Neural Data Science with **Python**

L2 : Time Series

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Examples of time series
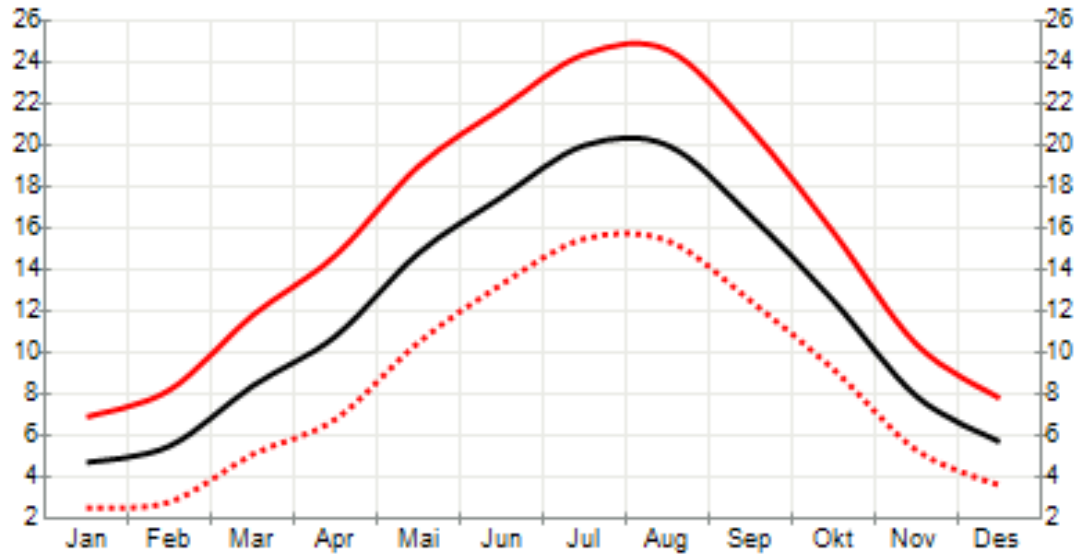
?

Examples of time series: stock prices

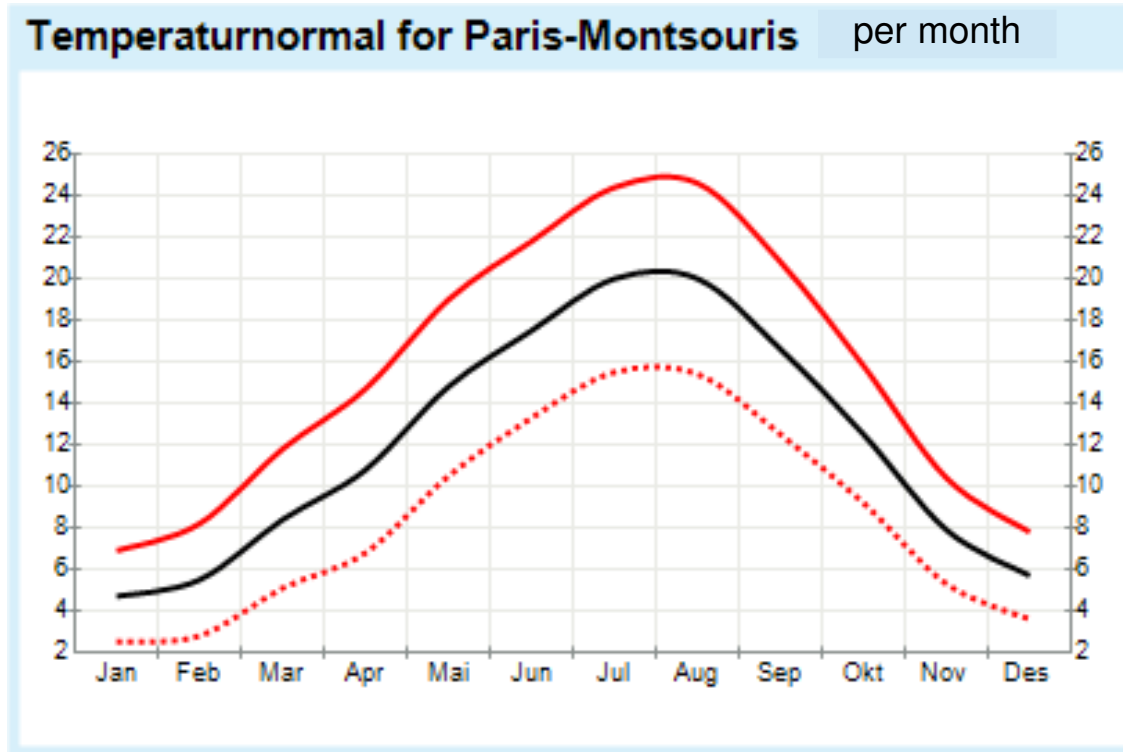## Apple's shares in 2018

Share price in US Dollars

Apple launches latest iPhones

$176.98

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov

Source: Bloomberg. Last update: 21/11/2018, 8:00am GMT

BBC

Examples of time series

?

