Self-organised motion: the choreography of nature with Philip Ball

(*automated transcript*)

SPEAKERS
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(Introduction: Renée Bellamy speaking in 2021 over spare guitar chords)

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This is a field recording of variable quality with a live audience at Siobhan Davies Studios.

(2017 audio file begins)

Philip Ball
Hello, everyone, thanks for coming out on Halloween night. I wasn't just going to kind of launch straight into it but then I though, oh, actually, I probably should say who I am, and what I do. First of all, I am writer and author I trained a long time ago as a physicist, and I trained in the area of physics, but actually most physicists do, although people don't know that they kind of think physicists smash particles together or study dark matter or things, but most of them study an area called condensed matter physics, that's what I did. All that really means is, it's the physics of stuff that you can actually touch, you know, solid stuff, and liquids and so on. When I started thinking about and looking into how patterns in nature form, which was about 20 years ago, or more, when I wrote my first book on this subject, and I sort of looked at pictures like this. This is, I guess, cattle or bison, or something, and I looked at that, and thought "crikey, that's condensed matter!" I'll explain what I mean by that shortly, but it's something that is not unfamiliar to a physicist who's worked in that area. When animals like this move together, it's pretty impressive, in fact, it's sort of compelling to watch, I mean, we do use or, you know, biologists sometimes talk about choreography in these sorts of movements, and it's kind of enviable, really the coherence and the coordination that they achieve. And particularly, I mean, you know, there are so many different examples of these kinds of these patterns that form but I guess, in particular ones like this in schooling fish, and in flocking birds, well starlings in particular, are very good at this. And these, I mean, you know, especially these are called murmurations, these flocking patterns, and they're just so compelling to watch, you know, you might have already seen examples on YouTube, if you haven't, do have a look, because there are some amazing ones there. It's almost as though when this happens is that these creatures have acquired some kind of group mind. And the question is, how? What's going on? How is that organisation and coherence possible? And it puzzled zoologists, for decades, how they did this, some ornithologists thought that there must be a leader somewhere that all the others are following, but they could never spot one. And in fact, it turned out that the birds reaction times just aren't fast enough for ones over here to be able to follow a leader over there let alone, whether they can see them or not. So, you know, how is it possible? Well, it's only in the past, I guess quite a few decades, that enough understanding has accumulated about this collective behaviour, to get an understanding of how these amazing feats are possible, and it turns out that all these creatures need to do is to look at what the others just in its immediate vicinity are doing and to respond to that. This understanding arose not really, through any sort of fundamental desire from biologists to know what was going on, but simply from attempts to simulate this behaviour on a computer. It was it was in the 1980s software engineer called Craig Reynolds working in California, tried to figure out a computer programme that simulated little particles to show this kind of movement and so he went to the he looked at blackbirds flocking in his neighbourhood and he

