Cognition all the way down

**Melanie Challenger**

Lately I've been thinking a lot about our minds. And what happens at the point of the cell. Are our cells almost like many minds with their own agendas? What brings our cells together in concert, and what causes them to flip into competition? In this episode, we'll be discussing the mind-altering ideas and research of renowned philosopher Daniel Dennett and his collaborator, Professor Michael Levin. Daniel is an American philosopher, writer, and cognitive scientist whose research centres on the philosophy of mind and biology. He’s the author, among others, of the books Consciousness Explained, and From Bacteria to Bach, and Back. Michael Levin is an American developmental and synthetic biologist at Tufts University, where he is the Vannevar Bush Distinguished Professor. He studies the morphological and behavioural information processing in living systems.

**Melanie Challenger**

Welcome, Michael. And, Dan, it's great to see you both. I want to start with a couple of papers that you've authored together recently, I took great delight in one in which you described a common view of the human mind as a black box of magical smart stuff. And you argue that perhaps we need to start thinking instead in terms of the mind as a part of a radical continuity of agency. Can you talk about why people have resisted that idea for so long? Dan, maybe you could talk from a philosophical perspective. And Michael, maybe you could suggest why in biology we favoured a more revolutionary view of the mind.

**Dan Dennett**

Well, the old idea here's mind and body and the mind is not material, and it's distinct from the body, it's your soul, basically, that's an idea. And the dualistic idea that's been around for hundreds of years was particularly articulated by Descartes, of course built by many others. And it just seems to stand to reason to many people that, you know, bricks don’t have minds and mountains don't have minds, but then neither do bacteria, or human blood cells, or antibodies. None of them have minds, because they're just, they're just mechanical things, or some sort of nano machines. Well what's come in better focus in the last 50 years, is that this won’t do. First of all, we want to just throw out dualism, but we don't want to throw out the mind. We want to allow that there are ancient smart, intelligent agents that are making decisions, appropriate decisions on the basis of information. And that's, of course an idea that's completely highlighted in computer science and AI and more particularly, but even in all computer science. One of the insights that say, Turing had was that if you have a machine that can identify a zero or a one, or a hole in a paper tape, then it can hinge its behaviour on whether it detects a zero or a one. And then we're off to the races. We've got conditional branching. And we can make things of indefinite complexity and subtlety and discriminatory capacity out of very simple parts.

That's just now obvious to everybody. But it still bothers a lot of people to do what computer scientists do all the time. And that is without making any apologies is to anthropomorphize a bit. And when they say tell your printer to do this, or when your computer prints a PDF or makes a PDF, it sort of thinks it's sending it to a printer. This is okay, we can understand how that how that all works. But we're saying this is a powerful tool. Learn to use it wisely. And it'll help you design experiments that will help you understand very complex things. In the same way, our own adoption of a mentalistic perspective on each other helps us to understand each other. Well, if you interpret cells and cell assemblies as agents of sort, and think about what they're doing as not just pushing and pulling, but as signalling, as learning from each other, as spreading the word and so forth, then things fall into place very well.

**Melanie Challenger**

Michael, do you think too that, because a lot of the knowledge has come from the neuroscience community, we've been a bit slow to get the gradualist view of where mind has emerged from?

**Michael Levin**

Well, I think there are a couple of components. Of course the history of biology and science has been that if you turn away from a kind of unsophisticated anthropomorphism, and drill down into the mechanistic aspects of living systems, great success follows, right. And this has been the strategy of biology, biochemistry, genetics, and so on. And so part of this kind of Teliophobia that is out there is a resistance to sliding backwards, people have this idea that we don't want to go back to thinking about things from that perspective, we want to keep drilling down lower and lower and continue to reap the benefits of a mechanistic understanding of nature.

