Genetics

Some definitions and explanations:

A **GENE** carries the genetic material from one generation to the next. A gene is a large group of proteins which are a template for a particular characteristic, feature or attribute.

Genes are carried on **CHROMOSOMES.** A chromosome is a long string of genes. Each chromosome will carry many thousands of genes. The chromosomes are present in each cell of that organism.

In most organisms, and particularly in both female castes of the honeybee, chromosomes occur in matched pairs. This is because when we are conceived we get one set of genetic material (ie chromosomes) from our father and a similar set from our mother.

A pair of genes for the same characteristic are called an **ALLELOMORPHIC PAIR** or a pair of **ALLELES.** The genes are called allelomorphs which we usually shorten to alleles.

Sometimes where a group of alleles is responsible for a characteristic (like hair colour in humans) we call it an **ALLELOMORPHIC SERIES.**

Genes can be for the same characteristic but they can demonstrate that characteristic in different ways. For example the gene for height can be for either shortness, tallness or somewhere in between. Sometimes one gene of a pair will override the other. We say one is **DOMINANT** and the other is **RECESSIVE.**

Let's take an example of the gene for eye colour. You will have received one gene for eye colour from your mother and the other from your father. In the main genes for "darkness" are dominant over genes for "lightness". So, if you get a gene for blue eyes from your mother and a gene for brown eyes from your father you will

have brown eyes. The gene for brown eyes is dominant over the gene for blue eyes.

We will see brown eyes. This is the actual expression of your genes and is called the **PHENOTYPE.** Your genetic makeup is one gene for blue eyes (this is a recessive gene and these are usually written with a small case letter, ie as “b”) and one gene for brown eyes (usually written as a upper case letter ie as “B”).

Your **GENOTYPE** for your eyes is Bb, and your phenotype is brown eyes. Thus you will be carrying the recessive gene for blue eyes even though you have brown eyes. If you then reproduce with a partner who also has brown eyes but is also genotype Bb then you could have offspring who receive a recessive “b” gene from you and a recessive “b” gene from your partner and you will have a blue eyed child, whose genotype will be “bb”.

When scientists investigate the chromosomal material of an organism they count only one of each matched pair. This is known as the **GENOME** and is designated by the letter “n”

So, in humans n=23, ie we have 23 chromosomes for characteristics, attributes etc. and each one has a matching chromosome. In reality we have 2 sets of chromosomes so we are said to have “2n” or to have 46 chromosomes.

In honeybees n=16. So, all female bees have 2n or 32 chromosomes.

If an organism has these two matching pairs of chromosomes they are said to be **DIPLOID** (remember D for diploid and for double).

Thus female honeybees (both queens and workers) are diploid

Male honeybees (drones) have no father but result from unfertilised eggs so they only have the set of chromosomes from their mother

(the queen). They don't have the matching set. They are said to be **HAPLOID.** (H for both half and haploid) and they are n, not 2n

Haploid males are a characteristic of the Order Hymenoptera.

In humans gender (sex) is determined by a pair of alleles. Females have XX, whereas males have XY. A woman will produce eggs, all of which will contain the X chromosome….they have to because these are the only sex chromosomes she has! A man will produce sperm which will either contain the X chromosome (in which case the baby will be a girl…XX) or the Y chromosome (in which case the baby wil a boy….XY).

If the two genes for a characteristic (any characteristic) are **DIFFERENT** then the organism is said to be **HETEROZYGOUS** for that gene and that characteristic. (human males are heterozygous for the sex gene)

If the two genes for the characteristic are the **SAME** then the organism is **HOMOZYGOUS** for that characteristic (human females are homozygous for the sex chromosome)

Drone honeybees have only one set of chromosomes and are said to be **HEMIZYGOUS.**

In the example above for eye colour, BB is homozygous for eye colour, whereas Bb is heterozygous for eye colour, but in each case the eyes will be brown.

Honeybees are different to us. Instead of an allelic pair determining sex they have an allelic series. There are up to about 12 genes which are sex determining and each queen will have any two of them, but they must be a different two. That is, she can't have two the same.

