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## **Animating Molecular Life: An Interview with Natasha Myers**

**Authors:** Joel McKim and Natasha Myers

### **Author Bios:**

Natasha Myers is Associate Professor in the Department of Anthropology at York University in Toronto, Canada. She is the author of *Rendering Life Molecular: Models, Modelers, and Excitable Matter* (Duke 2015). Myers is the convenor of the Politics of Evidence Working Group, the director of the Plant Studies Collaboratory and the co-organizer of Toronto's Technoscience Salon. She is on the editorial board of the journal *Catalyst: Feminism, Theory, Technoscience*. Her recent writing has appeared in the journals *NatureCulture*, *History and Anthropology* and *Social Studies of Science*.

Joel McKim is Lecturer in Media and Cultural Studies at Birkbeck, University of London. He is also the director of the Vasari Research Centre for Art and Technology. His book entitled *Architecture, Media and Memory: Facing Complexity in a Post-9/11 New York* is forthcoming in 2018 from Bloomsbury. His writing on digital culture, design theory and aesthetics has appeared in such journals and collections as *Theory, Culture & Society*, *Space & Culture*, and *DIY Citizenship: Critical Making and Social Media*.

### **Abstract:**

In this interview, conducted by special issue co-editor Joel McKim, anthropologist Natasha Myers discusses her ethnographic exploration of how protein modelers attempt to render visible the nano-scale molecular structures that make up cellular life. Myers reflects on the ways these scientists make use of computer animation and other forms of embodied knowledge (including dance) as essential tools that allow them "to see beyond the limits of vision." McKim and Myers discuss the tensions that arise when the goal of scientific accuracy meets the forms of aesthetics and style intrinsic to these activities of modelling. Myers identifies the "lively mechanism" involved in the animated machines generated by the molecular scientists she observes.

### **Key Words:**

Protein Modelling, Scientific Visualization, Computer Animation, Embodied Knowledge, Rendering, Molecular Life

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**Joel McKim:** The book is a fascinating look at the media representations, performativity, aesthetics and style that surrounds “hard” scientific research – biological protein modeling, more specifically. Could you briefly paint the picture of how the project and ethnographic work you conducted came about?

**Natasha Myers:** I started this project early on during my PhD. I had arrived in a science and technology studies graduate program at MIT. I was already interested in scientific visualization and was thinking a lot about the relationship between biological imaging and the biological imaginary; the relationship between the images being generated in life science research, the imaginations we have about how life works, and the forms of life we imagine could take shape. I came into the project through feminist science and technology studies. During my MA in Environmental Studies had been thinking with Donna Haraway, Karen Barad and Katherine Hayles, and many other scholars who had for decades been exploring questions about embodied knowledge in the sciences. I was inspired by Donna Haraway’s “situated objectivity” and her ideas about situated knowledge. I was trying to understand how embodied knowledge shaped the sciences. I had been reading Merleau-Ponty in my MA, looking into questions about the relationship between bodies and vision, the relationship between what we see and how we know. For me thinking has always felt like a deeply embodied practice.

My work in STS was indelibly shaped by my training in science, in the molecular genetics of plant and flower development. I had started a PhD in molecular genetics in the late 1990s, and I had spent a lot of time grappling with a field where the data itself was visual. Investigating the molecular genetics of flower development, I was taking pictures of flowers to make visual arguments about how genes are involved in the developmental process. When my experiments weren’t working I turned to making art in the laboratory. This helped me to think critically about image-making in the sciences. When I left the lab to start my MA, I was interested in questions related to scientific visualization, ways of knowing, and the imperceptibilities of life. I was concerned about the ways that organisms were reduced to genes, and how molecules are figured as machines at work inside of a cell. I was concerned about static modes of visualization in the sciences. I kept wondering whether a more living and dynamic study of life was possible.

Much of my experience in the laboratory was influenced by my training as a dancer and choreographer. During my undergraduate years as a student of the life sciences, I was thinking about how dance itself could be a medium for inquiry and for

understanding, how it might be a way to deepen our engagements with forms of life. I was *thinking in movement* when I arrived in the laboratory, and it was in that context that I got an opportunity to begin to explore how scientific visualization techniques can facilitate or impede our understanding of life as an unfolding, dynamic process.

