Chapter 11: Introduction to Genetics

DO NOW

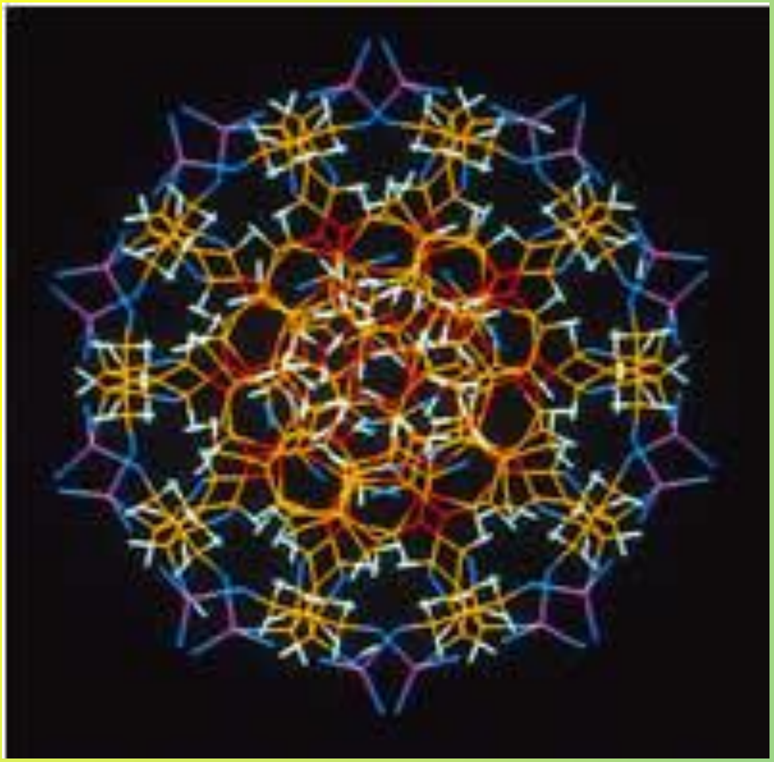
- Work in groups of 3
- Create a list of physical characteristics you have in common with your group.
- Consider things like eye and hair color, style/texture of hair, shape of nose/ears, and so on.
- Why do we all look different from each other?

DO NOW ANSWERED

- We all have different parents.
- Our parents have their own physical characteristics that are expressed.
- These characteristics have been inherited from their parents as you have inherited characteristics from your parents.

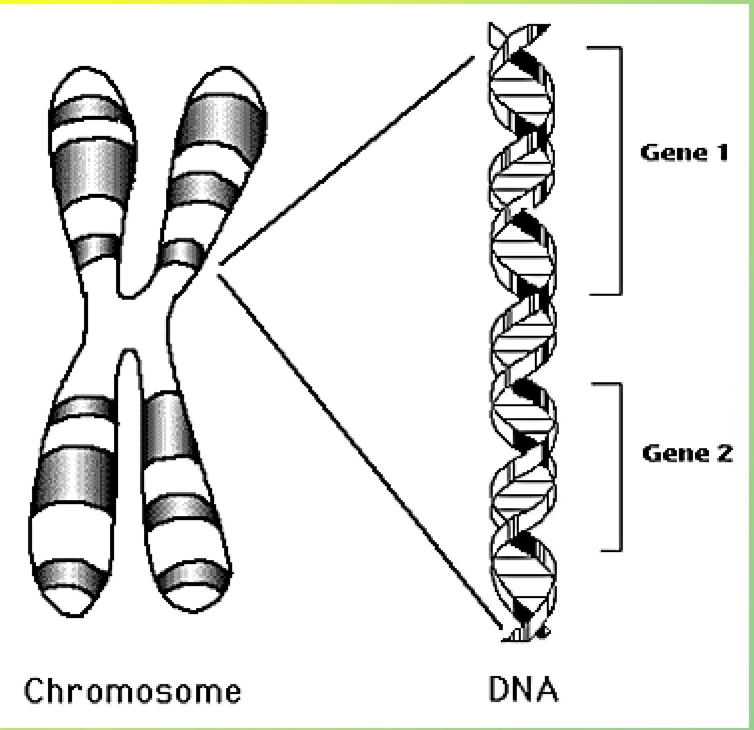
11-1: The Work of Gregor Mendel

- **heredity:** set of characteristics an organism receives from its parents
- **genetics:** study of heredity



11-1 The Work of Gregor Mendel

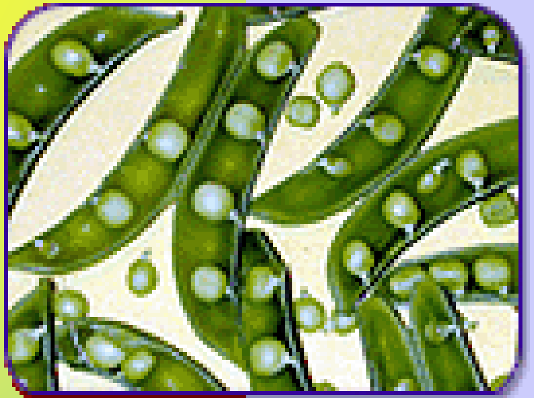
- **What is inheritance?**
- Every living thing—plant or animal, microbe or human being—has a set of characteristics inherited from its parent or parents.
- Your GENES!



Gregor Mendel’s Peas

- Austrian monk born in 1822.
- He laid the foundation of the science of genetics.
- As a result, **genetics**, the scientific study of heredity, is now at the core of a revolution in understanding biology.

In the 1800s, Gregor Mendel discovered the rules of genetics.



Pea plants are how Mendel's genetic studies began.

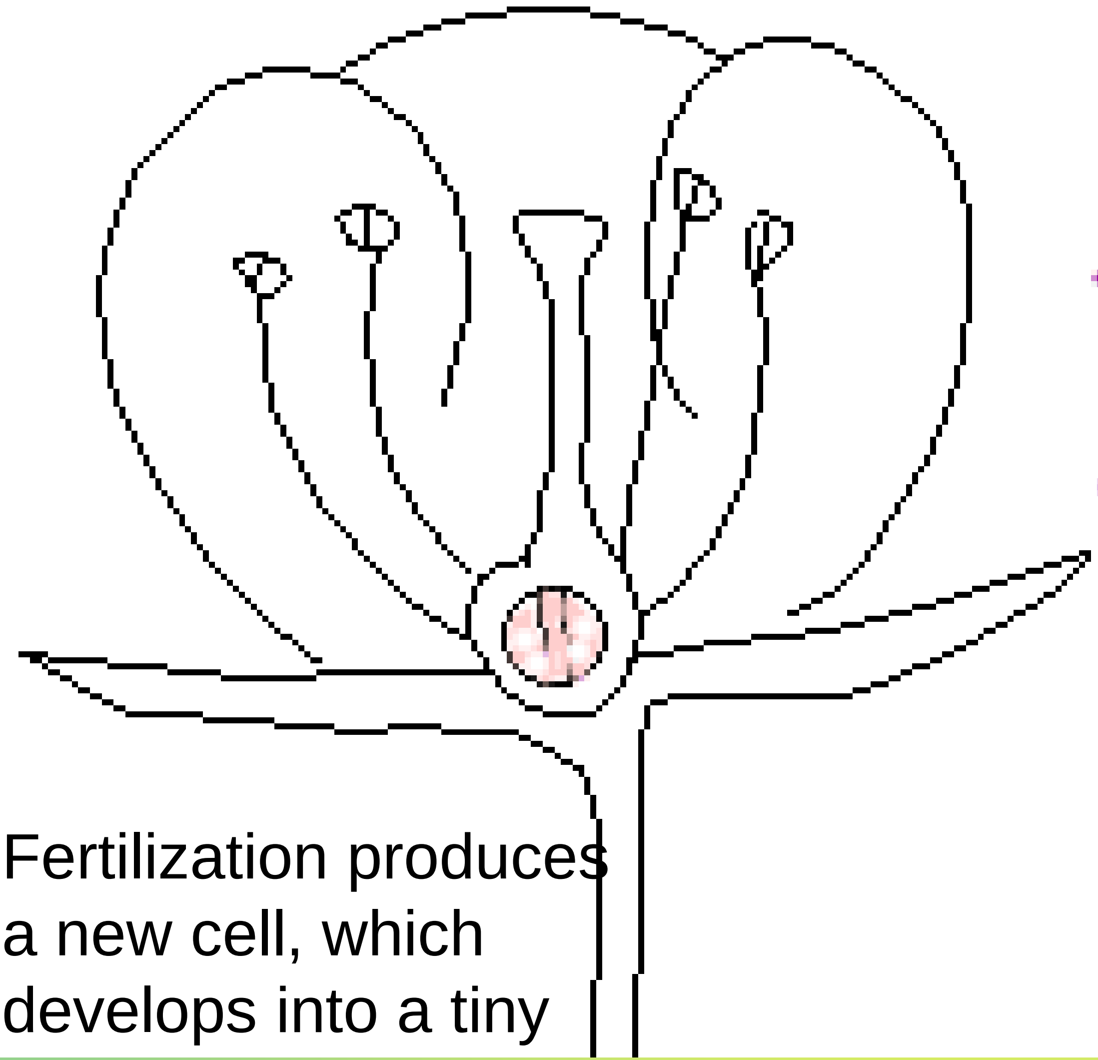
- Mendel attended the University of Vienna
- He spent the next 14 years working in the monastery and teaching at the high school. (he was in charge of the monastery garden)
- In this ordinary garden, he was to do the work that changed biology forever.

Actual Plot where Mendel had his Garden in the Czech Republic.

Mendel and the Experiment

- Test subject : garden peas
- He knew that part of each flower produces pollen, which contains the plant's male reproductive cells (sperm).
- The female portion of the flower produces egg cells.
- During sexual reproduction, male and female reproductive cells join, a process known as **fertilization**.

Fertilization



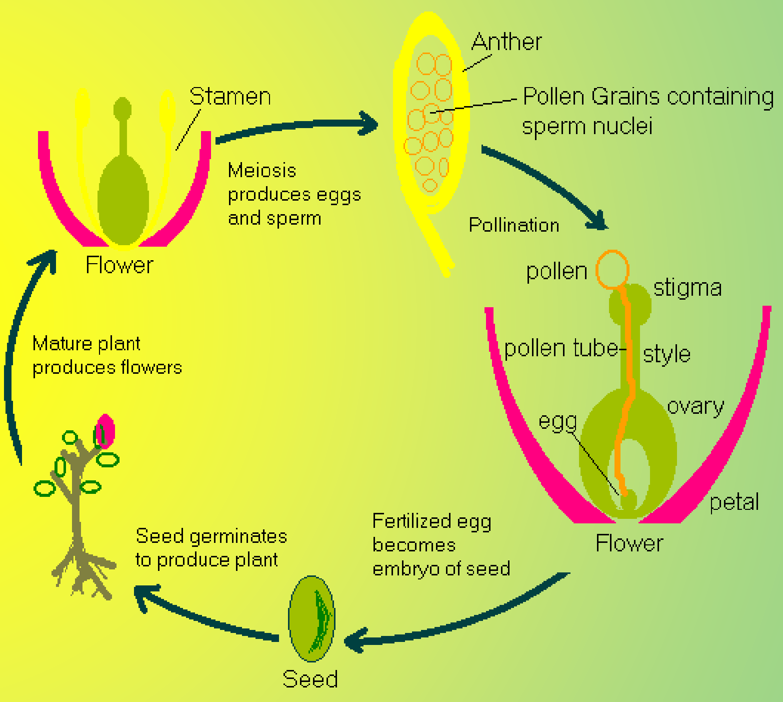
Pollen lands on stigma

Tube grows down the style and enters the ovary

Fertilization produces a new cell, which develops into a tiny embryo encased within a seed.

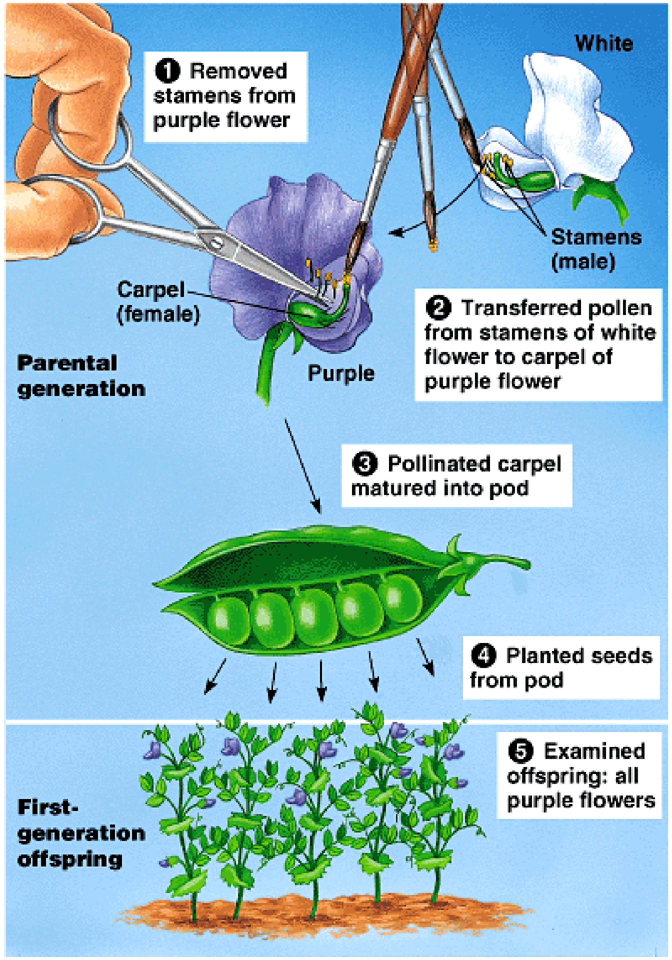
Reproduction in Pea Plants

- pollen is the male sex cell
- eggs are the female sex cell
- reproduce by **self pollination:** process in which pollen fertilizes an egg from the same plant
- reproduces by **cross pollination:** process in which pollen from one plant fertilizes an egg from another plant



Mendel's First Experiment

- prevented flowers from self pollinating
- controlled cross pollination
- cut off male parts of flowers and dusted flowers with pollen from another flower
- was able to cross plants with different characteristics
- used **purebreds:** an organism that only produces offspring with only one form of a **trait**
  - A specific characteristic such as seed color or plant height



Genes and Dominance

- Mendel studied **seven** different pea plant traits.
- A **trait** is a specific characteristic, such as seed color or plant height, that varies from one individual to another.
- Each of the seven traits Mendel studied had two contrasting characters, for example, green seed color and yellow seed color.

QUESTION

- Which of the following are not examples of heredity?
- A. the stripes of a zebra
- B. the rows of teeth in the mouth of a Great White Shark
- C. speaking a foreign language
- D. a tiger hunting prey

DO NOW

- If you crossed a Tall pea plant with a short pea plant, how would you predict the offspring produced?

DO NOW ANSWERED

- You would need to know which trait, Tall or short, was the dominant one.
- It is also necessary to identify the alleles from each parent that may be passed down to an offspring.
- This dominant trait will most likely be expressed.

- When Mendel took charge of the monastery garden, he had several stocks of pea plants.
- These peas were **true-breeding**
  - True breeding = A plant, that when self-fertilized, only produces offspring with the same traits.
  - The **alleles** for these type of plants are **homozygous**.

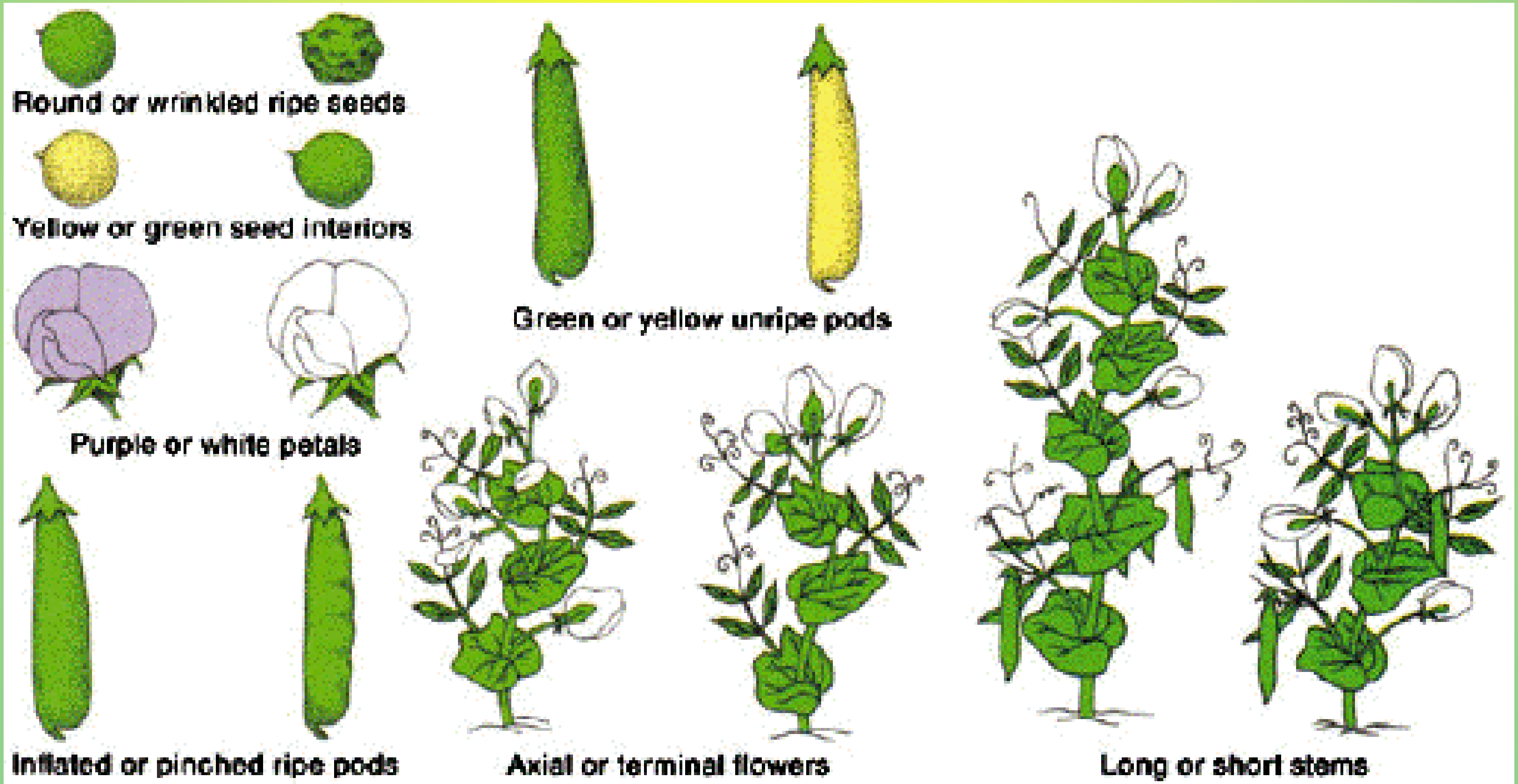
Gregor Mendel

True-Breeding

- True-breeding plants are plants that only carry one allele for a trait.

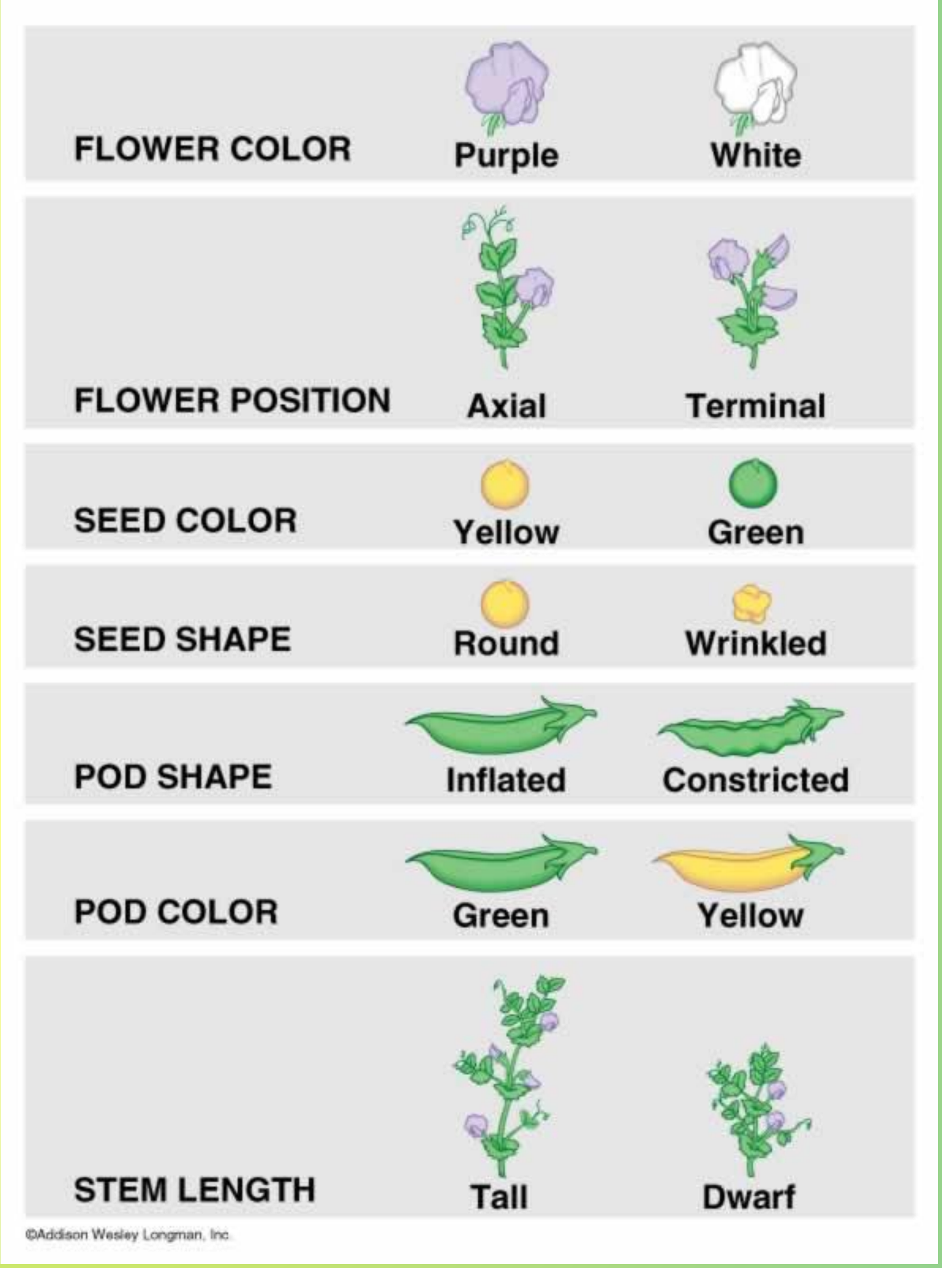
- If these plants are allowed to self-pollinate, they will produce offspring identical to themselves.
  - TALL plants produce TALL plants
  - Green seeded plants produce Green seeded plants

- One stock of seeds would produce only tall plants, another only short ones.
- These true-breeding plants were the basis of Mendel's experiments.



