Dung beetle guts!

A look at the critters that live inside other critters

Figure 1: A dung beetle rummaging through buffalo dung for something to eat.

Insects owe a lot of their success to unseen microorganisms that they have evolved symbiotic relationships with. A fascinating example is that of the dung beetle's gut symbionts.

Insects are the most diverse group of animals on the planet, with almost 1 million described species. They are widely considered to be one of the most successful groups, exploiting almost every resource. Their widespread success could be partially assigned to their close association with symbiotic microorganisms.

Symbiotic microorganisms are organisms that work together for mutual gain. In this case it may include bacteria, fungi, archaea and protists that work together with insects. Great assemblages of symbiotic microbes are found inside insect guts; this is what we call the gut microbiome or microbiota.

The gut microbiome of insects has allowed them to do amazing things. For example, the gut microbes of wood-feeding termites aid them in the digestion of plant cell walls. This allows termites to exploit and utilise a previously inaccessible resource. Some evidence suggests that insect gut microbes detoxify plant chemicals to overcome the plant's defences. This is especially prevalent in agricultural pest species, such as the coffee berry borer that detoxifies caffeine through its gut microbes. Symbiotic gut microbes are not only involved in nutrition. New research suggests that the gut microbiota of honey bees can regulate their immune system. The presence of a healthy core gut microbiota has also been shown to provide disease resistance to honey bees.

Dung beetles and their gut microbes

Although quite small and easy to miss, dung beetles have a disproportionate effect on their environment. They are referred to as *ecosystem engineers* as they provide many ecosystem services that positively affect their surroundings. Dung beetles most often feed and breed on mammal dung that they bury underground. This ultimately moves nutrients below the surface, preventing parasites or flies from breeding and provides fertiliser for plants to grow. Dung beetles are therefore important in agricultural areas, especially livestock farms, where they increase pasture health by removing and circulating animal waste. They are the real clean-up crew of the Earth!

Although dung beetles perform astounding feats, recent research suggests that they receive aid from microorganisms in their guts. These interactions are often overlooked due to their perceived insignificance and difficulty to investigate. The study of dung beetle gut symbionts has not received much attention. However, the few studies we do have show promising results and further our understanding of the complex interactions concerning symbiosis within living insects.

Dung beetles possess very specific gut microbiomes that differ greatly between species. Surprisingly, small changes in the gut microbial community of an insect could be fatal. How they came to acquire these symbionts is still up for debate, but diet plays a large role in dung beetle gut microbiome composition. This is due to the large majority of gut symbionts helping dung beetles (and other insects) digest food. This corresponds to what we know, since scientists have found an abundance of plant-degrading bacteria within some dung beetle guts.

Other notable gut symbionts break down amino acids, digest biomolecules and cellulose, or ferment carbohydrates. This, in turn, provides the dung beetle with essential nutrients. The symbiosis is so important, in fact, that some dung beetles have evolved fermentation chambers in their gut, where they house an abundance of symbiotic bacteria that help them digest food. It is clear that without these gut microbes, dung beetles would not be as successful as they are today.

Figure 2: One hypothesis is that dung beetles originally gained their gut symbionts through the food they ingested. Not all gut symbionts are present when the dung beetles emerge. Some are gained through the environment. Illustrated by Kara du Plessis.

Conservation threats to dung beetles and their gut microbes

Although very important, the symbiotic relationship between dung beetles and their gut microbiome is under increasing pressure. Gut microbes are usually very specific, and a disruption in this community can be catastrophic. When scientists swapped the gut microbes of two closely related dung beetle species, they observed catastrophic die-off. There are three main threats to this important symbiotic relationship.

1. Antibiotics

Most of the antibiotics sold around the world are used in livestock farming to promote growth and prevent infections. Up to 90% of antibiotics are excreted through the animal's urine or faeces. This poses a problem for dung beetles as their diet now consists of many antimicrobial compounds. Dung produced by animals treated with antibiotics changes the gut microbiome of dung beetles. The observed effects persisted even 23 days after the beetles were exposed to treated dung. Ultimately, this will likely disrupt the symbiotic relationship between dung beetles and their gut microbes, affecting their immunity and nutrient uptake. Antimicrobial compounds also have potential sublethal effects that could hinder their ability to recycle nutrients and contribute to pasture health. This highlights the fact that although antibiotics may not be directly toxic to some animals, they could have unforeseen side effects such as changing a non-target organism's symbiotic gut community. Antibiotics further increase greenhouse gas emissions as methane (CH_4)-producing bacteria are found to dominate antibiotic-treated dung.

