CH 11 Gregor Mendel, Probability, and Punnett Squares

Vocabulary:

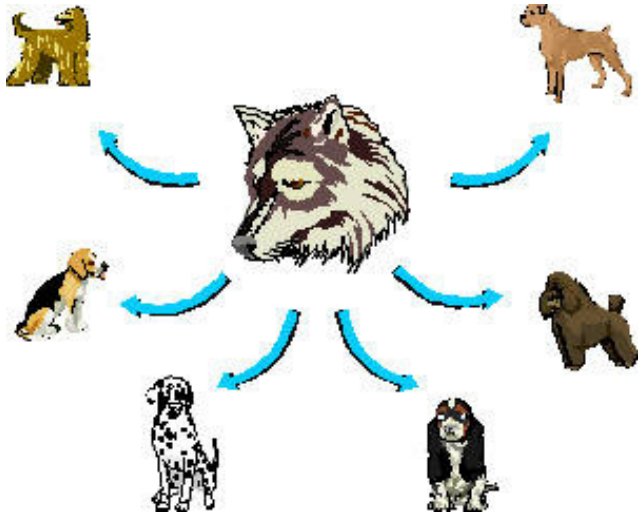
- Genetics
- True-breeding
- Trait
- Hybrid
- Gene
- Allele
- Segregation
- Gamete
- Probability
- Punnett Square
- Homozygous
- Heterozygous
- Phenotype
- Genotype

Key Concepts:

- What is the principle of dominance?
- What happens during segregation?
- How do geneticists use the principles of probability?

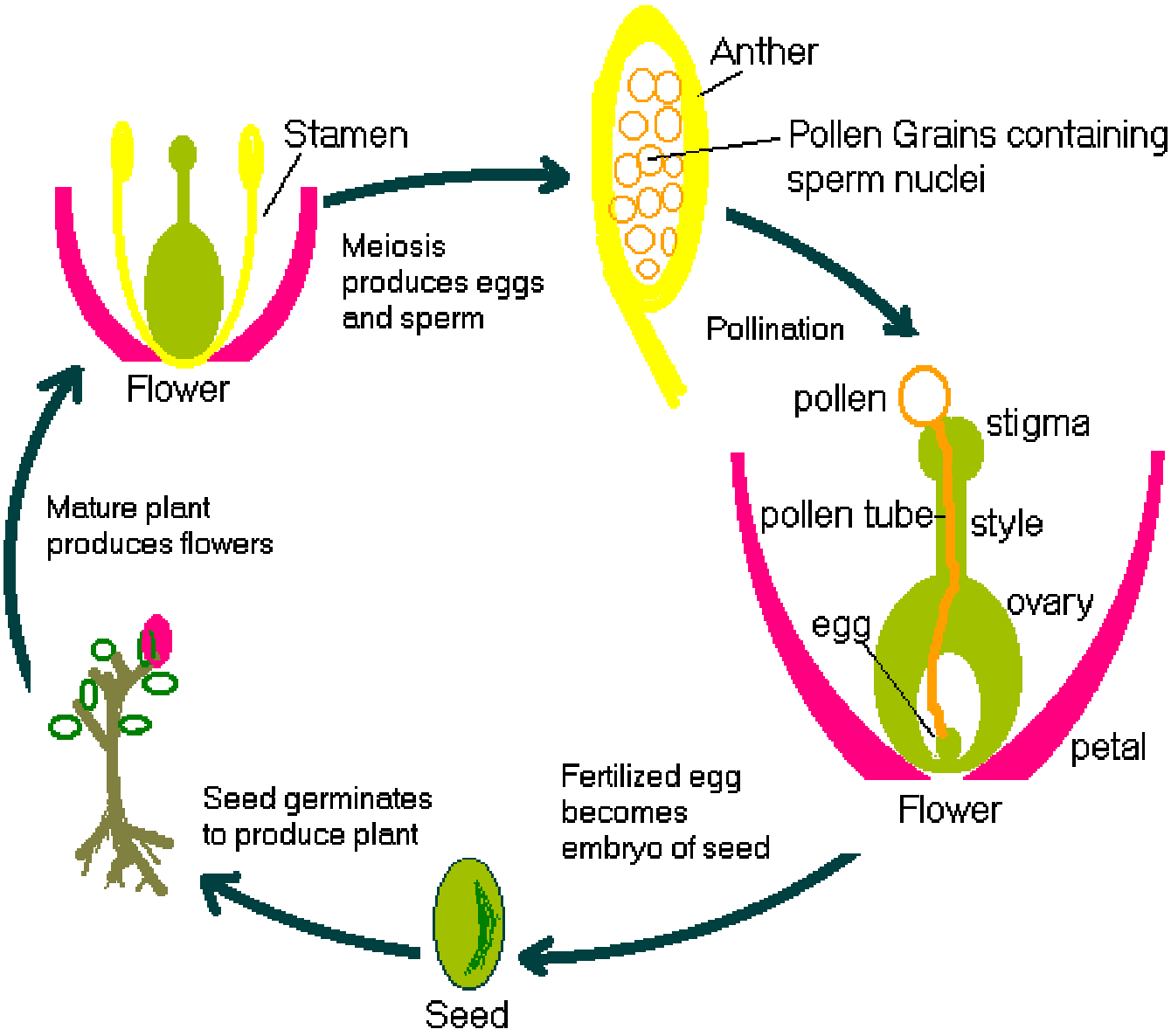
Background

- Mendel was an Austrian monk who was in charge of the monastery garden.
- His work with pea plants has led to him being considered the "Father of Modern Genetics."
- **Genetics**: <u>the scientific study of heredity</u>



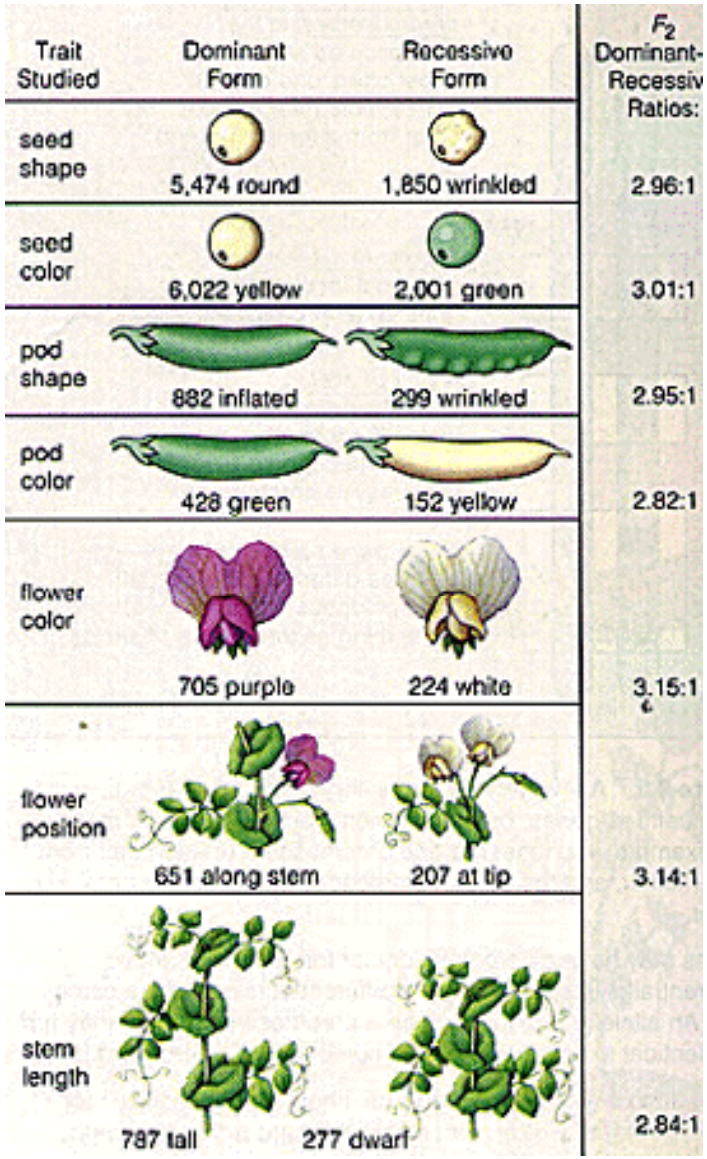
Pea plant structure:

