Jaw Dropping Algorithms That Allow Social Behavior to Thrive

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Robert Marks:

Greetings. I am your non-algorithmic host for this episode, Robert J. Marks. How do ants find the closest distance from the Milky Way bar you dropped on the sidewalk back to their anthill? How do bees know how to build their hives or termites, how to build their homes to control temperature? The answer is algorithms. Algorithms that these insects are born with, algorithms that are step by step procedures for doing something. Remarkably, insects again, are born pre-programmed to follow these algorithms. Our guest today is Eric Cassell. In his new book, Animal Algorithms, published by Discovery Press, he explores these and other remarkable innate algorithmic properties embedded in animals when they are born. Today, we talk about how simple bugs living together do remarkable, complex things. Eric, welcome.

Eric Cassell:

Thanks. It's good to be back, Bob.

Robert Marks:

Eric, what is the primary aspect of insect social behavior that makes it so complex?

Eric Cassell:

The thing that's interesting about insects is that many of them have social behavior where it involves significant numbers of the animals living in colonies. And these colonies are not just a case of a number of animals, just simply living together, sharing a nest, et cetera. The colonies themselves are actually quite complex. And as time has on and scientists investigate these in more detail, they're finding more and more information about just how complex these colonies are. Some of them, the ones that are the largest colonies, scientists define these as being eusocial. And that involves a number of things where, for example, there's a division of labor.

Robert Marks:

Okay, eusocial, you're you're about to define that. It means this division of labor.

Eric Cassell:

Right. That's one of the primary indications of what represents a colony of insects that would be eusocial. So there's a division of labor where some of the ants might be responsible for foraging, some of them for maintenance of the nest, some of them for tending to the queen, some of them for tending to or feeding the young, et cetera. There's that aspect. The other aspect of these types of social constructs is the reproduction, how reproduction occurs. And a number of them, in most cases, there's a single queen only that reproduces. Sometimes they have multiple Queens.

Eric Cassell:

But basically what is going on with this division of labor is there's actually different castes. That's a term, castes, where you're dividing up the group amongst specific subgroups of animals. And these are the subgroups then are the responsibility of doing these different tasks in the colony. And again, when it comes to reproduction, the queen would be the one primarily responsible for producing the offspring.

But then there's another caste of males that's responsible for inseminating the queen for reproduction. So there's a lot of division of responsible abilities. And that whole aspect of it becomes quite complex in these larger groups that we call eusocial.

Robert Marks:

So in eusocial swarms, not all insects are created equal. They can never obtain equality in any way.

Eric Cassell:

Right. That's right. Yeah. And there's some, and we'll talk about this a little bit later as well, but one of the castes, for example, typically does not even reproduce at all in these social colonies.

Robert Marks:

In your book, you talk about a super organism. What is a super organism?

Eric Cassell:

So that's a term that some of the scientists came up with to talk about these most advanced eusocial organizations. In other words, these are the largest ones and the reason they call them a super organism is because the attributes of the colony has a lot of analogy with an organism. So in other words, what they're saying is if you think of an organism, we have a number of different organs within our body, the heart, the lungs, brain, skin, et cetera, doing different functions within the body. And so what they're saying is, in these super organisms, colonies, again, they're made up of thousands or even some cases, millions of individuals, different groups of animals within that colony are doing different functions.

Eric Cassell:

So what they're saying is you can tend to think of that as the equivalent of an organism. It's just that it's made up of a bunch of different individual animals. And again, some of these super organisms, particularly ants, termites, they can be comprised of millions of individuals. And some of the research into these, as an example in the Amazon rainforest, these types of colonies actually make up a huge portion of the biomass, which is incredible when you think about it, about the fact that these animals types of animals and the colonies have really become kind of a dominant form of life in these regions.

Robert Marks:

It occurred to me that in a way, our functioning part of our bodies are kind of like swarms that don't move. We have a bunch of cells, for example, in our lung. Everything, as I understand from biology, starts out as stem cells, and then they become different types of cells. But it seems that in our lung, for example, we have a bunch of cells and they're not insects, but they're they're little individual agents that act together towards a greater good. I guess we're an organism. And the idea insect swarms are a super organism where these individual agents are crawling around and not directly connected to each other. You mentioned different castes, for example, in the swarm colony. Other than that, what role do algorithms play in insect social colonies?