watching closely and he decided that probably what they were doing was following these simple rules about just what their neighbours are doing. So he devised a computer programme, this was in the 80s so it was simple stuff and he called it these little sort of simulated birds 'boids'. It's like a sort of condensation of bird-like-droids, and he programme them to follow three simple steering rules. So here they are, so the each of the boids would avoid colliding with its flock mates, it would align its directional movement towards the average of what all its neighbours were doing and there would be some kind of tendency for them to stick together which can result which can arise just if they all kind of steer towards the centre of gravity. And all that really means is it's kind of like the centre of a little cluster. If they steer towards that, then it's as though there's some kind of attraction holding them together. These rules seemed guaranteed to make sure that the flock stays coherent, that's kind of what this third rule is going to do and you can sort of see that they're going to create some kind of lining up of these boids, what they don't include explicitly, there's nothing in here that tells you that what's going to come out of it is this large scale coordination across the whole group of how the movements happen. There's no prescription for that in these rules but when you do simulations on a computer according to these rules, then that's exactly what you find, you find motions that look uncannily like the real thing, and here are just some snapshots of a model like that on the computer, just in two dimensions here that sort of show you the kinds of movements that will arise under slightly different conditions, but basically the same rules. So here, you've got more tightly coordinated flocks and there less so, but they're all kind of aligned and if I was more ambitious, I'd sort of try and run the models online, because you can see them moving, you can do that for yourself, here, it's very easy to use this software, and it's just available online, and it's really instructive, I think, to see these, not only to see the patterns emerge, but to see how just tweaking the parameters of the model give you, just different variations on this same flocking theme. And computer programmes like this, are used in movies, they were used, you know, one of the first uses was in Batman Returns, I can't remember when that was, I guess it was in the 90s, for flocks of bats that way at the key point, though, is that the rules that are governing this behaviour are so called local rules, and all that means is each individual particle is just like I say, responding to its own little local environment. But what emerges are global modes of behaviour, all of these particles kind of somehow maintain coherence and behave in the same way and these rules are behavioural, ultimately they're rules that govern the decisions that these organisms or simulated organisms are making. Organisms don't have to be all complex to follow behavioural rules like that, insects will do it, ants for example, will respond to each other in their foraging behaviour and the way they do it is to lay down pheromone trails when they're foraging, which sort of act like attractors for other ants to you know, come and follow them, and the result of that is that you get these complex branching patterns that are actually very efficient for foraging over new territory. Or sometimes you get patterns like this. So, here they've got locked into a rotating sort of wheel, that's not getting anywhere, but they're just sort of following each other that way. Even single cells can communicate like this, so that they can self organise into flow structures or complex patterns, and here's an example of that, these are skin cells, that you can see are all kind of streaming in certain ways as they're proliferating. As it happens, these are my skin cells, that's another story but you know, I'm just intrigued to see that that's what they were doing and here's another example of single celled creatures doing something amazing. These are actual photographs of a kind of slime mould that signals to each other chemically. So they're individual cells that go about their business but under certain circumstances, if they have a lack of nutrients or water, they start to signal to each other, and they create these amazing patterns that are like waves that are sort of spreading out. This is actually the first stage in the sort of development, they start to sort of aggregate together and develop into multi-celled structures that eventually grow into this kind of multicellular structure made up of what would ordinarily just be individual, independent cells, and it's a way of surviving, basically. So some of these cells become spores that are stored in this head and get sort of scattered into the environment, see if they can find more amenable circumstances. So this is a coordinated pattern with a with a survival incentive and these self organised motions seem to deny any need for leaders but sometimes in animal movements in these flocking patterns. You do have individuals that know best if you like, that have some kind of privileged information. So, one or two of them may have spotted a predator or they might have found out where a food source is and so the question is, how do they get the rest of the flock to follow? And what's interesting in these models of this sort of behaviour is that this collective behaviour allows that information that maybe a few privileged individuals have to get spread very quickly throughout the swarm or throughout the flock. So it's been found, for example, that honeybees are like this so if just one in 20, honey bees in a swarm knows the way to a good location of food, then they'll be able to just sort of guide the whole swarm that way and clearly, you know, they're not saying follow me, they sort of bias these motions in the right way. And so this is actually sort of doing things this way is actually a very efficient way of letting the group know about the information that just a few of them have. But the main point is that the groups of these interacting individual organisms can respond to information gathered by just a few, and then that allows them to make good collective decisions. I mean, it's you could say, you know, it's an amazingly efficient form of democratic action that allows the wisdom of crowds to manifest itself, these processes of collective self organisation can apply to us, too. I mean, we, you know, obviously, we'd like to think that we're more complex than a slime mould and even than a starling. But humans do show this kind, I mean, we don't show it, there aren't really any circumstances in which we show flocking behaviour, or at least not in terms of our physical motions, we do show it in psychological terms, it's well known and people talking in economics about the herding behaviour and in fact, this is a kind of behaviour that standard, conventional economic models ignore, and that's why they're so stupid. But we do show some modes of this collective behaviour in physical space and in the 1990s, some researchers in Germany wanted to try to understand how that happens. And they came up with a simple model for how people move around space, which actually sounds almost insulting the simplistic, they assumed that people were just like particles, this is where the physics comes in, that just have forces of attraction and repulsion between them, this is all there is. Now, that might seem a very odd thing to imagine but you can see. So okay, we have these sort of modes of collective behaviour, you can see those forces, if you like, at work on a crowded beach where, you know, people as new people come and sit down, they tend to sort of position themselves, you know, not too close to other people, they go for the open spaces, it's as if there's a force of repulsion between them, that's forcing them into that place. Of course, there isn't, you know, a real force like that, like one that you can measure between two magnets say, but the key point is that people are acting as if there is, and so you can model the way people move in that way, and that's what these these researchers in Germany did. They set up the situations where they wanted to see what would people do if they behaved this way, you know, they have these sort of repulsions between them in different physical circumstances. So they thought, well, how do they move down a corridor, and they just let people come into this corridor, sort of at random and wander down it in both directions, but governed by this repulsion, that tends to keep them apart. And what they found is they get structures like this, where you get these streams forming, where people follow each other, and you know, who are going in the same direction or in the reverse direction, which of course we know this from Oxford Street, and from any crowded situation, that's exactly what happens, you get these streams forming. And that's actually an intelligent way to move about this space, because that vastly reduces the chances of colliding and makes the movement overall more efficient. But no one is directing that no one is actually even consciously deciding they're going to move that way on the whole it's just what emerges from these rules and because of these sorts of tendencies for you know, self organised movement to arise. These models can be useful for understanding how crowds move around, they were used, for example, there's a London based company called Space Syntax, which used some programmes like this, to plan the pedestrianisation of Trafalgar Square. They've also been used to look at how people move around the Tate Britain to try to you know, get that laid out more effectively and around the Notting Hill Carnival they've been used for crowd direction and to figure out where the points of congestion might be. And more recently, they've been used to try to relieve the dangers that exist that the Muslim pilgrimage to the Hajj in Mecca. There's something particularly interesting that happens when people move across open spaces like parks because there, it's bit like the apps I talked about earlier on, they leave a trail of where they've gone, just in terms of treading down the the grass across an open space. It seems as though that's going to be barely perceptible but if enough people do it, then gradually, you wear away a path, and so what are these paths like? And that's what these German researchers decided they would, they would look at next. So, in their model, they basically created this red grass, okay, so they have them coming in from the corners, these are the entrances to this Square Park, and the people are just coming in from these corners, and randomly going out of another corner could be you know, any of them, okay, and they assume that as people walk, they slightly wear away this grass very, very slightly, and they assumed that people have a slight tendency to walk where they can see others have walked. And we know that we kind of do this, if there is a slight track, we sort of tend to follow it, we don't necessarily do that, particularly, if it's very faint but we have a tendency to, you know, that biases, the way we go. Well, what happened was quite interesting. So these light blue bits are the bits where the grass is worn away and early on, everyone was taking the most direct route to wherever it was that they were going out of. But as time went on, and allowing for grass to regrow, if it wasn't walked over for a long time, this kind of trail mutated into this one, which looks, you know, much more sort of organic. And what's interesting about it is that no one is any longer taking the most direct route, in and out. It's something that is a kind of collective decision about how to walk across this space and of course, that is exactly what we tend to see in open spaces where these, these paths are worn down spontaneously. In fact, I've been noticing that that's starting to happen in Burgess Park and, you know, it almost always will. What's interesting about that, is that, these are the routes that path planners plan out, and then people subvert them by walking in the way that seems natural, which isn't necessarily the most obvious, I don't think, you know, a planner would have decided necessary any routes like this, but you know, wouldn't it make sense if actually, the park planners could put the parts where it seems people are likely to want to walk rather than trying to direct them in some other way that they're just going to ignore and subvert? And so this is the way some of these models might be used. And it's true also on the roads, and I want to talk a little bit about road traffic as well, which might seem even further removed from choreography I can imagine, but actually, there are some interesting things that come out of road traffic, which I hope will have some some relevance. First, it's just interesting that you can get quite complex modes of movement and organisation on the road. Secondly, road traffic provides a clear example of a general phenomenon that seems to crop up in these processes of self organisation, that I just want to talk about a little bit, and it's not a big deal in developing these models to go from pedestrians to road traffic, in some ways, road traffic is much