- Reproduction occurs through flowers
- Male part of the flower contains pollen → male sex cells
- Female part of the flower contains eggs → female sex cells
- When pollen fertilizes an egg cell, a seed for a new plant is formed
- Pea plants normally fertilize by SELF-POLLINATION (pollen and egg are from the same flower)


Anther
Pollen Grains containing sperm nuclei
Stamen
Meiosis produces eggs and sperm
Flower
Pollination
pollen
stigma
pollen tube
style
ovary
egg
petal
Flower
Mature plant produces flowers
Seed germinates to produce plant
Fertilized egg becomes embryo of seed
Seed

Background

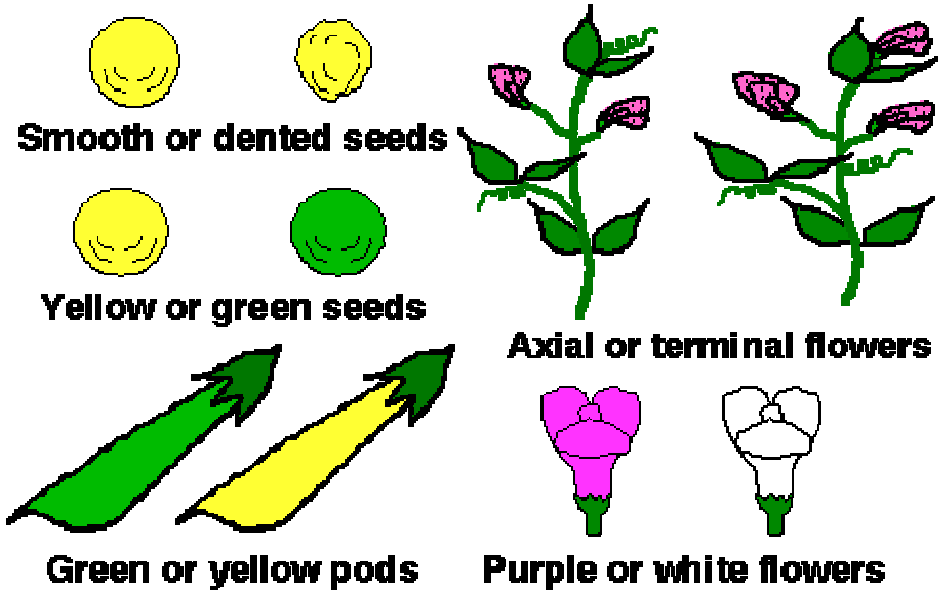
- When Mendel took charge of the monastery garden, he had several **true-breeding** plants (if allowed to self-pollinate, offspring would be identical)
- Some would produce only green seeds, others only yellow, some tall, and some only short



Mendel's Experiments

- Mendel *controlled* the reproduction of pea plants
- He would **cross-pollinate** plants (pollen and egg from different pea plants)
  - Two different pea plant parents
  - Prevented plants from self-pollinating

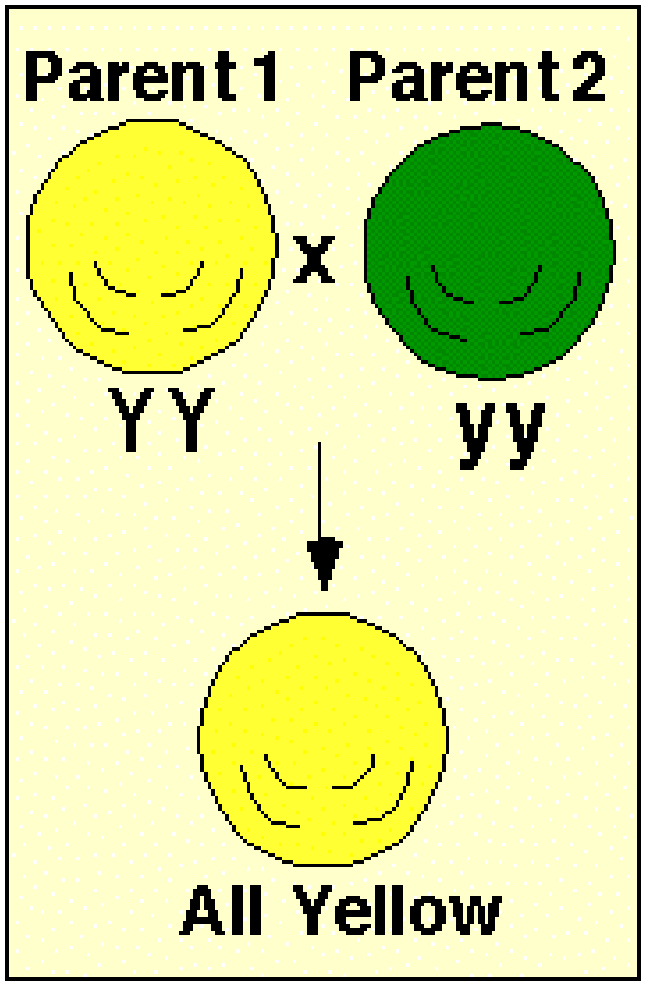
Pea Plant Options



GENES & DOMINANCE

- Mendel studied several different pea plant traits
  - Trait: a specific characteristic (ex: seed color or plant height) that varies from one individual to another
- Mendel's Labels for pea plant generations
  - Original pair of plants: **P (parental) generation**
  - Offspring of "P" generation: **F_1 (*first filial* is Latin for "first son") generation**
  - Offspring of crosses between parents with different traits (ex: yellow x green seeds): **HYBRIDS**

Hybrids



- What were the F_1 hybrids like? Did the characters of the parent plants blend in the offspring?

- **NO!** All of the offspring had the character of only ***ONE*** parent; the character of the other parent seemed to have *disappeared*

Mendel's 2 Conclusions

Conclusion #1

- ***Biological inheritance is determined by factors that are passed from one generation to the next***
  - "factors" = **GENES** (determine traits)
  - Each of the traits Mendel studied was controlled by one **GENE** that occurred in two contrasting forms
    - EX: **GENE** = seed color
      - 2 contrasting forms = yellow or green
  - 2 contrasting forms: ALLELES
    - ALLELE #1: yellow
    - ALLELE #2: green

Mendel's 2 Conclusions

Conclusion #2

- *Principle of Dominance: some alleles are dominant and others are recessive*
  - Inherit 2 dominant alleles: dominant allele will show
  - Inherit 2 recessive alleles: recessive allele will show
  - ***Inherit 1 dominant and 1 recessive allele, the DOMINANT allele will show!***