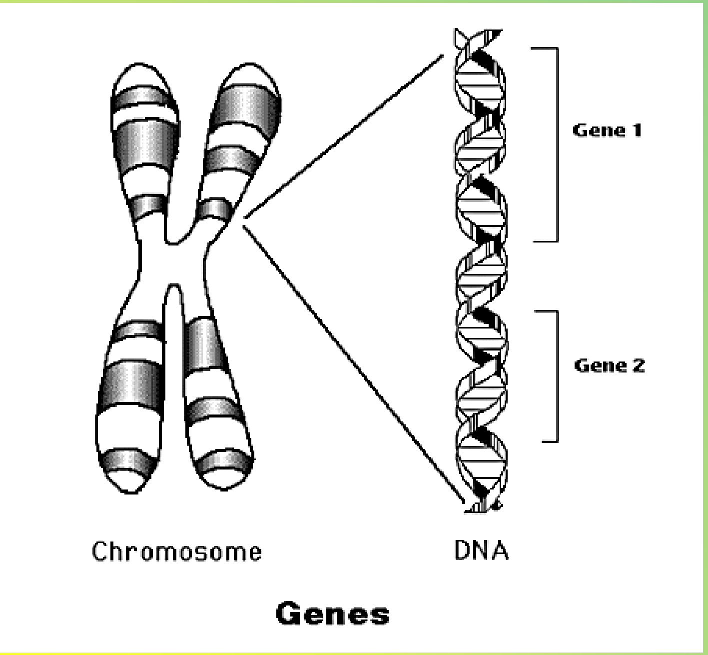
Pea Plant Traits

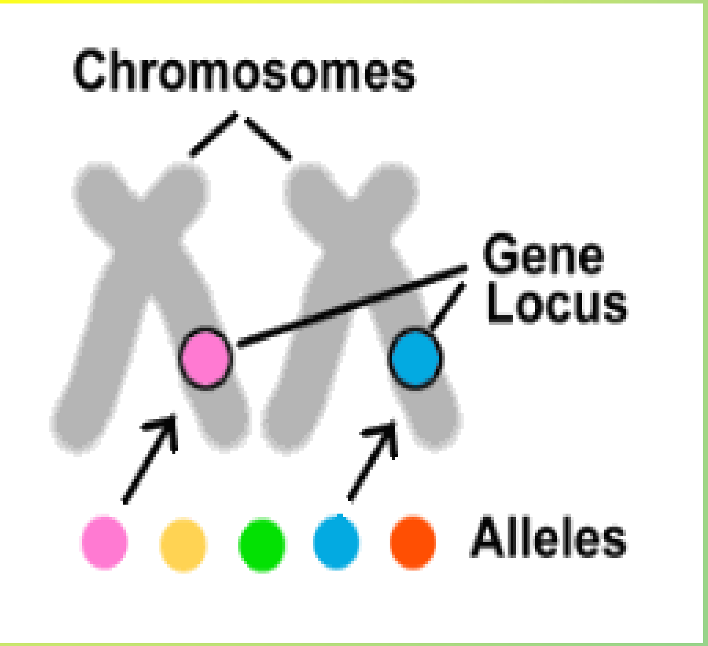
- studied only seven traits with only two options
- decided to cross pea plants with different characteristics for the same trait
- tall with short, green seeds with yellow seeds, round seeds with wrinkled seeds, and so on
- **alleles:** different forms of a gene



Genes and Alleles

- **genes:** chemical factor that determines traits
- **alleles:** different forms of a gene
  - have two alleles for each trait
  - one from each parent
  - sex cells contain one allele
  - when sex cells combine, create cells with two sets of genes





1) Biological inheritance is determined by factors that are passed from one generation to the next. (GENES)

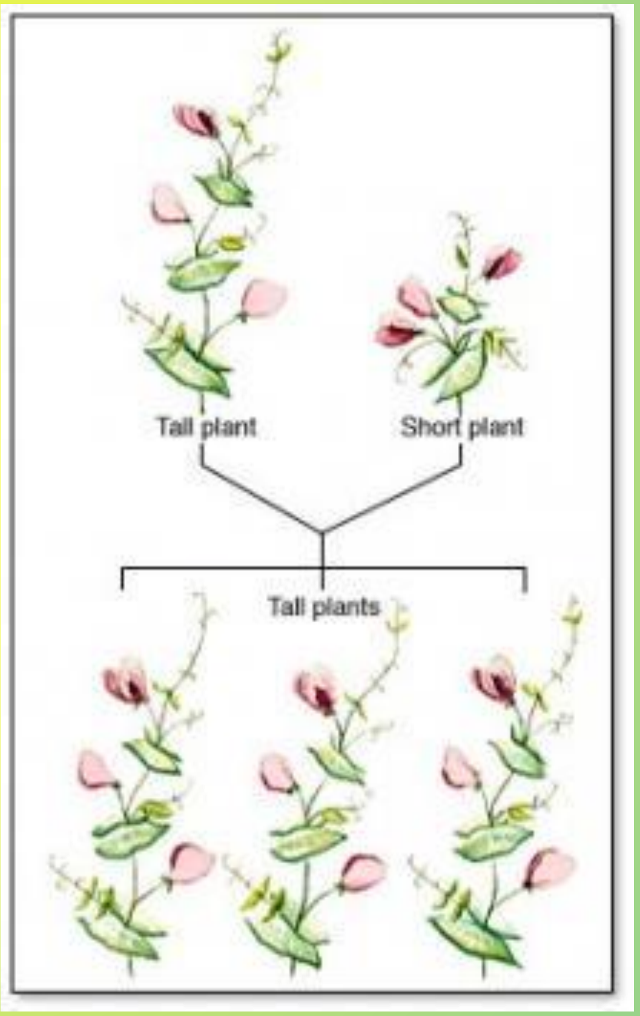
- The different forms of a gene are called **alleles**. (Height is either tall or short)

2) The principle of **dominance** states that some alleles are dominant and others are recessive.

- In Mendel's experiments, the allele for tall plants was dominant and the allele for short plants was recessive.

Mendel's Results

- offspring were **hybrids:** organisms produced by crossing parents with differing characteristics
- all hybrids had the characteristics of only one parent

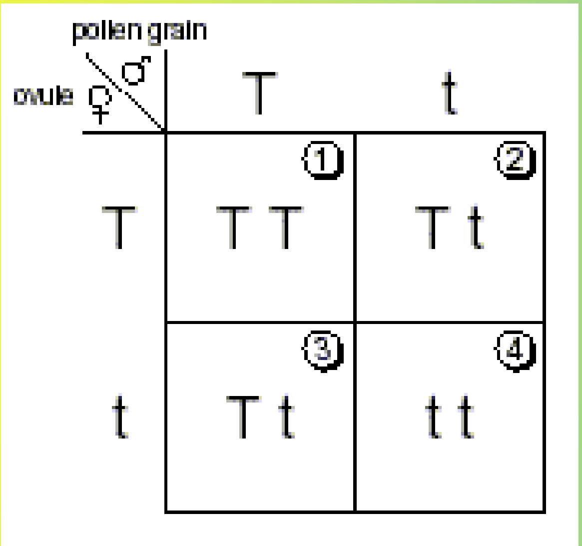


Mendel’s Conclusions

- 1. individual factors, called **genes**, control each trait
- 2. principle of dominance: some factors or alleles are **dominant** whereas others are **recessive**


Segregation

- the separation of alleles during gamete formation
- when **gametes**, or sex cells, come together, new combinations occur
- gene combinations can be represented in a chart using **Punnett squares**
- **monohybrid cross:** crossing one trait



Segregation

- Mendel wanted the answer to another question: Had the recessive alleles disappeared, or were they still present in the F_1 plants? (were they hiding?)
- To answer this question, he allowed all seven kinds of F_1 hybrid plants to produce an F_2 (second filial) generation by self-pollination.
  - Roughly one fourth of the F_2 plants showed the trait controlled by the **recessive** allele.

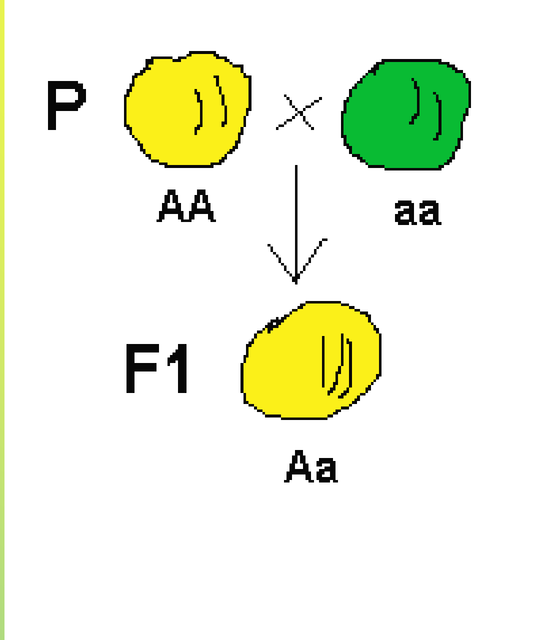
- Why did the recessive alleles seem to disappear in the F_1 generation and then reappear in the F_2 generation?

- Mendel assumed that a dominant allele had masked (hid) the corresponding recessive allele in the F_1 generation.

- However, the trait controlled by the recessive allele showed up in some of the F_2 plants.

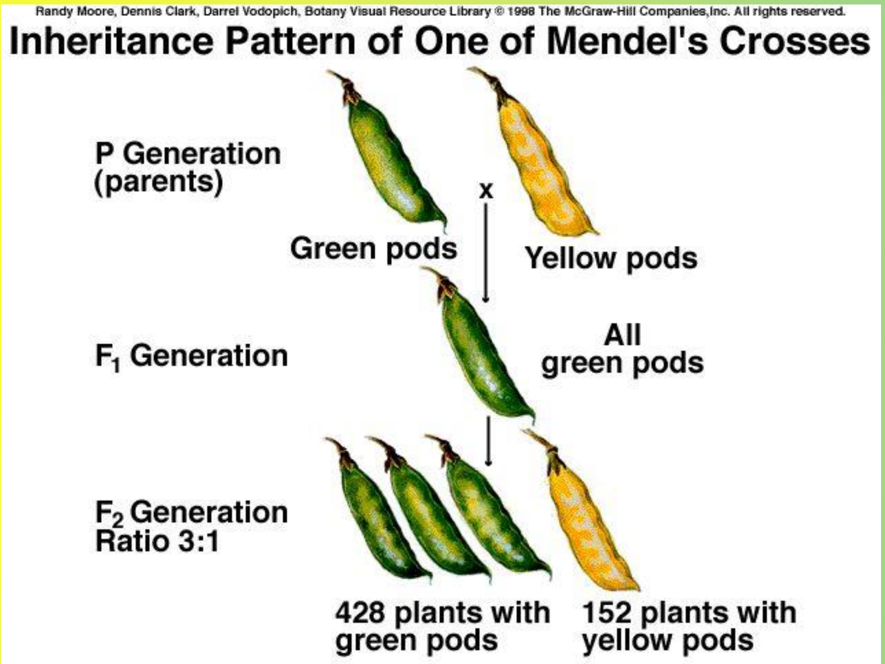
- This reappearance indicated that at some point the allele for shortness had been separated from the allele for tallness.
- When each F_1 plant flowers and produces gametes, the two alleles segregate from each other so that each gamete carries only a single copy of each gene.
- Therefore, each F_1 plant produces two types of gametes—those with the allele for tallness and those with the allele for shortness.

- This process, which is known as **cross-pollination**, produced seeds that had two different plants as parents.
- This made it possible for Mendel to cross-breed plants with different characteristics, and then to study the results.



Mendel's Second Experiment

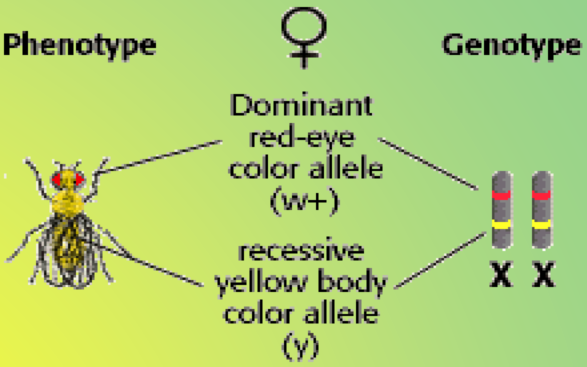
- allowed hybrid plants to reproduce among themselves
- kept groups in order
  - **P generation:** purebred group
  - **F_1 generation:** hybrid group
  - **F_2 generation:** offspring of hybrids
- in F_2 plants, the recessive traits reappeared

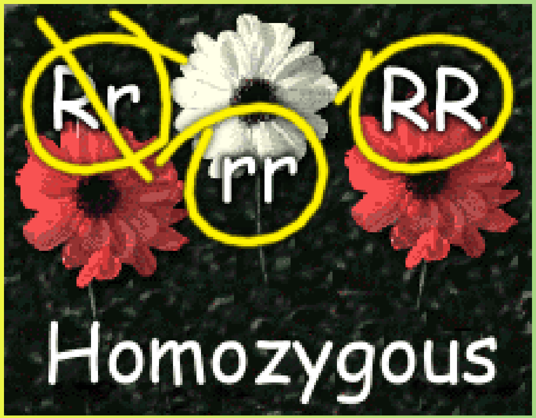


- Mendel crossed plants with each of the seven contrasting characters and studied their offspring.
- He named the plants.
- P = parental or parents
- F_1 = first filial (offspring)
- F_2 = second filial (offspring)
- The offspring of crosses between parents with different traits are called **hybrids**.

Mendel's Results

- in his F_2 generations, the recessive trait showed up in ¼ of the offspring
- **phenotype:** physical characteristics
- **genotype:** genetic makeup
- **homozygous:** two identical alleles for a particular trait
  - TT, homozygous dominant
  - tt, homozygous recessive
- **heterozygous:** having two different alleles for the same trait
  - Tt





Question

- An organism with a genotype of bb is called

- A. Heterozygous recessive
- B. Homozygous dominant
- C. Heterozygous dominant
- D. Homozygous recessive

DO NOW

- Determine the possible genotypes of a pea plant that is Tall and has white flowers.
- Tall is dominant over short
- Purple is dominant over white flowers

DO NOW ANSWERED

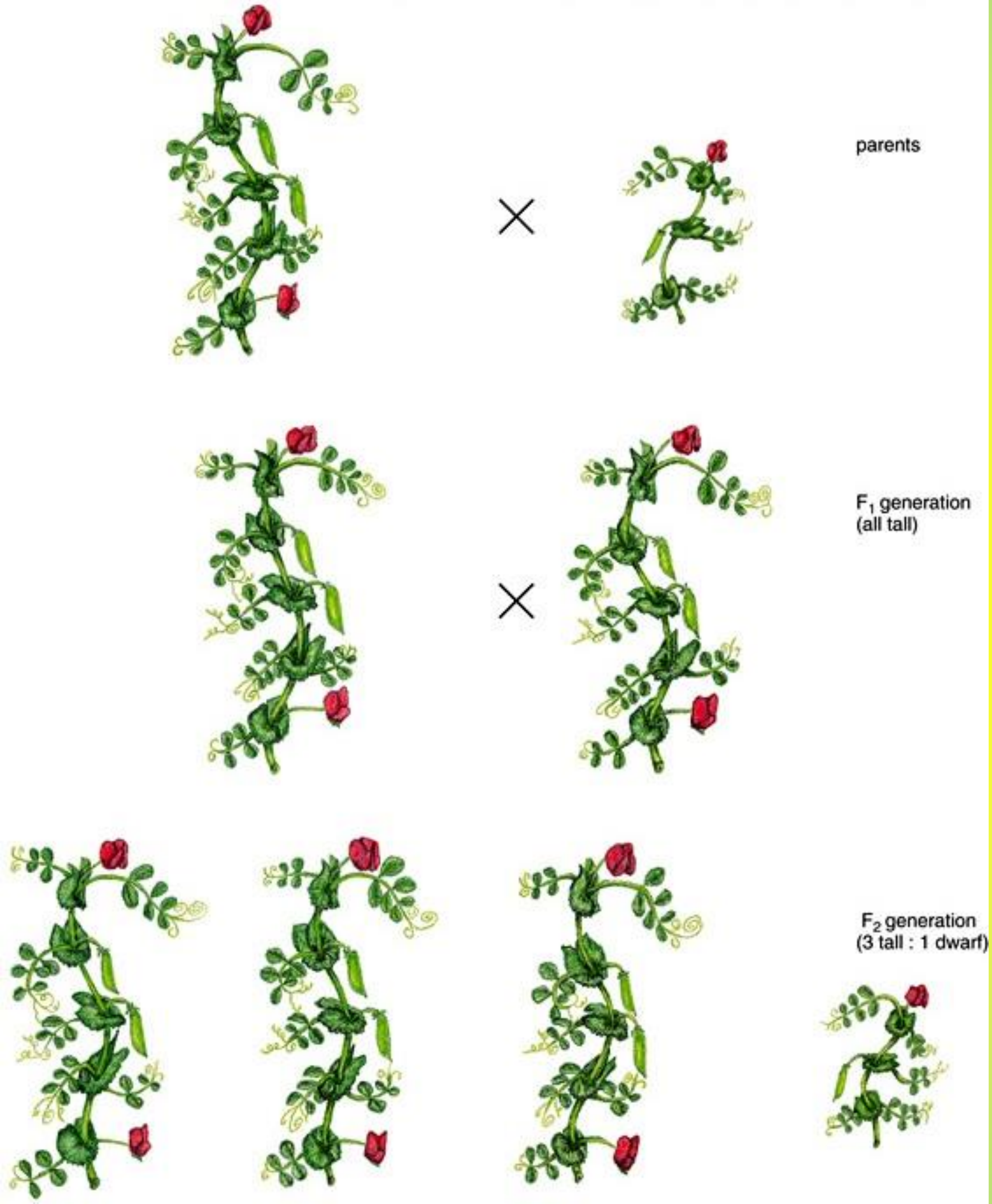
- Possible Genotypes

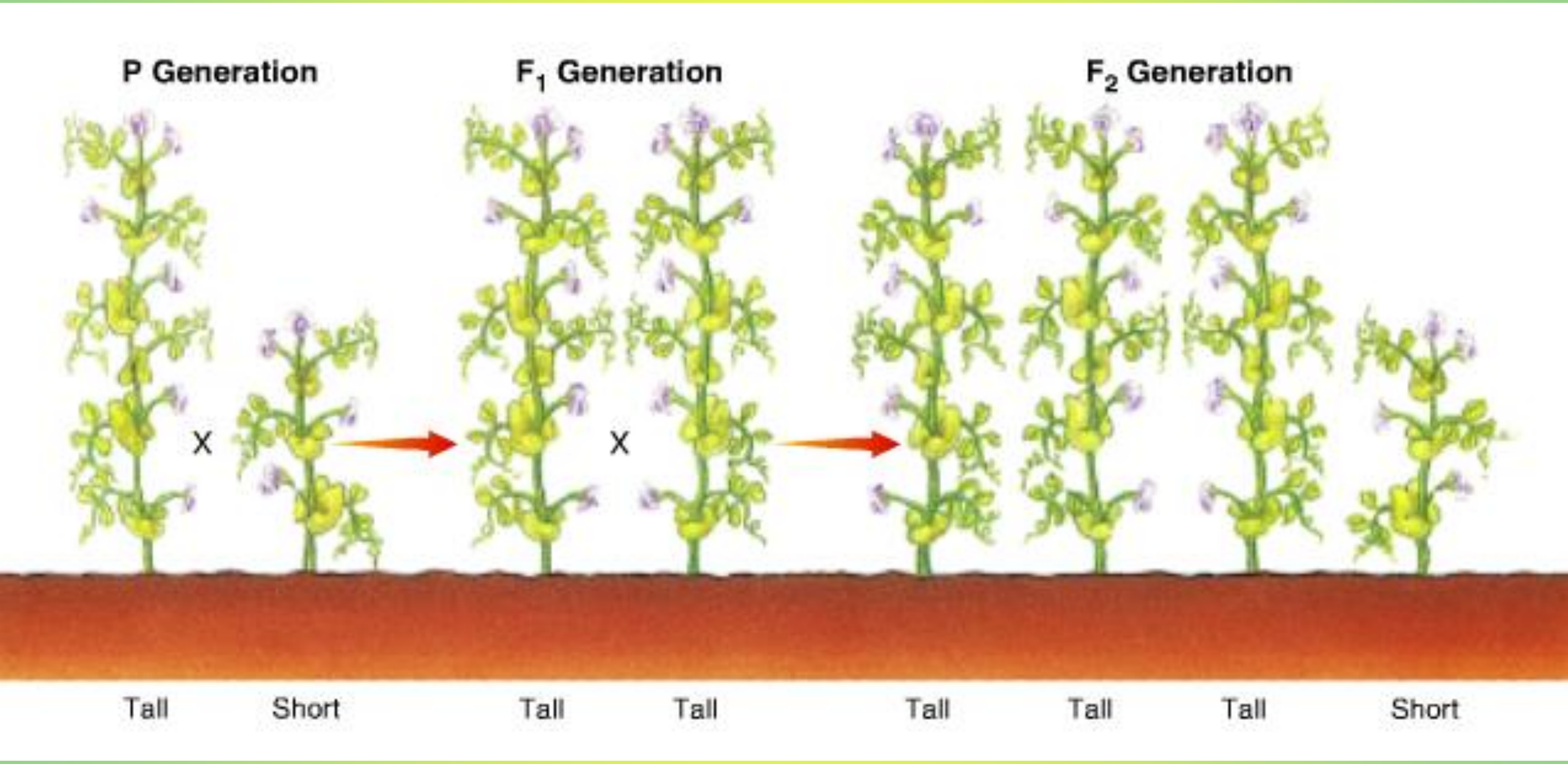
- **TT pp** **where T = Tall** **P = Purple**

  t = short p = white

- **Tt pp**

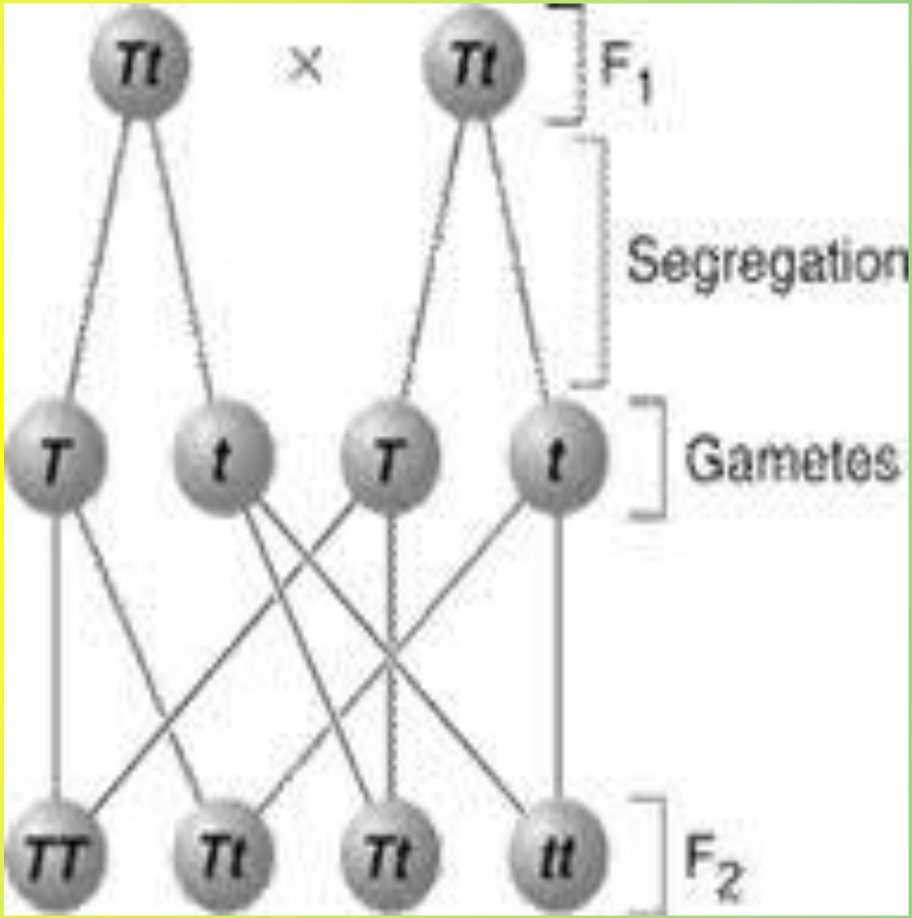
Mendel's pea plant experiment




P Generation
F_1 Generation
F_2 Generation
X
X
Tall
Short
Tall
Tall
Tall
Tall
Tall
Short

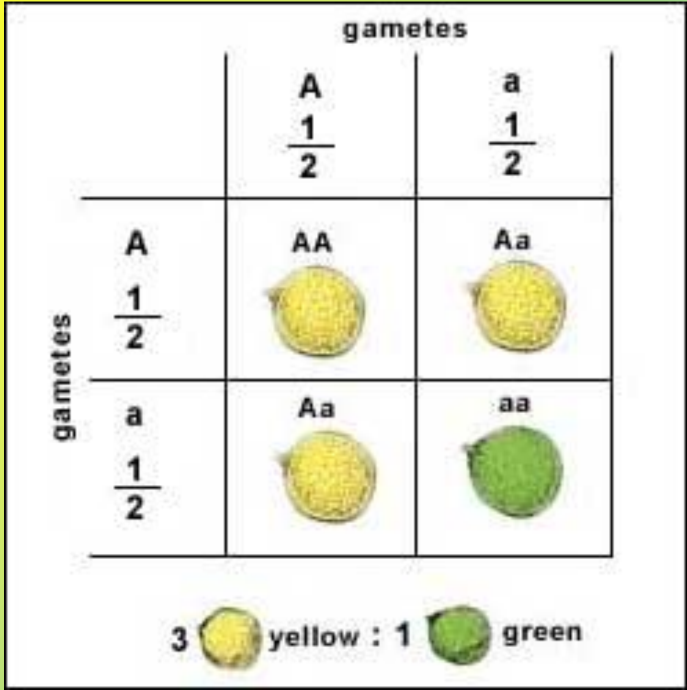
Segregation

- F1 plants each have one dominant and one recessive allele.
- When the F1 plants are crossed with each other, the recessive allele reappears in the offspring (F2 Gen)



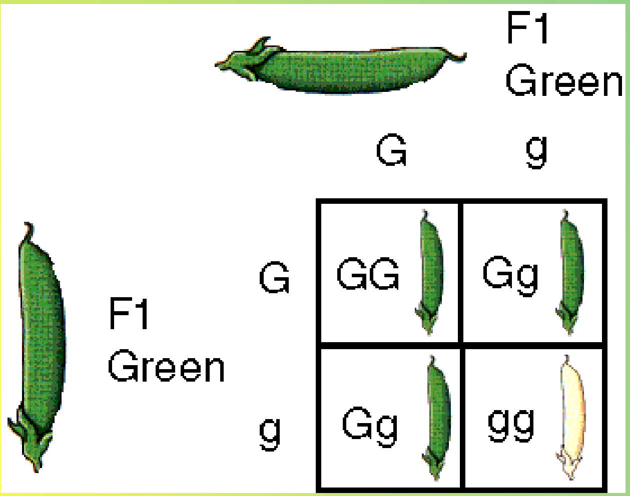
11-2 Probability and Punnett Squares

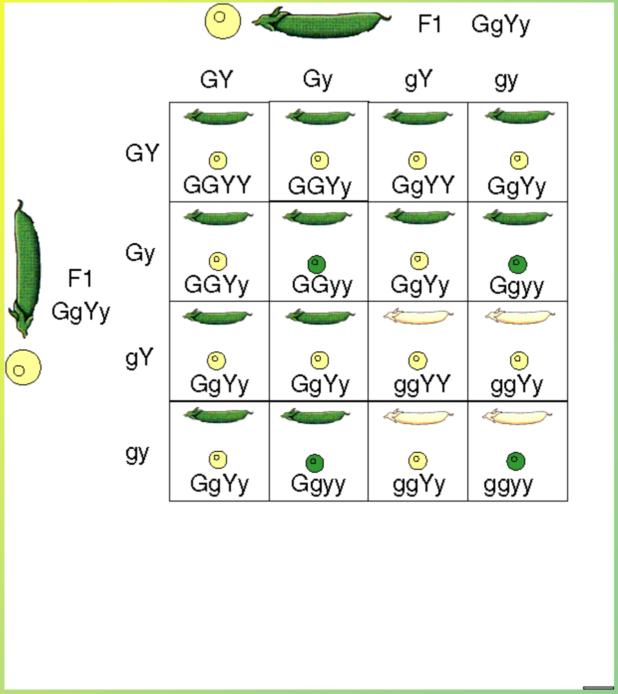
- Whenever Mendel crossed two plants that were hybrid for stem height (*Tt*), about three fourths of the resulting plants were tall and about one fourth were short.
- Mendel realized that the principles of probability could be used to explain the results of genetic crosses.