simpler, because you're just going in one direction, one after the other. And so again, you have these models, where there's just effectively a kind of repulsion between cars, you just build that into the model, which kind of mimics the way people are obviously going to slow down to avoid collision. Okay, and then what happens when you run a model like this? Well, here's what looks like a very complicated sort of plot of what comes out of some of these models, and all this is showing is drivers moving down just a single straight road at a certain density of traffic. Okay, according to these rules, these lines going up here, each one represents a vehicle. So it's a time distance graph, which is just if you remember graphs like this from school, then it's just a straight line, just going in a certain direction at a constant speed. So, when something else is happening, then something is disrupting that flow, and what's happened here is everyone's been going along smoothly, and then up here, one guy has just well in the model, they've just made a little perturbation, so basically, someone was breaking harder than they needed to, to avoid collision with the person in front and that just set up a little disturbance of the model, but look what happened. So, as time went by that little disturbance became this is a jam. Because what's happening here is that these lines are curving over, which means that time is passing, and you're not getting anywhere. So, these dark bits are where the lines are kinking because people are held up and this is that what's happening to the jam, it's over time, it's just getting worse, and then it's dividing into several jams, and you get these stop and go waves of traffic. And by the time someone is coming on here, they hit this, and they hit this and then they hit another jam and another jam, they think "oh god, I'm out of it, at last," but then they hit another one here, and they think, "what's going to be ahead, it's an accident or something?" But there's nothing ahead, because the thing that caused this was over here and that's in the past, that's gone. So these are this phenomenon of phantom jams. And these sort of simulations show another common feature of this kind of physics, which is that the movement, can abruptly switch between different modes. So what's happening is, it's smooth here, and then suddenly, there's a jam and this is really where the condensed matter physics comes in, because this is like, for example, the way water freezes, okay, so you have water, you cool it down, you cool it down, you get to two degrees, one degree, and it looks like nothing's happening, it's just staying the same, and then suddenly, you reach freezing point zero degrees, and all of a sudden, it changes and it becomes a solid everywhere. This kind of sudden change in the state of a system globally, is what physicists call a phase transition and boiling is a similar thing that you heat it up and up and up, and the water just gets hotter and hotter. And then suddenly, at 100 degrees, it evaporated, it becomes vapour. Okay, so that's, you know, this is the physicist side of the graph, and this is what is happening with the analogous situation with road traffic. So, for a certain density of traffic, you just go and do what you want. Above that, you get this traffic that's moving and you know, we all know this, it's moving, but it's all moving together, it's kind of a mobile state, but it's dense and there are interactions between the cars, it's like a liquid, you know, you get a little bit more dense, and at a certain threshold, it's frozen into a solid. There are some other quite, evocative things that have come out of this modelling of road traffic. One of them raises the question of, well, how do you avoid this kind of freezing up? What do you need to do? And you know, these models can help you explore this, one of the ways that it seems you can avoid this, under some conditions is that you have automated driver assistance systems fitted to the can and some cars have this so that they stop you from braking too suddenly, you know, an automated system kicks in. And of course, now we're talking about fully automated drivers talking about robotic drivers, which you know, that people feel nervous about and I can understand why, but actually, it's been shown that if you just have a scattering of these kinds of systems, amongst traffic that actually steer and drive more optimally, more intelligently, actually, given the conditions that we're able to, that can melt away, what would otherwise be a jam. So you know, that's one thing that comes out of it. Another interesting question is about traffic lights, because generally speaking, traffic controllers use big computer models to figure out how to sort of sync traffic lights, how to sequence them in a given area. But in some of these models, people have found that there can be a better way of doing it, which is to make each traffic light, autonomous, make its own decisions. The way it does that, is that there are sensors there to figure out how many cars are waiting at that junction and it decides how long the switching between green and red is according to how big the queue is. Each traffic lights is doing that independently, but what can arise out of it is a much more efficient way of dealing with the traffic than if you try to have this centralised control. That's really the message I wanted to get to because I think that's the important thing that in systems like this, sometimes top down control isn't the best way of doing it, bottom up organisation is better where it's a collective decision that's made from these sort of local rules of how the individual components behave. So it's clear then that these sort of complex choreographies of moving agents can arise from these simple rules, and this kind of behaviour can be adaptive can be flexible, it can be you know, more efficient than ones that we try to plan. I want to take this to a slightly more abstract level beyond a consideration of what the psychology of individual animals are doing, because you see a rule-based system like the one I started with, with these boids, these sort of computer models of swarms, you can think of it as a kind of algorithm. That's a word from computer science that just means you're following a set of rules that determine how a process unfold step-by-step. So, you feed in some input data and then the algorithm proceeds to manipulate that data until it produces an output. So, with boids for example, you start off with just a random scattering of these boys, but they've got an algorithm they're following and over time as that unfolds, this is the output and organised collective and beautiful way of moving. So, it's fair to say then, that you can think of these sorts of processes as actually a kind of computation. I don't mean, you can simulate them on the computer, I mean that the actual physical systems, cooling fish and swarming birds, can be thought of as conducting a kind of computation. So, you might think, well, what's the result, when you do a computation, you want an output or result, what is the result? Well, the result might be a way of avoiding predators, or the result might be an actual physical thing like this. So this is a kind of output of a computation performed by 1000s and 1000s of termites who are individually moving around, but collectively building this complex network of tunnels and channels. This is a plaster cast of what would otherwise just look like a mound of earth, this is the termite nest, and this is what it looks like inside. It really is a kind of, computation. It might seem an odd way to look at movements in the living world this way but it's kind of a thing that physicists do and I think it's fruitful. You could say, it stems from an initiative that began in the 1950s, when two physicists started to think in terms of a very simple model of complex behaviour that they called cellular, what became known as, cellular automata. The idea here is that you have a sort of checkerboard of squares that could be black or white and there are simple rules for determining whether any particular square will be of a certain colour, which could be for example, that if there's a white square that has at least between, let's say, between two and five neighbours that are also white, then it will turn black. Otherwise, it will stay white, that could be a rule, okay, you can create all kinds of rules like this and then you just sort of see what happens when you play these rules, and one of the things that happens is a case called the Game Of Life, it was invented by a mathematician called John Horton Conway in the 1960s, and he found that under a certain set of rules, you get complex patterns that move across the grid, they look really like living things just moving and sometimes mutating as they go just from these simple rules. And it turns out that, you know, lots of the patterns that I've talked about, in fact, all of the patterns I've talked about can be created by different cellular automata with slightly different rules. So, those spiral patterns that I talked about, that the slime moulds made, can be created this way, too. The reason it was invented actually was, well, these physicists were interested in whether computer systems could show a kind of thinking and an ability to evolve. So, they figured this might be a way to simulate it, particularly because you can imagine this as representing a computer system where you've just got memory elements that are binary that are either a one or a zero, like there are in all computers, so the white is zero, and brackets one and so you just see how these patterns of information unfold. So, what this implies is that this spontaneous patterning is a very complex, it's very common property of complex systems that consist of many interacting components and they have a delicate interplay between chance and determinism. So, chance in just the way you've set the system up and determinism in the rules that you've given it for unfolding. Now, forgive me if I'm kind of reinventing the wheel here, but I want to gently suggests that choreography too might be thought of as a kind of, computation that involves the transmission and the alteration of information between dancers and their environment, and that might sound like a very cold technical way of talking about it, but I don't think it need be and certainly when we look at the patterns that result, that are complex, adaptive, flexible, intelligent, problem solving, I think thought provoking as well and certainly rather beautiful. So I don't think there's anything cold in what can come out of that but I've also got the confidence to at least suggest that idea because I know that there are some choreographers who are interested in thinking about the work this way. I am here really because I have the privilege and the pleasure to work with Vanessa Grasse on a project in Leeds, that was using rule-based systems like this to coordinate a group of dancers in ways that could be responsive to the environment, in which they found themselves and they would go out into city centres and perform these sort of algorithms really, and see what came out of them. This isn't the only example, for instance, there's a biologist and engineer at Princeton called Naomi Leonard, who's collaborated with a choreographer Susan Marshall on a project called Flock Logic, in which dancers were assigned some of the rules that Naomi's work on flocking, birds and schooling fish had identified and just to see what, sorts of patterns might come out. Naomi, more recently has worked with the choreographer, Rebecca Lazier and the composer called Dan Truman in New York, on a piece called, There Might Be Others, and this is really interesting, because this is more like what engineers would call reverse engineering. So, Naomi and her collaborators were watching a devised dance piece, and trying to figure out what abstract, mathematical rules would give rise to those movements and then to see if they got them right, whether they could simulate the movements that were coming out, and then if they had that model, then they could use it creatively, they could figure out which dials to tweak which parameters to tweak so as to create new possibilities, new compositions. So I think that was a very interesting way of working. And I'm going to stop there, because I want to know what you make of all of this, and whether it's useful, whether it's at all inspiring, but I should just say that these ideas are ones that I've talked about in several books now. This one, looked at the application of some of these ideas and others to understanding human social behaviour from economics to this sort of traffic modelling to things like conflict and conflict resolution. But then in these books, I looked more at natural pattern formation, this one is mainly an image book. And I can happily say that it is absolutely gorgeous, because I can claim no responsibility for the images, they were found for me and they're really spectacular. And this one is a part of a trilogy of books about pattern formation but this is probably the most relevant as you guessed from the title because it's looking at flow patterns, like this in animals and groups, but also in fluids, which have another language of their own. So I'll stop there, thank you.