When I finally started my PhD in STS the problem of static visualization technologies (photographs, gel electrophoresis, chemical analysis, etc.) in the life sciences was a provocation for further study. I cared about biology and I wanted a more living and lively way of documenting what's going on inside cells, inside organisms, and in the relations that shape ecologies. Developmental biology is a great place to think about moving images as researchers in this field study growing bodies that transform over time. Time is precisely what is at stake for these practitioners. Don't we need better tools to animate these processes? Don't we need better tools for staying in the movements of living and dying?

So when I started the project that gave rise to the book, *Rendering Life Molecular*, I was thinking about dance, I was thinking about modes of visualization, and I was thinking about a critical way of addressing the politics of visualization in science. When I started my dissertation research, I began by interviewing a whole range of scientists who were grappling with different visualization modalities. And it was in an interview with the person who became a focal figure in the book, a protein crystallographer I call Diane, that I figured out what my dissertation was going to be about. She showed me through her body precisely how movement and knowing, intuition and embodiment, and aesthetic and performative forms were all folded into the practice of molecular visualization. I knew nothing about protein crystallography, yet here was an opening for the beginning of a study of the ways that researchers bodies are intimately entangled in visualizing and animating phenomena that are otherwise imperceptible, intangible and inaccessible. The challenge was then developing ethnographic methods that would allow me to examine how these practitioners learn to palpate the imperceptibilities of life through the animate medium of their moving bodies.

**Joel:** You've touched on this already, but one of the things that is so compelling about the particular area of research you examined is that these objects of science (the protein structures) simply aren't immediately available to visual perception. We are necessarily dealing with fundamentally indirect forms of access. Can you describe what it's like to work in such a domain of visual inexactitude, of probabilities rather than certainties? What role do techniques like simulation or speculation play in this case?

[Figure 1]

**Natasha:** Here are a group of scientists that are working with matter at the nano-scale. They want to understand the structure of molecules, to identify its chemical configuration, by locating the precise atomic coordinates of every atom and electron inside of a molecule. A given molecule might be made up of 10,000 atoms. The problem is that they have no direct visual access to molecular life (as if any vision was ever direct – we know from Ian Hacking that seeing through a microscope is quite an indirect form of vision). What was remarkable in this case is how these practitioners learn to see beyond the limits of vision: over time and with experience building crystallographic models, they are able to learn how to see, feel and know amazing things about molecular phenomena (see Figure 1). They make an otherwise inaccessible world palpable and manipulable. The way they do this is through techniques of X-ray diffraction, which allow them to take a very small object, like a crystal made of a molecule they are interested in, and see how it scatters light. This way of working is distinct from using a microscope lens to focus in on an object and produce a clear picture. But there isn't a microscope that can resolve the atomic structure of molecules the size of proteins. Protein crystallographers have to work in the shadows of the X-ray diffraction patterns made when light from X-rays gets scattered by crystalline proteins. And as they work in the shadows they rely on a range of computational techniques that allow them to just barely discern the shape of a molecule from the complex patterns that are generated in an X-ray diffraction experiment. Crystallographers use computer power and algorithms in order to calculate a three-dimensional electron density map. This is a map of probabilities, indicating the probability that an electron might be found here, or there, or over there. They then take these 3D maps that chart the probable locations of electrons in the molecule, and they begin to fill them in. To do this they draw on formal knowledge of the physical properties of chemicals (such as knowing how hydrogen and oxygen interact in particular ways in a molecule), but simultaneously, they have to rely on embodied knowledge and intuition about how these chemicals interact atom by atom. As they work they try to fit the known amino acid sequence of the molecule they are working with into the electron density map. Watching practitioners at work taught me that modelers have to call on a wide range of embodied, tacit knowledge in order to tune in to molecular phenomena. So protein crystallography is a site where embodied knowledge is essential, and it is also a discipline in which practitioners celebrate their embodied knowledge and the intuitive powers they build up over the long duration of training. It is the really experienced crystallographers who are most trusted to bring their embodied knowledge into play in building models from electron density maps (see Figure 2).

[Figure 2]

You asked about simulation and speculation. There are attempts to use computer power to simulate the process by which a protein polypeptide folds up into one of these molecular configurations, but because people mistrust computers so much in this field, other forms of speculation are essential to this practice. It turns out that embodied knowledge allows practitioners to speculate and hypothesize about

possible molecular configurations and movements. So there is a lot of speculation, but they wouldn't call it speculation so much as a kind of trained judgment.