So each egg she produces will contain one of her two. A drone will have only one of the 12, which one will depend on which of his mother's two went into the unfertilised egg that gave rise to him. There is no matching one from a father so he is stuck with just the one!

A queen mates with about 15 drones and this is why she does it.

Let's say a particular queen has genes 7 and 9 from the series, (another queen could/will have a different two). She mates with drones that have the sex genes 5, 8, 9, 10, 1 and 7 and others, but these will do to demonstrate the point.

She can produce eggs which contain either gene 7 or gene 9. She has sperm with genes 5, 8, 9, 10, 1, and 7 etc stored in her spermatheca

If egg 7 is unfertilised it will be drone (haploid and hemizygous)

If egg 9 is unfertilised it will be drone (again haploid and hemizygous)

If egg 7 is fertilised by a sperm with gene 5 then it is female (diploid)

If egg 7 is fertilised by sperm 8 it will be female (diploid)

If egg 7 is fertilised by sperm 9 it will be female, same if it is fertilised by sperm 10 and sperm 1.

In order to be female it has to be diploid **and the two sex genes have to be different. (ie heterozygous)**

Now if egg 7 is fertilised by a sperm 7 then we get a diploid individual but because the sex genes are the same it is not female. It's almost as if the two 7's are interpreted as a single 7 and we get a drone **but a diploid drone.**

Diploid drones give off the wrong pheromones and are eaten as eggs by the workers. This gives rise to spaces where there should be eggs

and leads to **pepperpot brood** and to a reduction in the number of workers. **This is inbreeding.** It is sometimes called inbreeding depression. It is the opposite of heterozygous vigour which results from outbreeding.

This is why it is important that queens are not mated with their own drones and why new stock should be brought into an area periodically. Breeders of black bees exchange queens for this reason. Breeding for a particular trait eg docility can lead to inbreeding if we constantly use the same stocks of bees. Over time it is likely they will become inbreed, ie have some of the same sex alleles.

This is also the reason that mutations, eg white eyes, turn up in drones rather than queens or workers. The females will have a matching gene that will be dominant or at least "good". This "good" gene will override the "dud" mutant gene so the "dud" gene will be masked.

Drones, being hemizygous will have no such matching "good" gene and the "dud's" gene characteristic will show.

Because the queen mates with about 15 drones there will be groups of bees in the colony with different fathers. So, 15 different drones, 15 different dads. Each group of workers with the same father is called a **patriline.** Each patriline has different attributes eg one patriline may be good at foraging for pollen, another may be good at hygienic behaviour or defending the colony.

The patrilines may not be closely related eg the drones may be from different colonies. But some may be brother drones coming from the same queen.

If the workers have the same father they are called **super sisters**. (the sperm from the drone is identical but all the eggs from the queen will all be slightly different just as they are with us).

If the drone fathers were brothers (ie they had the same queen mother) then the workers are **sisters.** The workers have the same mother (the queen) and their dads are closely related so will have some genes in common. These workers are 50% related to each other.

If the drones are from completely different colonies then the workers are **half sisters** and are only 25% related to each other. (The queen's eggs are all slightly different and the sperm is from unrelated drones so unlikely to have many genes in common)

So, if I am a worker bee in a colony I will have:

Super sisters…same patriline as me….same mother (queen) and same father ….75% related to the other workers in my patriline (only 75% related because all of the queen's eggs will be slightly different)

Sisters….different patriline to me but same mother (queen) and their father is the brother of my father so will have some genes in common with my dad….50% related to me

Half sisters….different patriline to me….same mother (queen) but dad totally unrelated to my drone father so few, if any, genes in common….only 25% related to me.

This is important for 2 reasons:

Each patriline will bring different skills to the colony.

And if a worker who is my half sister lays an egg, I'll eat it because I don't want her propagating her genes in my colony because she is only distantly related to me. In fact, I'm more related to the queen than I am to her, so I'll look after the queen's eggs but not hers.

But, if one of my super sisters lays an egg then I won't eat it and would be willing to look after it because we are closely related and have a lot of genes in common.

However, a worker from another patriline will eat it.

This is **worker policing** and it ensures that, normally, only the queen's offspring are looked after because nearly all of the workers are more closely related to the queen than they are to each other.

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