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Genetics of quantitative traits - qualitative and quantitative traits, decomposition of phenotypic variance, heritability?

Modul no.: Animal Genetics

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Phenotype

- **Phenotype** is a set of observable characteristics (traits) exhibited by an organism and depends on genotype and environmental factors.

- Phenotypic traits have qualitative and/or quantitative character.

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Qualitative traits

- Segregate in separated phenotypic categories.
- Determined by a low number of major genes (oligogenes).
- Negligible effect of environmental factors.
- Show alternative variation.
- Examples: coat type, coat color, horns presence x absence, blood group, type of milk casein, some genetic diseases (e.g., haemophilia, arachnomelia, BLAD, CVM).

Quantitative traits

- A large spectrum of phenotypes occurs (continuous variation).
- Determined by a high number of minor genes (polygenic inheritance).
- Different effect of environmental factors (depends on the specific trait).
- Show continuous variation.
- Examples: body size, production and performance traits, some diseases (e.g., joint dysplasia, osteochondrosis, diabetes, different allergies).

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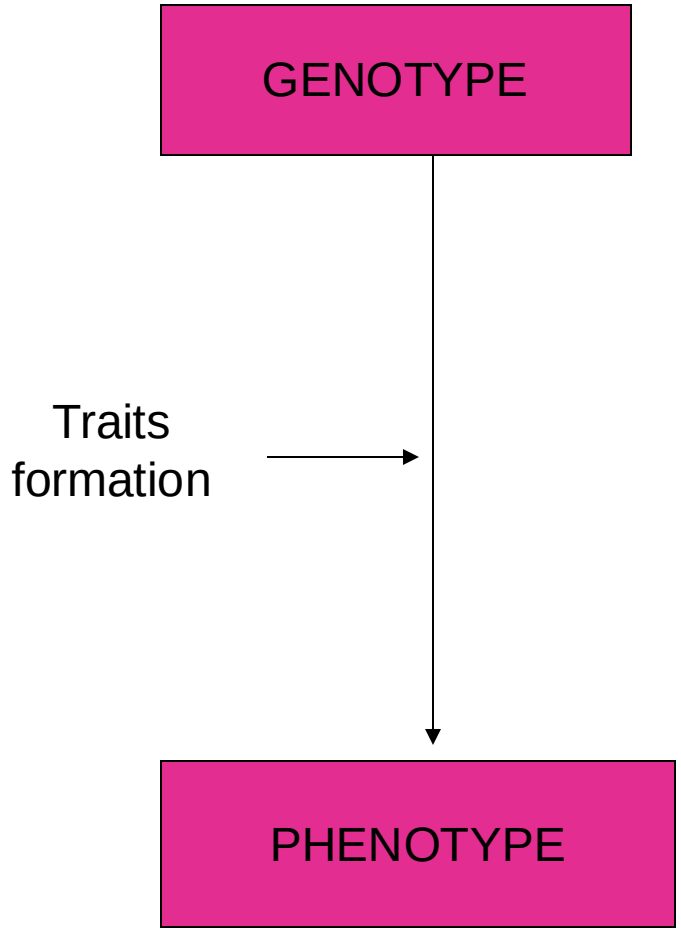
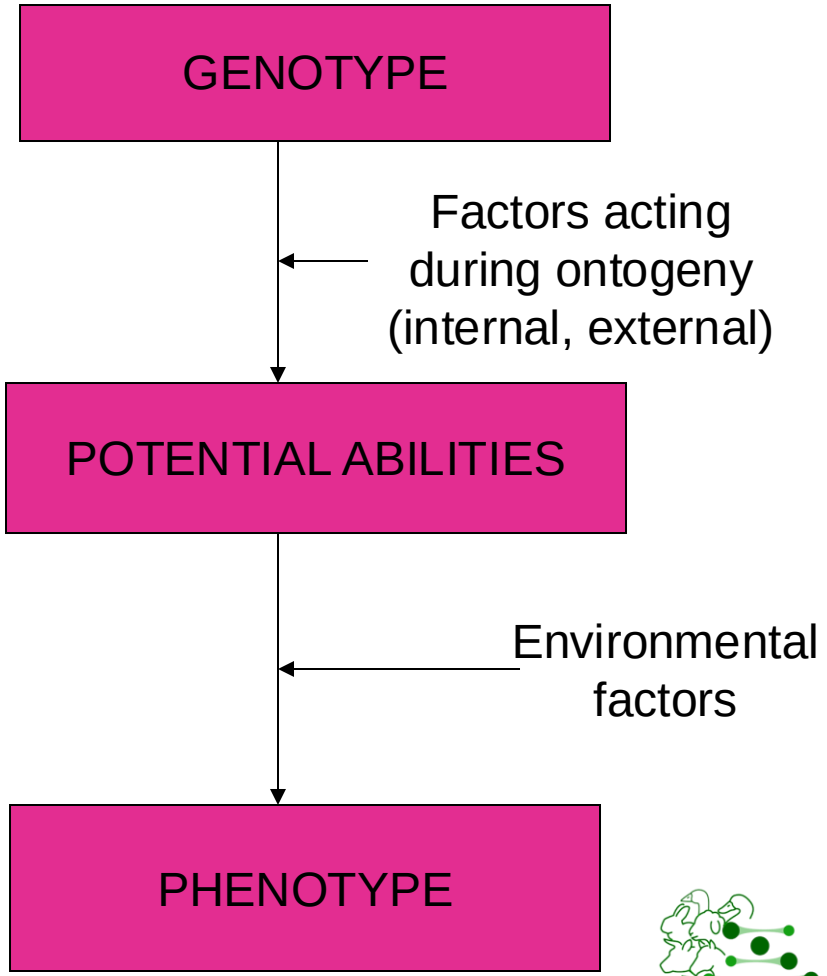
Genotype-phenotype relation





