Chapter 12

Fundamentals of Data Visualization

April 30, 2023

Associations among two or more quantitative variables

- height, weight, length, daily energy demands
- pH, alkalinity, nitrate/nitrite

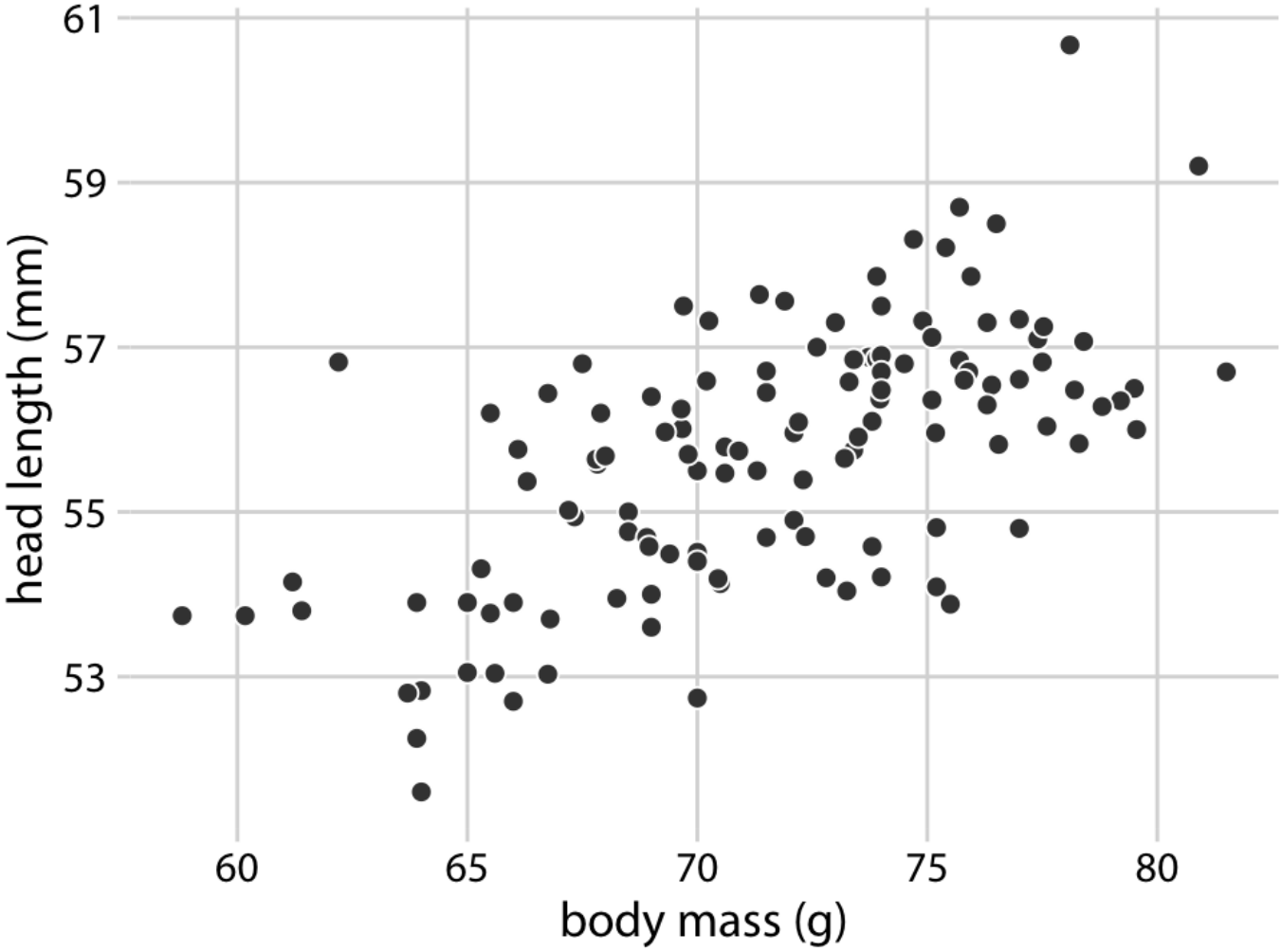
Associations among two or more quantitative variables

- scatter plot
- bubble plot
- scatter plot matrix
- correlogram
- dimensionality reduction
  - principal components

Bluejays dataset

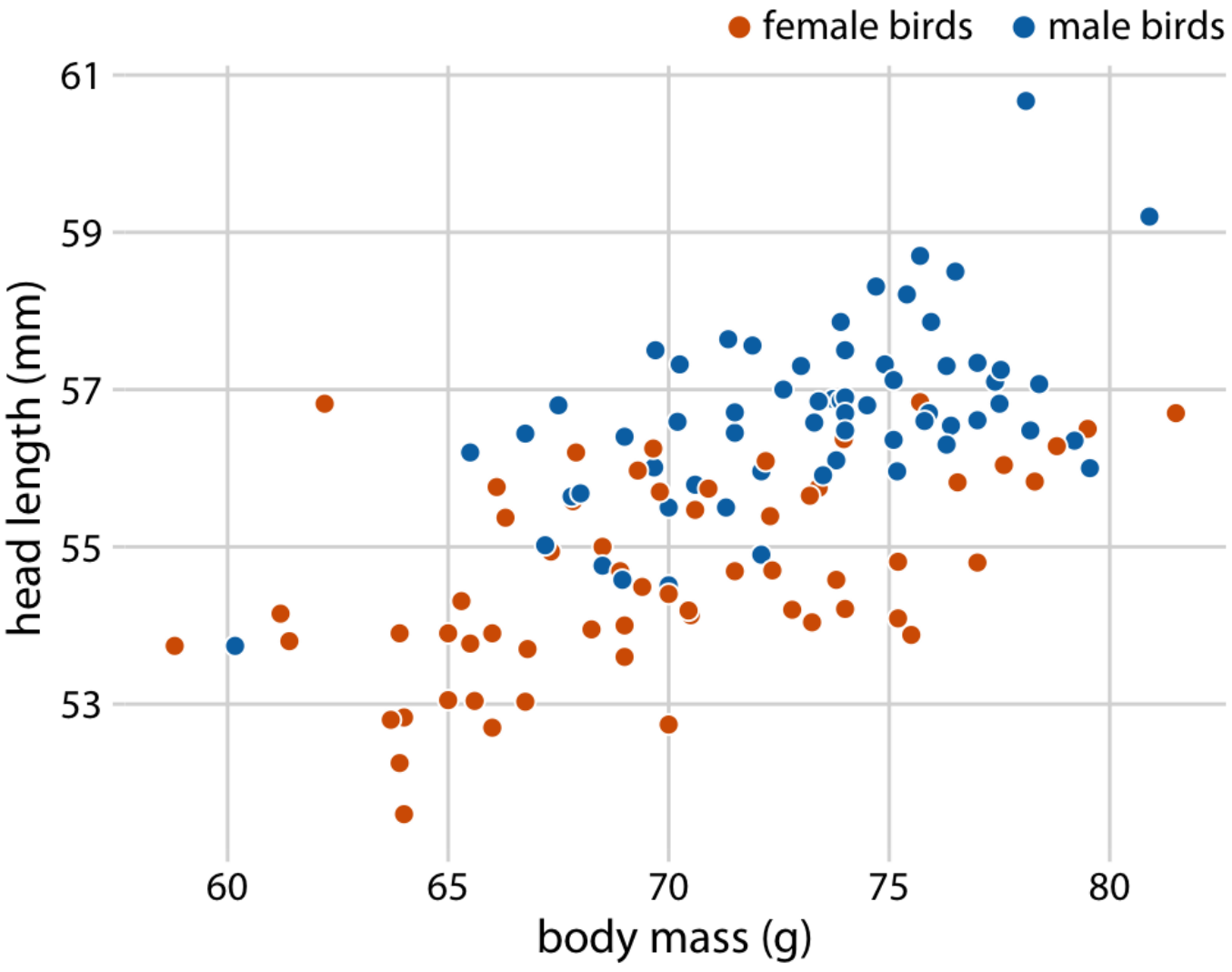
```
> library(Stat2Data)

> glimpse(BlueJays)
Rows: 123
Columns: 9
$ BirdID     <fct> 0000-00000, 1142-05901, 114...
$ KnownSex   <fct> M, M, M, F, M, F, M, M, F, ...
$ BillDepth  <dbl> 8.26, 8.54, 8.39, 7.78, 8.7...
$ BillWidth  <dbl> 9.21, 8.76, 8.78, 9.30, 9.8...
$ BillLength <dbl> 25.92, 24.99, 26.07, 23.48,...
$ Head       <dbl> 56.58, 56.36, 57.32, 53.77,...
$ Mass       <dbl> 73.30, 75.10, 70.25, 65.50,...
$ Skull      <dbl> 30.66, 31.38, 31.25, 30.29,...
$ Sex        <int> 1, 1, 1, 0, 1, 0, 1, 1, 0, ...
>
```