Examples of time series: temperature profiles

Temperaturnormal for Paris-Montsouris per month
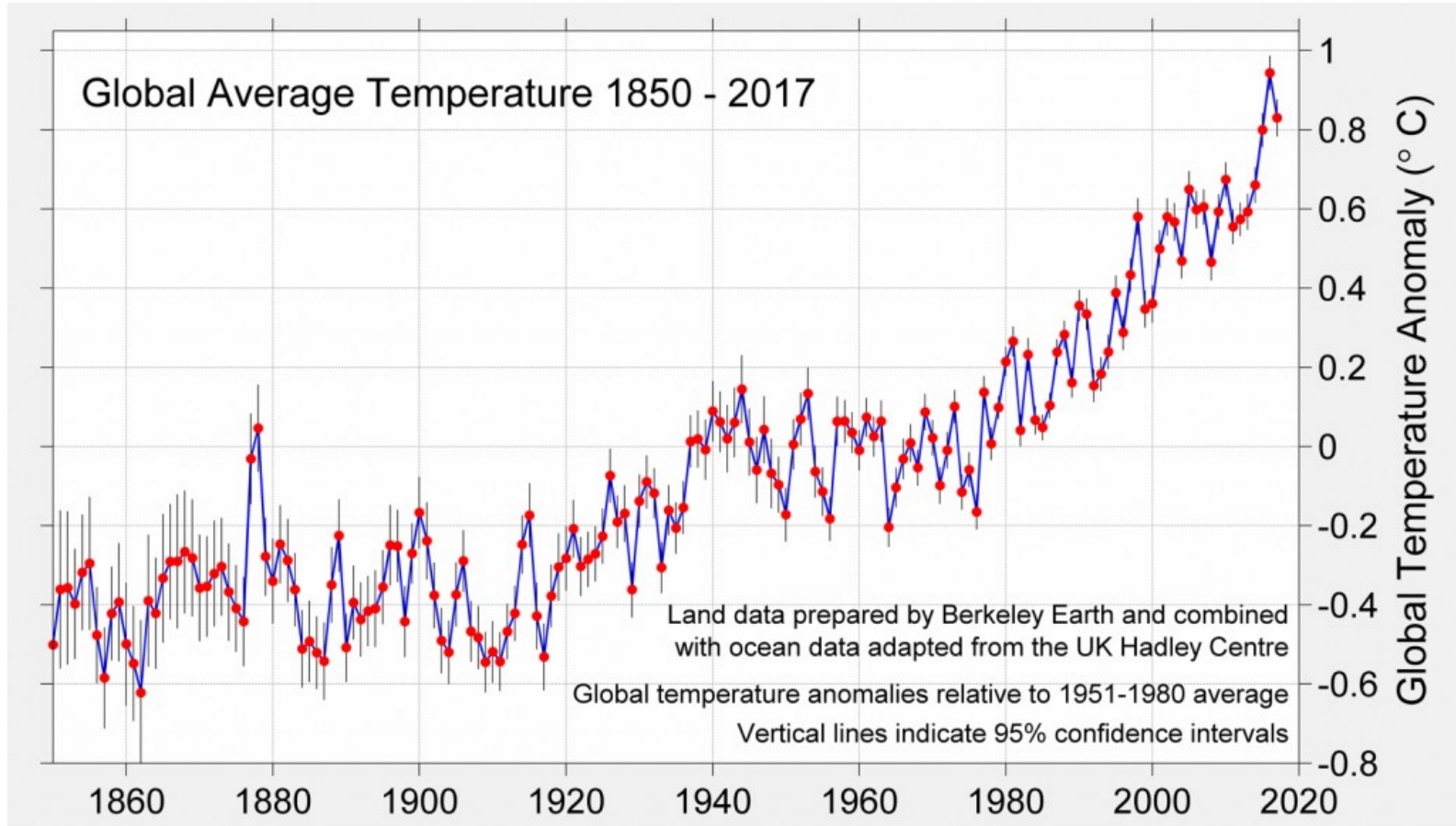
- Max temperature: Average max daily (24h) temperature per month
- Minimum temperature: Average minimum daily (24h) temperature per month
- Average temperature: Average daily (24h) temperature per month
- The temperature normals are measured in the period 1961–1990.
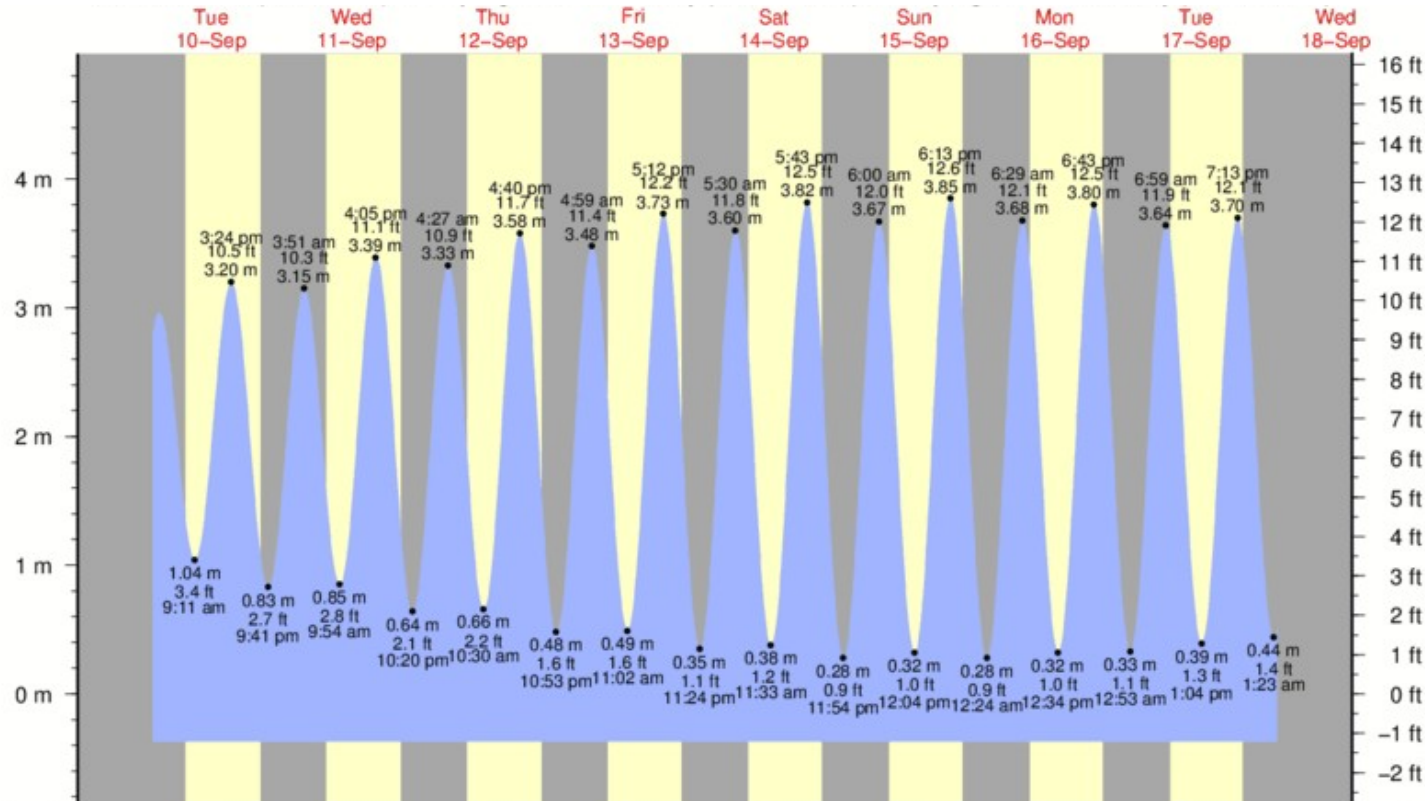
Examples of time series
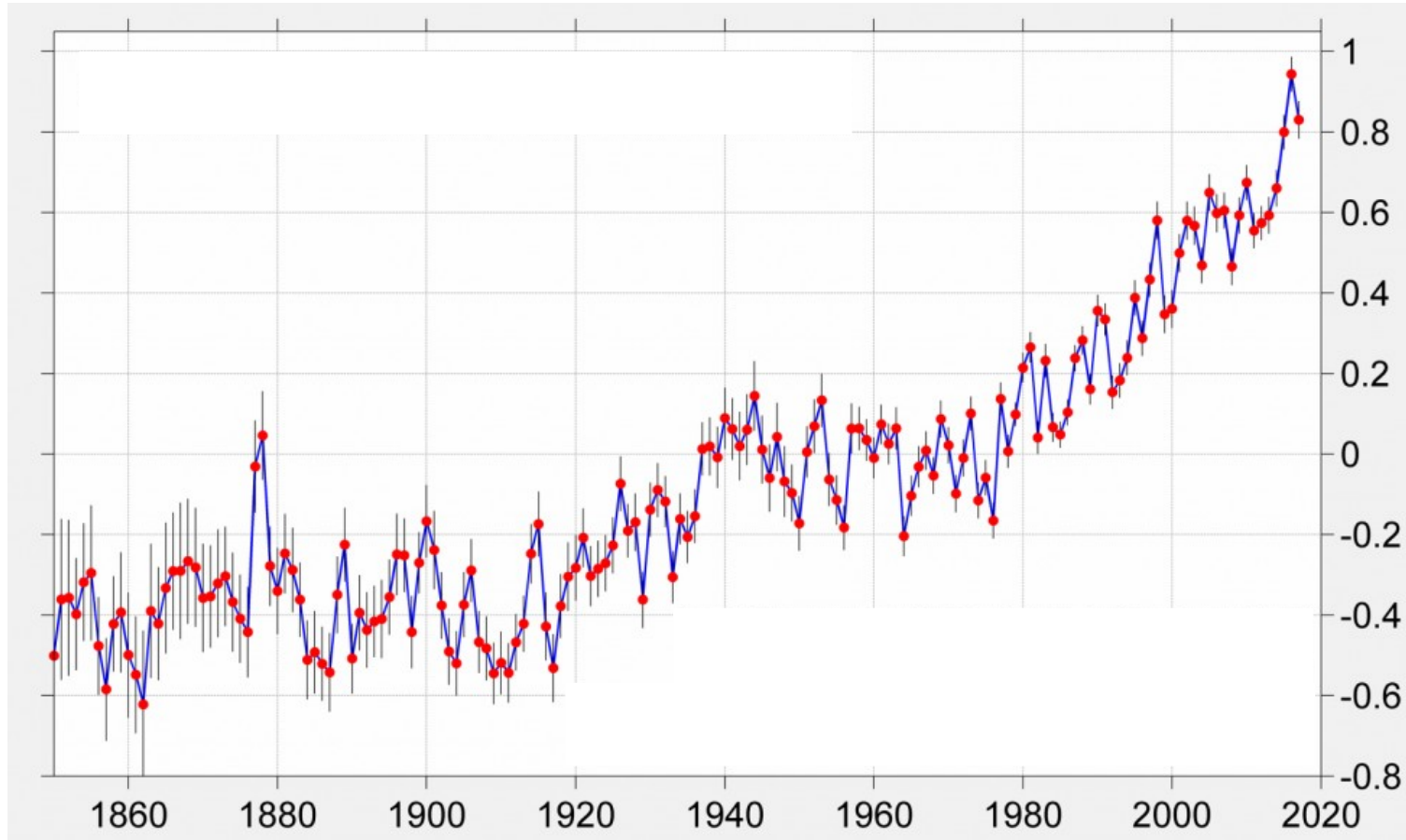
?

Examples of time series: temperature profiles

Global Average Temperature 1850 - 2017

Land data prepared by Berkeley Earth and combined with ocean data adapted from the UK Hadley Centre

Global temperature anomalies relative to 1951-1980 average
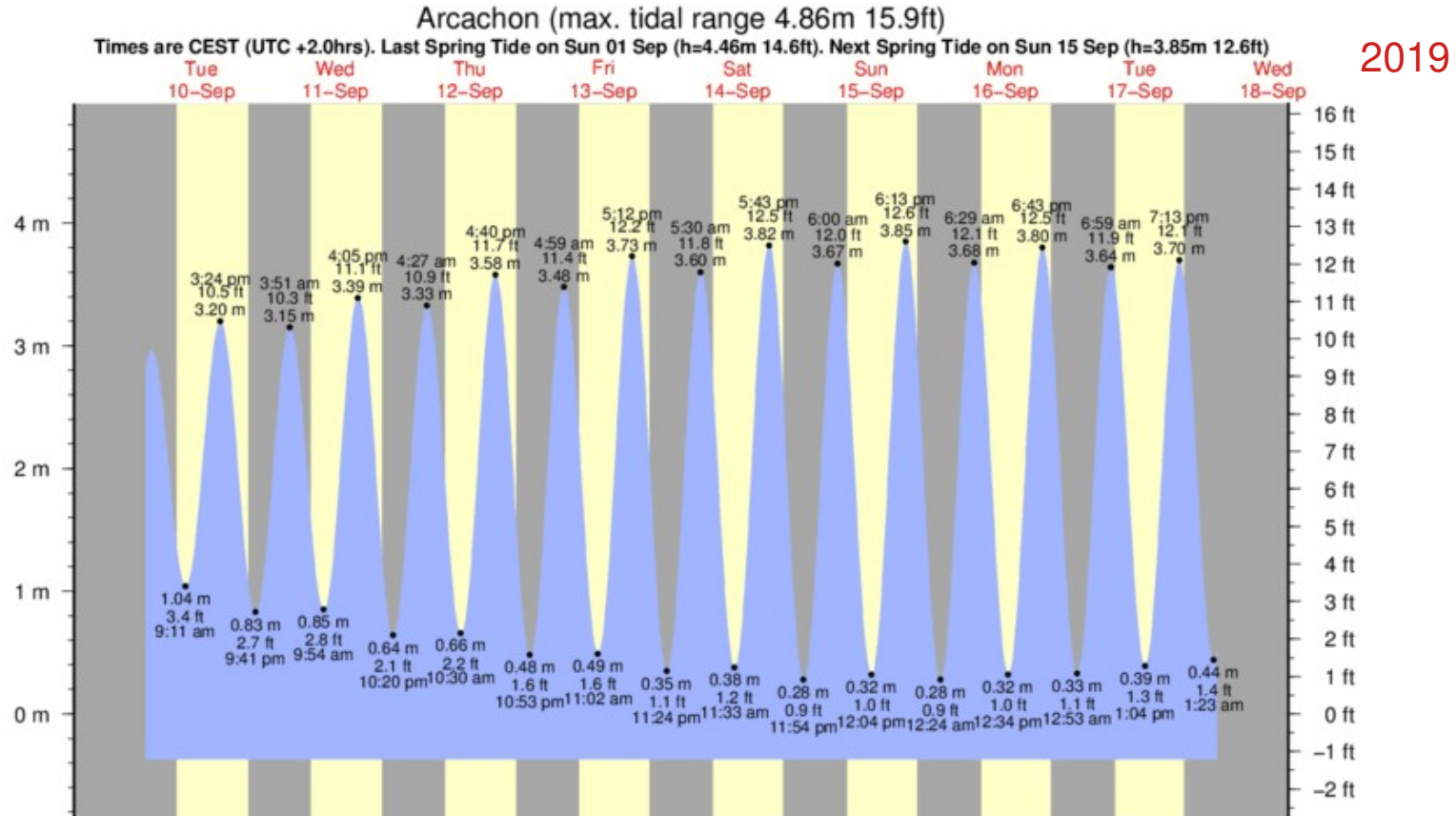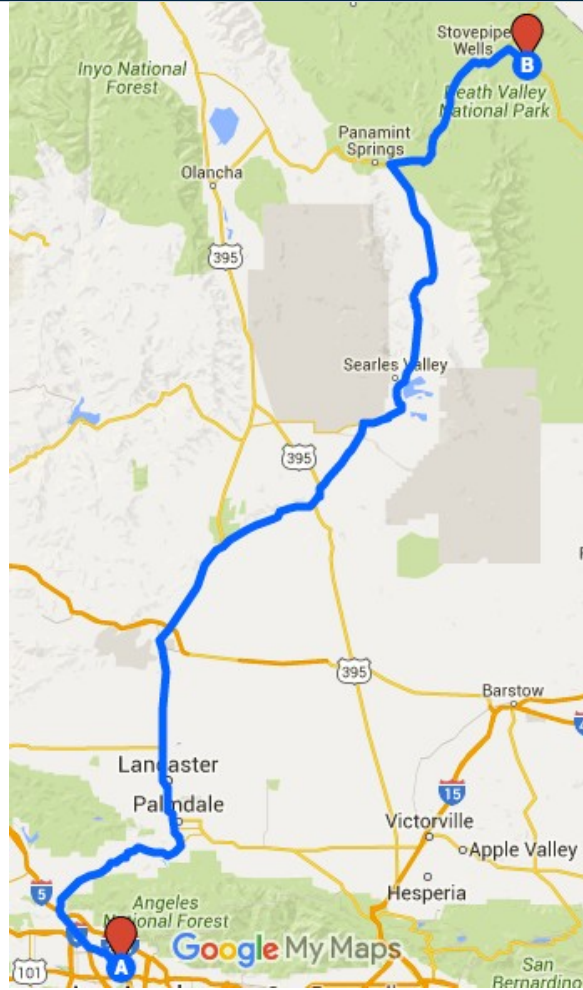
Vertical lines indicate 95% confidence intervals

