UNIVERSITY OF AGRICULTURE, ABEOKUTA
DEPARTMENT OF ANIMAL BREEDING & GENETICS

ABG 300 NOTES

Course Title: *Fundamentals of Animal Breeding & Genetics*
Unit: *2*
Lecture Period: *Wed. 10.00-12.00 (07/08 Session)*

1. *Simple Mendelian inheritance*
2. *Dominance (complete and incomplete)*
3. *Dihybrid ratios*

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Introduction

Genetics could be defined as science of heredity concerned with behaviour of **genes** passed from parents to offspring in the reproductive process. It is a branch of Biology concerned wit heredity and variation. It involves the study of cells, individuals, their offspring and the population within which organisms live.

Gene is the functional unit of heredity. (More recently, it is defined as a segment of linear or non-linear deoxyribonucleic acid (DNA) which encodes a polypeptide or protein).

Breeding deals with application of genetics principles for the improvement of economically important characteristics or traits.

Importance of Genetics

The modern science of genetics influences many aspects of daily life, from the food we eat to how we identify criminals or treat diseases (Encarta, 2006).

1. In **Agriculture**, some food crops (oranges, potatoes, wheat, and rice) have been genetically altered to withstand insect pests, resulting in a higher crop yield. Tomatoes and apples have been modified so that they resist discoloration or bruising.

Genetic makeup of cows has been modified to increase their milk production, and cattle raised for beef have been altered so that they grow faster.

2. In **Law**, genetic technologies have also helped **convict criminals**. DNA recovered from semen, blood, skin cells, or hair found at a crime scene can be analyzed in a laboratory and compared with the DNA of a suspect. An individual's DNA is as unique as a set of fingerprints, and a DNA match can be used in a courtroom as evidence connecting a person to a crime.

3. In **medicine**, scientists can genetically alter bacteria so that they mass-produce specific proteins, such as insulin used by people with diabetes mellitus or human growth hormone used by children who suffer from growth disorders.

Gene therapy is used in treating some devastating conditions, including some forms of cancer and cystic fibrosis. Genetically engineered vaccines are being tested for possible use against HIV.

Simple Mendelian inheritance

Gregor J. Mendel (1865) was the first scientist to discover the principles of heredity and deduce the laws which could explain the process of inheritance.

Mendel's work showed that:

1. There is existence of some factors now called **genes** which are responsible for the inheritance of traits or characteristics.
2. Genes occur in pairs: Alternative phenotypes of a character are determined by different forms of a single type of gene called **alleles**.
3. Each parent contributes one factor of each trait shown in offspring.
4. The two members of each pair of alleles segregate during gamete formation so that each gamete receives one of the alleles.
5. Genes are transmitted unchanged from generation to generation.

I. Monohybrid inheritance

The simplest experiments Mendel performed involved only one pair of contrasting characteristics. In a monohybrid cross, he mated individuals from two parent strains, each of which exhibits one of the two contrasting forms of the character under study. The original parents in the genetic cross are called **P1** or **parental generation** and their offspring are the **F1** or **first filial generation**. If individuals of the F1 generation undergo self-fertilization or selfing (**interse mating**), their offspring are called **F2** or **second filial generation**.

The cross between true breeding pea plants with tall stems and dwarf stems represents Mendel's monohybrid crosses. *Tall* and *dwarf* represent contrasting forms of one character (stem height). When **true breeding** tall plants (**TT**) were crossed with dwarf (**tt**) plants, the resulting F1 generation consisted of only tall plants.

Parental phenotype: Tall Short
Parental genotype (2n): **T T** **X** **t t**

Gamete (n) **T** **T** **t** **t**

F1 Genotype (2n): **T t** **T t** **T t** **T t**
Phenotype: All Tall

When members of the F1 generation were selfed, Mendel observed that 787 of 1064 F2 plants were tall, while 227 of 1064 were dwarf – a ratio of approximately 2.8:1 or about 3:1. Three-fourths(3/4) appeared like F1 plants while one-fourth (1/4) exhibited the contrasting trait which has disappeared in the F1 generation, only to reappear in the F2.

