




Multiple Gene Inheritance

Ch3.1 – 3.3

(skip the section on synthesizing pure lines and hybrid vigor)

Genes are inherited from one generation to the next in the form of chromosomes

	Organism	Number of chromosomes
	pea plant	14
	sun flower	34
	cat	38
	puffer fish	42
	human	46
	dog	78

Adder's-tongue fern is estimated to have 1440 chromosomes (720 pairs)

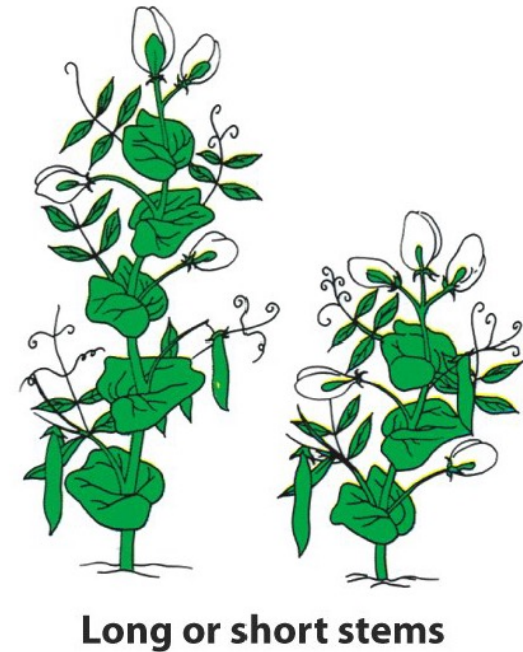
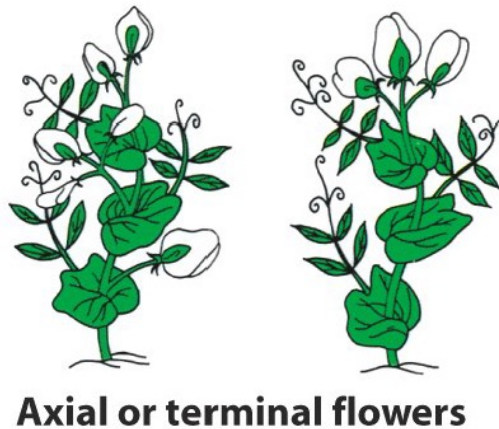
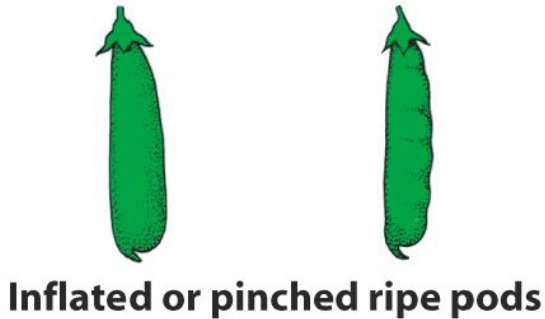
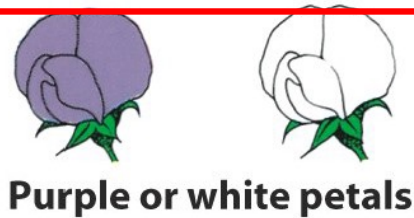
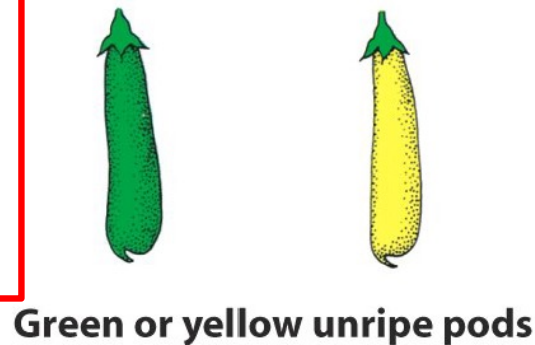
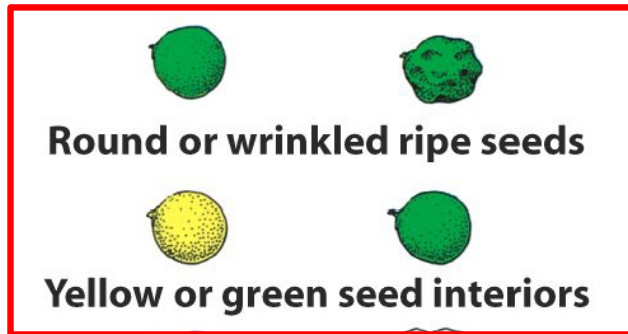
Atlas blue butterfly, 448–452 chromosomes (i.e. 224–226 pairs)

