

# Applied molecular biology

- Book: Glick, Pasternak, Molecular Biotechnology, *Principles and application of recombinant DNA*
- Biotechnology
- Molecular genetics

# What Is Biotechnology?

- Using scientific methods with organisms to produce new products or new forms of organisms
- Any technique that uses living organisms or substances from those organisms to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses

# Beer is an ancient foodstuff

Ancient beer was not just drink, but food

Thick drink with high caloric value as well as alcohol

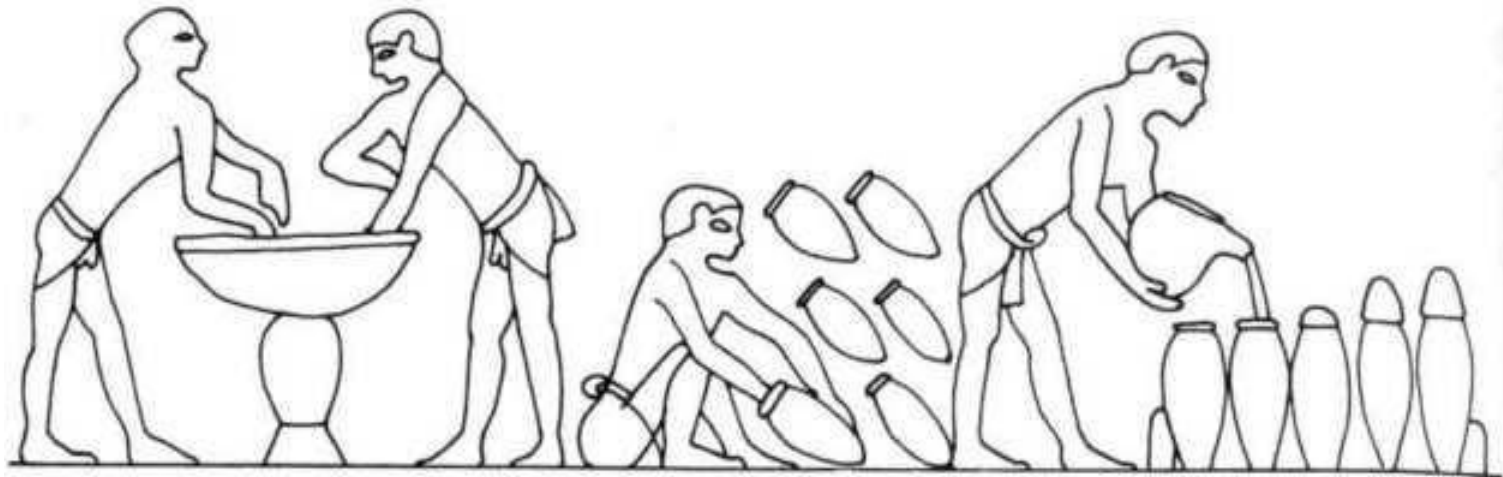
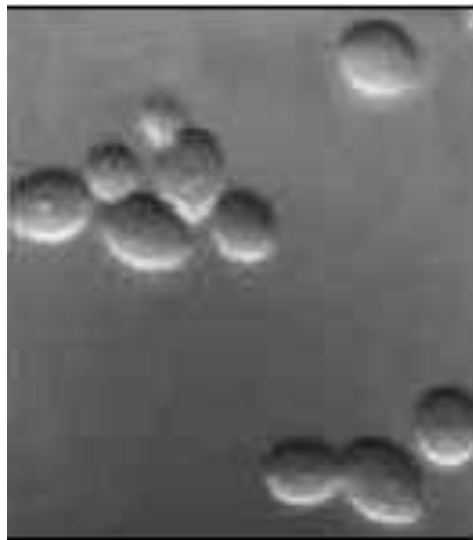


FIG. 106: *Beermaking in Egypt: a scene from a tomb of about 2500 B.C.*

Both beer and bread were developed around the same time in the middle east

Early bread was flat, but when wild yeast contaminated the dough, a fluffier, sweeter bread was created

Beer arose out of the liquid soaked bread



Yeast  
cells

Cheese & yogurt also came about due to microbial contamination



# Classical Biotechnology

- Refinement of fermentation techniques during 18<sup>th</sup> and 19<sup>th</sup> C.
- During 20<sup>th</sup> C. fermentation expanded to the production of:

Glycerol

Acetone

Butanol

Lactic acid

Citric acid

# Biopharmaceuticals

Herbal plants have been used since ancient times

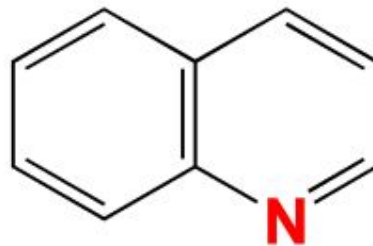
Even today, 25% of our common medicines contain at least some compounds obtained from plants

Why do plants create these compounds?

- Protection from herbivory and predation
- Allelopathy - plants secrete toxins from their roots that prevent the germination of other plants in their root zone

Alkaloids: Over 5,000 alkaloids have been identified in numerous plant families, most in the angiosperms

- Contain nitrogen
- Alkaline
- Bitter
- Physiological effect on animals, often on nervous system
- Names of most alkaloids end in "...ine"





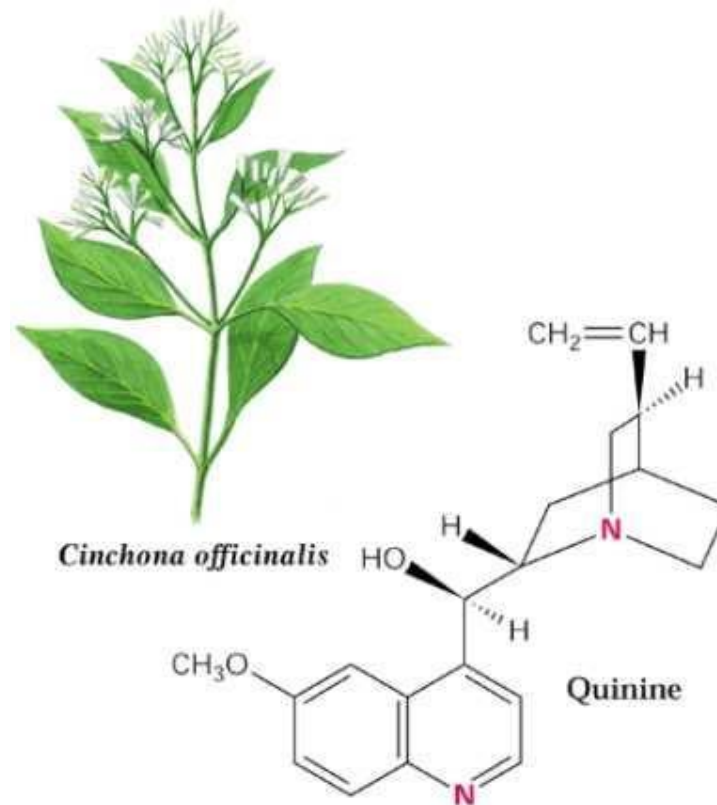
## Common Medicinal Alkaloids & their Sources:

Morphine	Poppies
Caffeine	Coffee/Tea
Nicotine	Tabacco
Emetine	Ipecac
Atropine	Belladonna
Quinine	Cinchona Tree

During 19<sup>th</sup> C. **quinine** was critical to British colonial expansion

Extracted from the bark of the cinchona plant

Not enough could be extracted, another source was needed



- Bayer discovered way to synthesize acetylsalicylic acid
- Known under its trade name, Aspirin

# BAYER

## PHARMACEUTICAL PRODUCTS.

We are now sending to Physicians throughout the United States literature and samples of

# ASPIRIN

The substitute for the Salicylates, agreeable of taste, free from unpleasant after-effects.

# HEROIN

The Sedative for Coughs,

## HEROIN HYDROCHLORIDE

Its water-soluble salt.