Examples of time series

Examples of time series: ocean tides

Arcachon (max. tidal range 4.86m 15.9ft)
Times are CEST (UTC +2.0hrs). Last Spring Tide on Sun 01 Sep (h=4.46m 14.6ft). Next Spring Tide on Sun 15 Sep (h=3.85m 12.6ft)
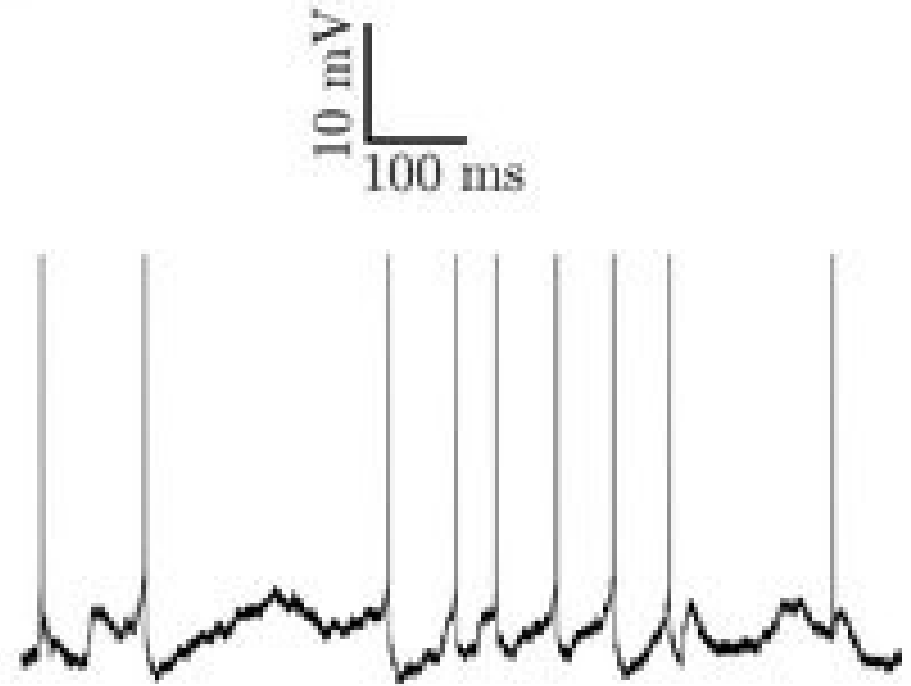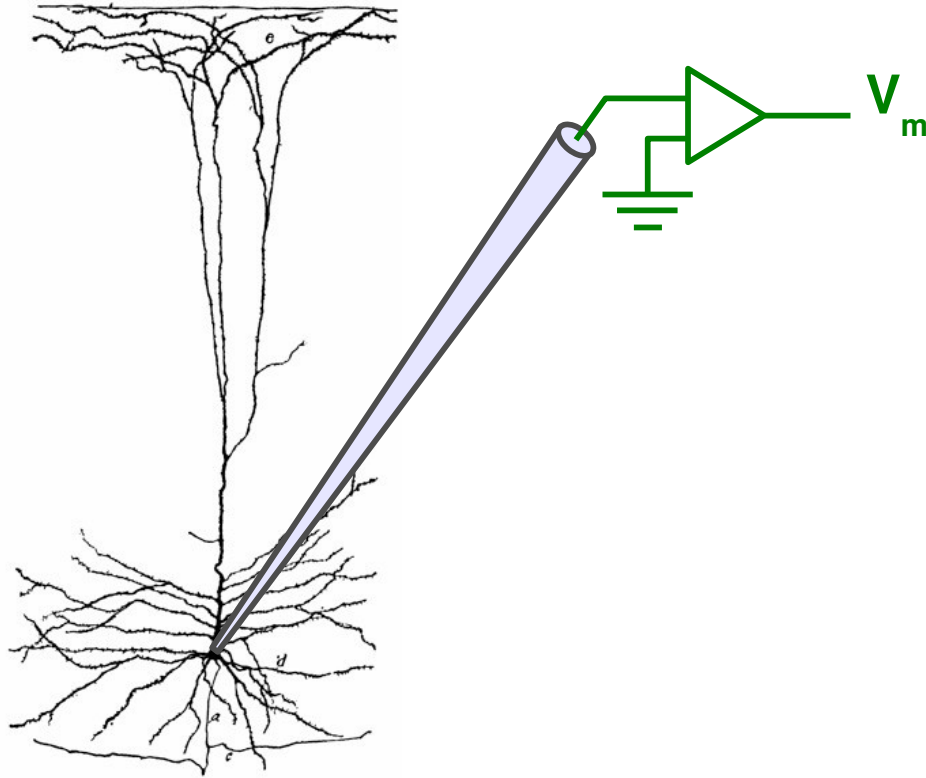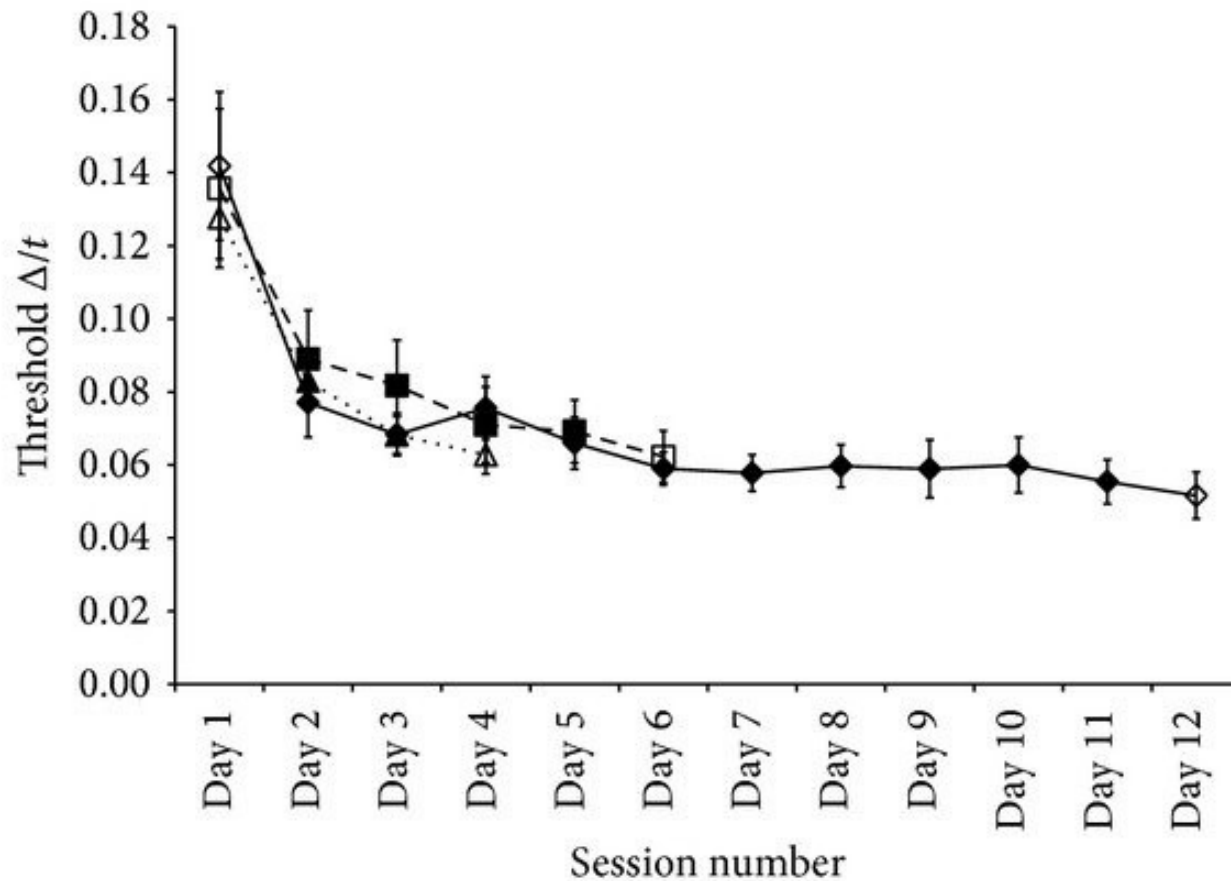
2019