In the process of building a crystallographic model, they are cultivating what I call their *kinesthetic imagination* of how a protein hangs together, to the point that they can feel the tensions and movements within the molecule as tensions and movements in their bodies. In the process of building models onscreen, their bodies become repositories of the most crucial information about that molecule. When they are away from their computers, their bodies become ready-to-hand proxies for the molecules they're modeling onscreen. And the nuances and possibilities of this kinesthetic imagination that they develop through their training allows them to hypothesize not only about how that protein hangs together, but also how it moves in the watery milieu of the cell. It turns out that protein molecules are quite dynamic, and many of the big research questions hinge on how one molecule might move and change shape in its interactions with other molecules. There's so much room in their practice to get the model wrong, and yet these practitioners are able to hold these static, provisional models together long enough to make sound arguments about what these proteins might be up to inside of a cell. So their methods demand a real dance between formalizable knowledge and tacit, embodied knowledge.

**Joel:** The way you describe that relationship it sounds like a form of empathy with the object and attunement. Yet the biologists' commitment to a mechanistic, rather than a vital or creative, theory of life was very pronounced. How does the use of animation potentially complicate this mechanistic viewpoint? You write, for example, about the common metaphor of animation "breathing life" into phenomena and how this is can be a problematic one for biologists.

**Natasha:** One of the ways I like to think about this book is that it is really about the failure of mechanism to fully disenchant matter, especially living matter. Here we see a group of scientists so well trained in mechanistic thinking, so well trained in neo-Darwinian logic, so well entrained to a script that would render the cell as a factory manufacturing little molecular machines. What I was able to do ethnographically was to tune in to the multiple registers in which they were telling their molecular stories. And this included stories they told not just through words but also by moving their bodies. And so what I found was that even in the same breath that they analogized molecules as machines, they also animated the molecules through their body movements – what I call a form of kinesthetic animation—and in doing so revealed a more animistic mode of feeling and thinking and sensing and attuning to molecular form. So what I kept seeing in my fieldwork was that, even as the scientists were meant to adhere to a mechanistic script, and many of their publications would follow through on those conventions (it would be

blasphemous to divert from this script), it was in my conversations with these practitioners, and by watching conversations among experts, and among experts and their students, that I started to see that there were multiple stories being told simultaneously. There was an oscillation, a wavering between metaphors of the molecule as machine and metaphors of the molecule as a lively body. In their hands, molecules could also become wily, or cunning, or desiring. What I started to sense was that these practitioners were not able to suppress the excitability of matter in their stories. These scientists were learning how to palpate the excitability of matter through their experiments, through their attempts to visualize it. And I was finding that this molecular excitability was transduced and propagated through the various models that modelers rendered through many different media. Even the 3D, physical models that they had built, models that appeared totally static, could be picked up and animated as the modeler told lively stories about the molecular practices of cells. Computer graphic models would never be left static on screen. Practitioners would stay in constant interaction with the model, keeping it moving to keep it animated on screen.

In many contexts modelers' don't have ready-to-hand visual representations of their models, so their own bodies became molecular proxies. Modelers would animate in quite lively ways the wiles and desires of their "molecular machines" explicitly reached towards dance as a medium for performing molecular movements. Some took up dance training, and others hired choreographers to animate molecular processes. In the early 1970s, one group staged a large-scale animation of protein synthesis on a football field at Stanford University to bring home the lively dynamics of molecular processes.

These bodily practices show that even as practitioners adhered so closely to mechanistic scripts, they continually failed to secure a hegemonic view of life as machine. What they generated was what I began to call a *lively mechanism*. Practitioners tried hard to police the animisms and anthropomorphisms of their lively articulations, and I repeatedly saw educators struggling to talk about molecules without vivifying them in the classroom. They knew that they weren't supposed to talk about what molecules "want" to do, but in the end they could rarely contain themselves. What you end up with is this remarkable multi-modal discourse that is neither fully mechanistic or animist.

These practitioners thus opened up a remarkable space to see that science isn't what we had long thought it was. I was able to show that all kinds of stories propagate through the sciences, not just the ones that put into print following the conventions of scientific publications. Following how researchers use their bodies, models and animations gives us other story lines to follow, and shows how analyzing storytelling in the life sciences requires remarkably nuanced ethnographic attention.

