Lecture 6. Chromosomal theory of inheritance.

Allelic interactions – Dominance vs. recessive, complete dominance, codominance, incomplete dominance, over dominance.

What is the relationship between the genes and chromosomes?

- Mendel established the existence of genes, without knowing anything about the chromosomes.
- Laws of inheritance proposed by Mendel, assumes that the hereditary materials are the particles, called as the genes (factors), found in the all living organisms.
- Thus, **Genes are the fundamental units of life**.

❑Where are genes found in a cell?

- Genes lie on chromosomes.
- Genes are stretches of DNA that specify proteins.

❑When Gregor Mendel began studying heredity in 1843, chromosomes had not yet been observed under a microscope.

❑Only with better microscopes and techniques during the late 1800s could cell biologists begin to stain and observe subcellular structures, seeing what they did during cell divisions (mitosis and meiosis).

❑Eventually, some scientists began to study Mendel's long-ignored work and re-evaluate his model in terms of the behavior of chromosomes.

❑ Around the turn of the 20th century, the biology community started to make the first tentative connections between chromosomes, meiosis, and the inheritance of genes.

- The regular and precise longitudinal division of chromosomes into two identical halves, and its equal distribution to the daughter cells by Mitosis
- Separation and reduction in the number of chromosomes from the diploid to haploid state during the formation of gametes by meiosis and
- The restoration of the diploid number of chromosomes in the Zygote by fertilization showed that the chromosomes are of great importance to the cell.
- It was then ultimately realized that **Chromosomes are concerned with inheritance**.

Who figured out that genes are on chromosomes?

Walter Sutton - American Biologist - Grasshopper
Theodor Boveri - German Cytologist - Sea urchins

They studied **chromosome and meiotic behavior; Published paper independently in 1902 and 1903.**

- Individual genes are found at specific locations on particular chromosomes, and the behavior of chromosomes during meiosis can explain why genes are inherited according to Mendel's law.
- Mendelian factors must be present in the chromosome and they assigned **genes to chromosomes** because the **behavior of chromosomes** at meiosis and fertilization resembled in a very striking way, the **behavior of genes.**
- This was observed in several breeding experiments