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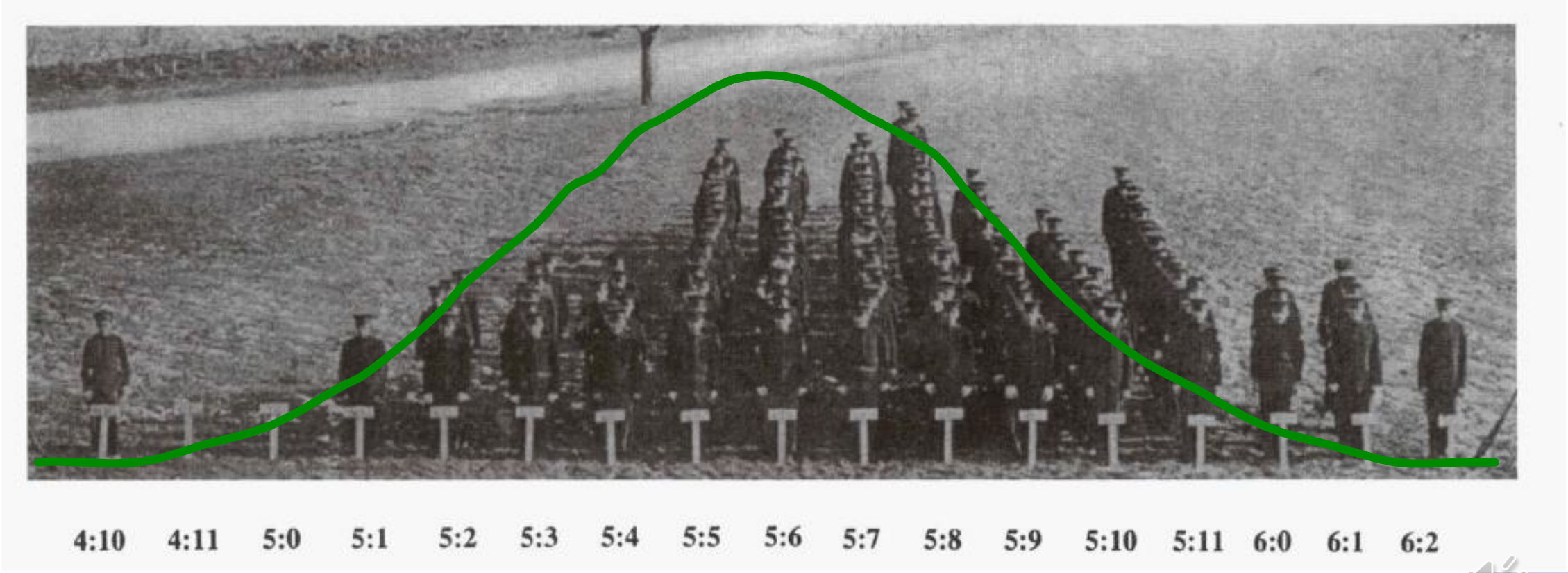
Normal distribution of height in humans