**Michael Levin**

Now, there are a couple of pieces to this that need to be unpacked first, people who say they are looking for a reductionist explanation in biology don't really mean that because no one really wants to go down to the level of quantum foam and things like this, what they mean is biochemistry. So for some reason, people have latched on to one particular favourite level of organisation. And that's where they'd like to stop. And so Dennis Noble has a very nice piece on there being no privileged level of causality. And I think he's absolutely right. You can try to go down but stopping at one particular level is a methodological and philosophical choice. It's not really mandated by any science in particular. And so the other thing that is important about this is that we now through advances in bioengineering and biology and so on, have reached the point where it's pretty clear that there are other aspects of both science and engineering that we would like to gain control of, for example complex, regenerative medicine, re, you know, producing things like arms and eyes, and so on, were manipulating at the lowest level is probably not going to be possible. And Dan’s already talked about the computer science version of this. There's also a physics version where something very important happened. When people decided that they weren't going to track every particle in a volume of gas, they were going to develop these large-scale metrics, you know, and you discover the laws of thermodynamics and Boyle's law and all these wonderful things that we wouldn't have and entropy and so on, that you wouldn't have if you were still stuck on tracking every possible every individual molecule. So both computer science and physics have made their peace with the fact that important things happen when you look at things from the correct level of organisation. And biology has done a great job moving downwards. But I think now, it's pretty clear that we need to, in order to do better experiments and have better control over growth and form, we need to exploit the intelligence of cellular collectives, this isn't a bad use of a metaphor. This is an entirely proper use of a metaphor that has very specific empirical predictions that can be tested. So whereas before, this might have been a kind of philosophical issue as to well, is it okay to speak of cellular collectives, knowing things? Well, if they're in the brain it is, but otherwise, it's not. Basically, this is no longer tenable. The advances of evolution of evolutionary biology and genetics are telling us that there is no harsh dividing line between neurons and non-neural cells. You know, all cells do the kinds of things that neurons do, most cells form networks like neural networks, and we have to take evolution seriously and understand that the kinds of things that have been attributed to brains, biology has been exploiting this long before brains came on the scene.

**Melanie Challenger**

For some people, they might not know what we're talking about here. When we're talking about agency, it's often to do with the fact that we're social primates, isn't it? So we've adapted for looking for intentions for trying to get into each other's minds. And we're super smart at that aspect of seeking out signature signs of agency and others. And that's a function of our social psychology. We're looking for intentions, for motivations, for reasons. But what does agency look like, at a cellular level?

**Dan Dennett**

Let me let me say a little bit, then Michael will fill in some details. And correct me if I'm wrong. One of the great methods of science is inducing mistake inducing pathology of one sort or another, by putting a strain on the system of, by just moving things around to see what it can handle. And if the system in question just never was bothered by, this never made a mistake never went off in the wrong direction, we'd be baffled as to how it works. So we learn a lot by seeing how we can get it to make a mistake. Now, the very idea of making a mistake shows that it's using information. You know stones can't make mistakes, but a lot of very simple mechanisms can make mistakes. And so you want to think, How can I as it were, trick this system, due to making a mistake, because then I'll know a bit about the mechanism? In the end, we want to get to mechanism. But in order to get to mechanism, it helps to explore the competence of the system. By seeing what it can do, what it can't do, what can it distinguish when does it know where it is? Or what it's doing? And asking the questions in these mentalistic terms, is a beautiful way of getting a preliminary picture of what the mechanism is. Now this has become absolutely standard in cognitive science, was articulated by people like David Marr and Alan Newell and others, I myself and everybody agrees now that you want to see if you can induce a false belief in the system, because if you can induce a false belief in this system, or if you a believe it can't correct, then it does something weird. And aha, we've learned something. So it's behaviourism on steroids, because we're still looking at behaviour. But we're looking at behaviour, anticipating what it's going to do on the basis of an attribution of information.

**Melanie Challenger**

Michael, can you talk us through this in as approachable way as possible, how the bio electrical properties of cells have a role in this idea of the agency of cells?