You will have call for them. Order a supply from your jobber.

Write for literature to

## FARBENFABRIKEN OF ELBERFELD CO.

40 Stone Street, New York,

SOLE AGENTS

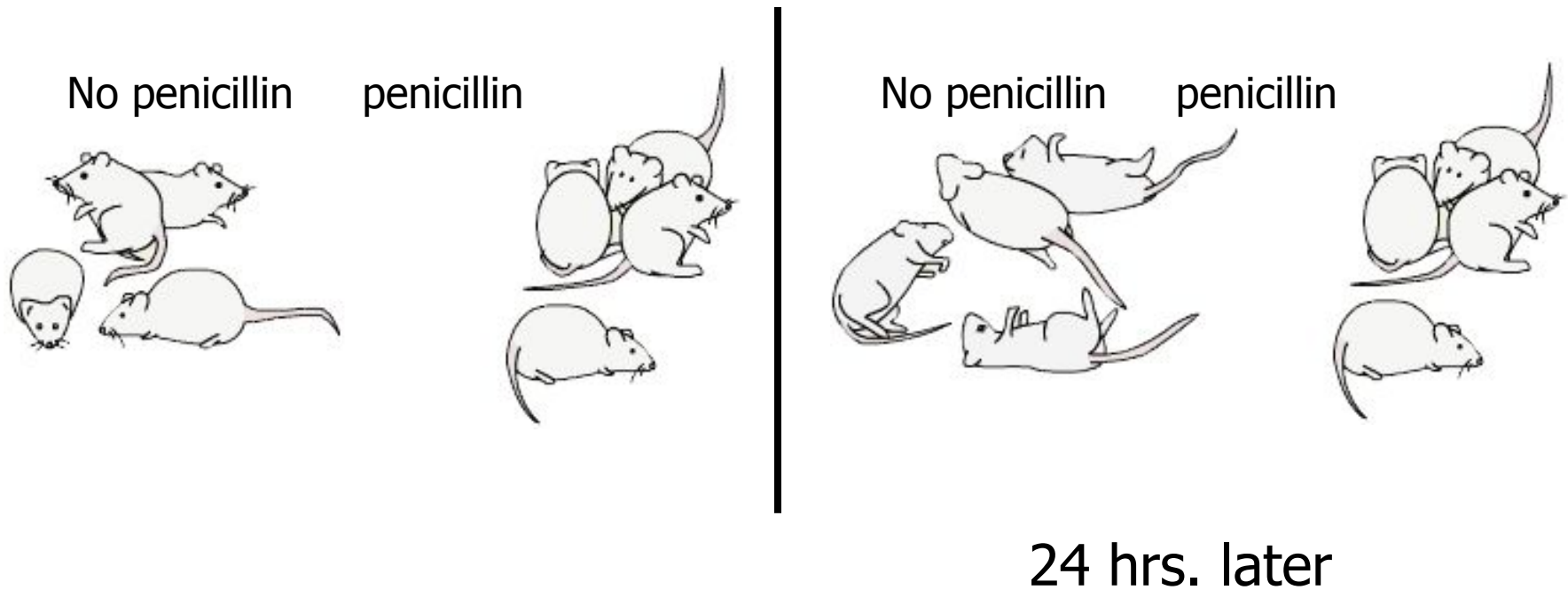
**Penicillin**

- In 1928 Alexander Fleming noticed something odd about a petri dish contaminated with mold
- The mold seemed to kill the bacteria
- Fleming was unable to isolate the bactericidal action



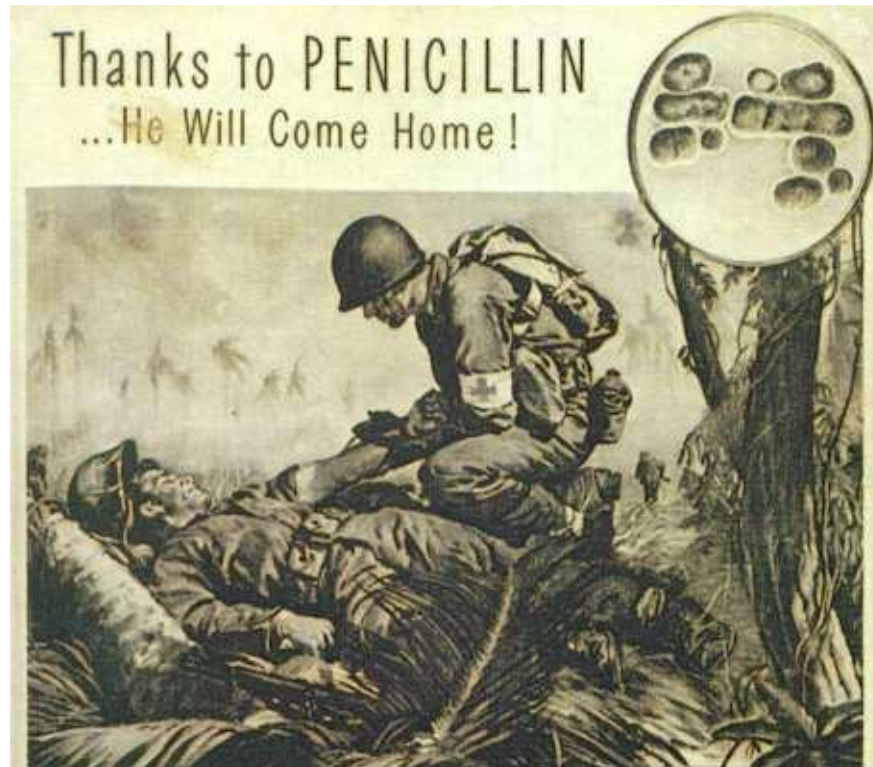
Penicillium mold

- In 1940 Norman Heatley finally showed that penicillin could stop infection
- Mice were infected with streptococcus bacteria
- Half were given penicillin.
- Those receiving penicillin survived, those that didn't died.