Probability and Punnett Squares

- **probability:** the likelihood that a particular event will occur
- probability = the number of times a particular event occurs ÷ the number of opportunities for the event to occur
- Punnett squares analyze the results of an experimental cross
- determines the probability of getting certain genotypes and phenotypes





Predicting Averages

- Probabilities predict the average outcome of a large number of events.

- Cannot predict the precise outcome of an single event.

- Also true for genetics.
- Larger numbers of offspring will produce results closer to the expected values/ratios.
  - In the F1 Gen of Mendel's pea plants, only 3 or 4 offspring may not the predicted offspring.
  - However, hundreds or thousands of these offspring will produce ratios very close to expectations of Mendel's results.

Question of the Day

- Which ratio did Mendel find in his F2 Generation of pea plants?
- A. 3:1
- B. 1:3:1
- C. 1:9
- D. 4:3

Genetics and Probability

- The likelihood that a particular event will occur is called **probability**.
- Ex: flipping a coin
- The probability that a single coin flip will come up heads is 1 chance in 2. This is 1/2, or 50 percent.
- How is this relevant?
- The way in which alleles segregate is completely random, like a coin flip.

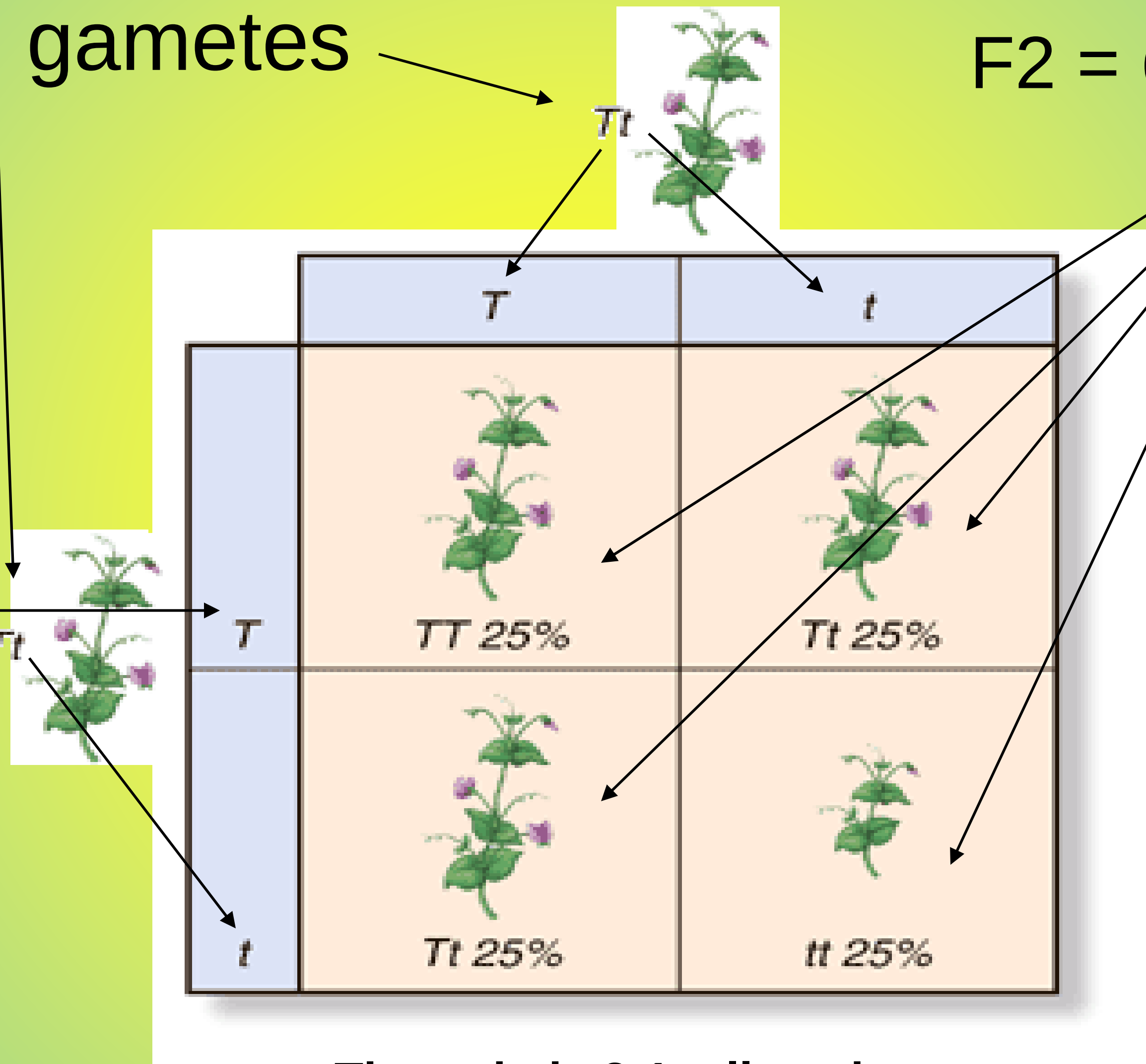
Punnett Squares

- The gene combinations that might result from a genetic cross can be determined by drawing a diagram known as a **Punnett square**.
- Punnett squares can be used to predict and compare the genetic variations that will result from a cross.

- Letters represent alleles= T,t,B,b,G,g
- Capital letters= dominance T,B,G
- Lowercase letters = recessive t, b, g
- For example: T = tall and t = short
- Homozygous= TT, BB, GG, tt, bb, gg
- Heterozygous= Tt, Bb, Gg
- TT = homozygous dominant = tall
- Tt = heterozygous = tall
- tt = homozygous recessive = short

F1= gametes

F2 = gametes

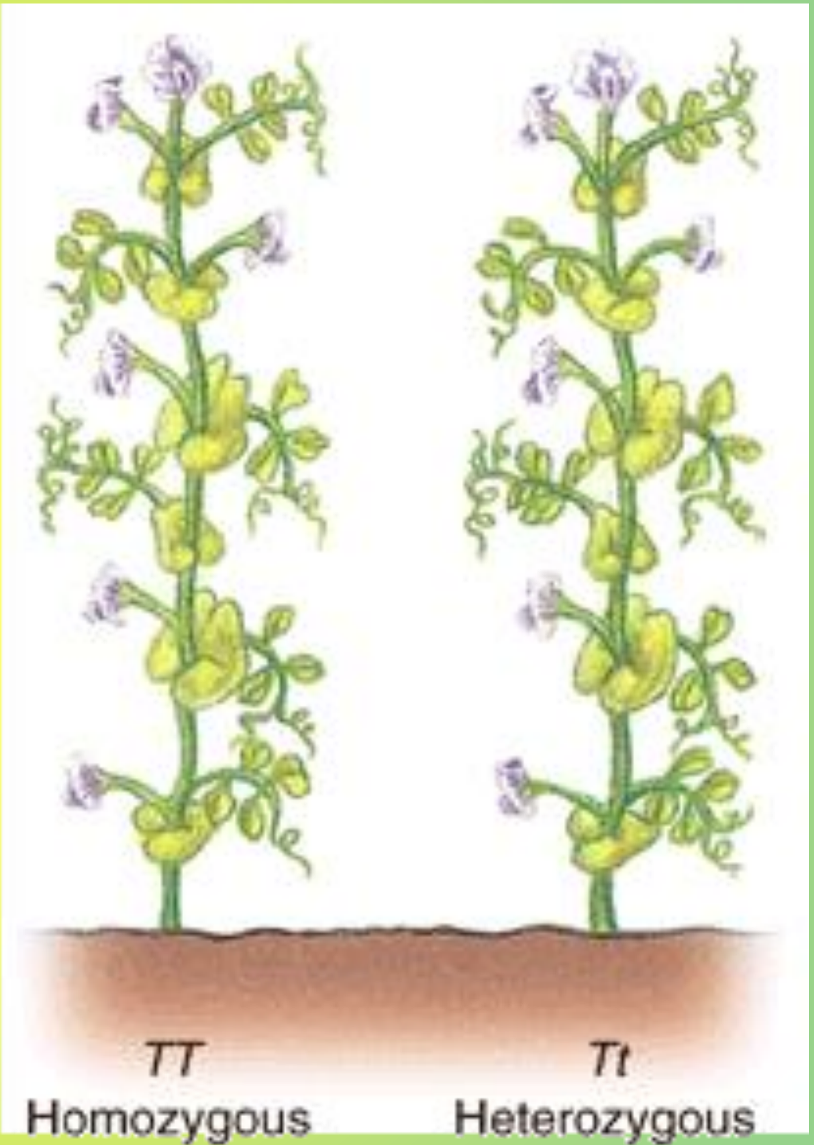


The ratio is 3:1 tall to short

- All of the tall plants have the same **phenotype**, or physical characteristics.

- They do not, however, have the same **genotype**, or genetic makeup.

- Same phenotype but different genotype. →



DO NOW

- Solve the following problem…

- Cross a Heterozygous Long-clawed panther with a short-clawed panther.
- List all of the possible genotypes and their phenotypes.
- What ratio of panther cubs with short claws?

DO NOW ANSWERED

- L = LONG CLAW DOMINANT
- l = short claw

	L	l
l	Ll	ll
l	Ll	ll

11-3 Exploring Mendelian Genetics

- After showing that alleles segregate during the formation of gametes, Mendel wondered if they did so independently.
- For example, does the gene that determines whether a seed is round or wrinkled in shape have anything to do with the gene for seed color?
- Must a round seed also be yellow?

Independent Assortment

- Mendel crossed true-breeding plants that produced only round yellow peas (genotype *RRYY*) with plants that produced wrinkled green peas (genotype *rryy*).

- All of the F_1 offspring produced round yellow peas.

Dihybrid Crosses

- **Solving for two different traits.**
- Parents --- **RrYy** and **RrYy**
- R = Wrinkled seed Y = Yellow seed
- Capital Letters = DOMINANT TRAITS

- Use the FOIL method to determine all of the possible genotypes of the parents.
- F=first O=outer I=inner L=last

Dihybrid Crosses

- Parent Genotypes – **RrYy**

- Use FOIL Method to find possible allele combinations.

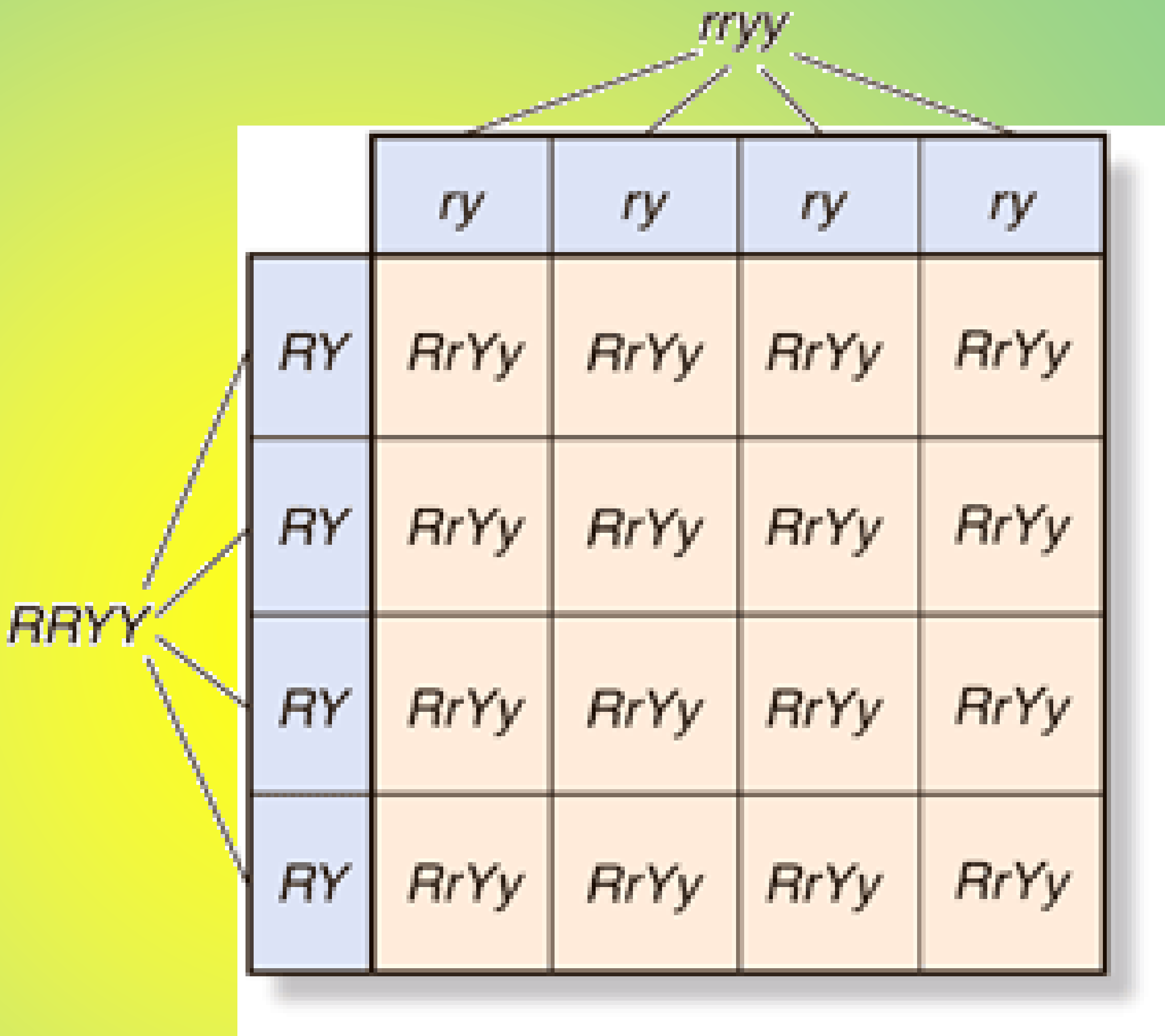
    - F – RY   O – Ry   I – rY L – ry

- Allele Combinations – **RY Ry rY ry**

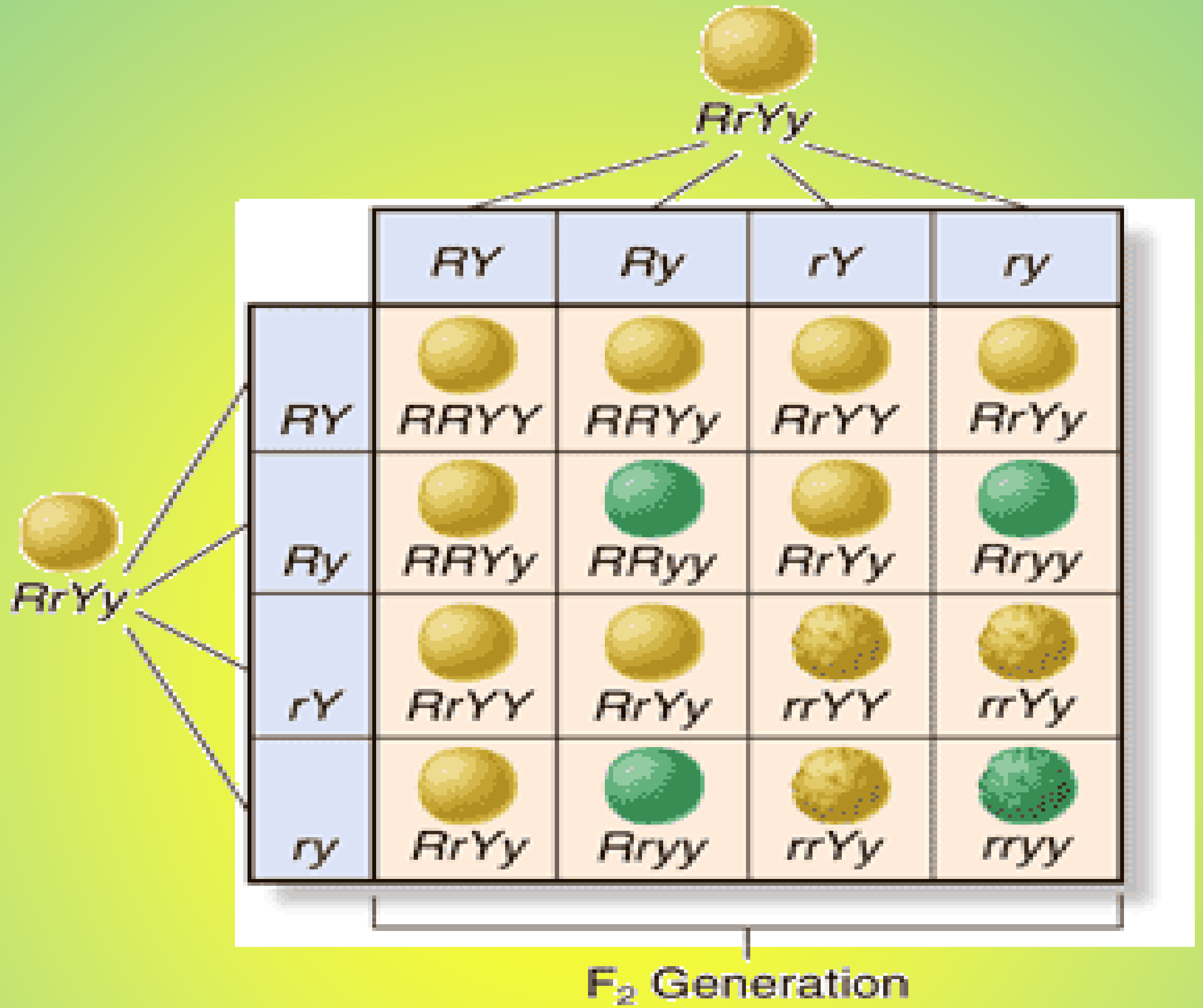
Dihybrid Crosses

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

R = round
r = wrinkled
Y = yellow
y = green



This cross does not indicate whether genes assort, or segregate, independently. However, it provides the hybrid plants needed for the next cross—the cross of F1 plants to produce the F2 generation.



When Mendel crossed plants that were heterozygous dominant for round yellow peas, he found that the alleles segregated independently to produce the F2 generation.

- In Mendel's experiment, the F2 plants produced 556 seeds. Mendel compared the seeds.
- 315 seeds = round & yellow
- 32 seeds = wrinkled & green
- 209 seeds = had combinations of phenotypes – and therefore combinations of alleles – not found in parents.
- This clearly meant that the alleles for seed shape segregated independently of those for seed color—a principle known as **independent assortment**.

- Mendel's experimental results were very close to the 9 : 3 : 3 : 1 ratio that the Punnett square shown below predicts.
- The principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes.
- Independent assortment helps account for the many genetic variations observed in plants, animals, and other organisms.

Summary of Mendel's Principle

- The inheritance of biological characteristics is determined by individual units known as genes. Genes are passed from parents to their offspring.
- In cases in which two or more forms (alleles) of the gene for a single trait exist, some forms of the gene may be dominant and others may be recessive.
- In most sexually reproducing organisms, each adult has two copies of each gene—one from each parent. These genes are segregated from each other when gametes are formed.
- The alleles for different genes usually segregate independently of one another.

Question of the Day

- All hybrids have which of the following genotypes?

- A. Homozygous dominant
- B. Heterozygous
- C. Homozygous recessive
- D. Both A and C

DO NOW

- Cross a homozygous Tall, heterozygous yellow seeded pea plant with a short, green seeded pea plant.
- What percentage of the offspring will be tall and green seeded?

DO NOW ANSWER

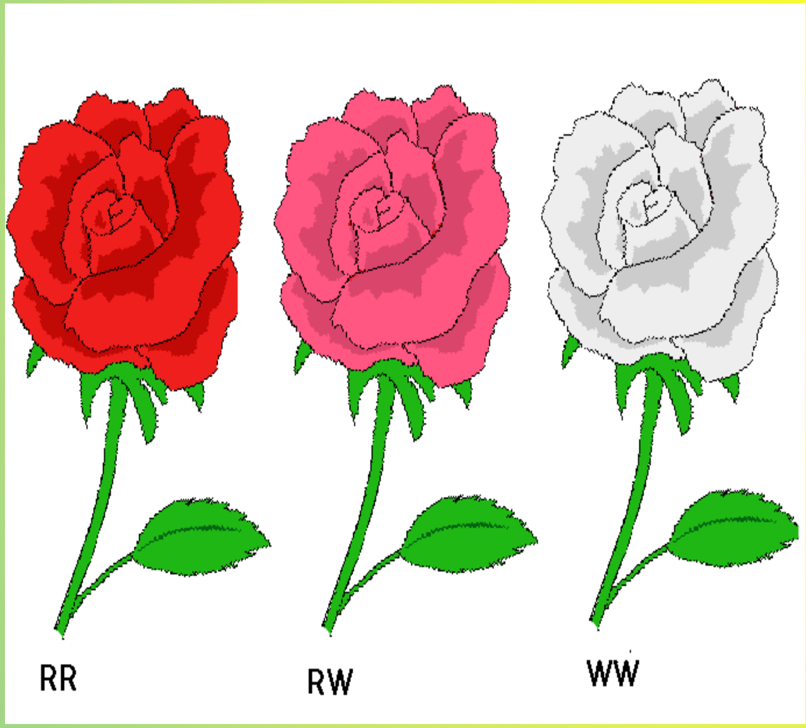
	TY	Ty	TY	Ty
ty	TtYy	Ttyy	TtYy	Ttyy
ty	TtYy	Ttyy	TtYy	Ttyy
ty	TtYy	Ttyy	TtYy	Ttyy
ty	TtYy	Ttyy	TtYy	Ttyy

Beyond Dominant and Recessive Alleles

- Majority of genes have more than two alleles.

