

# Lecture 11

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# Table of contents

- 1 Table of contents
- 2 Outline
- 3 Histograms
- 4 Stem and leaf
- 5 Dotcharts
- 6 Boxplots
- 7 KDEs
- 8 QQ-plots
- 9 Mosaic plots

# Outline

- ① Histograms
- ② Stem-and-leaf plots
- ③ Dot charts and dot plots
- ④ Boxplots
- ⑤ Kernel density estimates
- ⑥ QQ-plots

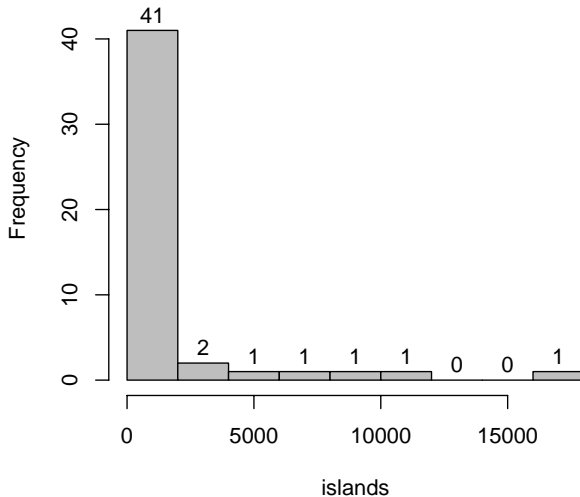
# Histograms

- Histograms display a sample estimate of the density or mass function by plotting a bar graph of the frequency or proportion of times that a variable takes specific values, or a range of values for continuous data, within a sample

# Example

- The data set `islands` in the R package `datasets` contains the areas of all land masses in thousands of square miles
- Load the data set with the command `data(islands)`
- View the data by typing `islands`
- Create a histogram with the command `hist(islands)`
- Do `?hist` for options

## Histogram of islands

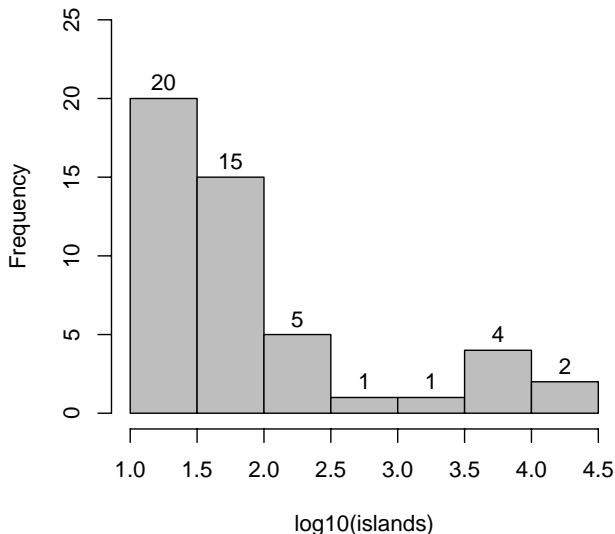


# Pros and cons

- Histograms are useful and easy, apply to continuous, discrete and even unordered data
- They use a lot of ink and space to display very little information
- It's difficult to display several at the same time for comparisons

Also, for this data it's probably preferable to consider log base 10 (orders of magnitude), since the raw histogram simply says that most islands are small

## Histogram of $\log_{10}(\text{islands})$





# Stem-and-leaf plots

- Stem-and-leaf plots are extremely useful for getting distribution information on the fly
- They display the complete data set and waste little ink
- Two data sets' stem and leaf plots can be shown back-to-back for comparisons
- Created by John Tukey, a leading figure in the development of the statistical sciences and signal processing

## Example

```
> stem(log10(islands))
```

The decimal point is at the |

```
1 | 1111112222233444
```

```
1 | 5555556666667899999
```

```
2 | 3344
```

```
2 | 59
```

```
3 |
```

```
3 | 5678
```

```
4 | 012
```

# Dotcharts

- Dotcharts simply display a data set, one point per dot
- Ordering of the dots and labeling of the axes can display additional information
- Dotcharts show a complete data set and so have high information density
- May be impossible to construct/difficult to interpret for data sets with lots of points

```
library(datasets)  
dotchart(log10(islands))
```