**Michael Levin**

Sure, and there are lots of people who have studied agency of individual cells in terms of individual cells’ ability to predict future stimuli and in remembering past events, and so on. But what I'd like to talk about is an example of multicellular agency, which I think is very important, it's this question, because all cognitive agents are made of parts. And the question is, how do those parts work together to enable a large-scale agency that doesn't belong to any of the parts individually. And I think Dan’s point of making a mistake is really critical. And so I'll show you an example of how that works. So imagine that you are a tadpole face. So the face of a frog embryo or a tadpole has various organs in particular organisations, and you need to become a frog. So in order to become a frog, you have to rearrange that face. So the eyes have to move, the nostrils have to move, the jaws have to move, there have to be some deformations because tadpoles don't look like frogs. And so normally, this all happens exactly the same way, because all normal tadpoles look the same, and all frogs look the same. It was thought that somehow what the genetics specifies is a set of hardwired movements for all these things. So we did an experiment some years back, where we basically produce what we call Picasso tadpoles. We scramble them in a way that everything is in the wrong position. So the eyes are off to the side, and nostrils are on the back of the head, everything is in the wrong position. And when you do this, you learn something remarkable. You learn that in those cases, you still get largely normal frogs, because all of the individual pieces move around through novel paths because they start off in the wrong configuration, but they undergo novel motions that they otherwise wouldn't have to get to the final correct frog face. Now what you're seeing here is something very interesting, that what the genetics actually specifies is a machine where the hardware is able to reach the same configuration from different starting positions. And what I think this illustrates is an example of basal cognition from the perspective of goal directedness, this is a very simple version of a collective agent. So the cellular groups trying to reach a goal. And what makes it a goal rather than simply an emergent thing that happens when you sort of, you know, turn the clock forward, is the fact that they're able to achieve the same goal, despite various deformations and problems along the way.

**Michael Levin**

So this is a collective agent made of cells, that is able to internally represent the final anatomical outcome and to do its best despite perturbations. So now let's get to Dan's point and see if we can make this thing make a mistake. So we'll switch model systems, and we'll talk about Planarian. So these are flatworms that have normally a head and a tail. And the amazing thing about, one of many amazing things about flatworms is that you can chop them into pieces, and every piece will regenerate exactly what's missing, no more, no less. So you chop a middle fragment, and it'll make a head and a tail at the correct location. So now, one question arises is how does it know what to do? How does it know where the heads and the tails go? And of course, how does it know to stop growing? This is really critical, because in order to know when to stop, you have to know what a correct Planarian looks like. Otherwise you don't know when to stop. So what we did in studying the system is we discovered an electrical circuit within the cells. No individual cell knows this. This is a large-scale electrical circuit, like a network, the kind that you would think about when you think about neural networks are neural circuits. Except that it's not made of neurons and it doesn't matter, all cells can do this. It's an electric circuit that has this really interesting property where it marks off how many heads and tails you're supposed to have and where they're supposed to go. You can literally see this information in the way that people now image this information in brains. We use very similar techniques, voltage reporting, fluorescent dyes, and you can literally see an image on your screen that shows you what the electrical content of that circuit memory is. And I'll tell you in a minute why I call it a memory. And so what happens is when you injure that animal and cut off the heads and the tails, that middle fragment is guided by that electric circuit to put the head and the tail in the correct place. So what we were able to do is to go in and rewrite that electrical information. We didn't do it by applying electrical fields, we used very specific pharmacology to turn native electrical processes in the cells on and off with a very specific purpose. So that we would rewrite that electrical memory of what a correct flatworm is supposed to look like. Now, when you do this, nothing much happens. The intact animal doesn't care about this, because that memory at the time is sort of latent to the animals not using it. When you cut the head and the tail, at that point, the middle fragment will consult that electrical memory. See the fact that oh, I'm supposed to make two heads. And then in fact it makes two heads, because that bioelectric encoding, is the encoding of the setpoint for the homeostasis or the ability of this thing to reach the correct anatomical outcome, despite perturbations, that's where that information is represented. So it's really, you know, to me, this is really the kind of early stages of things we recognize in behaviour.

