Why do ants work together in colonies?

Guy Palmer

1. **The complexity of ant colonies**
2. **Why animals are usually ‘selfish’ and how do genes become common**
3. **Relatedness in humans**
4. **Relatedness in ants**

The complexity of ant colonies

Ant colonies

- **Ants live in colonies, often numbering millions in a single colony**
- **Different ants in the colony play different roles ('eusociality')**
- **There are often distinct castes of female (workers, fighters, etc)**
- **Most ants are females (all bar a few male 'drones')**
- **Most females are sterile (all but the 'queen ant')**

The complexity of ant colonies

1. Ants as arable farmers
2. Ants as pastoral farmers
3. Ants as builders
4. Ants as slave makers
5. Ants as pantries

Ants as arable farmers

Ants as arable farmers

Ants as arable farmers

- **Q: What do the larvae of leaf cutter ants eat?**
- **A: fungus**
- **The ants:**
  - **The larger ants cut off bits of leaf and take them back to their nest**
  - **The smaller ants mash up these bits of leaf with their faeces and lay the mix around the fungus**
  - **Keep the fungus clean (cf. pests & moulds)**
  - **Stop feeding leaf types that make the fungus ill**
- **The fungus:**
  - **Produces ‘swellings’ which are fed to the ant larvae**
  - **Doesn’t produce spores**

Ants as arable farmers (cont)

- **Both the ants and the fungus benefit. This is called ‘mutualism’.**
- **When a young queen ant flies off to start a new colony, she takes a bit of the parental fungus garden (as well as 300 million sperm)**

Ants as pastoral farmers

Ants as pastoral farmers

- **Q: What is honeydew?**
- **A: a sugar-rich sticky liquid excreted by aphids**
- **Depending on species, the ants:**
  - **Protect the aphids where they are feeding**
  - **Milk the aphids by stroking them with their antennae**
  - **Carry the aphids from plant to plant**
  - **Store aphid eggs in their nests over the winter**
- **The aphids:**
  - **Excrete honeydew**
  - **Excrete the honeydew more often and with higher levels of protein when there are ants around**

Ants as pastoral farmers (cont)

- **Again, the relationship is mutualistic, with both the ants and the aphids benefitting**
- **When a young queen ant flies off to start a new colony, she takes an aphid egg with her (as well as a lot of sperm and maybe some fungus)**
- **Aphids can reproduce asexually**

Ants as builders

Ants as builders

An ant colony lives in an ant nest. The nest comprises four main types of thing:

- **Horizontal chambers**
- **Mostly vertical tunnels**
- **Hills of excavated earth**
- **Multiple exits/entrances**

Up to, say, 10 chambers in a vertical line of up to 4 metres connected by tunnels

Ants as slave makers

Ants as slave makers

Some ants are completely dependent on their slaves and would die without them:

- **Their slaves are a closely related, but different, species**
- **The fertile males and females do no work**
- **The sterile females (i.e. the workers) capture slaves but do nothing else. They can't make their own nests and can't feed their larvae. Even when they migrate, they have to be carried by their slaves.**
- **The slaves defend the nest and never try and escape**
- **The master ants only make slaves out of pupae that they have captured (at the same time, they kill the live ants and take them back to their nest for food)**
- **And they only make a particular species of ant their slave**

Ants as pantries (honeypot ants)

Leafcutter ant castes (and roles)

Why animals are usually ‘selfish’

and

how do genes become common

Two propositions

1. **Animals rarely do things for the benefit of other animals but when they do it is usually because they are related**
2. **The genes that are common within a species are those which help the animals that have those genes to successfully pass them on to future generations**

I'm going to assume that people broadly understand that organism pass some (usually half) of their genes onto their progeny

Some case examples re proposition 2

1. A gene which makes the animal sterile
2. A gene which increases the chance of an animal dying whilst young
3. A gene which decreases the chance of an animal dying whilst young
4. A gene which helps an animal successfully find food
5. A gene which helps an animal successfully find (or attract) mates