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Table of  
contents

Outline

Histograms

Stem and leaf

Dotcharts

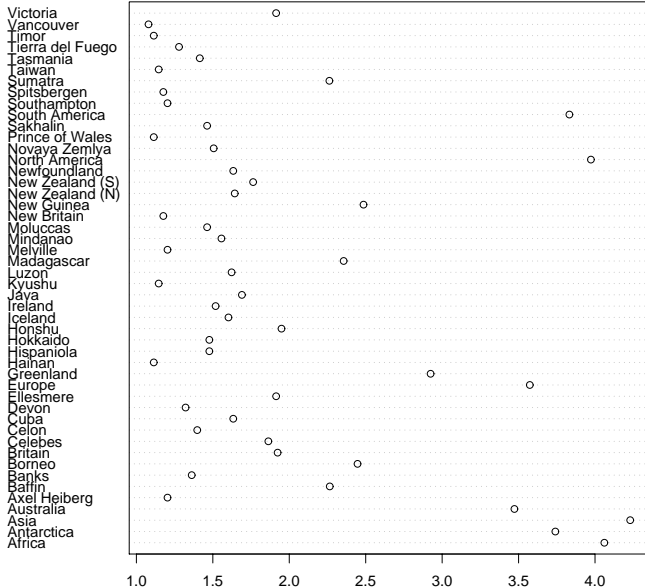
Boxplots

KDEs

QQ-plots

Mosaic plots

islands data: log10(area) (log10(sq. miles))



# Discussion

Table of  
contents

Outline

Histograms

Stem and leaf

Dotcharts

Boxplots

KDEs

QQ-plots

Mosaic plots

- Maybe ordering alphabetically isn't the best thing for this data set
- Perhaps grouped by continent, then nations by geography (grouping Pacific islands together)?

# Dotplots comparing grouped data

Table of  
contents

Outline

Histograms

Stem and leaf

Dotcharts

Boxplots

KDEs

QQ-plots

Mosaic plots

- For data sets in groups, you often want to display density information by group
- If the size of the data allows it, displaying the whole data is preferable
- Add horizontal lines to depict means, medians
- Add vertical lines to depict variation, show confidence intervals interquartile ranges
- Jitter the points to avoid overplotting (`jitter`)

# Example

- The InsectSprays dataset contains counts of insect deaths by insecticide type (A, B, C, D, E, F)
- You can obtain the data set with the command `data(InsectSprays)`

The gist of the code is below

```
attach(InsectSprays)
plot(c(.5, 6.5), range(count))
sprayTypes <- unique(spray)
for (i in 1 : length(sprayTypes)){
  y <- count[spray == sprayTypes[i]]
  n <- sum(spray == sprayTypes[i])
  points(jitter(rep(i, n), amount = .1), y)
  lines(i + c(.12, .28), rep(mean(y), 2), lwd = 3)
  lines(rep(i + .2, 2),
        mean(y) + c(-1.96, 1.96) * sd(y) / sqrt(n)
        )
}
```



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Table of  
contents

Outline

Histograms

Stem and leaf

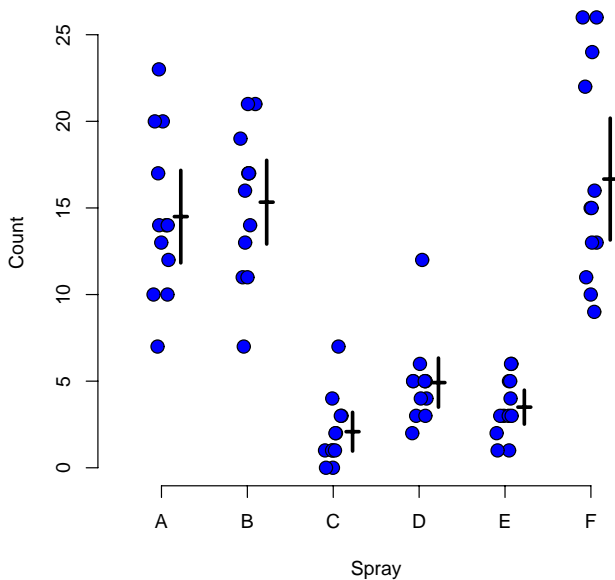
Dotcharts

Boxplots

KDEs

QQ-plots

Mosaic plots



# Boxplots

- Boxplots are useful for the same sort of display as the dot chart, but in instances where displaying the whole data set is not possible
- Centerline of the boxes represents the median while the box edges correspond to the quartiles
- Whiskers extend out to a constant times the IQR or the max value
- Sometimes potential outliers are denoted by points beyond the whiskers
- Also invented by Tukey
- Skewness indicated by centerline being near one of the box edges