- **Some alleles are neither dominant nor recessive, and many traits are controlled by multiple alleles or multiple genes.**

Incomplete Dominance

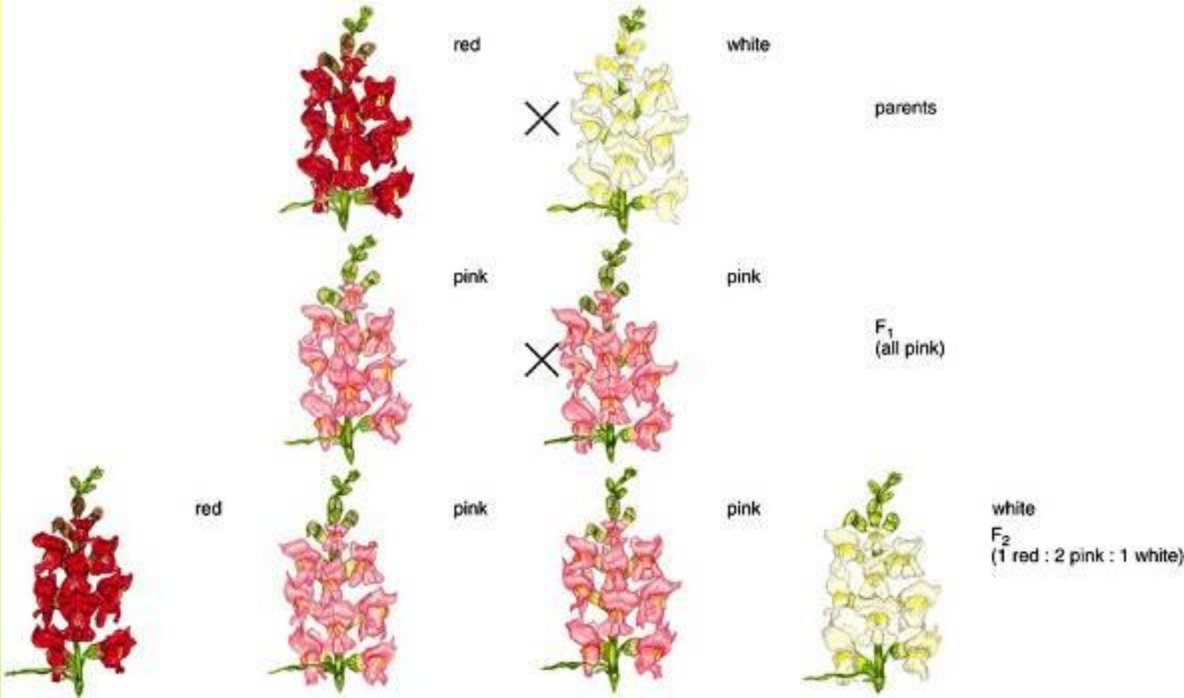


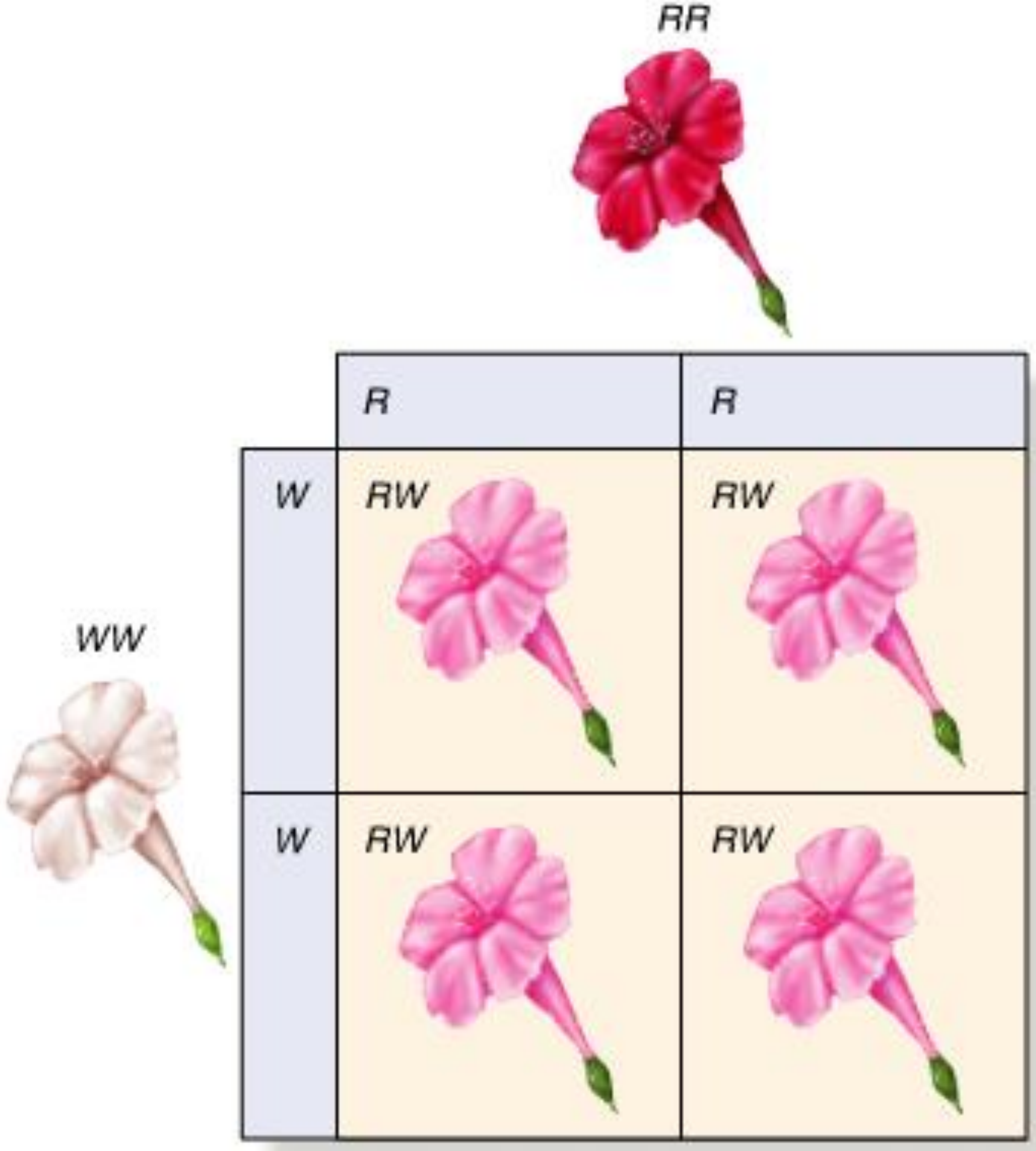
- Cross a Red Flowered plant with a White Flowered plant.
- What are the genotypes and phenotypes of the offspring?
- Will offspring have White Flowers?

Incomplete Dominance

- The F1 generation produced by a cross between red-flowered *(RR)* and white-flowered *(WW)* plants consists of pink-colored flowers *(RW).*
- Cases in which one allele is not completely dominant over another are called **incomplete dominance**.

Snapdragons




RR
R
R
W
RW
RW
WW
W
RW
RW

Codominance

- **codominance:** both alleles are expressed and contribute to the phenotype
- Example: Roan horse

- $C^W C^W$ → White Coat
- $C^R C^R$ → Red Coat
- $C^R C^W$ → Roan Coat

- Cross a Roan Horse with a Red coated Horse.

Codominance

- A similar situation is **codominance**, in which both alleles contribute to the phenotype.
- For example, in certain varieties of chicken, the allele for black feathers is codominant with the allele for white feathers.


FeatherSite.com

DO NOW

- A farmer has been told by his friend that white-coated horses are worth more money than red or roan coated horses. He decides to breed his own by crossing two Roan coat horses.

- Is he successful?
- List the genotypes and phenotypes of all the offspring.
- List the percentage of each phenotype.

DO NOW Answered

- CR CW x CR CW → RW x RW

	R	W
R	**RR**	**RW**
W	**RW**	**WW**

- Yes. 1 out of 4 horses has a WHITE Coat.

Multiple Alleles

- Many genes have more than two alleles and are therefore said to have **multiple alleles**.
- This does not mean that an individual can have more than two alleles. It only means that more than two possible alleles exist in a population.
- One of the best-known examples is coat color in rabbits and **blood type** in humans.

Full color: CC, Cc^{ch}, Cc^{h}, or Cc

Chinchilla: $c^{ch}c^{h}$, $c^{ch}c^{ch}$, or $c^{ch}c$

Himalayan: $c^{h}c$ or $c^{h}c^{h}$

Albino: cc

Key

C = full color; dominant to all other alleles

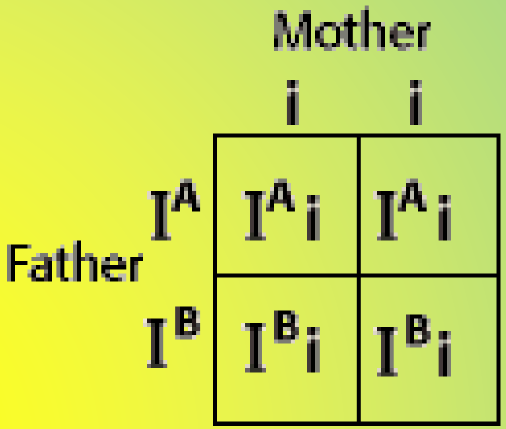
c^{ch} = chinchilla; partial defect in pigmentation; dominant to c^{h} and c alleles

c^{h} = Himalayan; color in certain parts of body; dominant to c allele

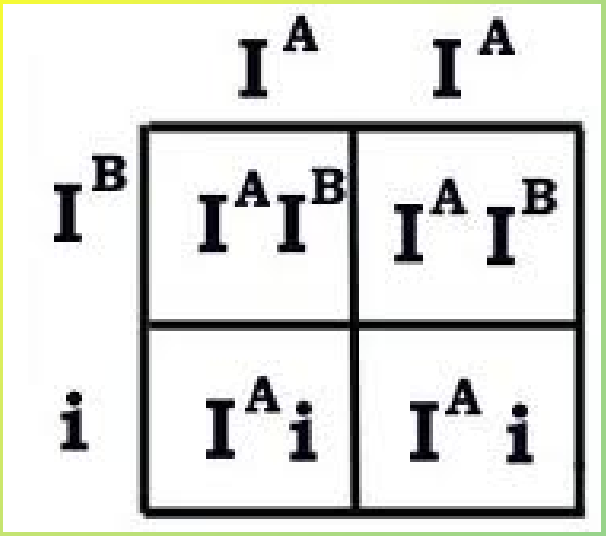
c = albino; no color; recessive to all other alleles

BLOOD TYPES

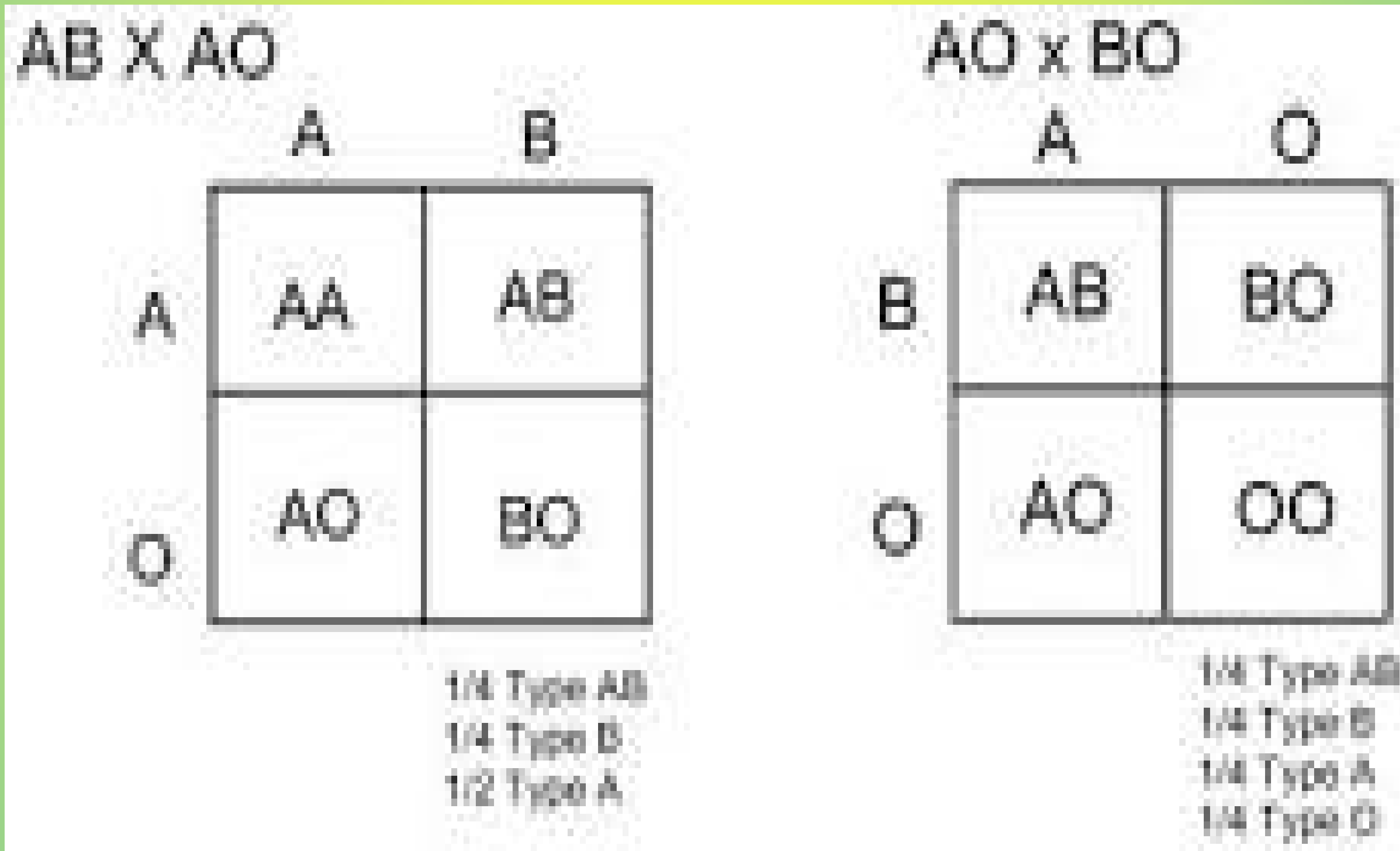
- Controlled by 3 Alleles
  - A (I^A), B (I^B) and O (ii)
- A and B are codominant
- Both dominant over O



Half of the children predicted to be **Type A**, and half **Type B**.



Blood Type Punnett Squares



Question of the Day

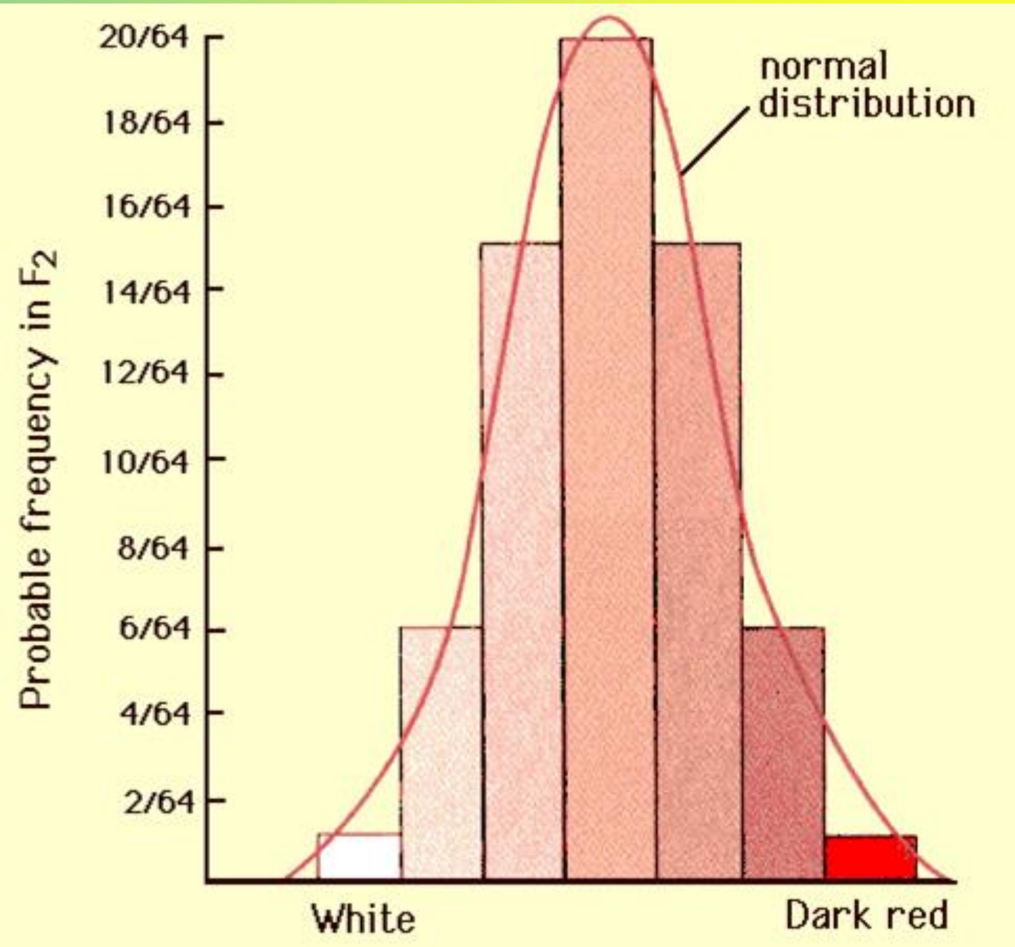
- Human blood types are known as ___________ and are controlled by ____________ alleles.

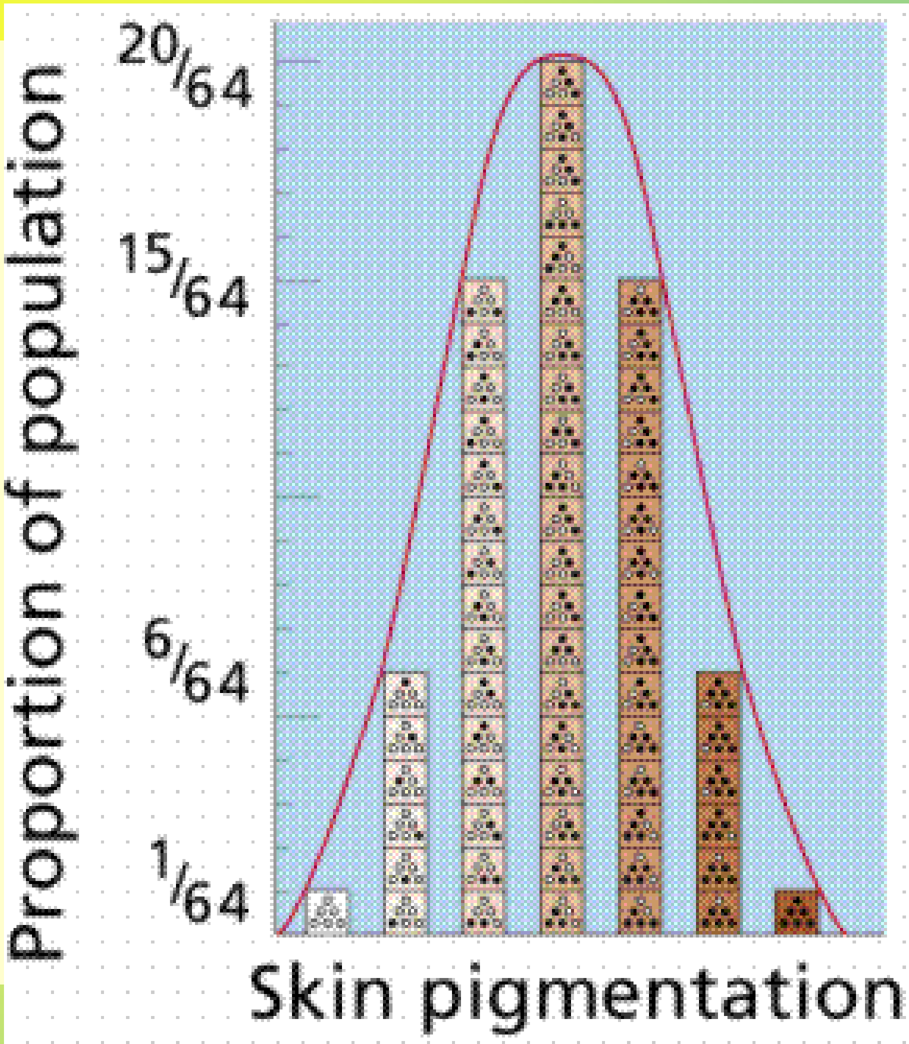
- A. polygenic traits, 3
- B. multiple alleles, 4
- C. polygenic traits, 4
- D. multiple alleles, 3

Polygenic Traits

- Many traits are produced by the interaction of several genes.
- Traits controlled by two or more genes are said to be **polygenic traits**, which means "having many genes."
- For example, at least three genes are involved in making the reddish-brown pigment in the eyes of fruit flies.

- Skin Color, hair color, height, and eye color are come of the many polygenic traits in humans.





Polygenic inheritance: additive effects (essentially, incomplete dominance) of multiple genes on a single trait

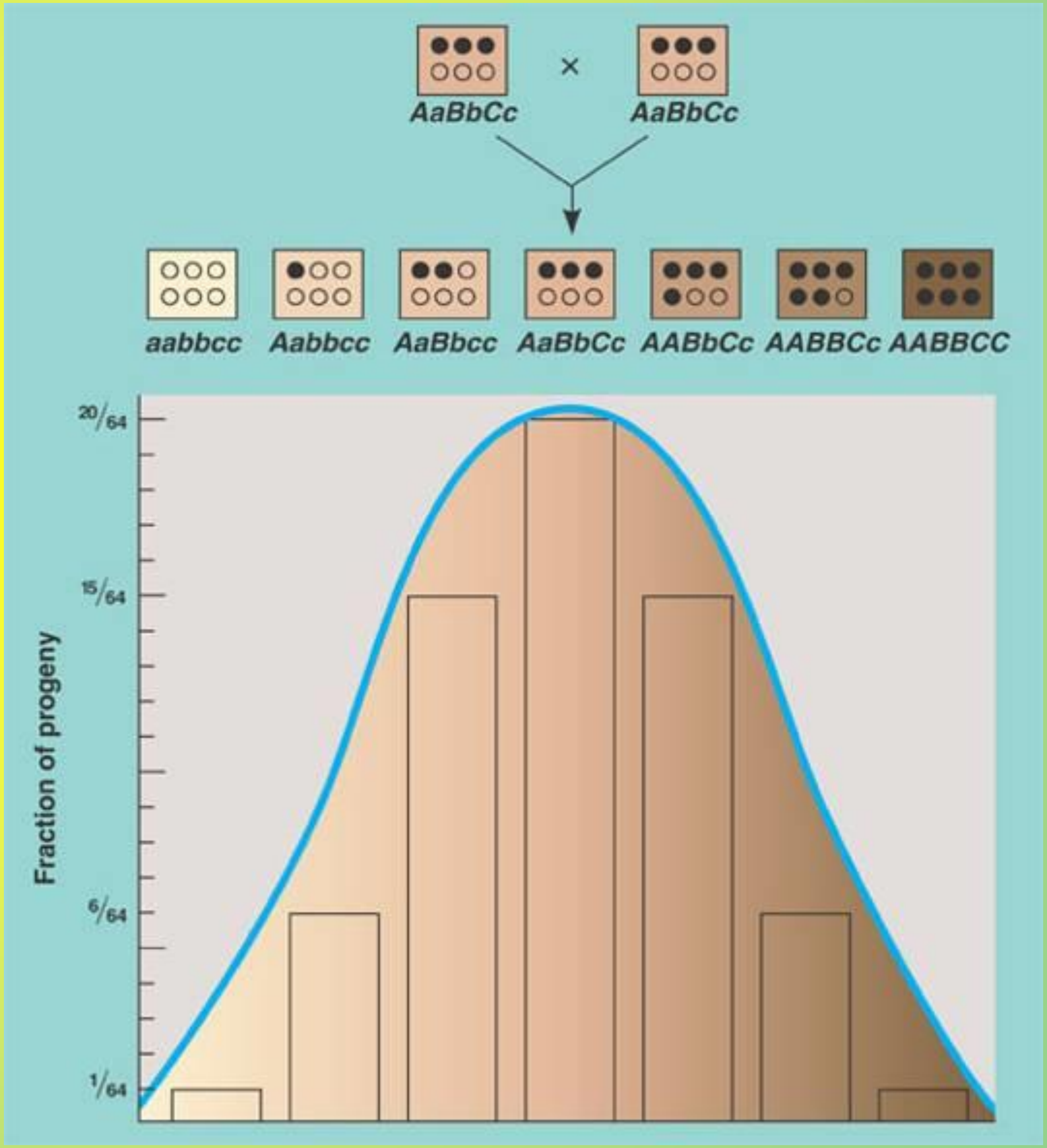
AA = dark

Aa = less dark

aa - light

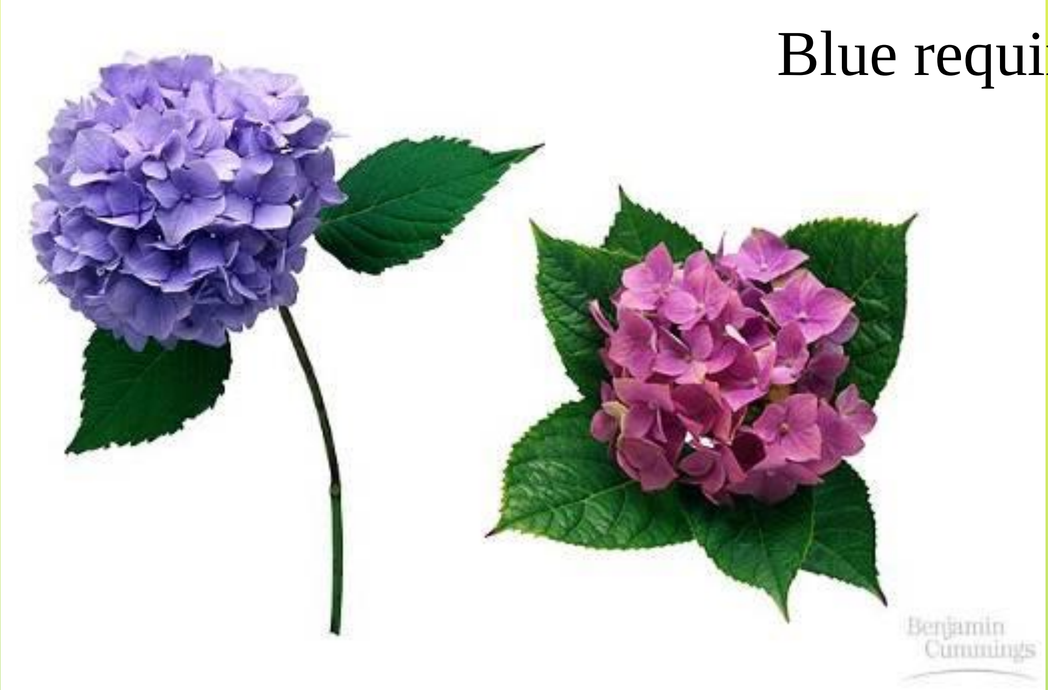
And similarly for the other two genes - in all cases dominance is incomplete for each gene.