<http://www.genomenewsnetwork.org/>

Genes on the **same** vs. **different** chromosomes

Mendel's pea plant has 7 pairs of chromosomes

7 traits that Mendel used to demonstrate independent assortments, all monogenic traits



Gene for seed color is located on chromosome 1

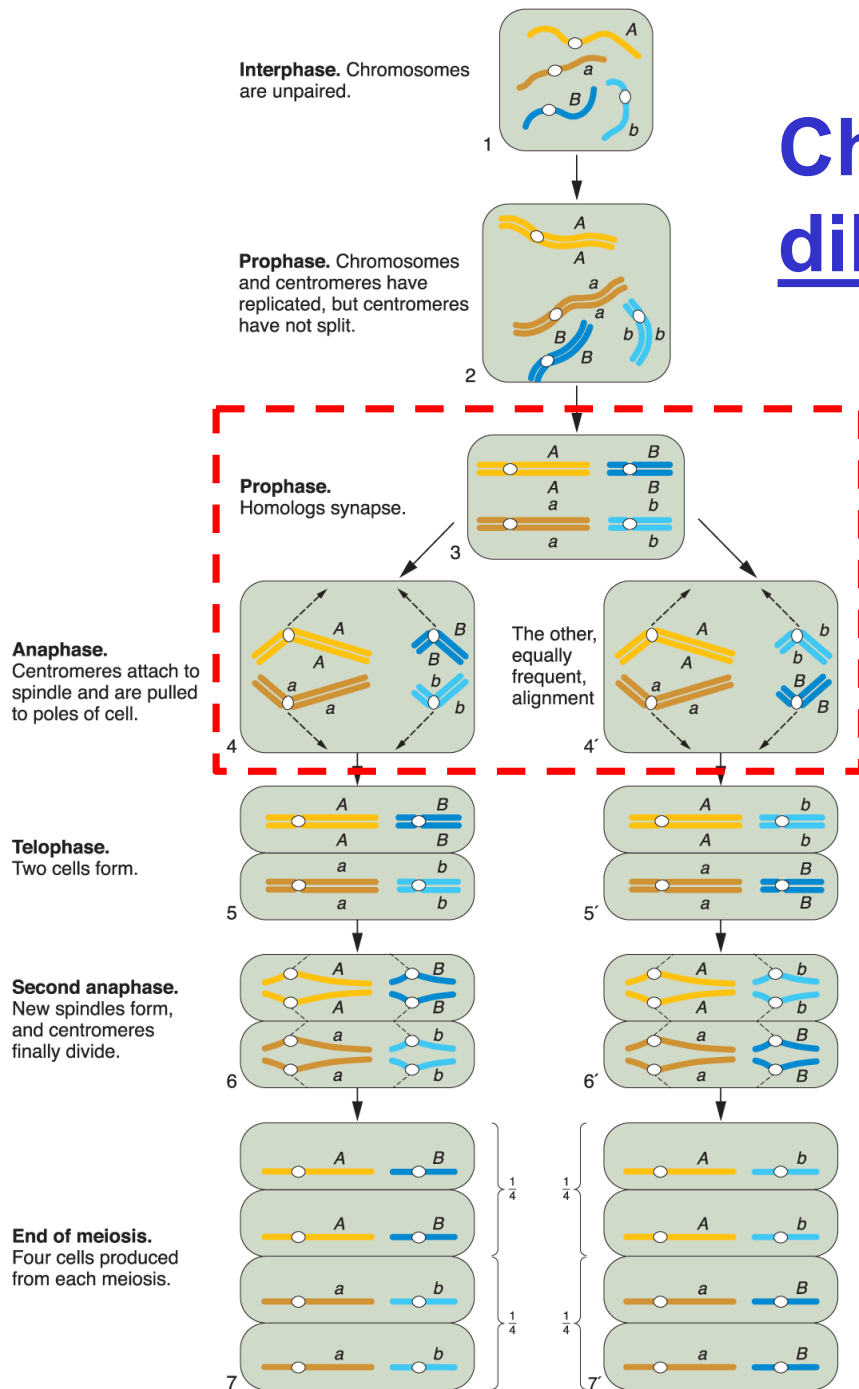
Gene for seed shape is located on chromosome 7