Examples of time series: location profiles

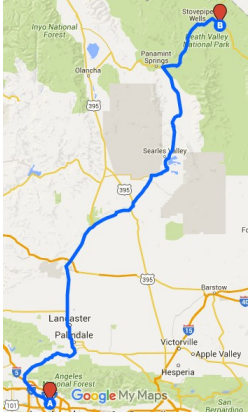# Time series in biology: electrocardiogram
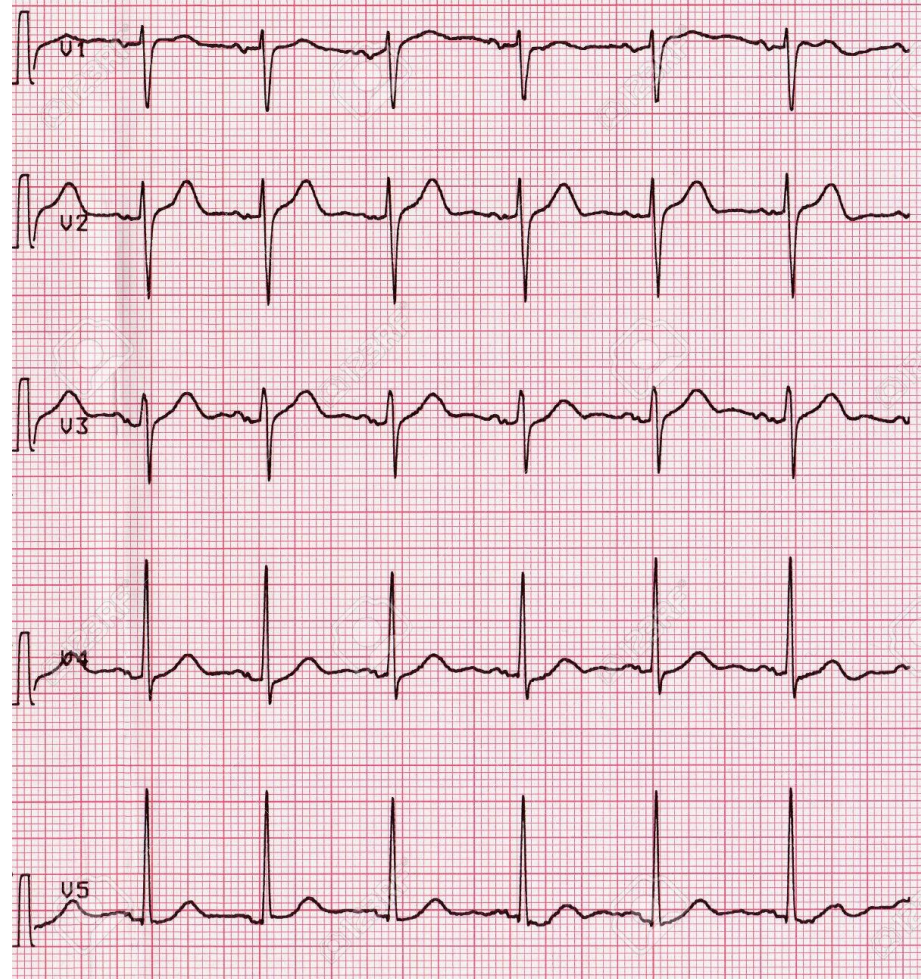
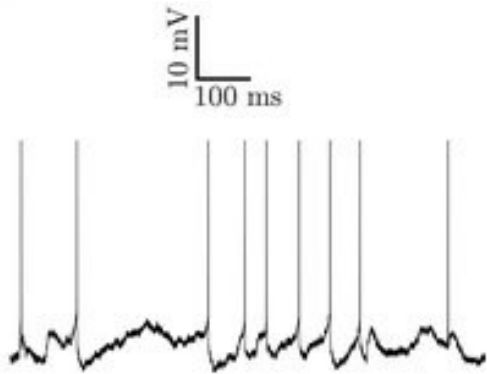# Time series in neuroscience: membrane potential

Time series in neuroscience: learning curves

Time series: definition

Anything that is observed or measured at many points in time forms a time series.

Time series: properties

time	value (°)
Jan	3.3
Feb	4.2
March	7.8
April	10.8
May	14.3
June	17.5
July	19.4

e.g. interval 1 month

⋮

- list of pairs : time point and data point of specific unit
- listed in time order (ascending time)
- entries are separated by specific intervals (years, months, seconds, ...)

Interval between data-points

equally spaced points in time
- interval determines frequency
of measurement as 1/interval

irregular spaced points in time

time (month)	value
Jan	3.3
Feb	4.2
March	7.8
April	10.8
May	14.3
June	17.5
July	19.4

all intervals =1 month

time (hh:m)	value
13:20	45.4
13:22	40.1
13:30	38.3
13:35	37.4
13:43	36.1
14:01	35.9
14:08	36.0

2 min
8 min
5 min
8 min
18 min
7 min

Data can refer to time point, interval, elapsed time

Apple's shares in 2018

Share price in US Dollars


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Source: Bloomberg. Last update: 21/11/2018, 8:00am GMT

BBC

- timestamps – specific instants in time (e.g. every day at 4pm)
- fixed periods : e.g. a month, a year (data represents often average during that period; can be given with further statistics, e.g. standard deviation)
- intervals : indicated start and end of timestamp (general case of fixed periods)
- elapsed time relative to particular start time (often the case for neural data; start is the beginning of a recording)
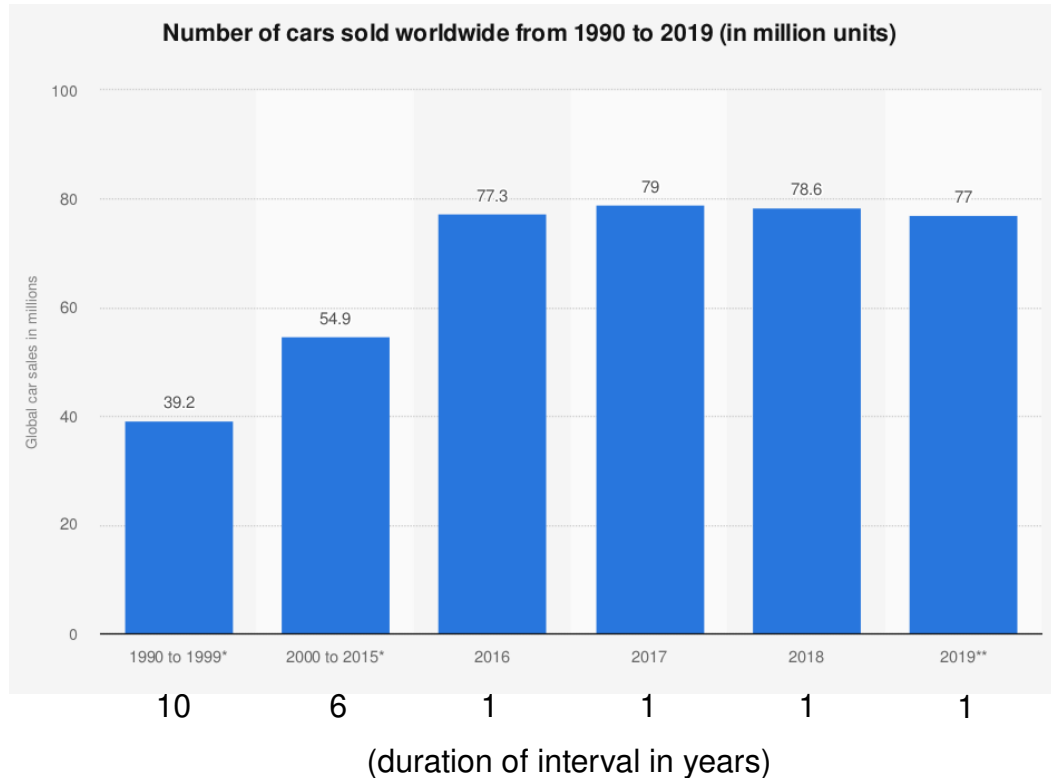
Data can refer to time point, interval, elapsed time
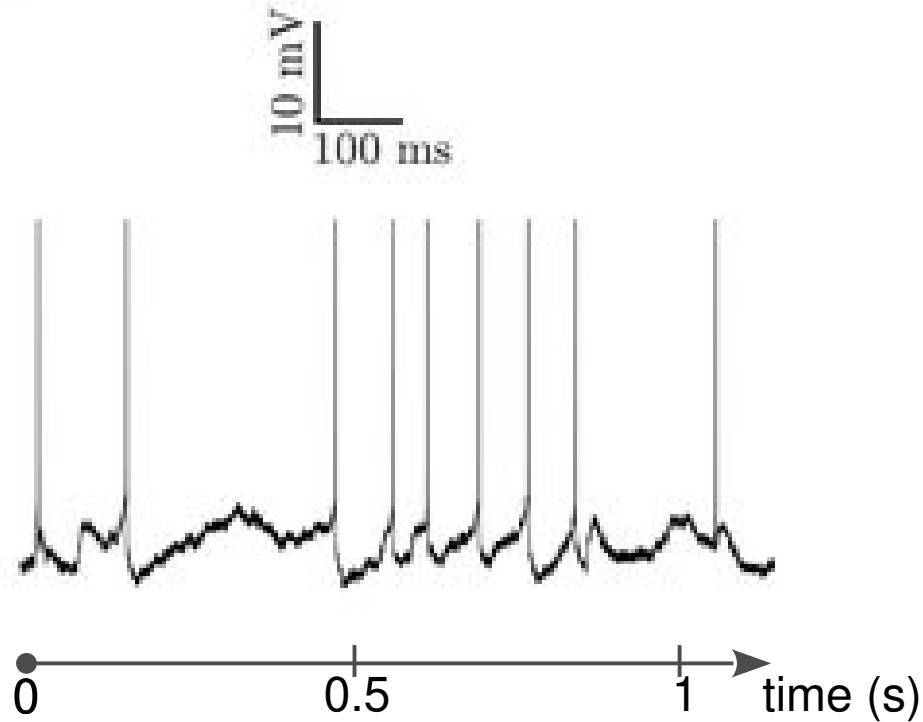
world population
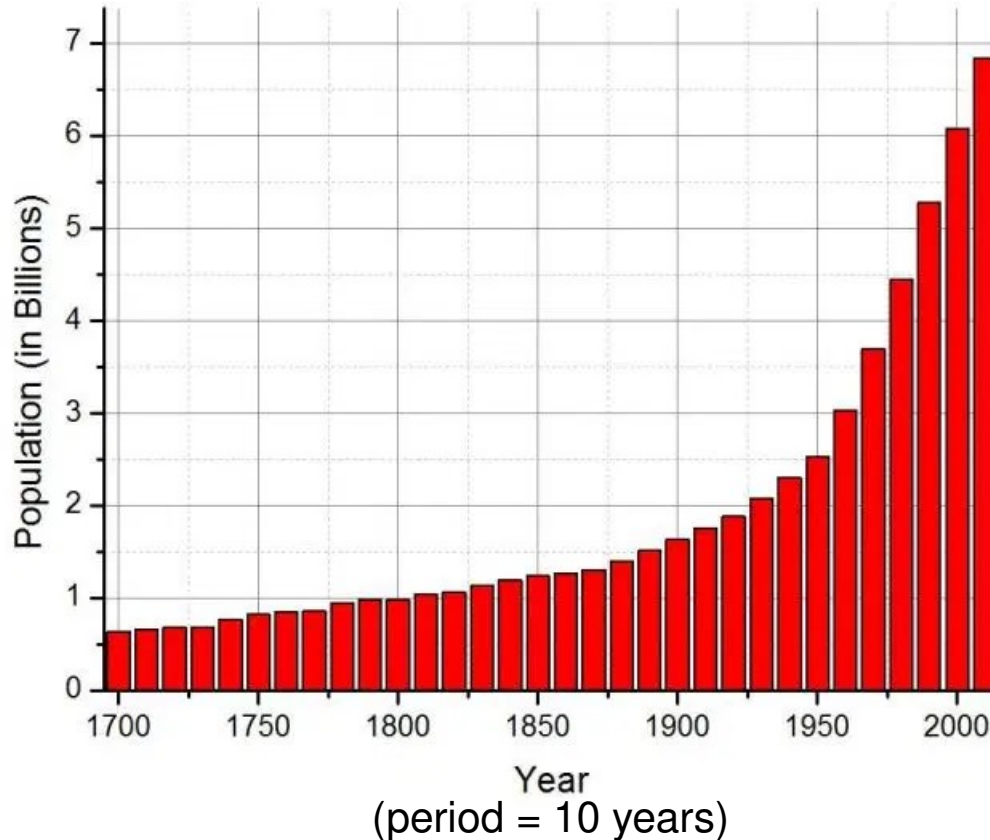
(period = 10 years)

