# Lessons 14
Allele segregation

Alleles

- **Allele** = alternate form of a gene
  - Variation of a gene relative to some reference gene
- Reference gene = wild-type gene
  - Alleles = variations relative to the wild-type gene
- Alleles are due to DNA sequence variations (differences)
  - Alleles are gene variants that govern related traits
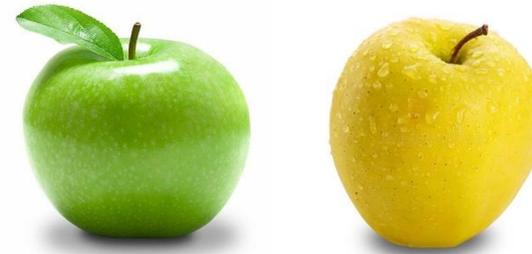 - Alleles ensures traits variations in all species

Alleles

Eye Color Chart
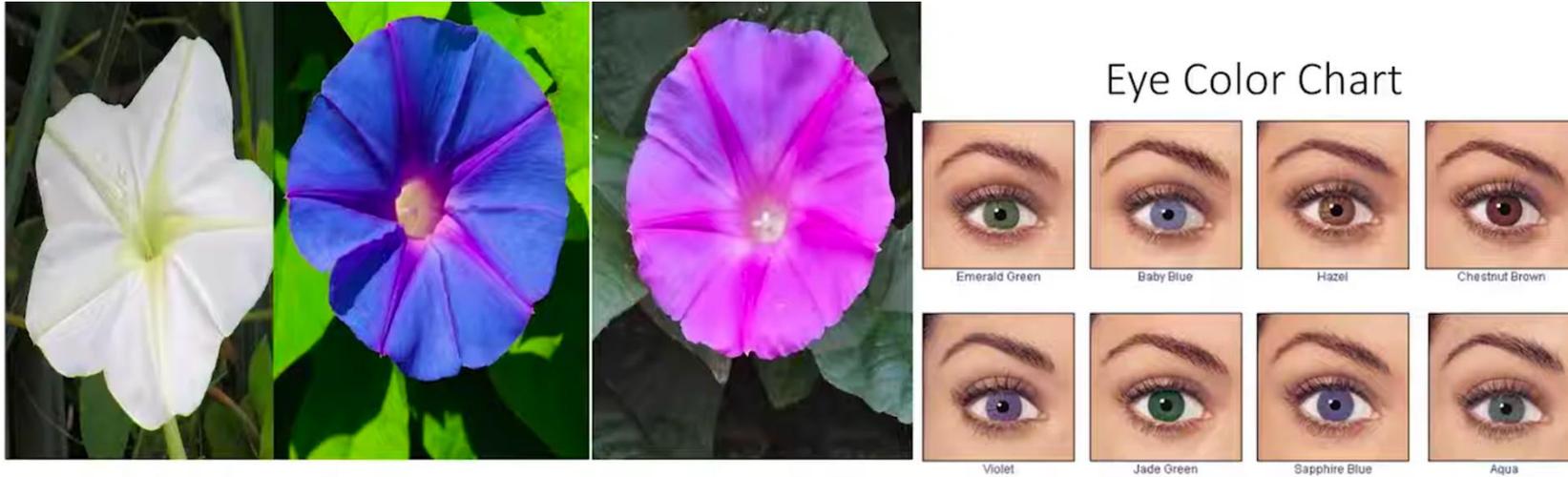
Alleles are gene variants that govern related traits