Scientists behind the theories

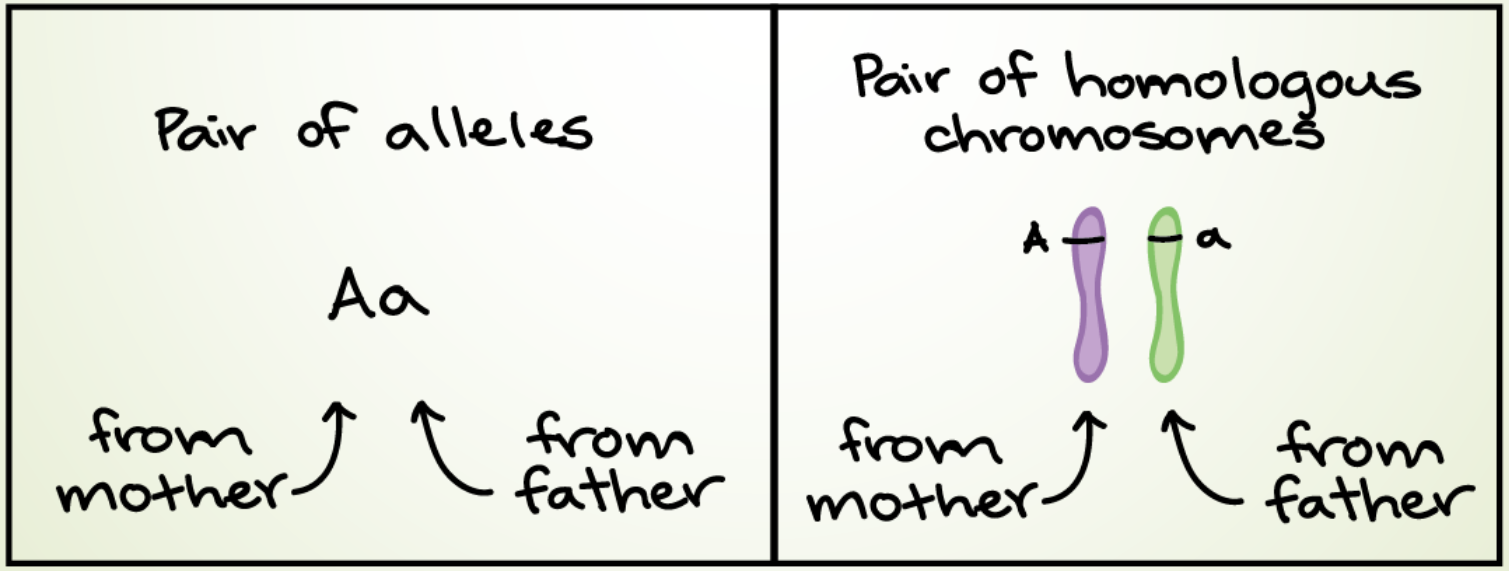
Walter Sutton

Theodor Boveri

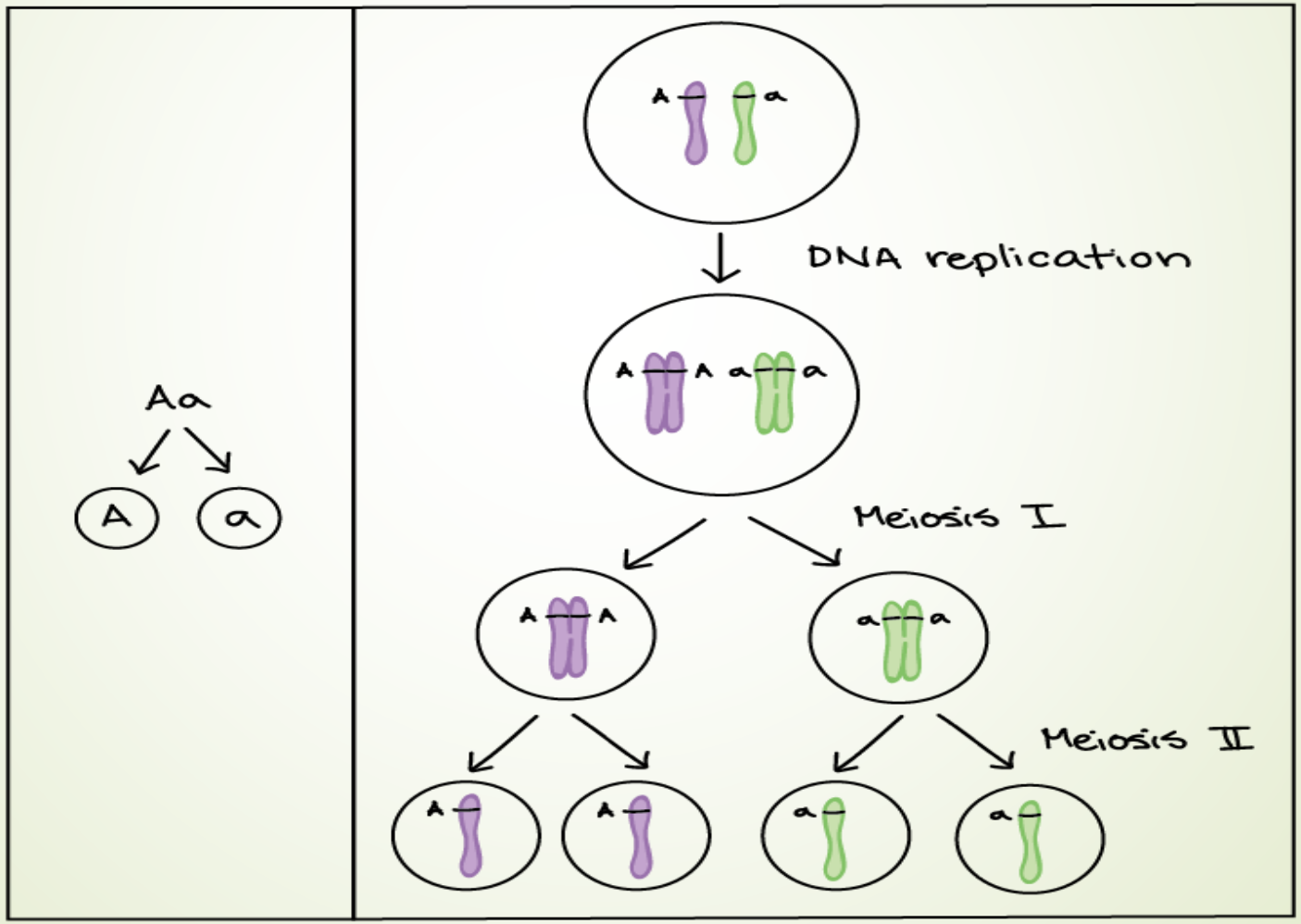
Thomas Hunt Morgan

- ✓ Chromosomes, like Mendel's genes, come in matched (homologous) pairs in an organism.

