# Inheritance 1

## Genetic terminology

| Term | Definition |
|---|---|
| Gene | The physical unit of heredity |
| Locus | The site on a chromosome occupied by a gene |
| Allele | Different forms of the same gene |
| Dominant | A gene always expressed when present |
| Recessive | A gene only expressed in a homozygous pair |
| Codominant | Both alleles contribute to the phenotype |
| Phenotype | The characteristics of an organism |
| Genotype | The alleles contained in an organism |
| Homozygous | Alleles are the same e.g. HH or hh |
| Heterozygous | Alleles are different e.g. Hh |
| F1 | First generation in a genetic cross |
| F2 | The second generation |
| Autosomes | Pairs 1-22 of the chromosomes |
| Sex chromosomes | Pair 23 that determines sex (male/female in the human.) |

**Codominance -** Both alleles are expressed in the phenotype.

**Eg 1- Blood typing**

| | |
|---|---|
| $I^AI^A$ | A antigen on blood cells |
| $I^BI^B$ | B antigen on blood cells |
| $I^AI^B$ | Both A and B antigens on blood cells |

**Eg 2 – Colouring in cows**

Some cows are Red (RR)

Some white (WW)

Offspring can be roan (RW)

| | R | R |
|---|---|---|
| W | RW Roan | RW Roan |
| W | RW Roan | RW Roan |

**Incomplete dominance -** A blend of both alleles can be seen in the phenotype.

e.g. Red, white and pink carnations.

A cross between red and white

Carnation produces an all pink F1.

In the F2 -a cross of 2 pink parents

there is a phenotypic ratio of:

1 red:2pink:1white.

| F2 | R | W |
|---|---|---|
| R | RR Red | RW Pink |
| W | RW Pink | WW White |

## Mendelian inheritance

Gregor Mendel studied inheritance in pea plants. He chose easy to distinguish characteristics which importantly:

- were controlled by single genes
- on different chromosomes.

**Monohybrid crosses -** Single gene inheritance.

1. Identify the characteristic and designate a letter to represent the dominant and recessive allele.

Tall plants – T

Dwarf plant - t

2. Give the genotype and phenotype of the parents.

Phenotype: Tall plant x Dwarf plant

Genotype: TT x tt

3. Identify the gametes produced by both parents:

Phenotype: Tall plant x Dwarf plant

Genotype: TT x tt

Gametes: T T t t

4. Place the gametes in a **Punnet square** and show all 4 possible crosses at fertilisation. Label each new genotype with the phenotype.

| F2 | T | t |
|---|---|---|
| T | TT Tall | Tt Tall |
| t | Tt Tall | Tt Dwarf |

| F1 | t | t |
|---|---|---|
| T | Tt Tall | Tt Tall |
| T | Tt Tall | Tt Tall |

**The F2 shows the mendelian phenotype ratio 3:1.**

**All the offspring in the F1 are tall.**

Mendel's 1st law: the law of segregation - The characteristics of an organism are determined by factors (*genes*) which occur in pairs. Only one member of a pair of factors (*genes*) can be represented in a single gamete.

# Inheritance 2

## Dihybrid inheritance- 2 gene inheritance

### Independent assortment

The independent assortment of chromosomes in meiosis explains why unlinked genes (found on different chromosomes) can combine to form all 4 kinds of gametes shown opposite.

Mendel experimented with seeds he knew to have dominant yellow/round characteristics and recessive wrinkled/green traits.

| Parental phenotypes | Round/yellow | Wrinkled/green |
|---|---|---|
| Parental genotypes | RRYY | rryy |
| gametes | RY | ry |
| F1 generation | RrYy | |
| F1 Phenotype | Round/yellow | |
| F2 parental genotype | RrYy | RrYy |
| F2 gametes | RY Ry rY ry | |