- timestamps – specific instants in time (e.g. every day at 4pm)
- fixed periods : e.g. a month, a year (data represents often sum or average during that period; can be given with further statistics, e.g. standard deviation)
- intervals : indicated start and end of timestamp (general case of fixed periods)
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Data can refer to time point, interval, elapsed time

Number of cars sold worldwide from 1990 to 2019 (in million units)

(duration of interval in years)

- timestamps – specific instants in time (e.g. every day at 4pm)
- fixed periods : e.g. a month, a year (data represents often average during that period; can be given with further statistics, e.g. standard deviation)
- **intervals : with indicated start and end of timestamp (general case of fixed periods)**
- elapsed time relative to particular start time (often the case for neural data; start is the beginning of a recording)

Data can refer to time point, interval, elapsed time

- timestamps – specific instants in time (e.g. every day at 4pm)
- fixed periods : e.g. a month, a year (data represents often average during that period; can be given with further statistics, e.g. standard deviation)
- intervals : indicated start and end of timestamp (general case of fixed periods)

- **elapsed time relative to particular start time (often the case for neural data; start is the beginning of a recording)**

Common visualizations

line chart
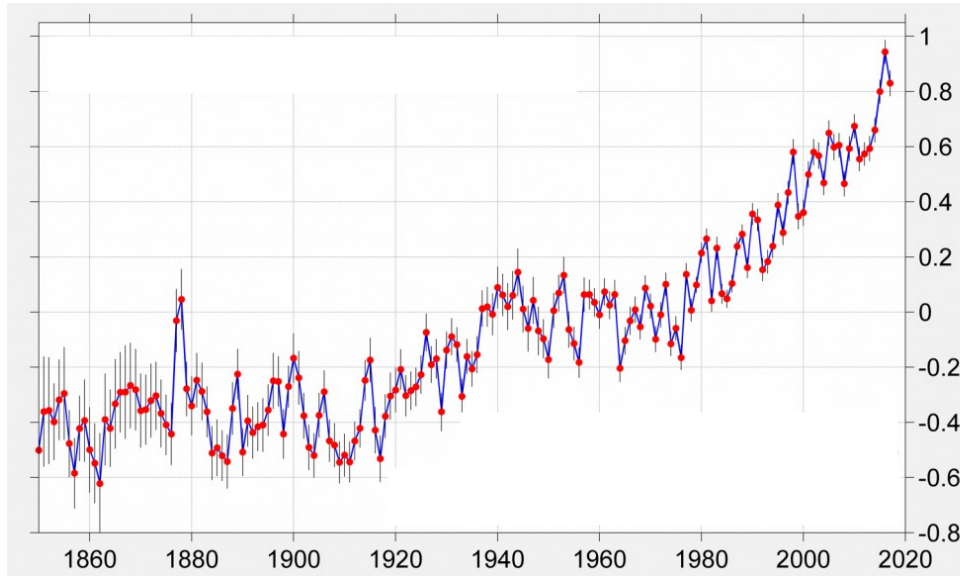
- data-points connected by line
- points themselves can be shown or not

bar graph

Number of cars sold worldwide from 1990 to 2019 (in million units)
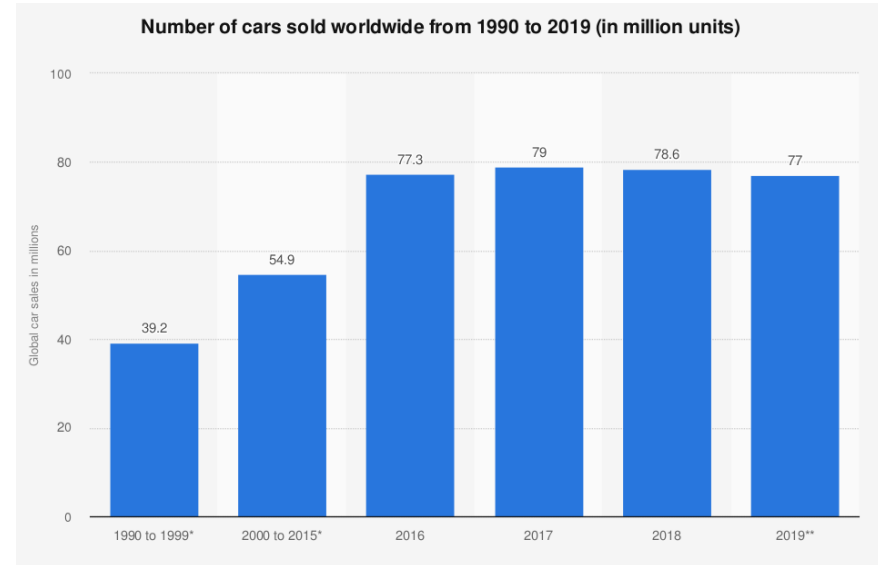
- value shown as height of bar
- limited to displaying few data-points

I want to quantify and compare two membrane recordings, which information would be useful?
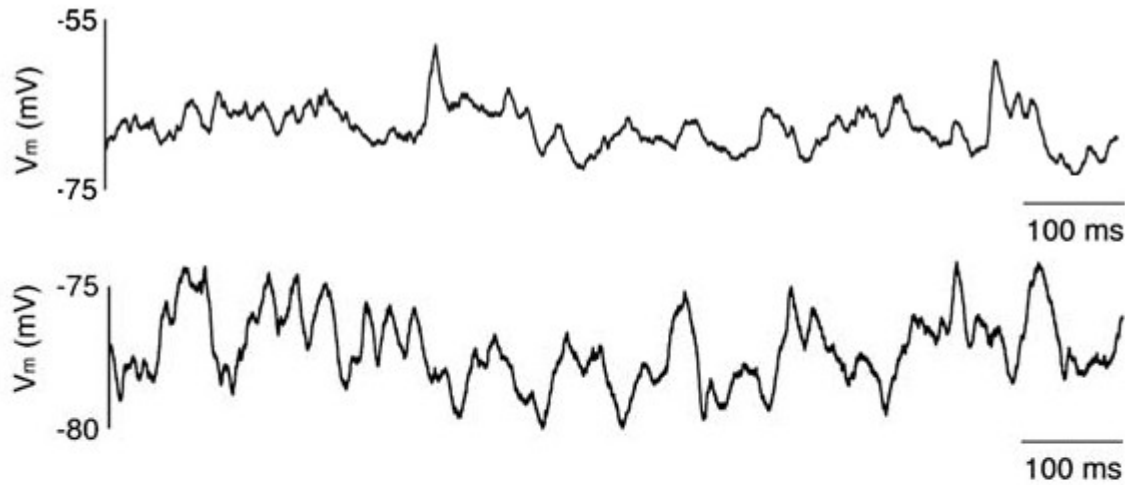
Basics statistics I : max, min, mean, SD
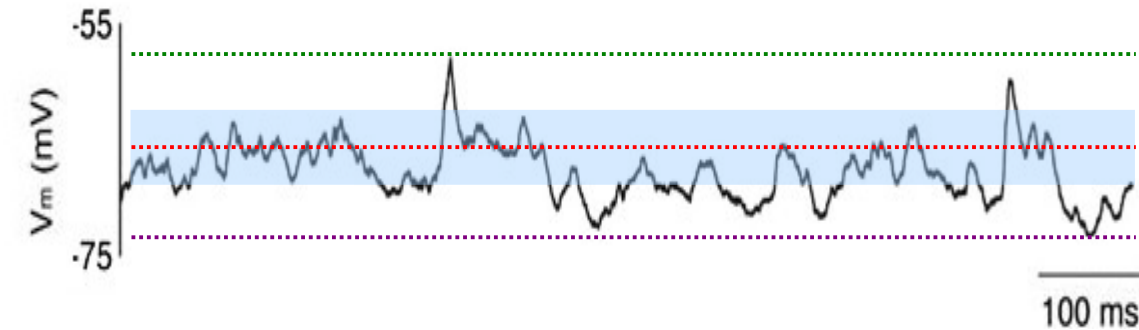
- maximum/minimum