Alleles and chromosomes

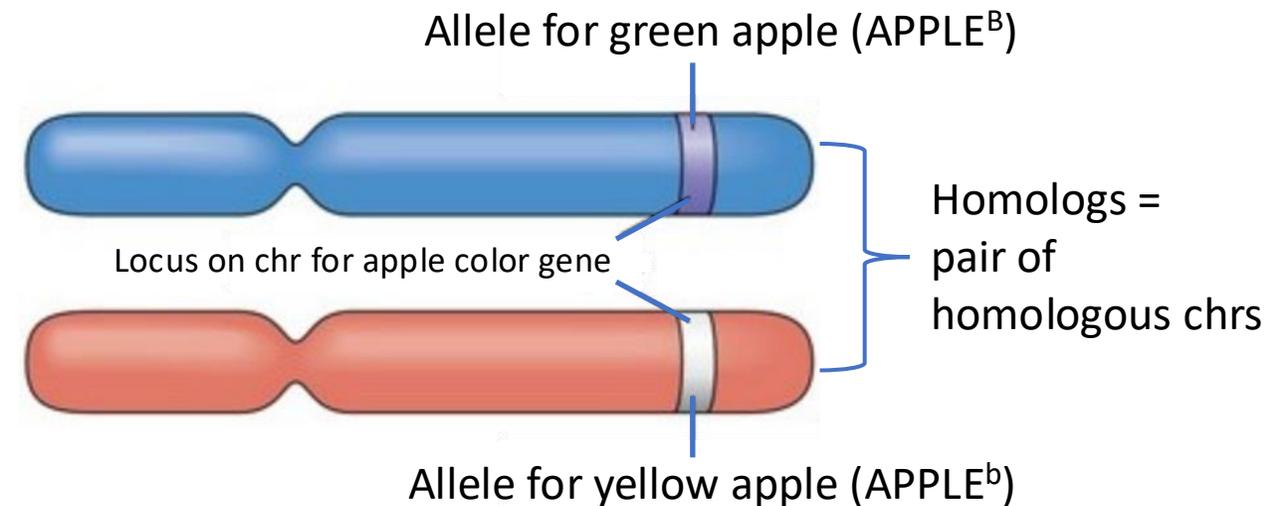- For example: let's be APPLE the gene that encodes an apple color

  - $APPLE^B \rightarrow$ gives you a green apple
  - $APPLE^b \rightarrow$ gives you a yellow apple

- How do alleles relate to chromosomes (chrs)?

Alleles and chromosomes

- For example: let's be APPLE the gene that encodes an apple color

  - $APPLE^B$ → gives you a green apple
  - $APPLE^b$ → give you a yellow apple

- How do alleles relate to chromosomes (chrs)

- In a diploid cell:
  - each of these alleles would be on one of the matching chrs
  - In diploid cells (2n) each chr pair has **the same or different alleles of particular genes**

Allele for green apple ($APPLE^B$)

Locus on chr for apple color gene

Homologs = pair of homologous chrs

Allele for yellow apple ($APPLE^b$)

Alleles, chromosomes and proteins

Template strand →

5' ATGTGGCTCCTGG**AT**TAA 3'
3' TACACCGAGGACC**T**AATT5'

Gene APPLE^B

mRNA → 5' AUGUGGCUCCUGG**A**UUAA 3'

protein → N-Met-Trp-Leu-Leu-Asp-C (stop)

5' ATGTGGCTCCTGG**T**TTAA 3'
3' TACACCGAGGACC**A**AATT 5'

Template strand →

Gene APPLE^b

mRNA → 5' AUGUGGCUCCUGG**U**UUAA 3'

protein → N-Met-Trp-Leu-Leu-**Val-C** (stop)

Alleles APPLE^B and APPLE^b are both apple color genes but encodes for slightly different proteins!

Cell division and alleles

- Somatic (body) cells (diploid) undergo replication via mitosis
- **Mitosis outcome** → daughter cells (diploid) that **have alleles identical to those of the parent cell**
- Germs (sex) cells (diploid) undergo replication via meiosis
- **Meiosis outcome** → daughter cells (gametes = eggs and sperms, haploid) that **DO NOT have alleles identical to the parent cell**
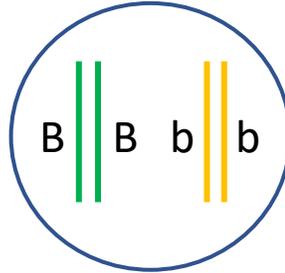
Mitosis (somatic inheritance) - revisited