Chromosome segregation of a dihybrid during meiosis

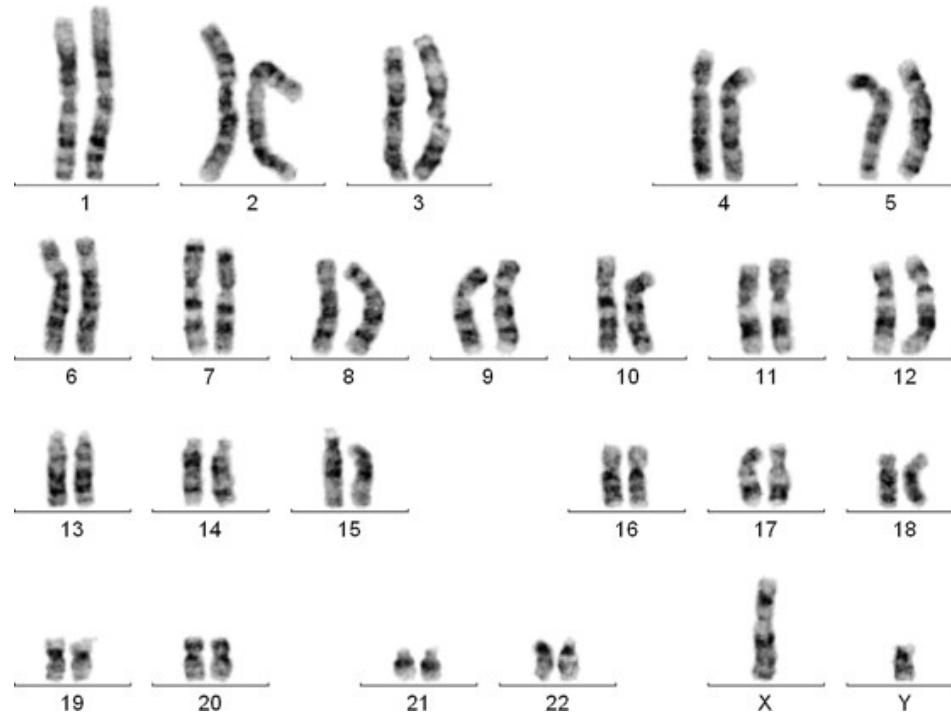
Fig 3-8

Animation on E-book

Independent assortment,
resulting in the equal ratio of
four different genotypes of
gametes, A B, a b, A b, a B.