Dominant vs. Recessive

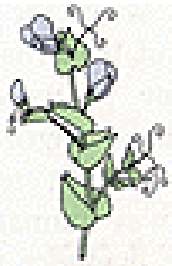
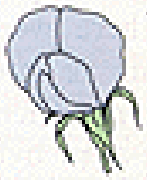
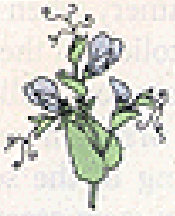
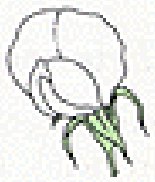
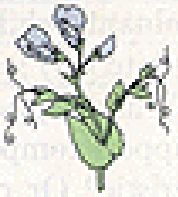
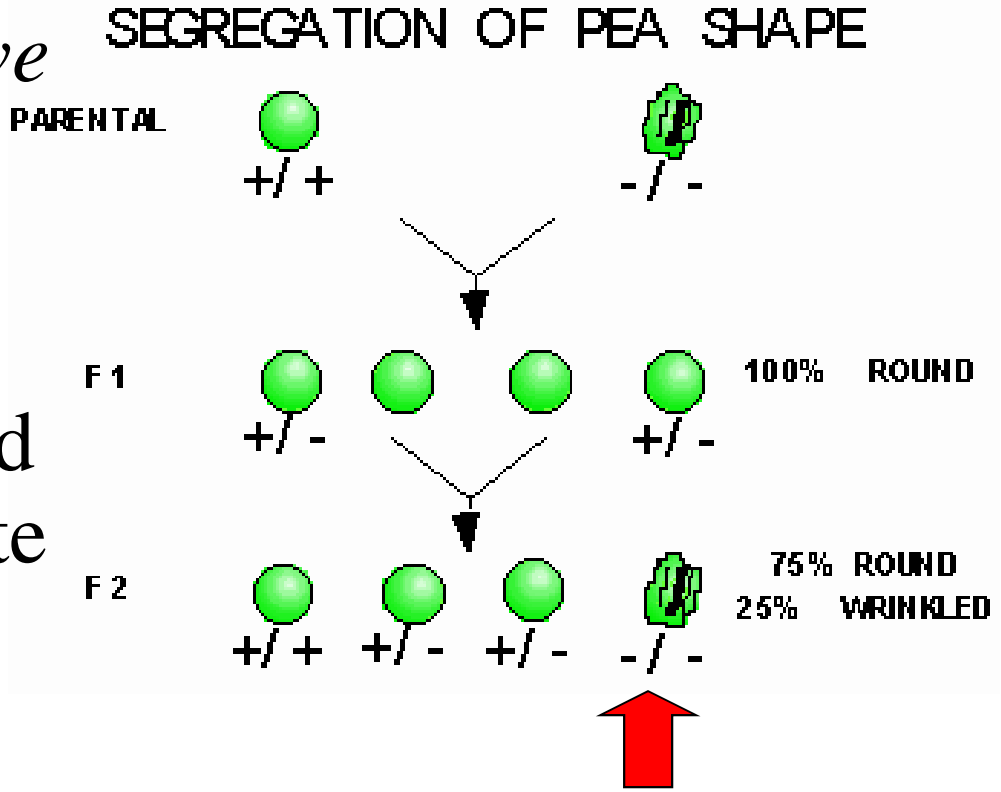
	Stem length	Flower color	Seed color	Seed shape	Pod color	Pod shape	Flower position
Dominant characteristic (dominant allele)	 Long	 Purple	 Yellow	 Round	 Green	 Round	 Axial (along stem)
Recessive characteristic (recessive allele)	 Short	 White	 Green	 Wrinkled	 Yellow	 Pinched	 Terminal (at tip)

Figure 8.5 Mendel Studied Seven Pairs of Traits in Pea Plants. Each of the seven traits (stem length, flower color, seed color, and so on) can appear in two forms: a dominant form and a recessive form.

Segregation

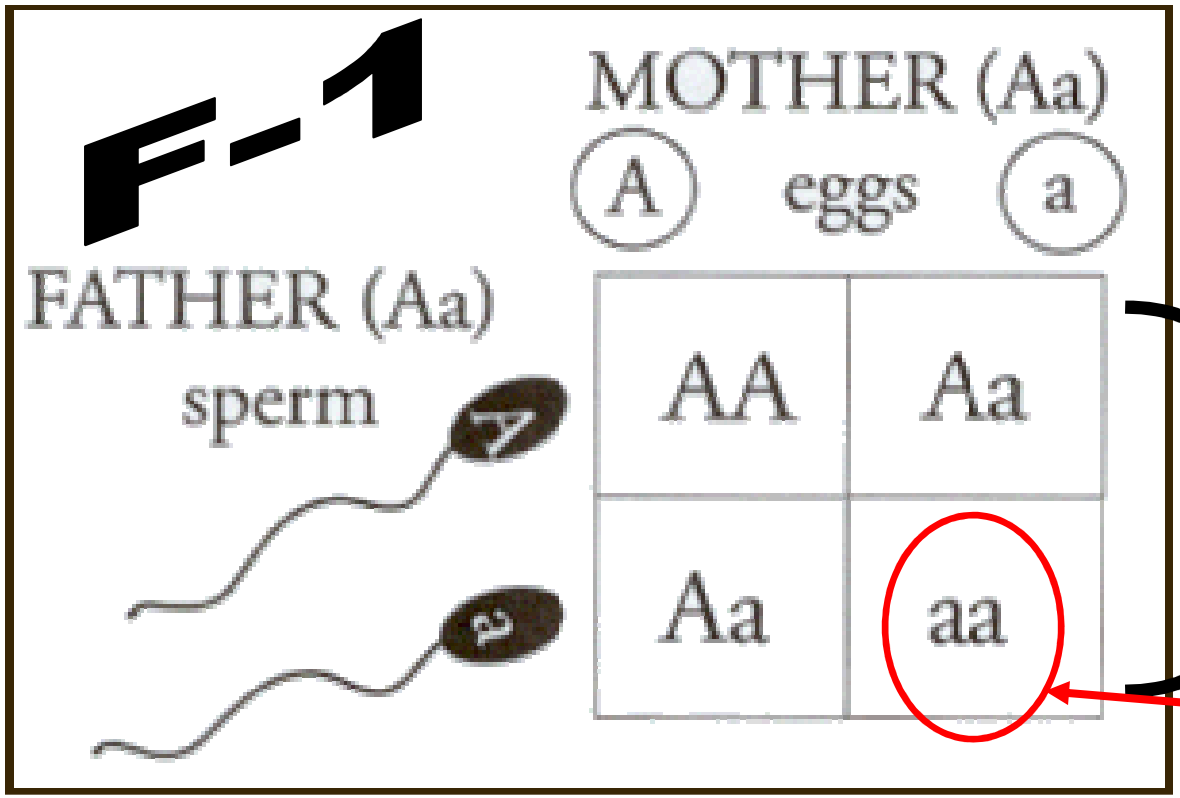
- This led Mendel to ask: *Had the recessive alleles disappeared forever?*
- To answer this he allowed the F1 hybrid plants to self-pollinate to produce an <u>F2 generation</u>



HOW?

"P" generat. ↱	T	T
t	Tt	Tt
t	Tt	Tt

F_1



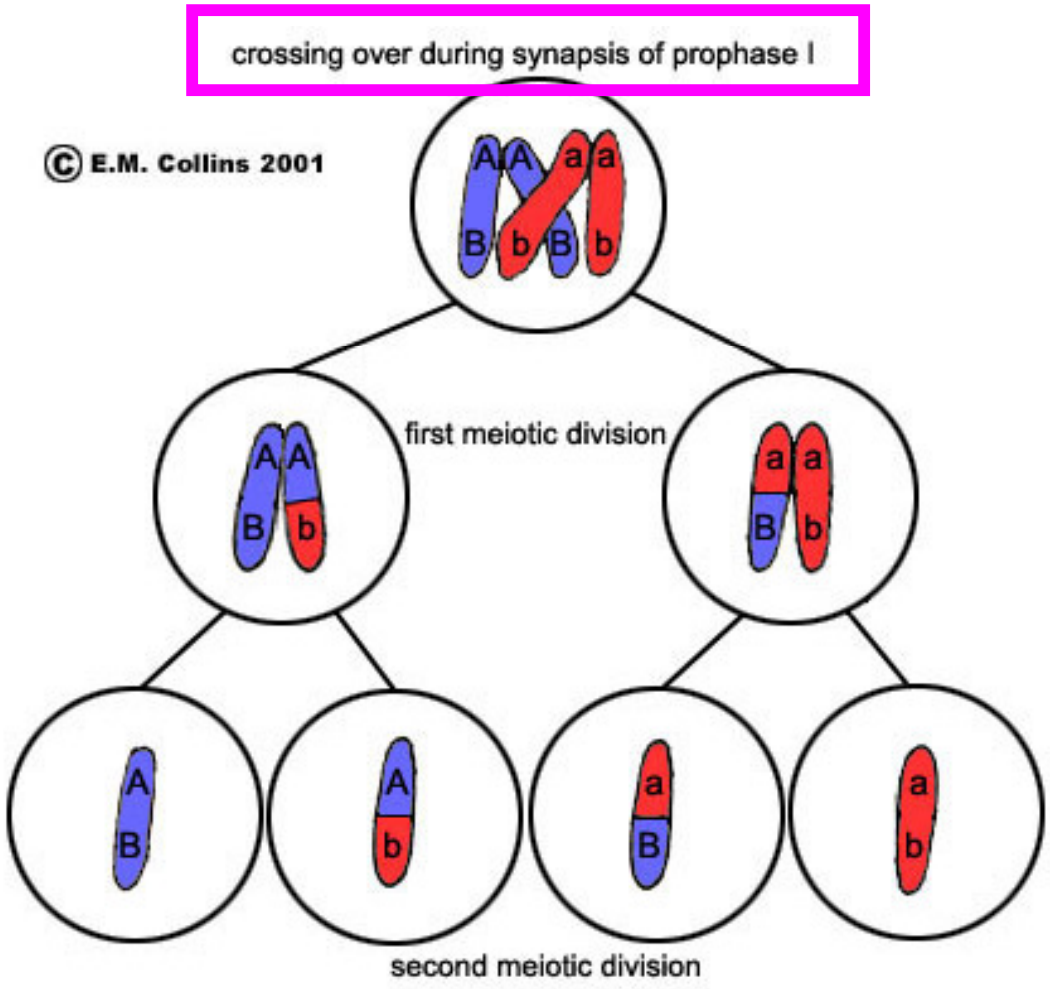
F_2

Recessive allele reappeared!