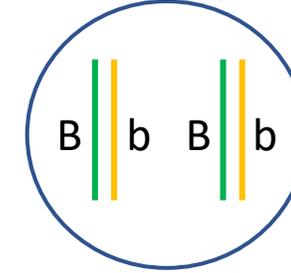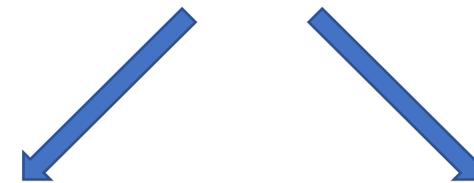Diploid (2n) cell with 1 homolog
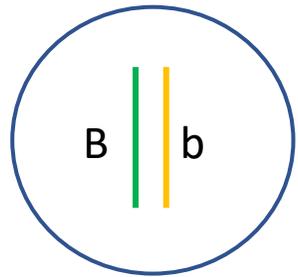
Sister chromatids

DNA REPLICATION
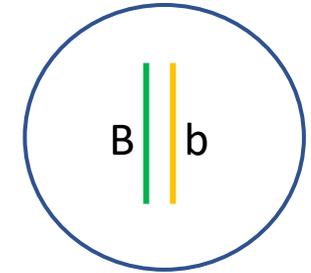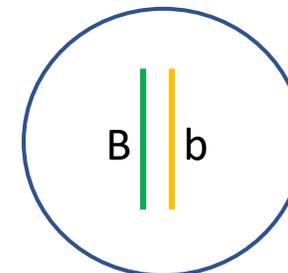
HOMOLOGS SEGREGATION

Apple color gene
APPLE^B and APPLE^b alleles

Homologs partitioning into daughter cells

Two diploid (2n) daughter cells **identical** to the parent cell

Meiosis (germline inheritance) – revisited & simplified

Diploid (2n) cell with 1 homolog

Sister chromatid

B | b

DNA REPLICATION →

B || B b || b
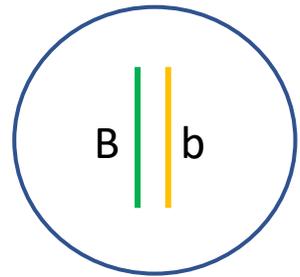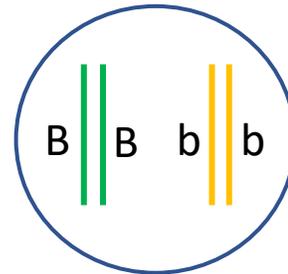
Sister chromatid aggregation* →

b b

B B
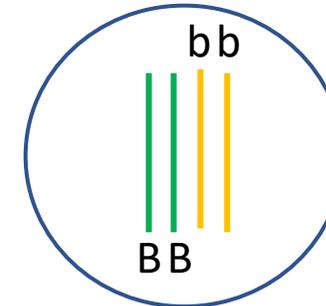
*Chiasma formation and possible crossing-over

Apple color gene
$APPLE^B$ and $APPLE^b$ alleles

↓ SISTER CROMATID SEGREGATION

Two diploid (2n) daughter cells non-identical to the parent cell

Four haploid (n) daughter cells non-identical to the parent cell

B | | B

B | | b
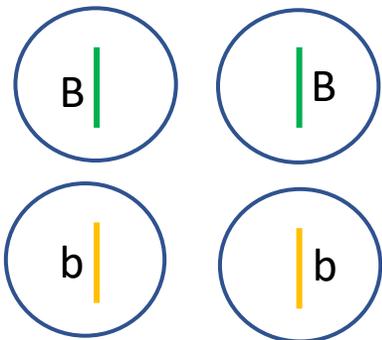
← SISTER CHROMATID PARTITIONING INTO DAUGHTER CELLS

MEIOSIS 2

B || B

b || b
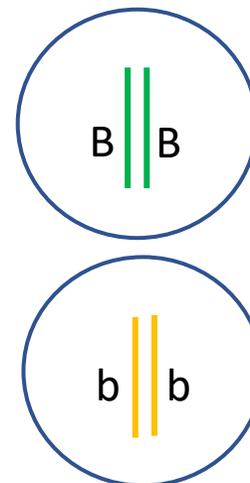
← SISTER CHROMATID PARTITIONING INTO DAUGHTER CELLS

MEIOSIS 1

B || B b || b
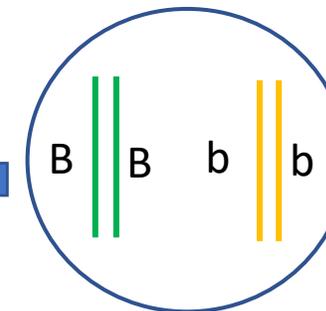
Meiosis (germline inheritance) – independent allele segregation (simplified)

Diploid (2n) cell with 2 homologs

Apple color genes
APPLE^B and APPLE^b alleles
Apple taste genes
APPLE^S and APPLE^s alleles
S = sweet, s = sour

DNA REPLICATION

Remember: in meiosis sister chromatids segregate!