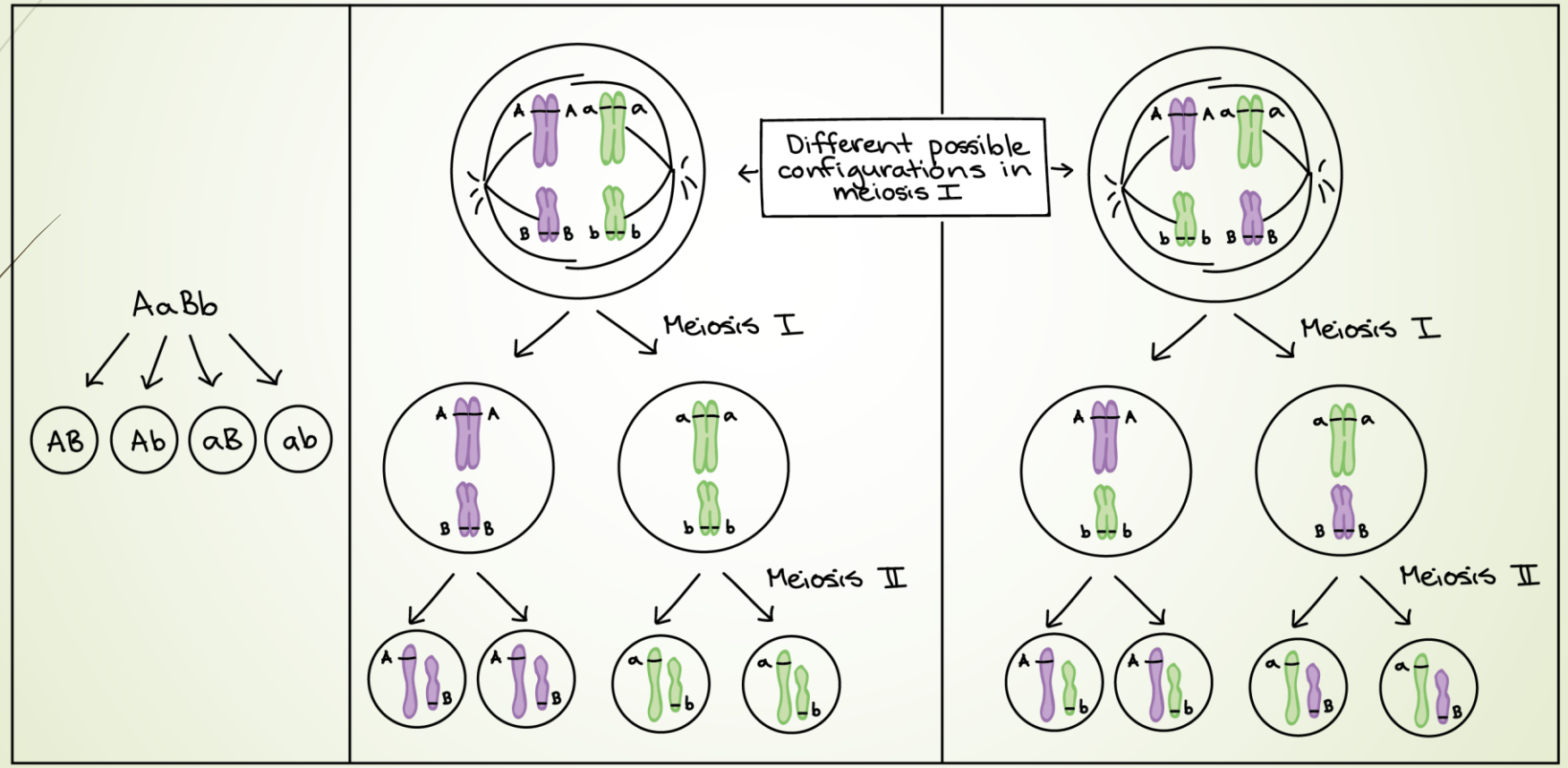
- ✓ For both genes and chromosomes, one member of the pair comes from the mother and one from the father.