Gitta Wigro *(30 minutes)*
This is not directly related to choreography, but it is now in my head and I want to get it out. Something that strikes me is that we think of organisation, when humans do it, I think we think of that always as something planned. You know, organising means something that isn't emergent patterns even though they might be more effective. I was reading something that I think a subway system or transport system was modelled first by putting slime moulds or something down having little food pockets where the different interesting bits of you know, there's a shopping mall here and there's a thing here and then

putting little bits of food on the thing and then watching where the mould grows, and then using that instead of planning something. But I think it's interesting that there are these highly efficient systems but somehow humans we think of the planning always as the way of organising that is efficient. I wonder whether I just can't think of enough other examples or whether you think more so that is the case that we rely on planning more than emergent organisation?

Audience
Well, I mean, I think we do but this is a really big debate, discussion, particularly amongst urban theorists, one of the first people to really argue the case for what in science is now thought of as complex systems was the urban theorist Jane Jacobs in the 1950s, who really insisted on the fact, she was looking at the redevelopment of parts of New York, and she was really insistent on the fact that cities are spontaneously emergent organisms, really. I mean, that idea actually goes back even further to the theorist Lewis Mumford in the 1930s. He talked about cities as organisms, but Jane Jacobs really made the case strongly. Her key book was the life and death or the rise and death of American cities, and you know, there are plenty of people in urban theory, who now advocate this, that cities in particular have to be thought of as organisms. But, you know, the conventional way of thinking about how to plan urban spaces was very much that top down idea. I mean, this is what, you know, this is Le Corbusier, and it's the Aylesbury Estate, you know, that was the way you did things then and it's now clear, that's not the right way to do things but it's not because the buildings were badly designed, it was because the philosophy was wrong, and I think there is now a real sort of emerging understanding. In fact, in London, it's one of the places that has really driven this forward at the Bartlett Centre at UCL and, it's really becoming understood that this is a more sensible way to do things that urban spaces are spontaneous and if you try to force them into a certain way, you create problems, but I think the message is much wider than that and that's only very slowly catching on, you know, the ways companies are organising. Yes I was thinking about organisations of people because in a way to say, "okay, we'll put down a park, we'll see for a year how people behave, and then we'll pave the bits that people want to walk on". Whereas if you set up an organisation, it's very difficult to say, "we'll just pile some staff in there, see how they get on, and then give them job titles, once we know how they interact," you know, it's harder to come up with a structure that would serve that, but actually, I think seeing choreographers or collectives, or, I think in the arts, there are examples of that kind of behaviour happening on a smaller scale, because, you know, groups of people start working together and things arise out of that, but I don't know, that might be too much to do with personalities as well to be truly applicable. Yeah, I mean, you know, that obviously complicates it and in particular, you know, a lot of the systems are ones where you're dealing with very large numbers of things. So , you're getting very average behaviour coming out of it, when you're getting down to small numbers, then little perturbations, like personality can make a big difference. So it's much harder to anticipate what the sort of emergent modes of behaviour would be, funnily enough, in a way, when you get to smaller and smaller systems, but you know, I think that is starting to become a philosophy of doing things. I suppose that the point really is that, it's not a recipe for anarchy, because you actually have very clear rules for how things should happen, and the people, have to follow, but those aren't rules about what the end result should be, they're not trying to reach some pre-existing objective, it's just that you will trust the out of those rules will come an efficient solution and absolutely, that's the way nature does it. It's the way nature does just about everything is the only way nature can do just about everything. I feel like we all instinctively know, or unconsciously knew this without thinking about it and feel like it's now revealed how we operate. So, it is now shown to us how we operate and it has always been like this. Then it's applicable from macro to micro to all series of levels and it's related to what you just said about the personalities. I come from Japan, and the Japanese cities are much more orderly, because I think the culture operates to think of others, more than independently moving so we are always aware of what's happening around us. More so in London, so we find more flows and corrugations and we understand how the mass is moving, especially in the tube situations or the crossing and that's because we are open to the locals

Phillip Ball
Well, that raises the very interesting point about cultural specificity or cultural differences, because, you know, that, again, is talked about by urban theorists that you see different spontaneously emerging patterns of settlement and even city, in particular, it's been looked at in the Middle East, and in African villages that you wouldn't see in a village, you know, in rural England, they're both solutions to a problem if you like, but they're different ones, because social interactions are different. I mean, it's the same, even at the level of crowd behaviour. Sometimes it's little things like, there are sort of just subconscious expectations about on which side, you pass a person, it's why, when we're in an unfamiliar country, we are often bumping into people because we don't know. So there is a cultural specificity, that is just like a tweaking of the dials, really but you can still have, you know, different emergent patterns and I think you're absolutely right. I mean, you know, so often, people who are, urban theorists who are interested in this, they look at traditional modes of organisation, or things like villages, and are starting to really appreciate that they are intelligent modes, if you like, because they haven't had this, imposition. I mean, it's the same in London, actually, you know, London is a classic city that developed organically, and that's almost impossible to plan for now, because of that, in the infrastructure, it's only in somewhere like, you know, when you have a big

intervention, somewhere like Paris where the boulevards were very much planned that you can, you know, necessarily do something about that. But it's interesting, after the great fire, Christopher Wren had this fantastic programme of how, you know, this wonderful city that was going to arise from it, this planned city, was very much of its time the Enlightenment idea, but London, you know, just took over too quickly you know, that's what happens and it's probably the best thing that did happen. So yeah, I think we have always, if we've not known it, we've always done it at least Yeah.

