BIOL 153: INTRODUCTORY GENETICS

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Principle of Independent Assortment

- What happens when two traits (dihybrid) are considered simultaneously?
- E.g. yellow, round seeds with green, wrinkled, seeds (GGWW with ggww)

- Mendel formulated the law of independent assortment, which states that;

- **Genes for different characters are inherited independently of one another.**

- He derived this law from the results of crosses between plants that were different with respect to two separate characters.

- He crossed plants having round, yellow seeds with wrinkled, green seed plants.

- The F1 plants all had round, yellow seeds.

Yellow, Round
Seed Parent

Green, Wrinkled
Pollen Parent

P : GGWW X ggww

GW gw

F_1 :

Seed Parent
GgWw

GgWw
selfed
X

Pollen Parent
GgWw

GW Gw gW gw
Male Gametes

GW Gw gW gw
Female Gametes

F_2 :

- When the F_1 hybrids could self-fertilize, they produced an F_2 generation that had all four possible combinations of the two seed characteristics.

- The phenotypes were observed in a definite pattern.

	GW	Gw	gW	gw
GW	GW GW	Gw GW	gW GW	gw GW
Gw	GW Gw	Gw Gw	gW Gw	gw Gw
gW	GW gW	Gw gW	gW gW	gw gW
gw	GW gw	Gw gw	gW gw	gw gw

556

Phenotypes	Genotypes		Genotypic Frequency	Phenotypic Ratio
Yellow, Round	GGWW		1	9
	GGWw	315	2	
	GgWW		2	
	GgWw		4	
Yellow, Wrinkled	GGww	101	1	3
	Ggww		2	
Green, Round	ggWW	108	1	3
	ggWw		2	
Green, Wrinkled	ggww	32	1	1

Figure 1.3 Diagram and Summary of a cross between a variety of garden peas with yellow, round seeds and a variety with green, wrinkled seeds. The $F_1 \times F_1$ represented illustrates a dihybrid cross.

- The distribution from a total of 556 seeds were;

  - ✓315 round, yellow
  - ✓108 round, green
  - ✓101 wrinkled, yellow
  - ✓32 wrinkled, green

- These results closely fit a ratio of 9:3:3:1

- The results look like two monohybrid crosses, each expected to result in a 3:1 ratio, operating together.

$(3:1)^2$ or $(3+1)^2 = (9+3+3+1)$

- This conforms to the law of probability called the "product rule"

- Not only did the members of each pair of alleles segregate, but the allelic pairs of different genes behaved independently with respect to each other.

- There are four types of gametes from the F_1 plants:

  F_1 : GgWw

  Gametes: GW; Gw; gW and gw

- The gametes occur in equal frequencies.

- This made him conclude that, members of different pairs of alleles assort independently into gametes

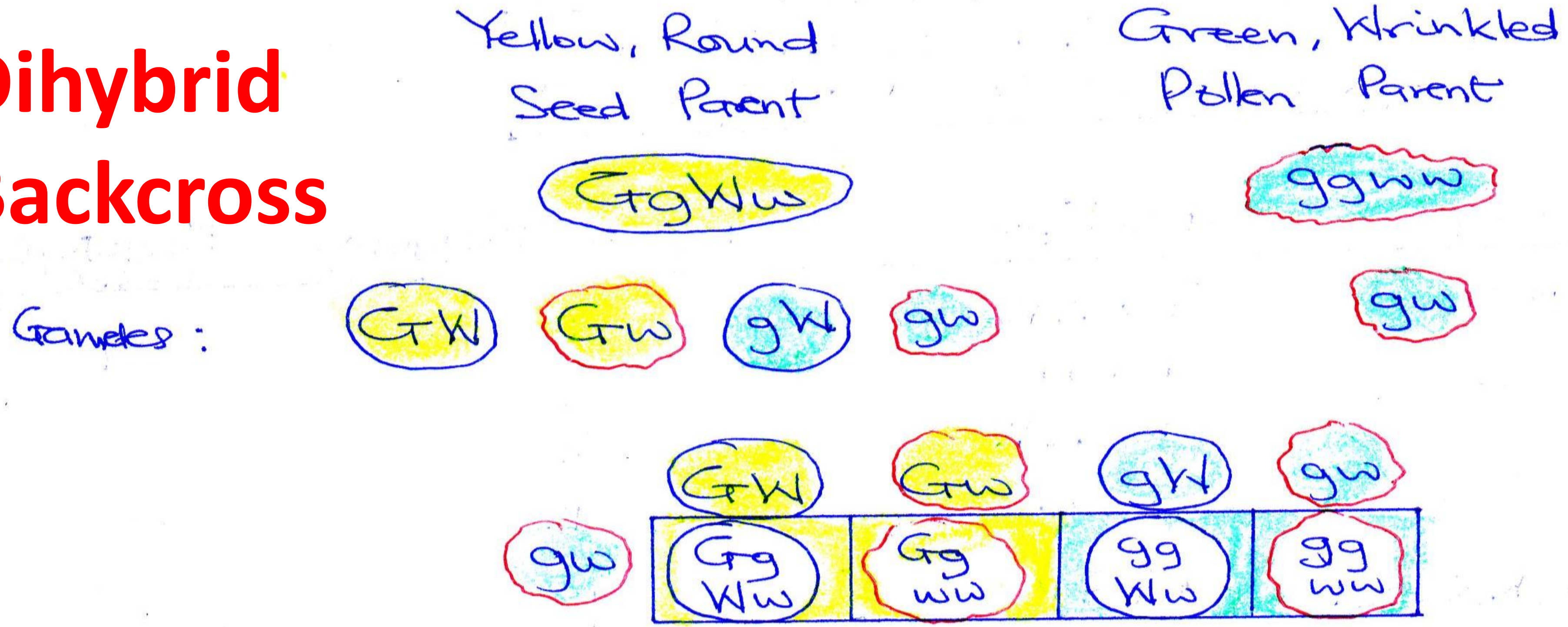
- Understanding of this principle is one of the key components considered in the design of many experiments in plant and animal breeding aimed at improving the quantity and quality of agricultural products.