## Lecture 11

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Table of  
contents

Outline

Histograms

Stem and leaf

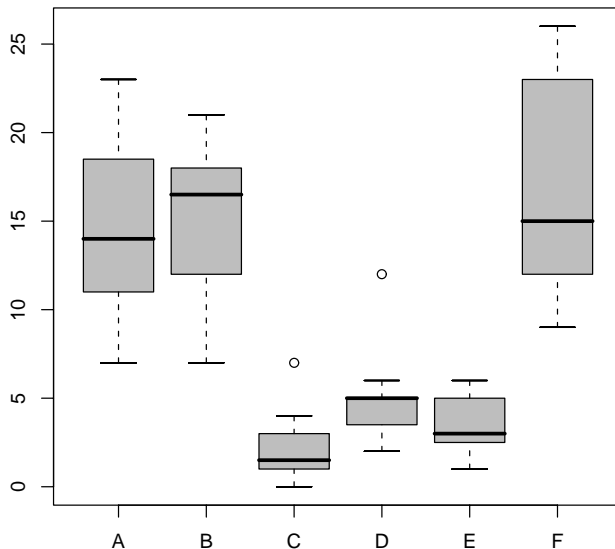
Dotcharts

**Boxplots**

KDEs

QQ-plots

Mosaic plots



# Boxplots discussion

- Don't use boxplots for small numbers of observations, just plot the data!
- Try logging if some of the boxes are too squished relative to the other ones; you can convert the axis to unlogged units (though they will not be equally spaced anymore)
- For data with lots and lots of observations omit the outliers plotting if you get so many of them that you cant see the points
- Example of a bad box plot  
`boxplot(rt(500, 2))`

## Lecture 11

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Table of  
contents

Outline

Histograms

Stem and leaf

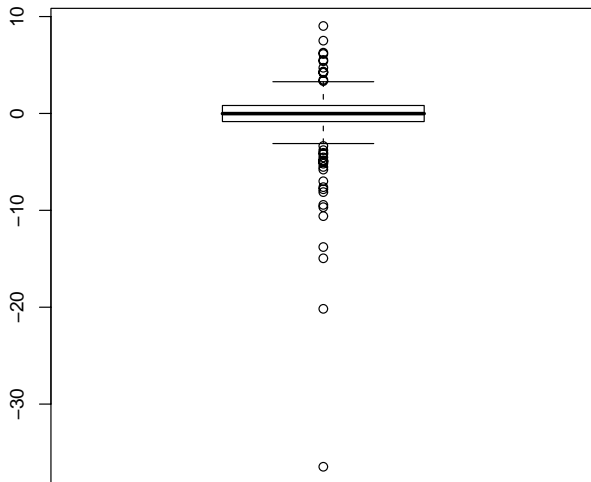
Dotcharts

**Boxplots**

KDEs

QQ-plots

Mosaic plots



# Kernel density estimates

Table of  
contents

Outline

Histograms

Stem and leaf

Dotcharts

Boxplots

KDEs

QQ-plots

Mosaic plots

- Kernel density estimates are essentially more modern versions of histograms providing density estimates for continuous data
- Observations are weighted according to a “kernel”, in most cases a Gaussian density
- “Bandwidth” of the kernel effectively plays the role of the bin size for the histogram
  - a. Too low of a bandwidth yields a too variable (jagged) measure of the density
  - b. Too high of a bandwidth oversmooths
- The R function `density` can be used to create KDEs

# Example

Data is the waiting and eruption times in minutes between eruptions of the Old Faithful Geyser in Yellowstone National park

```
data(faithful)
d <- density(faithful$eruptions, bw = "sj")
plot(d)
```