**Michael Levin**

They are goal directedness, they are explicit representations of counterfactual future goals. So this normal, one headed animal has an electrical pattern memory of a two headed form. So it's not a memory of what's happening right now. Because right now, it's a one headed animal, it's a memory of what will be in the future, it's a representation of a future state that isn't true right now. I mean that's really a building block of advanced cognition, is to be able to conceive of a state of affairs, that isn't actually true right now. So it's not just you know, perceiving or feeling what your sense organs are telling you. Now, it's the ability to hold a state that either has been true in the past or might be true in the future. And so what happens is, when you reset this electrical pattern memory, the cellular collective works towards that pattern, they rebuild, they build a perfectly viable two headed worm. And the best part is, if you continue to cut that two headed worm in the future, it continues to generate two headed worms, because that electrical pattern memory is in fact a memory once you've rewritten it, it stays. And this is all in the context of totally normal genetics, the genome has not been edited, the genetics has not been touched. All of these cells are completely wild type standard worm cells, and yet they're building something completely different, again, a hallmark of cognition, that on the same hardware on the same machine, you're able to perform lots of different behaviours based on your experiences of the past.

**Melanie Challenger**

This sets a lot of thoughts in my mind. The first thing is, so I get purpose of agency in a single cell, when you see experiments like the origins of life experiments, that sort of petri dish stuff, and you see cells emerge and begin to move, I can see that sense of agency. But what I get intrigued about here, if we're looking at agency and then we're scaling up to multicellular organisms, I start imagining competition and conflict. Obviously, that can be good because biology exploits that kind of thing. But are you seeing any signs of competition in your work? And is that a new way of looking at the inevitability of mind? Then instead of seeing that the emergence of our kind of consciousness is some sort of rare event in biology? Or are we seeing that life is almost kind of fecund with the potential for mind at the cellular level?

**Dan Dennett**

Well, opponent processes are everywhere in biology, it just turns out that a very good way of solving the problem of getting something to control itself is to put opponent processes which will have little tugs of war of one sort or another. And the outcome is usually right. You can perturb these and get all sorts of weird results. But we see opponent processes everywhere, everywhere at every level, down to the cellular level and in higher levels. Michael is an expert on finding these and exploiting them. They're also of course very important at the human cultural level. Many good systems have been designed that avail themselves of opponent processes. And they sort of take care of themselves. So it's useful to see all of these processes as having a common source and the common rationale. There are control systems and they're control systems that work by balancing different things. And nature has invented a lot of them and human beings have invented a lot of them too. But nature was there first

**Michael Levin**

Yeah. There's lots of competition in, as Dan says, there's lots of competition at every level. And so for example, organs in the developing embryo are in competition with each other for both informational and metabolic resources. And these kinds of competitive interactions are really critical, both for coordinating activity across complex systems, and for developing this kind of robustness to external perturbations, exactly as Dan said, and even specifically these kinds of bio-electrics that I mentioned, you know, in the Planaria, we found out that there's a bacterium that lives on these Planaria that has basically learned to hijack this head determination system. And if these bacteria get out of control, and they're overpopulated, you end up with worms in fact, with multiple heads because these bacteria have evolved to manipulate the host to some extent, and we're only beginning to understand this. But yeah, I think competitive interactions are extremely important along with cooperative interactions to give you the kinds of robust, complex systems that we see.

**Melanie Challenger**

That's something I was going to ask. Because I would assume in a biological system, that you get exploited and you will get defence mechanisms, and then you'll get arms races. Are there any other examples like that, that you've come across yet?