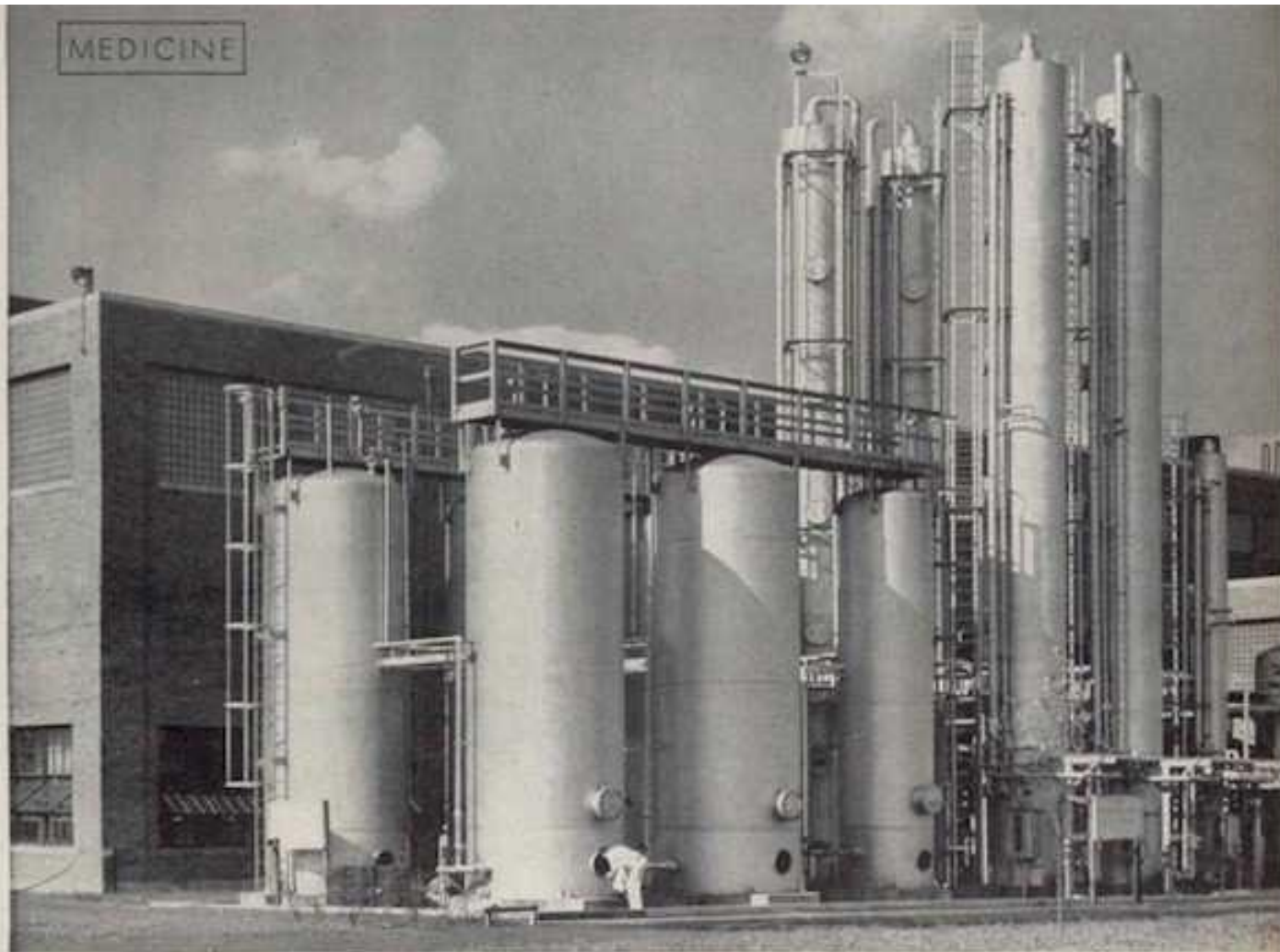
- 1<sup>st</sup> human patient was a policeman with staphylococcal & streptococcal infections which had already taken part of his face and an eye
- He began to recover, but later died
- 2<sup>nd</sup> patient was a 15 yr. old boy septic from a hip operation
- Two days after receiving penicillin his temperature dropped back to normal after being at 100° for 2 wks

- By D-Day the U.S. was making millions of doses.
- Unfortunately, neither Heatley nor his boss patented the discovery. This was done by U.S. firms.
- Thus for 25 yrs. England had to pay royalties on its own discovery.





MEDICINE



MUCH TANKS AND STILLAS ARE PART OF THE COMMERCIAL SOLVENTS' PENICILLIN PLANT IN TERRE HAUTE, IND. THIS IS ONE OF 10 U. S. PLANTS MASS-PRODUCING THE DRUG

# PENICILLIN

MASS PRODUCTION OF DRUG REPLACES SLOW LABORATORY METHODS TO MEET MILITARY NEEDS AND PROVIDE A LIMITED CIVILIAN SUPPLY

## Genetics - historical perspective

- Practical genetics 7,000 years ago
- corn breeding - Central America
- rice breeding - China
- horse pedigree - Babylon

## Genetics - science - Mendel

A **domesticated animal** is one which has been bred in captivity  
Thru **artificial selection** they are modified from their ancestors  
for use by humans



Before



After

Wolf/Dog domestication lead to:

Alteration in body size

Reduction in skull & tooth size

Shortening of the jaw bones

Affection for humans

Variation in coat color

Tendency towards barking

By 6000BC dog skeletons are found along side human remains



Modern sheep have been bred not to lose their wool

Most domesticated species arose in SW Asia  
or China

- Of the ~150 species of terrestrial non-carnivores >100 lbs, only 14 have been domesticated
- 13 are of Eurasian origin, one from mesoamerica
- None derive from Australia or sub-Saharan Africa

# Desirable Characteristics for Domestication of an Animal Species

- Value to humans as food, draft, fiber, or hunting
- Large herbivores offer energy use advantages
- Rapidly reach their desired size
- Must be able to breed in captivity
- Good disposition & social structure

# Plant Domestication

The switch from hunter-gatherer to farmer took place between 10 000 & 5 000 years ago

- Both Eurasia & the Americas developed large numbers of domesticated crops
- The development of agriculture required changes in wild plants such that they were amenable to cultivation
- Many of these changes were either brought about by humans or were capitalized by them