MEIOSIS 1

MEIOSIS 2

Gametes
4 kinds
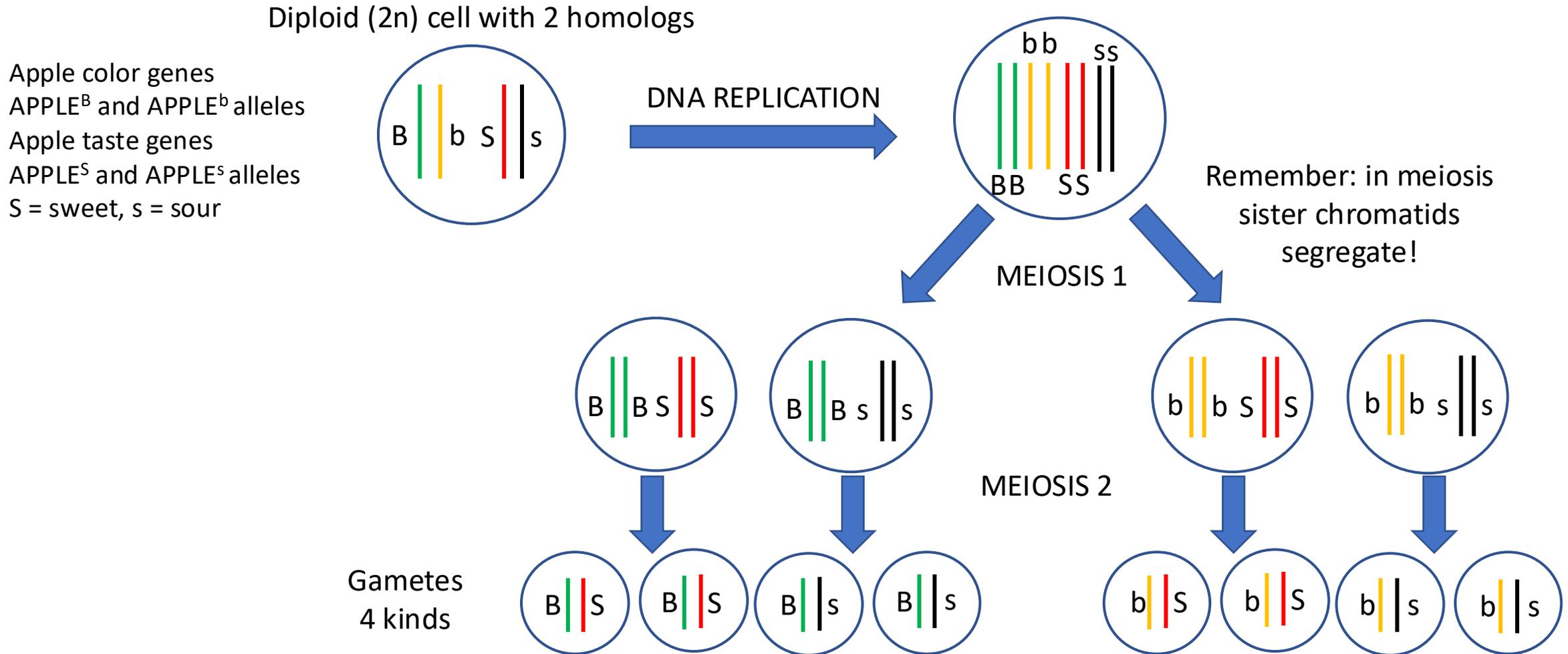
Independent allele segregation

- Independent allele segregation dictates what the next generation of the organism is going to look like
  - For the given example, we can have:
    - Green apples with sweet taste (APPLE^B,APPLE^S)
    - Green apples with sour taste (APPLE^B,APPLE^s)
    - Yellow apples with sweet taste (APPLE^b, APPLE^S)
    - Yellow apples with sour taste (APPLE^b, APPLE^s)