Two propositions

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Some case examples re proposition 1

1. **An animal which sacrifices itself to save some others of its species**
2. **An action which helps another unrelated animal a lot and only harms the 'actioneer' a little**
3. **An action which helps another related animal a lot and only harms the 'actioneer' a little**
4. **An animal that does another animal a favour in the hope that the favour will be returned at a later date**

Two propositions

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Genetics 101 – definitions of terms

- **Gene: a piece of DNA that can do something (usually cause a protein to be created)**
- **Allele: the genetic sequence of a particular gene in a particular organism. An allele is a particular variant of a gene.**
- **Gene pool: the set of all genetic information in the population of a species. For each gene, it is the percentages in the population of each allele.**
- **Sexual reproduction: a union between a male and a female, where (for most organisms) each child inherits half their alleles from their mother and half from their father**

For example, eye colour

- **Assume that a single gene defines your eye colour (it is actually around 6 genes)**
- **Assume that there are 2 possible eye colours: brown and blue (7 eye colours are actually recognised)**
- **So, there is a brown allele and a blue allele**
- **Humans (and most organisms) have 2 instances of each gene**
- **Around 10% of the human population have blue eyes**
- **But you only have blue eyes if both your eye genes are the blue allele**
- **So, around 30% of the eye genes in the human gene pool are the blue allele and 70% are the brown allele**

The concept of a ‘gene pool’

- **The set of all genetic information in the population of a species**
- **For each gene, it is the percentages in the population of each allele**
- **For example, with the gene for eye colour in humans: 70% brown and 30% blue**
- **For most genes in any species, the gene pool is uniform (and part of the definition of the species)**
- **For some genes in any species, the gene pool has multiple alleles (otherwise all the individuals would be identical)**
- **Over time, natural selection changes the frequencies of the alleles**
- **The study of this subject is called population genetics**

Allele frequency and natural selection

- **If one allele is clearly superior to all the other alleles in getting itself reproduced, then it will become more common over time**
- **It is only if two alleles are equivalent in getting themselves reproduced, that they may both continue within the gene pool**
- **(I am avoiding complexities such as polymorphism and genetic drift)**
- **The most direct way that an allele can help get itself reproduced is by the animal successfully having children**
- **Another weaker and more indirect way is by the animal helping a relative successfully have children**

Why do ants work as part of a colony?

- **For reasons to be explained, ants (which are nearly all female) are more closely related to their sisters than they would be to their (hypothetical) daughters**
- **So, in terms of passing on their genes, it is more effective for an ant to encourage and help raise sisters than to have daughters**