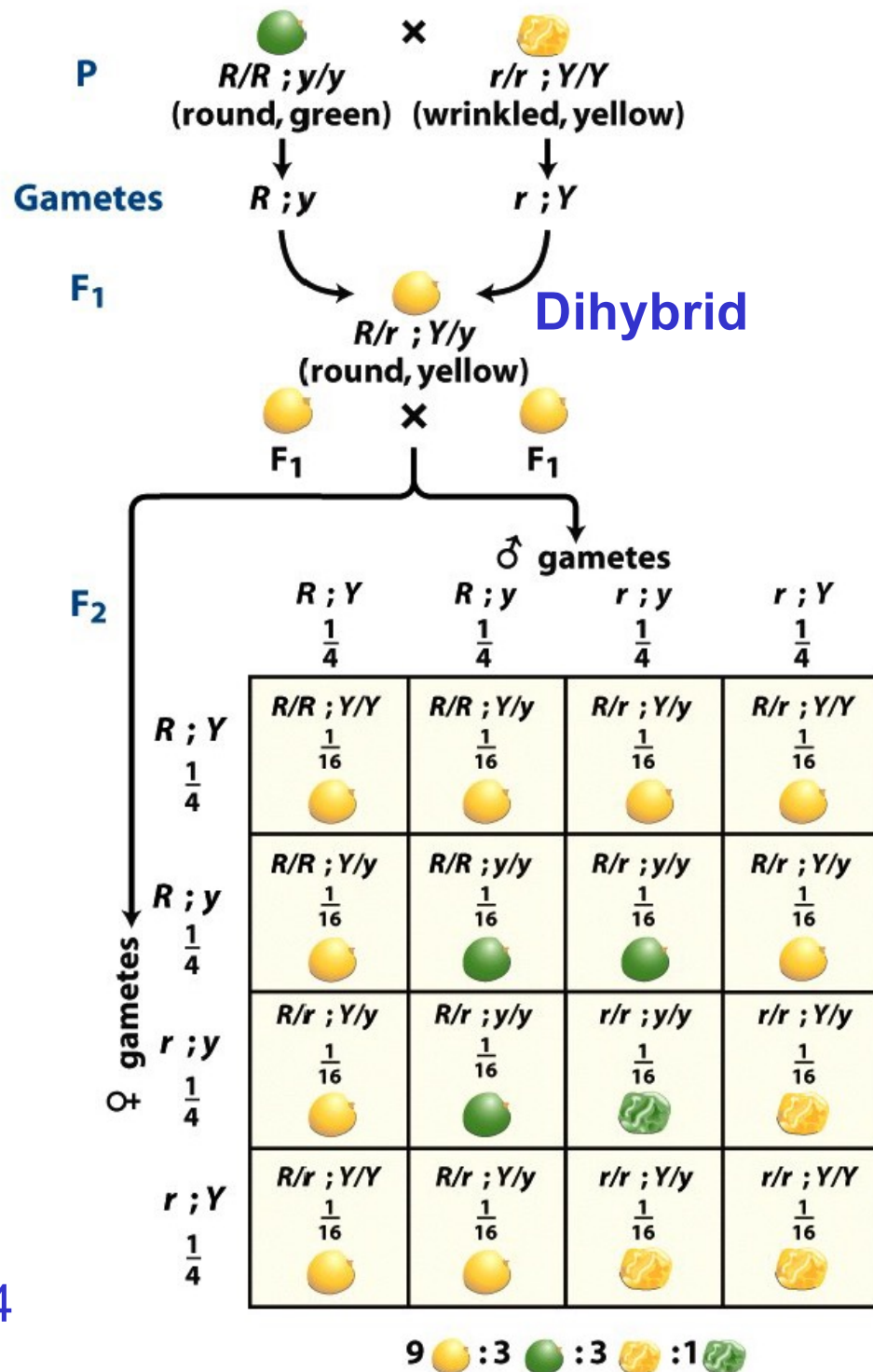


Independent assortment in humans



How many different genotypes of gamete can a human produce solely via independent assortment?

What is the probability that the paternal chromosome 1 and 2 are transmitted to a single gamete in human?



4 X 4 = 16 different combination of fertilization patterns

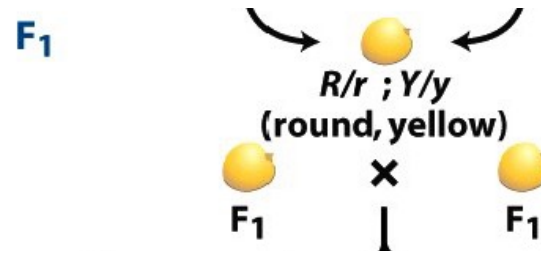
Some of them produce progeny with the same genotype while others result in a unique genotype.

In terms of phenotype, they result into 4 different phenotypes in 9:3:3:1 ratio

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

Fig 3-4

Another way to think about dihybrid cross....



round, yellow

round, green

wrinkled, yellow

wrinkled, green

Assume that we have two plants of genotypes

$A/a; b/b; C/c; D/d; E/e$

&

$A/a; B/b; C/c; d/d; E/e$

From a cross between these plants, we want to recover a progeny plant of genotype $a/a; b/b; c/c; d/d; e/e$. What proportion of the progeny should we expect to be of that genotype?