Bluejays scatterplot

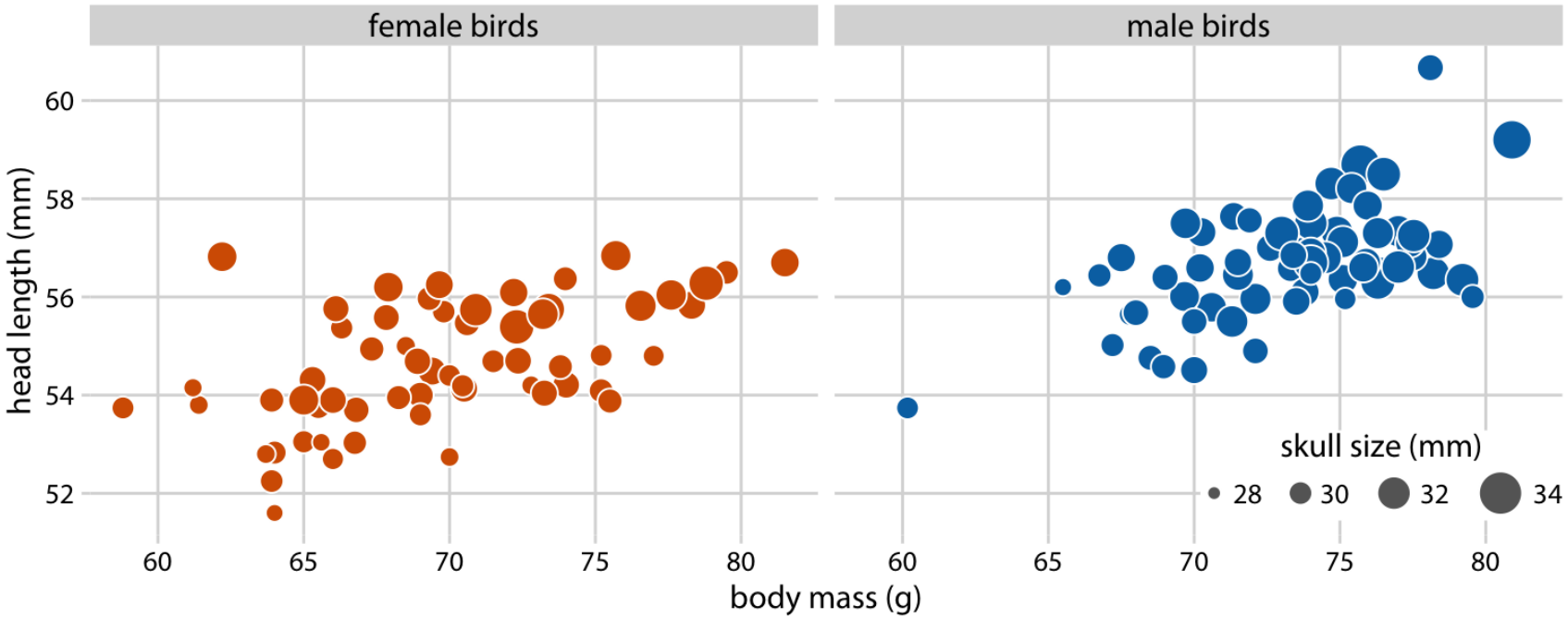


John Snow's 1854 cholera map

Bluejays scatterplot by sex



Adding skull size with bubbles

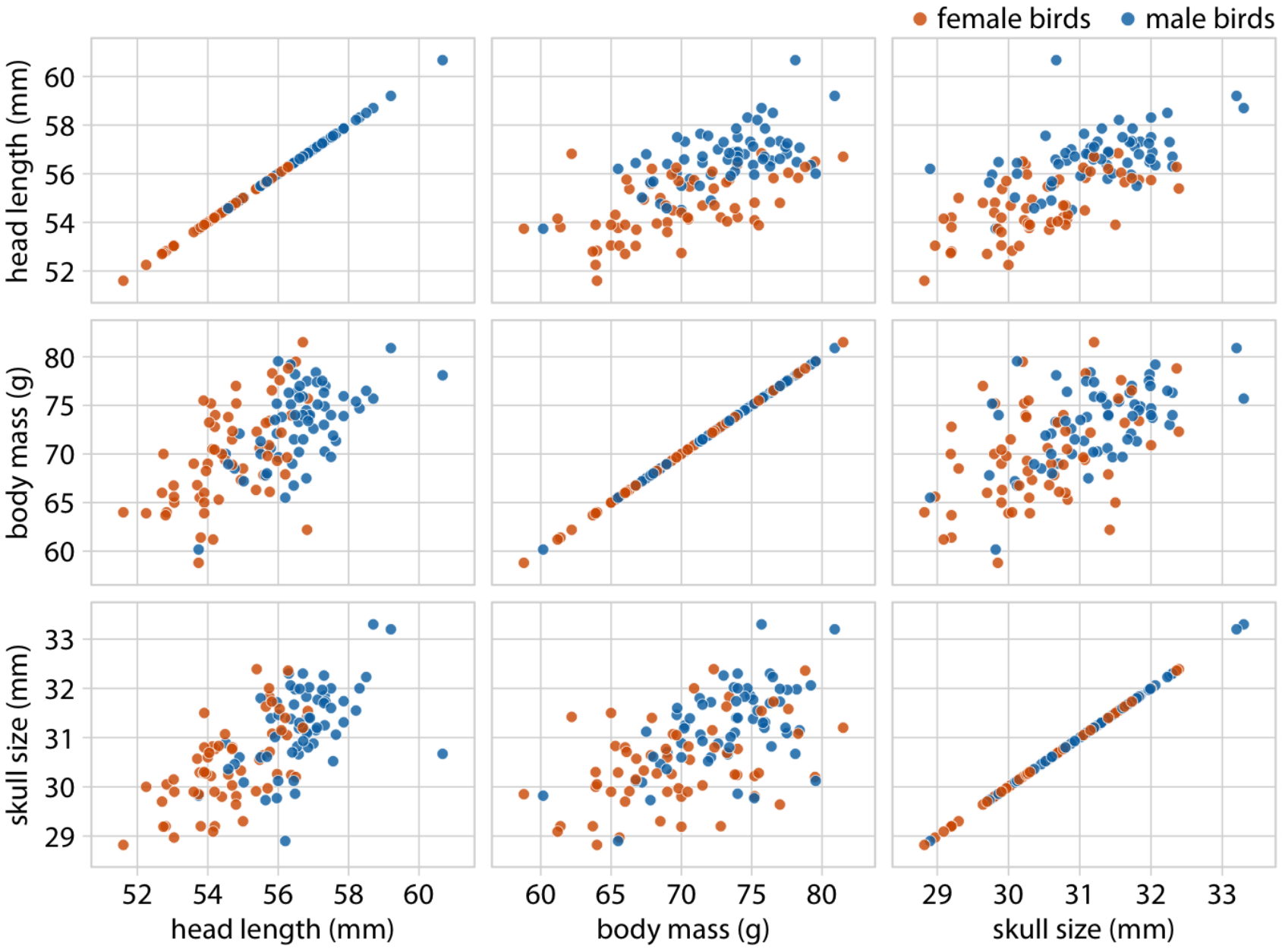


- Head length is from tip of bill to back of head.
- Skull size does not include the bill.
- Plotting a fourth variable with bubble size

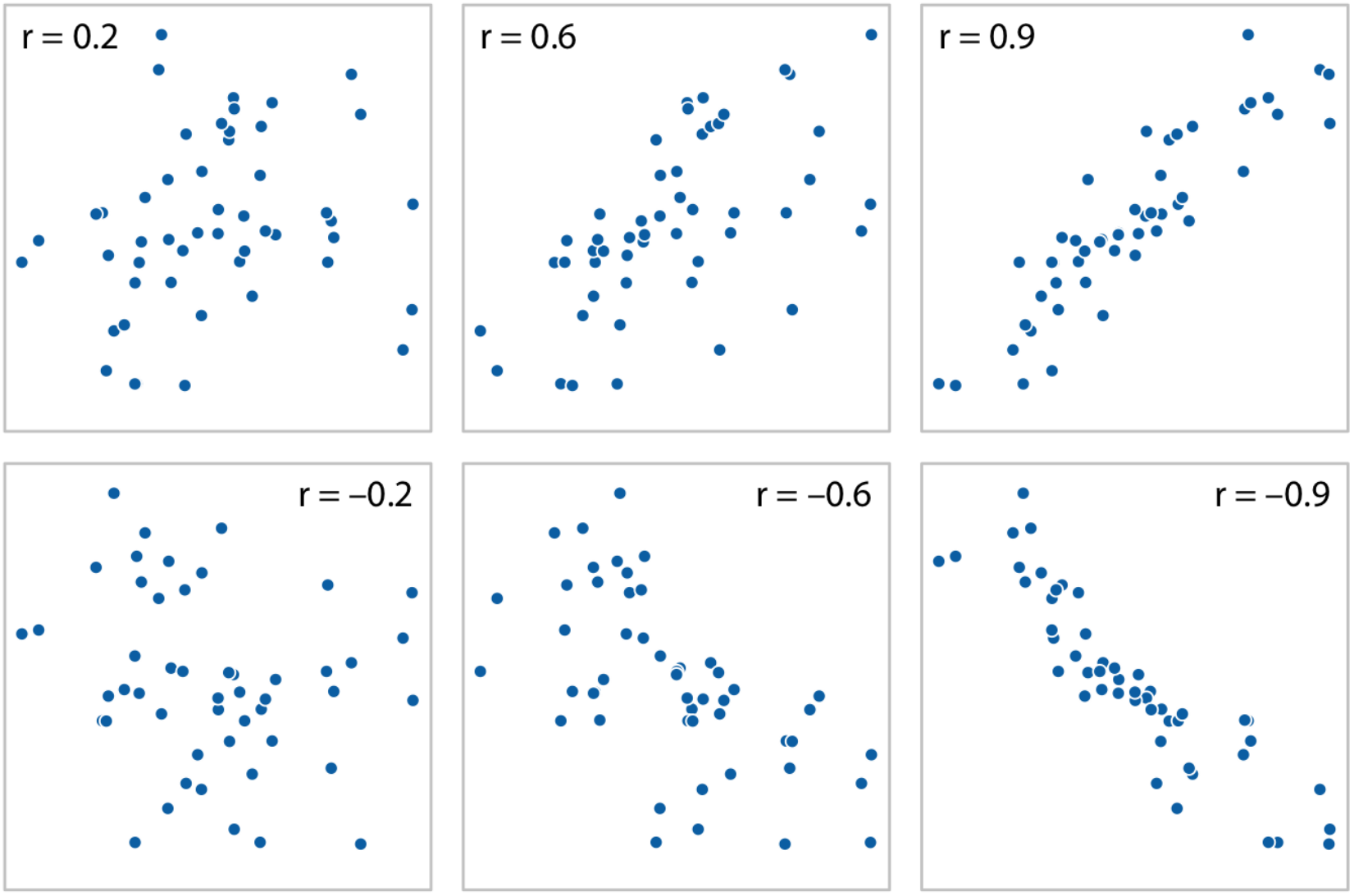
Bubble charts

- Bubble charts show quantitative variables with two aesthetics:
  - position
  - size
- Difficult to visualize the strength of association.
- Bubble size is harder to perceive than position

All-against-all scatterplot matrix



Correlation coefficients



Correlation coefficients

$$r = \frac{\sum_i (x_i - x)(y_i - y)}{\sqrt{\sum_i (x_i - x)^2}\sqrt{\sum_i (y_i - y)^2}}$$

where x_i and y_i are two sets of observations and x and y are the sample means.