P2 phenotype: Tall Tall
P2 genotype (2n): **T t** **X** **T t** (*Selfing*)

P2 gamete (n) **T** **t** **T** **t**

F2 Genotype (2n): **T T** **T t** **T t** **t t**

F2 Phenotype: 3 Tall (787/1064) 1 Dwarf (227/1064) (3/4 tall: ¼ dwarf)

The crosses could be made either ways, that is, pollen from the tall plant pollinating dwarf plants or vice versa. These are called **reciprocal crosses**. To explain these results, Mendel proposed the existence of what he called particulate **unit factors** or genes for each trait which served as the basic unit of heredity and are passed unchanged from generation to generation.

Mendel's first law

It states that two members of a gene pair segregate from each other into the gametes, so that half of the gametes carry one member of the pair and the other half of the gametes carry the other member of the pair.

Modern genetic terminology

Genes are factors responsible for the inheritance of traits or characteristics.
Alleles are different forms of one type of gene, e.g **T** or **t**.
Phenotype of an individual is the physical expression of a trait or outward appearance.
Genotype is the genetic make up of an individual e.g TT, Tt or tt.
Homozygotes or pure lines are individuals having identical alleles (TT or tt).
Heterzygotes or hybrids are individuals with un-identical alleles (Tt).

Summary of seven pairs of contrasting traits and results of Mendel's monohybrid crosses using the garden pea (*Pisum sativum*)

Character	**Contrasting trait**	**F1 results**	**F2 results**	**F2 ratio**
Stem	Tall/dwarf	All tall	287 Tall 277 Dwarf	2.81:1
Seeds	Round/wrinkled	All round	5474 Round 1850 Wrinkled	2.96:1
	Yellow/green	All yellow	6022 Yellow 2001 green	3.01:1
	Full/constricted	All full	882 Full 299 Constricted	2.95:1
Pods	Green/Yellow	All green	428 Green 152 Yellow	2.82:1
	Axial/Terminal	All Axial	651 Axial 207 Terminal	3.14:1
Flowers	Violet/White	All Violet	705 Violet 224 White	3.15:1

Punnett Square

A convenient method of predicting the relative ratios of the progeny in any cross is by constructing a **Punnett Square** named after R.C. Punnett, who first devised the approached. After the gametes are entered in rows and columns, we can predict the new generation by combining the male and female gametic information for each combination and entering the resulting genotypes in the boxes. This process represents all possible random fertilization events.

F1 cross : **T t** X **T t**

Tall *Tall*

Gamete formation by F1 parents: T t → T, t   T t → T, t

Setting up Punnet square:

Male/Female	**T**	**t**
T	**TT** *Tall*	**Tt** *Tall*
t	**Tt** *Tall*	**tt** *Dwarf*

	Genotype	**Phenotype**
	1 TT 2 Tt	¾ Tall
	1 tt	¼ Dwarf
Ratio:	1:2:1	3:1

Test Cross: one character

The organism of a dominant phenotype but unknown genotype is crossed to a homozygous recessive individual (tester). Consider a test cross illustrated with a single character in the following cases:

1. *If the tall parent is homozygous,*

Parental phenotype: Homozygous tall Homozygous dwarf

Parental genotype (2n): **T T** **X** **t t**

Gamete (n) **T T t t**

F1 Genotype (2n): **T t T t T t T t**

Resulting phenotype: All Tall

2. *If the tall parent is heterozygous,*

<u>*Assignment</u>: Similarly draw the crosses and clearly show the resulting phenotype if the tall parent is heterozygous.

