Ivan's Chapter 6 Study Guide
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Body Cells and Gametes

- **Somatic Cells** (also called body cells) make up your tissues and organs
  - The DNA in these cells is not passed down to your children
- **Germ Cells** are cells which reside in your reproductive organs
  - Testes in men and ovaries in women
  - Develop into **Gametes**
- Gametes are sex cells
  - Ova/eggs in women
  - Spermatozoa in men
  - The DNA from these cells can be passed down to your children
- Besides mutations, your somatic cells are genetically identical

Chromosomes

- Each species has a different number of chromosomes per cell
  - Humans have 46 chromosomes which come in 23 pairs
    - Can be divided into two sets, 23 of which came from your mother and 23 of which came from your father
- **Homologous chromosomes** are two chromosomes which have the same appearance, length, and genes (although each copy may differ)
- Chromosomes 1 - 22 are called autosomes
  - These contain genes which are not related to an organism's sex
- The 23rd pair of chromosomes are sex chromosomes
  - **Sex chromosomes** directly control sex characteristics
  - Are represented as an "X" and "Y"
    - Males have XY chromosomes and females have XX chromosomes
- The X chromosome is larger than the Y chromosome
  - Contains many genes unrelated to sex, as well as genes which are related
- The Y chromosome is the smallest chromosome and has the fewest genes
  - Contains genes which relate to the development of male traits

Reproduction

- *Sexual Reproduction* requires the fusion of two gametes
  - This fusion of egg and sperm is known as *fertilization*
- The nuclei of the egg and sperm fuse
  - The unified nucleus contains a full set of chromosomes
    - This means that the egg and sperm only have 23 chromosomes each

Diploid and Haploid Cells

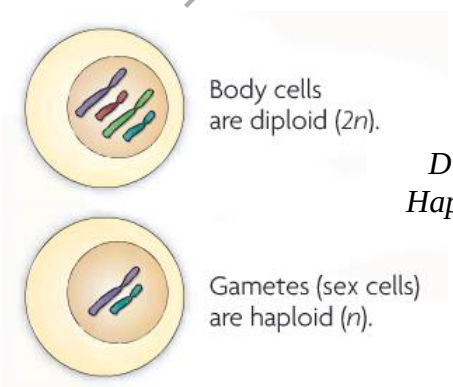
- **Diploid cells** have two copies of each chromosome (One copy from mom, one copy from dad)
  - Are represented as "*2n*"
  - Body cells are diploid since they contain a full set of 46 chromosomes
- Haploid cells only have one copy of each chromosome
  - Are represented as "*n"*
- Each sperm or egg cell has 22 autosomes and 1 sex chromosome
  - Eggs always contain the X chromosome
  - Sperm can either contain an X or a Y
- Although a change in chromosome number is usually harmful, sometimes it can result in a new species
  - The fertilization of nonhaploid gametes has created many plant species with more than two sets of chromosomes
  - Some plants have 4 copy of each chromosome
    - Tetraploidy (*4n*)

What is Meiosis?

- **Meiosis** is a form of nuclear division that divides diploid cells into haploid cells
  - Undergone by germ cells to produce gametes
  - Called "Reduction division" because it halves the chromosome number
  - Results in genetically unique haploid cells from diploid cells

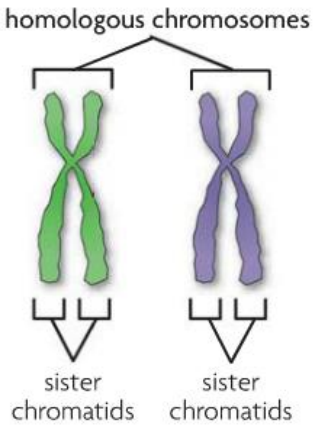
Homologous chromosomes vs Sister chromatids

- **Homologous chromosomes** are two separate chromosomes
  - One from your mother, one from your father
  - Divided during meiosis I
- Very similar to each other
  - Have the same length and same genes
  - However, they aren't genetically identical
- Sister chromatids are two halves of a duplicated chromosome joined at a centromere
  - Divided during meiosis II