Think of each “capital” allele (A, B, C) as adding a dose of brown paint to white paint.



Environmental Effects

- **environment often influences phenotype**
- **The phenotype can change throughout an organism’s life**



Blue require low pH

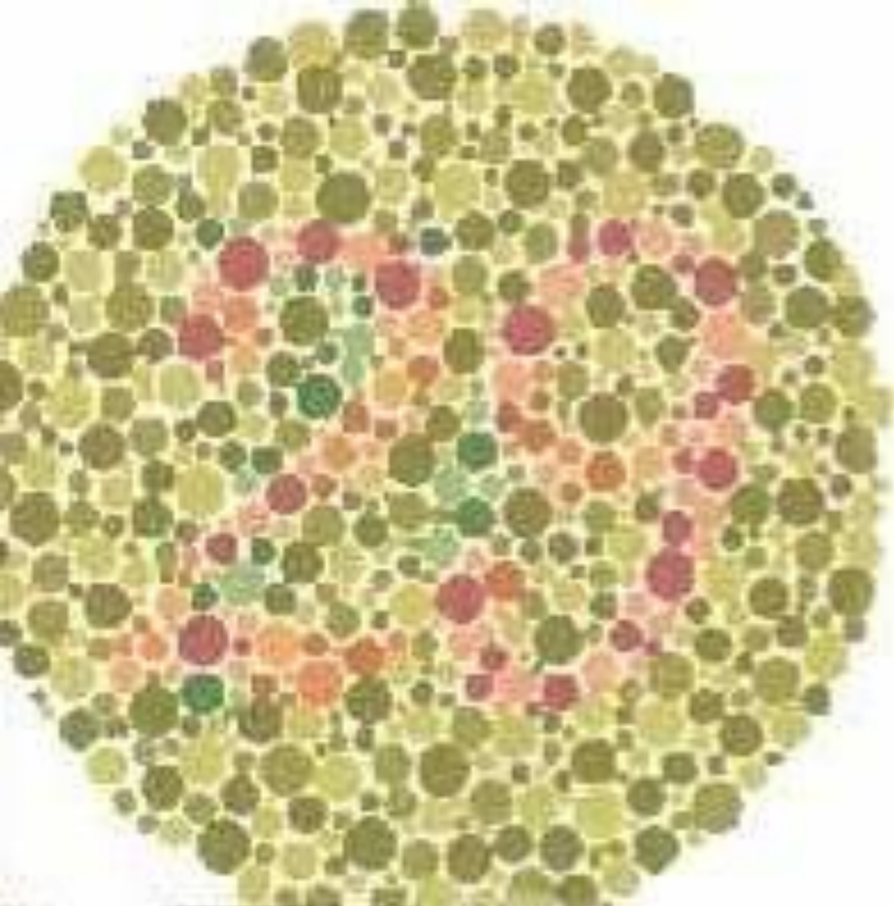
Environmental effects: effect of temperature on pigment expression in Siamese cats

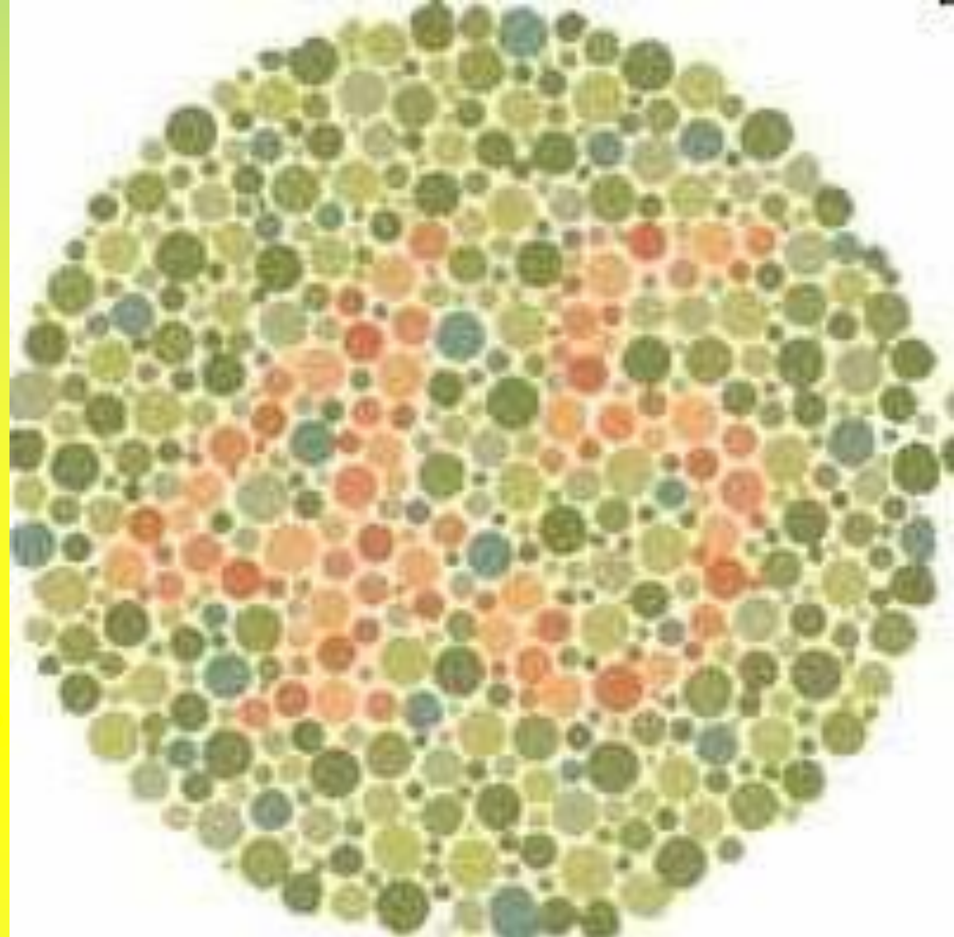
Arctic Hare

Arctic Fox

Sex Linked Traits

- Traits that are coded for by genes that are located on the sex chromosomes
  - Usually found on the X chromosomes
- More common in males
- Examples:
  - Red-green colorblindness
  - Duchenne Muscular Dystrophy
  - Hemophilia



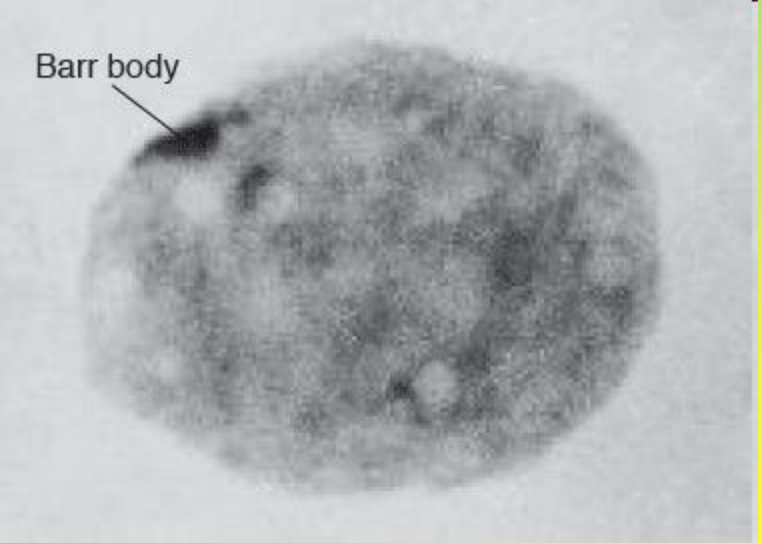


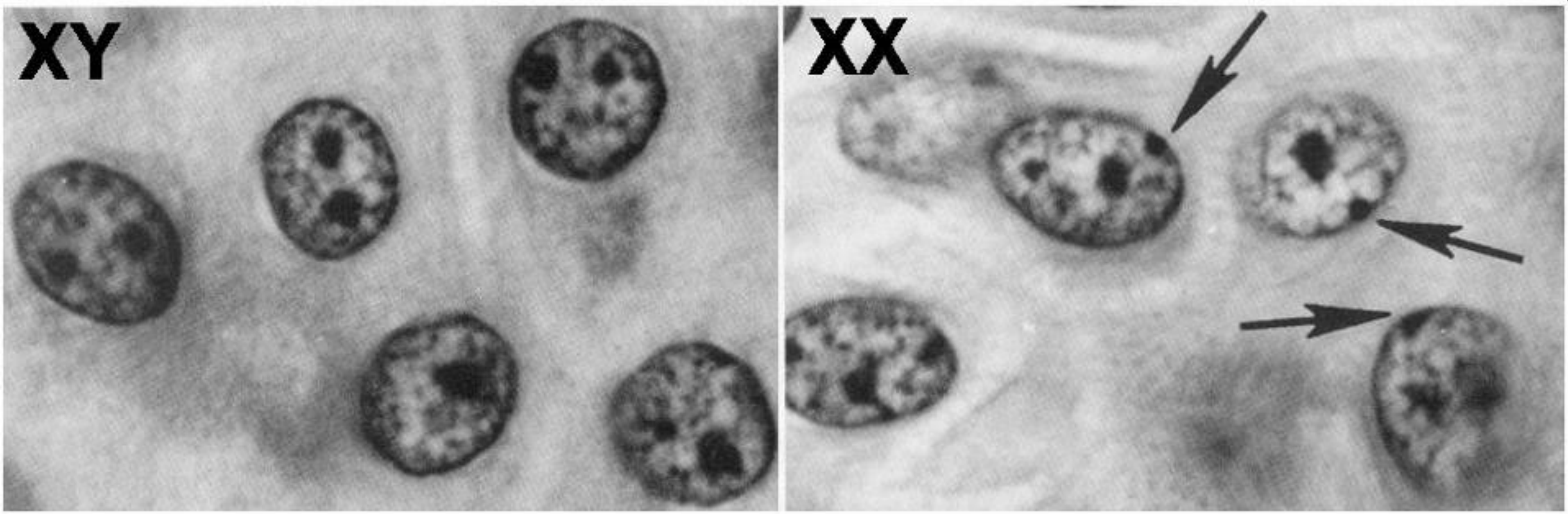
Sex influenced Traits

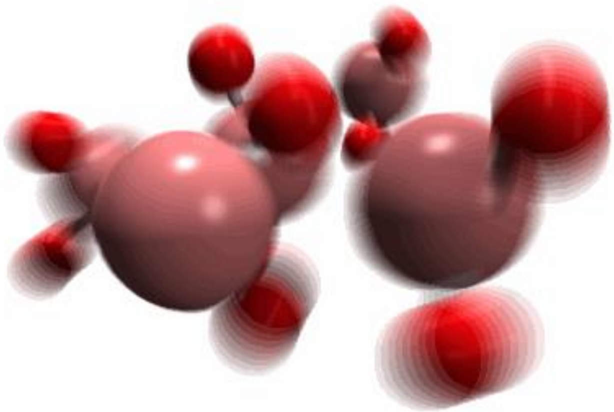
- Autosomal genes that are expressed differently depending on gender.
- Ex: patterned baldness
  - expressed in the heterozygous form in males because of their high levels of testosterone but not in females.

Barr Body

- the inactive X chromosome in a female somatic cell (rarely in males but can happen)
- Can affect phenotype of an organism
- Ex: Calico Cats


Barr body


XY
XX



SECTION 11-4

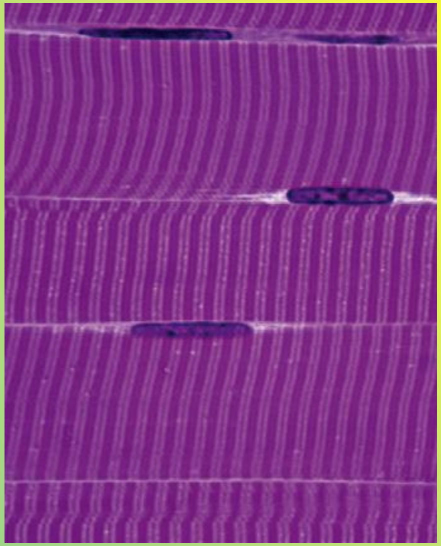
Meiosis

Key Concept Questions

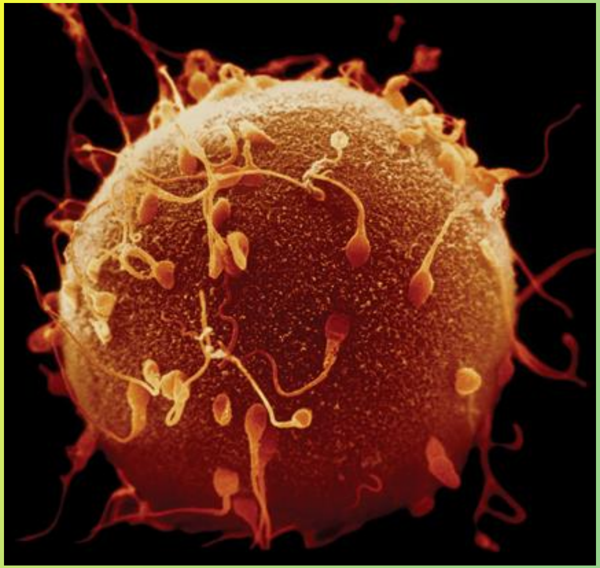
- What happens during the process of meiosis?
- Why is crossing over important?
- How is meiosis different from mitosis?

You have body cells and gametes.

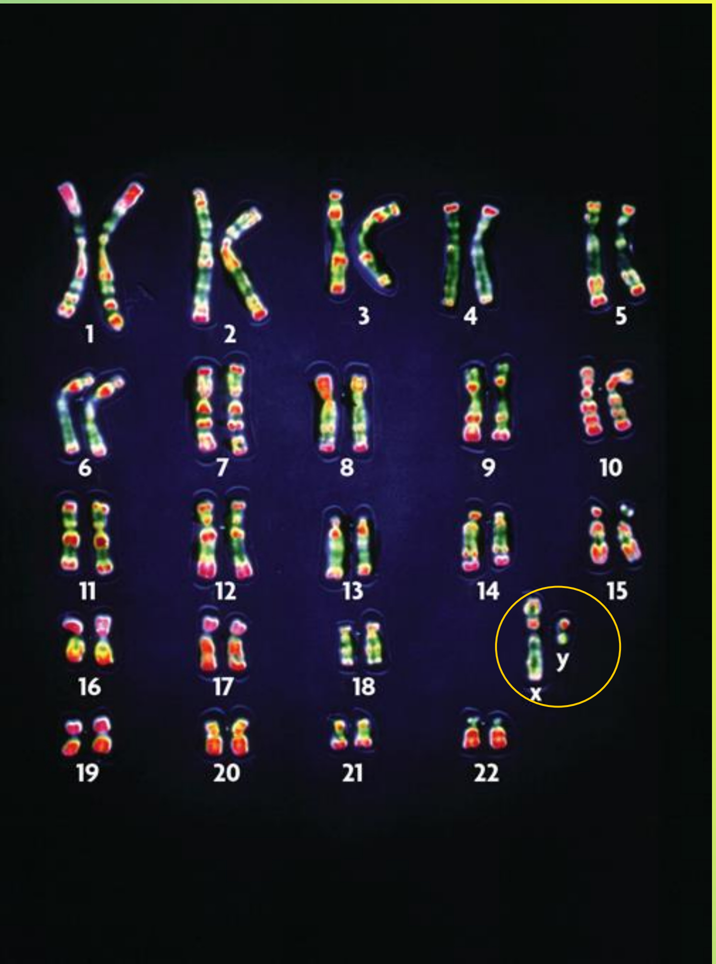
- Body cells are also called **somatic** cells.
- **Germ** cells develop into **gametes**.
  - Germ cells are located in the **ovaries** and **testes**.
  - **Gametes** are sex cells: egg and sperm.
  - Gametes have DNA that can be **passed** to offspring.


body cells


sex cells (sperm)


sex cells (egg)

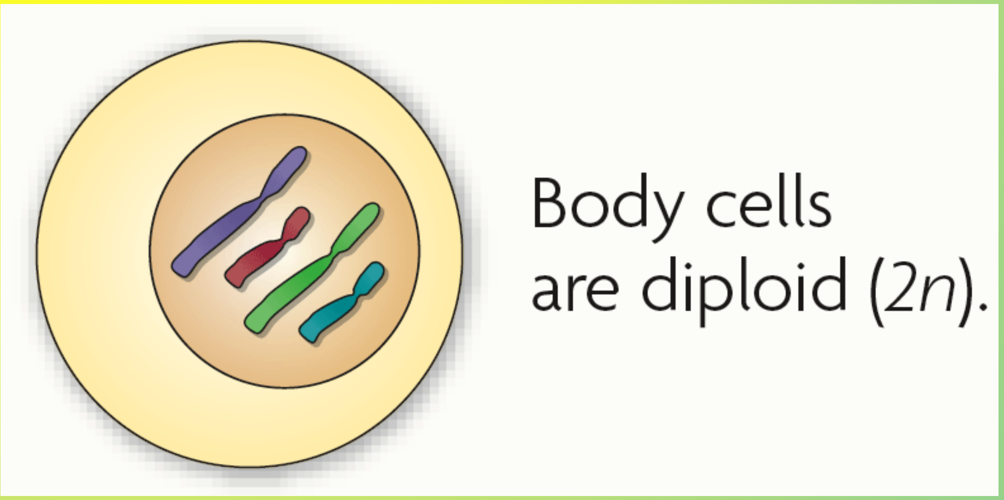
Your cells have autosomes and sex chromosomes.



- Your body cells have **<u>23</u>** pairs of chromosomes.
  - **<u>Homologous</u>** pairs of chromosomes have the same structure.
  - For each homologous pair, one chromosome comes from each **<u>parent</u>**.
- Chromosome pairs 1-22 are **<u>autosomes</u>**.
- Sex chromosomes, X and Y, determine **<u>gender</u>** in mammals.

Body cells are diploid; gametes are haploid.

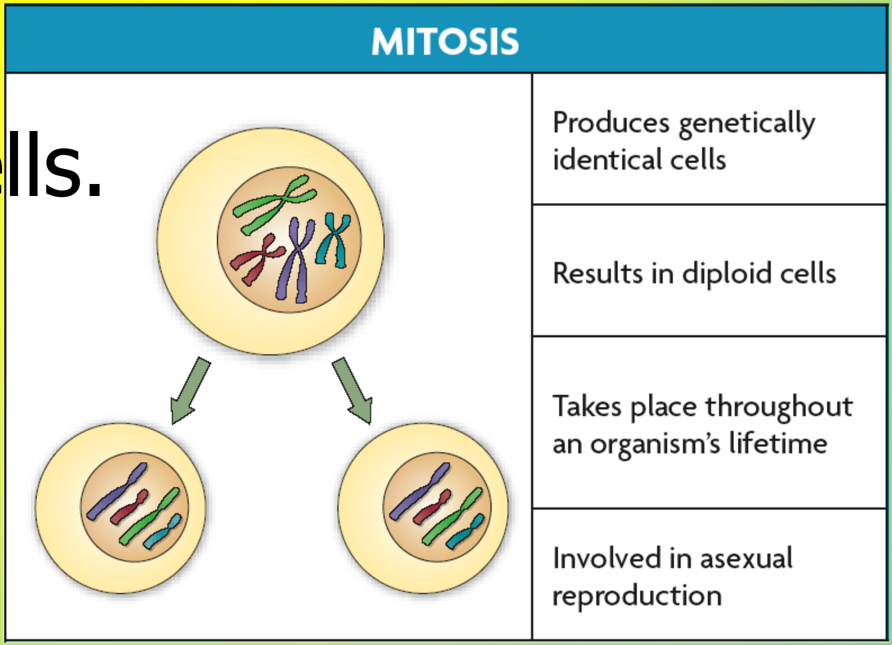
- Fertilization between egg and sperm occurs in **sexual** reproduction.
- **Diploid** (2*n*) cells have two copies of every chromosome.
  - Body cells are **diploid**.
  - Half the chromosomes come from each parent.



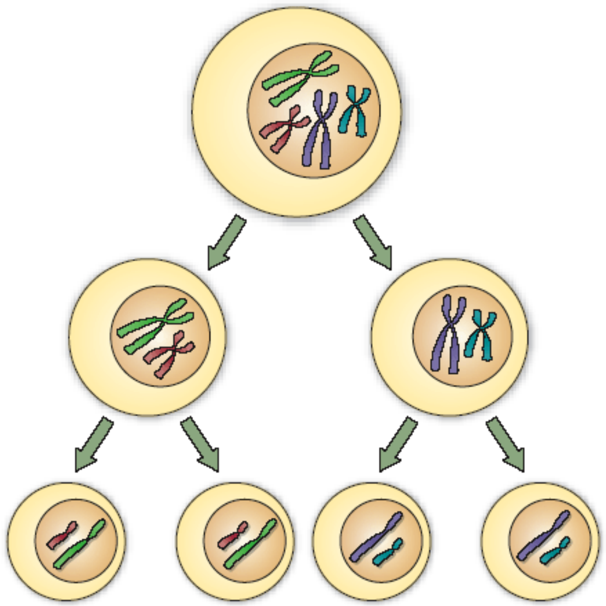
- **<u>Haploid</u>** (*n*) cells have one copy of every chromosome.
  - **<u>Gametes</u>** are haploid.
  - Gametes have 22 autosomes and 1 sex chromosome.

- Chromosome number **must** be maintained in animals.
- Many plants have **more** than two copies of each chromosome.
- Mitosis and meiosis are types of **nuclear** division that make different types of cells.
- Mitosis makes

more **diploid** cells.

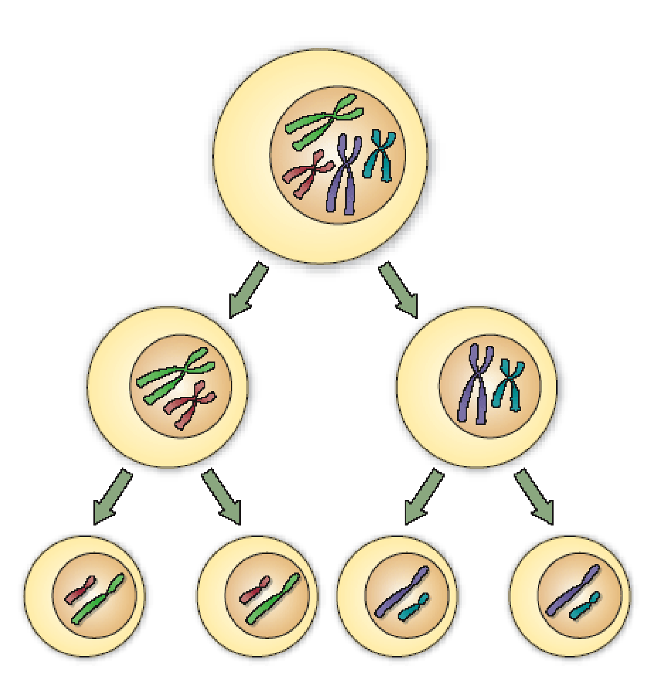


- Meiosis makes **haploid** cells from diploid cells.
  - Meiosis occurs in **sex** cells.
  - Meiosis produces **gametes**.