Lesson 15
Punnett squares
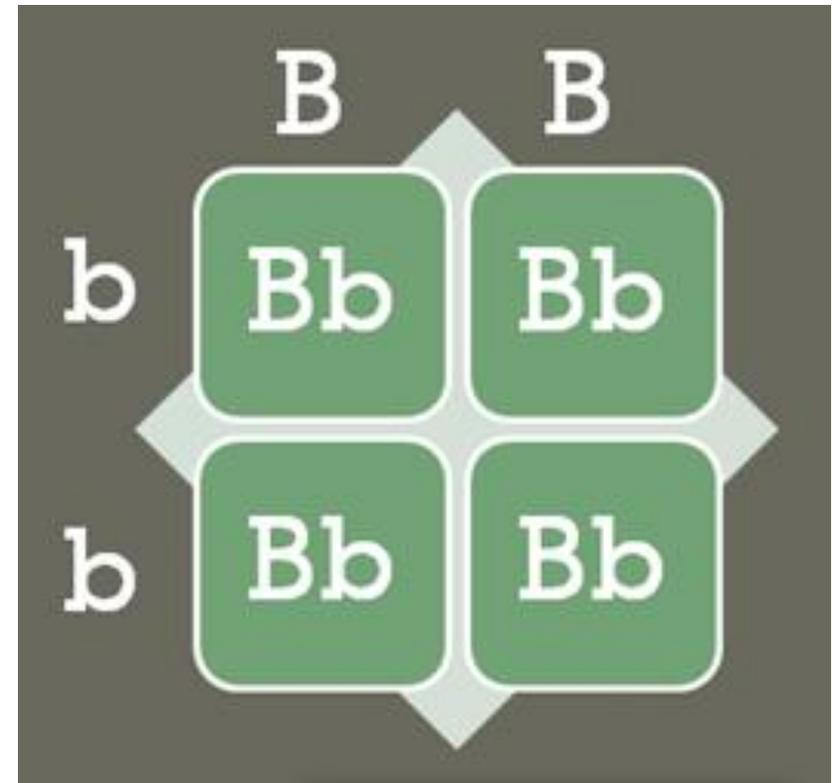
Genetics & crosses

- We need to know:
  - What are the DNA sequences that confer a particular trait
  - How traits are inherited
  - How a particular gene – and hence trait – might be regulated
    - Mostly important in diseases
- **Genetics** = set of tools to understand gene functions and inheritance

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"Our mistake. We introduced a politician's genes in that one!"

- **Genotype** = full set of genes of an individual
  - In a more narrow sense, the term can be used to refer to the alleles that are carried by an organism (*e.g.*, APPLE^B,APPLE^B can also be also called a genotype)
- **Phenotype** = observable characteristics = traits
  - *e.g.*, the color green is associated with the APPLE^B,APPLE^B genotype
  - Note that phenotypes are equally, or even sometimes more greatly influenced by environmental effects than genetic effects
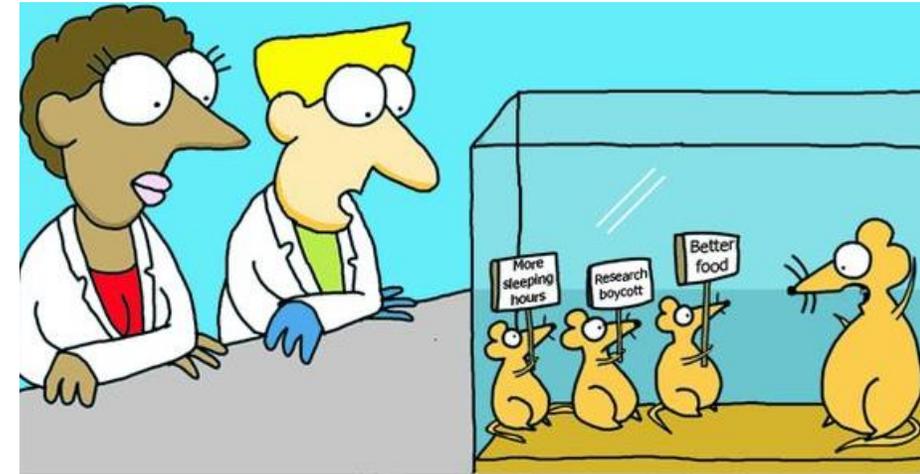
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  - In genetics DNA = hereditary unit
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- **Alleles** = alternate gene forms
- **Generation (gen)** = individuals born at the same time from the same parents
    - P gen = parents
    - F1 gen = first generation offspring
    - F2 gen = second generation offspring…..