**Michael Levin**

I mean the most obvious classic example is the biologist or the bio-engineers attempt to hijack these systems, right? Because all of these animals have developed bioelectric networks that are quite robust to external conditions. So for example, if you're a frog, you should be able to handle lots of different concentrations of potassium in the water, otherwise you're not going to be a very successful frog. So all of these systems are extremely robust, and they function wonderfully well under novel circumstances. And it is our job as biologists to find the trigger points to understand the sort of native software of life so that we can see what the mechanisms are that are taking measurements that are storing memories that are making decisions, to understand the logic of this process. And by virtue of this to learn to control it at the appropriate level. So a lot of what we do for Regenerative Medicine is learn to trick the system into doing things that it otherwise wouldn't have done, but not by micromanaging the lowest level components, but actually by manipulating the information that the system has.

**Melanie Challenger**

Dan does this research that is grounded in the biology like this, does it make you reflect differently on the projects for synthetic intelligence within cognitive science?

**Dan Dennett**

Oh, yes, I think that cognitive science has gone through waves of enthusiasm. And one wave was the sort of top down good old-fashioned AI, where you've tried to design the whole system in a very bureaucratic way, with subsystems talking to subsystems. And the trouble was that these were very brittle systems, and they did not respond gracefully to perturbation. And gradually this lesson sank in. I don't think it would have, if we hadn't had that brilliant research for many years. We wouldn't have known how fragile these systems were, how vulnerable they were to break down, if we hadn't had some very smart people building them and being terribly frustrated. And finally coming to realise that it wasn't that they were stupid, that their machines were poorly built, it was that they were designing them wrong. They were not designing them in ways that were fault tolerant in ways that had graceful degradation, in ways that could sort of, you know, bend with the wind. And so we've had waves of subsequent research, which have taken that much more seriously. And, and one of the main messages of that is the message of the title of our article, it's *cognition all the way down*. One of the main stumbling blocks, the one that keeps me up at night now scratching my head, is to see how we can translate a lot of the good work that was done into a new more biological AI, where the smallest parts aren't all microscopically identical the way they are in a computer, where they aren't all beautifully synchronised in time. You have to realise that a body like yours or mine has got trillions of cells. And they're not all synchronised, there's no master clock, and they have different agendas. And yet, somehow they can all pull together. And understanding, cashing out that somehow, that's the work of the future. And we've now got a lot of tools we didn't have 30,40, 50 years ago.

**Melanie Challenger**

Do you think though, and this is for either of you, and I should say here that I am sold on this idea that something we might usefully call agency is there right from the get go, you know, a kind of minimal agency. And it's also logical for me that if we focus too much on the mind as a brain-based event, we lose this exciting opportunity to start to examine agency in really small discreet forms. It is a great opportunity for a just so story of the mind. But it also shows us how incredibly complex biological systems are. And for me, you know, I start thinking well synthesising, it's got to get harder. It's got to be wetter and messier than we imagined. But you know, argue against that, if you think that's wrong.

**Dan Dennett**

But the thing is we have so many more tools to use now. Yes it's complex, it's much more complex. You go back a few 100 years to Descartes. And he was so sure that you could never make a machine that could have a conversation? Well, that's because his idea of a machine was if we pressed him, he would probably have said, well, it could have, you know, 1000 wires and pulleys and 10,000 cogs, and that's about it. No, no, we're talking about machines with trillions of moving parts. Now, you're not going to make sense of that part by part. You're going to have to find higher levels at which to understand the system. But we also have all these concepts that they didn't have 100 or 200 years ago, we have all the concepts of control theory and information theory in computer science and, and genetics and all the rest so that this is a golden age.

**Melanie Challenger**

Where does the work go next, Michael, is there any possibility of some kind of crazy intention editing machine you know, what's the Sci Fi future of this?