Diploid vs Haploid Cells

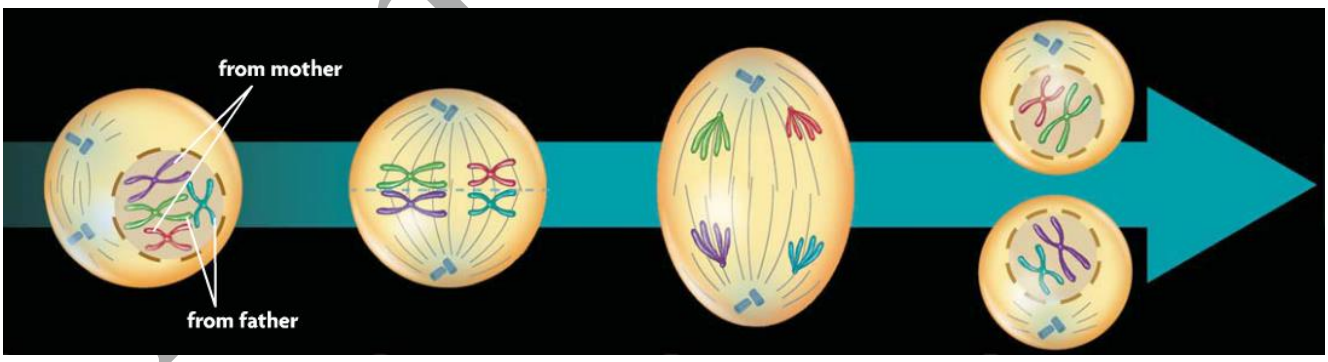
Homologous chromosomes and sister chromatids



Meiosis I

- DNA has already been copied
- Divides homologous chromosomes
- Produces two haploid cells with duplicated chromosomes

1. **Prophase I**
   - The nuclear membrane breaks down
   - Centrosomes and centrioles move to opposite poles of the cell
   - Spindle fibers assemble
   - Duplicated chromosomes condense
   - Homologous chromosomes separate into pairs
2. **Metaphase I**
   - The 23 chromosomes line up across the cell equator
   - Some from the father, some from the mother
   - Mixes up chromosomal combinations
   - Meiosis may result in 8,388,608 possible chromosomal combinations
3. **Anaphase I**
   - Paired homologous chromosomes separate
   - Move to opposite sides of the cell
   - Sister chromatids remain together and throughout meiosis I
4. **Telophase I**
   - In some species, the nuclear membrane reforms
   - Spindle fibers disassemble
   - The cell undergoes cytokinesis
   - Results in two cells with unique combinations of 23 chromosomes sourced from each part

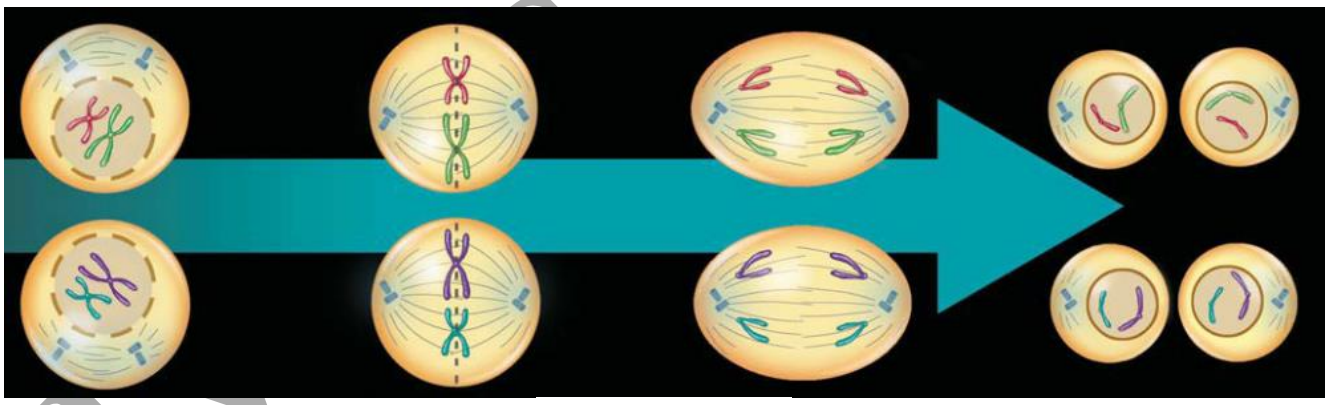


The process of Meiosis I

Meiosis II

- Divides sister chromatids
- Results in undoubled chromosomes
- Applies to cells produced in meiosis I
- DNA is not copied again

5. **Prophase II**
   - The nuclear membrane breaks down
   - Centrosomes and centrioles move to opposite sides of the cell
   - Spindle fibers assemble
6. **Metaphase II**
   - Spindle fibers align the 23 chromosomes at the equator
     - Each chromosome still has two sister chromatids
7. **Anaphase II**
   - Sister chromatids are pulled apart
     - Move to opposite sides of the cell
8. **Telophase II**
   - The nuclear membrane reforms
   - Spindle fibers disassemble
   - The cell undergoes cytokinesis
   - Results in four haploid cells with a combination of chromosomes from the mother and father.