Relatedness in humans

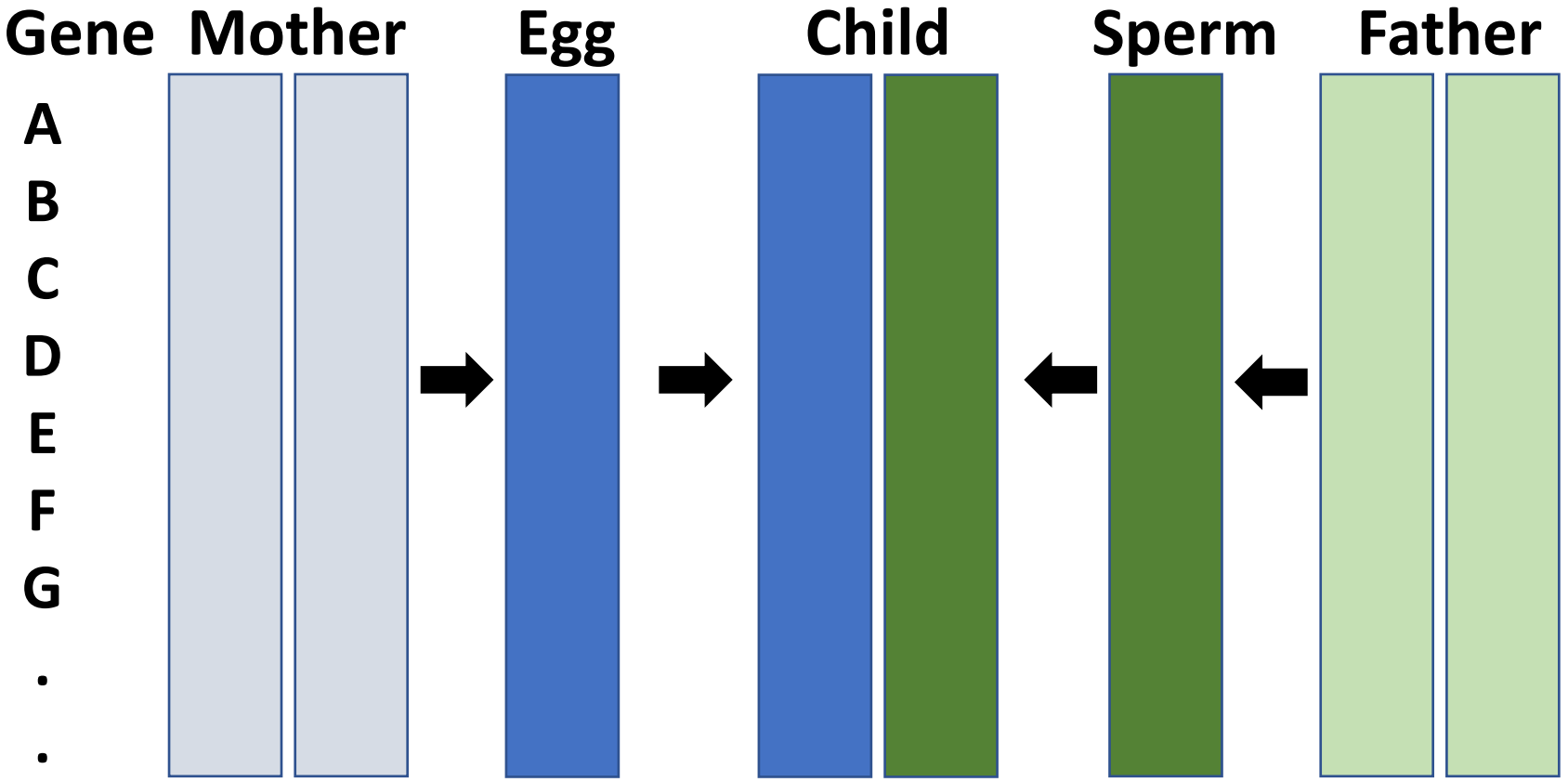
Relatedness in humans

You have:

- **50% of your genes ‘in common with’ each of your parents**
- **50% of your genes ‘in common with’ each of your children**
- **(On average) 50% of your genes ‘in common with’ each of your siblings**

Relatedness in humans

- You have two versions (‘alleles’) of each of your genes
- Each of your eggs/sperm has one of these versions
- Where it is random which version it has



