Why individuals differ

Variation means differences among individuals in a population. Phenotypic differences may arise from genetic factors, environmental factors or both.

1. MUTATION: NEW ALLELES

A mutation changes a DNA sequence and can create a new allele. It may affect a gene product, have no detectable effect, or alter phenotype. In animals, a mutation must enter the germ line to be inherited through sexual reproduction; a body-cell mutation is not automatically passed to offspring.

2. SEXUAL REPRODUCTION: NEW COMBINATIONS

Crossing over	In prophase I, non-sister chromatids of homologous chromosomes exchange corresponding DNA segments.
Independent assortment	Random orientation of homologous pairs at metaphase I produces different chromosome combinations.
Random fertilisation	Which genetically different gametes fuse adds another combination of parental alleles.

3. ENVIRONMENT: DIFFERENT EXPRESSION

Nutrition, light, temperature and disease can affect development or physiology. For example, genetically identical plants may differ in growth when water supply differs. The phenotype can change without a change in DNA sequence.

4. OFTEN, GENES AND ENVIRONMENT ACT TOGETHER

Human height depends on many genetic variants and on conditions during growth. Inherited potential is not a guaranteed outcome. For selection to produce an inherited evolutionary response, relevant differences must have a heritable component.

DNA changes and inheritance: NHGRI, Mutation.
Meiotic recombination and fertilisation: OpenStax, Biology 2e 11.1.
Genotype and environmental influences: NHGRI, Phenotype.

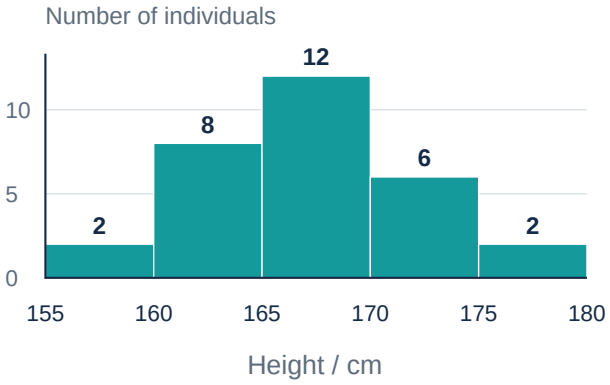
Scope: Cambridge 9700, 17.1.1-3, p. 43; normal distribution as in the lesson outline.

A range or separate categories?

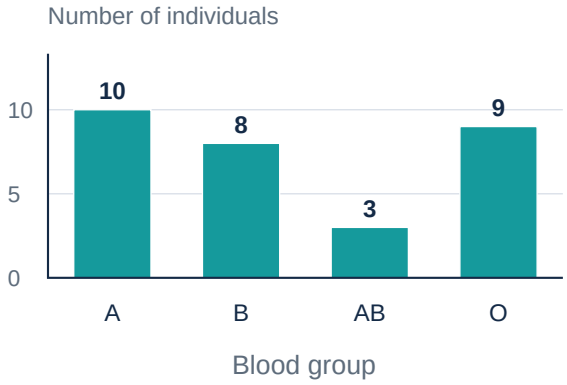
Classify the characteristic, not just the appearance of a small sample. Recording a measurement to the nearest whole number does not make the underlying trait discontinuous.

1. COMPARE TWO PATTERNS

Continuous: height



Discontinuous: ABO group



Illustrative data only: 30 individuals in each chart, not real population frequencies. Height bins are 155 to <160 cm, 160 to <165 cm, and so on. Equal-width histogram bars touch; category bars are separated.

2. CONTINUOUS VARIATION

Values form a range with intermediates, as for height or leaf length. Often many genes contribute small effects (polygenic inheritance), creating many possible values. Environmental variation can broaden the range. Measure values and group them into intervals for a histogram.

3. DISCONTINUOUS VARIATION

Distinct categories have no intermediate forms, as in the standard ABO blood-group model. One or a few genes with major effects often underlie the categories. Count individuals in each category. Multiple interacting genes can still produce discontinuous outcomes; graph shape alone cannot establish genetic control.

Types of variation and their genetic basis: Cambridge 9700, 17.1.1-3.
Many-gene control of traits: NHGRI, Polygenic Trait.

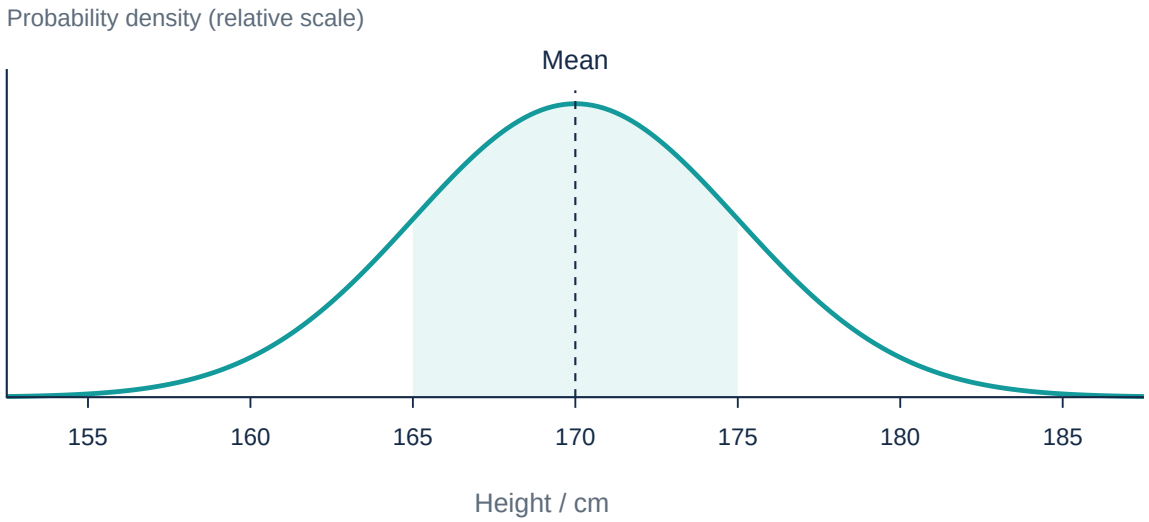
Scope: Cambridge 9700, 17.1.1-3, p. 43; normal distribution as in the lesson outline.

Read the distribution carefully

Many continuously varying traits can be approximately normally distributed within a defined population. Continuous does not automatically mean normal: inspect the data first.

1. THE NORMAL MODEL IS SYMMETRICAL

Illustrative height model: mean = 170 cm; standard deviation (SD) = 5 cm. This is a theoretical curve, not a measured sample.



2. CENTRE AND SPREAD ARE DIFFERENT

In an ideal normal distribution, mean, median and mode coincide. SD describes spread: a larger SD means more variable values. About 68% lie within one SD of the mean (165-175 cm here), and about 95% within two (160-180 cm). These percentages apply to the normal model.

3. DRAW CONCLUSIONS THE DATA SUPPORT

Define the population, sample without systematic bias, use consistent measurements and report sample size. Mixed ages or conditions can change the distribution. A broad range does not prove environmental control, and a bell-shaped graph does not prove polygenic inheritance. Use controlled comparisons to investigate causes.

Normal distribution, centre, spread and interval probabilities: NIST e-Handbook.
Phenotypic variation can have genetic and environmental causes: Cambridge 17.1.

Scope: Cambridge 9700, 17.1.1-3, p. 43; normal distribution as in the lesson outline.