- The members of a homologous pair separate in meiosis, so each sperm or egg receives just one member.
- This process mirrors segregation of alleles into gametes in Mendel's law of segregation.



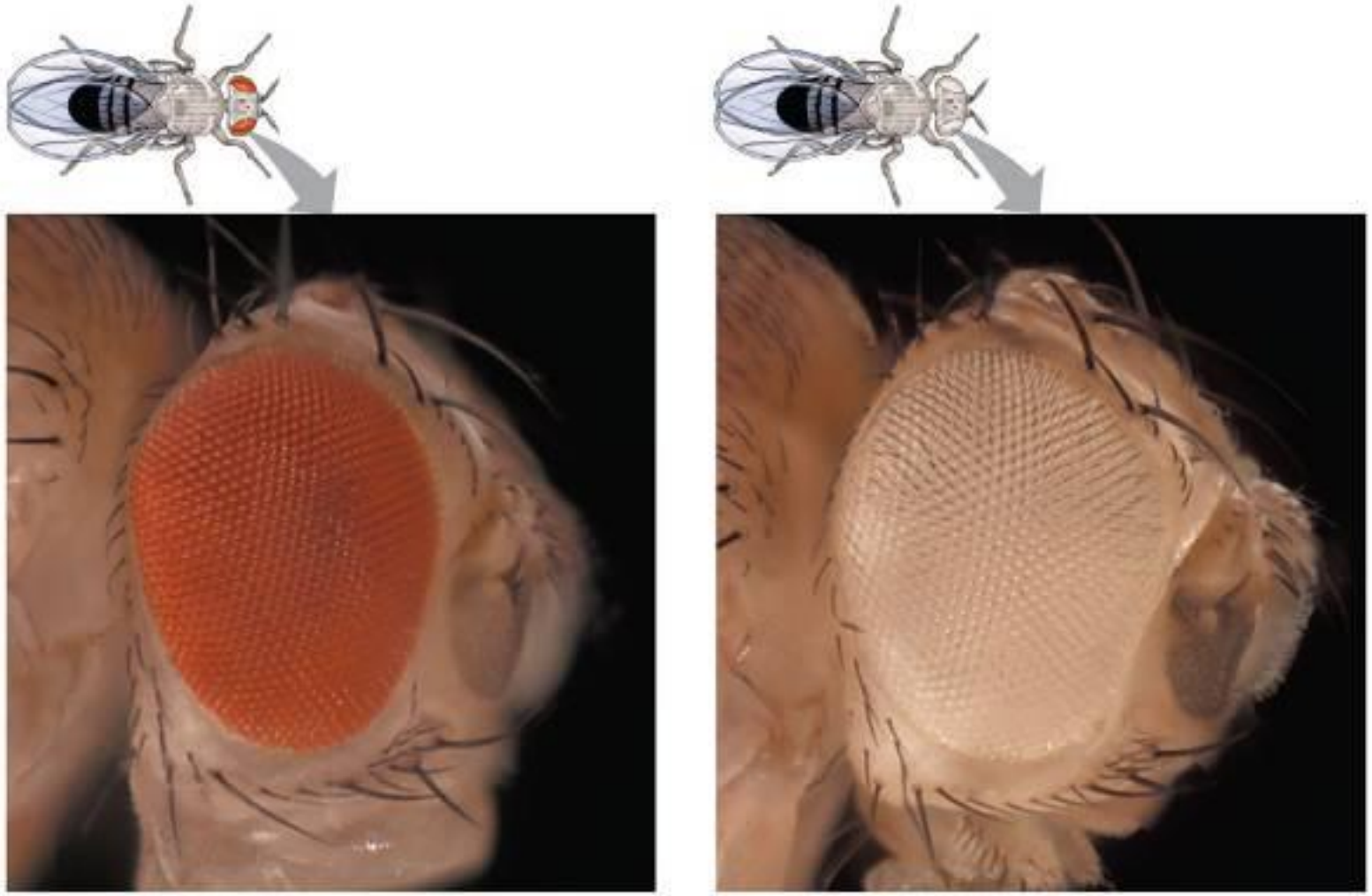
- The members of different chromosome pairs are sorted into gametes independently of one another in meiosis, just like the alleles of different genes in Mendel's law of independent assortment