Female gametes

| Male gametes | RY | Ry | rY | ry |
|---|---|---|---|---|
| RY | RRYY Round yellow | RRYy Round yellow | RrYY Round yellow | RrYy Round yellow |
| Ry | RRYy Round yellow | RRyy Round green | RrYy Round yellow | Rryy Round green |
| rY | RrYY Round yellow | RrYy Round yellow | rrYY Wrinkled yellow | rrYy Wrinkled yellow |
| ry | RrYy Round yellow | Rryy Round green | rrYy Wrinkled yellow | rryy Wrinkled green |

### Dihybrid cross phenotypic ratio:

**9** round yellow: **3** Round green:**3** wrinkled yellow: **1** wrinkled green

#### Ratios

If you take each characteristic individually in the dihybrid cross above, the monohybrid phenotypic ratio still stands.

**Yellow: green seeds = 12: 4 = 3:1**

**Round: wrinkled seeds =12:4 = 3:1**

Mendel's second law of segregation. The law of independent assortment.

#### Test crosses

**Monohybrid -** To determine if an organism showing a dominant phenotype is a homozygote or heterozygote. Cross organism with a known pure breed (homozygote) rr.

**Dihybrid -** cross each genotype with homozygote for both characteristics rryy. If the parent was heterozygous for 1 characteristic, offspring would be produced in a 1:1. If the parent is heterozygous for both a 1:1:1:1 ratio would be seen.

50% Dominan phenotype

| | R | r |
|---|---|---|
| r | Rr | Rr |
| r | Rr | Rr |

100% Dominan phenotype

| | R | R |
|---|---|---|
| r | Rr | Rr |
| r | Rr | Rr |

## Recognising linkage

The mendelian **9:3:3:1 ratio** is therefore **expected** in any experiment where **genes are not linked.**

**Linkage**, meaning genes occurring on the same chromosome and therefore being inherited together, can be detected if the **expected ratio is not found** in the offspring.

Small numbers of recombinant phenotypes can still occur due to 'crossing over' in meiosis.

## Chi squared

A statistical test used to determine if the numbers and phenotypes of offspring produced in a genetic cross is close enough to the expected Mendelian ratio that any difference is due to chance and not for any other reason.

### 1. Null hypothesis

A statement e.g. **There is no difference between the observed and expected results of a genetic cross.** If the test shows that the deviation from expected ratios is by chance the hypothesis is **accepted**, if not it is **rejected**.

### 2. Calculate expected numbers

Calculate of all the offspring produced how many would you expect e.g. if 3744 off spring are produced:

3744/16 = 234 so

**9:** (9 x 234 =2106) **3:** (3x234= 702) **3:** (3x234= 702) **1:** 234

### 3. Chi$^2$

$$\chi^2 = \sum \frac{(\text{observed value} - \text{expected value})^2}{\text{expected value}}$$

### 4. Calculate the degrees of freedom

The number of outcomes -1 e.g. in a 9:3:3:1 there are 4 possible outcomes so the degrees of freedom used would be 3. Use this to find the $X^2$ critical value at 5%.

### 5. Accept or reject the null hypothesis

If the calculated value for $\chi^2$ < the critical value for $\chi^2$ then null hypothesis is accepted.

If the calculated value for $\chi^2$ > the critical value for $\chi^2$ then null hypothesis is rejected.

# Inheritance 3

**Sex linkage -** Genes that are sex linked can be found on the sex chromosomes.

Remember females have XX sex chromosomes and males have XY.

In males, the Y chromosome is smaller than the X chromosome. There are genes on the X chromosome that do not have the homologous locus on the Y chromosome.

Sex linked genes are written as superscript on the chromosome e.g. $X^hY$.

**Haemophilia -** a disease caused by a recessive allele for Factor 8 that does not code for the normal blood clotting factor.

In this case the father has the normal gene, but the mother carries the abnormal recessive allele.

Male children born in this cross have a 50% chance of having the disease.

| Gametes | $X^H$ | Y |
|---|---|---|
| $X^H$ | $X^HX^H$ | $x^HY$ |
| $X^h$ | $x^HX^h$ | $X^hY$ |

A lack of corresponding gene on the Y chromosome means this disease can be inherited by males with only 1 recessive allele. For a female to inherit this disease, both parents need to be carrying the recessive allele.