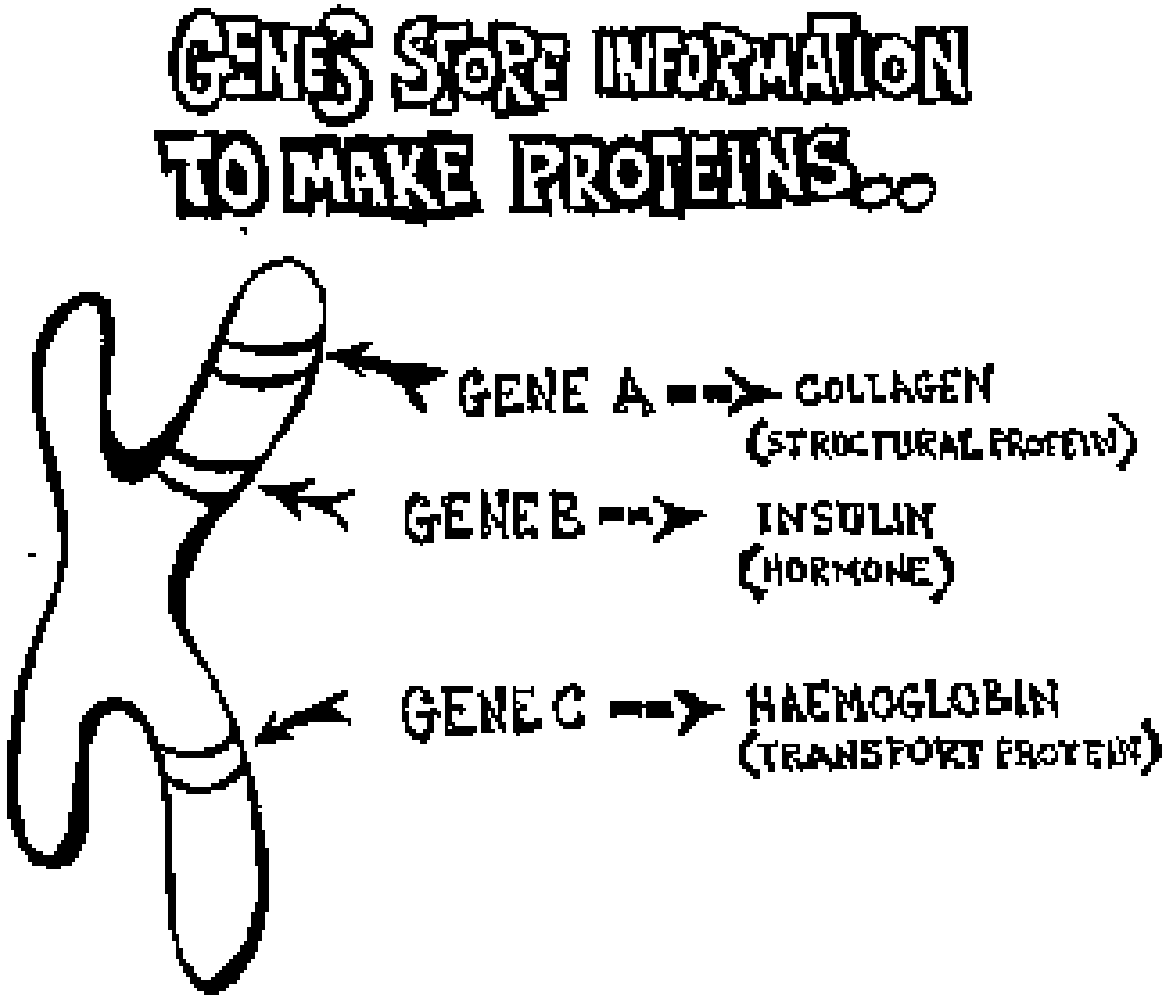
- When each F_1 plant flowers, the 2 alleles are segregated (separated) from each other so that each **gamete (SEX CELL)** *carries only a single copy of each gene*
- Therefore, each F_1 plant produces 2 types of gametes
  - those with an allele for yellow seeds
  - those with an allele for green seeds

pollen = sex cell

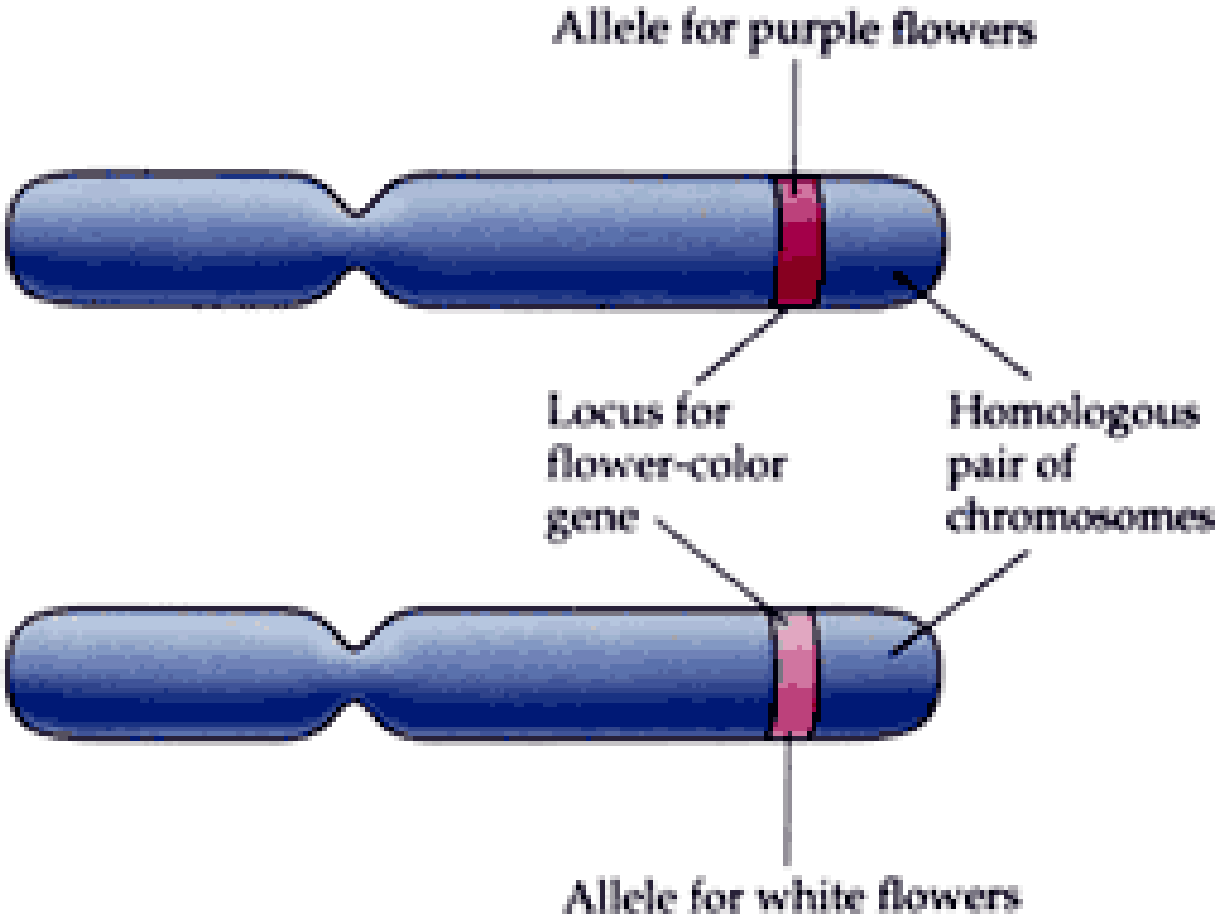
Segregation of gametes:



Genes are on chromosomes



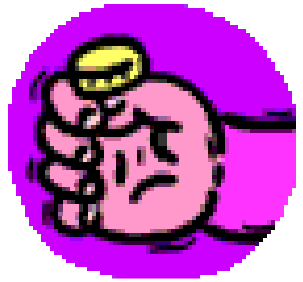
- **ALLELES: versions or copies of a gene**



A little more background info…

- Every time Mendel performed a cross with his pea plants, he carefully counted the offspring
- Out of the over 20,000 plants he counted he noticed there was a **PATTERN!**
  - Whenever he crossed 2 plants that were **hybrid** for stem height (**Tt**), about ¾ of the resulting plants were TALL and ¼ were short ***(3:1 ratio)***
  - He realized that the **principles of probability** could be used to explain his results!