**Michael Levin** 29:50

Yeah, I mean, with the intention editing machine we actually, I think already have in the sense that we can rewrite the target of the intentions of cellular collective. So for example, in the Planarian, their default intention is to make a one headed worm, we can go in and change their intention without really knowing how. I mean we don't know how to make a two headed worm, but the collective does. What you need to do is basically convince it that's what they need to be building. And so I think that for me, the most exciting technology that's coming online now, is chimeric bioengineering. So the idea is that we can now make novel bodies, and those bodies will have some sort of mind, you know they can muster, that have never existed on Earth before. So we've had a paper showing how you can make novel synthetic living organisms out of frog skin, and they don't look anything like frogs or tadpoles, they have their own behaviours, they have their own ability to regenerate and to act in a group and to do various interesting things. And this enables you to ask a very profound question at the bench, which previously, I guess was a purely philosophical question, which is, where do the goals of collective agents come from? So if I put together a number of cells in a new configuration and it immediately starts doing something very coherent, and very interesting, there is no lengthy evolutionary backstory that has rewarded for that specific behaviour, where do they come from? You know, how do you scale the individual, the individual capabilities and agendas of small competence subunits into one larger one, with goals that have not been explicitly shaped by an evolutionary history? So that I think is an incredible opportunity for empirical research into these deep questions.

**Melanie Challenger**

Dan, where do you see this going for philosophy of mind? Now I can see how for you it's a continuity of your sort of materialist line of thought. But where are you going with this now?

**Dan Dennett**

Well a few years ago, I wrote a paper called, *My body has a mind of its own*. *So what does it need me for?* A lot of the things that we do and we think we do, thanks to our conscious thought, are taken care of without any help from conscious thought at all. And even some fairly complicated things. One of my favourite examples is from my farm in Maine, is just picking blueberries. And I can sort of sit down on a little stool in the field and pick blueberries while having a conversation. And my hands, I can sort of watch them. It's like watching somebody else's hands, they're doing the job. And then they're not only picking berries, they're picking the right berries. And I don't have to think about it, just you know. And there's lots of things like that, where if you think about it, your competence goes way down. A lot of them are things that you have to think about it first, like learning to drive. But after you've learned to drive, this all becomes in a new way as one says second nature. I think what's finally I hope, coming clear to people is a lesson that I've been trying to pound home now for 30 years, is you don't have a theory of consciousness, a theory of the mind, until you have the whole story, at least in principle, that is, if you have a theory which says, you know, the light comes in the eyes, and then it goes up through the optic nerve, it gets to the occipital cortex, and then it bursts into consciousness and you stop. That's less than half the theory. Now you got to explain and then what happens. And you have to tell a mechanical, ultimately mechanical, biological story of that. And people don't even know how to begin to do that, in general. I like to point out to them that they no more know but their brain is doing when they are responding to a conscious event, than they know what their spleen is doing. They don't have any direct insight, which realises their reactions, the laying down of memories, the changes of dispositions, the reminders, all the things that happen that we have, you know, first person access to how that all happens. Nobody's even trying to ask those questions most of the time. Some of us are, and we think once we've answered those questions the mystery is going to go away.

**Melanie Challenger**

So one last curveball. So I sit on various ethics bodies and I naturally have a moral inclination anyway, I always like to ask these questions of ‘ought’ not because there's any easy or straightforward answer. But we've emphasised what a particular stage of consciousness is doing. Now human beings have really emphasised what's exceptional about our consciousness. And that consciousness we often forget, is a kind of reproductive human consciousness. It's the sort of consciousness that emerges in the kind of higher level social exchanges that happen, you know, when we're of reproductive age. This work reminds us though, that there are many other kinds of goals in nature and that there are intentions, if you like, and incredible complexity, all the way down, cognition all the way down. What does that do to our traditional moral frameworks? You know, particularly those sorts of neuro exceptionalist frameworks, and how do you think about these new organisms or systems of cognition that we're playing around with now?