Audience
Sorry, very different example of the Mississippi River, there's beautiful Mississippi floods and then over the history of the US, they always needed to redirect the river for the human use to reclaim the land. But over centuries or decades, the flood comes and the weather changes and the river goes back to how it used to be. So it's a history of these movements of water and there is a huge scale model of the river made to see the behaviour of the water and of course, it's a water topography.

Phillip Ball
Thank you, because rivers are a fantastic example and in fact, you see that even more clearly in Chinese culture, where, since ancient times, there has been a debate that, broadly speaking it's between the Confucian and the Daoist way of managing rivers. And it's explicitly sort of talked about in those terms and so the Confucian way, is you have rules and basically, you build the dikes high on either side, to confine the river and get the river to go where you want it to go in the Daoist way is, you let it do its thing and you just, make sure it has a big floodplain to do that. There's a constant debate between hydraulic engineers in China since the earliest time since the Qin and Han era of what is the best way to manage the rivers, and it completely draws on these different philosophies that have a much broader application that has had huge consequences for Chinese society. So yeah, rivers are a really good example of that: to what extent do you try to get nature to do your bidding, and to what extent do we have to let it do its thing?

Audience
So, in that case, is it kind of like a form of computation as well? Where, it's fine. I mean, my assumption is that the river is that intelligent that somehow it finds its own way, depending on how the environment changes.

Phillip Ball
Yeah, it is, and you absolutely can see it as a kind of computation. I mean, that's the important thing to understand is that computation doesn't mean intelligence at all. I mean, it depends how you want to think about it as an intelligence, it doesn't mean intention. T ere isn't necessarily a goal that it's trying to get to, it's simply the unfolding of an algorithm of a set of rules and with rivers, for example, those rules involve things like how the flow effects erosion, and how the amount of erosion affects the amount of deposition of silt on the bottom of the river, and you can formalise these as a kind of algorithm that, is a computation and out of it will arise a certain kind of river. In fact, this is exactly what geomorphologists do when they want to try to understand rivers, and so they find that under some circumstances, those processes will give rise to these so called lovely braided rivers where you have lots of channels, intersecting. In other situations, you'll just get a big thing called meandering river. So, those are the solutions to the computation that the river is performing and I do think, it sounds like an odd way of thinking about it but I do think it absolutely makes sense to talk about it that way, not only because it helps you to model it, but also because I think that is what nature is really, really doing it. It's part of a general movement in all the sciences, which is really interesting to think about what happens in nature as processing of information. Physicists are doing that, biologists are doing that, even chemists to doing that, actually. So yes.

Kirsty Alexander
There's something about bacteria, it's not that they swim towards sugar, it's that they work out, which direction there's more sugar. So, they're essentially doing kind of that kind of mathematical equation working that out. I read something about that, because you were talking about single cells and bacteria do something quite complicated in terms of where they, how they, travel.

Phillip Ball
One way of looking at, it could be to say that they are using calculus, because what they're looking at is a gradient and that's what calculus is all about, at least, differentiation, it's all about looking at rates of change. So, what bacteria are doing, they have the sensors within their membrane, to work out what the gradient is, and how the gradient of concentration of sugar, let's say, in which direction is it going up? And then that's what they'll follow? So it is, again, it's a kind of computation, but it's a mathematically quite sophisticated one but the way their metabolism is set up, allows them to do that. You know, that's what evolution has given it, if you like.

Kirsty Alexander
I don't know if I can articulate this, but it makes me think about this kind of thought can start with metabolism and the metabolism as a source of thought, rather than we tend to think of thought as nervous system and brain and all of that but actually metabolism is a kind of way of thinking.

Phillip Ball
Yeah, I think that's a very valid way of thinking about it. I mean, even thinking about things like the origin of life, people are thinking about it much more in terms of not, how did DNA start? And how did you pass on genes? But in terms of what the energetics, the metabolism is, what do you need? What you need to get these kinds of patterns is a system that has some kind of force driving it, so it doesn't settle down into some equilibrium, all of these patterns come from that. So, you know, we're throwing water, it's just gravity is keeping the flow going but it's keeping the flow going forever and as long as that flow goes, the water will form itself into patterns and that's really what metabolism is about. That is what is keeping a cell away from equilibrium, which in the cells case means death, it's keeping it dynamic. So that's absolutely right, whereas, the genes are just, they're static, they're just sitting there a lot of the time but the way they're being used actually, that's also dynamic, that's also changing. It's not like a predefined programme that's just being read out, it's responding. The genes are responding to the environment, the environmental signals, so that's being kept out of equilibrium as well. So, all of this is about having some kind of energy input, ultimately, that is going to keep the system away from equilibrium, and out of that, arises these dynamic patterns. Once you get equilibrium it's death, you're over, you're sort of frozen into, you know, an interesting, solidity.

Audience
Does there have to be some kind of almost steadiness to the state of disequilibrium. So that there's almost a sense of equilibrium and disequilibrium happening simultaneously? But the equilibrium never quite settles?

Phillip Ball
Yes

Audience
Because otherwise it's almost too chaotic.

Phillip Ball
Yeah, that's a good way of putting it, a lot of these systems find what's called a steady state, which is a balance like that. So, if your driving force, if your energy input is too great, then you do actually get chaos, you get randomness, you get turbulence, it's out of control. But if you can find a balance, then you find a steady state and won't try to find it quickly but what I can do is to show you that actually. This is, it looks like the spiral patterns, but you see exactly the same kind of pattern in certain mixture of chemicals that are reacting, and you just leave them in a dish, and this is actually what this is really simulating, you leave them in a dish, and they form these patterns that are these waves that are constantly moving out, and so on. What's happening, there is exactly that kind of steady state where the chemicals are reacting with each other but if they just did that, they would, you'd run out of stuff, what's also happening is they're diffusing through the system so that if you run out, you're going to get replenished by stuff diffusing from elsewhere. And that diffusion happens, you know, it always smooths things out, so even if you're running out of an ingredient here, then stuff will come in from the outside. So, it's that kind of balance that under certain circumstances sets up this steady state and you get this regular pattern under slightly different circumstances, if the driving is bit harder, these spirals break up, and you just get kind of fairly, you know, chaotic looking patterns, which are actually quite interesting, but they're not organised that way. So, you're absolutely right, that's really, it's finding that dynamic balance that is creating these patterns.

Gitta Wigro
That actually fits with what I was going to ask. So, the rules that govern this kind of pattern building, like the boid rules, the simplicity of them, are they sort abstractable characteristics that mean that they are more likely to work or not, because I'm thinking about improvisation scores, and you develop a hunch of what kind of scores might produce interesting, dynamic but legible patterns that translate to an audience that's going to watch them as opposed to just, you know stuff happening. Are there other characteristics in this kind of world that you can abstract that you can tell this might work better as a rule, and this might work less well as a rule?

