GENETICS & INHERITANCE 15 APRIL 2015

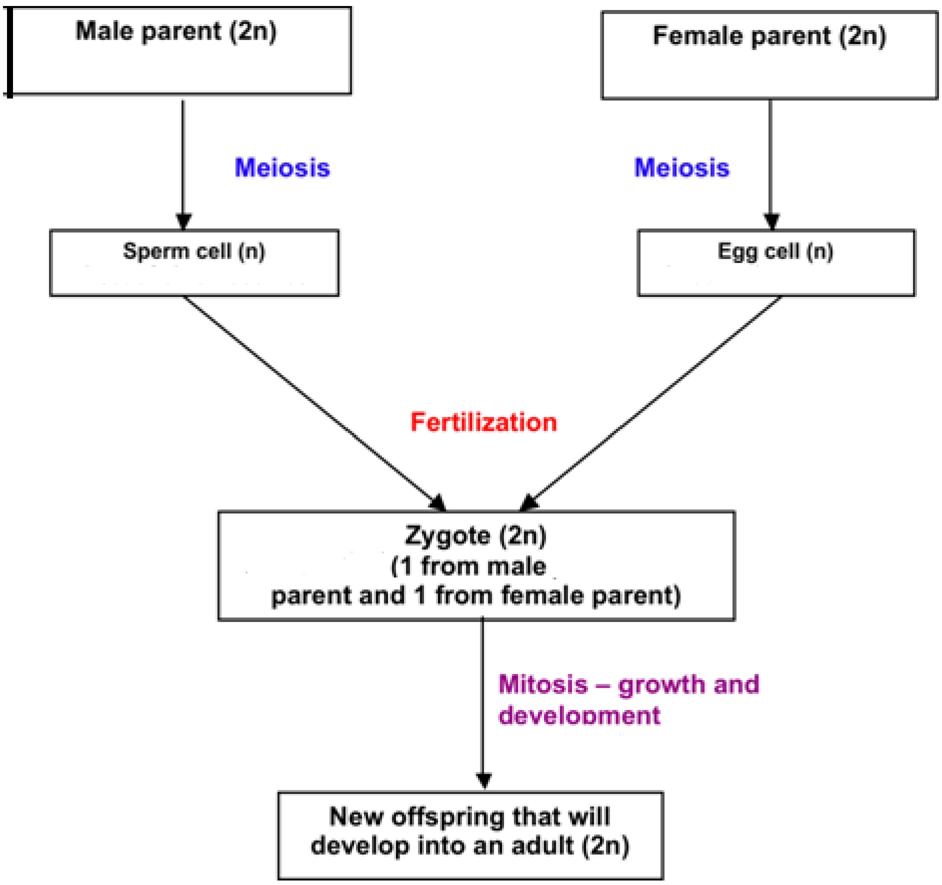
Section A: Summary Content Notes

You MUST understand the link between meiosis and genetics. During the crossing over in prophase I of meiosis and the metaphase I, chromosomes share information and during metaphase, separate randomly. This determines the combination of chromosomes and genes that you have as an individual. Genetics determines individual variation (to be different) and survival of the fittest. You MUST have a clear understanding of the genetic terminology in order to study genetics and answer genetic problems.

Genetics

Genetics is a science. Genetics is the study of the principles of **heredity and variation**. A unique genetic code is found in the DNA of each organism and is passed on to the offspring during reproduction. Since there are **two parents** required for sexual reproduction, **genetic variation** will occur to ensure survival of the fittest.

The Role of Gametes in Inheritance



- DNA molecules on the chromosomes consist of sections called **genes**
- Each gene contains the hereditary **traits,** e.g. skin and hair colour, height, body structure and blood group are represented by the genes on each of the two homologous chromosomes
- During the process of Meiosis, **haploid** gametes are produced and the gametes will contain one set of genes
- During fertilization, the gametes fuse and a **diploid zygote** results
- One set of genes will come from the female parent (maternal) and one set from the male parent (paternal)

- The two sets of genes may be the same or different for a trait, e.g. the mother may have genes for black hair and the father may genes for have blonde hair
- The offspring inherits two sets of genes, **50% from the mother** and **50% from the father** and may therefore be different from each of the parents
- The **diploid zygote** therefore contains a **double set of DNA** and is a **combination** of both parents

Genetic terminology

Genetics is a science and specific terms are used. Make sure that you know and understand the following terms very well as they form the basis for ALL the genetics that you will study.