The process of Meiosis II

Gametogenesis

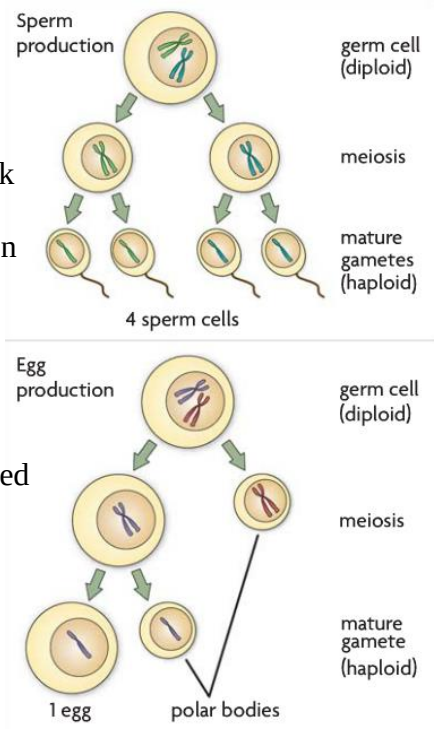
- **Gametogenesis** is the production of gametes
  - Includes meiosis and other changes which produce a pure gamete
  - The final stages differ between males and females
- **Sperm cells** = The male gamete
- **Egg cells** = The female gamete, larger than sperm cells
- The sperm cell's main contribution is DNA
  - Must swim to the egg to fertilize it
- Sperm start off as round cells and end up as streamlined cells with flagella for locomotion
- Egg cells are formed before birth
  - Includes periods of active development and inactivity
- Egg cells contribute DNA, organelles, molecular building blocks, and other materials needed to support life
- Only one cell out of the four produced by meiosis makes an egg
  - This cell receives most of the materials
- The rest of the molecules and materials are distributed into **polar bodies**
- **Polar bodies** are small cells with little more than DNA which are broken down and not used
- In many species such as humans, polar bodies produced by meiosis I do not undergo meiosis II

Mendelian Genetics

- **Traits** = Distinguishing characteristics which are inherited
  - Eye color, skin tone, flower color, etc.
- **Genetics** = The study of biological inheritance and genes
- One of the first people to study genetics was an Austrian monk named Gregor Mendel
  - Discovered the ruling principles and laws of genetics in the mid 1800s
- Mendel recognized that traits are inherited as discrete units from the parent
- Organisms inherit two copies of each discrete unit (genes)
  - Describes how traits are passed through generations
- Mendel controlled breeding, used purebred plants, and observed traits that only appeared in 2 alternate forms

Experimentation and Fertilization

- **Purebred** plants = A line of genetically uniform plants resulting from repeated self-pollination
  - Offspring inherit all of their parents' characteristics
  - Chosen so Mendel could know that variations in the offspring a result of his experiments
- Controlled fertilization by removing the stamen (male) and fertilizing the pistil (female) with pollen from a specific plant



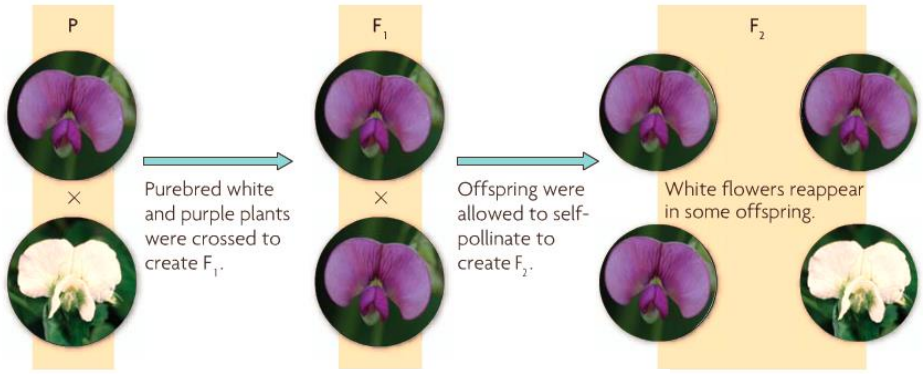
The process of Gametogenesis

Results and Crosses

- **Cross** = The mating of two organisms
  - Purebred white-flowered plant with a purebred purple-flowered plant
    - The parental (P) generation
    - Traits that were hidden after crossing the P generation reappeared after the F_1 generation self-pollinated
- The offspring of the P generation are called the first filial (F_1) generation
- The offspring of the F_1 generation are called the second filial (F_2) and so on
- Each cross of Mendel's yielded similar F_2 ratios of around 3:1