- Symmetric in x and y
- Only depend on the differences from the mean, so independent of shifting.
- Independent of scaling, too, since a constant C will appear in both numerator and denominator

Root mean square

Correlation coefficient:

$$r = \frac{\sum_i (x_i - x)(y_i - y)}{\sqrt{\sum_i (x_i - x)^2} \sqrt{\sum_i (y_i - y)^2}}$$

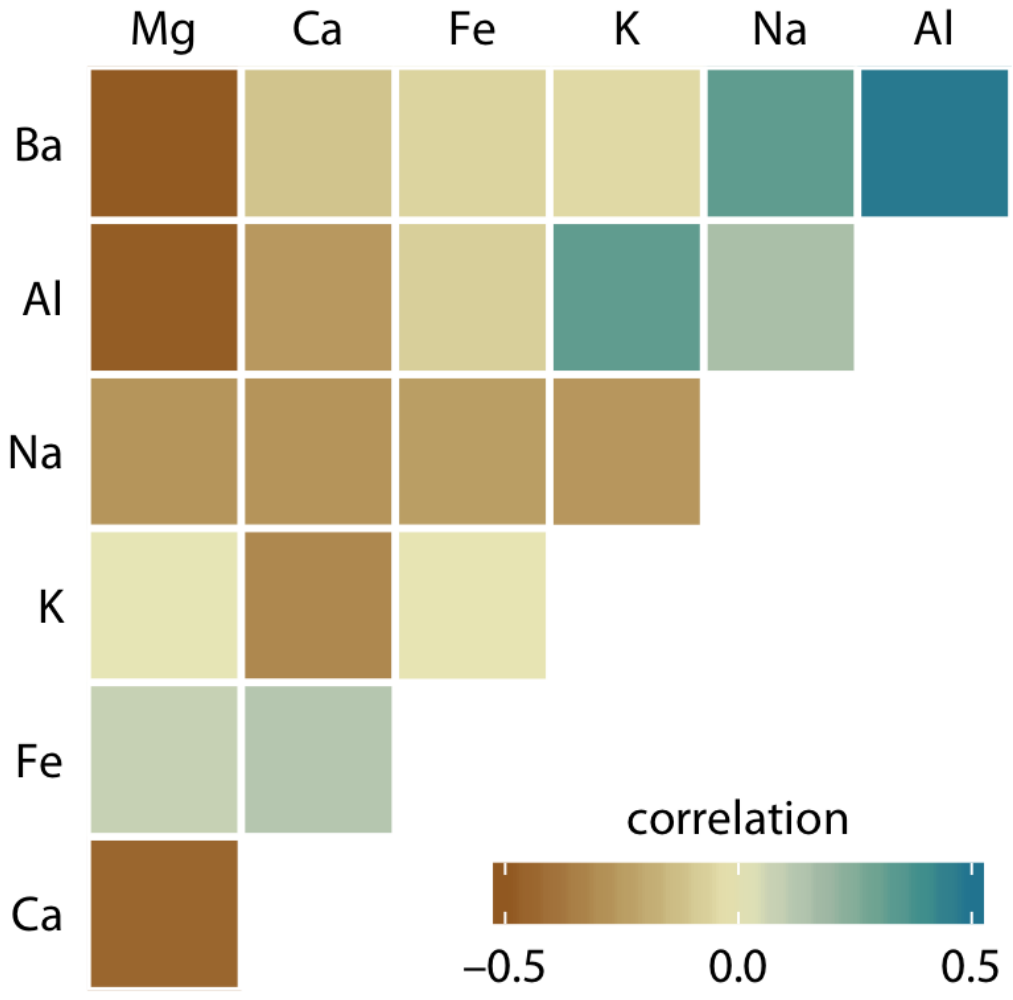
Root mean square:

$$\sqrt{\frac{\sum_i a_i^2}{n}}$$

Standard deviation:

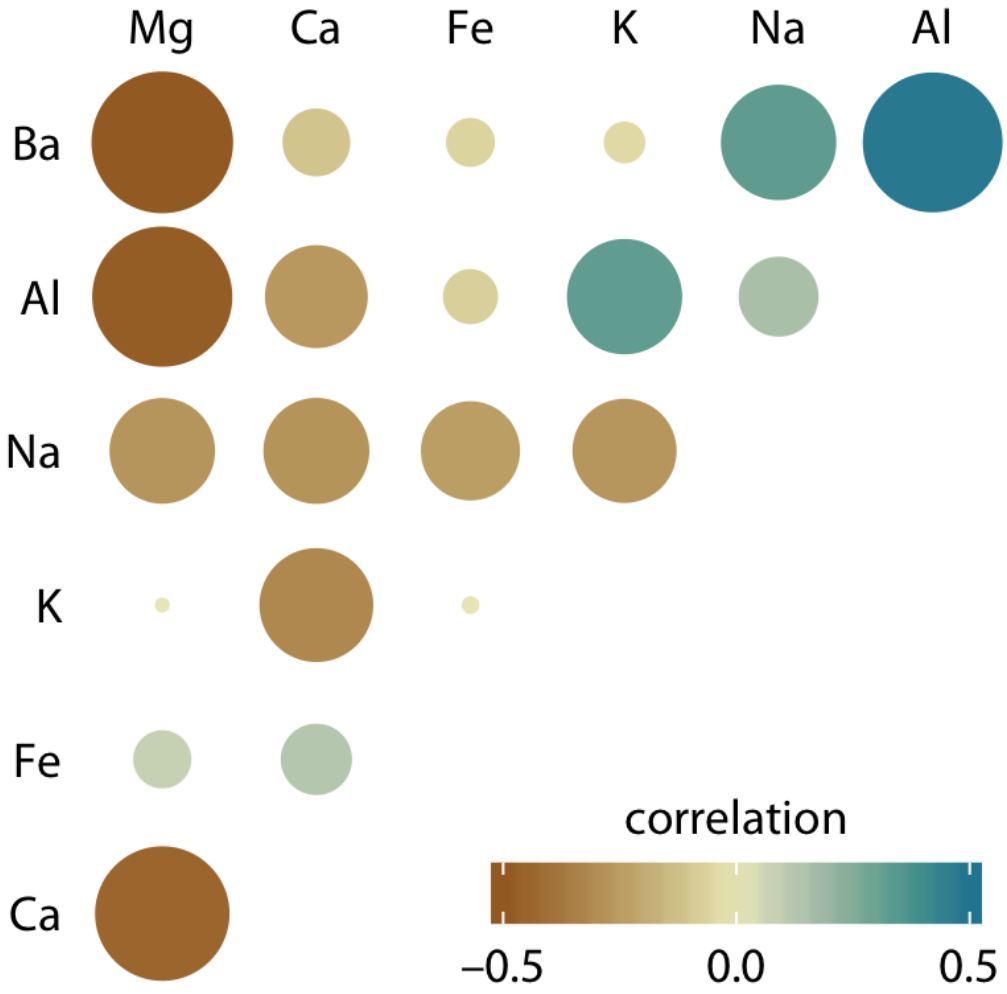
$$\sqrt{\frac{\sum_i (x_i - x)^2}{n}}$$

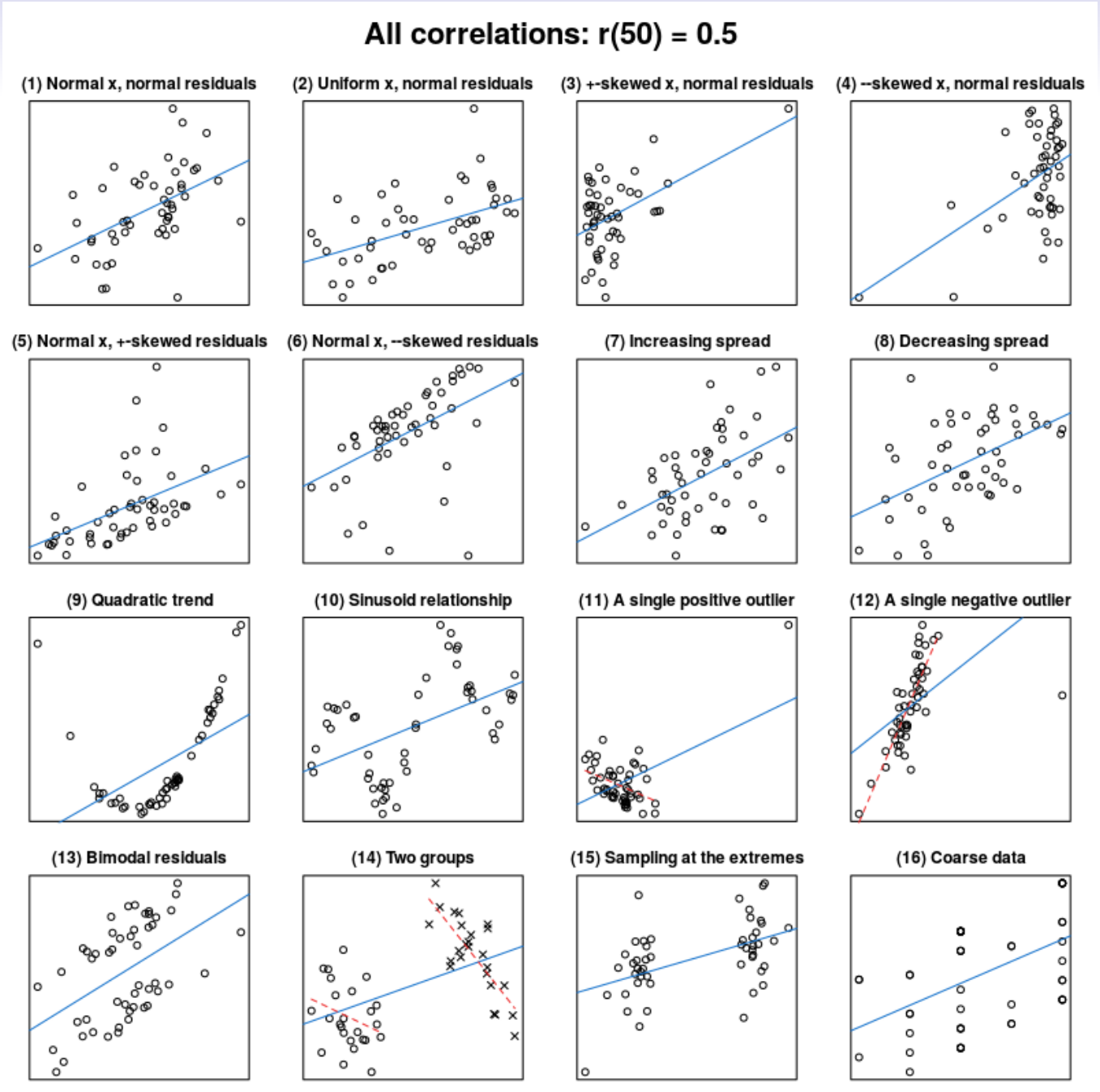
Correlegram maps the correlations to a visualization