**Joel:** Yes, it's fascinating the interplay between knowledge and rhetoric or narrative taking place. Perhaps we can focus for a moment specifically on computer graphics animation as one of the repertoires of representations available to the researchers. This form of animation seems to be a source of both excitement and considerable anxiety in the scientific communities you've engaged with. Animation involves time and movement by definition, but these basic elements of animated images are points of serious concern when it comes to protein visualizations, aren't they?

**Natasha:** Absolutely. Computer graphic animations were both very generative for the scientists I was working with and they also posed incredible risks for them. One of the issues was that there was an inherent mistrust of automation and animation. What worried them most was that the computer graphic animations (and I'm talking about many different kinds of animation in this project) rendered time in such a way that set a time course of how molecular processes take shape over short durations. An animation imposes a telos on biological processes, giving it a beginning, middle and an end. Practitioners know that they can't designate a time course and a directionality on a process happening over the course of nano-seconds, time-scales that are nearly impossible for them to resolve with any confidence. The proteins they work with are folding and unfolding in the cell or experimental media over the course nano seconds. And while they have some techniques to help them figure out the shape of a molecule at any one moment, their techniques can't give them clarity on the trajectory between those moments. To produce an animation that runs in time in one direction would be to fabricate the arcline of a process. While you can slow down, speed up, or reverse a computer graphic animation, you can't change the relationship between the elements once they are set in code. This is one aspect of that raised grave concerns for them, especially those protein folding researchers who knew that a protein could be moving wildly within the cell. There was an kind of anxiety about sedimenting and *rending* time. If computer animations rend time in ways that are not agile enough for these modelers, it seemed that their kinesthetic animations, the ways they animated the molecules with their bodies, left them lots of room to experiment and hypothesize.

**Joel:** The scientists you worked with seemed to associate animation technologies with marketing and mass media. You write about their reluctance to "apply advertising techniques to biology." This brings up the topic of whether scientists are willing to acknowledge the role of style and aesthetics in the presentation of knowledge. Some researchers saw the addition of colours in digital animations, for example, as an appropriate teaching aid and others saw it as garish or sensational. Does animation expose a tension between research and the promotion or publicity of that research?

**Natasha:** There's one really important animation that I describe in the book which is "The Inner Life of the Cell," a remarkable animation commissioned by Harvard for undergraduate training in the life sciences. The image that appears on the front of the book is a still from this animation which was developed by professional animators using computer graphics to render visible the unseen dimensions of cellular life. The concept of rendering is really central to the book which takes up various forms of animation. As a concept, the term *rendering* holds together the tensions, desires, and aesthetic predilections of the modeler in the action of pulling a phenomenon into perception. This act of rendering inner processes of the cell includes making aesthetic decisions about the colour of the molecule, qualities that couldn't possibly be attributed to matter at that scale. Thus there is a way in which "The Inner Life of the Cell" embellished, anthropomorphized and constrained ideas of what was taking shape inside a cell. In the book I document the comment section of a Ted Talk delivered by one of the animators. That thread features the vitriol of several voices rallying against this animation precisely because it applies "advertising techniques" to biology. Commentators worry that it dumbs it down the phenomena and gives us views that we couldn't possibly have. They were angry that animators were fabricating molecular phenomena.

The book raises the question about how these animations are treated. If animations are treated as *representations* of what is supposed to be going on in nature, they induce all kinds of anxieties for practitioners and their critics. When they are approached as representations of molecular phenomena, these animations are supposed to describe a world "out there," which is somehow ready and waiting for us to develop the right tools to discover it. But this approach to scientific models and animations ends up producing a kind of epistemic anxiety: as hand-crafted artifacts, models and animations will always fail to do justice to that reality "out there." The book attempts to read these animations in a performative mode that pushes past representationalist assumptions. I read molecular models and animations for what they set in motion, rather than what they fail to do or foreclose. I treat these models and animations as *renderings* in ways that keeps the work of visualization in view as an enactment, as a practice. A rendering is not just the end-point of the labour of visualization; rather, it includes the long process of making and doing that not only produces a model or image, it shapes a practitioners' form of knowing. By focusing on rendering as an enactment, I can stay with the practitioners in their inquiry, and observe them participate actively in generating situated, embodied knowledge of molecular phenomena. If computer graphic animations generate such intense epistemic anxiety as flawed representations of molecular worlds, kinesthetic animations induce much less. When a researcher pulls their body into play to animate the forms and movement of the molecule, and so becomes a proxy for the molecule, they don't set a time stamp on the process. Their renderings are open-ended, improvisational, interchangeable, editable, mutable. Practitioners were much more comfortable giving the labour of animation over to their bodies. Kinesthetic animations provided opportunities for modelers to get

inside of the excitability of the protein molecule without setting a time stamp or a telos on the process.

