predictive distribution for data (e.g., `height`):

```
extract.samples(mdl, 1000)
```

  - Sample from the posterior of the model link (`mu`):

```
link(mdl, w_lst)
```

- Tidyverse (`library(tidyverse)`)

```
library(tidybayes)
library(tidybayes.rethinking)
```

  - Sample from the posterior predictive distribution for data (e.g., `height`):

```
predicted_draws(mdl, w_lst, ndraws = 1000,
                value = "height")
add_predicted_draws(w_lst, mdl, ndraws = 1000,
                    value = "height")
```

  - Sample from the posterior of the model link (`mu`):

```
linpred_draws(mdl, w_lst, ndraws = 1000,
              value = "height")
add_linpred_draws(w_lst, mdl, ndraws = 1000,
                  value = "height")
```

- `add_` versions are the same, but reverse the order of the first two arguments (model object and new data).