Dihybrid backcross ratios

- When a 9:3:3:1 ratio results in experiments from which parental genotypes are not known, geneticists may postulate that two independent pairs of alleles are involved and that, one member of each pair behaves like dominant over its allele.

- A 1:1:1:1 ratio is expected from a dihybrid backcross to the recessive parent.
- That is, a cross between an F_1 and a parental type with the full recessive combination for these two genes.

Dihybrid Backcross



Phenotypes	Genotypes	Genotypic Frequency	Phenotypic Ratio
Yellow, Round	GgWw	1	1
Yellow, Wrinkled	Ggww	1	1
Green, Round	ggWw	1	1
Green, Wrinkled	ggww	1	1

Trihybrid Ratios

- Mendel performed experiments in which the parents differed simultaneously with three characters, called a ***trihybrid cross.***

- Such crosses are complicated.

Trihybrid Ratios

- A cross between homozygous parents that differ in three gene pairs is a combination of three-pair crosses operating together.

- (AA X aa) (BB X bb) and (CC X cc) could be combined in the same way as:

  AABBCC X aabbcc

Example

- A cross in which the seed parent is homozygous for the genes producing a **tall, yellow** and **round** vine seeds (DDGGWW) and the pollen parent is homozygous for **dwarf, green** and **wrinkled** vine seeds (ddggww) can best answer the question.

The F_1 can be illustrated as follows:

P	: DDGGWW x ddggww
Gametes	: DGW dgw
F_1	: DdGgWw

- When the F_1 plants are crossed with the full recessive type (DdGgWw x ddggww), **eight** kinds of gametes are produced by the F_1 parent and only **one** by the full recessive parent.

DGW; DGw; DgW; Dgw;

dGW; dGw; dgW; and **dgw**

- The recessive gamete is ***dgw***

Figures 1.5

back cross

Tall, Yellow, Round Seed Parent		Dwarf, Green, Wrinkled Pollen Parent
DdGgWw	×	ddggww

DGW DGw DgW Dgw dGW dGw dgW dgw   dgw

	DGW	DGw	DgW	Dgw	dGW	dGw	dgW	dgw
dgw	DGW dgw	DGw dgw	DgW dgw	Dgw dgw	dGW dgw	dGw dgw	dgW dgw	dgw dgw

Phenotypes	Genotypes	Genotypic Freq.	Phenotypic Ratio
Tall, Yellow, Round	DdGgWw	1	1
Tall, Yellow, wrinkled	DdGgww	1	1
Tall, green, Round	DdggWw	1	1
Tall, green, wrinkled	Ddggww	1	1
Dwarf, Yellow, Round	ddGgWw	1	1
Dwarf, Yellow, wrinkled	ddGgww	1	1
Dwarf, green, Round	ddggWw	1	1
Dwarf, green, wrinkled	ddggww	1	1

Forked-Line Method

- If F_1 x F_1 trihybrid crosses are to be represented by a Punnet square, 64 or $(8)^2$ squares would be required with a phenotypic ratio of 27:9:9:9:3:3:3:1
- The process is cumbersome and time consuming, so, a less tedious method must be evolved.
- This is the forked-line method.