**Joel:** So the body is in some way more trustworthy than the machinic or digital representation.

**Natasha:** Exactly, because it can be corrected and transformed in the midst of a conversation between experts. I would often watch two modelers in conversation with each other testing out whether the molecule worked in one way or another. They would be actively moving their bodies to animate the movements, for example holding tension between their crossed arms to suggest the kinds of forces that were taking shape within a given molecule. What ensues is almost like an improvisational dance that takes shape among practitioners as they try to work out with their bodies what the forms and movements of the molecule might be. This way of rendering molecular life is a sometimes tacit and sometimes explicit part of the very process of communicating research.

**Joel:** All of these decisions regarding what constitutes a responsible or irresponsible representation, leads to the quite pragmatic question of disciplinary standards. Is there any kind of consensus forming regarding visual standards or protocols for modeling in this area?

**Natasha:** This question regarding responsible or irresponsible representation becomes a real issue when you realize how much of the modeling process requires intensive training. A modeler's intuition and sensorium must be attuned to molecular form properly before a sound model can be built. What these practitioners deem irresponsible is when the labour of modeling or animation is deferred to computer algorithms. This is because computers can make glitches easily. The book documents a case where a modeler relies too heavily on computer algorithms and does not check the models against embodied knowledge. Five major publications are retracted when one laboratory realizes that a computer glitch has propagated errors in a number of their prominent models featured in top tier journals. This kind of error is disruptive in a community that has to rely so heavily on trained judgment in order to do its work well. The research community was galvanized around this event and a couple of other ones, and hosted public debates around the best practices for training students. Some so actively resist the automation of these techniques, and insist that their students acquire the embodied knowledge required render accurate molecular models. Pedagogy and training become major themes in the book. Good modelers, it turns out, must have a well-trained kinesthetic imagination that is attuned to protein form. If you defer key

parts of the model making process to algorithms, you would lose the opportunity to build up this embodied knowledge that would help you develop the intuition to discriminate between good and bad data and models.

What I find so interesting about this community is that practitioners explicitly avow their own embodied contributions to the facts they are producing in a laboratory. It turns out that the professional jurisdiction of these modelers hinges on an acknowledgment of their embodied knowledge. It is possible to discern in this community a practice of “situated objectivity.” These practitioners show us that objectivity isn’t what we thought it was; it is, in fact, shaped by remarkable forms of knowing that are deeply situated, and embodied, and felt. Their laboratories are spaces in which we can learn remarkable things about the relationship between feeling and knowing. And so “responsible” modeling includes those practices that align with the forms of situated objectivity that Donna Haraway describes in her work, and after her, I call this a kind of “modest modeling.”

**Joel:** It sounds like a kind of balancing of the assemblage. The work is always going to involve the embodied human researcher, some machinic or technical element and the biological material itself, but finding the right balance of that assemblage is a necessary goal.

**Natasha:** Yes and in this field, there is no pretense of omniscience, there is always the admission of mediation and some attempt to identify the limits of vision. In certain visual modalities in it is easier to erase the body of the scientist, but here researchers’ bodies and all their proclivities are insistently present.

**Joel:** You comment in interesting ways about how protein models have a tendency to “travel” once their created, ending up in sometimes unforeseen or unplanned contexts. Media theorists, particularly in the digital age, have remarked often about the uncontrollable and unruly nature of media images and objects – they have a tendency to spread and reproduce. And of course biological metaphors are often used to describe these processes, “viral media,” for example. Can you speak about the “life” that these scientific models and animations have beyond the space of the lab?

**Natasha:** Some animations don’t leave the laboratory. Most are experimental devices that are used by researchers to support their efforts to hypothesize molecular events. Others, like “The Inner Life of the Cell” animation, are circulated very widely with hundreds of thousands of views on YouTube and other platforms.