Dominance-recessive

It is a result of interaction between alleles at a singe locus in which one allele completely suppresses or covers the expression of the alternative allele which is said to be **recessive**. **Dominance** is said to be complete when both the heterozygotes and dominant homozygotes cannot be distinguished phenotypically. That is, they have the same phenotypic value. E.g. Among breeds of poultry used for meat production, the gene for white skin (**W W**) is dominant to that for yellow skin (**ww**). F1 progeny have white skin but heterozygotes. *(Assignment: *Draw the crosses*).

Exceptions to Mendel's rules

1. Incomplete dominance

The inheritance of a dominant and a recessive allele results in a blending of traits to produce intermediate characteristics, so that heterozygotes can be distinguished phenotypically from the dominant homozygotes. There are two types:

i. Co-dominance:
The phenotypic expression of the heterozygote is intermediates between the two homozygotes. For example, **in plants**: four-o'clock paint plants may have red, white, or pink flowers. Plants with red flowers have two copies of the dominant allele *R* for red flower color (*RR*). Plants with white flowers have two copies of the recessive allele *r* for white flower color (*rr*). Pink flowers result in plants with one copy of each allele (*Rr*), with each allele contributing to a blending of colors. *(*Draw the crosses*).

In poultry, blue Andalusian fowls results when pure breeding black (**BB**) and splashed white (**B^wB^w**) parental stock are crossed. All F1 heterozygotes (**BB^w**) are 'blue', while 50% of the F2 offspring have the F1 phenotype. *(*Draw the crosses*).

ii. Over-dominance: Phenotypic expression of the heterozygote exceeds that of either homozygotes. Example is found in white Wyandotte breed of poultry. The gene for Rose comb **R**, is dominant to the gene for single comb, **r**. Heterozygous males have normal fertility while homozygous dominant males have lowered fertility.

	RR (Rose comb)	**Rr** (Rose comb)	**rr** (Single comb)
Male:	*Lower fertility	Normal fertility	Normal fertility
Female:	Normal fertility	Normal fertility	Normal fertility

2. Multiple alleles

A single characteristic may appear in several different forms controlled by 3 or more alleles of which any two may occupy the same loci on the homologous chromosome. This is known as multiple allele (multiple allelomorph) and control such characteristic such as coat and eye colour in mice, and blood group.
Inheritance of blood groups: Blood group is controlled by and autosomal gene locus I, standing for Isohaemaglutinogen and there are 3 alleles representing the symbols **A, B, O**. A and B are equally dominant and O is recessive to both.
Human blood group genotypes:

Genotypes	Blood group
I^AI^A	A
I^AI^O	A
I^BI^B	B
I^BI^O	B
I^AI^B	AB
I^OI^O	O

Presence of single dominant allele results in the blood producing a substance called agglutinin which acts as an antibody. E.g. I^AI^O *produces Agglutinin* ***A***.

3. Lethal genes

A single gene may affect several characteristics including mortality. E.g. In chickens which are homozygous for an allele controlling feather structure called 'frizzled', several phenotypic effects results from the incomplete development of the feathers. These chicken lack adequate feather insulation and suffer from heat loss leading to high mortality rate. The effect of lethal gene is also clearly illustrated by the inheritance of fur, a condition known as agouti. Some mice have yellow fur. Crossbreeding yellow mice produces offspring in the ratio, **2 yellow: 1 agouti** (*Yellow is dominant to agouti and all yellow coat mice are heterozygous*). A ratio of 2:1 instead of the typical Mendelian ratio of 3:1 is explained by the fetal death of the dominant homozygous coat mice.

Let Y represent yellow fur (dominant)
y represents agouti (recessive)

Parental phenotype: Yellow fur Yellow fur
Parental genotype (2n): **Y y** **X** **Y y**

Gamete (n) **Y** **y** **Y** **y**

F1 Genotype (2n): ***Y Y** **Y y** **Y y** **y y**

Phenotype: **1** : 2 : 1
Yellow fur *Yellow fur* *Agouti*
(*Dies before birth)
*YY is a lethal genotype.