- First, visualize the trihybrid cross as three monohybrid crosses, thus,

  F_1 x F_1 = DdGgWw x DdGgWw

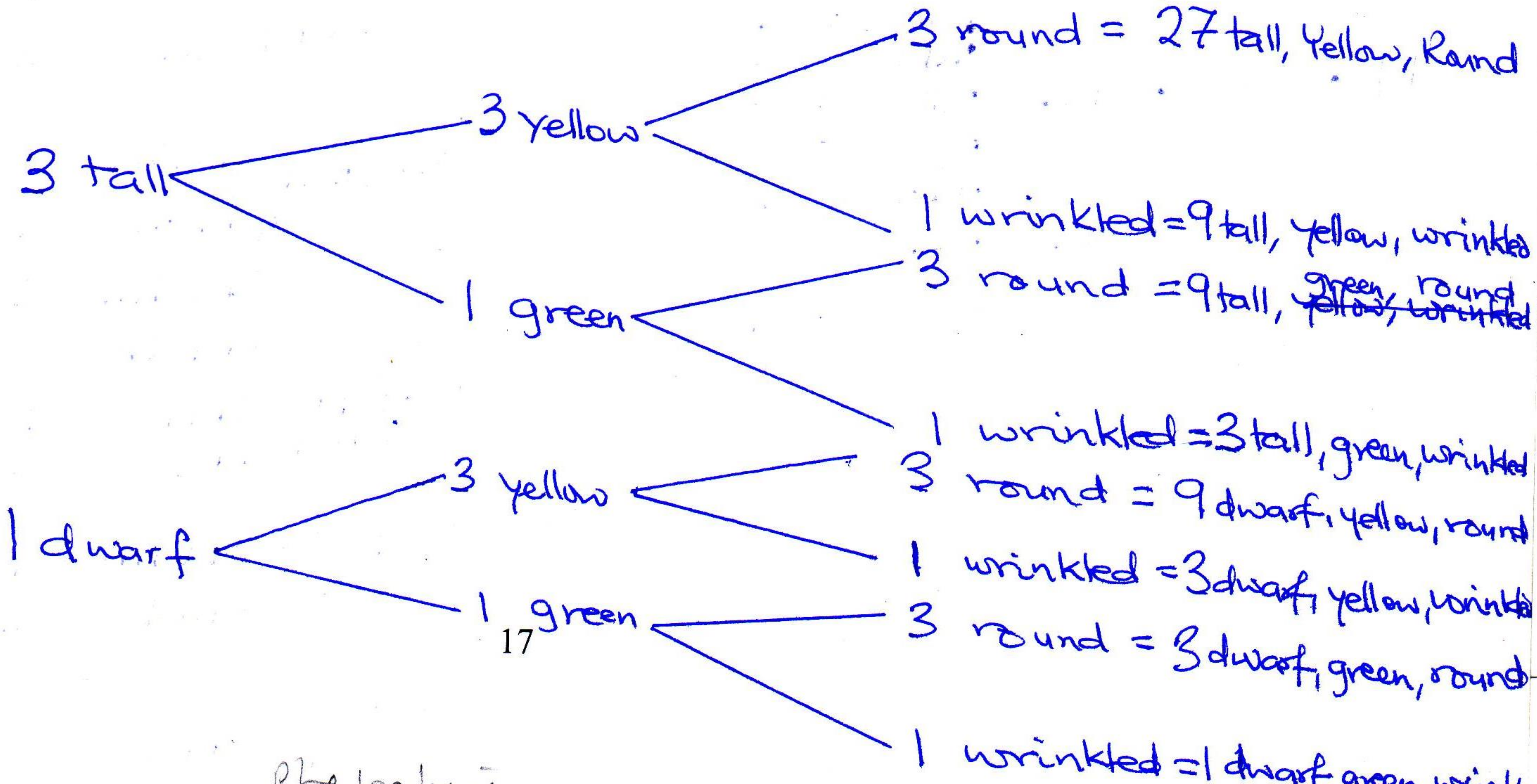
  becomes

- Dd x Dd ; Gg x Gg ; and Ww x Ww, operating together.

- If one member of each pair is dominant, a 3:1 would be predicted from each monohybrid cross.

- Since the three pairs are independent, each monohybrid segregant may occur with any combination possible from each pair of alleles.

- The combinations can therefore be systematically arranged together.


3 tall
3 yellow
3 round = 27 tall, Yellow, Round
1 wrinkled = 9 tall, yellow, wrinkled
1 green
3 round = 9 tall, green, round ~~yellow, wrinkled~~
1 wrinkled = 3 tall, green, wrinkled
1 dwarf
3 yellow
3 round = 9 dwarf, yellow, round
1 wrinkled = 3 dwarf, yellow, wrinkled
1 green
3 round = 3 dwarf, green, round
1 wrinkled = 1 dwarf, green, wrinkled

phenotypes

- The same forked-line system may be employed to represent and combine genotypes expected from monohybrid crosses.