Genetic trait dominance

Traits (observable characteristics) can be:

dominant

co-dominant

recessive

incompletely dominant

Dominant and recessive traits

- In combination traits can be dominant or recessive
- AA = red

- aa = white

- A is **dominant** to a (a is **recessive** to A)
  - AA and Aa will always give you a red flower
  - Only aa will give you a white flower

Codominance and incomplete dominance

- Aa is **codominant**

both alleles are fully expressed
(in different parts of the organism)

- Aa is **incompletely dominant**

the two alleles mix together to create
an entirely different phenotype

Gene crosses – monohybrid crosses

- Genetic crosses that follow a genotype
- **Monohybrid crosses** → (likely) 1 trait and 1 gene involved

  - Parents
  - Genotype
  - Gametes (egg/sperm)
  - First gen offspring

  Theoretical breeding experiment

Gene crosses – monohybrid crosses
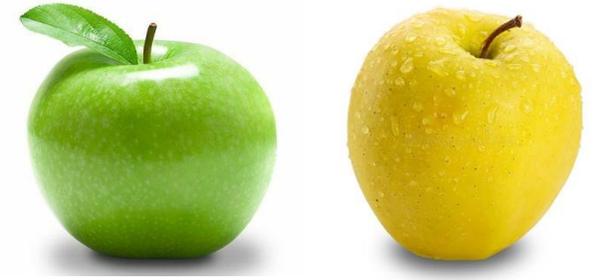
- Let us reconsider our apple example
- Let us abbreviate the apple color gene alleles APPLE^B with B (green) and APPLE^b with b (yellow)
  - In genetics:
    - Dominant allele = capital letter (B)
    - Recessive allele = small letter (b)
- Parent apples: P1 and P2
- Genotype of P1: BB (diploid) Genotype of P2: bb (diploid)
- Gametes of P1: B (aploid, 2x) Gametes of P2: b (aploid, 2x)

Gene crosses – monohybrid crosses

Parents   P1   P2

Genotype   BB   2n   bb

Gametes   B   n   b

Note: total of 4 gametes:
2 gametes B
2 gametes b

X

First gen (F1)   **Bb (2n) (100%)**
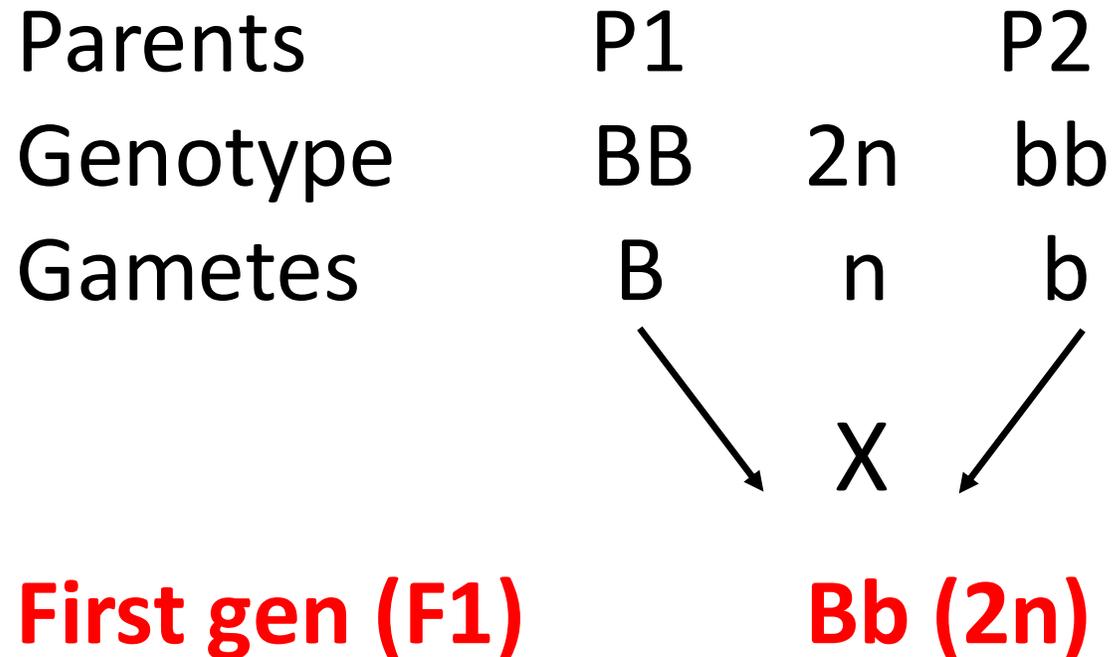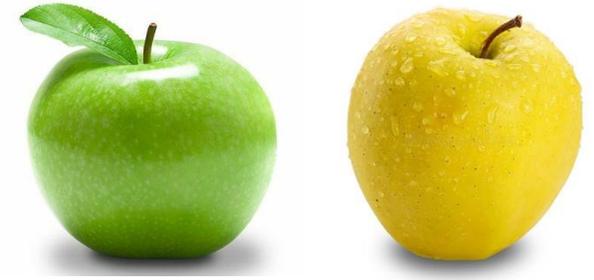
A few more terms