## Duchenne muscular dystrophy

A progressive muscle disease caused by a sex-linked recessive allele that does not code correctly for the protein dystrophin.

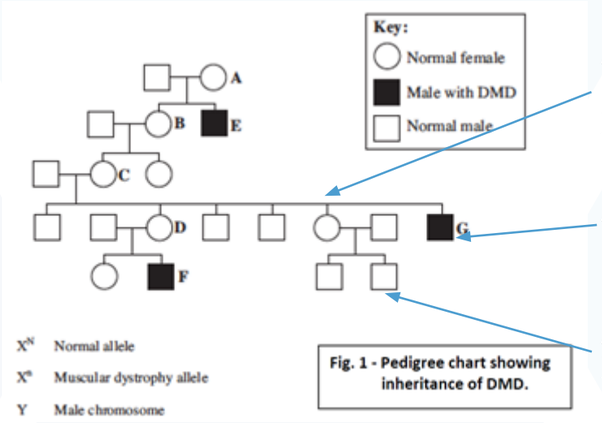



Fig. 1 - Pedigree chart showing inheritance of DMD.

A normal female could have the genotype $X^NX^N$ or $X^NX^n$

A male with DMD must be $X^nY$

A normal male must be $X^NY$

## Mutation

A mutation is **a spontaneous, random change in a gene.**

Mutation rates are increased in organisms with short life cycles or frequent cell division.

Occurs mostly during crossing over in prophase 1 and non-disjunction in anaphase I and II.

| Advantageous mutations | Disadvantageous mutations |
|---|---|
| Mutations affect protein synthesis and so change the phenotype of the organism. This leads to variation in species that causes evolution by natural selection. | Some genes called proto-oncogenes can mutate to become oncogenes, which are involved, causing uncontrolled cell division to form a cancer. |

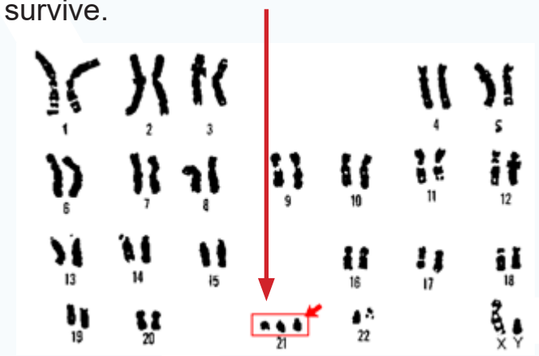
**Gene point mutation.** E.g. Sickle cell anaemia

- One mutated base in the DNA code for haemoglobin.
- So incorrect amino acid added into a polypeptide chain.
- Red blood cell forms a sickle shape and is less efficient at carrying oxygen.

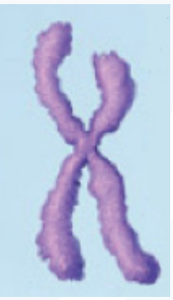
**Chromosomal mutations** E.g. Down's syndrome

Failure of chromosome 21 to separate from its homologous pair during anaphase I in meiosis forms gametes with 2 copies and at fertilisation the zygote then has 3 copies of chromosome 21.

Normally an extra chromosome would be fatal to an organism but chromosome 21 is small, only a few hundred genes, so the organism can survive.




## Epigenetics



Every nucleus in cells of an organism contains a full set of genes, but in specialised cells only some genes are expressed, others are switched off.

**Epigenetics is the study of changes in gene expression without any changes to the DNA sequence.**

**Epigenetic changes result from • Diet • Drugs • Development • Aging.**

### DNA methylation

DNA bases become methylated which reduces the transcription of the gene and so affects protein synthesis.

### Histone modification

Modification of histones means they can coil more tightly, preventing gene expression, or they can coil loosely allowing transcription and protein synthesis.

**Epigenetic changes can cause • Cancer • Autoimmune disease • mental disorders • Diabetes.**