Eric Cassell:

Well, and you just sort of touched on that. The problem here is the fact that these are separate individuals. When we think of a single organism, there is overall control and coordination amongst the different organs, if you will, within an animal. So that's all embedded within the animal and controlled within the animal. In the case of these colonies, these are actually separate animals. They are all individual completely separate autonomous animals. Then the question arises, okay, how is the behavior of all these individuals controlled? And the first answer is there is no overarching overall control. In other words, there's not some higher level mechanism that controls the behavior of the individuals within the colony, that we know of. So that means that the behaviors of the individuals somehow is program into each individual, such that these algorithms that must reside within the individual ant or termite, for example, must be programs such that they know what task they're supposed to be doing at any given time. That in it itself is, must be extremely complex.

Eric Cassell:

And we know that there's a lot of information that actually is being used and exchanged for these animals to make these decisions. One of the ways that they do this is that they use pheromones, chemicals, that are exchanged between the individual animals. And these chemicals, or pheromones, are actually used as an indication, okay, something is going on in the environment or something is going on amongst this other group of individuals in the colony. Therefore, I must be doing this task, for example, foraging, tending to the queen, et cetera.

Eric Cassell:

And one of the things that's been found is that there are some ant species that use as many as 30 or 40 different pheromone or chemical compounds that are exchanged amongst the colony. And that also is just in and of itself is a highly complex mechanism because you have to have the mechanism within the animal to actually just simply detect the presence of this chemical compound. And then once you detect it, that information is then used to govern the behavior. So there's a lot going on in these colonies that's controlling their overall behavior as a group. Because again, there's a goal here that the behavior of the entire group must be governed to benefit the overall life of the colony.

Robert Marks:

I found this fascinating in your book, all of these different pheromones. So you're have one pheromone, for example, that tells the ant how to get home. I mentioned in the beginning about the shortest distance between the Milky Way bar and the anthill. And the way that's accomplished, as I understand is, is that the ants lay down pheromone and that the answer marching back and forth with little pieces of your Milky Way bar to the anthill. And they follow a pheromone path.

Robert Marks:

In fact, I have had fun. If you ever see one of these ant trails, there's a little line of ants going back and forth. If you dampen your fingers and you break that trail, the ants go up to where you've broken the trail and they get confused. They don't know what to do. They don't know what path to follow. Now eventually, they break on through to the other side and they rediscover the path going back and forth. But just by interrupting that with wetting your fingers and interrupting that path, you have ruined their day. They don't know how to get back and forth. And of course, I would advise if anybody did this, wash your hands after you're done, because you got ant pheromone on them.

Eric Cassell:

That's exactly right. But that's also an illustration of, in this case, ants, there is a lot of programming going on. In other words, these algorithms are programed. But the other interesting part of that is that they are actually able to adapt in real time. So in other words, like in the example you cited, you broke the path, they still figure out a way to adapt.

Robert Marks:

They do.

Eric Cassell:

And the same thing is true for other parts of their behaviors, where if something's going on in the environment, like part of the nest, for example, gets destroyed, you'll see the ants immediately stop what they're doing and go repair the nest. So there's a lot of adaptability in the way they behave, which again means these algorithms are highly adaptive and programmed to account for these different contingencies.

Robert Marks:

Yeah. There's lots of engineering applications where we have learned from swarm. One is called the ant colony optimization. It is literally an optimization algorithm that's based on swarm. I have a friend, Russ Eberhart, who with a colleague named Kennedy, had particle swarm, which was based on social insect swarms that also performed optimization. And I tell you one of the most chilling things I think that we have to face today is swarms of drones, where these drones come along in a swarm. And it's just like the anthill you mentioned, you kick it over and you come back in a week and it's rebuilt. It's the same thing with these drone swarms of say thousands of different drones. And they attack it, and if a few get through, they can accomplish their mission. This has been chilling. I think that there's ways to counteract those military swarms. But again, these are things that we are learning from swarm technology and the techniques that you're talking about that we can apply to everyday applications in engineering. We're learning from the swarms.

Eric Cassell:

Yeah. And a related aspect of that is artificial intelligence because obviously drones and a lot of other devices that are being developed today involve artificial intelligence. Right? One of the things that they're learning about it is the fact that it's much more complex to program these drones, even to just mimic what animals do, because the behaviors are actually way more complex than people thought. But then the implication of that is the artificial intelligence, the computer programs, do end up having to be really complex and sophisticated, which again is a further indication of how sophisticated the algorithms are in these animals.