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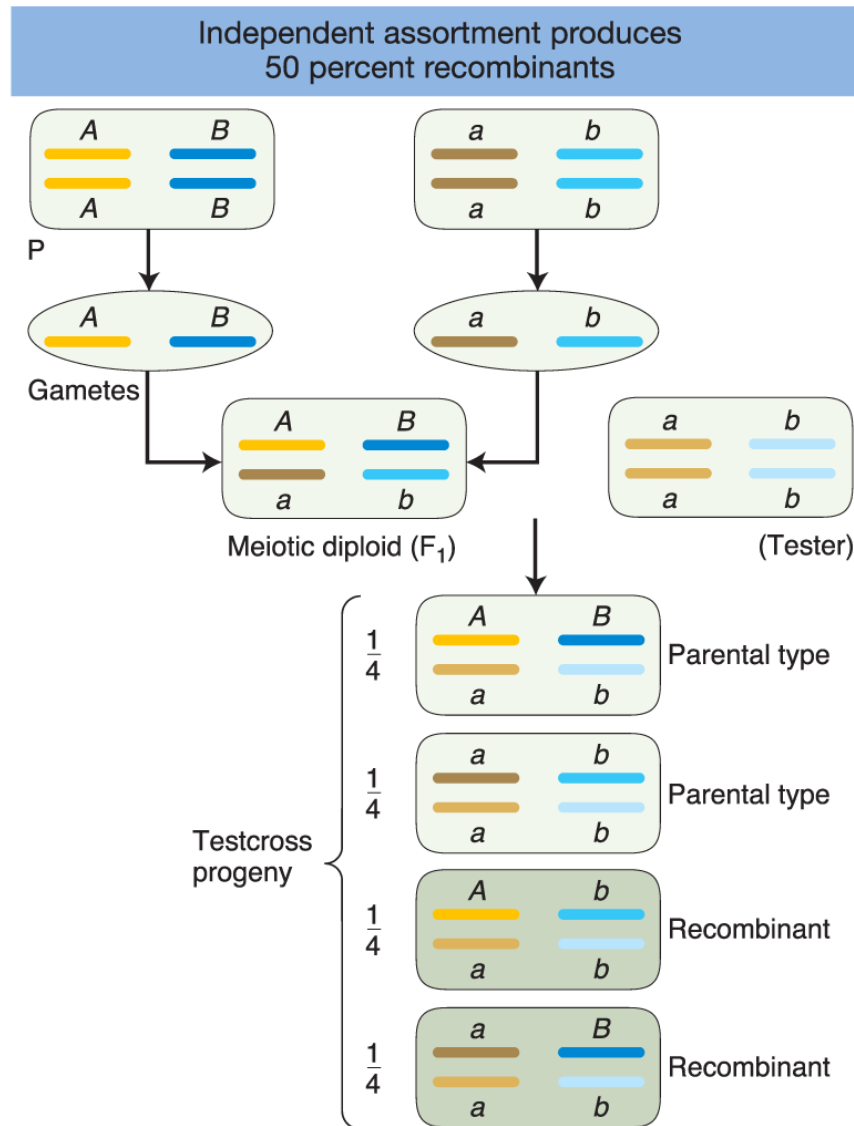
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From a cross between these plants, we want to recover a progeny plant of genotype $a/a; b/b; c/c; d/d; e/e$. What proportion of the progeny should we expect to be of that genotype?