4. **Gene Linkage**

An exception to independent assortment of genes develops when genes appear near one another on the same chromosome. When genes occur on the same chromosome, they are inherited as a single unit and do not assort independently. Genes inherited in this way are said to be linked. For example, in fruit flies the genes affecting eye color and wing length are inherited together because they appear on the same chromosome. In many cases, genes on the same chromosome that are inherited together produce offspring with unexpected allele combinations from a process called crossing over during meiosis.

5. **Sex-Linked Traits**

Genes located on the sex chromosomes display different patterns of inheritance than genes located on other chromosomes. In human females, the sex chromosomes consist of two X chromosomes (**XX**), while males have an X chromosome and a shorter Y chromosome with many fewer genes (**XY**). A male's X chromosome may contain a recessive allele associated with a genetic disorder, such as hemophilia or muscular dystrophy. In this case, males do not have a normal second copy of the gene on the Y chromosome to mask the effects of the recessive gene, and disease typically results. Red-green colour blindness in humans and baldness are also sex-linked traits.

6. **Quantitative Inheritance**

Mendel focused his studies on traits determined by a single pair of genes, and the resulting phenotype was easy to distinguish. A tall plant can be markedly different from a short one, and a green pea can easily be distinguished from a yellow one. Traits such as skin color differ from the ones Mendel studied because they are determined by more than one pair of genes. In this form of inheritance, known as quantitative inheritance, each pair of genes has only a slight effect on the trait, while the cumulative effect of all the genes determines the physical characteristics of the trait. At least four pairs of genes control human skin color. Multiple genes also control many traits important in agriculture, such as milk production in cows and ear length in corn.

II. Dihybrid inheritance

A dihybrid inheritance involves <u>inheritance of 2 pairs of contrasting characteristics</u>. It can be considered theoretically as consisting of 2 monohybrid crosses conducted separately.
E.g. Crosses between plants that are different with respect to 2 separate characters (pea <u>shape</u> and cotyledon <u>colour</u>). Pure breeding (dominant) homozygous) plants having round and yellow peas (**RRYY**) were crossed with pure breeding recessive plants having wrinkled and green peas (**rryy**) to produce F1 generation seeds that were round and yellow (**RrYy**).

Round (**R**) is dominant to wrinkle (**r**), and
Yellow (**Y**) is dominant to green (**y**)

Parental phenotypes: Round-yellow wrinkled-green
Parental genotypes (2n): **RRYY** X **rryy**

Gamete (n): **RY** **ry**

F1 Genotype (2n): **RrYy** (*Round-yellow*)

F1 heterozygote plants were self pollinated to produce F2 generation from four kinds of gametes.

<u>F1 cross</u>: **RrYy** X **RrYy**

Gametes (n) **RY** **Ry** **rY** **ry**

	R	r
Y	**RY**	**rY**
y	**Ry**	***ry***

<u>Note</u>: Segregation of alleles (**R, r, Y, y**) and their independent assortment (recombination) result to RY, Ry, rY and ry which are four possible arrangements of alleles in each of the male and female gametes.

Mendel's second law (Law of independent assortment)

The law states that gene pairs assort independently during gamete formation.

Male/Female	Sperms				
		RY	Ry	rY	Ry
Eggs	RY	**RRYY** *Round-yellow*	**RRYy** *Round-yellow*	**RrYY** *Round-yellow*	**RrYy** *Round-yellow*
	Ry	**RRYy** *Round-yellow*	**RRyy** *Round-green*	**RrYy** *Round-yellow*	**Rryy** *Round-green*
	rY	**RrYY** *Round-yellow*	**RrYy** *Round-yellow*	**rrYY** *wrinkled-yellow*	**rrYy** *wrinkled-yellow*
	ry	**RrYy** *Round-yellow*	**Rryy** *Round-green*	**rrYy** *wrinkled-yellow*	**rryy** *Wrinkled-green*