- If your gene has two of the same alleles (*e.g.*, BB or bb)
  - **Homozygous**

- If your gene has two different alleles (*e.g.*, Bb)
  - **Heterozygous**

Parents	P1		P2	
Genotype	BB	2n	bb	**Homozygous**
Gametes	B	n	b	

First gen (F1)   **Bb (2n) (100%)**   **Heterozygous**

Punnett squares

Parents	P1 X P2
Genotype	BB bb

P1	gametes	
P2	B	B
b	Bb	Bb
b	Bb	Bb

gametes

F1 offspring

Shows F1 genotype and proportions
100% Bb

BB, bb = homozygote   Bb = heterozygote

Genetic crosses follow phenotypes (traits)

Parents   P1   P2

Genotype   BB   2n   bb

Phenotype   Green   Yellow

Gametes   B   n   b

Note: total of 4 gametes:
2 gametes B
2 gametes b

X

First gen (F1)   **Bb (2n) Green**
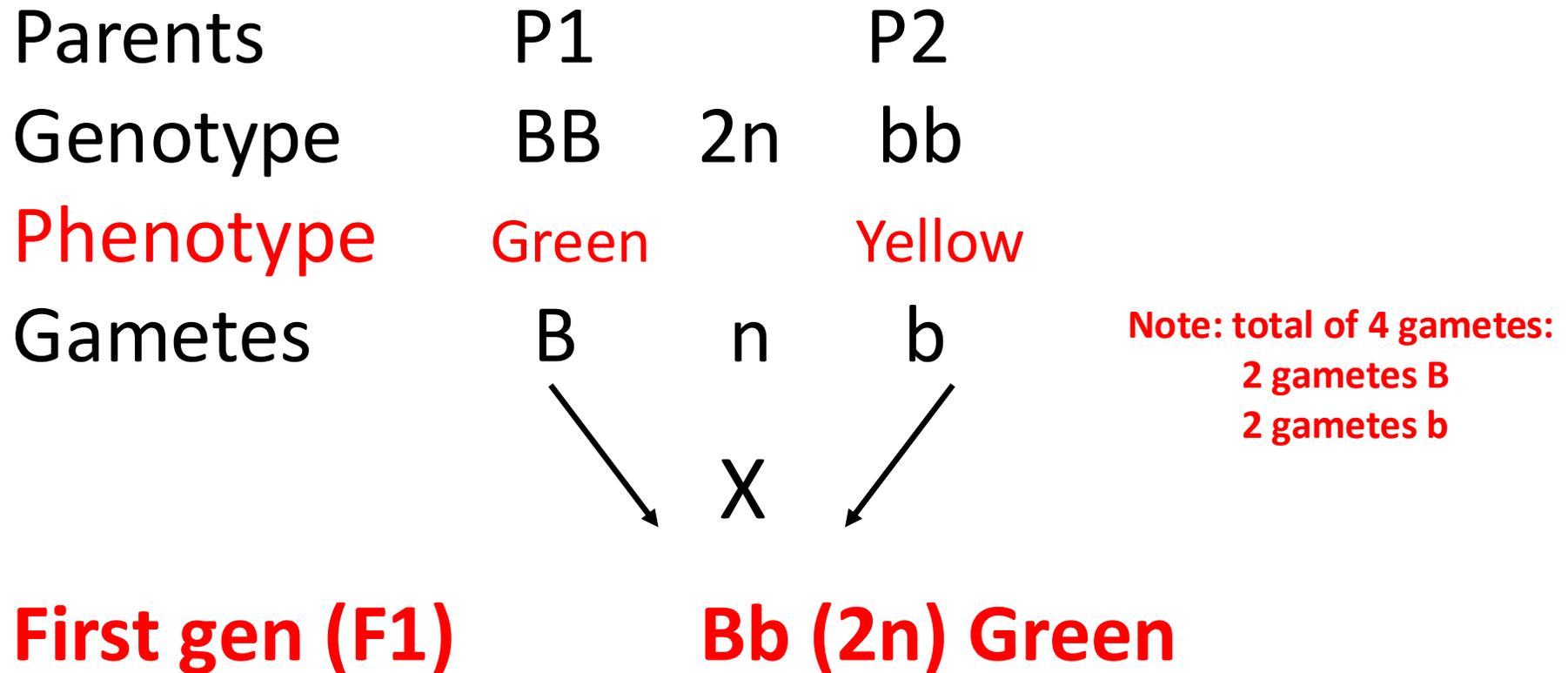
In this example green = dominant = B allele and yellow = recessive = b allele
The first gen will all be green apples (Bb)