- average (arithmetic mean) :
  - sum of all elements divide by total number of elements

$$\text{AM} = \frac{1}{n} \sum_{i=1}^{n} a_i = \frac{a_1 + a_2 + \cdots + a_n}{n}$$

- standard deviation (SD):
  - measures variation/dispersion in data-set

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2},$$

$\bar{x}$ ... mean value

Comparing data-sets

Recording 1 (R1)
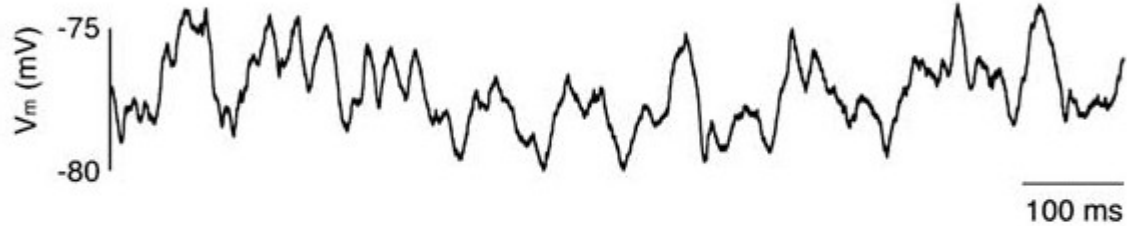
Recording 2 (R2)

	Comparison
max.	?
min.	
mean	
SD	

Comparing data-sets

Recording 1 (R1)

Recording 2 (R2)
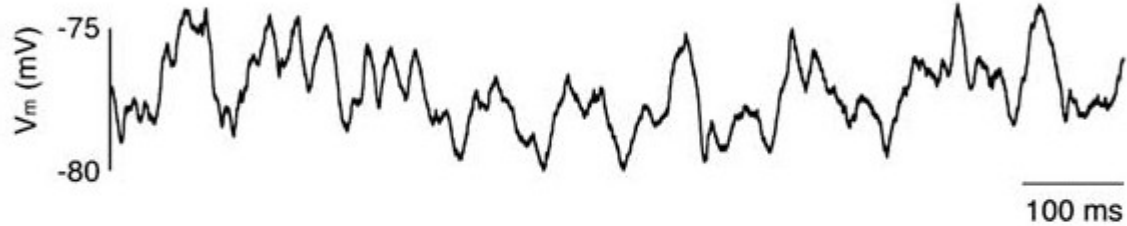
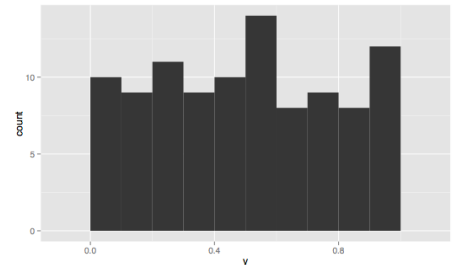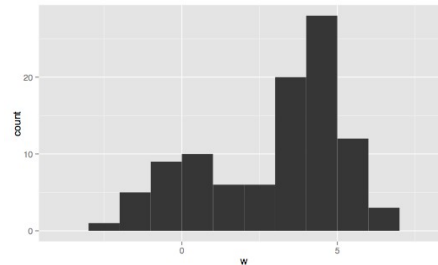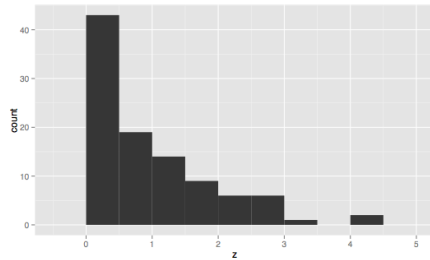|	Comparison
max.	R1>R2
min.	R1>R2
mean	R1>R2
SD	R1<R2

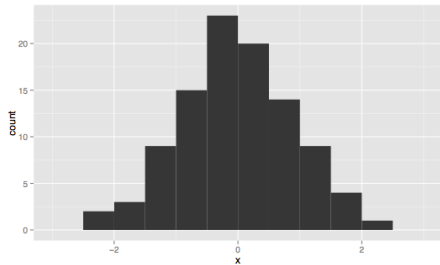# Histogram – representation of data distribution
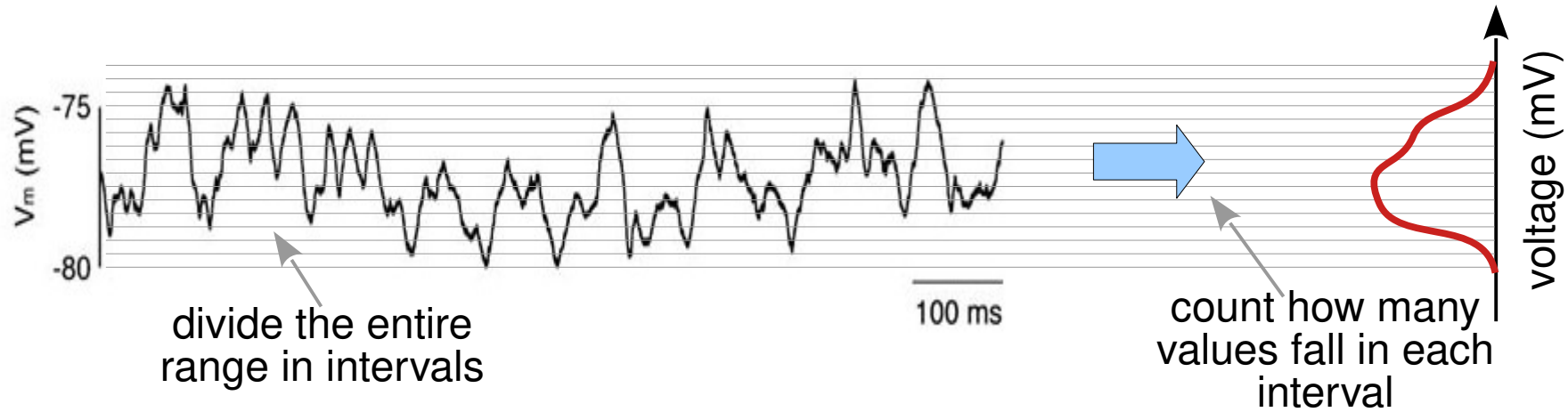
Histogram – shapes
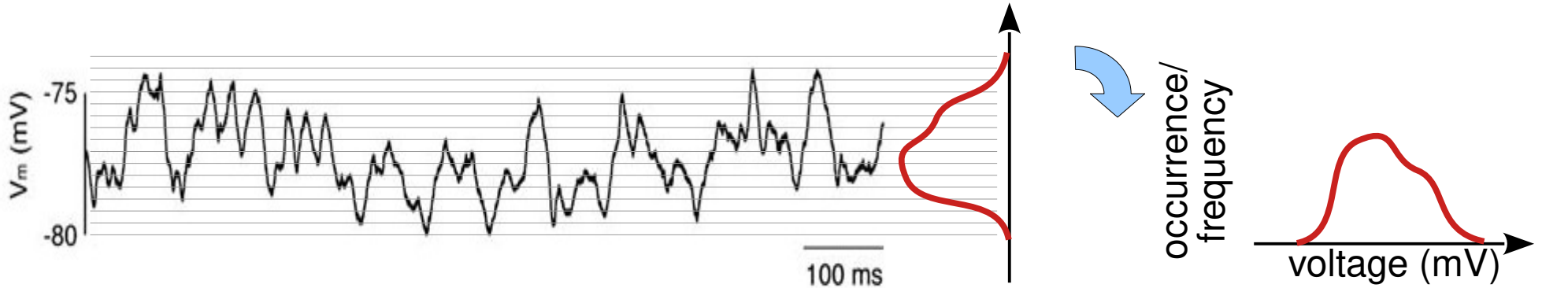
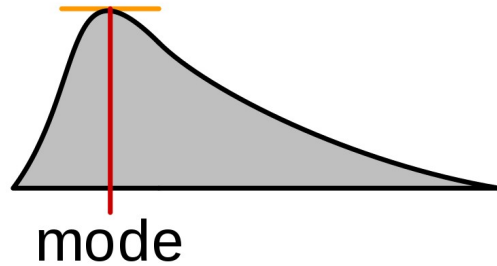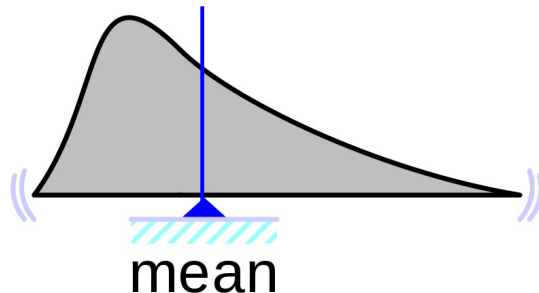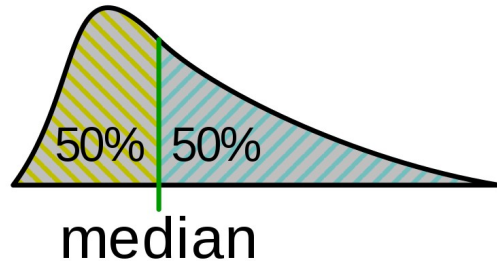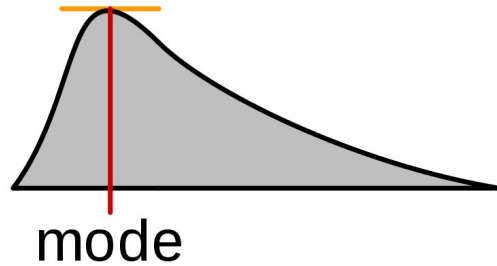symmetric, unimodal

skewed right

bimodal

symmetric

- good idea to plot histogram with several bin widths to learn more about the data