Other examples in the textbook

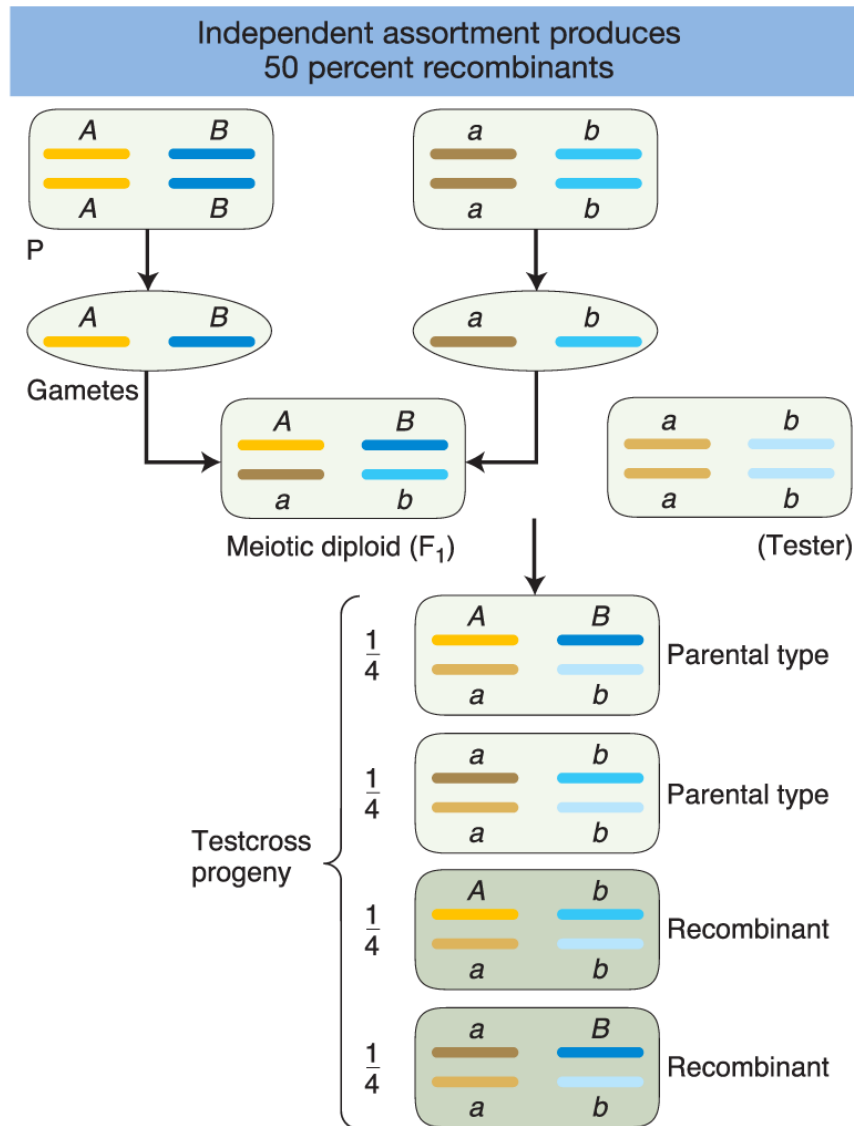
Dihybrid testcross produces equal number of parental and recombinant type



The testcross is an easy way to determine the genotypes of gametes that a testee can produce.

Due to “independent assortment”, equal number of parental and recombinant types are observed in the progeny of a dihybrid

What if A and B are on the same chromosome?



What would be the ratio between the “parental” and “recombinant” ?

Thomas Hunt Morgan: “Chromosome theory of inheritance”



The Nobel Prize in Physiology or Medicine 1933

“His work confirmed that genes are stored in chromosomes inside cell nuclei. He came to understand that genes are organized in a long row inside chromosomes and how traits related to each other correspond to genes that lie close to one another on the chromosomes. He also discovered the crossover phenomenon, in which parts of different chromosomes can trade places with one another.”

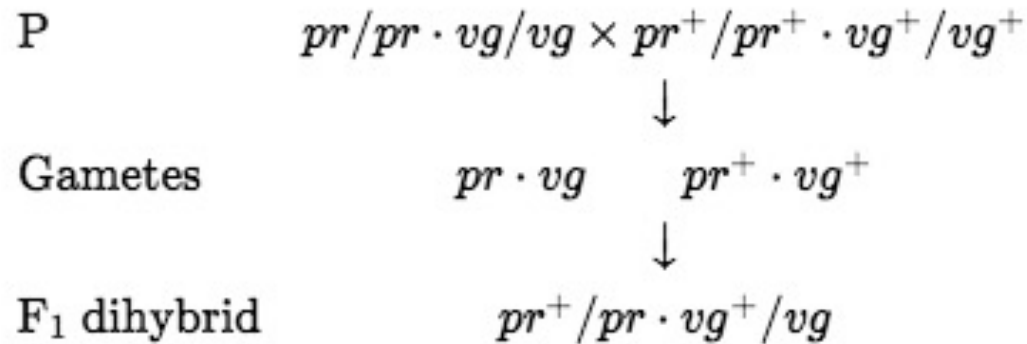
<https://www.nobelprize.org/prizes/medicine/1933/morgan/facts/>