**Dan Dennett**

This is perhaps a little bit flippant, but one thing it does is it throws into the rubbish heap the philosophical claims about sentience that some people think of is the foundation and basis and key to moral thinking, because come on, what about bacteria? What about trees? Every living thing is a cognizer. Yeah, you know, Athlete's Foot, it's a cognizer. If that's your test for what you can't interfere with, then we all just going to have to commit suicide. And so it's a funny point, but it's also a serious point. We shouldn't expect science or philosophy to give us a clean, bright line. Above the line these are things that are worthy of care and compassion and so forth, and below the line, do what you like. The lines are always going to be political. And they're always going to be compromises and exceptions. One of my favourite examples is the fact that the Octopus, Octopus Vulgarus is an honorary vertebrate in the UK, before this rule, which came about what 10 years ago or so, just the way you can, you know, you can throw live prawns on a grill or throw a live lobster into a pot of boiling water. But you couldn't do that with a vertebrate, that was against the law. Well, octopuses are so clever. There are some wonderful books about octopuses recently, that they were elevated, they were given the legal status of honorary vertebrates and maybe there's others should be as well, but I don't think escargot are going make the list.

**Melanie Challenger**

Michael, have you got a final note, you know, just in terms of feelings of awe, or, you know, what you're starting to peer into?

**Michael Levin**

Yeah, I mean, to continue Dan point, which I think is right on the money as far as the fact that this kind of moral responsibility is a spectrum not a binary line of do what you will on one side of it, I think that Darwin had this phrase of ‘endless forms most beautiful’ and I think what we are going in our lifetime, what we are going to be surrounded by are a space of possible agents of which you can't even begin to conceive now. And because every possible mix of biological engineered nano material, machine learning, all of these things will work together. You will have devices that are partly evolved, partly designed, they will be running around your house, some of them will be doing other things that you don't want them to be doing you know, like any good animal does. There will be an incredible range of bodies and minds of all different types, having human cells and electronic components mixed for various purposes. And the future we will have to develop an ethics of what it is that we owe to different kinds of organisms that cannot be based on where they come from, in the sense of having a clear biological, evolutionary path. The notion of what is a machine versus what is a robot, we just wrote a paper, Josh Bongard I just wrote a paper on this. Basically blowing up all of this, you know, previous definitions of these terms is no longer viable. A new level of ethics is going to need to remember to consider essential aspects of their cognition that has nothing to do with what they look like and what material they're made of. This will be a real upheaval to old fashioned sort of easy distinctions that were readily made in previous decades, but are not supportable in the future.

**Melanie Challenger**

As I said, earlier on, we focus so much on our biases about mind, about agency, but maybe this work gives us a chance to start again. Today, when people think about agency, they often think it must be intentional, deliberate. Agency is about making choices and thinking things through and deciding things. So for many people, when we talk about agency, we’re talking about an aspect of human agency, the way we think about what we’re going to do and act to further our goals. But then what do we call the actions of the lion who waits and waits, watching, gathering information, before she acts. Lions are careful, observant hunters. She, too, has a clear goal, a clear reason for her action, and a host of adaptations that assist her in achieving those goals. If we say agency is the ability to act purposively, doesn’t the hunting lion have agency? And then what about the ant that encounters a novel obstacle and exploits every available resource in his or her body to get around this obstacle and return to the nest? This seems less deliberate than the watchful lion, but is this still agency? All of these cases presuppose cognition. But what of the bacterial cell that responds intelligently and adaptively to the resources in its environment? Through history and still today there is considerable debate on these aspects of agency and disagreement about what we mean. And that’s to say nothing of how this is approached within ecology and evolutionary thinking, where trying to understand the mechanisms of goal-directed behaviour or even talking about the idea that there truly is goal-directed behaviour can bring people out in hives. Wherever you sit on these debates, Dennett and Levin provoke us into thinking again. And I have to say, I love the idea that life might be defined as the shift from an errorless state, a state in which it makes no sense to talk about mistakes, into a state in which error becomes possible. Because life as the beginning of mistakes is also the beginning of meaning.