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for people: favorite color, blood pressure, gender, age, height, ...

for samples: color, surface tension, pH, particle size, organic carbon concentration, ...

Variables

Variables can be classified into categories - it sometimes helps in deciding how you should summaries the variables.

- What is growing in the wood?
- How thick is human hair?

Before we do the experiments, can you think how the outputs will look like?

Categories of variables

Quantitative	Rational	Continuous or Discrete	How many times?
	Interval		What is the diffence?
Qualitative	Ordinal		Larger? Smaller?
	Categorical	Discrete	Equal?

Why teacher should never calculate an average from grades?

The tests were given to students and each of the tests was evaluated by points from 0 to 100. Here are the results of five students (named A to E):

A 99, 89, 89, 79, 69, 59
B 91, 81, 71, 61, 51, 51
C 99, 99, 89, 79, 69, 59
D 99, 98, 89, 88, 87, 60, 59, 58, 39
E 99, 91, 89, 75, 74, 60, 59, 40, 39, 0, 0, 0, 0

Students A, B, C were graded equidistantly (1 <100; 90>, 2 <89; 80>, 3 <79; 70>, 4 <69; 60>, 5 <59; 0>).
Students D and E were graded progressively (1<100; 90>, 2 <89; 75>, 3 <74; 60>, 4 <59; 40>, 5 <39; 0>).

Why teacher should never calculate an average from grades?

a) Calculate the average score for each student and grade him accordingly.

b) Grade each test separately. To obtain a final grade, average the individual grades from tests.

Compare the grades obtained by the approaches a) and b). In case of different results, which grade is the correct one?

What is a cause of possible errors?

Describing a categorical variable

Type of the Tree	Number of Trees
Sprouce	20
Pine	15
Juniper	5

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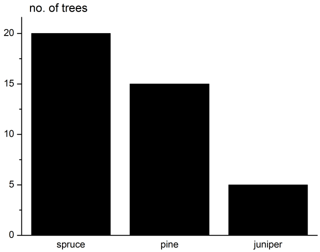

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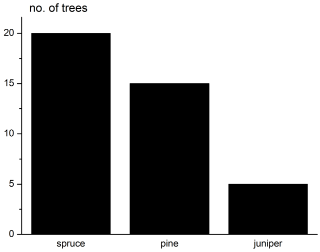
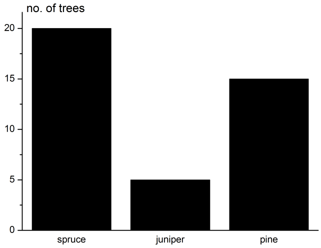
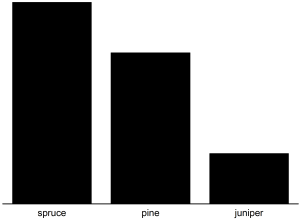




Bar graph without vertical axis; proportions and percents

Type of the Tree	Number of Trees	Proportion	Relative Amount / %
Sprouce	20	4	50.0
Pine	15	3	37.5
Juniper	5	1	12.5



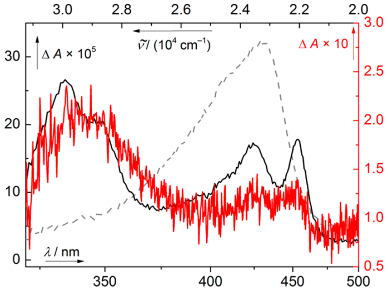
Physical quantities and their notation

Table 1.1 *The SI base quantities*

Base quantity			SI unit	
Name	Symbol for quantity	Symbol for dimension	Name	Symbol
Length	l	L	metre	m
Mass	m	M	kilogram	kg
Time	t	T	second	s
Electric current	I	I	ampere	A
Thermodynamic temperature	T	Θ	kelvin	K
Amount of substance	n	N	mole	mol
Luminous intensity	I_V	J	candela	cd

$$Q = \mathrm{Q}[\mathrm{Q}]$$

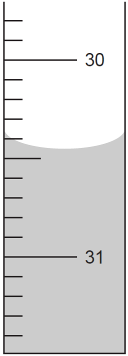
$$l = 5\ \mathrm{cm}$$



<table>
<tr><th rowspan="2">pH</th><th rowspan="2">c (acetic acid)/ mM</th><th colspan="2">k obs / s^{-1}</th></tr>
<tr><th>12b$^-$</th><th><b>12c$^-$</th></tr>
<tr><td>4.92</td><td>8.14</td><td>(9.4 ± 0.1) × 10^6 (2)</td><td>n.d.</td></tr>
<tr><td>4.75</td><td>1.00</td><td>(4.35 ± 0.50) × 10^6 (3)</td><td>(4.21 ± 0.96) × 10^6 (4)</td></tr>
<tr><td>4.52</td><td>0.32</td><td>(1.41 ± 0.17) × 10^6 (4)</td><td>(1.38 ± 0.31) × 10^6 (4)</td></tr>
</table>

Significant figures (Platné číslice)

The digits in a measured quantity, including all digits known exactly and one digit (the last) whose quantity is uncertain.



Mathematical operations:

$+$ or $-$ on n decimal places
* or / on n significant figures

n being the smallest in any number used in the calculation.

Accuracy, precision, and uncertainty

[1] J. Zar:Biostatistical analysis

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It is tempting to assume that:
if we know the answer precisely (přesně), then we also know it accurately (správně).