- For each monohybrid cross in the system, a genotypic ratio of 1:2:1 may be predicted.

P_1 GGWW ggww

F_1 = GgWw × GgWw

Gg × Gg Ww × Ww

Genotypes : GG 2Gg gg WW 2Ww ww

GG	WW	GGWW
	2Ww	2GGWw
	ww	GGww
2Gg	WW	2GgWW
	2Ww	4GgWw
	ww	2Ggww
gg	1WW	ggWW
	2Ww	2ggWw
	ww	ggww

Assignment #1

- Using the forked-line method, draw a cross of DdGgWw x DdGgWw
- Show the phenotypes, genotypes, genotypic frequency as well as the phenotypic frequency.
- Assume that one member of each pair is dominant.

- DD
  - GG
    - WW = 1 DDGGWW
    - 2 Ww = 2 DDGGWw
    - ww = 1 DDGGww
  - 2Gg
    - WW = 2 DDGgWW
    - 2 Ww = 4 DDGgWw
    - ww = 2 DDGgww
  - gg
    - WW = 1 DDggWW
    - 2 Ww = 2 DDggWw
    - ww = 1 DDggww
- 2Dd
  - GG
    - WW = 2 DdGGWW
    - 2Ww = 4 DdGGWw
    - ww = 2 DdGGww
  - 2Gg
    - WW = 4 DdGgWW
    - 2Ww = 8 DdGgWw
    - ww = 4 DdGg ww
  - gg
    - WW = 2 DdggWW
    - 2Ww = 4 DdggWw
    - ww = 2 Ddggww
- dd
  - GG
    - WW = 1 ddGGWW
    - 2Ww = 2 ddGGWw
    - ww = 1 ddGGww
  - 2Gg
    - WW = 2 ddGgWW
    - 2Ww = 4 ddGgWw
    - ww = 2 ddGgww
  - gg
    - WW = 1 ddggWW
    - 2Ww = 2 ddggWw
    - ww = 1 ddggww

Phenotypes	Genotypes	Genotype Frequency	Phenotypic Ratio
Tall, Yellow, Round	DDGGWW	1	27
	DDGGWw	2	
	DDGgWW	2	
	DdGGWW	2	
	DDGgWw	4	
	DdGGWw	4	
	DdGgWW	4	
	DdGgWw	8	
Tall, yellow wrinkled	DDGGww	1	9
	DDGgww	2	
	DdGGww	2	
	DdGgww	4	
Tall, green round	DDggWW	1	9
	DDggWw	2	
	DdggWW	2	
	DdggWw	4	
Tall, green wrinkled	DDggww	1	3
	Dd gg w	2	
Dwarf, Yellow, Round	ddGGWW	1	9
	ddGGWw	2	
	ddGgWW	2	
	ddGgWw	4	
Dwarf, yellow wrinkled	ddGGww	1	3
	ddGgww	2	
Dwarf, green round	ddggWW	1	3
	ddggWw	2	
Dwarf, green wrinkled	ddggww	1	1

Summary

- The number of gametes, genotypes, and phenotypes expected from different numbers of ***heterozygous*** pairs of genes can be calculated without going through the Punnet square or the Forked-line.

- The number of kinds of ***gametes*** is a multiple of 2, i.e. 2^n.

- The number of F_2 ***genotypes*** is a multiple of 3, i.e. 3^n.

- The number of ***phenotype*** is 2^n when dominance is present.

Relationships among Pairs of Independent alleles, Gametes, F_2 Genotypes, and F_2 Phenotypes when dominance is present.

Number of Heterozygous Pairs	Number of kinds Of Gametes	Number of F_2 Genotypes	Number of F_2 Phenotypes
1	2	3	2
2	4	9	4
3	8	27	8
4	16	81	16
n	2^n	3^n	2^n

Assignment #2

1. How many different gametes, F_2 phenotypes and F_2 genotypes can potentially be produced from individuals of the following genotypes?

(i) AaBb

(ii) AaBB

(iii) AABbccDdEE

2. A pure strain of Mendel's peas, dominant for all seven of his independently assorting genes, was testcrossed.

(a) How many different kinds of gametes could each of the parents produce?

(b) How many different gametes could the F_1 produce?

(c) If the F_1 was testcrossed, how many phenotypes would be expected in the offspring and in what proportion?

(d) How many genotypes would be expected in the F_2?