- Forensic data on glass samples

Size and color together visualize small values better



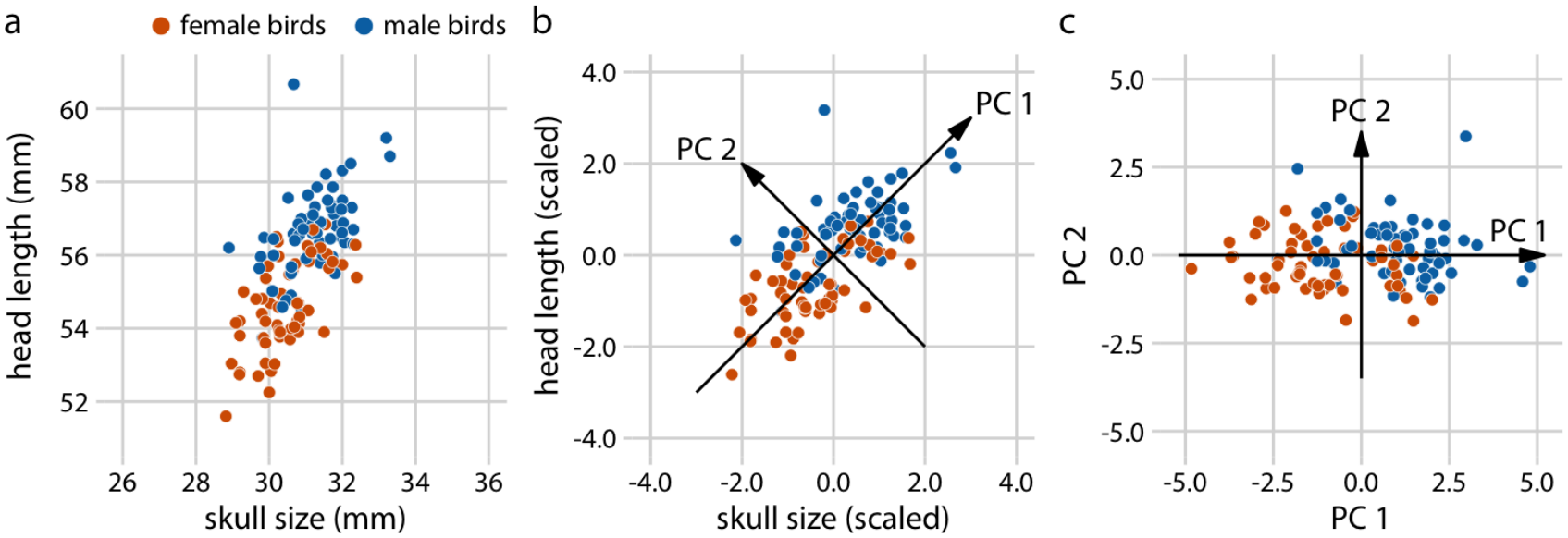


https://janhove.github.io/teaching/2016/11/21/what-correlations-look-like

Dimensionality reduction

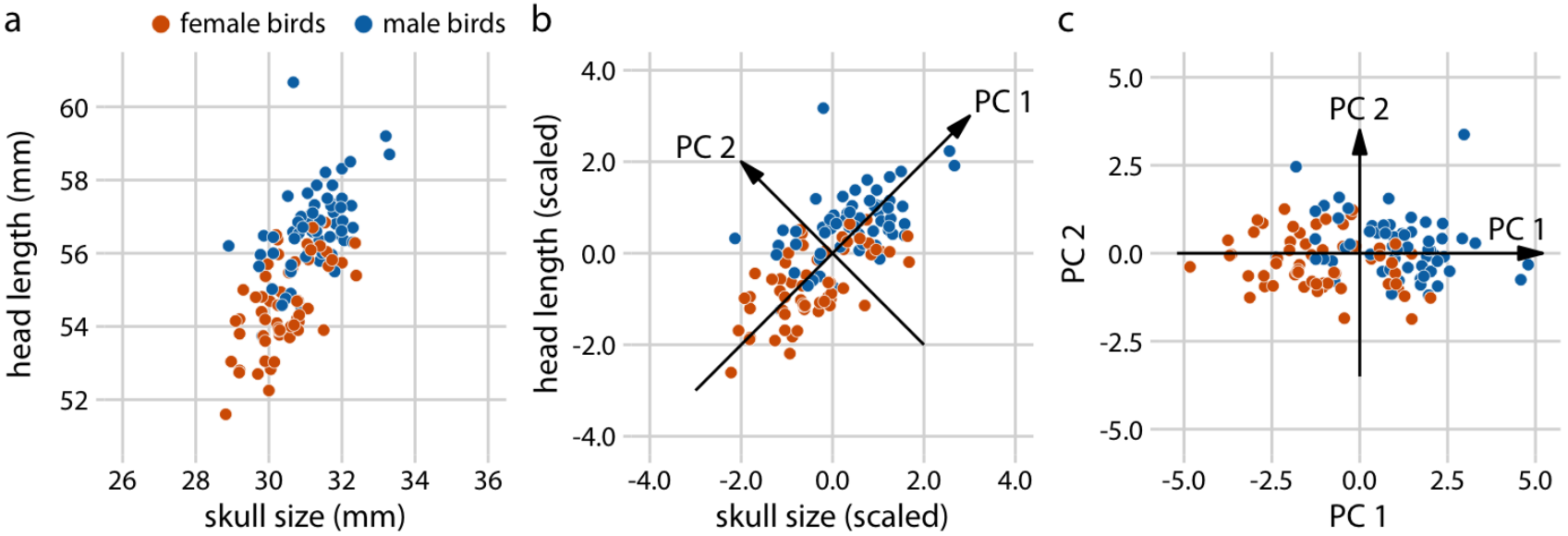
- Many variables are correlated:
  - height
  - weight
  - arm length, leg length
  - chest, waist, leg circumference
- If we combine these into a single super-variable we may be able to see other, more subtle factors.

Principal components



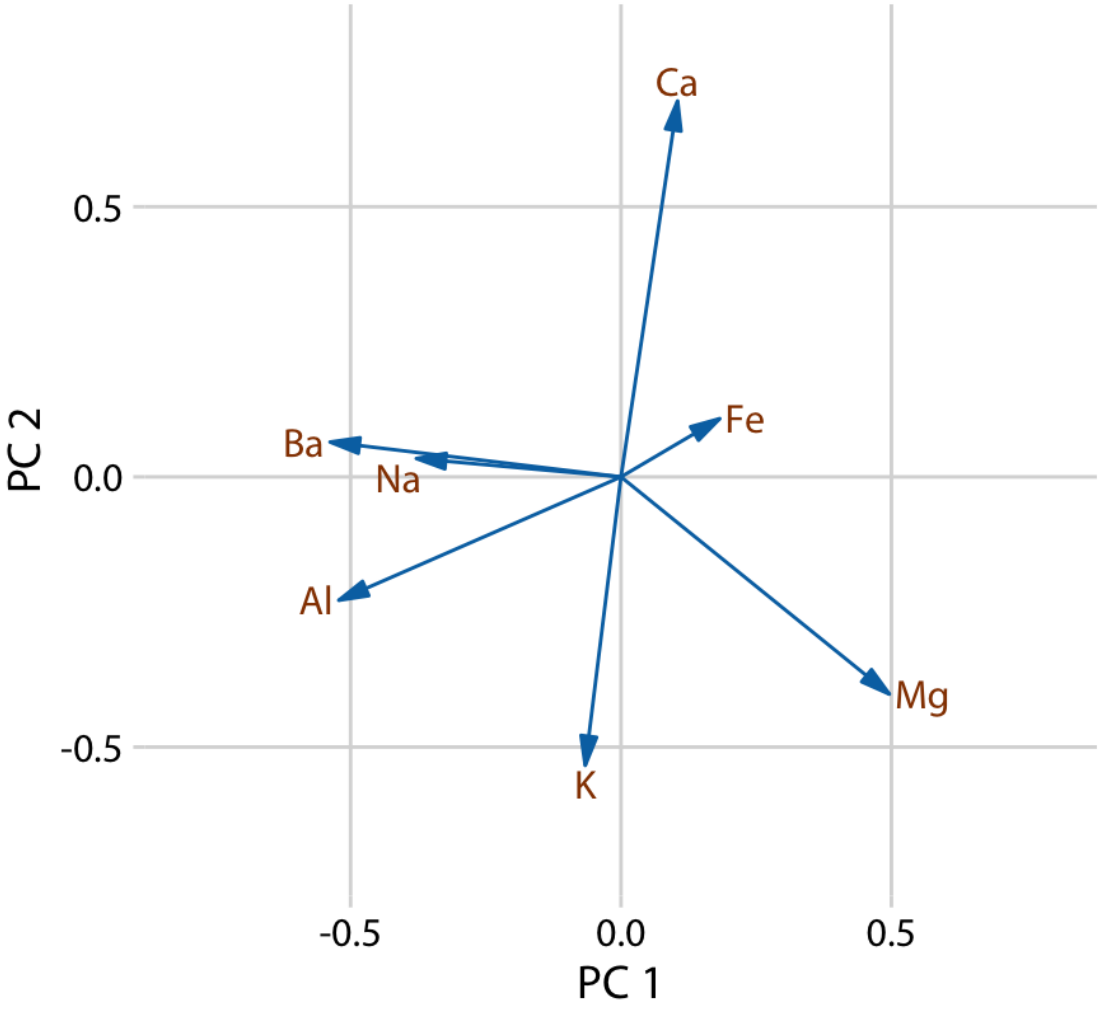
- Scale each variable to zero mean and unit variance
- A rigid rotation of the data around the origin
- Each component has zero correlation with the others
- The first component has the most variance, the second the second most, *etc.*