2. Pesticides

Pesticides are used by farmers for various purposes: some are used to protect crops from pest insects and others to protect livestock from parasites. Farmers commonly use Ivermectin to kill lice, ticks and other parasites associated with their livestock. Unfortunately, these pesticides also negatively affect both the animals and those feeding on their dung. Ivermectin has been found to disrupt the gut microbiome of cows and up to 98% of the Ivermectin administered to cattle is excreted in their dung. Dung beetles then take up this pesticide while feeding or breeding in the cow dung. Scientists found that Ivermectin gets stored in the gut and fat bodies of dung beetles up to 12 days after exposure. As diet plays an important role in insect gut microbes, Ivermectin could ultimately disrupt the dung

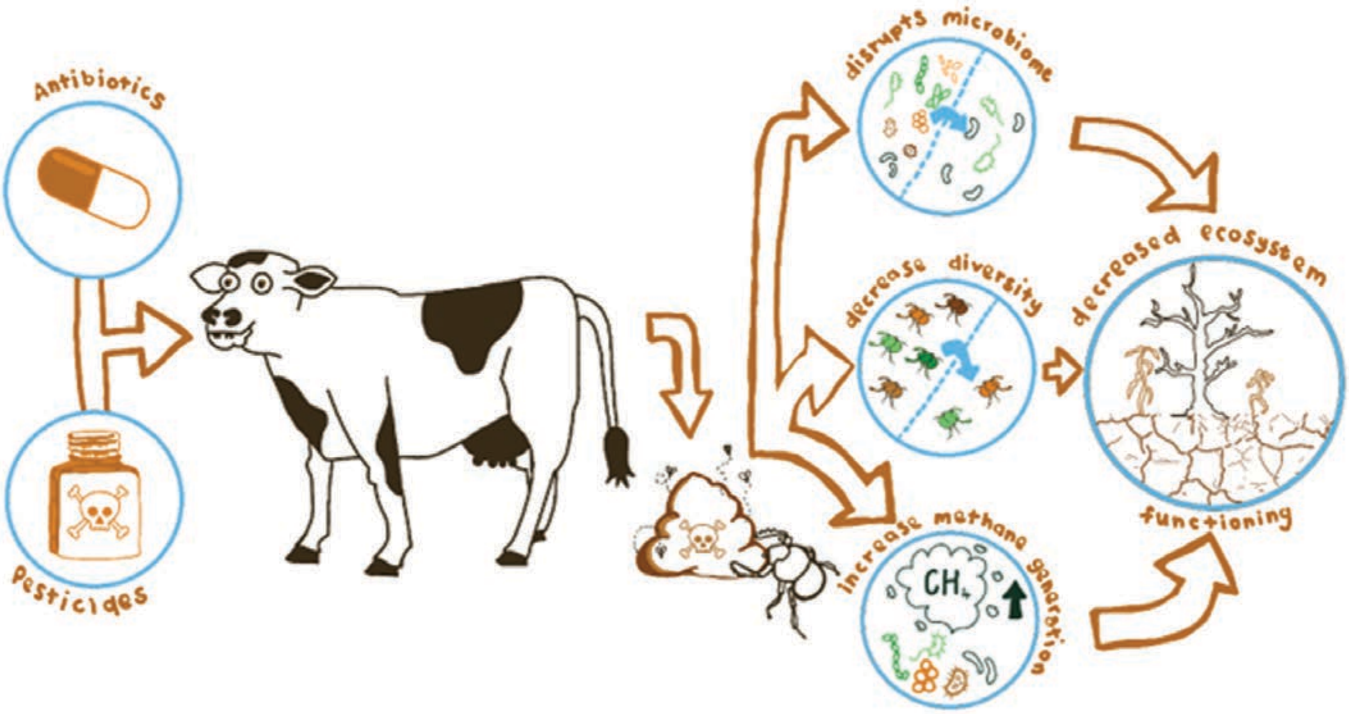

Figure 3: The dung by mammals treated with antibiotics or pesticides has disastrous consequences for all animals that depend on dung. Antibiotics and pesticides are ingested by the dung beetle subsequently affects their gut microbiota. Many sublethal effects have also been reported and can lead to disastrous consequences for the ecosystem. Illustrated by Kara du Plessis.

beetle's gut microbial community structure. This will cause important microbes to die off or be replaced. Ivermectin residue is further linked to lower dung beetle diversity and a reduction in the ecosystem services they provide. Other pesticides, such as pyrethroids that are used in crop protection, are also known to disrupt insect gut microbiomes. Chronic exposure to these pesticides will ultimately lead to a disrupted gut microbiome in most insect groups. This causes an array of negative effects for insects and there is no reason to believe that dung beetles won't be affected in the same way.

3. Climate change

The effect climate change has on dung beetle gut microbes has not yet been studied in detail. Climate change research requires us to have years of prior data to track changes over time, however, dung beetle gut microbe research is a recent phenomenon. For that reason, we use the data we have now to predict what might happen when temperatures increase on the Earth. If temperatures increase by 2°C, studies show that the insect gut microbiome will get disrupted. This trend is observed in multiple animals and shows how temperature-sensitive the gut microbiota of insects are, because insects are ectothermic and therefore rely on external heat. We will know the full extent of this effect once we have long term datasets.

Conclusion

Dung beetles rely on symbiotic gut microbes to help solve a range of problems. This is especially true in their digestion of food. The evidence is convincing that the disruption of this symbiosis will cause many negative consequences. For a sustainable future where dung beetles remove our waste and recycle nutrients, we need to farm and live responsibly. This includes reducing our reliance on antibiotics, and only using them when absolutely necessary. We should stop regular and unsustainable pesticide use and reduce our carbon footprint by improving our understanding and adhering to long term strategies.

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