Basics statistics II : median, percentile

mode

median

mean

- **mode :**
  - most frequent data point

- **median** :
  - value separating higher half from the lower half of a data-set
  - comparison with mean quantifies skewness of data

- percentile :
  - indicating the value below which a given percentile of data-points fall
  - e.g. the median is the 50th percentile
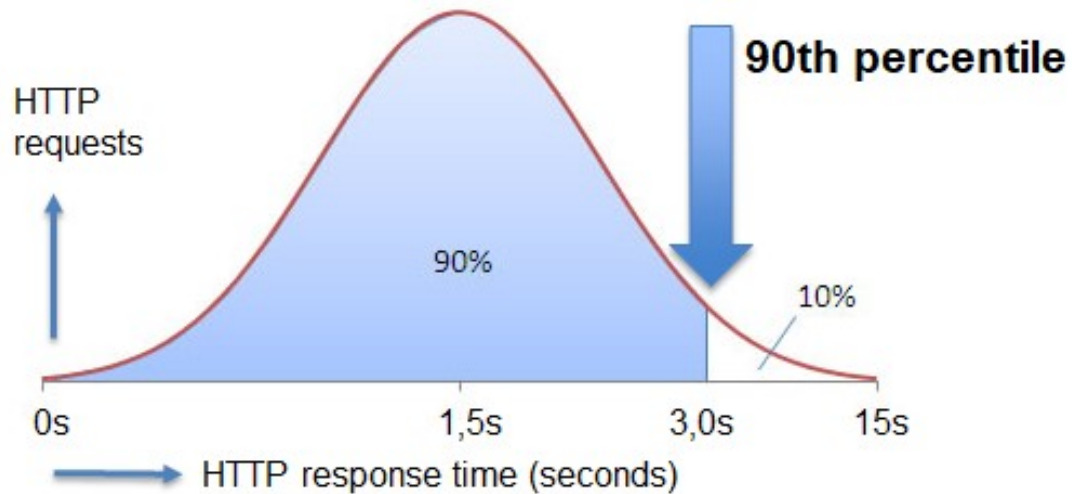
Basics statistics II : median, percentile

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# Basics statistics II : median, percentile

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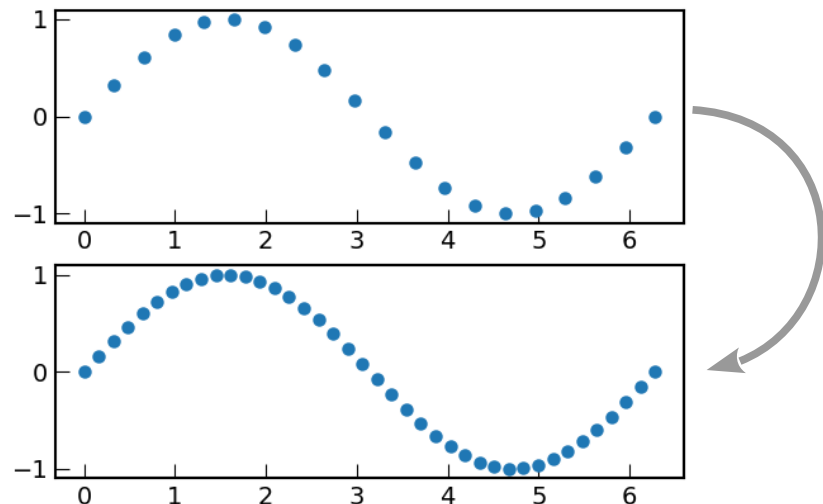 - e.g. the median is the 50th percentile

Resampling

Resampling refers to the process of converting a time series form one frequency to another.

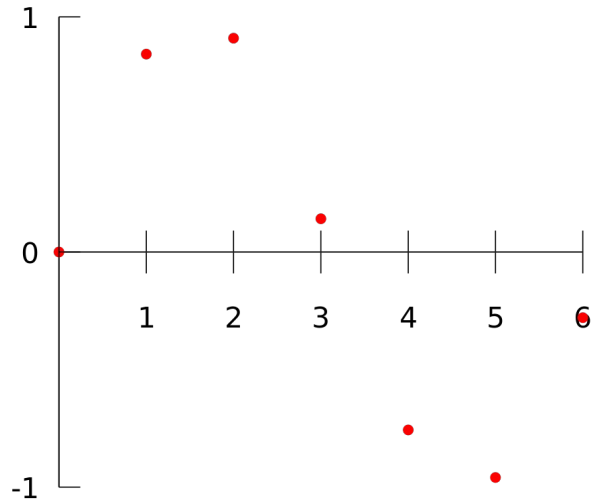Aggregating higher frequency data to lower frequency is called **downsampling**
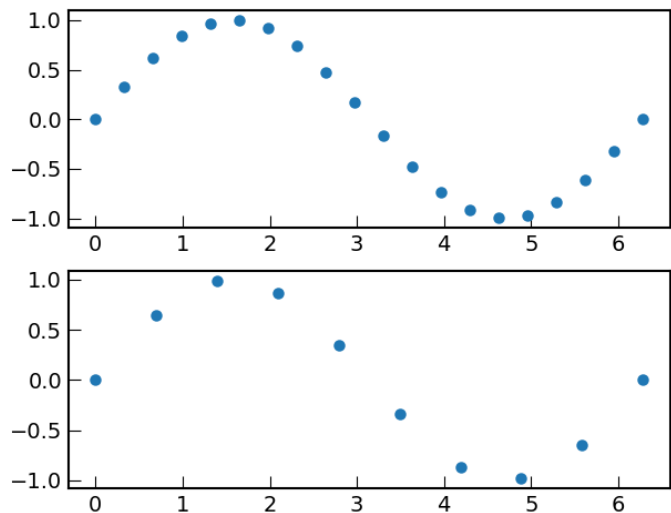
Converting lower frequency data to higher frequency is called **upsampling**
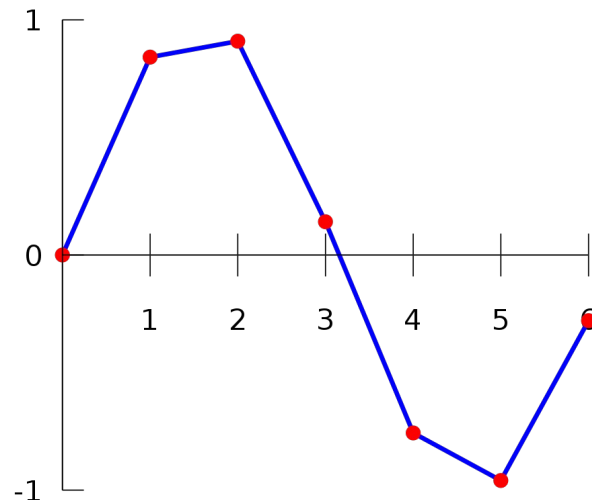
Interpolation

Interpolation is the method of constructing new data points within the range of a discrete set of known data points.
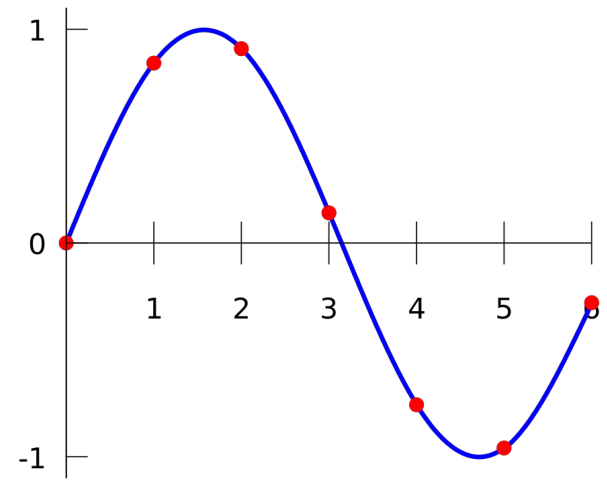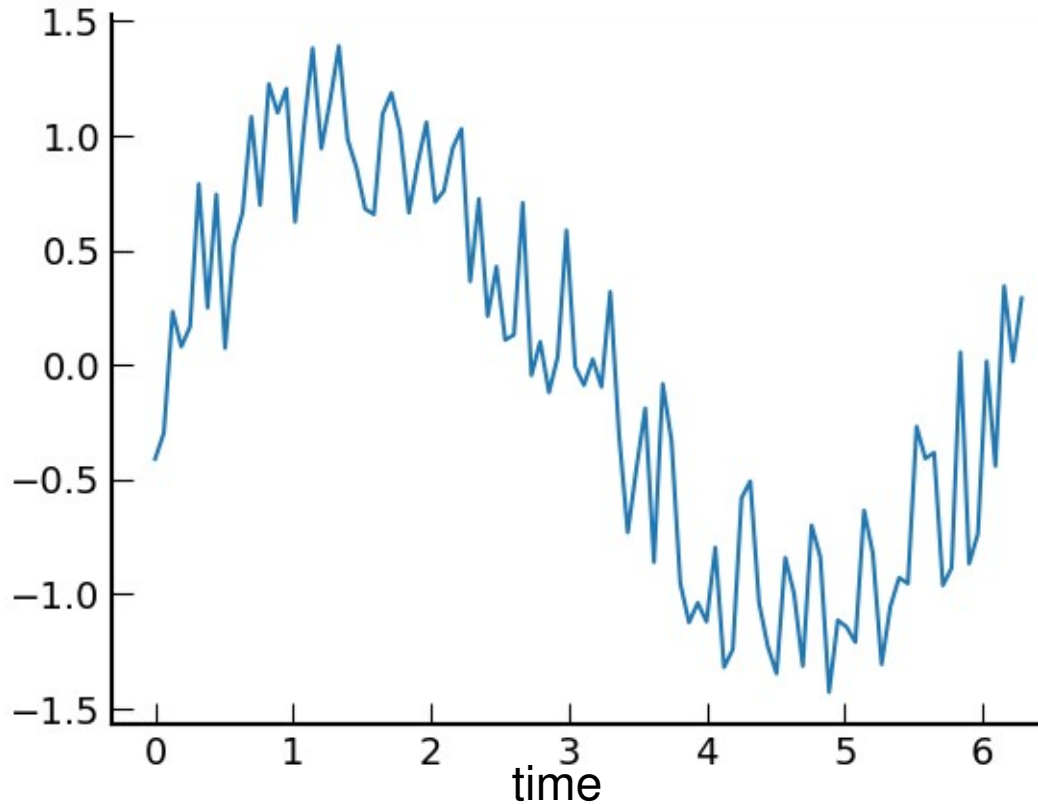