Robert Marks:

Yes, yes. And there is a field of artificial intelligence called swarm intelligence that specifically investigates the application of social insect, swarms to engineering. What can we learn out of insect social behavior? And it's really a fascinating field. We still get back to, where does this come from? What are some of the challenges for naturalism and explaining this behavior, this complex behavior we see in social insect colonies?

Eric Cassell:

Yeah, there's a number of challenges I believe for Darwinian evolution in explaining this. The complex algorithms is one part of it. Again, as we mentioned before, if you have a complex algorithm. And if we think of it in terms of, for example, a computer program that is large, has a number of lines of code that we would program, it's again, trying to develop such a system that works properly through a simple trial and error process. In other words, random mutations and natural selection. It's very difficult to see how that kind of a process could result in such a highly complex functional system.

Eric Cassell:

The other aspect of this, that's a little bit sort of a side issue and terms of what I've examined in terms of the book and the social behaviors is the notion of altruism, where, as I mentioned before, there are some castes in these large social colonies of particularly insects that don't reproduce. Which, okay, you would say, "Qell, okay, so what?" But the problem that presents for regular Darwinian evolution is that for example, under the Richard Dawkins theory of the selfish gene, if an animal doesn't reproduce at all, how does it advance the progeny and contribute to the next generation? Why would such an animal even exist? But they do exist in these large social colonies. So that has presented a problem.

Eric Cassell:

And actually, Darwin even recognized this in his time. He wrote about it where this kind of phenomena with particularly the social insects presented a problem for his theory, the fact that these types of these castes actually exist in these colonies where they don't even reproduce at all. He wrestled with that. He did not have an explanation. More recently, evolutionary biologists have come up with a theory. They call it inclusive fitness, which basically means that when you examine the group as a whole, the group or species or population in this case, in a colony, benefits from the fact that some subgroups do not reproduce, but they're contributing to the overall existence of the colony, and propagating the colony over time by doing certain roles and tasks within the colony, but actually not reproducing.

Eric Cassell:

Really, it's a complex mathematical calculation to show that, okay, you're sharing your genes or at least the portion of your genome with the other animals in the colony. Therefore, in a indirect way, you are benefiting, even though that group of animals is not actually reproducing. It's a controversial theory. Many evolution advocates believe that that's a reasonable explanation. Others have contested that, and there's a lot of discussion in the literature that's gone back and forth about this, about whether that area is actually adequate or not. That issue doesn't really impinge directly on what my assertions are about these issues in terms of social insect colonies and the origin of these behaviors. That is a related issue, but a more fundamental issue again, is where does the information come from that programs these complex algorithms and controls the behaviors of all these individuals in a colony.

Eric Cassell:

And again, another aspect of this that there actually has been quite a bit of research done that's in the literature is examining the genomes of a number of these insects and bees, ants, termites, et cetera. And what they have found is that the species that engage in the larger social colonies, again, in the super organism type of colonies, the genomes indicate that there's actually a large number of either novel or genes that have been modified in these animals. And that they range from hundreds, in some cases, thousands of genes, again, that are either completely novel genes that have no common ancestry and the related animals previous, or they're modified in some way.

Robert Marks:

I think I've heard those called orphan genes. Is that right?

Eric Cassell:

Yeah. That's the term they use. They're called orphan genes.

Robert Marks:

They have no ancestry.

Eric Cassell:

Right. So again, the question is, does regular Darwinian evolution provide a good explanation for that? And the answer really is no. That's one of the problems that's been a challenge for Darwinian evolution is that really is again, random mutation, natural selection. How do you explain, for example, hundreds of these novel genes, all of a sudden appearing in a population or species. Darwinian evolution really can't explain that. Whereas, from a more of a design perspective, that's a little bit better, and I think much better explanation that this could be a result of design.

Robert Marks:

Next, we're going to get together one more time, and we're going to talk more about where the algorithms in animals come from. That's going to be, to me, a very, very exciting podcast. We've been talking to Eric Cassell about his new book entitled, Animal Algorithms. So until next time, be of good cheer.

Announcer:

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