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Accuracy, precision, and uncertainty

It is tempting to assume that:
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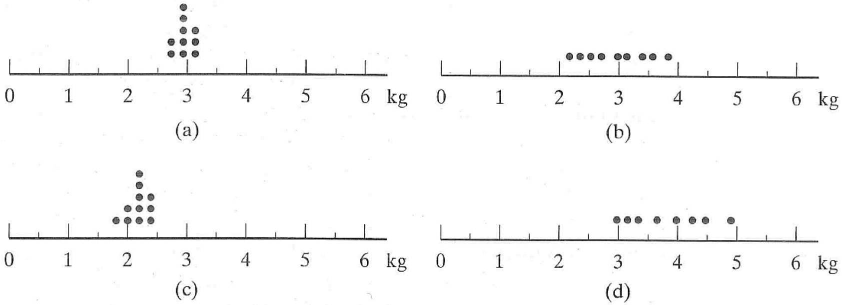
A 3-kilogram animal was weighed 10 times.



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[1] J. Zar:Biostatistical analysis

Errors

Name of error	affect	Example
random (indeterminate)	precision	
systematic (determinat)	accuracy	sampling, instrument, method,person
		constant × proportional
gross		

Accuracy (Správnost)

Accuracy is a measure of the agreement between an experimental result and its expected value.

Absolute error E_a (bias) in the measurement of a quantity x_i is given by the equation
$E_a = x_i - x_t$
where x_t is the true, or accepted, value of the quantity.

Relative error E_r
$E_r/\% = \frac{x_i - x_t}{x_t} \times 100$

Absolute error of the mean $E_{\bar{x}}$
$E_{\bar{x}} = \bar{x}_i - x_t$

Precision (Přesnost)

Precision is a closeness to each other of repeated measurements of the same quantity.

Can be divided into **repeatability** and **reproducibility**.

Reproducibility cannot be better than repeatability.

Uncertainty of measurements (Neurčitost měření)

Uncertainty of measurements expresses the range of possible values that a measurement or result might reasonably be expected to have.

Measurement uncertainties can never be completely eliminated, but we should do maximum to minimize it and to express its probable amplitude.

Uncertainty accounts for all errors - systematic (determinate) and random (indeterminate = stochastic)

Data of unknown quality are worthless!

Excercise: Precision of balance

Table 4.3 Measurement Errors for Selected Balances		
Balance	**Capacity (g)**	**Measurement Error**
Precisa 160M	160	±1 mg
A & D ER 120M	120	±0.1 mg
Metler H54	160	±0.01 mg

What is the possible relative error for weighting 1, 2, 6, 8, 16 a 24 mg on balance with an absolute precision of $\pm$ a) 0.1 a b) 0.01 mg?

Excercise: Precision of pipettes

Table 4.2 Measurement Errors for Selected Glassware[a]

Glassware	Volume (mL)	Measurement Errors for Class A Glassware (±mL)	Measurement Errors for Class B Glassware (±mL)
Transfer Pipets	1	0.006	0.012
	2	0.006	0.012
	5	0.01	0.02
	10	0.02	0.04
	20	0.03	0.06
	25	0.03	0.06
	50	0.05	0.10
Volumetric Flasks	5	0.02	0.04
	10	0.02	0.04
	25	0.03	0.06
	50	0.05	0.10
	100	0.08	0.16
	250	0.12	0.24
	500	0.20	0.40
	1000	0.30	0.60
	2000	0.50	1.0
Burets	10	0.02	0.04
	25	0.03	0.06
	50	0.05	0.10

[a]Specifications for class A and class B glassware are taken from American Society for Testing and Materials E288, E542 and E694 standards.

Excercise: Precision of pipettes

Guaranteed tolerance:

Excercise: Precision of pipettes

Guaranteed tolerance: (10.00 ± 0.02) ml
Calibration:

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rounding to:

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Guaranteed tolerance: (10.00 ± 0.02) ml
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rounding to:(9.9915 ± 0.0061) ml
standard error (standard deviation of the mean) $= 0.001939358$ ml

Recommendations by Jerrold Zar: The standard error (standard deviation of the mean) should be given on two significant figures (e.g. 0.0019 ml). Then the standard deviation and the mean will be reported with the same number of decimal places.

What was the guaranteed uncertainty?

Excercise: Precision of pipettes

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What was the guaranteed uncertainty? 0.02 ml
What was the systematic error?

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What was the guaranteed uncertainty? 0.02 ml
What was the systematic error? $E = 0.0085$ ml
What is the precision after calibration?

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What was the guaranteed uncertainty? 0.02 ml
What was the systematic error? $E = 0.0085$ ml
What is the precision after calibration? $s = 0.0061$ ml

Percentile

Formal definition of **percentile**

The p^{th} percentile of a list of numbers is the smallest number that is at least as large as p % of the list.

P-tý percentyl z řady čísel je takové nejmenší číslo, které je nejméně tak velké jako p % čísel v řadě.

Percentile

Mechanism for medin finding:

- order the list
- identify the place that is p % of the away from the bottom of the list
- if that's a place on the list, take the number in that place, if not, take the next one up

Infromation sources

https://courses.edx.org/courses/BerkeleyX/Stat_2.1x/
Jerrold H. Zar: Biostatistical Analisis (Chaper 1)
David Harvey: Modern Analytical Chemistry, (Chapter 4)
http://www.stat.berkeley.edu/ stark/SticiGui/ (Chapter 3)
Klán, Wirz: Photochemistry of Organic Compounds, From Concepts to Practice