We're definitely in an era where tracking the movements of animations outside of the laboratory becomes crucial, especially as they move through social media spaces.

One of the more surprising movements of molecular animations the way that they have been taken up by intelligent design researchers and creationists who argue that it wasn't nature that designed the clever little devices that they call molecular machines; rather, it was God that designed them. Here we have the neo-Darwinists and the intelligent design community both assuming that the world is made up of molecular machines, and both groups make use of the same animations to shape their arguments in favour of what seem to be such divergent world views. This phenomenon points to the malleability of animation in the life sciences.

Another example of these unexpected movements of molecular animations is the "dance your PhD contest" sponsored by Science Magazine and the American Association for the Advancement of Science. Beginning in 2008 (the competitions are still going on), the contest encouraged scientists to use movement to communicate the finer nuances of their research. These videos circulate widely on YouTube and other forms of social media. Just the very idea of scientists moving their bodies expressively to demonstrate their research incited significant interest when the competitions were first announced. Trying to document this ethnographically requires getting to know how images of science and scientific images move both in and out of the lab, troubling our received notions about the insides and outsides of scientific laboratories. The book asks what are the aesthetic forms, desires and imaginations that shape lives and labours in and beyond laboratories? Conventional media forms are clearly shaping the aesthetic forms of these molecular renderings. We see character animators in "The Inner Life of the Cell" making molecules look like lively little animals. Or we see aestheticized models that make molecules look like they are literally bits of machinery, complete with cogs and wheels, and ratchets and joints. Aesthetic forms travel, and these scientists are contributing to contemporary visual culture, just as as their models index it.

**Joel:** It's been some time since you conducted the research for this book. Is the intersection between animation and science still part of your ongoing work?

[Figure 3]

**Natasha:** My research has turned to plants and plant ecologies to understand how plants do life and how people are learning how to conspire with plant life for more livable futures. One element of this larger project is "Becoming Sensor", a research-creation project that I'm doing with a filmmaker and dancer, Ayelen Liberona (see <http://becomingsensor.com>). The goal of the project is to decolonize the ecological sensorium. If ecology is indebted to capitalism, colonial expansion, resource extraction, the neo-Darwinian imperative for organisms to survive and reproduce, we are looking for ways to *do ecology otherwise*. In an era when the resourcing of

nature has reached livable limits, we are exploring how altered modes of attention and perception might open up new ways of relating to the more-than-human world. Ayelen and I are experimenting with rendering techniques that tap into the deep time and ephemeral happenings of oak savannah lands in Toronto's High Park, lands that are ten thousand years in-the-making. More-than-natural formations, these are lands that have been cared for over millennia by people using fire to shape the land and its relations. There are remnants of these oak savannahs throughout Toronto, signs of vibrant Indigenous life. As settlers on this land were exploring ways to ally ourselves with Indigenous resurgence projects that imagine decolonial futures even in this urban, industrial, colonizing present.

We are working between art, ecology, and anthropology to experiment with modes of attention that might do justice to documenting forms of life that colonial ecology cannot fathom, including and especially the sentience of lands and bodies. In one of our experiments we're using long-exposure photography, which we're calling a kind of kinesthetic imaging (see figure 3). We are hacking into our cameras to hold open the aperture long enough that the image remembers the movements of the photographer. These kinesthetic images allow the photographer to stay in a dance with phenomena they draw into view. The images pull at light and colour, to render affects and energies that evoke the qualities of an encounter, a happening, or an event. I started thinking about kinesthetic imaging when I was working with protein modelers whose expertise hinged on their ability to move with and be moved by the molecular phenomena they tried to make palpable as 3D models. We are taking the best parts of scientific practice – its embodied, and kinesthetically and affectively entangling modes of inquiry – while casting aside its mechanistic, economizing, and colonial commitments.

We are treating kinesthetic imaging as a kind of animation, showing how even a static image can animate relations among bodies and energies. These kinesthetic images are for us one among a growing number of data forms that feed an expanding archive of an *ungrid-able ecology* of this *naturalcultural happening*. We shuffle them in and out of relation to see what stories emerge between. Doing ecology otherwise means learning to document the affective charge, the push and pull between bodies, the resistances, the propulsions, the attractions that are taking shape between all kinds of sensing and sentient bodies.