RESULTS OF MENDEL'S MONOHYBRID CROSSES OF PEA PLANTS			
F_2 Traits	Dominant	Recessive	Ratio
Pea shape	5474 round	1850 wrinkled	2.96:1
Pea color	6022 yellow	2001 green	3.01:1
Flower color	705 purple	224 white	3.15:1
Pod shape	882 smooth	299 constricted	2.95:1
Pod color	428 green	152 yellow	2:82:1
Flower position	651 axial	207 terminal	3.14:1
Plant height	787 tall	277 short	2.84:1

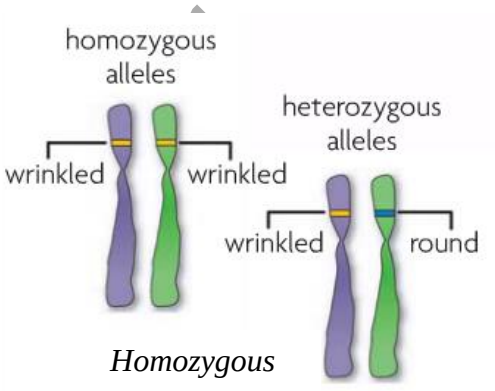
- Mendel concluded that…
  - Traits are inherited as discrete units
    - Explained why traits persisted without blending together
  - Also concluded the **law of segregation**
- The **law of segregation** (Mendel's first law) states that…
  - Organisms inherit two copies of each gene, one from each parent
  - Organisms give only one copy of each gene to their gametes
    - The two copies of each gene segregate/separate during gamete formation



Hidden traits reappeared in the F_2 generation

Alleles and Genes

- **Genes** = Pieces of DNA which provide instructions for making certain proteins
- Each gene has a **locus**, which is a specific position on a pair of homologous chromosomes
  - Tells where a gene is located on a chromosome
- **Alleles** are different forms of a gene located at a specific locus
  - Each gene has two alleles, one on each of your homologous chromosomes
- During fertilization, each parent gives one allele
- **Homozygous** = Two of the same alleles at the same locus
  - Ex: CC (Dominant) or cc (Recessive)
- **Heterozygous** = Two different alleles are the same locus
  - Ex: Cc
- All of an organism's genetic data is known as a **genome**
  - Everybody except for identical twins has an identical genome
- The genetic makeup of a specific set of genes is known as a **genotype**
  - Ex: All of the genes (even masked ones) which code for flower color
- The physical characteristics produced by the genotype are known as the **phenotype**
  - Ex: A flower having purple petals despite the presence of a hidden gene for white petals



Homozygous versus Heterozygous

Dominant and Recessive Alleles

- **Dominant** alleles are expressed in the phenotype even when only one is present
  - Represented by uppercase letters
  - Ex: **C**c, **CC**
- **Recessive** alleles are expressed in the phenotype only when two copies are present
  - Represented by lowercase letters
  - Ex: C**c**, **cc**
- Despite overpowering recessive alleles, dominant alleles aren't necessarily present in more of the population or better than recessive alleles
  - For example, the allele polydactyly is dominant even though it isn't present in most of the population
- If the dominant allele P represents purple petals and p represents white petals, then P must code for pigment while p codes for nothing (the absence of pigment)
  - Even if the genotype is Pp, the dominant allele is still telling the cell to produce pigment
- Not all genotype are just dominant and recessive alleles
  - Codominance
  - Incomplete dominance

Punnett Squares and Monohybrid Crosses

- **Punnett Squares** are grids which are used to predict all possible genotypes which result from a cross
  - Developed by R. C. Punnett
- The ratio of genotypes in a generation can be found by counting the number of squares with a specific combination of alleles
- During meiosis, the alleles are separated
- Each gamete gets one allele
- **Monohybrid crosses** examine the inheritance of a single specific trait
- A **test cross** is a cross between an organism with an unknown genotype and a purebred organism with a recessive phenotype
  - The purebred organism must be homo. Recessive
  - Offspring will show the genotype of the organism in question