PROBABILITY:

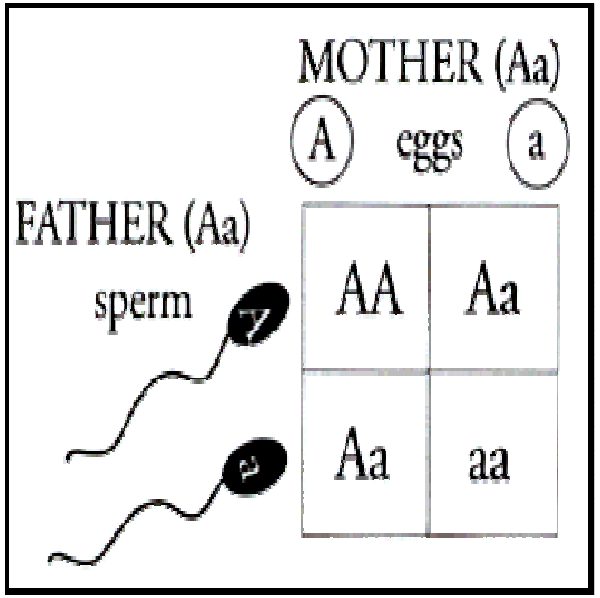


- ***Definition:*** the likelihood that a particular event will occur
  - Ex: flip a coin: ½ or 50% chance it will come up heads
- If you flip a coin 3 times in a row, what is the probability it will come up heads 3 times in a row?
  - Each coin flip is an independent event therefore it is:

    ½ x ½ x ½ = 1/8
  - Past outcomes do not influence future outcomes
- The principles of probability can be used to predict the outcomes of **genetic crosses**

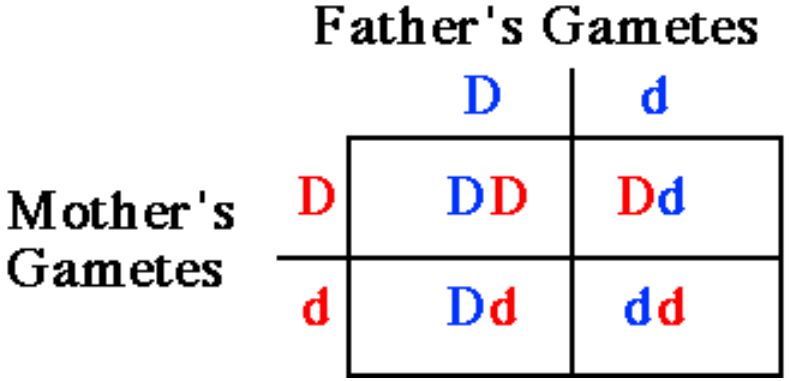
PUNNETT SQUARES:

- The gene combinations that **MIGHT** result from a genetic cross can be determined by drawing a **Punnett Square**
- The parents go on the **outside** of the square along the side and top
- The possible outcomes of the cross are on the **inside** of the squares
- ***The letters in the Punnett Square represent ALLELES***



Alleles in a Punnett Square:

- "T" represents the **DOMINANT** allele: **TALL**
- "t" represents the **RECESSIVE** allele: **short**
  - Organisms with 2 identical alleles (TT or tt) for a trait are said to be **HOMOZYGOUS**
    - Mendel called these: **true-breeding**
  - Organisms with 2 different alleles for a particular trait are said to be **HETEROZYGOUS**
    - Mendel called these **hybrids**



MORE VOCABULARY!

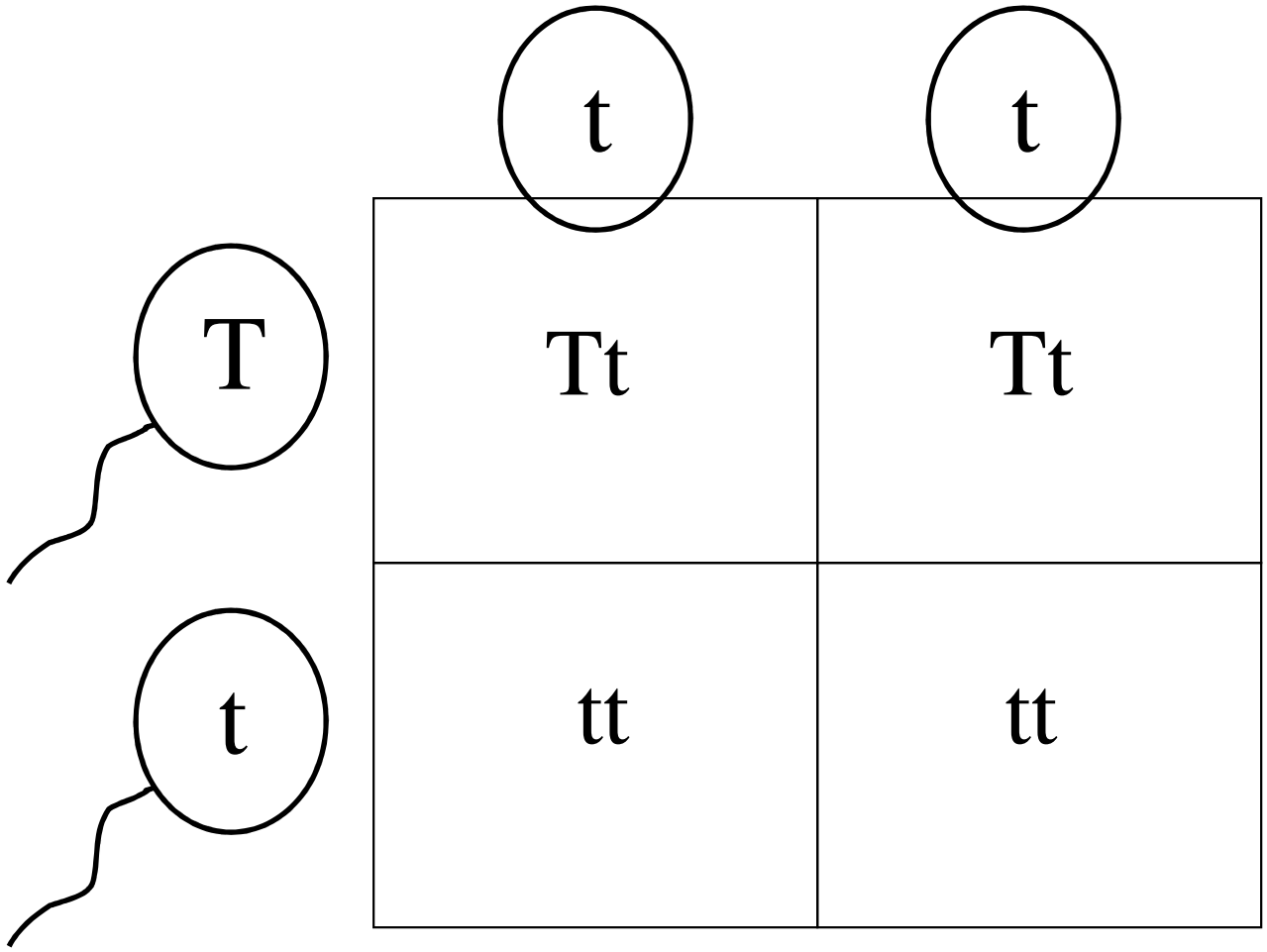
- **Phenotype**: the physical characteristics of the organism (what the organism looks like)
  - Ex: **Tall; short**