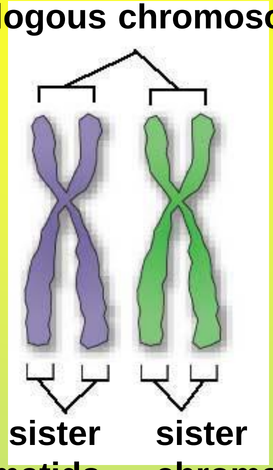
MEIOSIS	
Produces genetically unique cells	
Results in haploid cells	
Takes place only at certain times in an organism's life cycle	
Involved in sexual reproduction	

- Cells go through **two** rounds of division in meiosis.
- Meiosis **reduces** chromosome number and creates genetic **diversity**.

MEIOSIS
Produces genetically unique cells
Results in haploid cells
Takes place only at certain times in an organism's life cycle
Involved in sexual reproduction

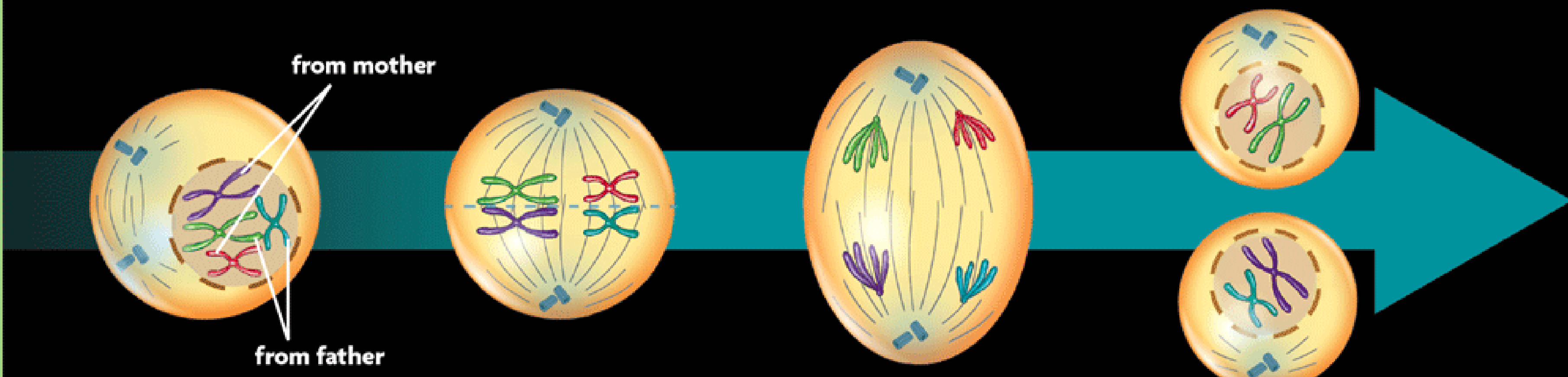


- Meiosis I and meiosis II each have four phases, similar to those in mitosis.
  - **Pairs** of homologous chromosomes separate in meiosis I.
  - Homologous chromosomes are **similar** but not identical.
  - Sister **chromatids** divide in meiosis II.
  - Sister chromatids are **copies** of the same chromosome.



- Meiosis I occurs after DNA has been replicated.
- Meiosis I divides homologous chromosomes in four phases.

Meiosis I divides homologous chromosomes.



1. **Prophase I** The nuclear membrane breaks down. The centrosomes and centrioles begin to move, and spindle fibers start to assemble. The duplicated chromosomes condense, and homologous chromosomes begin to pair up.

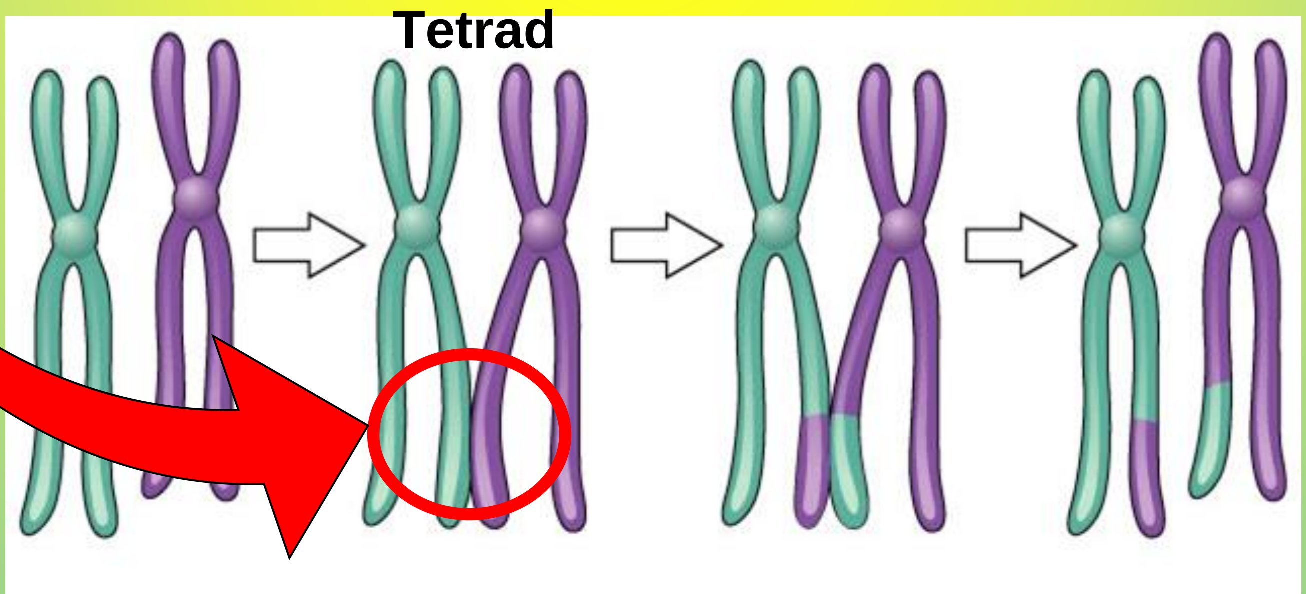
2. **Metaphase I** Spindle fibers align the homologous chromosomes along the cell equator. Each side of the equator has chromosomes from both parents.

3. **Anaphase I** The paired homologous chromosomes separate from each other and move toward opposite sides of the cell. Sister chromatids remain attached.

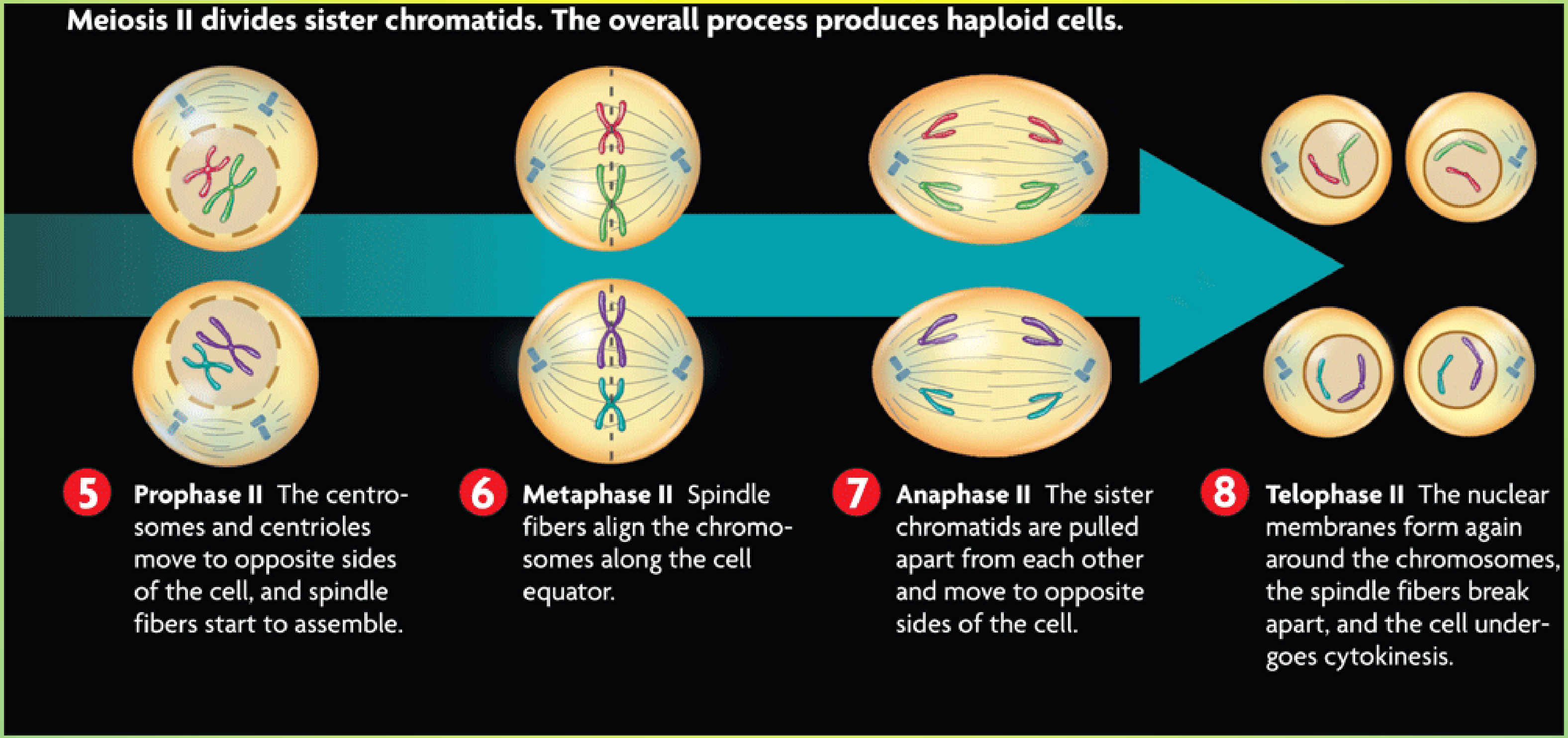
4. **Telophase I** The spindle fibers disassemble, and the cell undergoes cytokinesis.

Crossing over

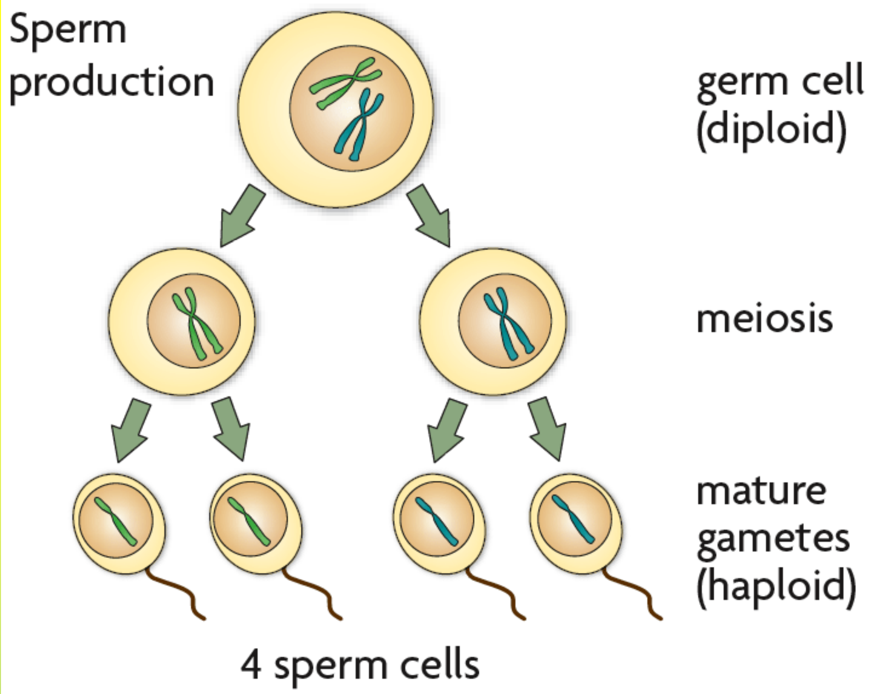
- 3 steps
  - cross over
  - breakage of DNA
  - re-fusing of DNA
- **New combinations of traits**



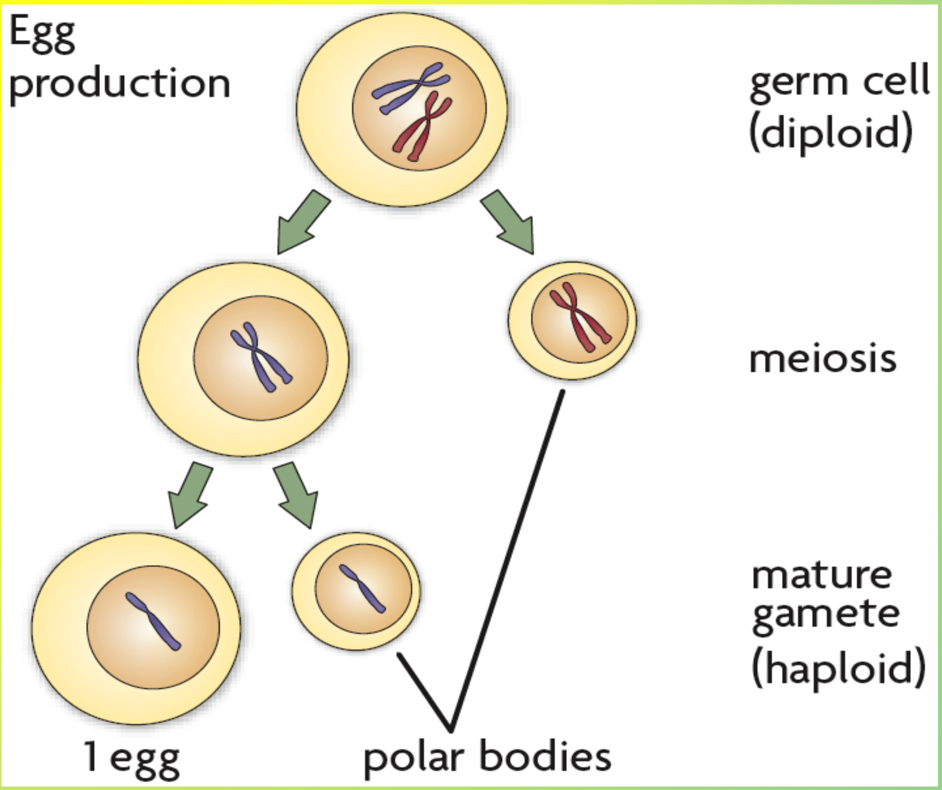
- Meiosis II divides **sister** chromatids in four phases.
- DNA is **not** replicated between meiosis I and meiosis II.



- **Haploid** cells develop into mature gametes.
- **Gametogenesis** is the production of gametes.
- Gametogenesis **differs** between females and males.
  - Sperm become streamlined and **motile**.
  - Sperm primarily contribute **DNA** to an embryo.



- **<u>Eggs</u>** contribute DNA, cytoplasm, and organelles to an embryo.
- During meiosis, the egg gets most of the **<u>contents</u>**; the other cells form **<u>polar</u>** bodies.



- **<u>Eggs</u>** contribute DNA, cytoplasm, and organelles to an embryo.
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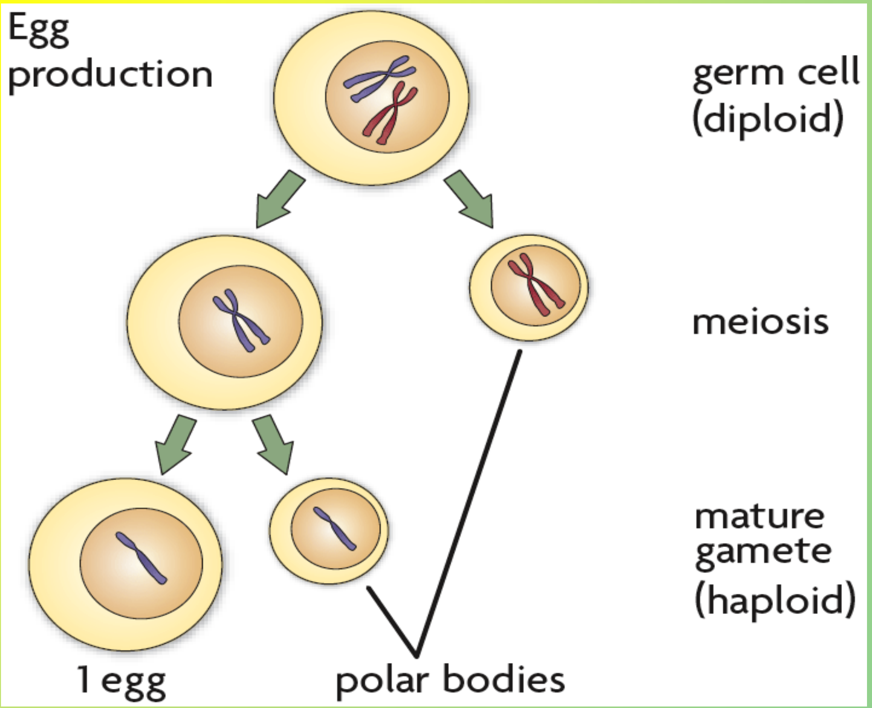
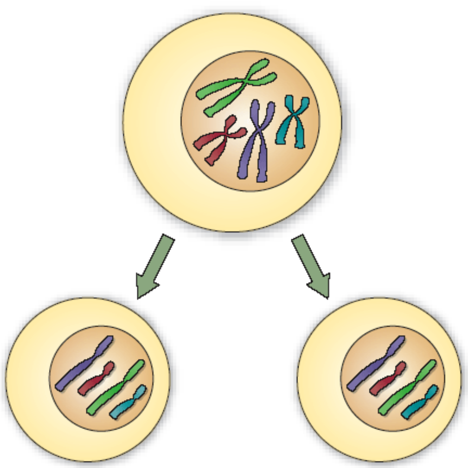
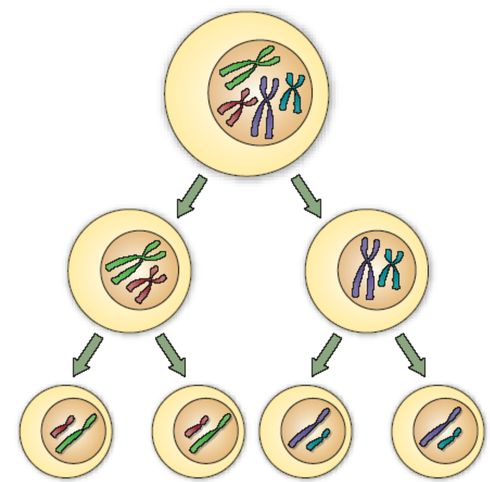
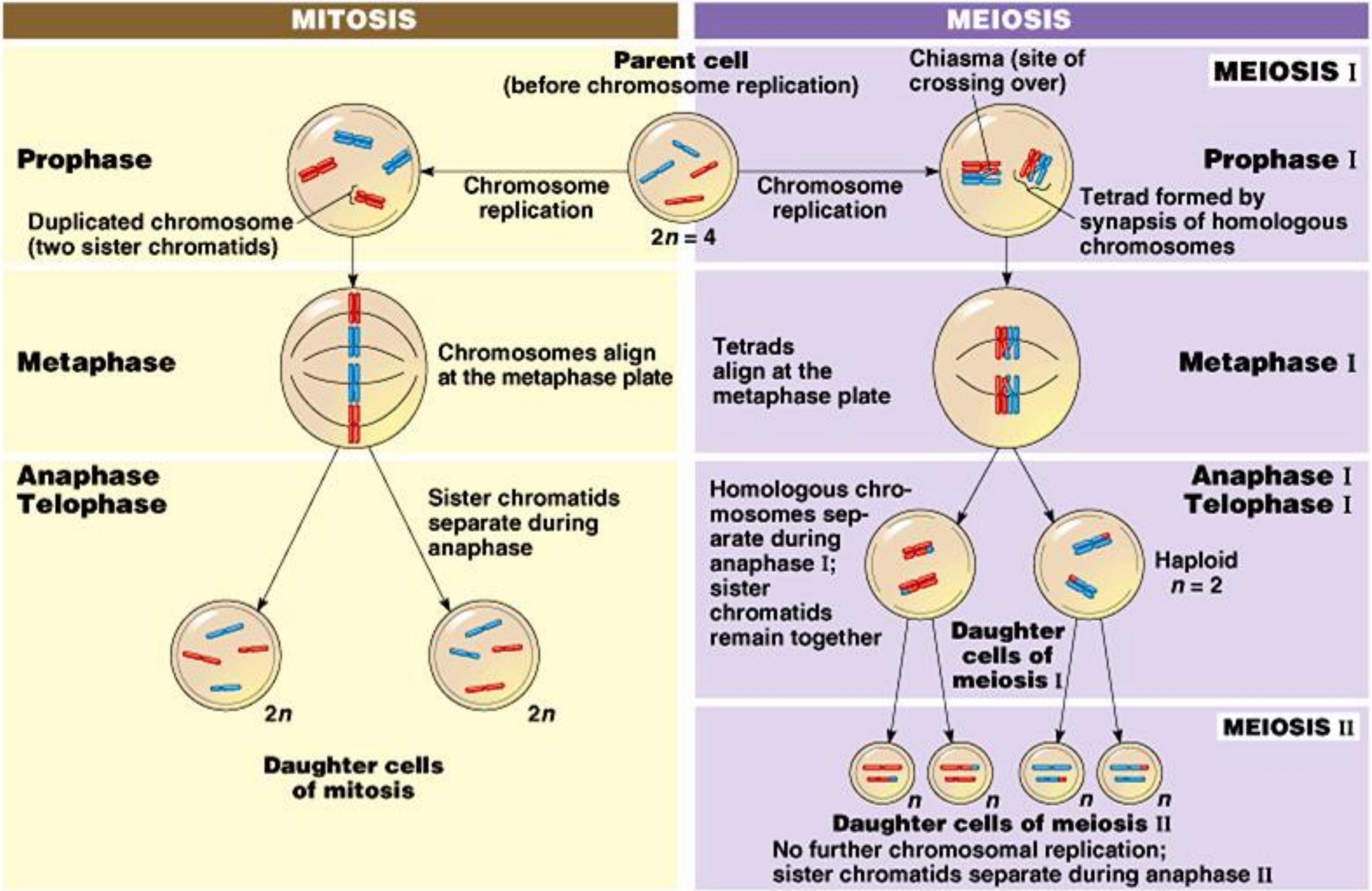


- Meiosis differs from mitosis in significant ways.
  - Meiosis has **two** cell divisions while mitosis has **one**.
  - In mitosis, homologous chromosomes **never** pair up.
  - Meiosis results in **haploid** cells; mitosis results in **diploid** cells.