		Alleles from Father	
		A	a
Alleles from Mother	A	AA	Aa
	a	Aa	aa

Pheno. Ratio – 3:1
Geno. Ratio – 1:2:1

Hetero x Hetero Monohybrid cross

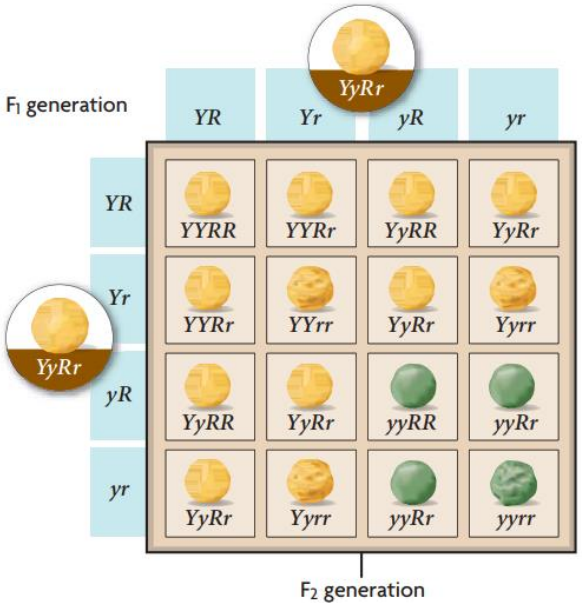
Dihybrid Crosses

- **Dihybrid crosses** examine the inheritance of two different traits
- After finding a 9:3:3:1 phenotypic ratio in the F_2 generation when using purebred plants for the P generation, Mendel formed the…
- **Law of Independent Assortment** (Also known as Mendel's second law)
  - States that allele pairs separate independently of each other during meiosis, and different traits are inherited separately

Heredity and Probability

- The likelihood of an event occurring is **probability**
- $Probability = \frac{number\ of\ ways\ that\ an\ event\ can\ occur}{number\ of\ total\ possible\ outcomes}$

Punnett Probability



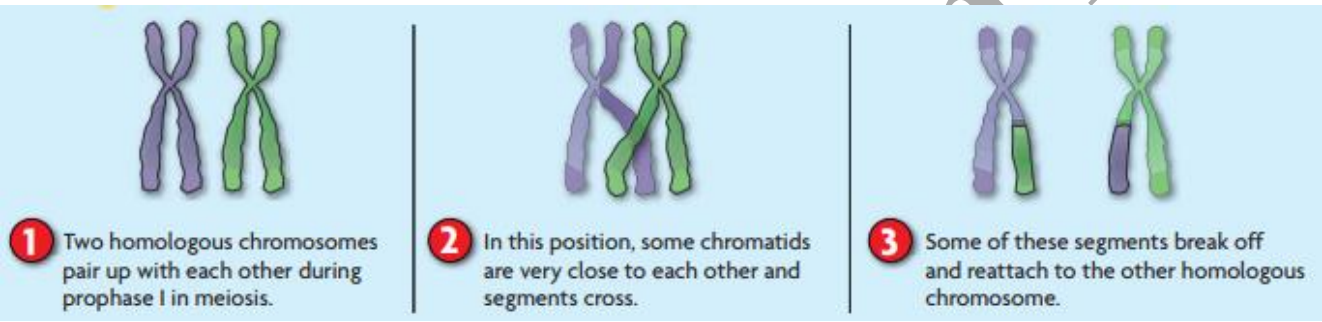
A dihybrid cross

Sexual reproduction and genetic variation

- Egg and sperm cells have 2^{23} (around 8 million) combinations
- The total number of possible combinations formed from fertilization is around 70 trillion
- Sexual reproduction creates unique combinations of genes

Crossing Over and Recombinant Chromosomes

- **Crossing over** is the exchange of gene segments between homologous chromosomes
- Since the chromatids are very close, part of each chromatid breaks off and reattaches to the other one
  - Known as **genetic linkage**
  - Results in recombinant chromosomes
- Crossing over happens whenever germ cells divide



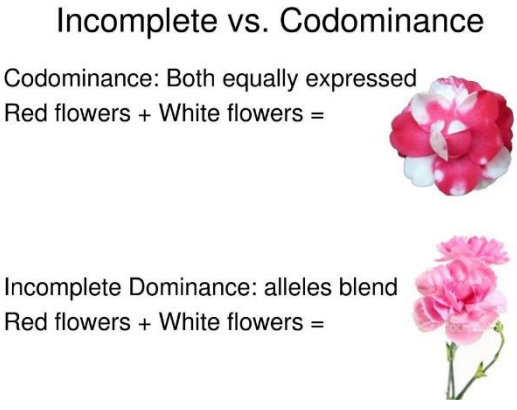
The process of Crossing over

- **Recombination** refers to the mixing of parental alleles
  - Also includes events other than crossing over
- The farther apart that genes are located, the more likely that they will separate when crossing over
  - More likely to assort independently
- Genes which are close together are inherited together, which is known as **genetic linkage**