- The chromosome theory of inheritance was proposed before there was no any direct evidence that traits were carried on chromosomes, and it was controversial at first.
- In the end, the solid evidence was given by geneticist Thomas Hunt Morgan, an embryologist and by his students, who studied the genetics of fruit flies.
- Morgan noted **wild type or normal,** phenotypes that were common in the fly populations
- Traits **alternative to the wild type** are called **mutant phenotypes**

Morgan's Choice of Experimental Organism

- Several characteristics make fruit flies a convenient organism for genetic studies
  - They produce many offspring
  - A generation can be bred every two weeks
  - They have only four pairs of chromosomes



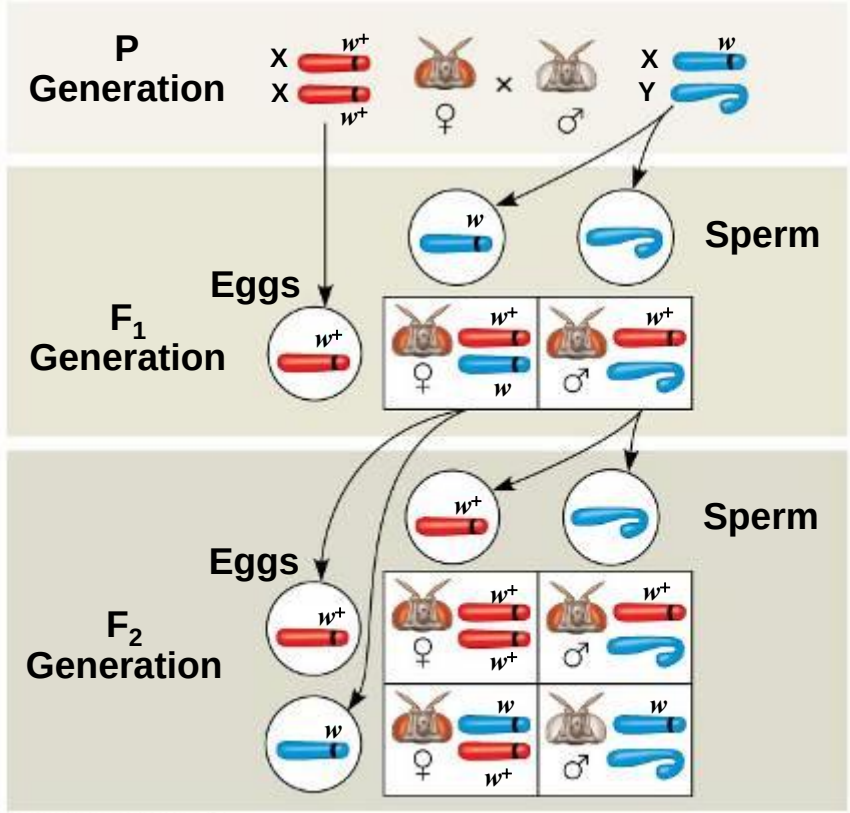
Correlating Behavior of a Gene's Alleles with Behavior of a Chromosome Pair

- In one experiment, Morgan mated male flies with white eyes (mutant) with female flies with red eyes (wild type)
  - The F_1 generation all had red eyes
  - The F_2 generation showed the 3:1 red:white eye ratio, but only males had white eyes
- Morgan determined that the white-eyed mutant allele must be located on the X chromosome
- Morgan's finding supported the chromosome theory of inheritance