- **Locus:** This is the exact position or **location** of a gene on a chromosome.
- **Alleles:** Alternate forms of a gene that are located at the **same point** on each of the two **homologous chromosomes** and represent a specific trait – one from the father and one from the mother.
- **Homozygous:***Homo* = same and *zygous* = zygote. When two alleles of anagene are the **same** for one trait e.g.: both alleles are for red flowers, the cross will result in a **pure breed** for red.
- **Heterozygous:** Hetero = different and zygous = zygote. When two alleles of a gene are **different** for a trait e.g.: one of the alleles is for red flowers and one is for white flowers, the cross will result in a mixture of the two genes called a **hybrid**.
- **Dominant trait:** A heterozygous offspring will display the dominant trait because it will **dominate** over the other recessive gene of the allele pair, e.g.: red colour will **dominate over** the gene for white colour, so the offspring will look red.
- The **dominant allele** is always written with a capital letter: **R** = red and the recessive is written in lower case **r** = white.
    - **Homozygous dominant alleles** means that both genes are the **same** for the same dominant trait. It will be represented by **RR,** which represents both the genes for red flowers. The offspring will be red because **two dominant genes** are present.
    - **Heterozygous alleles** means that **one gene is dominant** and **one gene is recessive** for the same trait, e.g. red flowers. It will be represented by **Rr,** which represents one gene for red and one gene for white. The offspring will display red flowers, because red is **dominant** over white.

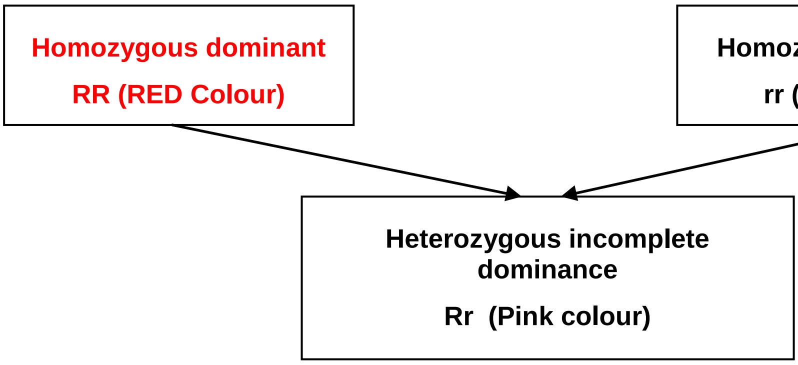
Homozygous dominant
RR (Red colour)

Homozygous recessive
rr (White colour)

Heterozygous dominant
Rr (Red colour)

- **Recessive trait:** The recessive allele is the trait that **is dominated over** by the dominant gene. It is written with a small letter: **r** = white.
- **Homozygous recessive alleles** means that both recessive genes are the same, i.e.: **rr** – two genes for are present for white flowers. The offspring will display the **recessive white** colour only. The recessive trait will only ever be seen when it is in the homologous state.

- **Complete dominance**: the type of dominance where the dominant allele completely masks the recessive allele. Even when the recessive allele is present in a heterozygote, it is not demonstrated.
- **Codominance**: the type of dominance where both alleles in a gene pair are expressed fully. An example is human blood groupings.
- **Incomplete dominance:** when the dominant gene allele is not able to completely dominate over the recessive gene allele, a mix of the two genes results, e.g.: red + white = pink. When the offspring is heterozygous with incomplete dominance, you will be able to see the combination of the two gene alleles traits:



- **Genotype:** This is the **genetic** composition of an organism and represents the information that is present in the gene alleles, for example RR, Rr, rr. You **cannot see this because it is in the genes**.

- **Phenotype:** This is the **physical** appearance of an individual, i.e.: what you will see when you look at the offspring. The phenotype is determined by the genotype. You **will see** white flowers for rr, but you will see red flowers if the genotype is RR or Rr.

- **Monohybrid cross:** Mono = ONE so, when **one pair** of contrasting traits is crossed to determine the possible inheritance of the offspring. There will be 4 possible combinations that result from the cross – 2 possibilities from the male and 2 possibilities from the female (2 x 2 = 4).

- **Dihybrid cross:** Di = TWO, so when **two pairs** of contrasting traits are crossed to determine the possible inheritance of the offspring. There will be **16 possible combinations** that result from the cross – 2 possibilities from the male and 4 possibilities from the female (4 x 4 = 16).
- **Filial generation:** The parents are represented by **P_1**. The parents reproduce to produce offspring that result from the cross. The offspring are the **first filial generation** and this is represented by **F_1**. When the offspring become mature and reproduce, they are represented by **P_2**. Their offspring will be the second filial generation represented by **F_2**.

- **Punnet square:** This is a schematic representation of a cross. Take careful note of the way the information is written.