- **Genotype**: the actual genetic makeup of the organism (the 2 alleles the organism inherited)
  - Ex: **TT; Tt: tt**

Probabilities Predict **Averages:**

- Probabilities predict the outcomes of a **LARGE** number of events
- ***Probabilities cannot predict precise outcomes of an event***
  - Ex: flip a coin twice you may get 100% heads
  - You need to flip the coin many, many times to get close to 50%

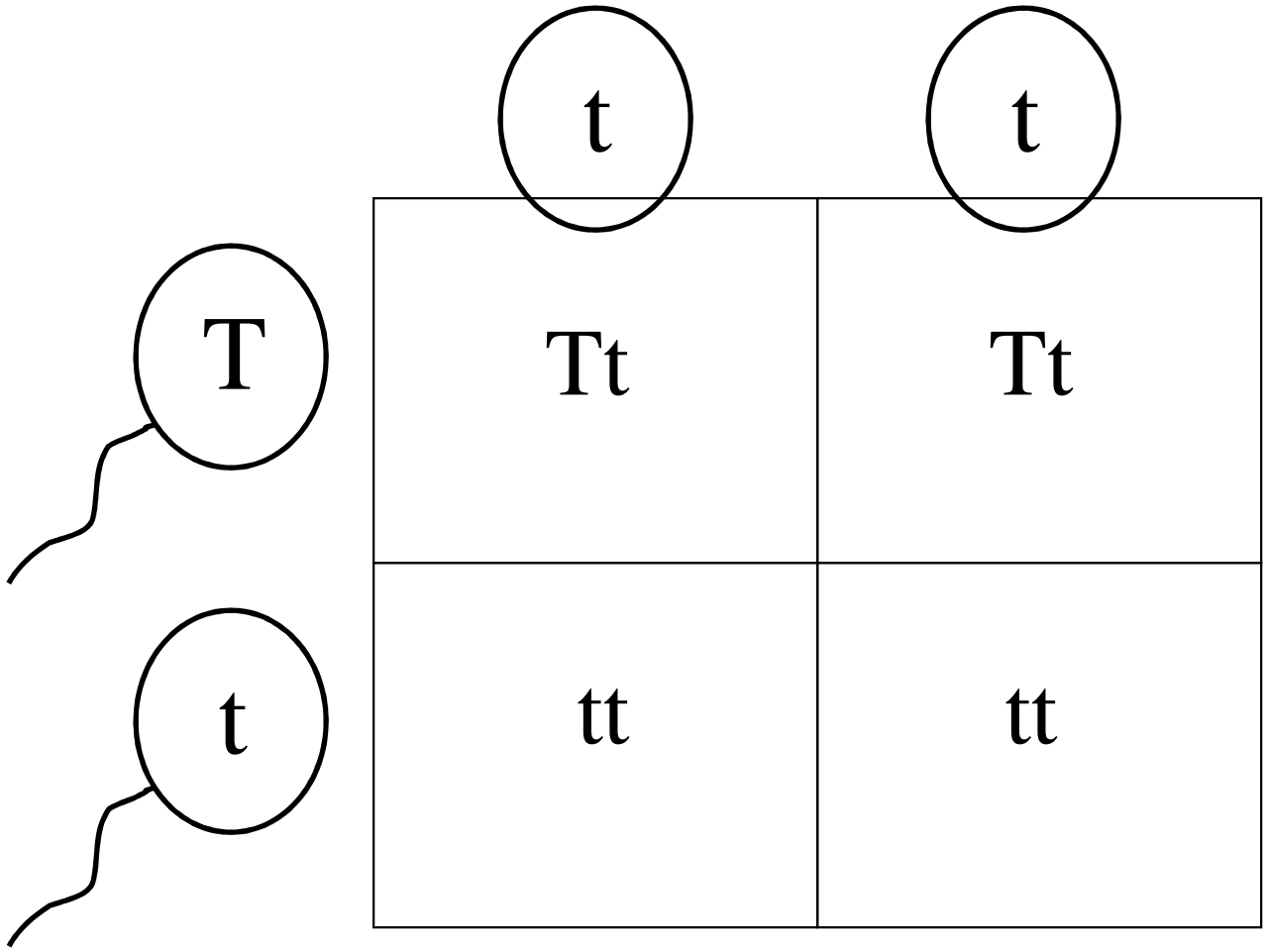
What is the expected ratio for this cross? Tt x tt



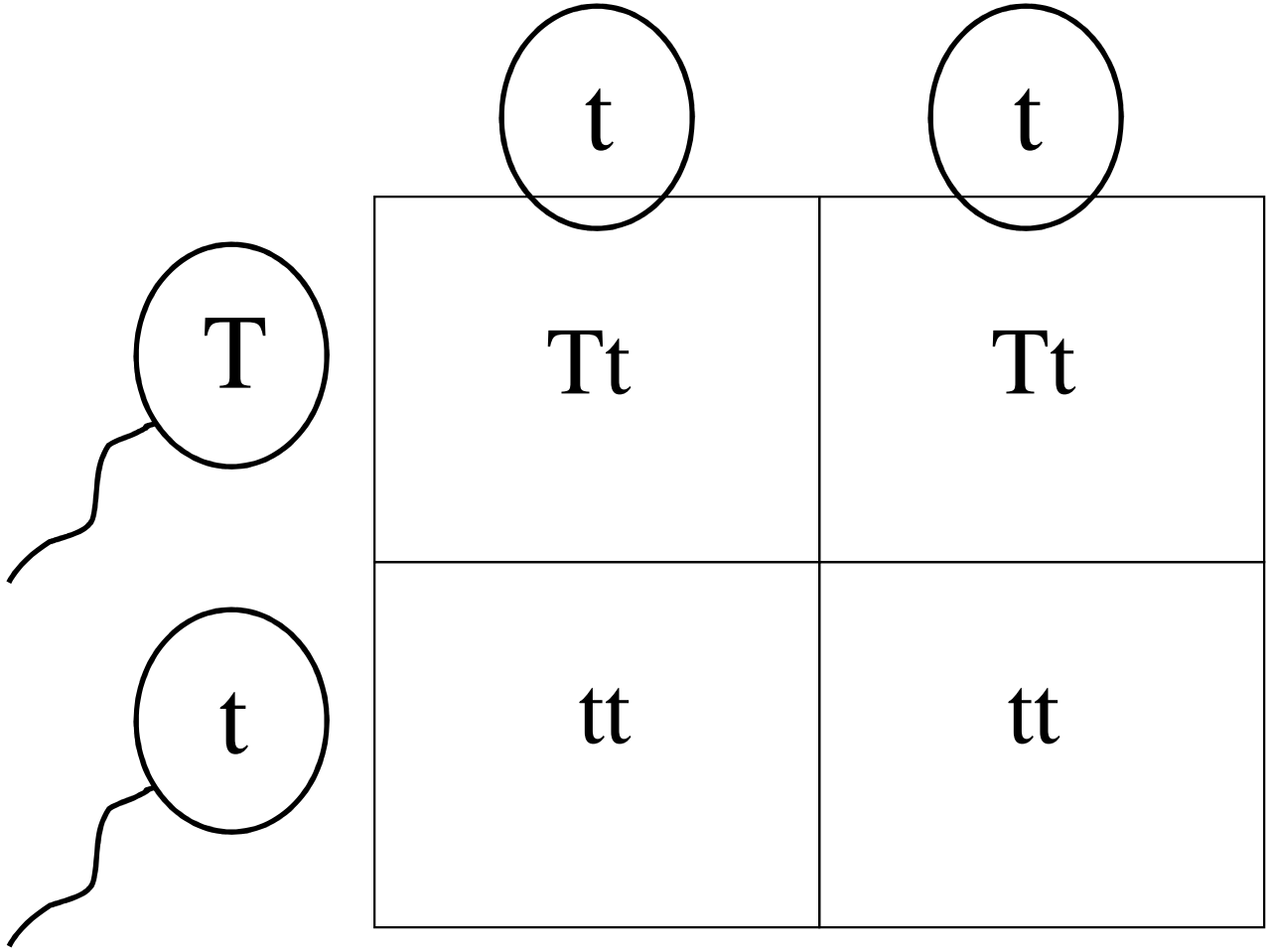
Punnett Square Rules:

1. Choose a letter to represent the **dominant** allele and capitalize it (choose a letter that is easy to distinguish between upper-case and lower-case).
2. Use the same letter but use lower case to represent the **recessive** allele.
3. Put the male's alleles down the left side of the square and the female's alleles across the top.
4. Write "genotype" and "phenotype" below the square.
5. Use "x" to indicate a cross.
6. Write the dominant allele first if you are writing out a hybrid.