F2 ratios:

Genotypic	Phenotypic ratios	Actual plant counts	Ratios
1/16 RRYY 2/16 RRYy 2/16 RrYY 4/16 RrYy	**16** Round-yellow (**R- Y-**)	315	9
1/16 RRyy 2/16 Rryy	**3/16** Round-green (**R- yy**)	108	3
1/16 rrYY 2/16 rrYy	**3/16** Wrinkled-yellow (**rr Y-**)	101	3
1/16 rryy	**1/16** wrinkled-green (**rryy**)	32	1

The proportion of each phenotype in the F2 generation approximated to a ratio of **9:3:3:1**, known as the **dihybrid ratio**. This applies to characteristics controlled by genes on different chromosomes, with alleles showing complete dominance in their interaction.

Law of product probability

It states that "If two events are independent, the probability that both events will occur simultaneously is the product of their separate probabilities".

The dihybrid ratio is also obtained by multiplying the expected monohybrid ratios for two gene pairs considered separately.

Ratios		**3**		**1**
	X	¼ RR	½ Rr	¼ rr
3	¼ YY			
	½ Yy	**9/16 R-Y-**		**3/16 rrY-**
1	¼ yy	**3/16 R-yy**		**1/16 rryy**

Summary:

No. of genes (**n**)	Gametes (**2^n**)	F2 genotypic ratio (**3^n**)	F2 phenotypic ratio **$(3:1)^n$**
1	$2^1 = 2$	1:2:1	$(3:1)^1 = 3:1$
2	$2^2 = 4$	1:2:2:4:1:2:1:2:1	$(3:1)^2 = 9:3:3:1$
3			

Example 2: In cattle, pollness (**P**) is dominant to horned (**p**), and black (**B**) is dominant to red (**b**). When homozygous polled-black bull (**PPBB**) is mated to homozygous horned-red (**ppbb**) cow, the first filial generation was polled-black with genotype **PpBb** under complete dominance. The F2 generation was produced by mating the F1 generation among themselves (**interse** mating). 16 individuals in the F2 contained 9 different genotypes and 4 different phenotypes of ratio 9 polled-black: 3 polled-red: 3 horned-black: 1 horned-red.

***Draw these crosses with the aid of a Punnet square**.

What is the probability that F2 genotype will be: (i) **PpBb** (ii) **P-bb** (iii) **ppB- ?**

Test cross: Two characters

It applies to individuals that express two dominant traits, but whose genotypes are unknown. E.g. The expression of a round-yellow phenotype may result from **RRYY, RRYy, RrYY or RrYy** genotypes. If an F2 round-yellow plant is crossed with a recessive wrinkled-green **(rryy)** plant which is the **tester,** analysis of the offspring will indicate the exact genotype of the round-yellow plant.

1. Test cross results of **RRYy** will be as follows:

Parental phenotypes: Round-yellow Wrinkled-green

Genotypes (2n): **RRYy** X **rryy**

Gametes (n):

	R
Y	RY
y	Ry

ry

Offspring genotype:

	RY	**Ry**
ry	RrYy	Rryy

Phenotypic ratio: **½ Round-yellow: ½ Round-green**

***Assignment**

2. Similarly draw the test cross results of RRYY, RrYY and RrYy.

Haploid and diploid cells

Every species have a characteristic chromosome number as illustrated on Table 1. The sex chromosome plus autosomes constitute a **genome**. Species having 2 sets of chromosomes are referred to as **diploid** (2n). The great majority of animal species and about half the plant species are diploid with 2 sets of chromosomes per nucleus or cell. A few simple organisms have only one set or half the number of chromosomes and are referred to as **haploid** (n). e.g. gametes, alternation of generation in fern.