Punnett squares

Parents   P1   x   P2
Genotype   BB   bb
Phenotype   Green   Yellow

Punnett square representation Genotype + phenotype

		Gametes	
	P1		
P2		B	B
Gametes	b	**Bb** **green**	**Bb** **green**
	b	**Bb** **green**	**Bb** **green**

F1 offspring

F1 100% heterozygous Bb
F1 100% green

F1 cross

Parents   F1   X   F1

Genotype   Bb   Bb

Phenotype   Green   Green

Gametes   B and b   B and b

**Note: total of 4 gametes:
2 gametes B and b
2 gametes B and b**

2nd gen (F2)   ?

Remember: in this example green = dominant = B allele and yellow = recessive = b allele

Punnett squares

3 genotypes: BB, bb, Bb
F2 will be 50% homozygous
25% BB
25% bb
and
50 % heterozygous (Bb)

2 phenotypes: green and yellow
F2 will be 75% green + 25% yellow as B is dominant (3:1)

Parents   F1 =P1   x   F1 =P2
Genotype   Bb   Bb
Phenotype   Green   Green

Punnett square representation
Genotype + phenotype

		Gametes	
P1			
P2		B	b
Gametes	B	BB green	Bb green
	b	Bb green	bb yellow

F2 offspring

B is dominant
b is recessive

Molecular Biology for Engineering – Lesson 15

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Test cross

- The parent genotype might be unknown
  - You want to figure this out

- For the apple example:
  - Is a parent genotype BB, Bb or bb?

- **Test cross**: you cross the parent with a true breeding strain (TBS)

- **True breeding strain = individual with two alleles of a recessive gene**
  - Gene b (yellow apple) is recessive, your TBS will be a yellow apple with genotype bb
  - Crossing two TBS both with genotype bb will always and only give you apples with genotype bb and phenotype yellow

Test cross

Parents	P1	X	P2
Genotype	BB? or Bb?		bb (true-breeding)

Obviously, if P1 has a (bb) genotype you will get an all bb and all yellow Punnett square

		P1 gametes	
P2		B	B
gametes	b	Bb	Bb
	b	Bb	Bb

F1 offspring

		P1 gametes	
P2		B	b
gametes	b	Bb	bb
	b	Bb	bb

F1 offspring

If P1 is BB
100% offspring are green (Bb)

If P1 is Bb
50% offspring are green (Bb)
50% are yellow (bb)