Morgan's finding

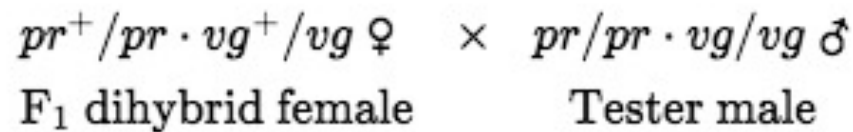
two recessive mutations

pr: purple eyes

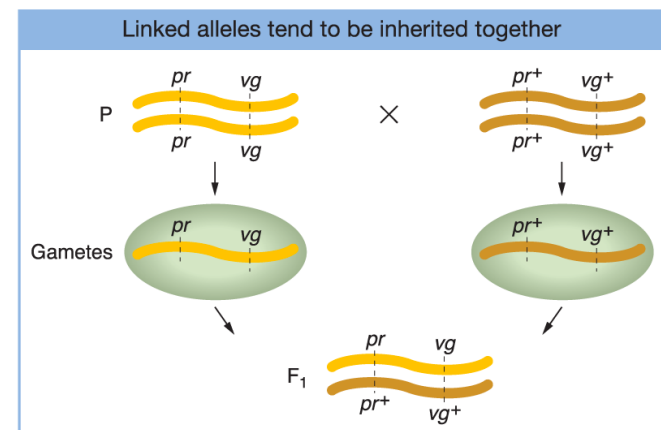
vg: smaller wings



Testcross



Parental	$pr^+ \cdot vg^+$	1339
	$pr \cdot vg$	1195
Recombinant	$pr^+ \cdot vg$	151
	$pr \cdot vg^+$	154
		<hr/> 2839



Griffiths et al., *Introduction to Genetic Analysis*, 12e, © 2020
W. H. Freeman and Company

Fig 4-2

Recombinants are produced during meiosis

$pr^+ \cdot vg^+$	1339
$pr \cdot vg$	1195
$pr^+ \cdot vg$	151
$pr \cdot vg^+$	154
	<hr/>
	2839

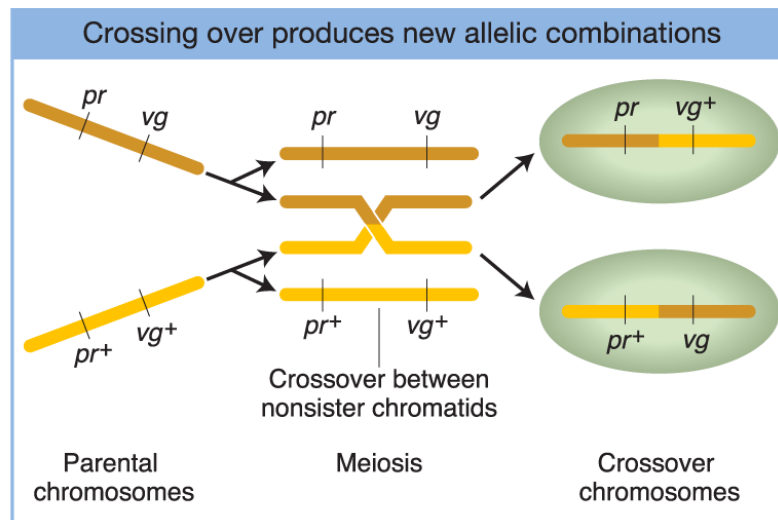


Fig 4-3

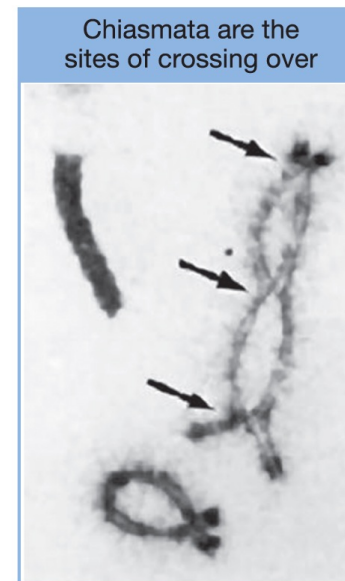


Fig 4-4

In real-life experimental settings, the observed numbers will not completely match the expected number