Phillip Ball

I guess I'd say, to some extent, but it's quite hard to build. People who work in these systems do build up intuitions about that, but it's very hard to generalise what those intuitions are, I would say, a general one is don't have too much energy, but that's not hard to intuit, because things will just get out of hand. I think that's one of the issues that has sort of come out of studies of cellular automata, that they fall into just actually four different classes of types of pattern, and this is one of them. One of those classes is quite sort of regular, and you get a pattern like this, that settles down, you could think of this as a timeline of a strip of these things, and it settles down just into regular stripes, that just stay the same, you got to fix that steady pattern. It's still a pattern, but it's not particularly interesting, if you have slightly different rules, like you know, you just need a few more neighbours before you die if you like, or you change the colour, then you get interesting patterns. It's hard to say what is interesting about them, but there's something about them that we respond to, you know, like this and if you tweak them a little bit more than you get ones that just look too random, I don't think it is really possible to generalise about what rules you want beyond that, it's trial and error depending on the system you've set up but a trial and error you can eventually develop intuition for

Audience
Is it wrong to call this a different form of intelligence?

Phillip Ball
No, it's not at all. I mean, like I said, that is completely the motivation for setting this up in the first place to see, whether you could get something like that. I also had recent medical brain research, that the brain is not the only one thinking, all parts are actually thinking and information is fully processed by all parts of our bodies.

Phillip Ball
Well, that's one of the interesting things that some people in artificial intelligence are starting to acknowledge, there's been this idea, and there still is this idea in some areas that you're going to make a kind of brain out of silicon chips or something, and it's going to think, and a lot of people now who think about cognition and artificial intelligence in a more sophisticated way, recognise there's a somatic element to that there's, you have to have an embodied brain, for it, to think it has to be in some way connected to its environment, even to be able to think, you know, it's not a question of, oh, if that's the only way it can respond to its environment, to actually have something coherent enough to be called thinking, you have to have that input. Philosophers are really interested in the whole notion of a brain in a jar, and they talk about, is it possible for a brain in a jar to actually it's the kind of Matrix scenario, you know, is it possible for that to exist? And to be thinking in some sense, and, there's a line of response to that question that says, "no, it isn't," that you only qualify as a thinking agent, if you have connection to your environment, and you have a somatic input to that. So yeah, I think, that's probably what you heard about, and it makes a lot of sense to me, that actually, I would say it's in a sense, it is, you know, that we're thinking with our whole bodies. This is the kind of control centre of it but there's more to it than that.

Kirsty Alexander
I'm just thinking that when we looked at the swallows and the fish, there's something about the intelligence was distributed if you like, throughout the whole flock or the whole swarm or whatever and there's something about that distribution on that kind of cellular level, in terms of intelligence, and that idea is quite familiar in a lot of somatic practices that talk about different kinds of cellular breathing or cellular awareness or Deborah Hay with her, what if I could keep all my 13 million cells and my awareness at once? So, it's kind of an idea that has come around a lot.

Phillip Ball *(1 hour)*
Yeah, well I'm about to be confronted by this in quite an interesting way because it's, just thinking about neurons and how and what's going on, you were saying, you know, is there some kind of communication between them, is that thinking? Those skin cells that I showed you, they were taken from my arm, and they're being developed by people at UCL and being taken into a stem cell like state from which they will cultivate them into neurons, and they will grow into a clump of neurons, that, when it gets big enough starts to become a brain like structure, they call them mini brains, they grow to about the size of a pea and by the time they get to that size, they're starting, they're not just a random bunch of neurons, they're starting to take on the structures of a brain, like you'd see in. Yeah, the neurons are signalling to each other, and you even start to see, because this is just how cells work, that they're intelligent in the sense that they know what to do. They know how to start forming these different structures that the brain has and you even see the development of a kind of proto spinal column from them, in fact you see several of them, it comes back to the environment again, because it's not happening in a bodily environment, it doesn't have the right signals. So, it starts to develop these little structures, but they they don't have the right organisation because they don't have the right input from their environment, and this isn't just, you know, it's in being weird. It's the motivation behind this, that people at UCL are doing this in particular to understand what the genetic processes are,

that are involved in congenital or early Alzheimer's. So it's the neurology department that's doing it and I'm involved in a project they're doing, that's kind of an outreach project about that. So, you know, this, this project is to sort of communicate that work and why it's being done but it's also just to see what responses that it will create in me, and I think it does raise the question, it makes me think, I'm not at this stage, at least, I'm not concerned about thinking, "oh my god, this brain is you know going to be starting to think, let me out or something." I don't think that's possible, but does it qualify as thinking, once you have enough of these that, you know, they'll be signalling to each other, and they'll be starting to organise, to show some kind of self organisation. I don't think it qualifies as thinking or awareness, but it comes kind of semantic at some point. It's not going to get any bigger than that but no, don't worry, because it can't I mean, unless it has a vascular system, a blood supply, then cells start to die off, and, there's no reason to grow it bigger than that. Ultimately, it'll be used as a healthy control sample for the research they're doing. But it's, really interesting in terms of this question of, is this intelligence? Is this thinking? And neuroscience is really confronting us with those questions of, what do we mean by that? And is there some kind of threshold? Beyond which this qualifies as thinking or what? We don't know.

Audience
When is that choreographing? You know, when the pea-sized brain starts to organise some choreography, I think that's when we're in business.

Phillip Ball
I mean, it's interesting, because, you mentioned, the case of slime moulds, and it's not dissimilar to that. There are cells that are signalling to each other there, and they are used, like you say, they are used to find solutions that, you know, they, for example, they've been used to find the most efficient way through a maze, and they do that, collectively, they grow in the most efficient way. That's a computation that, you know, find the right solution, and it's not obviously, so different from what's going on in a bunch of neurons that's trying to perform computation. So yeah, you know, these questions really do arise.

Audience
That makes me think of communities, you know, how this little cluster of how a community kind of self organises itself and works together.

Phillip Ball
Yeah, well I think absolutely, that's the right way to think about it. This is really what Jane Jacobs was saying that it's not just that cities have this particular sort of organic structure, which we should respect she's saying, cities are intelligent, communities are intelligent. This is a kind of intelligence that the community collectively finds spontaneously, and to think that we're somehow going to come in with a top down solution that will do better than that is naive and destructive. And I absolutely think that's the right point of view. So yeah, that's why I think that, there is this value in preserving communities, not just for a sentimental reason, but because it makes sense because it's more intelligent in that way.

Audience
It seems like it was it absorbs diversity better to allow things to just interact as they are than to impose a system upon them.