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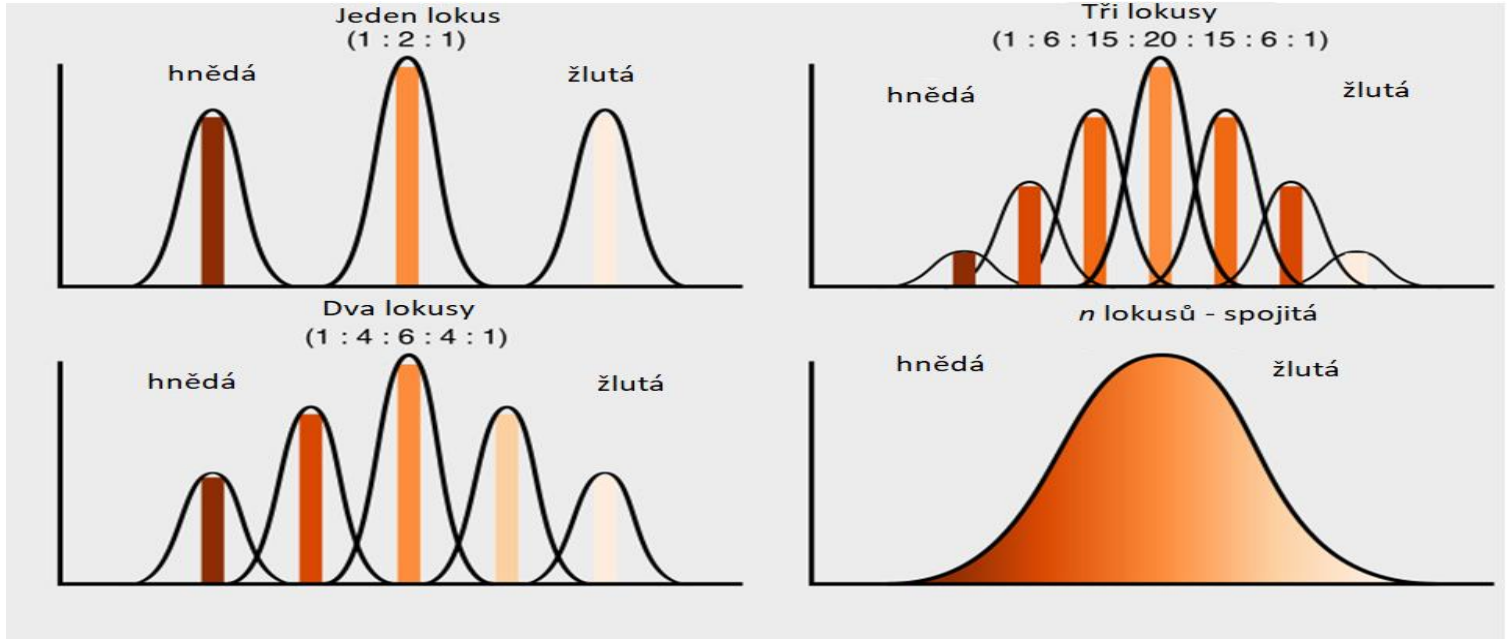
Principles of genetic variability



Mendelian genetic → Quantitative genetic

population – statistic – parameters (mean, variance, etc.)

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Mean value

$$\bar{x} = \frac{1}{n}\sum x_i$$

Variance

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{n - 1}$$

Standard deviation

$$s = \sqrt{s^2}$$

x	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
60	1.80	3.24
74	15.80	249.64
58	−0.20	0.04
61	2.80	7.84
56	−2.20	4.84
55	−3.20	10.24
54	−4.20	17.64
57	−1.20	1.44
65	6.80	46.24
42	−16.20	262.44

$$\Sigma(x_i - \bar{x})^2 = 603.60$$

$$\bar{x} = (582/10) = 58.20$$

$$s_x^2 = \frac{\Sigma(x_i - \bar{x})^2}{n - 1} = \frac{603.60}{9} = 67.07$$

$$s_x = \sqrt{s_x^2} = \sqrt{67.07} = 8.19$$

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Biometric definition of phenotype

$$P = G + E + G \times E$$

P = phenotypic value

G = effect of genotype

E = effect of environmental factors

G×E = interaction genotype x environment

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$$V_P = V_G + V_E + 2cov_{GxE}$$

V_P = total phenotypic variance

V_G = genetic variance

V_A = aditive variance

V_D = dominance variance

V_I = interaction (epistasis) variance

V_E = environmental variance

V_{Ep} = systematic (permanent) varinace

V_{Et} = non-systematic (temporal, random) environment variance

cov_{GxE} = relationship between genotype x environment

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Additive effect

Each gene has some effect, and it is generally assumed that the dominant allele exhibits a higher value of a given trait (e.g., 5 kg) than the recessive one (e.g., 2 kg).
The genetic value of a given genotype affected only by the additive effect (A) is:

A a B B c c D d E E f f
5+2+5+5+2+2+5+2+5+5+2+2 = <u>38 kg</u>.

Dominance

For example, if there is superdominance, this means that if the alleles at one locus are heterozygous, productivity is increased by 10 kg.
The genetic value of a given genotype affected only by the dominance effect (D) is:

Aa BB cc Dd EE ff
10 0 0 10 0 0 = <u>20 kg</u>.

Interaction

Interaction (epistasis) between two alleles of different loci (e.g., A and B – increases by 10 kg).
The genetic value of a given genotype affected only by the interaction effect (I) is **<u>20 kg</u>**.

The total genotype value (G) is then 78 kg (G = A + D + I = 38 + 20 + 20).

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ENVIRONMENTAL VARIANCE

Systematic effects

- Affect a group of animals in the same direction and value.
- Can be eliminated by calculation procedure or standardization.
  - internal: age, number of offspring, parity, number of lactation, sex, etc.
  - external: farm, region, stud, year, season, etc.

Non-systematic (random) effects

- Affect an individual in an unknown direction and of unknown value.
- No possibility to eliminate them.
- Cause inaccuracies (noise) in genetic estimations and predictions.
- Residual error.

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Thank you for your attention!

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Picture sources

- https://www.csun.edu/~hcmth031/ihhb.pdf
- Vostrý, L. (2018): Úvod do šlechtění. Česká zemědělská univerzita v Praze, 108 s., ISBN: 978-80-213-2848-8.

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