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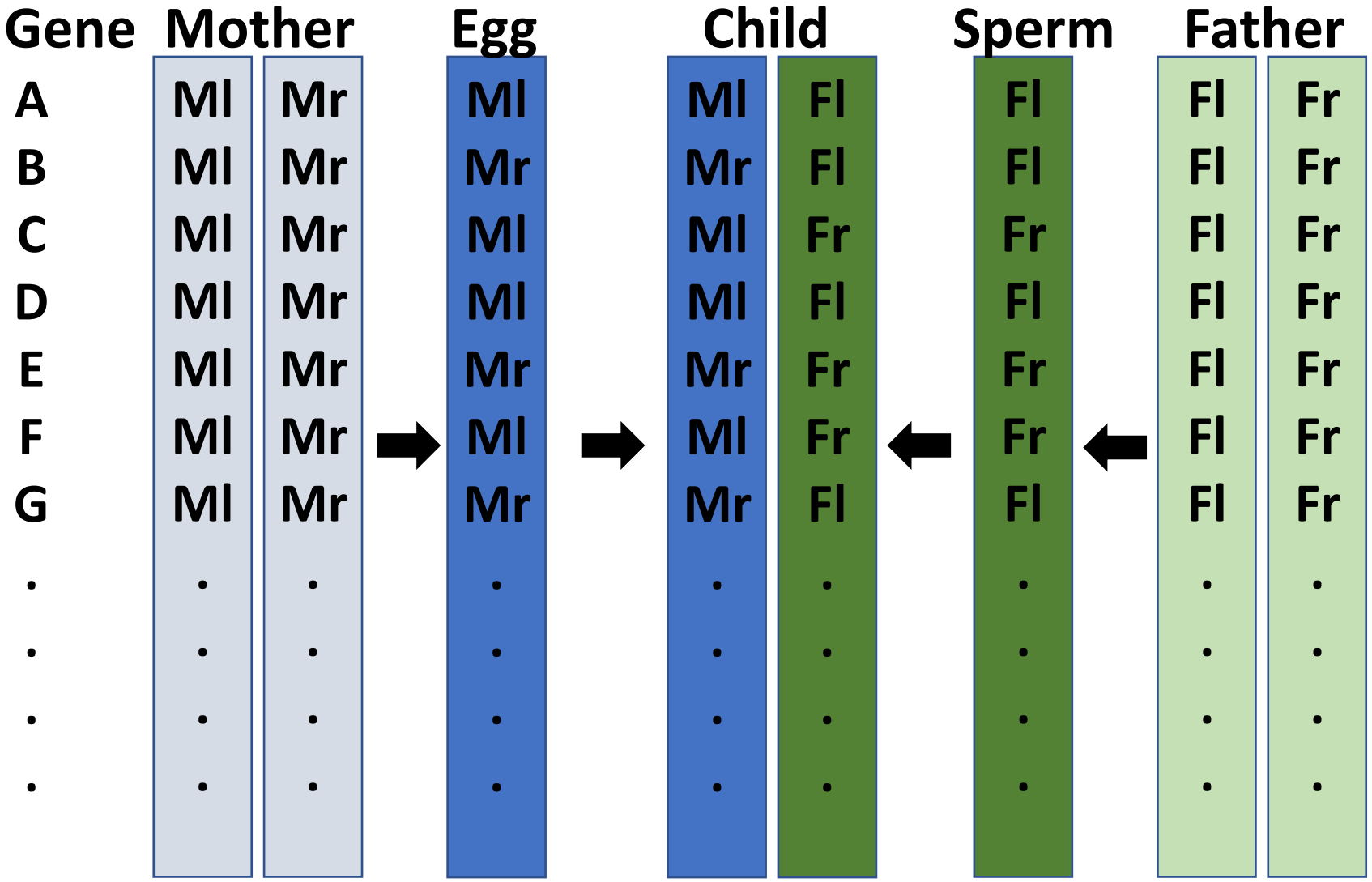
Mother	Egg	Child	Sperm	Father
M1M2	M1	M1F1	F1	F1F2
	or	or	or	
	M2	M1F2	F2	
		or		
		M2F1		
		or		
		M2F2		

Relatedness in humans



Relatedness in humans

Relationship	Relatedness
Identical twin	100%
Clone	100%
Parent	50%
Offspring	50%
Sibling	50%
Grandparent	25%
Grandchild	25%
Aunt/uncle	25%
Nephew/niece	25%
First cousin	12.5%
Second cousin	3.13%
Third cousin	0.78%
Fourth cousin	0.20%

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Relatedness in humans

- **So, if you successfully have a child, then 50% of your genes will have successfully passed down a generation**
- **More than 2 children, and your genes will have become more common in the gene pool (assuming a constant population)**
- **If you cause your sibling to successfully have a child then 25% of your genes will have successfully passed down a generation**

Relatedness in ants

Relatedness in female ants

A female ant has:

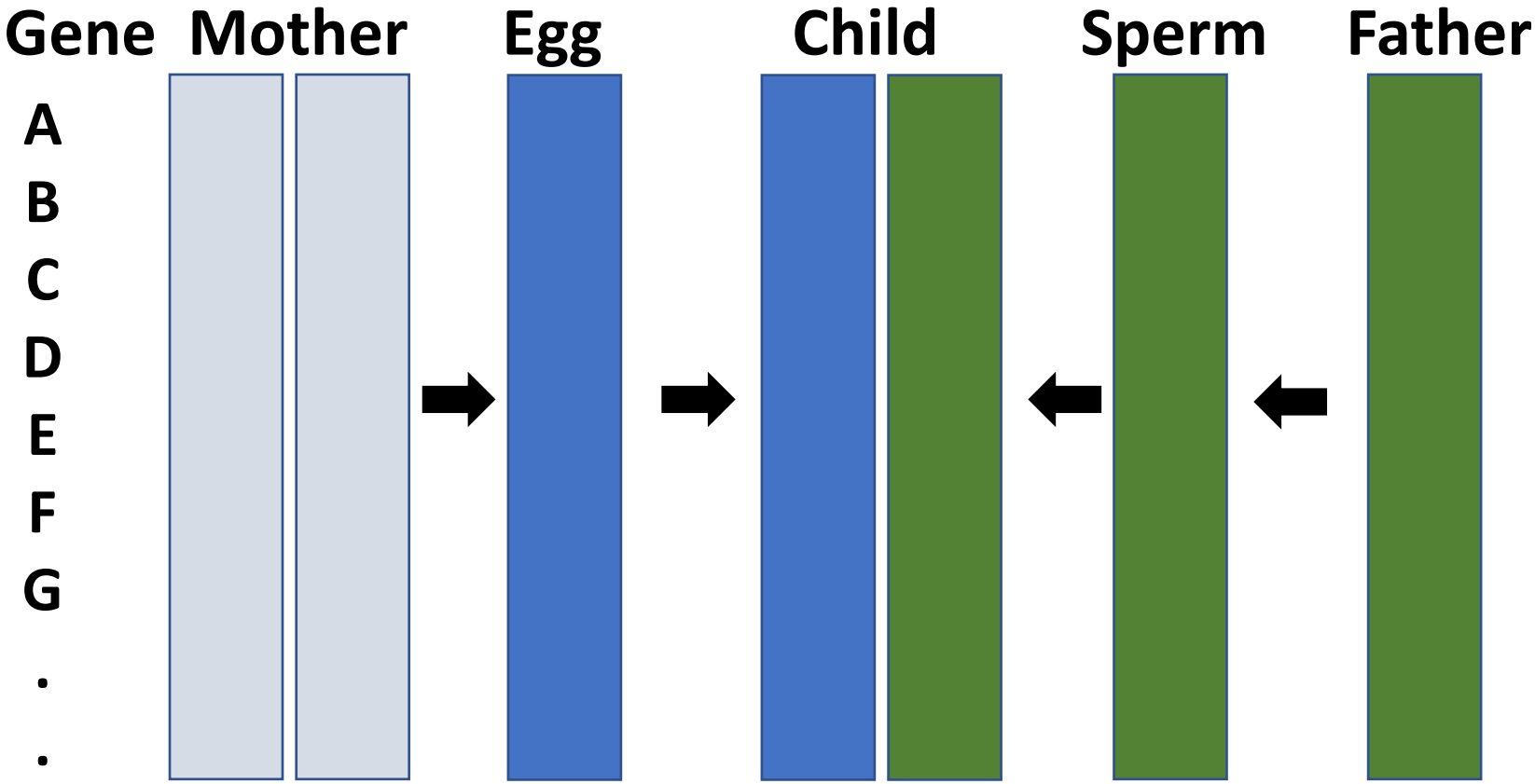
- **50% of its genes ‘in common with’ its mother**
- **50% of its genes ‘in common with’ each of its (hypothetical) daughters**
- **(On average) 75% of its genes ‘in common with’ each of its sisters**