Principal components



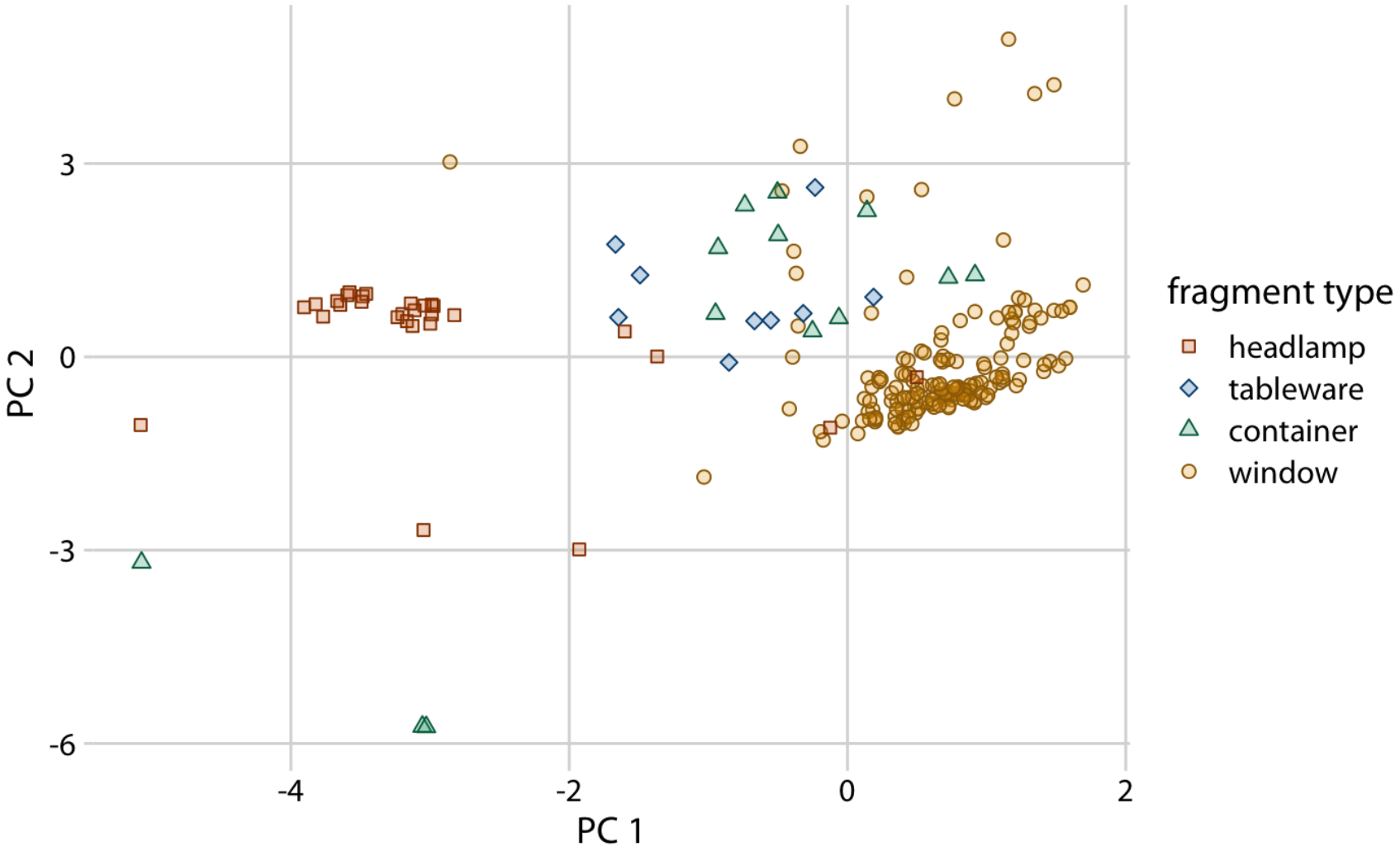
- Usually key features of the data can be seen in the first two or three components.
- Two things to look at:
  - the composition of the components
  - the positions of the points on the components