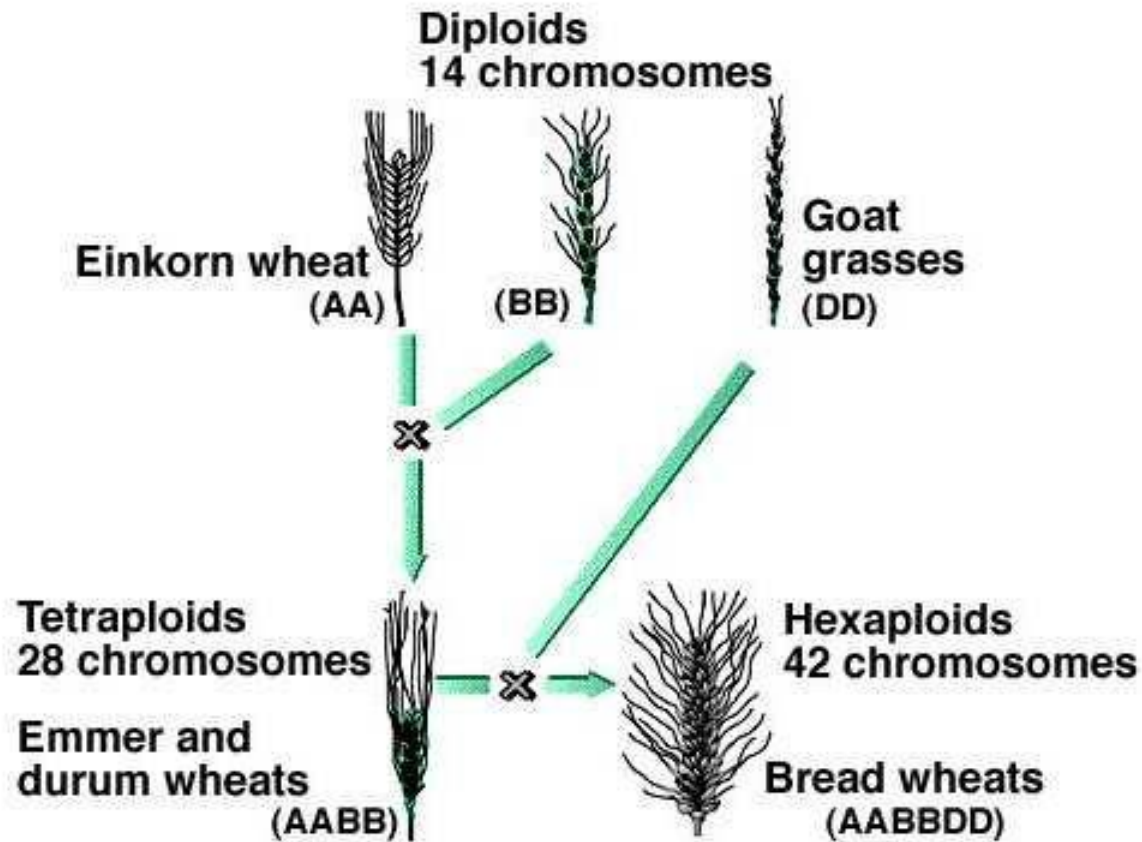


## Example

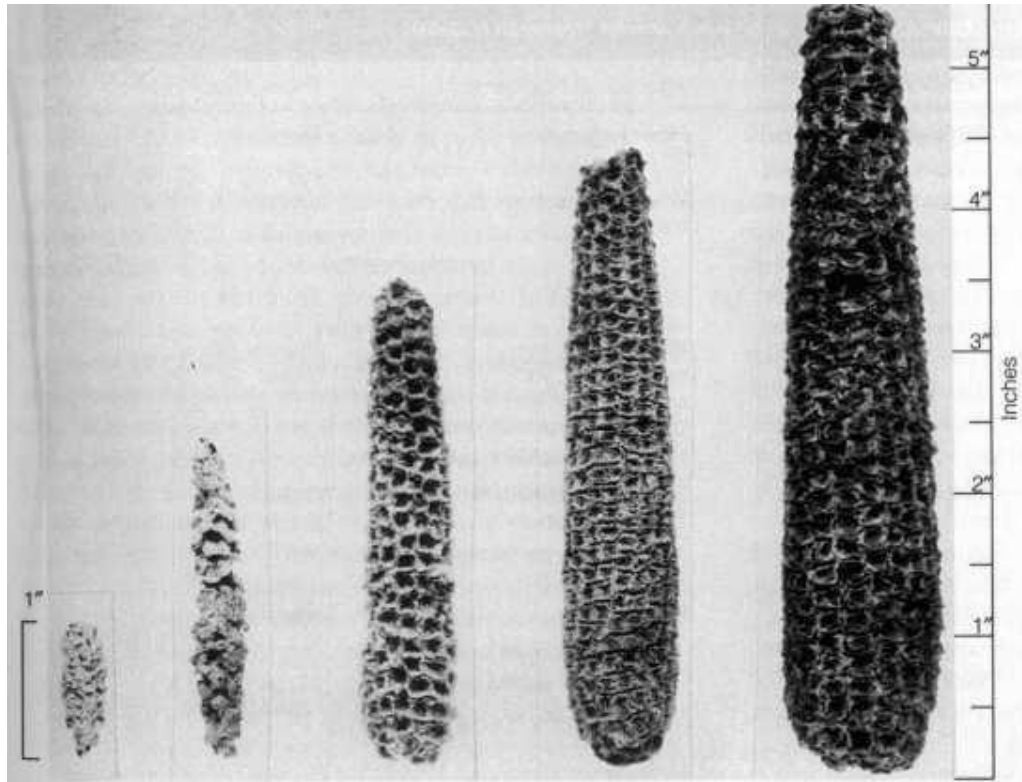
- Wheat is a grass spread seeds called grains
- Mutants developed that did not lose seed
- This made it easier for humans to collect



Hybridization played a role in the evolution of modern grains



The evolution of modern corn took several thousand years  
Selection for larger ears by mesoamericans created modern corn by the time Europeans had reached the Americas



Changes in corn size from 5000 BCE to 1500CE

Mutation responsible for this change has been identified

It is not a change in a gene itself, rather it is a decrease in the expression of the gene *tb1*



Selection for  
ear and plant  
morphology



⇓⇓ Regulation  
of *tb1* gene





## Mendelian Analysis

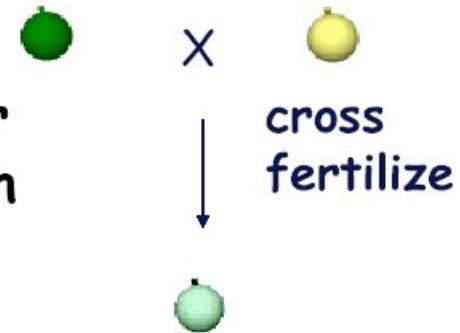
Gregor Mendel,  
Father of  
Genetics

1822-1884

# Prevalent Theories

- Blending inheritance:

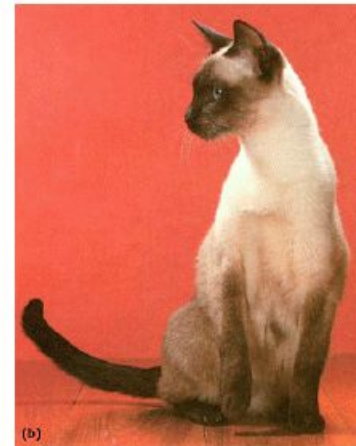
- Substances blended together to yield unique individual with traits from both parents



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- Darwin:

- Particles, called gemmules, were collected from all parts of body and became concentrated in germ cells



Mendel was skeptical of these ideas, and was particularly intrigued by some early observations by Kolreuter, 1840.

Crossed purple flowered plants with white flowered plants, the progeny were all purple, but then in the next generation, white flowered plants reappeared.

How can it be that traits can be lost in the hybrid, and then reappear in the next generation.

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# Who was Mendel?

## What did he do differently?



Mendel was trained in several disciplines.

- Physics (with Christian Doppler)
- Mathematics
- Botany

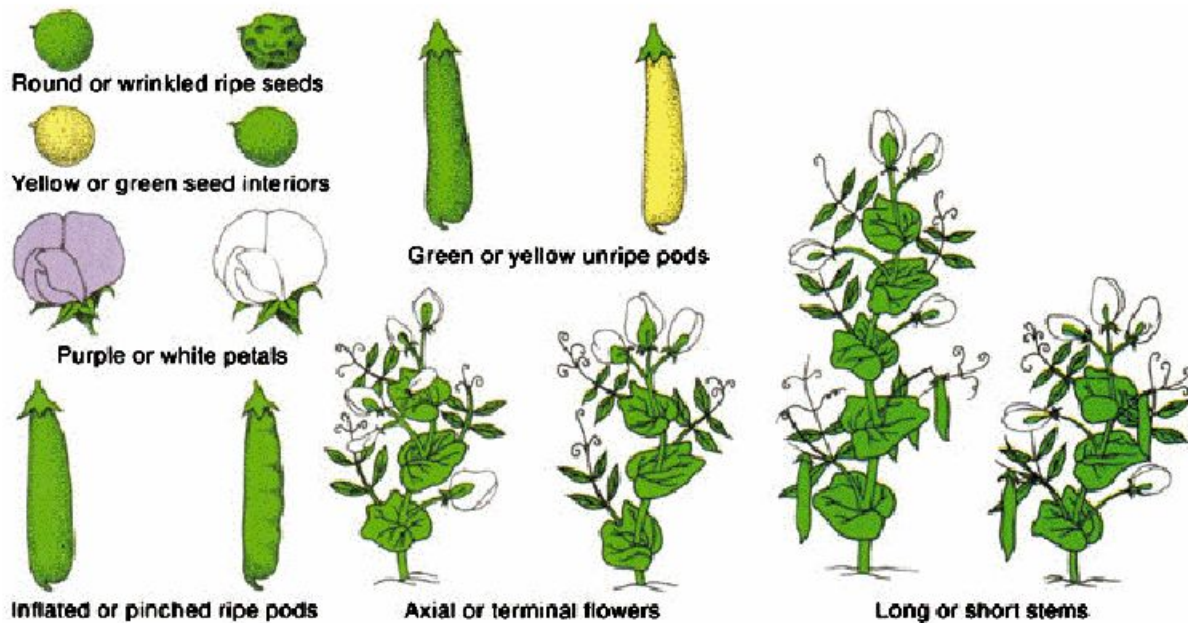


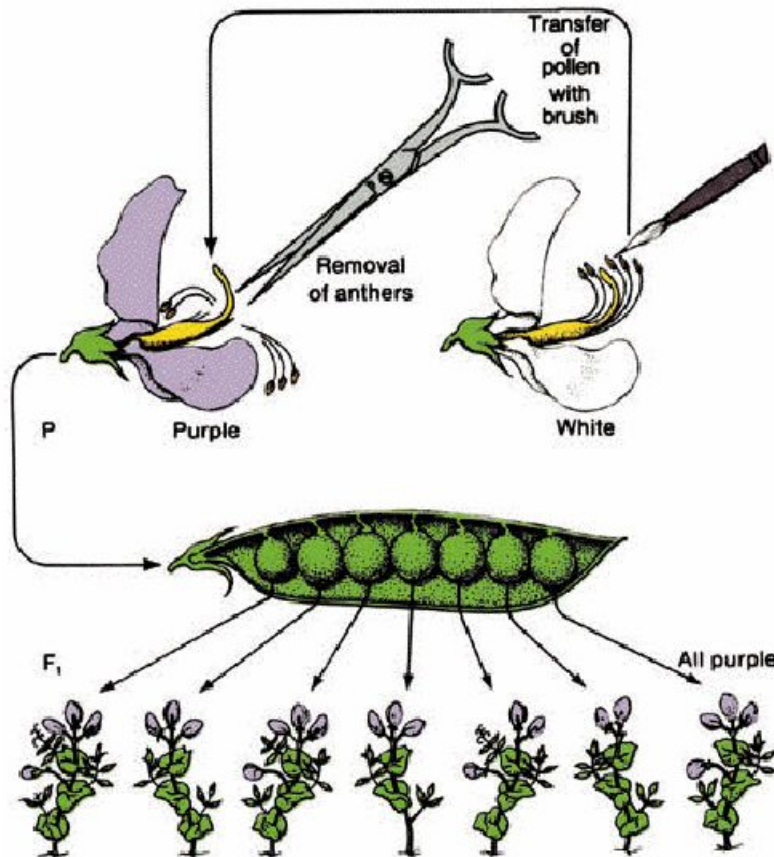
# **Mendel brought to Biology methods that were standard in Physics**