Ants and haplodiploidy

- For ants, fertilised eggs always result in females whilst unfertilised eggs always result in males
- This is called ‘haplodiploid’
- This, in turn, means that males only have half as many chromosomes as females
- In passing, this means that males have grandfathers, but no fathers; grandsons but no sons
- Importantly, it also means a male’s sperm is all genetically identical
- So, all the male’s daughters receive the same genes from their father
- Only ants, bees and thrips are haplodiploid

Relatedness in female ants

- Male ants come from unfertilised eggs
- So, male ants only have half the usual number of genes
- And, all of their sperm is identical



Relatedness in female ants

- Male ants come from unfertilised eggs
- So, male ants only have half the usual number of genes
- And, all of their sperm is identical

Mother	Egg	Child	Sperm	Father
M1M2	M1	M1F1	F1	F1
	or	or		
	M2	M2F1		

Relatedness in female ants

- **Assume that the female is genetically AB and the male is genetically C**
- **Then each of their female offspring will be a random half of AB + the whole of C**
- **On average, therefore, they will have 75% of their genes in common with their sisters**
- **By contrast, they will only have 50% of their genes in common with their mothers**
- **And therefore they would only have 50% of their genes in common with their (hypothetical) daughters**
- **So, they are more closely related to their sisters than to their daughters**

Relatedness in female ants

A female ant has:

- **50% of its genes 'in common with' its mother**
- **50% of its genes 'in common with' each of its (hypothetical) daughters**
- **(On average) 75% of its genes 'in common with' each of its sisters**

The phenomenon, whereby fertilised eggs give rise to females and unfertilised eggs give rise to males, is called haplodiploidy

Relatedness in female ants

- **So, genetically speaking, it is more in the interests of a female to raise their sisters than to have children of their own**
- **So, a colony where the vast majority of the population are sterile, is stable**

How ants breed

- **‘All’ the ants in a colony are the children of the same queen ant and king ant**
- **They are therefore all female and all sisters of each other**
- **They are potentially fertile but ‘choose’ not to have children and to look after their sisters instead**
- **In other words, they act for the benefit of their colony**
- **(I am avoiding complexities such as multiple matings and multiple queens)**

The queen ant

- **The queen ant lives for at least 10 times as long as the other females (e.g. 30 years)**
- **The queen ant only mates once, on the ant equivalent of her maiden flight. Both the queen and all the males therefore have wings (although the other females don't).**
- **(I wouldn't be surprised if the males died after mating, and the queen lost her wings)**
- **But a queen ant has the same DNA as other female ants. In other words, it is <u>not</u> different because it has different DNA.**

How to make an ant fertile?

- If (and only if) an ant (or bee) larva is fed ‘royal jelly’, it becomes a fertile queen
- This is only done when the old queen dies
- Any female larva fed ‘royal jelly’ will become a fertile queen
- The ‘royal jelly’ works by something called ‘DNA methylation’
- More specifically, it removes the ‘methyl glue’ surrounding the ‘royal genes’ and thus turns them on
- (Some biologist found a way of removing the ‘methyl glue’ around some bee genes and the resulting bees were mostly queens)

How to make an ant fertile (cont)?

- **This is an example of ‘epigenetics’, whereby organisms can look and behave very differently even though they have the same DNA**
- **As well as causing fertility, the effects of the DNA methylation on an ant can be (and usually are) much wider**
- **So, that explains why queen ants can look so different from other ants: they have the same genes but different ones are switched on**

Ants – castes

- The above explains how queen ants can look different to other female ants
- But it doesn't explain how worker and soldier ants can look so different (they have the same DNA and the same methylation)
- Darwin tried, but failed, to explain
- Guy doesn't know either
- And science speculates but also doesn't seem to know

Summary

1. Ants are ‘haplodiploid’, which means that fertilised eggs are always female and unfertilised eggs are always male
2. Most ants are female and, within a colony, have the same mother and father
3. Ants are more closely related to their sisters than to their hypothetical daughters
4. Ants ‘choose’ to work together for the good of their colony