MITOSIS	
	Produces genetically identical cells
	Results in diploid cells
	Takes place throughout an organism's lifetime
	Involved in asexual reproduction

MEIOSIS	
Produces genetically unique cells	
Results in haploid cells	
Takes place only at certain times in an organism's life cycle	
Involved in sexual reproduction	

Mitosis vs. Meiosis



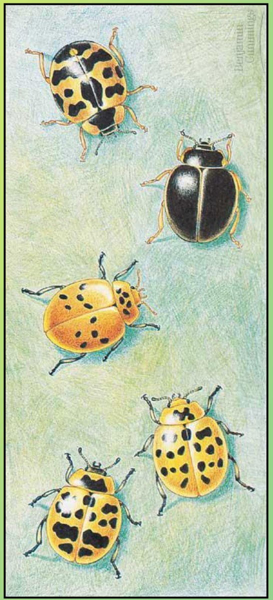
Mitosis vs. Meiosis

- **Mitosis**
  - **1** division
  - daughter cells genetically **identical** to parent cell
  - produces **2 cells**
  - 2n → 2n
  - produces **cells for growth & repair**
  - **no** crossing over

- **Meiosis**
  - **2** divisions
  - daughter cells genetically **different** from parent
  - produces **4 cells**
  - 2n → 1n
  - produces **gametes**
  - **crossing over**

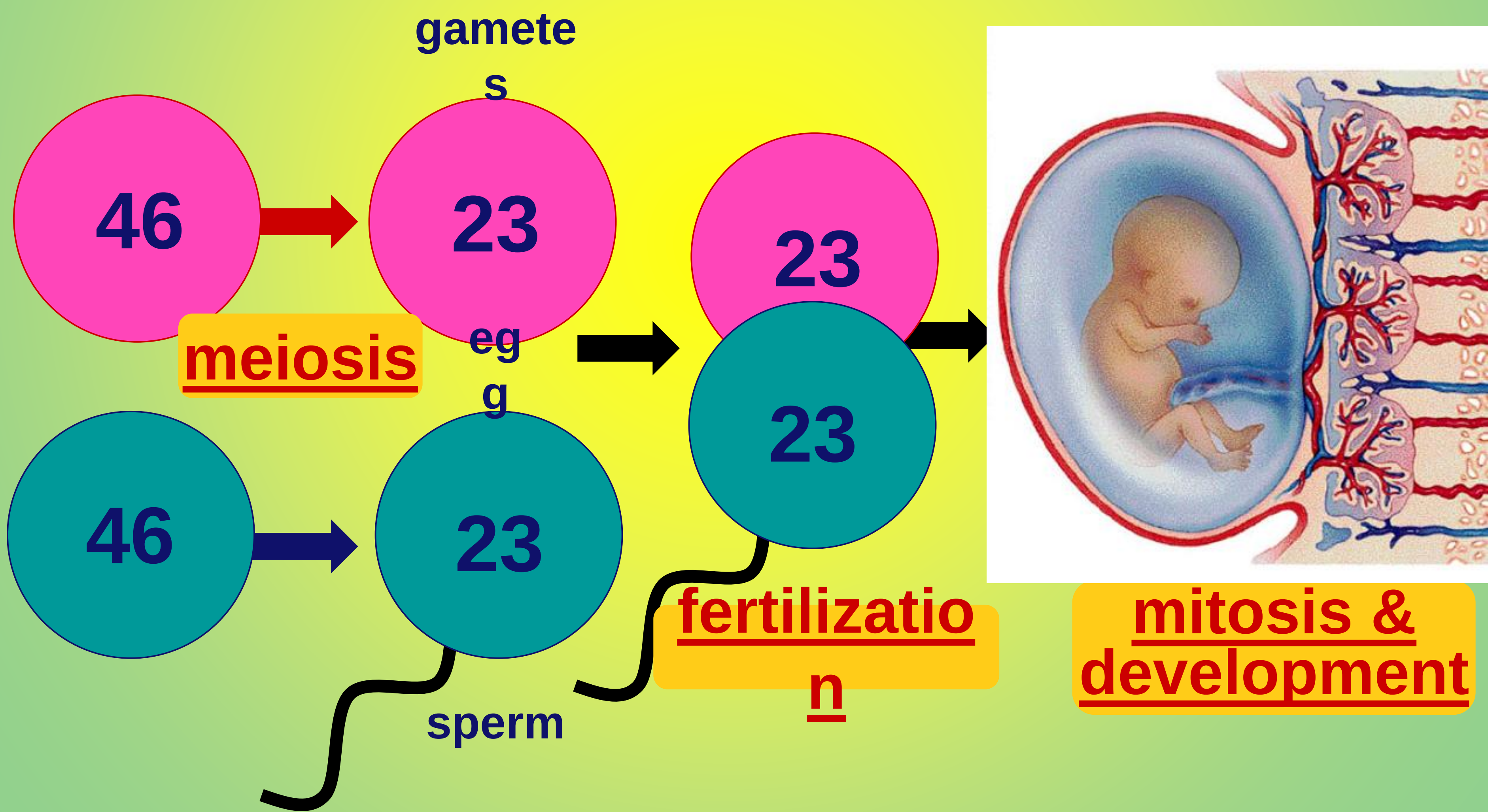
The value of sexual reproduction

- Sexual reproduction introduces genetic variation
  - **genetic recombination** during meiosis
    - **independent assortment** of chromosomes
      - random alignment of homologous chromosomes in Meiosis 1
  - **crossing over**
    - mixing of alleles across homologous chromosomes
  - **random fertilization**
    - which sperm fertilizes which egg?
- Driving evolution
  - **variation** for natural selection



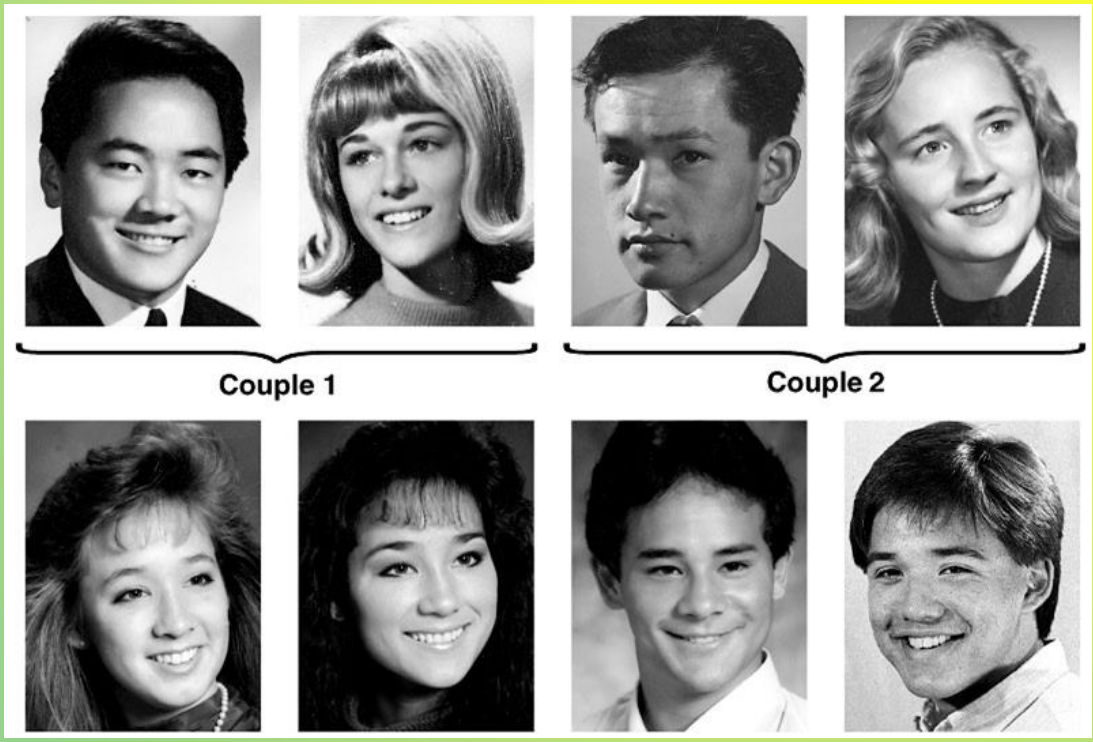
Putting it all together…

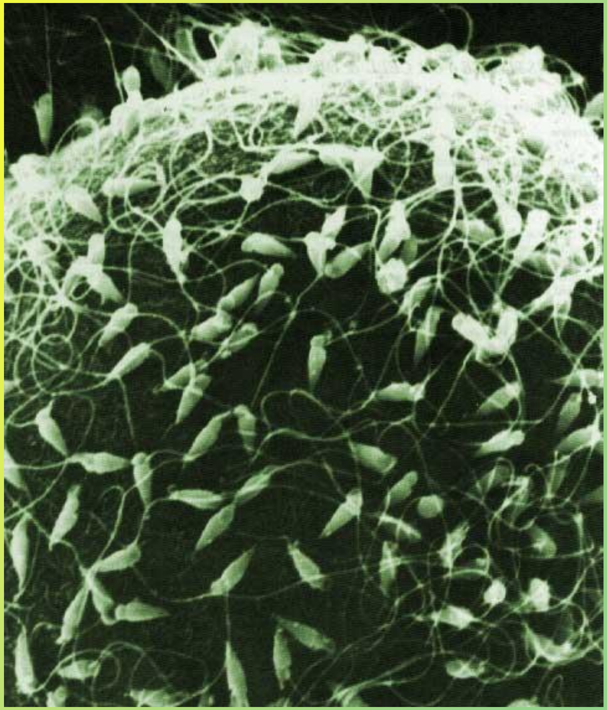
meiosis → fertilization → mitosis + development



Variation from random fertilization

- Sperm + Egg = ?
  - any 2 parents will produce a **zygote** with over 70 trillion (2^{23} x 2^{23}) possible diploid combinations

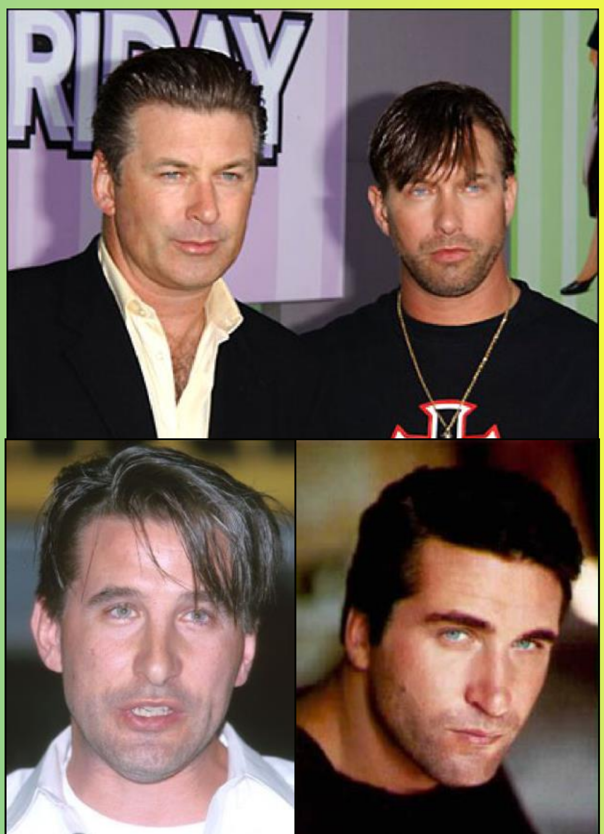




Sexual reproduction creates variability

Sexual reproduction allows us to maintain both genetic **<u>similarity</u>** & **<u>differences</u>**.

Michael & Kirk Douglas

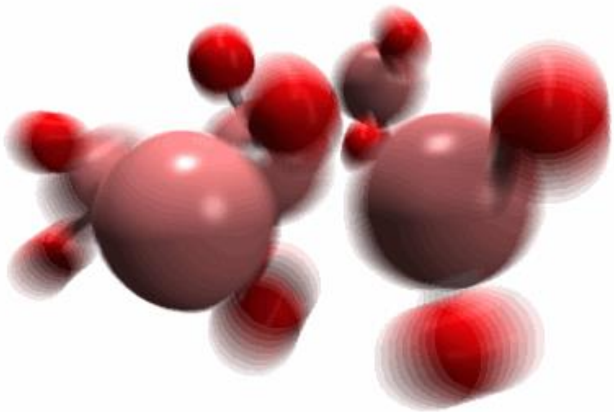


Baldwin brothers

Martin & Charlie Sheen, Emilio Estevez

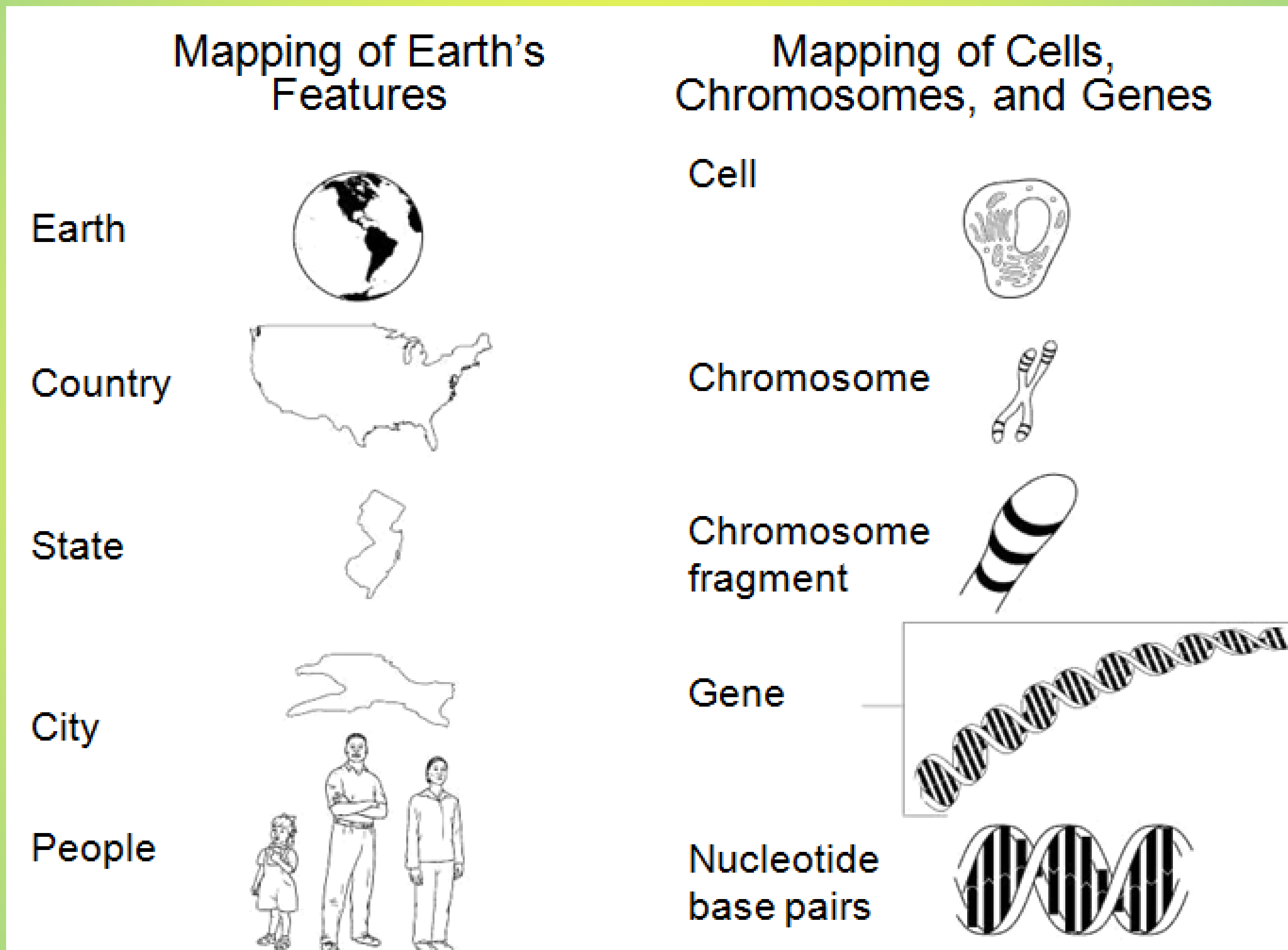
Key Concept Questions

- What happens during the process of meiosis?
  - **The chromosome number is reduced by half**
- Why is crossing over important?
  - **It creates new genetic combinations and more variety.**
- How is meiosis different from mitosis?

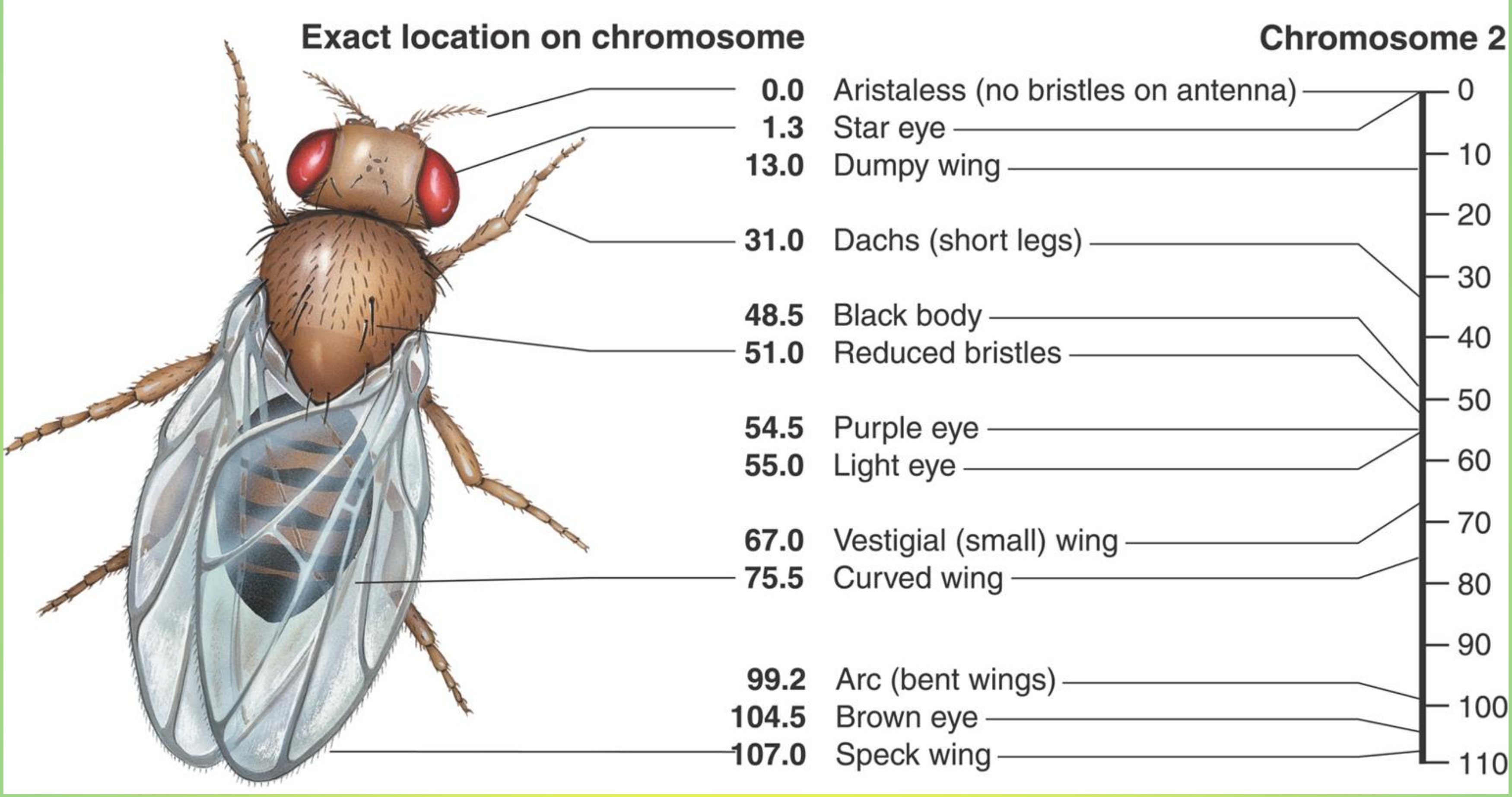


SECTION 11-5

Linkage and Gene Maps


Mapping of Earth's Features
Mapping of Cells, Chromosomes, and Genes
Earth
Country
State
City
People
Cell
Chromosome
Chromosome fragment
Gene
Nucleotide base pairs

11-5 Linkage and Gene Maps



Key Concept Question

- What structures actually assort independently?

Linked Genes

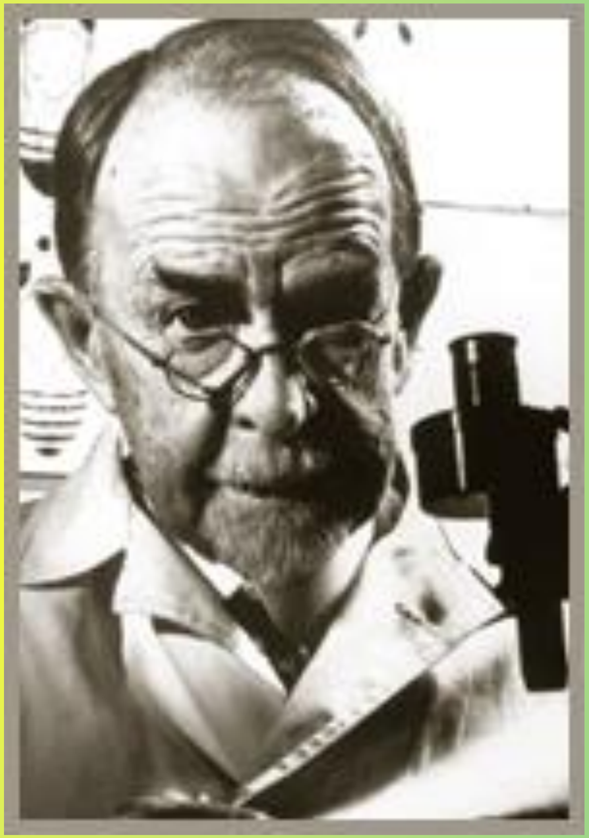
Linked genes tend to be inherited together because they are located near each other on the same chromosome

Each chromosome has hundreds or thousands of genes (except the Y chromosome)

Genes located on the same chromosome that tend to be inherited together are called linked genes

Gene Linkage

Thomas Hunt Morgan's research on fruit flies led him to the principle of linkage.



Morgan discovered that many of the more than 50 *Drosophila* genes he had identified appeared to be "linked" together.

They seemed to violate Mendel's principle of independent assortment.

Morgan did other experiments with fruit flies to see how linkage affects inheritance of two characters

Morgan crossed flies that differed in traits of body color and wing size

EXPERIMENT P Generation (homozygous)

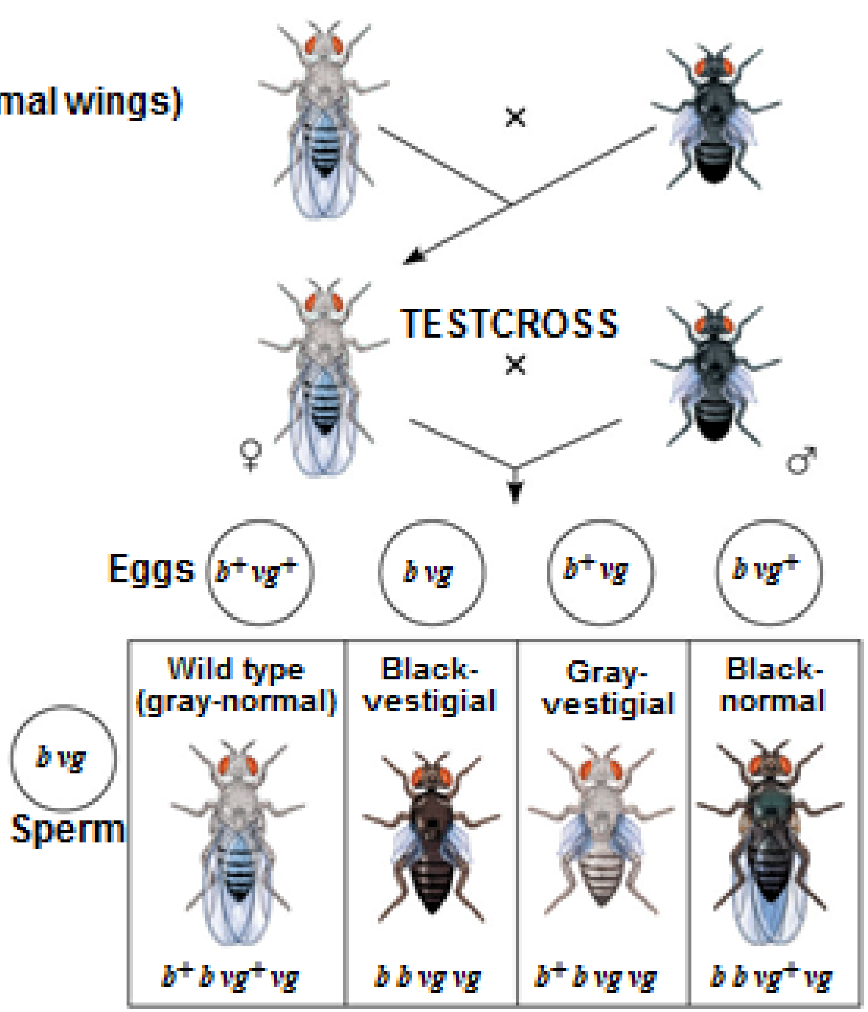
Wild type (gray body, normal wings) — $b^+ b^+ vg^+ vg^+$

Double mutant (black body, vestigial wings) — $b\ b\ vg\ vg$

F₁ dihybrid (wild type) — $b^+ b\ vg^+ vg$

Double mutant — $b\ b\ vg\ vg$

Testcross offspring



Parental phenotypes
Predicted- 50%
Result- 83%

Recombinant phenotypes
Predicted - 50%
Result 17%

PREDICTED RATIOS

If genes are located on different chromosomes:	1	1	1	1
If genes are located on the same chromosome and parental alleles are always inherited together:	1	1	0	0

RESULTS 965 : 944 : 206 : 185

Gene Linkage

Morgan and his associates grouped the linked genes into four linkage groups.