Composition of the components



- The components are linear combinations of the variables

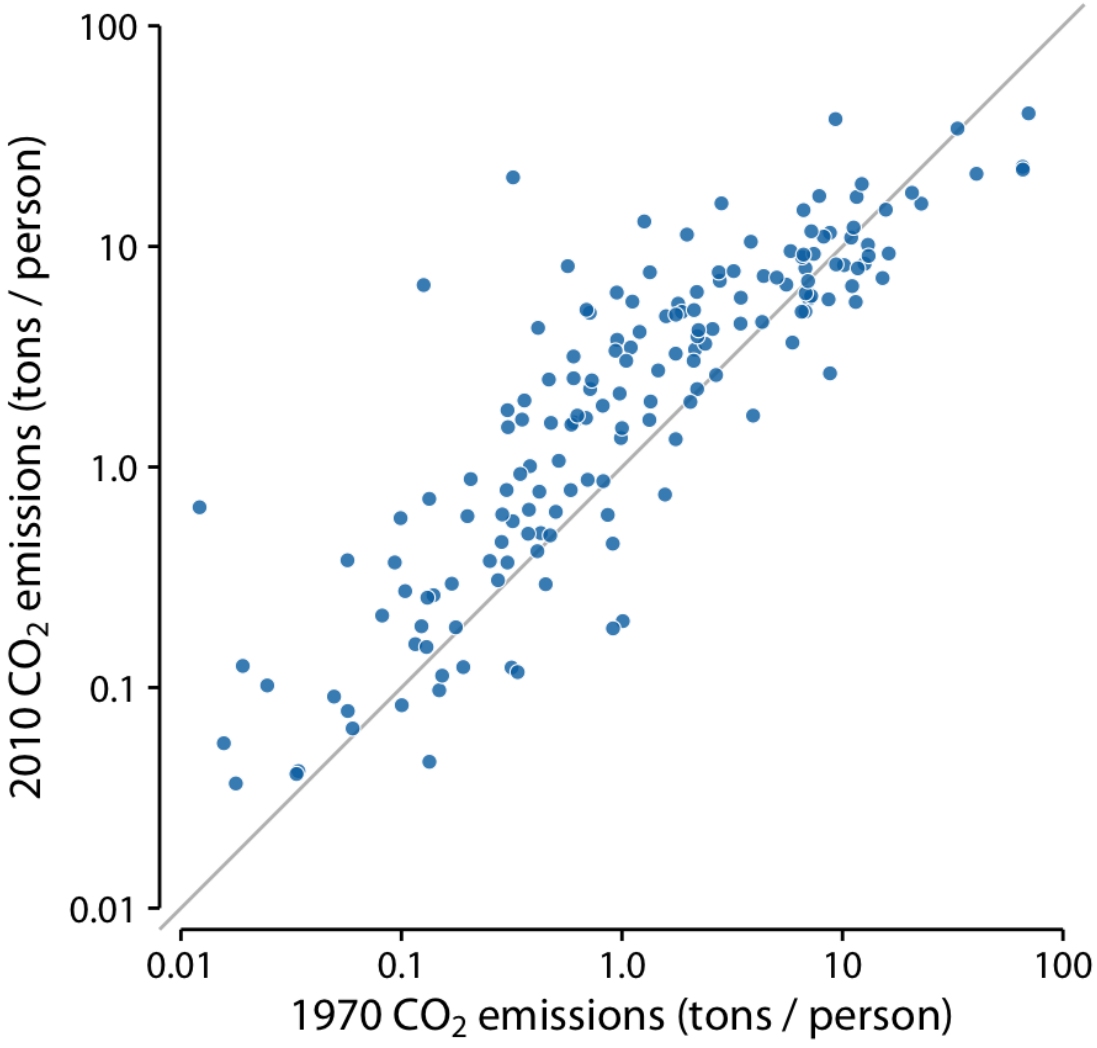
Project points onto the components



Paired data

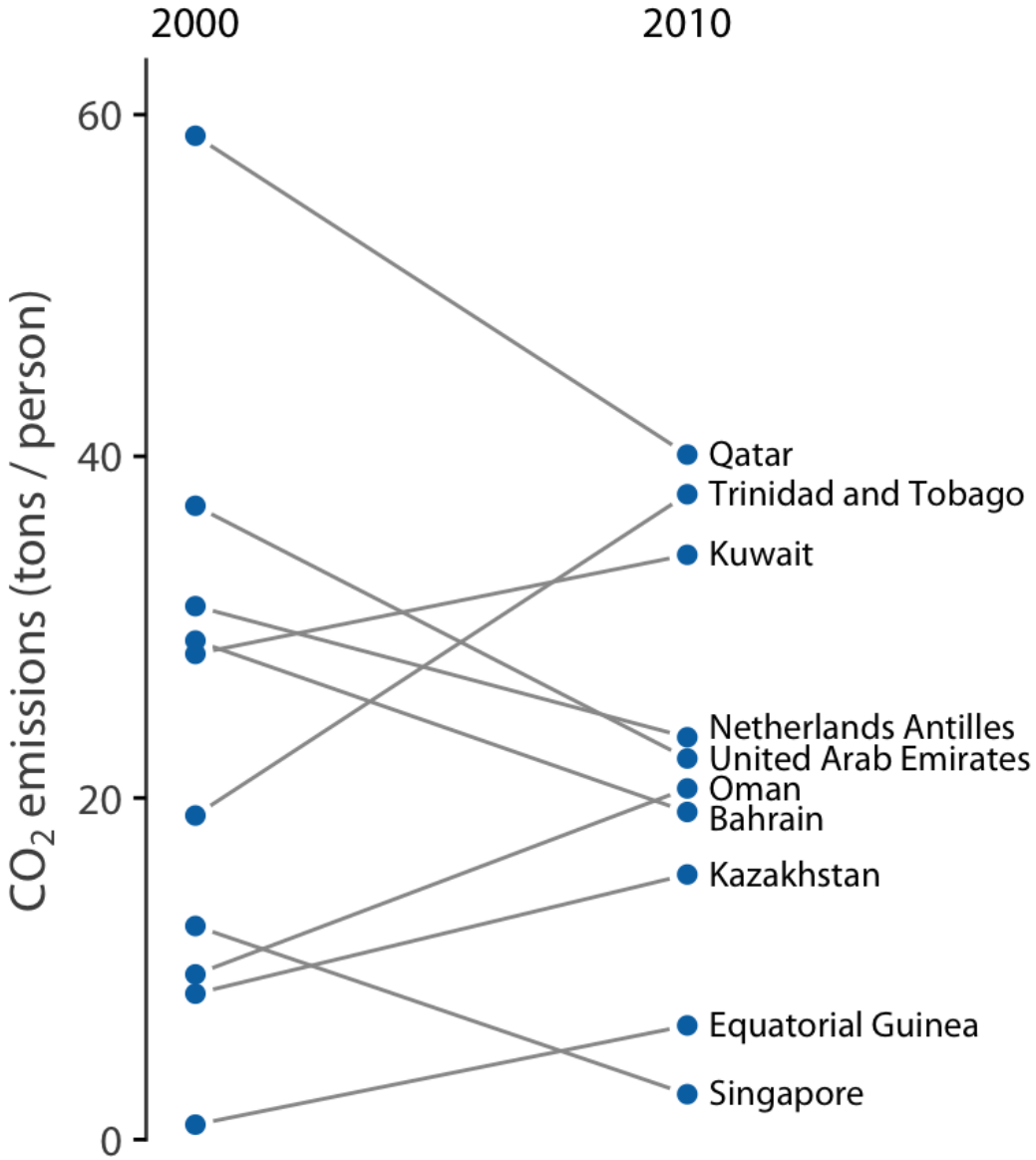
- Data where there are two or more measurements of the same quantity under slightly different conditions.
- Examples include:
  - two comparable measurements on each subject (e.g., the length of the right and the left arm of a person),
  - repeat measurements on the same subject at different time points (e.g., a person's weight at two different times during the year),
  - or measurements on two closely related subjects (e.g., the heights of two identical twins).

Scatter plot with diagonal line where $x = y$



- Countries are consistent over the decades
- Systematic shift to higher emissions

Slopegraph, for smaller numbers of subjects



Slopegraph can be used for multiple years