Phillip Ball
Well, that's another issue that has emerged from this sort of study of complex systems, particularly, you know, in human contexts, that diversity aids, the finding of intelligent solutions of good solutions. You might think, well, yes, we'd like to think that, wouldn't we, but actually, whether or not we'd like to think that it's the simple fact that it does, and it you know, obviously it makes sense that it would because if you're looking for a solution to complex problems, maybe it's even interesting that you know, there's been work on, again, coming back to companies looking for, the best way of managing, they find that the best way of doing that, is not to put all your people who you think are most smart into a room together and let them find a solution. It's to utilise the diversity in a company you need people who will come up with different ideas, otherwise you just get stuck in these kinds of, frozen patterns. So, it's very clear that diversity is an important element in any of these collective decision-making processes. So, thank you for that.

Audience
I was doing some research on permaculture, and it's exactly what you're talking about when you grow things together, they're naturally going to form patterns, and there's going to be other life forms that will come about that support those systems and react to those systems and encourage that spread.

Phillip Ball

Yeah, one of the key issues that ecologists are talking about and actually anyone who's doing this work is talking about, but ecologist perhaps particularly, is robustness. Where does robustness come from? And that's exactly the point, it comes from diversity that, it's very clear now in ecology, that once you have too much of a monoculture, it becomes really fragile, it becomes unable to adapt to unforeseen circumstances, it might seem to be performing brilliantly, until something unforeseen comes along, and something unforeseen will always come along in ecology or in human society. So that's really the key that robustness and adaptability comes from that diversity.

Kirsty Alexander
And for having the freedom to respond, I guess, in terms of not being over obliged and constrained.

Phillip Ball
Yeah, well that's the only way that you'll make effective use of the resources that you have available.

Kirsty Alexander
I was thinking about the river again, that whole lemniscate movement of a river where it's taking nutrients from one side, and then they end up on the other side, and then it takes the nutrients from that side. There's something about what the river is always going to go back and try and do is to keep that diversity going of what's on what side of the river. In terms of nutrients from one side to the other, or disturbed by depositing a bit of gravel picked up on one side and on the other side there's a kind of.

Phillip Ball
Yeah well, often the discussion is about, it sort of makes sense that if an ecosystem has grown up around a river that does that in a certain way, that it's kind of tuned to the river doing that, but sometimes it goes beyond that, as well, that ecosystems feed back on the geological environment. That's absolutely clear, and so, in some ways, you could say they tune their geological, their nonliving environment, to suit them, that it's, they're completely interwoven. That's not kind of controversial, or mystical stuff that just what we know, happens. So, that, I guess is why it's particularly important, and ecologists recognise this, not only to think about the biosphere, but to think about the interactions it has with the oceans, and the atmosphere and the geology because they are interdependent.

The rivers must also be affected by global warming, the human influence of what's happening, the weather, water, gravity, the weight, the velocity, topography, the artificial grass, must be affecting each other, all the floods are happening everywhere now.

Phillip Ball
Yeah, absolutely, you know, that's clearly a disturbance, that's going to happen, and the ecosystem will respond in some way, but it won't necessarily be a way that will be good for, the human environment, let alone the ecological ones.

Audience
Do you have any thoughts about how human violence is a necessary component, if you like, of a dynamic equilibrium. On a large scale, I don't mean sort of small but large groupings, global.

Phillip Ball
There are lots of thoughts about how the opposite is a component or not, I mean, one of the big areas of interest in again, in ecology, but also actually in human society is game theory. Thinking about how cooperative and individualistic behaviours let's say, what sort of stable states they might give rise to and it's interesting that in simple models of that, I mean simple models of that they can be a bit like sort of cellular automaton models, where, for example, you know, very simple one is that you say that, one type of square is cooperative and so it allows others like it to, you know, arise around it, but another type of square is what they call defectors. So, it's kind of selfish and you know, tries to colonise the other squares and the question is what are the stable states of the system and you get very complex behaviour that arises out of that, including sometimes, you know, patterns like this, where you get spreading of cooperative behaviour, or spreading of, or colonisation of defective behaviour, or defecting behaviour. There's all kinds of modelling of that done that has now become much more sophisticated than that and people who are interested in conflict, are really looking into to what that can tell us, for example, and, again, it comes back to sort of this diversity question, there have been people who have been modelling Jerusalem, looking at different patterns of settlement and degrees of segregation between the different populations there, and under which circumstances you're likely to get tensions between the groups, and under which circumstances they coexist peacefully. The

modelling can get quite sophisticated about that, and it's very interesting to see what can arise out of that, and that perhaps is no surprise, in some ways that if you have too much segregation, you have more tension and more likelihood of conflict, where the different regions meet. So, you know, if it's possible to find ways, rules or ways to guide the system without imposing it top down so that there is more integration, you know, that can ease those tensions but it's complicated, it's very hard to generalise that in some cases, you know, too much mixing or certain kinds of mixing can increase tensions. But absolutely, there's lots of interest now in how these sorts of ideas play out in areas of conflict.

Audience
It makes me think about in classes, when someone goes to a dance class it will either be taught or facilitated by, and that kind of like difference, for me taught might imply more of an imposition than facilitate, which is like more of an encouragement to, like self-manage in a way.

Phillip Ball
I mean, is this a kind of tension that exists? I imagine it is but you know, to what extent does the group choreographer impose their vision? And to what extent is it one that is allowed to arise? And how adaptive is it?

Kirsty Alexander
I think people work in different ways. Certainly, you know, there are the traditional model of the person that comes in steps and goes 5678 has made all in their own body or in their own imagination and transmits it and the dancers are the bodies that realise that, that still exists. There's also more people working in a much more self organising way where there might be someone who's identified as the choreographer, because they might be the person who takes responsibility for the project in a way they might be the person that raises the money and has the starting point of the idea and organises the other collaborators, or is responsible for where it's going to be performed but actually, in the studio, how the actual work arises might be anywhere on a continual from the traditional way to kind of quite self organised.

Gitta Wigro
And that can be made explicit or not or sometimes when crises appear, it's because it's phrased a certain way, but not lived a certain way, I guess, that there is sometimes a discrepancy between how that's set up or perceived or named. I think something that's been rolling around just that these systems don't have a pre-existing objective, which is an interesting thing to play with if you're thinking about devising a piece of choreography using input and scores and improvisation

Kirsty Alexander
I guess they are the objectives of survival sometimes like the slime or whatever they organise themselves to get the objective of continuing in a way sometimes.