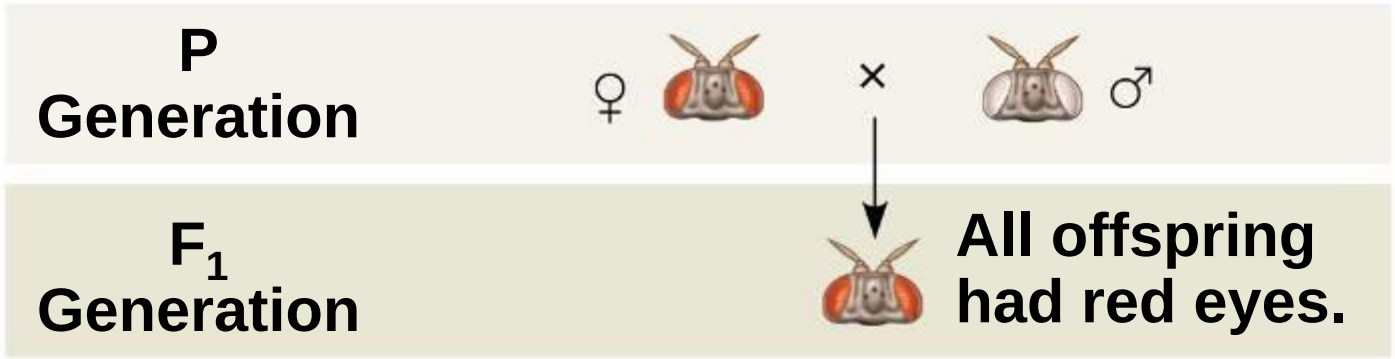
EXPERIMENT

RESULTS

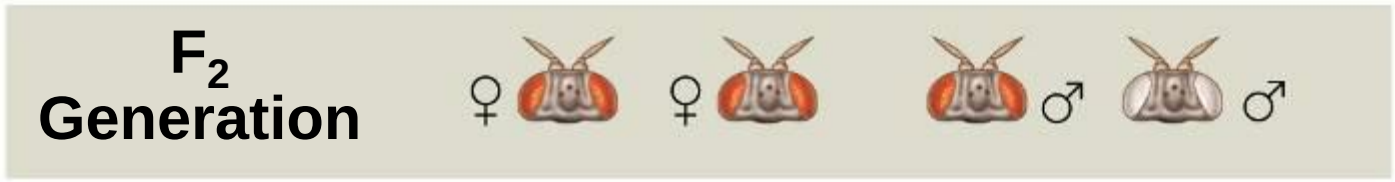
CONCLUSION



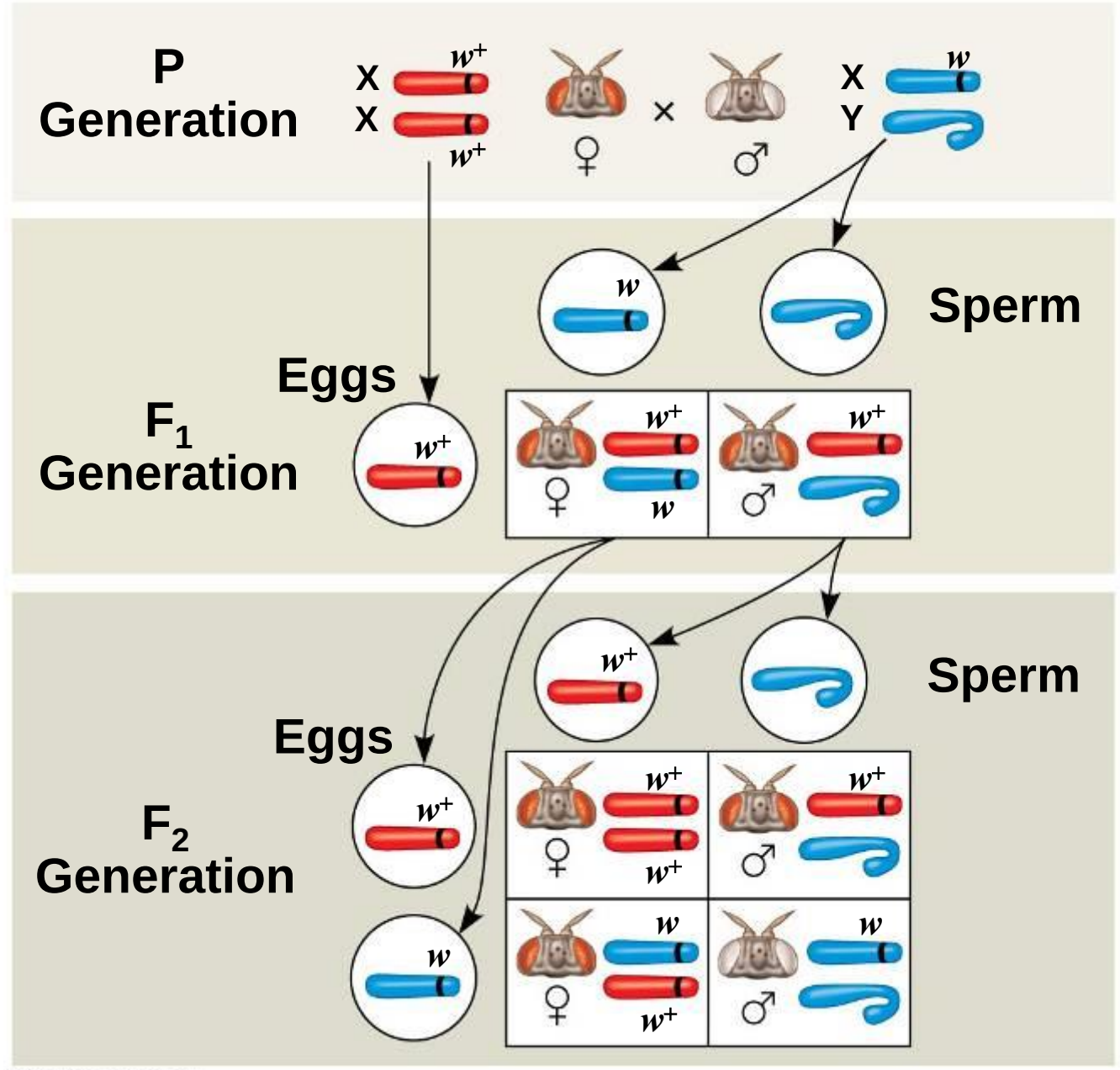
EXPERIMENT



RESULTS



CONCLUSION



- Morgan found that the pattern of transmission of white eye gene was identical with that of the x chromosome of Drosophila.
- This prompted Morgan to postulate that the gene for white eye was located in the x chromosome.
- Based on the genetic and cytological studies on Drosophila,
- Morgan postulated that,

“genes are arranged in a linear order
along the length of the chromosome,
each gene having a fixed place on the chromosome,
and its allele in corresponding position
on the homologous chromosomes”.

Extension of Mendels Concepts

New concepts – at variance with the findings of Mendel
Called Mendelian deviations or exceptions or anomalies

- Incomplete dominance
- Codominance
- Multiple alleles
- Linkage
- Lethal genes
- Gene interactions
- Pleiotropic genes effects
- Polygenes
- Environmental effects
- Cytoplasmic or Maternal effects

Allelic interactions or intra allelic gene interactions

Intra allelic interaction – interaction of alleles within a gene

These kind of genetic interactions occur in between the two alleles of a single gene is referred as **Allelic interaction or intra geneic interaction.**

Allelic interactions- Types of dominance

- **Complete dominance**
- **Incomplete dominance**
- **Co-dominance**
- **Over dominance**

Complete dominance