original data

linear interpolation

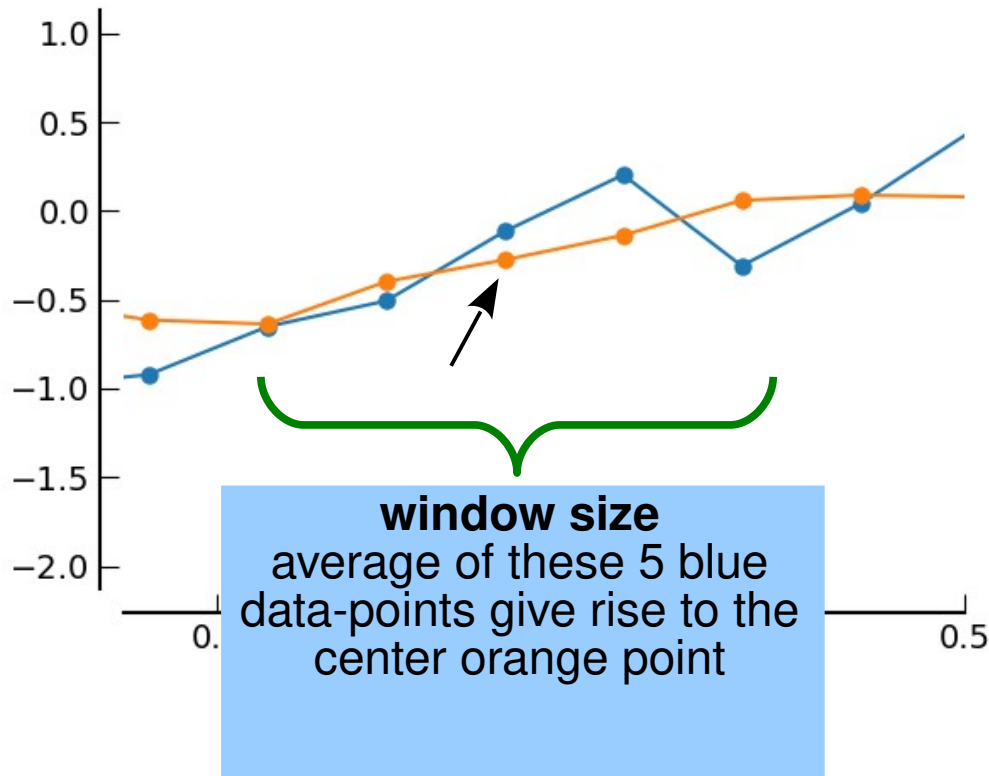- points are connected by line

spline interpolation

- low-degree polynomial for each interval, with smooth transitions

Noisy data

How to reduce noise while preserving characteristics (such as dynamics) of the data ?
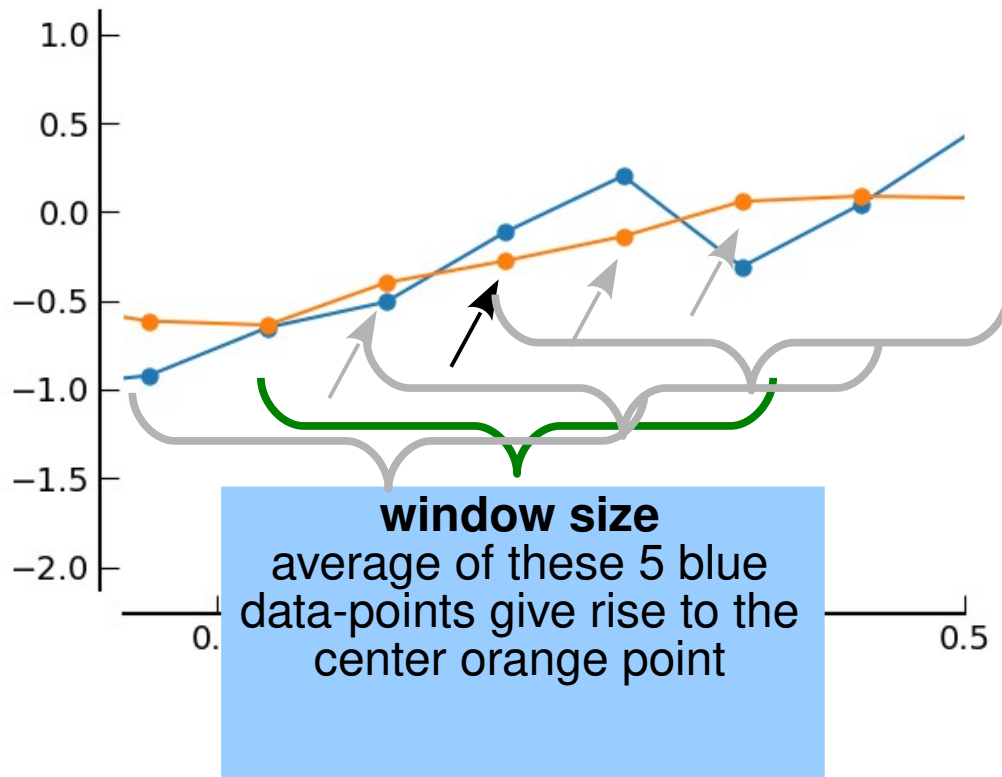
Moving average

window size
average of these 5 blue
data-points give rise to the
center orange point

Moving Average (or moving mean, rolling mean) : analyze data by creating series of averages of different subsets of the full data

- often used to smooth out short-term fluctuations (an example of low-pass filter)
- mathematically, moving average is a convolution of the data with a flat, normalized kernel

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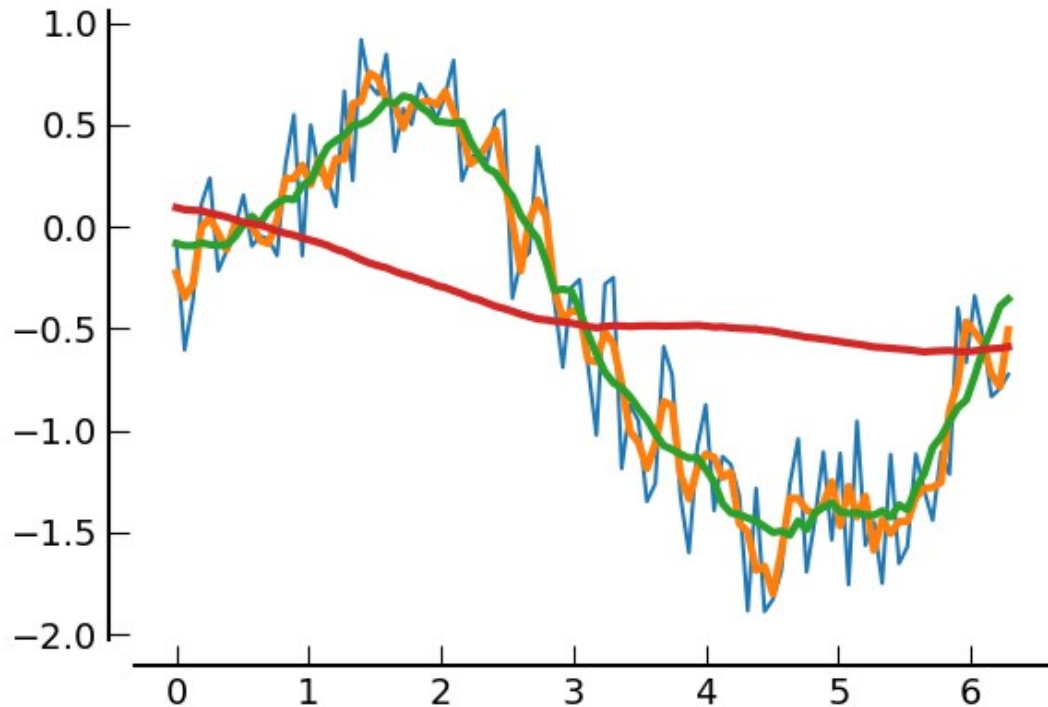
window size
average of these 5 blue data-points give rise to the center orange point

Moving average: window size

Window size
Pick the smallest window size where the signal starts to flatten out, without affecting dynamics of interest.

window size = 3
window size = 11
window size = 99