## Lecture 11

Ciprian M.  
Crainiceanu

Table of  
contents

Outline

Histograms

Stem and leaf

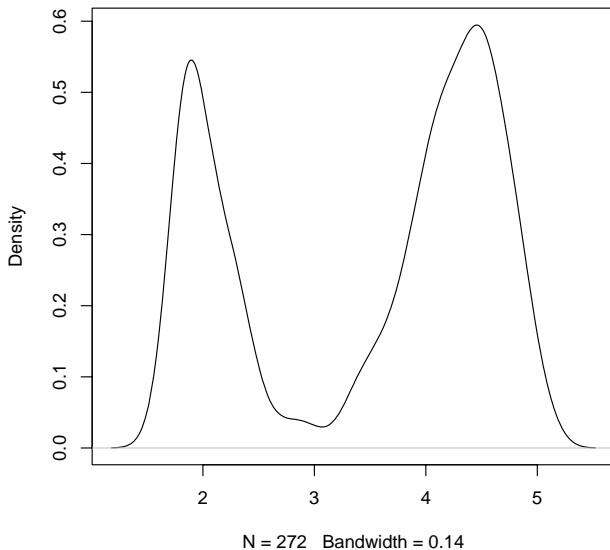
Dotcharts

Boxplots

**KDEs**

QQ-plots

Mosaic plots





# Imaging example

- Consider the following image slice (created in R) from a high resolution MRI of a brain
- This is a single (axial) slice of a three-dimensional image
- Consider discarding the location information and plotting a KDE of the intensities