- In case of complete dominance, the phenotype produced by heterozygotes is identical with that produced by homozygotes for the concerned dominant allele. The dominant allele in such a situation is known is completely or fully dominant.
- Eg: In peas, round seed shape is produced by the dominant allele W, while wrinkled shape is determined by its recessive allele w.

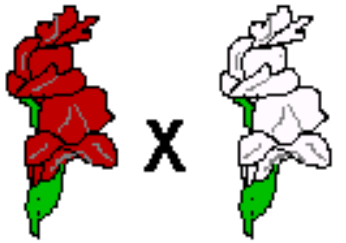
Complete dominance

- Seeds having the genotype Ww are round and indistinguishable from those having the genotype WW.
- As a result, characters showing complete dominance yield the typical 3:1 monohybrid ratio in F2.

Incomplete / partial dominance

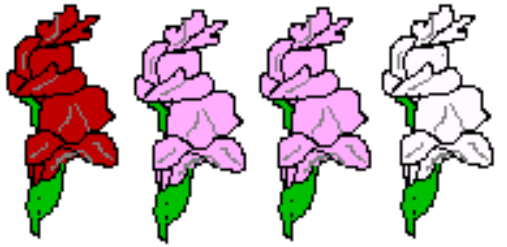
- The phenotypic expression of heterozygote for a gene being intermediate between those of the two concerned homozygote. Such a situation is known as incomplete or partial dominance
- Dominance is incomplete and the hybrids resemble neither parent exactly but are more or less intermediate between the two.

Incomplete / partial dominance



Parental (P) generation

F_1 generation all pink



F_2 generation

Four O' Clock plant – *Mirabilis jalapa*

P RR x rr

F_1 Intermediate flower colour (Pink) **Rr**

F_2 RR **Rr** **Rr** rr

Red : Pink : White

1 : 2 : 1

Incomplete / partial dominance

Dr. DD

Codominance

Both alleles can be expressed

For example, RED cows crossed with WHITE will generate ROAN cows. Roan refers to cows that have red coats with white blotches.