Mendel's Laws:Background:

Gregor Mendel (1822–1884) was an Austrian Augustinianmonk who enjoyed experimenting with plants and investigating the outcome. He is known as the first **biogeneticist**. He studied the characteristics of garden peas grown in the monastery garden and recorded his findings. The laws he wrote are based on these findings and are used by geneticists today.

Mendel's first law:

The Law Segregation:

During gamete formation each member of the allelic pair separates from the other member to form the genetic makeup of the gamete. When two individuals with **contrasting homozygous** (pure-bred) characteristics are crossed, the individuals of the **F_1 hybrid generation** will all resemble the parent possessing the dominant characteristic. This law shows the principles of dominance and recessiveness using the characteristic of height. Pea plants either grow tall (TT or Tt) or are short plants (tt). Mendel crossed the pure bred homozygous tall and homozygous short varieties to prove his theories.

P_1/parent	*phenotype*	**Father purebred tall**	**x**	**Mother purebred short**
	genotype	TT	x	tt
Meiosis				
gametes		T, T	x	t, t
Fertilisation				

Gametes	*t*	t
T	Tt	Tt
T	Tt	Tt

F_1/offspring
Genotype: 100% Tt
Phenotype: 100% Tall
(Note that the F1 offspring show characteristics from both parents.)

The plants of the F1 grow and mature. When they are ready to reproduce, they produce gametes for tallness (T) and shortness (t) because the **gametes segregate** (T + T + t + t) during meiosis. One half of the gametes will contain the characteristic of one of the parents - for tallness and the other half will contain the characteristic of the other parent plant - for shortness. The characteristic for shortness is the **recessive** characteristic and it will appear in the second cross offspring called the **F_2 generation**.

P_2/parent Phenotype heterozygous tall father x heterozygous tall mother

Genotype	Tt	x	Tt
Meiosis			
Gametes	T, t	x	T, t
Fertilisation			

Gametes	T	t
T	TT	Tt
t	Tt	tt

F_2/offspring
Genotype: 25% TT, 50% Tt, 25% tt

Phenotype: 75% tall
25% short

Section B: Exam practice questions

Question 1

In horses black coat colour (B) is dominant over white (b). A white mare mates twicewith the same black stallion. She produces a white foal on the first occasion and a black foal on the second occasion. Use the letters B and b as indicated above and write down the genotypes of:

1.1. the mare and stallion (2)

1.2. the first and second foal (4)

Question 2

In guinea-pigs, the gene for black coat is dominant to the gene for white. Two heterozygous black guinea-pigs are crossed.

2.1. By means of a diagram, show the genotypic results that would be expected in the F_1 generation. (6)

2.2. One of the white F_1 offspring was crossed with its black parent. By means of a diagram show the expected F_1 genotypic results of this new cross. (6)

Question 3

Fur colour in mice is controlled by a gene with two alleles. A homozygous mouse with black fur was crossed with a homozygous mouse with brown fur. All the offspring had black fur.

Using the symbols B and b to represent the two alleles for fur colour, show as a punnet square, a genetic cross between a mouse that is heterozygous for fur colour with a mouse with brown fur. Show the possible genotypes and phenotypes of the offspring. (6)

Section C: Solutions

Question 1

1.1. Mare is bb √x stallion Bb √(if the stallion were BB, then they would not be able to produce a white foal). (2)

1.2. The genotypes of the foals will either be Bb ✓✓or bb ✓✓ (4)

Question 2

2.1. Black = B White = b

P_1√

Phenotype **Black fur** **x** **black fur**

Genotype **Bb x Bb** **-**

Meiosis √

Fertilisation

Gametes	**B**	**b**	
B	BB	Bb	
b	Bb	bb	

F_1

Genotype: 1/4 BB , 2/4 Bb ,

1/4 bb

Phenotype: 75% black

25% white (6)

2.2.

P_1/ parent

Phenotype	black fur	x	white fur ✓
Genotype	**Bb**	**x**	**bb** ✓-
Meiosis ✓			
Gametes	**B,b**	**x**	**b,b**
Fertilisation ✓			

Gametes	**B**	**b**	
B	Bb	bb	
B	Bb	bb	
√			

F_1

Genotype: 50% Bb , 50% bb ✓

Phenotype: 75% black, 25% white ✓ (6)

Question 3

P_1 phenotype Black x Brown✓

genotype Bb x bb✓

Meiosis

G B, b x b

Fertilisation

F_1 genotype Bb and bb✓

phenotype Black and brown✓

OR

gametes	**b**	**b**
B	Bb	Bb
b	bb	bb

1 mark for correct gametes
1 mark for correct genotypes

1 mark for stating **P_1 AND F_1**✓ (*must have both*)

1 mark for stating **meiosis AND fertilisation** ✓ (*must have both*) (Any 6) [6]