What is the expected ratio for this cross? Tt x tt



What is the expected ratio for this cross? Tt x tt



Genotype ratio: 2 Tt : 2 tt

Phenotype ratio: 2 tall : 2 short

More Mendelian Genetics…

- **Key Concepts:**
  - What is the principle of independent assortment?

- **Vocabulary:**
  - Independent assortment

Independent Assortment

- Two-factor cross / dihybrid cross of Parent Generation:
  - Crossed *true breeding plants* (Parents)
    - Round Yellow x Wrinkled Green
      - F_1 phenotypes = **all yellow, round**
- Which alleles are dominant?
  - **Round shape** and **Yellow color**.
- **Why is this called a *DIHYBRID* or two-factor cross**?

  ➔ Because the experiment tests **two characteristics** controlled by **two factors = genes.**

Summary of Mendel's two factor cross (F1 Generation)

- Mendel crossed plants that were **homozygous dominant** for round yellow peas (**RRYY**) and plants that were **homozygous recessive** for wrinkled green peas (**rryy**).

- **All** of the F_1 offspring were **heterozygous dominant** for round yellow peas (**RrYy**).

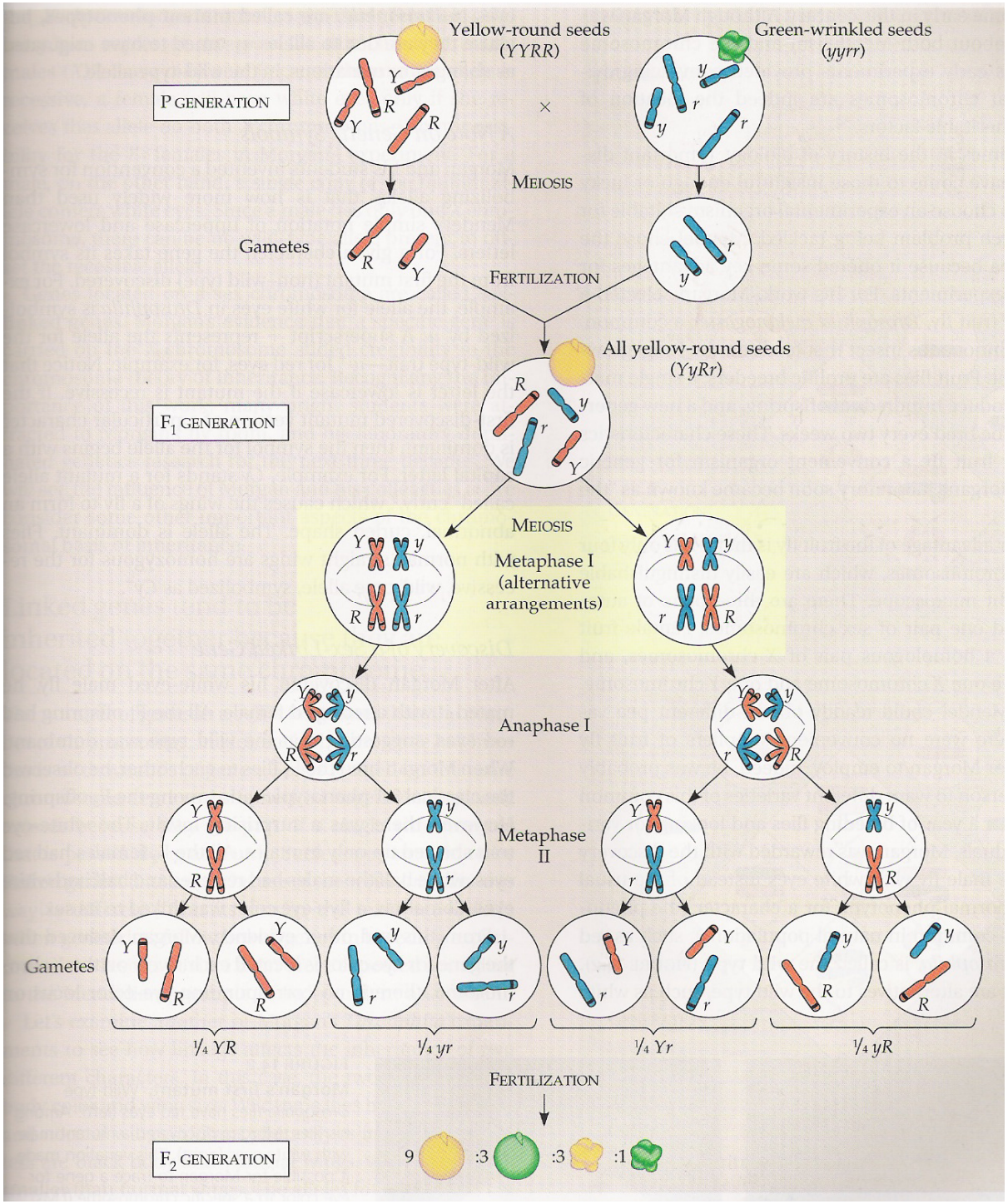
The Two-Factor Cross F_2

- Mendel knew all of the F_1 plants were **RrYy**
  - **but how would these alleles interact if the F_1 plants were crossed?**
- Would the two dominant alleles stay together (R and Y) or would they **segregate independently**?
  - In his experiment, F_2 plants produced 556 seeds.
    - 315 were round and yellow (looked like Parental)
    - 32 were wrinkled and green (looked like Parental)
    - **209 had combinations of the phenotypes**
- Therefore, the alleles for seed shape **segregated independently** of the alleles for seed color.

This phenomenon is known as…

Independent assortment

Definition: genes for different traits segregate independently during the formation of gametes (**meiosis**).


Yellow-round seeds
(YYRR)
Green-wrinkled seeds
(yyrr)
P GENERATION
×
MEIOSIS
Gametes
FERTILIZATION
All yellow-round seeds
(YyRr)
F1 GENERATION
MEIOSIS
Metaphase I
(alternative
arrangements)
Anaphase I
Metaphase
II
Gametes
1/4 YR
1/4 yr
1/4 Yr
1/4 yR
FERTILIZATION
F2 GENERATION
9 :3 :3 :1