## Lecture 11

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Crainiceanu

Table of  
contents

Outline

Histograms

Stem and leaf

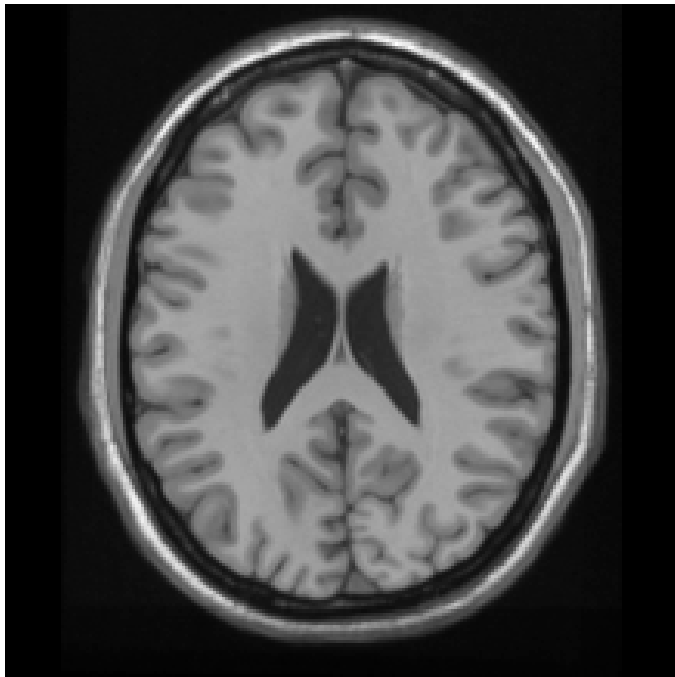
Dotcharts

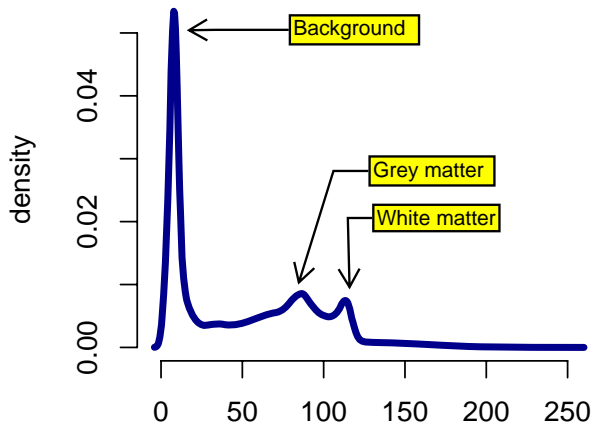
Boxplots

**KDEs**

QQ-plots

Mosaic plots



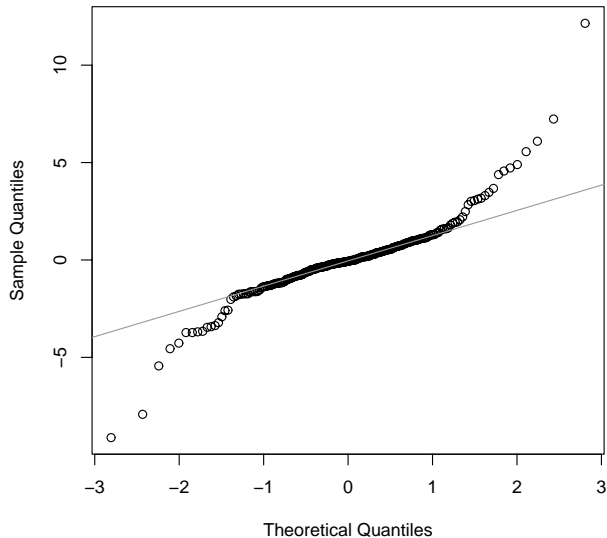


# QQ-plots

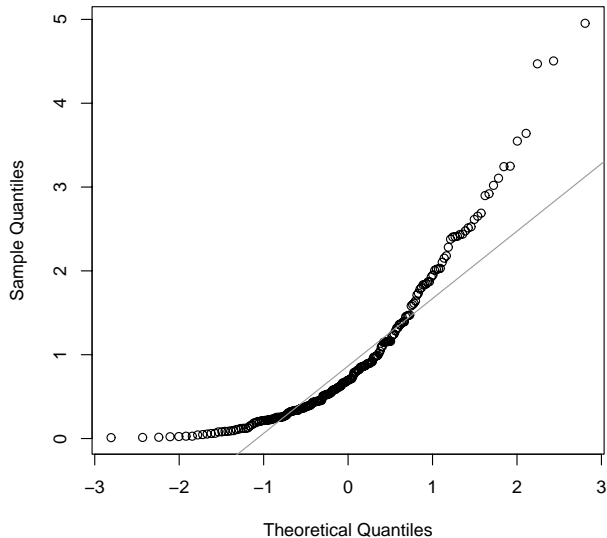
- QQ-plots (for quantile-quantile) are extremely useful for comparing data to a theoretical distribution
- Plot the empirical quantiles against theoretical quantiles
- Most useful for diagnosing normality

- Let  $x_p$  be the  $p^{th}$  quantile from a  $N(\mu, \sigma^2)$
- Then  $P(X \leq x_p) = p$
- Clearly  $P(Z \leq \frac{x_p - \mu}{\sigma}) = p$
- Therefore  $x_p = \mu + z_p \sigma$  (this should not be news)
- Result, quantiles from a  $N(\mu, \sigma^2)$  population should be linearly related to standard normal quantiles
- A normal qq-plot plot the empirical quantiles against the theoretical standard normal quantiles
- In R `qqnorm` for a normal QQ-plot and `qqplot` for a qqplot against an arbitrary distribution

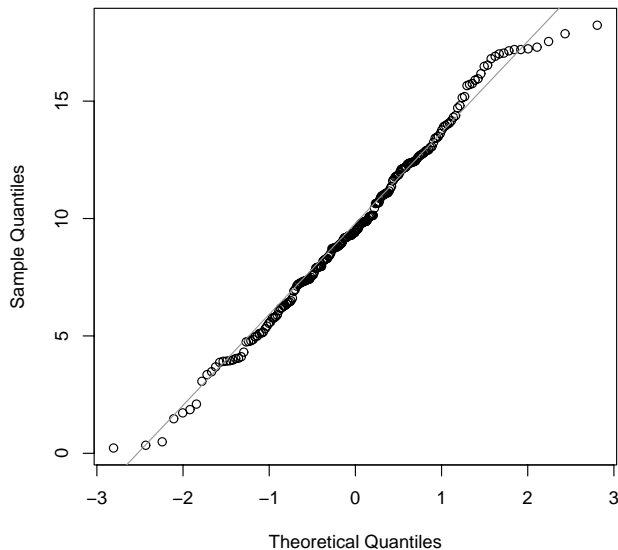
## Normal Q-Q Plot



## Normal Q-Q Plot



## Normal Q-Q Plot





## Mosaic plots

- Mosaic plots are useful for displaying contingency table data
- Consider Fisher's data regarding hair and eye color data for people from Caithness

```
library(MASS)
data(caith)
caith
mosaicplot(caith, color = topo.colors(4),
            main = "Mosaic plot")
```

	fair	red	medium	dark	black
blue	326	38	241	110	3
light	688	116	584	188	4
medium	343	84	909	412	26
dark	98	48	403	681	85

## Mosaic plot