This phenotype might deviate from incomplete dominance. (which predicts pink F_1 progeny.)

coat colour in cattle

CR CR x CW CW

(Red) (White)

F1 CR CW (Roan)

F2 1 CR CR : 2 CR CW: 1 CW CW

Also called as mosaic dominance

Codominance - example

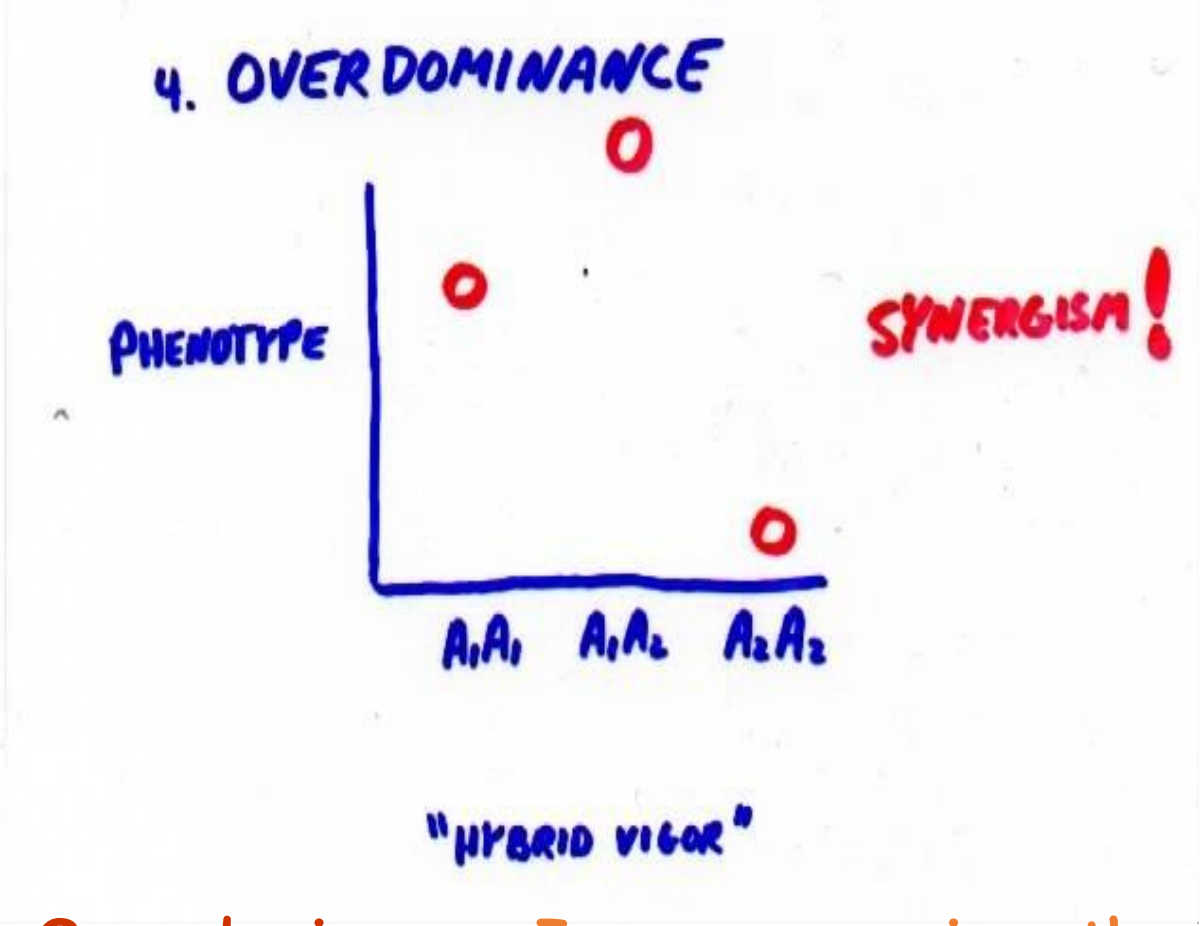
- Eg. Blood group antigens of man.

I A IB x I A IB

(AB) (AB)

I A IB : 2 I A IB : 1 IB IB

1 A : 2 AB : 1B



F1 is superior to the dominant parent.

It is called as **Hetero**, **Super** (or) **over dominance.**

Over dominance: In some occasions the hetrerozygote may exceed the phenotypic measurement for both homozygous parents. Such heterozygotes are described as over dominance.