TABLE 2-1 Results of All Mendel's Crosses in Which Parents Differed in One Character

Parental phenotypes	F ₁	F ₂	F ₂ ratio
1. round × wrinkled seeds	All round	5474 round; 1850 wrinkled	2.96:1
2. yellow × green seeds	All yellow	6022 yellow; 2001 green	3.01:1
3. purple × white petals	All purple	705 purple; 224 white	3.15:1
4. inflated × pinched pods	All inflated	882 inflated; 299 pinched	2.95:1
5. green × yellow pods	All green	428 green; 152 yellow	2.82:1
6. axial × terminal flowers	All axial	651 axial; 207 terminal	3.14:1
7. long × short stems	All long	787 long; 277 short	2.84:1

$pr^+ \cdot vg^+$	86
$pr \cdot vg$	93
$pr^+ \cdot vg$	34
$pr \cdot vg^+$	55

How can we confidently say that pr and vg are not independently assorted?

Chi-square test

A way of determining if the of observed values significantly deviate from expected values?

$$\chi^2 = \sum (O - E)^2 / E$$

O: Observed

E: Expected

This formula helps us to determine if the degree of deviation from the expected value is significant? In science, we like 95% confidence level.

Hypothesis: *pr* and *vg* are independently assorted

		Observed		Phenotype	Expected
Parental	$pr^+ \cdot vg^+$	86		$pr^+ vg^+$	67
	$pr \cdot vg$	93		$pr vg$	67
Recombinant	$pr^+ \cdot vg$	34		$pr^+ vg$	67
	$pr \cdot vg^+$	55		$pr vg^+$	67
		Total: 268			

$$\chi^2 = \sum (O - E)^2 / E$$

Phenotype	Observed	Expected	(O-E) ²	(O-E) ² /E
$pr^+ vg^+$	86	67	361	5.3880597
$pr vg$	93	67	676	10.0895522
$pr^+ vg$	34	67	1089	16.2537313
$pr vg^+$	55	67	144	2.14925373
			SUM	33.880597

Critical value



Critical value is then used to determine the confidence level

TABLE 3-1 Critical Values of the χ^2

df	<i>p</i>									df
	0.995	0.975	0.9	0.5	0.1	0.05	0.025	0.01	0.005	
1	.000	.000	0.016	0.455	2.706	3.841	5.024	6.635	7.879	1
2	0.010	0.051	0.211	1.386	4.605	5.991	7.378	9.210	10.597	2
3	0.072	0.216	0.584	2.366	6.251	7.815	9.348	11.345	12.838	3
4	0.207	0.484	1.064	3.357	7.779	9.488	11.143	13.277	14.860	4
5	0.412	0.831	1.610	4.351	9.236	11.070	12.832	15.086	16.750	5
6	0.676	1.237	2.204	5.348	10.645	12.592	14.449	16.812	18.548	6
7	0.989	1.690	2.833	6.346	12.017	14.067	16.013	18.475	20.278	7
8	1.344	2.180	3.490	7.344	13.362	15.507	17.535	20.090	21.955	8
9	1.735	2.700	4.168	8.343	14.684	16.919	19.023	21.666	23.589	9
10	2.156	3.247	4.865	9.342	15.987	18.307	20.483	23.209	25.188	10
11	2.603	3.816	5.578	10.341	17.275	19.675	21.920	24.725	26.757	11
12	3.074	4.404	6.304	11.340	18.549	21.026	23.337	26.217	28.300	12
13	3.565	5.009	7.042	12.340	19.812	22.362	24.736	27.688	29.819	13
14	4.075	5.629	7.790	13.339	21.064	23.685	26.119	29.141	31.319	14
15	4.601	6.262	8.547	14.339	22.307	24.996	27.488	30.578	32.801	15

df: **degree of freedom** (number of independent value -1)

$p=0.05$ means that there is 5% chance of getting observed number even if independent assortment is true. If $p < 0.05$, you can reject the hypothesis with the confidence level of 95% or greater