Audience
Well, I think it's a really interesting and really difficult thing to talk about the biologists are really wrestling with, of how do you talk about objective? Because in a sense, you're absolutely right there is that imperative, you have to survive and often what that means in living systems is, you have to find efficient ways of doing things. Not necessarily because if you don't, you won't survive, but because if you don't, another system or another individual will do so and will outcompete you and so you won't survive in the long term, and that's evolution but how do you talk about that without making it sound like that's the intention or the purpose or the motivation? And there isn't, you know, biologists don't have a sort of language for talking about that, but I think that what's coming out of some of these studies is that actually, it's not just biology that has that, issue, rivers, for example, river networks are really interesting, because you can talk about them as having an objective, they actually self organise themselves when they're complex branching networks, to be, in a sense, also the most efficient at dissipating the energy that goes in the headwaters, dissipating it into the environment. Now, there, it's clear, there's no kind of thinking there's no, being that's kind of saying this is what you have to do, but the river network is finding that solution. So in a sense, you know, you could say it has that objective.

Gitta Wigro
but it is, I mean, the way I heard it is, it's propelled by living the energy that's entered into the system, and for me, I can make a metaphorical jump to a lot of the artists whose work I see where it's not that someone walked up to them and say, I would like you to make some art, please. There's a living of an energy that you know, I have to mess with this, I have to make this I have to try this. I have to see what happens when I go like this.

Kirsty Alexander

And the interesting because when you were talking just now I was thinking, oh, yeah, rather than think of it as an objective that sort of proceeds you, to get to in terms of ahead of you to get to when you were talking. It did sound much more like a propulsive force, pushing you along. I think that's absolutely right, in terms of art making, there's a drive to do it.

Phillip Ball
I find it, just because I'm more familiar with it, I find it, you know, easier to think about in terms of music. I guess, it wouldn't mean very much to say that, for example, the objective of an orchestra is to, you know, get to the end of Beethoven's Ninth, that's not, you know, that's what they have to do, but that's not the objective of you know, that it doesn't mean anything to say that's what they're trying to do. So, you know, there it's almost as though actually, what Beethoven has done is to set them some rules that are notated on paper, and they have to find a solution to those rules. And it's a solution that somehow is going to be one that, you know, will resonate with people, but it's very hard to put into words, what that solution what that process is, but again, it's you know, it's a collective one, but it's, you have that same kind of balance, you know, is it the conductor imposing their vision of what this could be like? Or is it you know, at the other end, it's a jazz group, who are completely doing it collectively. So you have that same continuum, and that same kind of tension. But I suppose, you know, again, you have you're not just, I mean, even in the most freeform jazz, I think you're not, you have some rules, you have to have rules, because it seems to me that's the only way that creativity can actually arise by giving yourself certain constraints that you can even if it's to rub up against them.

Audience
Can I ask a question? We recognise a pattern because of repetition, like we see 1 and 1 and 1 within variations but that's how we recognise pattern. I'm just curious in the moment, also we were speaking about conflict. Is there a moment in which there is almost like a conflict within the system. So that the repetition has to stop, so that another pattern will have to emerge? I wonder scientifically how that happens?

Phillip Ball
Yeah I think it's interesting about one pattern and what I mean by pattern, because you're right, that very often what we mean by it is, there is this repetition, but the patterns that sort of seem to somehow resonate, are I think one's more like this, rather than a zebra crossing. Because there are places where it sort of goes wrong and often where those places are, in natural patterns is at boundaries, because it has to stop there, you have to find some solution to bring it to an end. And in a structure like this, you often find really interesting, the pattern slightly changes at the edge of a pattern like this. Because it's almost like, the pattern itself is finding some solution to the problem of the boundary that just emerges, boundaries are really interesting places boundaries, and imperfections. If there was a plant here, you know, then that would disrupt it in some way and the pattern would change around there. And that's very often what you find in natural patterns, boundaries and what you call defects are everywhere, in natural patterns, and the pattern has to find the solution to them. But I also think that, although often we think of patterns as repetition, again, I will have a picture on here, but I don't need it, because you all know what to look for. If you think of a tree in winter, looking at it, we would think 'there's a pattern there', but there's no bit of it that is repeating like any other. In fact, that's actually true here, but no bit is identical to anywhere else, but with a tree, it's even more clear. So what exactly is the pattern there? And actually, I think in that case, the pattern is it's a fractal one, it's that you're sensing, I think we're sensing that there's an algorithm that's being played out here and the algorithm says, go a certain distance and then branch, and then if you know and get a bit thinner, and then because you're thinner, go a smaller distance and branch and that's basically the algorithm for a tree. So it's kind of a more abstract thing, but we intuit that and that's why it engages us and interests us in a way that a wallpaper pattern doesn't so much.

Gitta Wigro
Kevin Rowland, the composer says," things must change, but the rate at which things change must also change." So there's something about we delight in the pattern, and we enjoy the recognition. But we also need that irregularity, to lift it into something that isn't as evercrossing, but something where we can enter.

Phillip Ball
Yeah, and you know music is such a great example of that. I think, it's a great example, because it's useless in a way that it's not, you know, we're not trying to solve a problem with it. And so it's pure play, it's playing with our instincts to find patterns in things. And what we seem to find in music is we need some regularity in order for us to be able to hear it as music, but we, if we have too much of it, it's a nursery rhyme. It's boring, we so we need to put defects into it really, you could say and boundaries, so that there's some enrichment of that pattern.

Audience

Can I ask a really stupid question? The birds flocking, when the murmur happens. Are they really negotiating the air? The aerodynamics, they're not actually getting any, there's no intention to get anywhere is there? They're just out for the ride?

Phillip Ball
Yeah, well, they're generally they are looking for a place to perch, to roost. You know, that's why they do it at certain times of day but, you know, I know that's what in biological terms is going on, but I have that same sense of crikey, that's an amazingly not only complicated, but you know, astonishingly beautiful way to go about it. Is that the best way of doing it? But, you know, it clearly is because I suppose, you know, when you think about it, it kind of does make sense if you're a flock of that size, how else are you, you've got to have some collectivity to make that decision. And it's the structures that emerge, the self organisation that emerges it's a kind of what scientists would call an epi phenomenon. It's, you know, to the birds, it's kind of well, okay, I'm making an assumption about birds, but I think it's kind of irrelevant to the birds that they're doing this, you know, they're looking for a solution to this problem. It's us that are responding to those patterns. But that is an assumption, actually, because I'm just aware, you know, there are some people who, feel that the reason birds sing not necessarily why they flock but why they sing. It's not purely a kind of, you know, mating instinct or something, that there, there's an argument that there's an element of that, that they're singing because they can, whether you think that they're getting pleasure from it, it's really hard to know what that means but I guess for me, I think it raises a genuine question of whether it's valid, and I kind of think it probably is valid to talk about creativity in nature. Because, you know, it seems to me that a lot of our creativity comes from setting ourselves problems and looking for effective solutions and that's really what's happening in nature and responding to chance events in ways that are, you know, not just kind of random, and that's kind of what you know, these systems are doing in nature. So I think there's you can argue a case that there's creativity there.

(Outro: Renée Bellamy speaking in 2021)
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