- Limited the number of variables
- Quantitated results
- Came up with models that could be tested

# Mendel did the following:

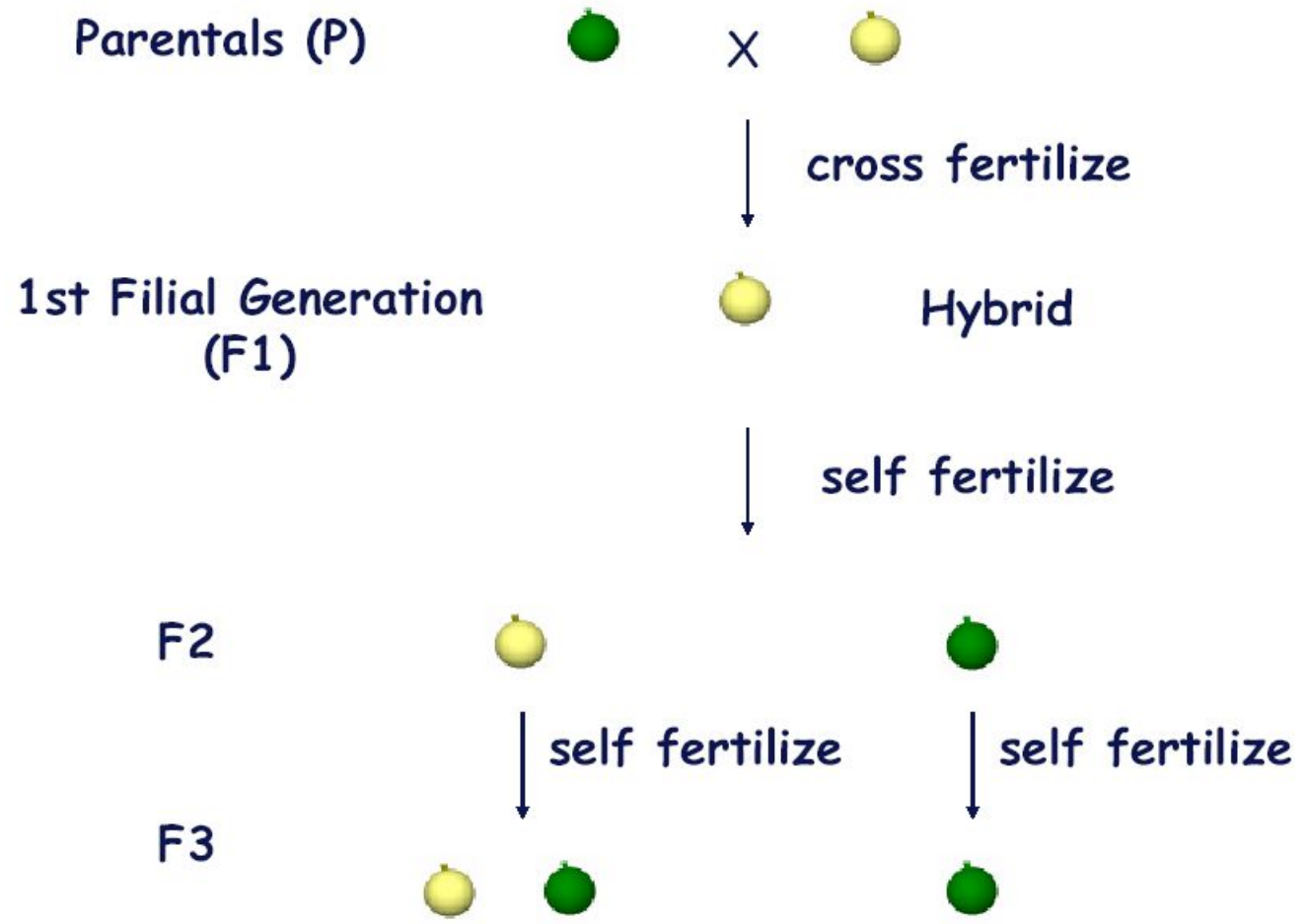
1. Isolated pure true-breeding lines of peas for seven different characteristics (plants that breed the same characteristics after selfing for at least two generations).





**Cross fertilize:**  
 Transfer pollen from one plant to the ovule of the second plant

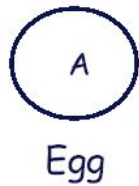
**Self fertilize:**  
 Allow pollen of the plant to fertilize its own ovules



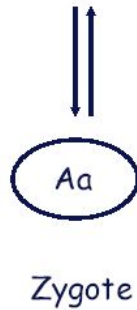
Parents	F1 (hybrid)	self	F2
yellow	yellow	yellow	green
X		6022	2001
green			3:1

How could one explain the 3:1 ratios observed in monohybrid crosses?

Mendel had a strong background in probabilities and quickly developed a model



Single determinant in egg and sperm that come together in the zygote.



The simplest

## Mendel's Theory

- 1-Hereditary determinants are of a *particulate* nature
- 2-Each adult pea has 2 determinants (which we now call alleles) for each character
- 3-The *gametes* only have 1 determinant for each character
- 4-Each determinant *segregates* equally into gametes
- 5-Union of 2 gametes occurs *randomly* with regard to genetic determinants

## **Schematically:**

**Y - dominant allele\*, yellow**  
**y - recessive allele, green**

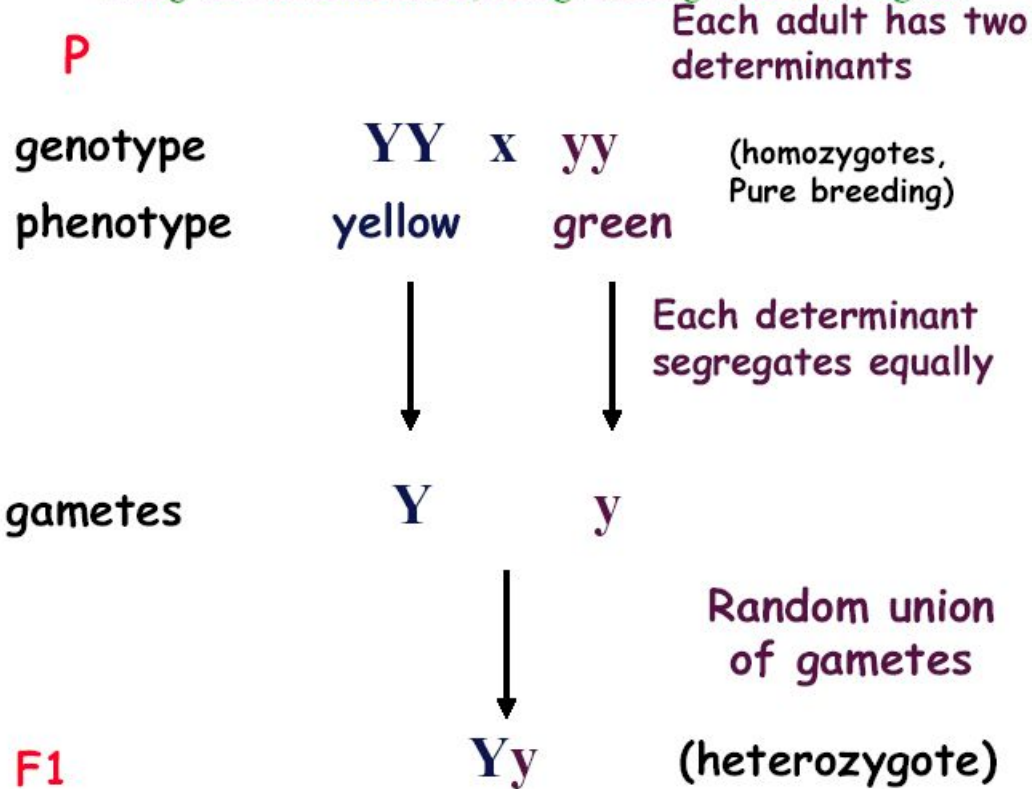
Each adult has two determinants:

If both are the same, **homozygous**

If they are different, **heterozygous**

**\* different forms of same gene**

Using this nomenclature, lets go through the cross again.





**F2 results**

Equal segregation  
of determinants



**F1 male gametes (pollen)**

$1/2 Y$     $1/2 y$

**F1 female gametes (egg)**

$1/2 Y$	<b>YY</b>	<b>Yy</b>
$1/2 y$	<b>Yy</b>	<b>yy</b>

Punnett Square

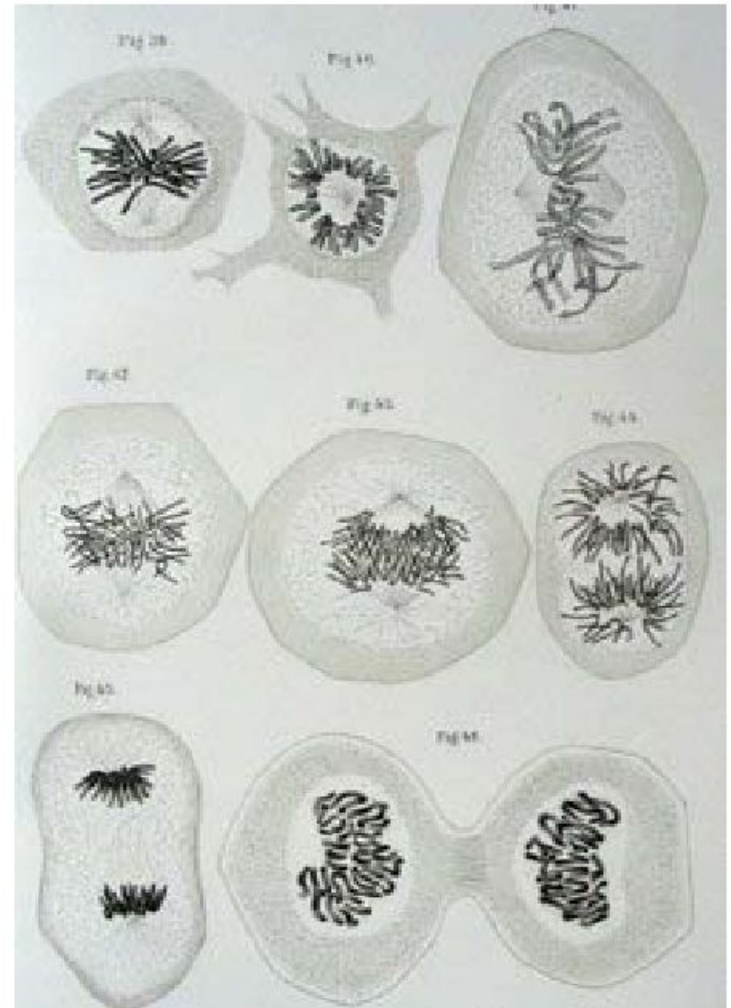
$1/4 YY + 1/2 Yy + 1/4 yy$

Genotypic ratio.

**1 : 2 : 1**

# 1882 - Walter Fleming

- Stained cells with dyes and discovered rod-shaped bodies
- Chromosomes – colored bodies

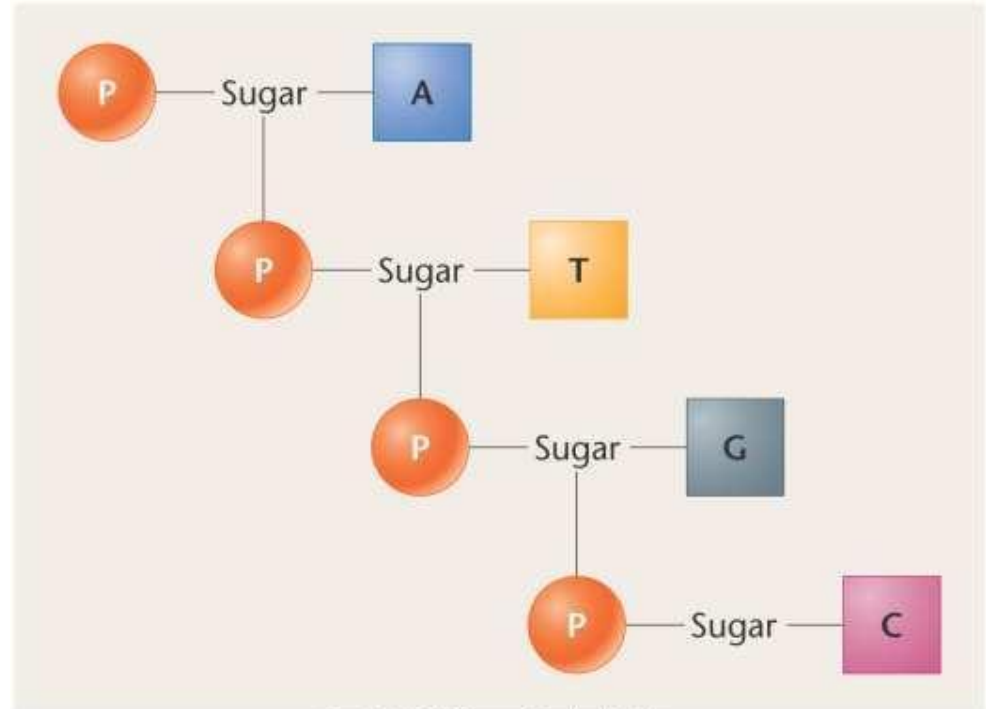


# Later Concepts

- 1900 - Not until 34 years after its publication did Mendel's work receive additional attention, with publications in 1900 by three Botanists: Hugo de Vries, Carl Correns, and Erich von Tsernak;
- 1902 - Walter Sutton first integrated the concepts of chromosomes with Mendel's laws, in studies of grasshopper reproduction and cell division and concluded that Mendel's heritable factors must be on the chromosomes.
- 1907 – T.H. Morgan began his work with fruit flies, ultimately mapping gene locations.

# First Structure

- By 1910 actual components known (nucleotides)
  - Phoebus Levene proposed a tetranucleotide structure for DNA



- Tetranucleotide repeat of ATCG
- Own data showed nucleotides not in 1:1:1:1 ratio
  - Differences “probably experimental error...”