Each linkage group assorted independently but all the genes in one group were inherited together.

Helped to determine each chromosome is actually a group of linked genes.

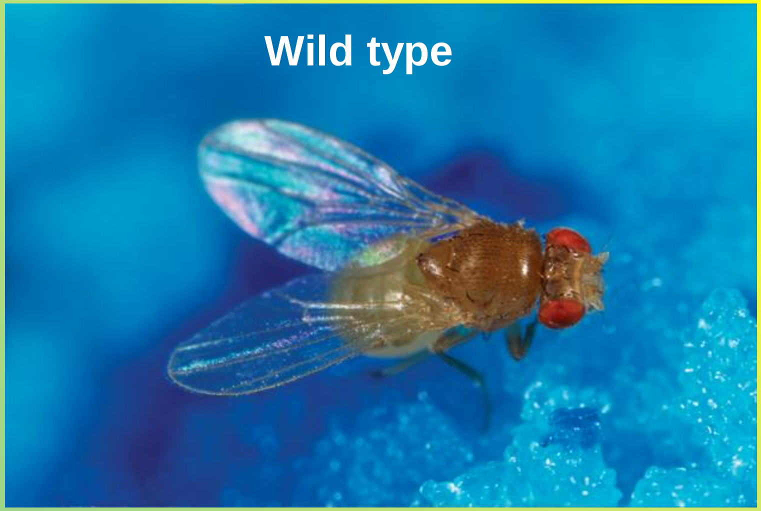
Morgan concluded that Mendel's principle of independent assortment still holds true.

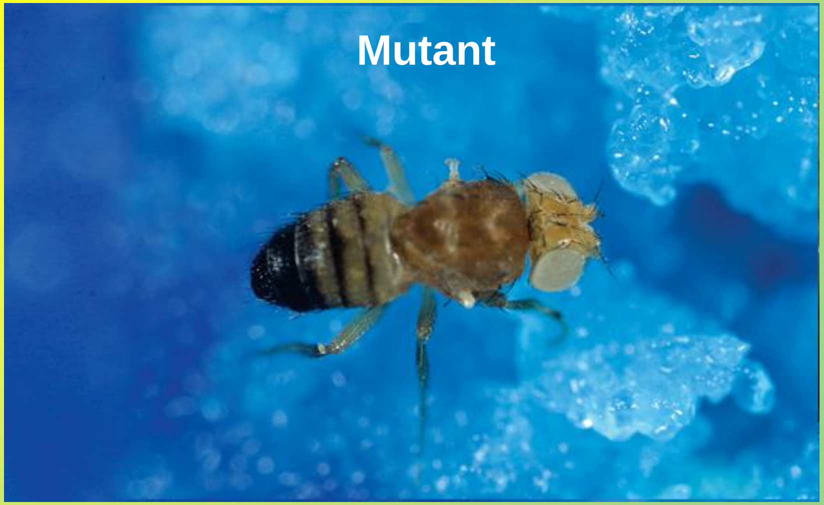
Chromosomes assort independently, not individual genes.

Mendel DID miss gene linkage.

Gene linkage was explained through fruit flies.

- Morgan found that **linked** traits are on the **same** chromosome.
- Chromosomes, not **genes**, assort **independently** during meiosis.





Gene Maps

Crossing-over during meiosis (during what phase????) sometimes separates genes that had been on the same chromosomes onto homologous chromosomes.

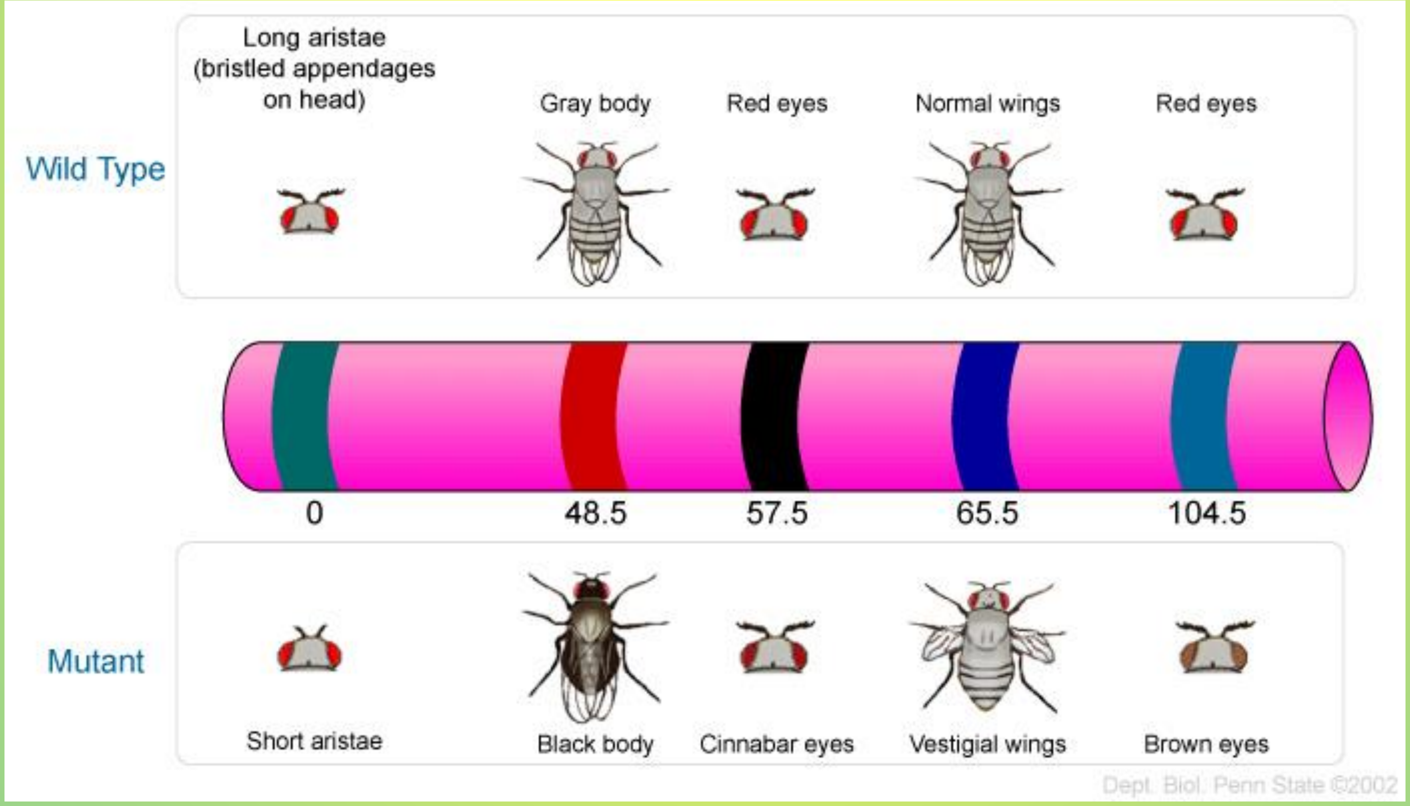
Crossover events occasionally separate and exchange linked genes and produce new combinations of alleles.

Gene Maps

Alfred Sturtevant, a student of Morgan, reasoned that the farther apart two genes were, the more likely they were to be separated by a crossover in meiosis.

Recombination frequencies can be used to determine the distance between genes.

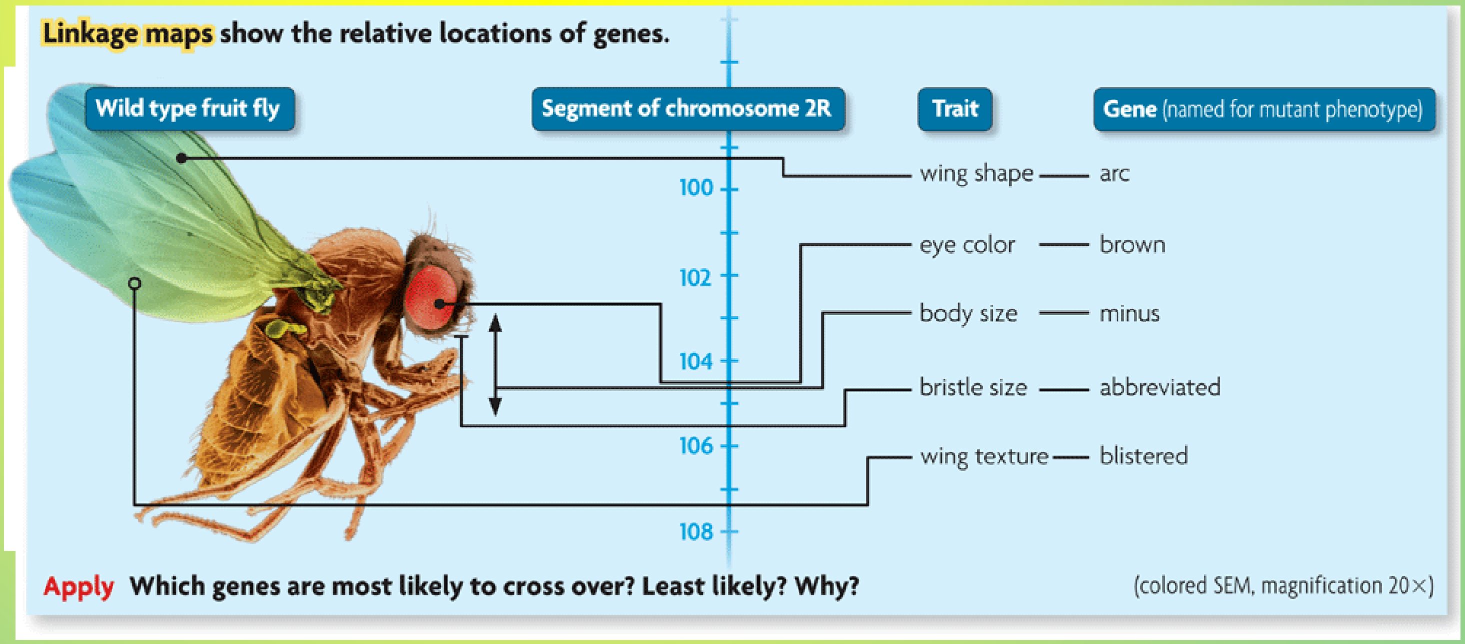
Sturtevant created a **gene map** showing the relative locations of each known gene on one of the *Drosophila* chromosomes.



- The genes for this fruit fly’s reddish-orange **eyes** and miniature **wings** are almost always inherited together. The reason for this is the genes are **close** together on a **single** chromosome

Linkage maps estimate distances between genes.

- The **closer** together two genes are, the more likely they will be inherited **together**.
- **Cross-over** frequencies are related to distances between genes.
- Gene linkage maps show the relative **locations** of genes.

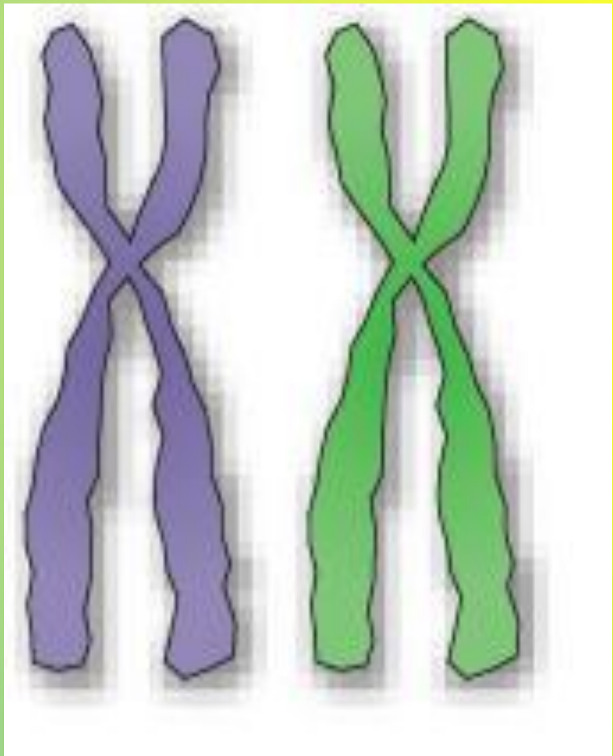


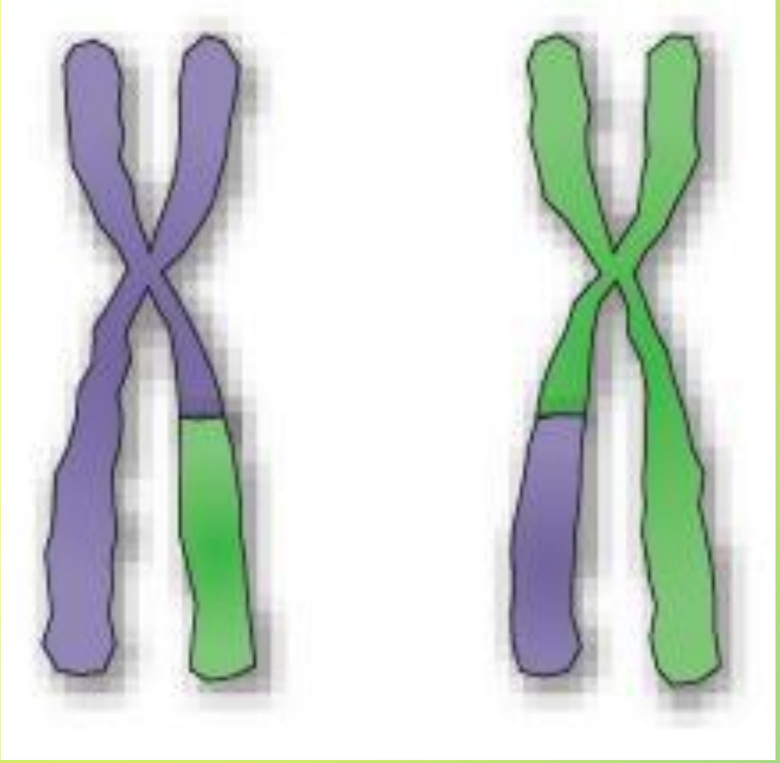
If two genes are close together, the recombination frequency between them should be low, since crossovers are rare.

If they are far apart, recombination rates between them should be high.

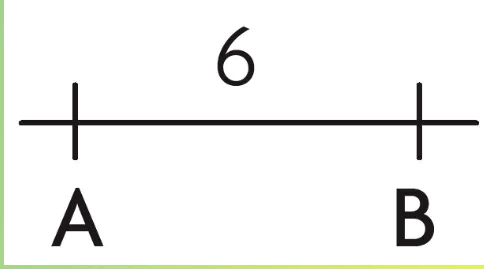
Alleles “A” and “E” are less likely to crossover together b/c they are farther apart from each other .

- Linked genes are **<u>not</u>** inherited together every time.
- Chromosomes **<u>exchange</u>** homologous genes during meiosis.

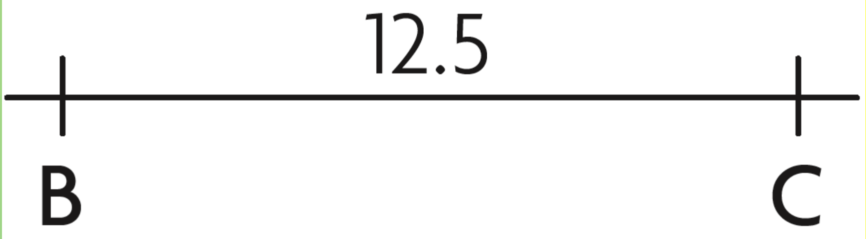




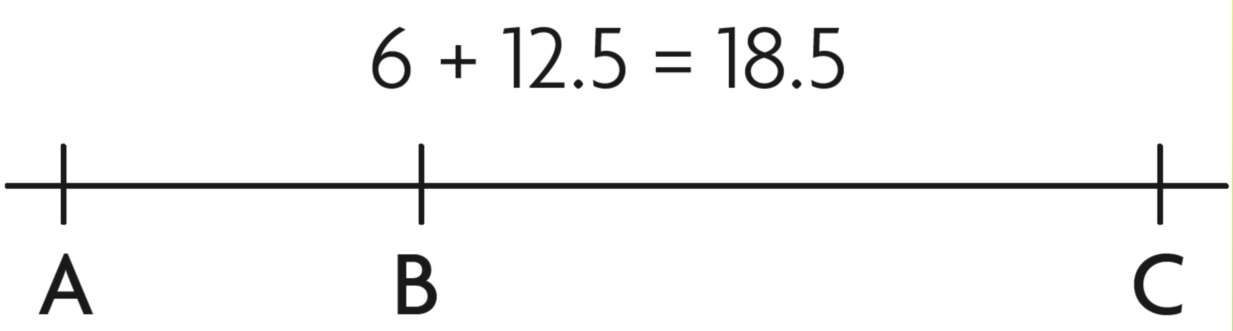
Cross-over frequencies can be converted into map units.



- gene A and gene B cross over 6.0 percent of the time



– gene B and gene C cross over 12.5 percent of the time



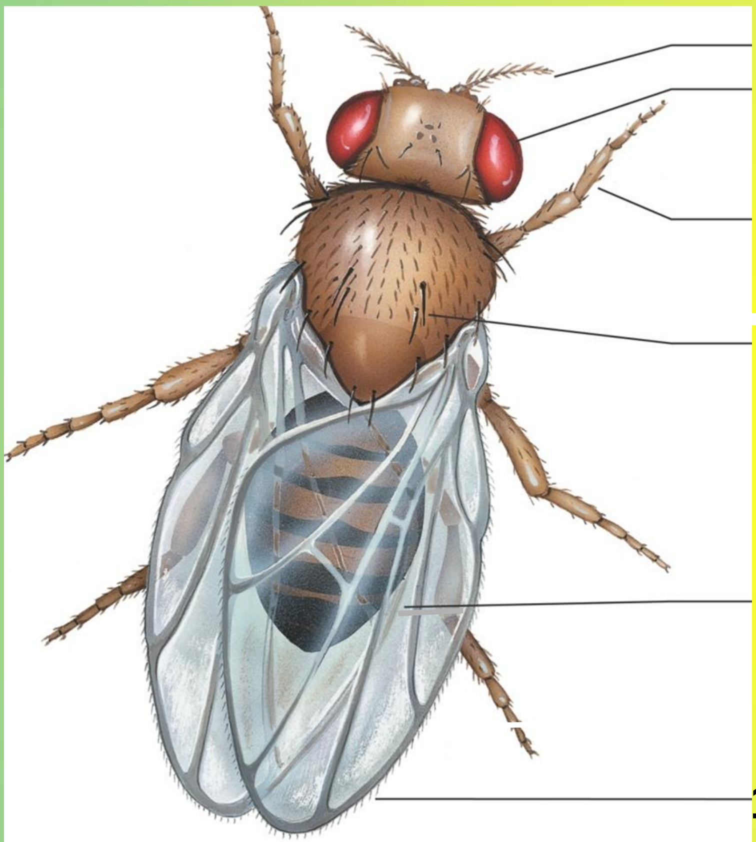
– gene A and gene C cross over 18.5 percent of the time

Why Is This Important to Us?

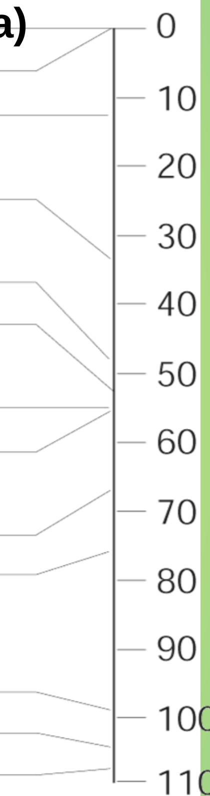
1. The rate at which linked genes are separated and recombined can be used to produce a "map" of distances between the linked genes.
2. This information can be used to determine the relative position of genes on chromosomes.
3. Sturtevant's methods have been used to construct genetic maps of many species, INCLUDING the Human Genome!!!

Gene Maps

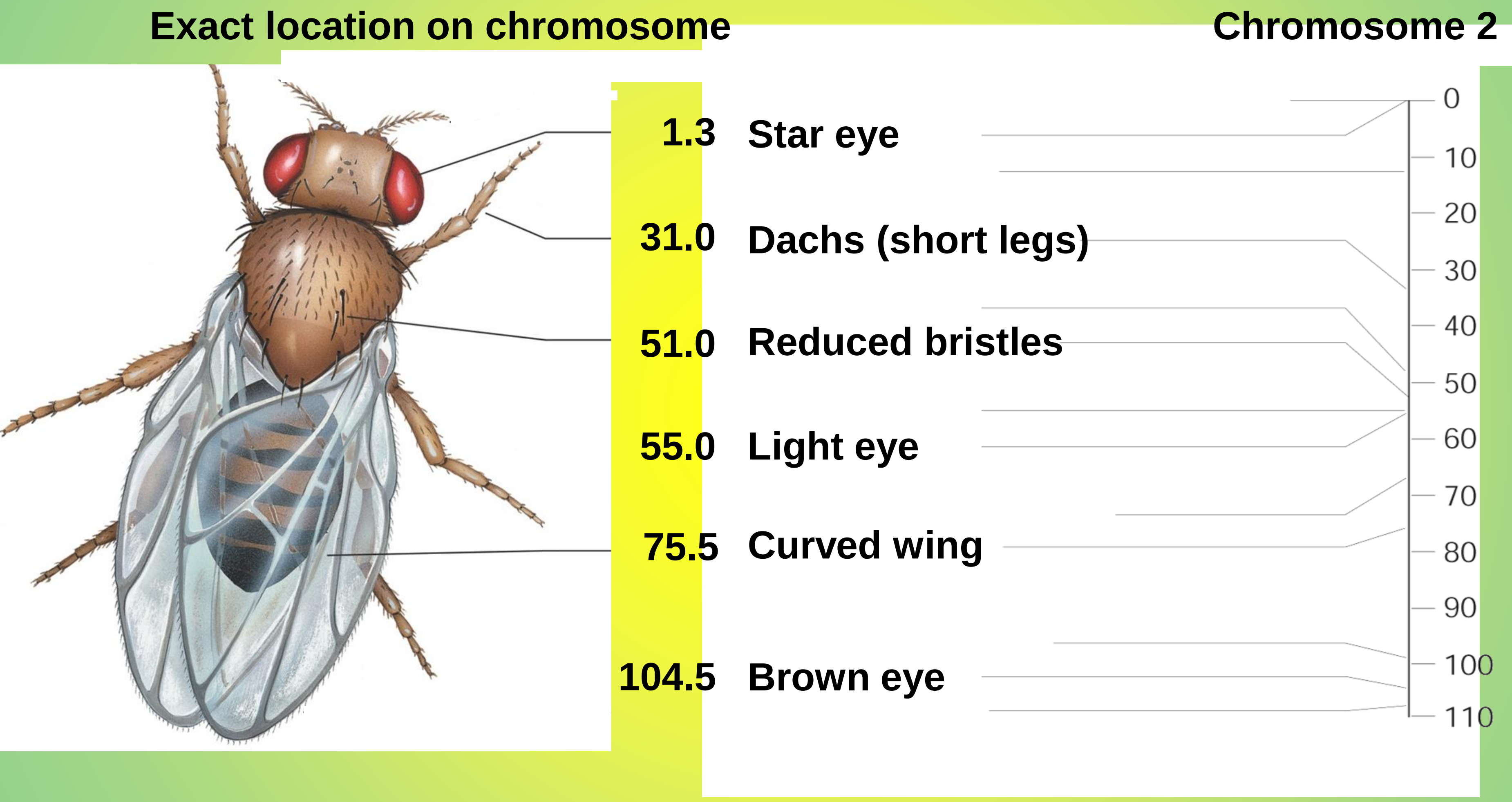
Exact location on chromosome | **Chromosome 2**



0.0	**Aristaless (no bristles on antenna)**
13.0	**Dumpy wing**
48.5	**Black body**
54.5	**Purple eye**
67.0	**Vestigial (small) wing**
99.2	**Arc (bent wings)**
107.0	**Speck wing**



Gene Maps



Exact location on chromosome
Chromosome 2
1.3 Star eye
31.0 Dachs (short legs)
51.0 Reduced bristles
55.0 Light eye
75.5 Curved wing
104.5 Brown eye
0
10
20
30
40
50
60
70
80
90
100
110

<u>Key Concept Question</u>

- What structures actually assort independently?
  - **<u>Chromosomes</u>**

Gene Mapping

Genes	Recombination Frequency
vg - b	17%
vg - cn	8%
cn - b	9%