Making Gametes

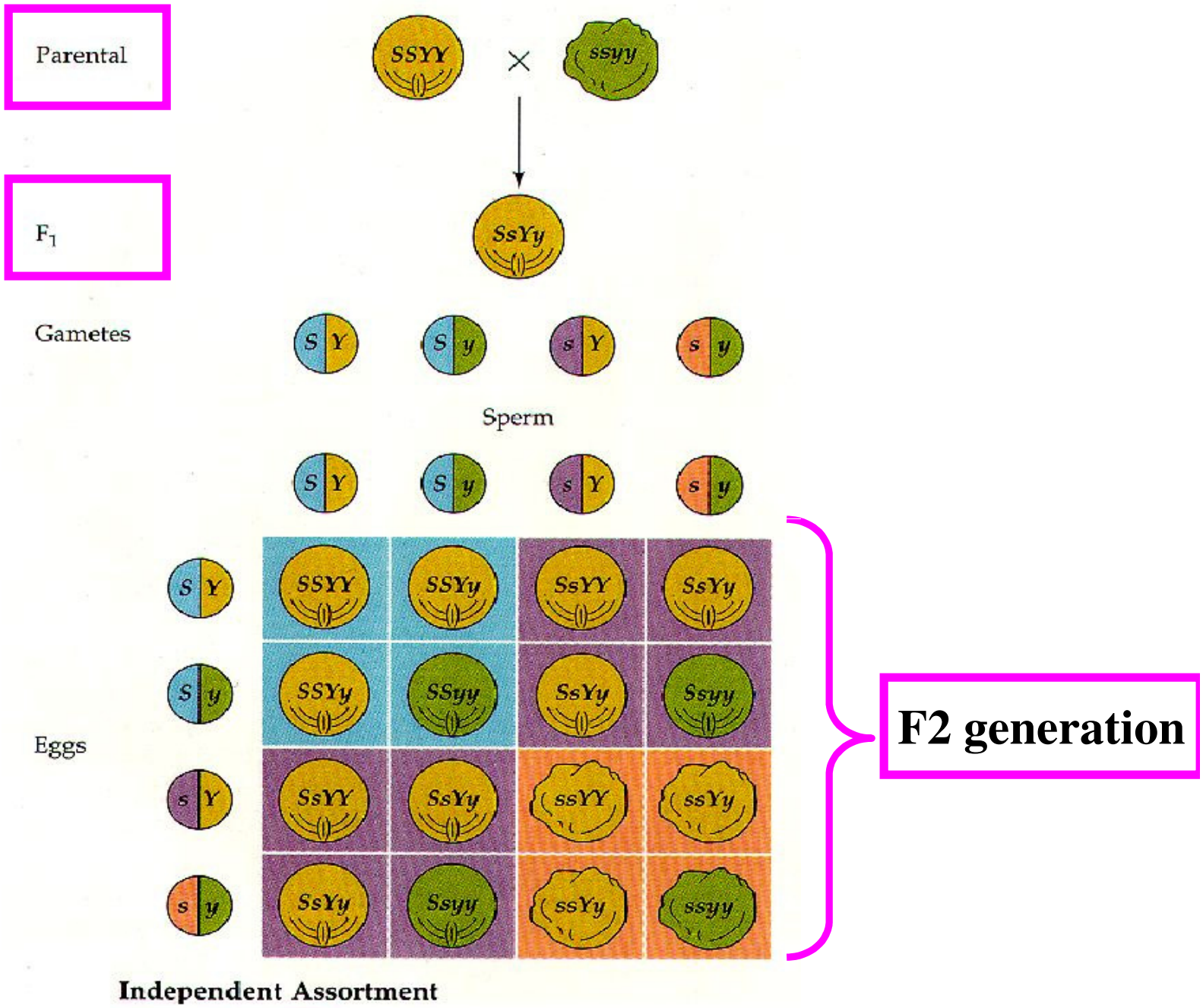
- If the genotype of a plant is **RrYy**, (**round, yellow seeds**) what are the four possible combinations of gametes?

- **RY, Ry, rY, ry**

- These are **FOUR** possible gametes, each with two alleles!!!

Independent Assortment..in other words…

- **Does the segregation of one pair of alleles affect the segregation of another pair of alleles?**
  - **EX: does the gene that determines seed shape have anything to do with the gene that determines seed color?**
- **The answer: NO**
- **If genes are not connected, then they should separate (segregate) independently: *Independent Assortment***


Parental
SSYY
×
ssyy
F1
SsYy
Gametes
S Y
S y
s Y
s y
Sperm
S Y
S y
s Y
s y
Eggs
S Y
S y
s Y
s y
SSYY
SSYy
SsYY
SsYy
SSYy
SSyy
SsYy
Ssyy
SsYY
SsYy
ssYY
ssYy
SsYy
Ssyy
ssYy
ssyy
F2 generation
Independent Assortment

CROSS: RrYy x RrYy

	RY	**Ry**	**rY**	**ry**
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

CROSS: RrYy x RrYy

	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

F_2 Generation Phenotype ratio:

9:3:3:1

Can you see the ratio of phenotypes in the Punnett square?

9 round, yellow:
3 round, green:
3 wrinkled,yellow:
1 wrinkled, green

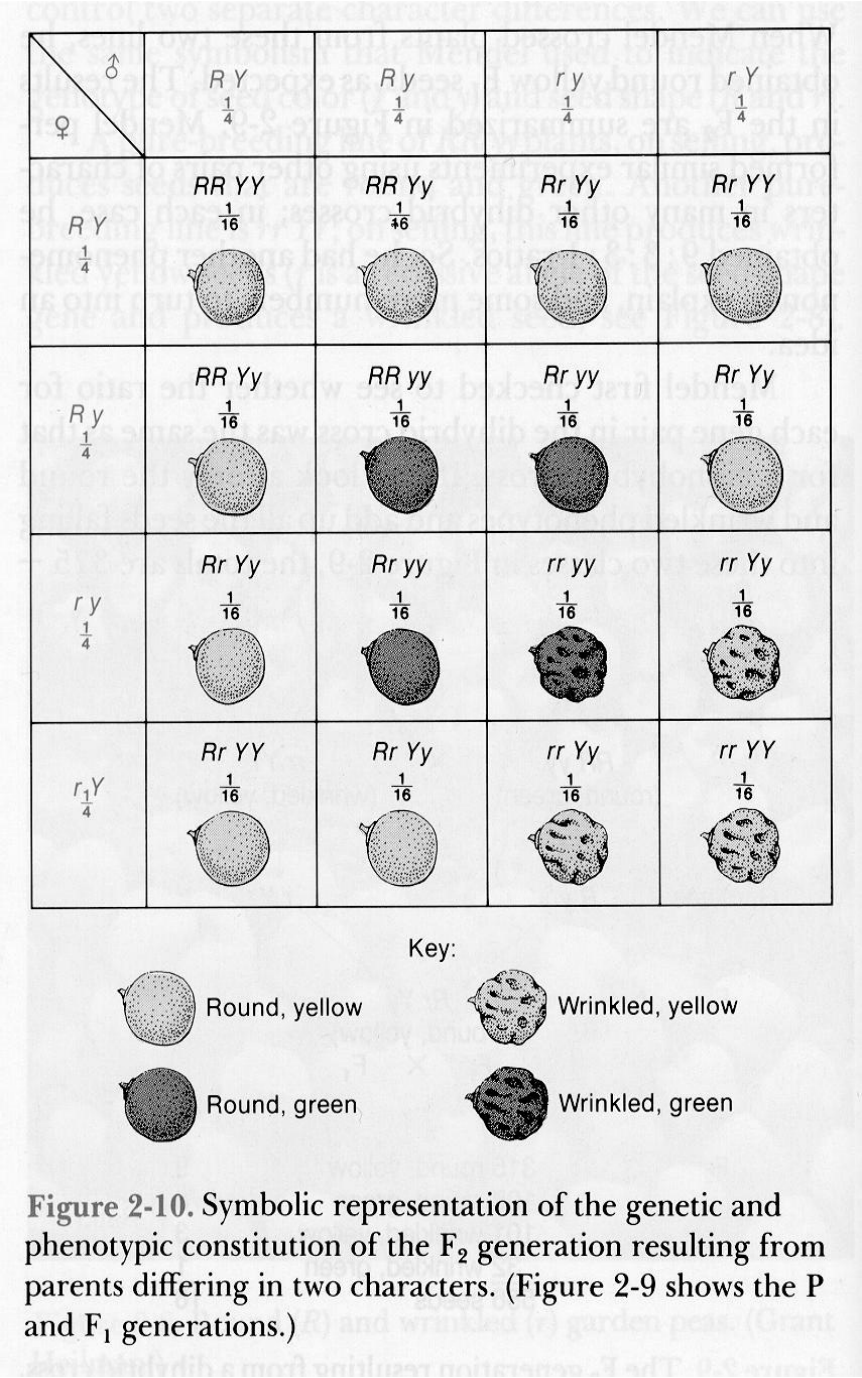


Figure 2-10. Symbolic representation of the genetic and phenotypic constitution of the F_2 generation resulting from parents differing in two characters. (Figure 2-9 shows the P and F_1 generations.)

A Summary of Mendel's Principles:

1. Inheritance is determined by **GENES**
2. Some genes are **DOMINANT** and some are **RECESSIVE**
3. Each sexually reproducing adult has **2 copies of a gene**.
   - These genes are **segregated** during gamete formation.
4. **Alleles** for different genes USUALLY segregate independently *(independent assortment)*