Figure 1. Human Male Karyotype

This karyotype of a human male shows the 23 pairs of chromosomes that are typically present in human cells. The chromosome pairs labeled 1 through 22 are called autosomes, and have a similar appearance in males and females. The 23rd pair, shown on the bottom right, represents the sex chromosomes. Females have two identical-looking sex chromosomes that are both labeled X, whereas males have a single X chromosome and a smaller chromosome labeled Y.

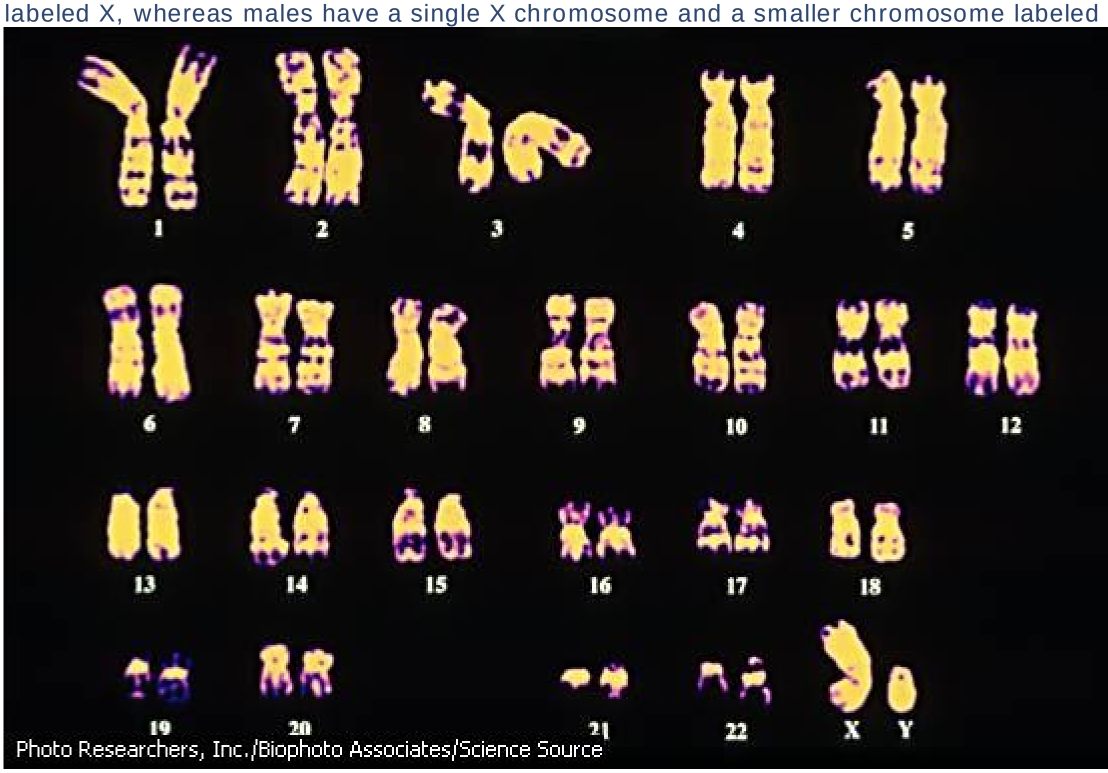

Table 1. A karyotype of eight common domestic animals

Common name	**Specific name**	**Haploid No. (n)**	**Diploid No. (2n)**	**No of Metacentrics**	**No of Telocentrics**	**X**	**Y**
Dog	Canis familiaris	39	78	0	38	M	A
Cat	*Felis catus*	19	38	16	2	M	M
Pig	*Sus scrofa*	19	38	12	6	M	M
Goat	*Capra hircus*	30	60	0	29	A	M
Sheep	*Ovis aries*	26	54	3	23	A	M
Cattle	*Bos Taurus*	30	60	0	29	M	M
Horse	*Uquus caballus*	32	64	13	18	M	A
Donkey	*Equus asinus*	31	62	24	6	M	A