## So...

- If DNA was a single covalently bonded tetranucleotide structure then it couldn't easily encode information
- Proteins, on the other hand, had 20 different amino acids and could have lots of variation
- Most geneticists focused on “transmission genetics” and passively accepted proteins as being the likely genetic material

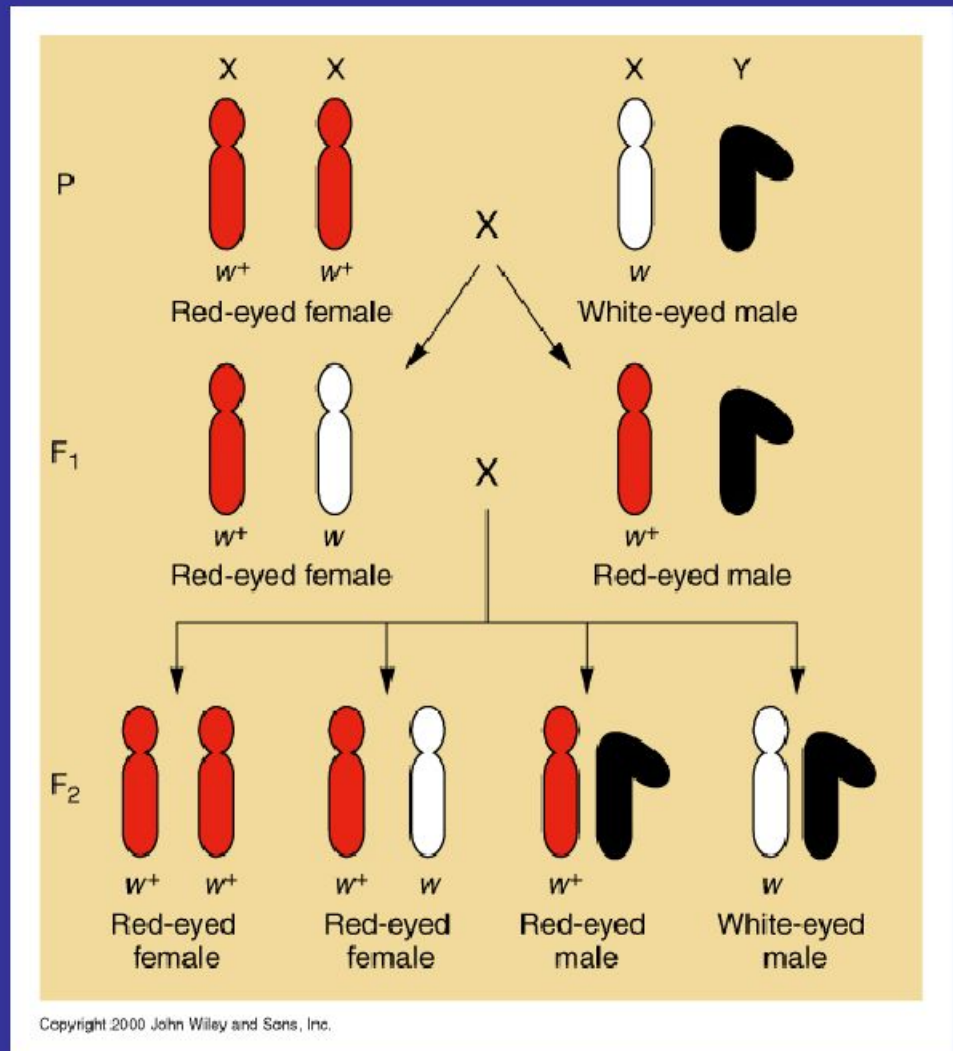
# T. H. Morgan's Fruit Flies 1907-1930s



# Fig. 6.3 Morgan's hypothesis diagramed

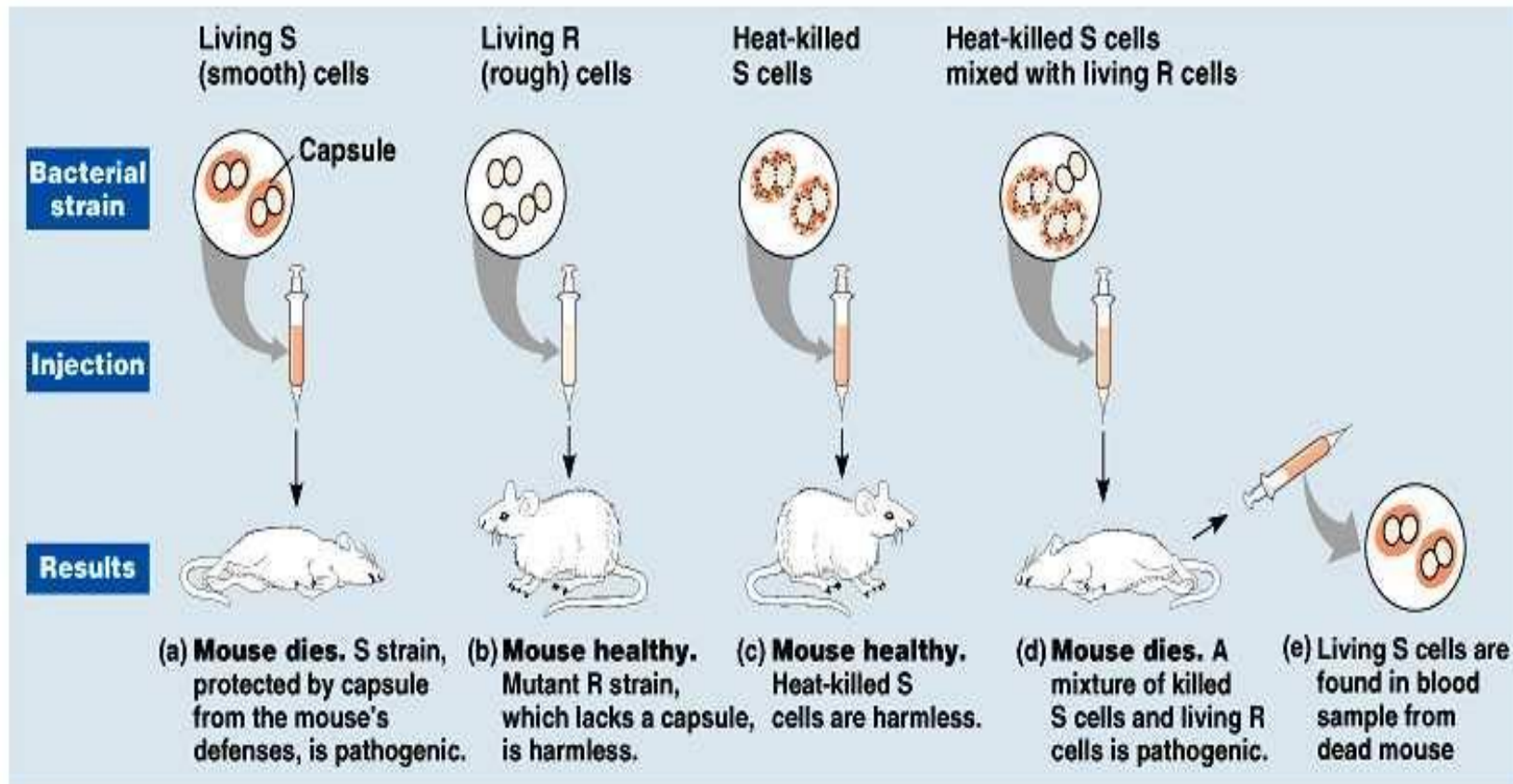
$w$  is on X chr.

There is no  $w^+$  allele on Y



# Frederick Griffith, 1928

## Transformation of Bacteria



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Transforming factor ?