Incomplete Dominance

- The phenotype is in-between
- Red flower x white flower = 100% Pink Flowers

	R	R
W	RW	RW
W	RW	RW



Incomplete vs Codominance

Codominance

- Both phenotypes are equally present
- Homo. red bull x homo. white cow = 100% Roan Cows

	C^r	C^r
C^w	C^rC^w	C^rC^w
C^w	C^rC^w	C^rC^w

Blood Typing

- Blood is codominant
- Four blood types expressed by antigens (glycoproteins) on red blood cells
  - A, B, AB and O
- There are three alleles; A, B and O
  - However, you can only have two
  - Expressed as I^A, I^B, and i
- If you give somebody the wrong blood type, it will coagulate (clump)

Cross a Homozygous B male with a heterozygous A female

	I^B	I^B
I^A	$I^A I^B$	$I^A I^B$
i	I^B i	I^B i

Phenotype:
AB = 50%
B = 50%

	Type A	Type B	Type AB	Type O
Genotype	$I^A I^A$ or I^Ai	$I^B I^B$ or I^Bi	$I^A I^B$	i i
Antigens	A antigen	B antigen	A & B antigens	None
Antibodies	Anti-B	Anti-A	None	Anti-A & Anti-B

Blood Types, Genotypes, Antigens and Antibodies

- There is more than one blood type due to mutation, natural selection, illness, and cultural isolation

Rh Factor

- Another protein on red blood cells
  - Named after the Rhesus Monkey
- 85% of humans have the Rh factor proteins
- Rh+ signifies that you have the protein
- Rh- signifies that you don't have it

[Dihybrid] Hetero. A+ father x Hetero AB+ mother

	A+	O-
A+	A+A+	A+O-
B-	A+B-	B-O-

Phenotype
50% A+
25% AB+
25% B-

Rh and Pregnancy

- When a Rh- mother is pregnant with an Rh+ child, the fetal blood crosses the placenta
- The mother's immune system sees the antigens as foreign invaders and begins to build up anti-Rh antibodies
    - Nothing happens to the first baby, since the antibodies haven't had enough time to build up
- During the next pregnancies, the antibodies can enter the fetus' immune system and cause blood coagulation
    - This is known as Rh disease

TYPE	CAN GIVE TO	CAN RECEIVE FROM
A+	**A+, AB+**	**A+, A-, O+, O-**
O+	**O+, A+, B+, AB+**	**O+, O-**
B+	**B+, AB+**	**B+, B-, O+, O-**
AB+	**AB+**	**EVERYONE**
A-	**A+, A-, AB+, AB-**	**A-, O-**
O-	**EVERYONE**	**O-**
B-	**B+, B-, AB+, AB-**	**B-, O-**
AB-	**AB+, AB-**	**AB-, A-, B-, O-**

Blood Donor compatibility

Sex Chromosomes

- Thomas Morgan (USA) studied genetics in the 1900s
    - Studied the Drosophila Melanogaster (fruit fly)
    - Discovered the X and Y chromosomes
- Fruit flies have 4 pairs of homologous chromosomes
    - 3 pairs of autosomes and 1 pair of sex chromosomes
- Mendel didn't study sex chromosomes since pea plants don't have sex chromosomes

The chromosomes of a drosophila melanogaster

Cross a male and a female

	X	Y
X	X X	X Y
X	X X	X Y

50% Male
50% Female

- Morgan observed eye color in fruit flies
  - Red and white
- The typical phenotype is known as the **wild type**
- Morgan also found that the genes for the fruit flies' eye color are stored in the "X" sex chromosome
  - Not true for humans

Cross a white eyed male with a red eyed female

	X^r	Y
X^R	$X^R X^r$	$X^R Y$
X^R	$X^R X^r$	$X^R Y$

50% red eyed
50% white eyed

Sex-Linked Genes

- The X chromosome has more influence than the Y chromosome since it's longer and contains more genes
- It has been shown that over the years, bits of the Y chromosome have been absorbed by the X chromosome
- Men, who have only one X chromosome, are more susceptible to X-linked disease