# Avery, McCarty and MacLeod

- After 10 yrs of effort published work using Griffith's approach to assay for the genetic material
  - Used
    - Cell-free extract of S cells
    - From 75 liters of cell culture obtained 10-25 mg of “active factor
    - Proteases, RNases, DNases, etc.
  - Transforming factor is DNA

# Erwin Chargaff

- 1949-1953
- Digested many DNAs and subjected products to chromatographic separation
- Results
  - $A = T, C = G$
  - $A + G = C + T$  (purine = pyrimidine)
  - $A + T$  does not equal  $C + G$ 
    - Members of a species similar but different species vary in AT/CG ratio

TABLE 10.3

## DNA BASE COMPOSITION DATA

## (a) Chargaff's data\*

Molar proportions<sup>a</sup>

Organism's/Source	1	2	3	4
	A	T	G	C
Ox thymus	26	25	21	16
Ox spleen	25	24	20	15
Yeast	24	25	14	13
Avian tubercle bacilli	12	11	28	26
Human sperm	29	31	18	18

## (c) G + C content in several organisms

Organism	%G + C
Phage T2	36.0
<i>Drosophila</i>	45.0
Maize	49.1
<i>Euglena</i>	53.5
<i>Neurospora</i>	53.7

## (b) Base compositions of DNAs from various sources

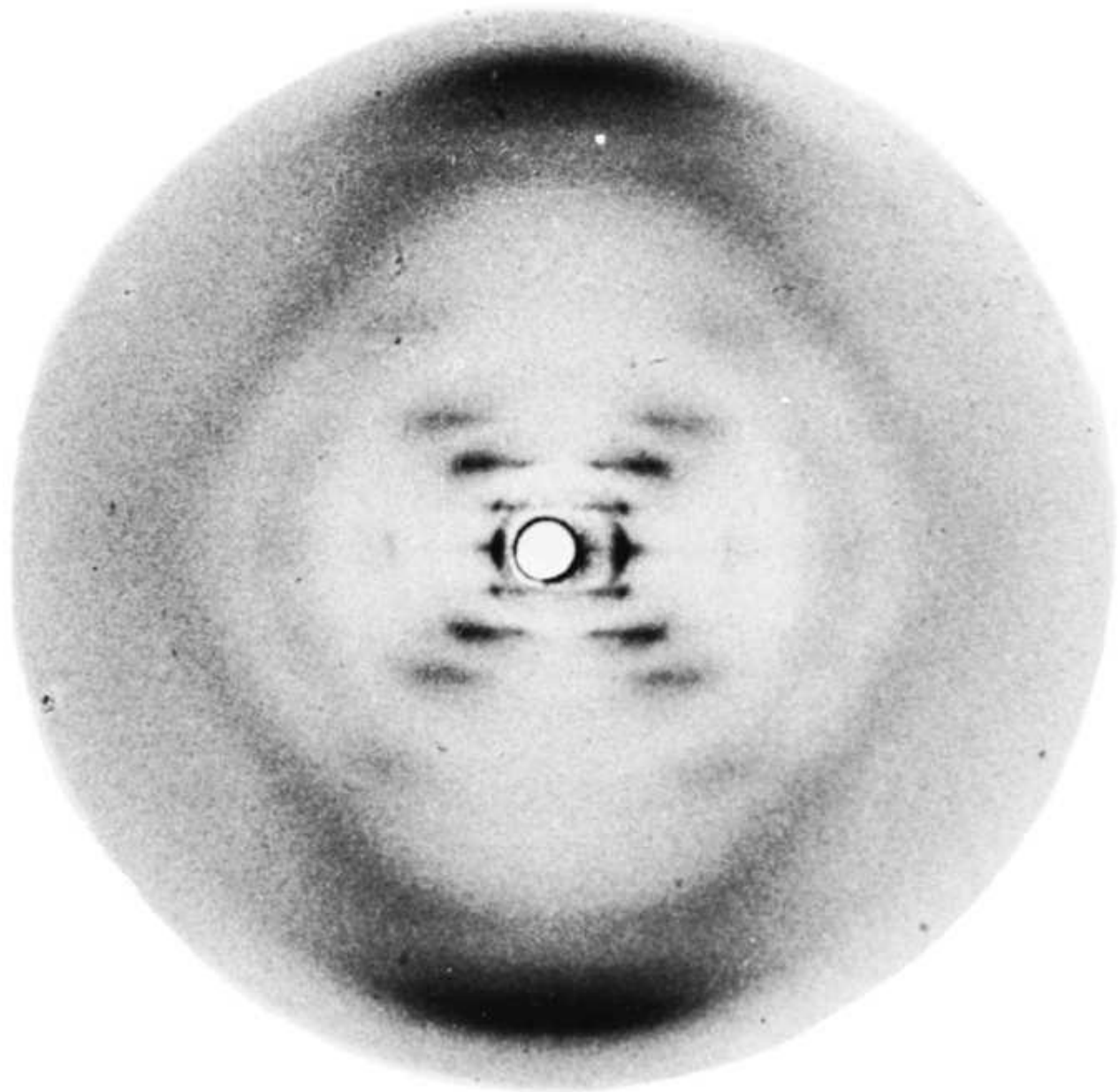
Source	Base composition				Base ratio		A + T/G + C ratio	
	1	2	3	4	5	6	7	8
	A	T	G	C	A/T	G/C	(A + G)/(C + T)	(A + T)/(C + G)
Human	30.9	29.4	19.9	19.8	1.05	1.00	1.04	1.52
Sea urchin	32.8	32.1	17.7	17.3	1.02	1.02	1.02	1.58
<i>E. coli</i>	24.7	23.6	26.0	25.7	1.04	1.01	1.03	0.93
<i>Sarcina lutea</i>	13.4	12.4	37.1	37.1	1.08	1.00	1.04	0.35
T7 bacteriophage	26.0	26.0	24.0	24.0	1.00	1.00	1.00	1.08

\* Source: From Chargaff, 1950.

<sup>a</sup>Moles of nitrogenous constituent per mole of P. (Often, the recovery was less than 100 percent.)

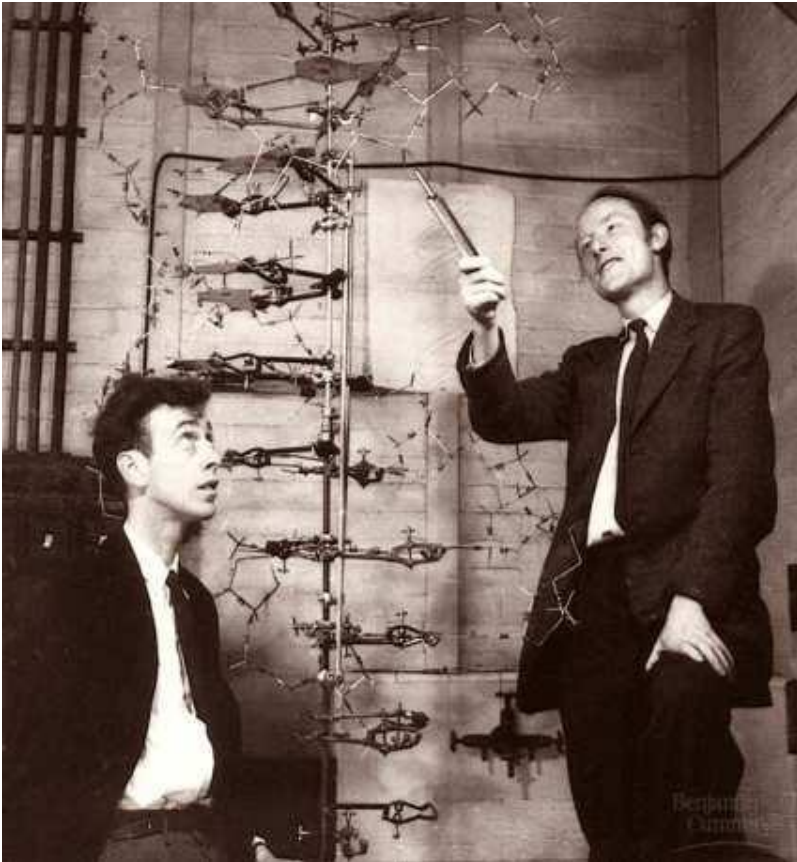
# X-ray Crystallography of DNA

- Franklin and Wilkins



# Watson and Crick

- 1953 propose double helix model
  - Right-handed double helix



Collaborated at Cambridge, England.

# Impact

- Article in *Nature*
  - “It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copy mechanism for the genetic material”
    - Second paper 2 months later describes semiconservative replication and that mutations must change bases in DNA (information encoded in the bases and their order)
- DNA became the genetic material...

# DNA Replication

