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Abstract

In 2008 *Science Magazine* and the American Academy for the Advancement of Science hosted the first ever Dance Your PhD Contest in Vienna, Austria. Calls for submission to the second, third, and fourth annual Dance Your PhD contests followed suit, attracting hundreds of entries and featuring scientists based in the US, Canada, Australia, Europe and the UK. These contests have drawn significant media attention. While much of the commentary has focused on the novelty of dancing scientists and the function of dance as an effective distraction for overworked researchers, this article takes seriously the relationship between movement and scientific inquiry and draws on ethnographic research among structural biologists to examine the ways that practitioners use their bodies to animate biological phenomena. It documents how practitioners transform their bodies into animating media and how they conduct *body experiments* to test their hypotheses. This 'body-work' helps them to figure out how molecules move and interact, and simultaneously offers a medium through which they can communicate the nuanced details of their findings among students and colleagues. This article explores the affective and kinaesthetic dexterities scientists acquire through their training, and it takes a close look at how this body-work is tacitly enabled and constrained through particular pedagogical techniques and differential relations of gender and power. This article argues that the Dance Your PhD contests, as well as other performative modalities, can expand and extend what it is possible for scientific researchers to see, say, imagine and feel.

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Prelude – Cellular Practices and Mimetic Transductions: A Dance in Four Scores

It is June 2006 and the stage is set at the Universiteitstheater at the University of Amsterdam where the Society for Science, Literature, and the Arts (SLSA) has gathered for its 4th Biannual European Conference titled *Close Encounters*. As the lights go down, conference-goers whisper in hushed tones. On the program this evening is the premier performance of 'Cellular Practices and Mimetic Transductions: A Dance in Four Scores'.

A narrow beam of light casts its glow on a small black rectangle set off on an angle at the centre of the stage. This rectangle, etched with clean, silver lines, is the stage of a microscope ramped up to human scale. The ocular lens of this microscope is a video camera perched on a tripod, and life on the microscope stage is amplified and projected onto a screen suspended in the rear. Two dancers cloaked in shimmering, translucent lab coats take their places: one stands on the microscope stage while the other operates the ocular lens.

The rhythmic whirring of machinic sounds floods the theatre. A woman's recorded voice reads from an instruction manual detailing techniques for operating a microtome, a machine used to prepare specimens for view under a microscope. The voice enumerates the 12 steps required to slice once-living tissues into thin sections. The dancer on the microscope stage elaborates specimen preparation techniques. With long limbs tracing arced lines, she slices through space. The other dancer zooms in with her ocular lens to amplify onscreen the techniques of this embodied machine.

The performers switch places to begin a second score. The microtome keeps whirring and a different voice splices together stories about the electricity that courses through living bodies. A biological 'specimen' comes alive on the microscope stage and the microscopist zooms in on a tiny pulsing thickness of the specimen's ankle, which is anchored to the stage. Abstracted and amplified, this *excitable tissue* twitches onscreen while the specimen's far-flung gestures propagate electrical transductions across the stage.

The two dancers switch roles again, for a third dance, and then again for a fourth. It is a 'scientist' who is set under the microscope in this last dance. She moves with the rhythms of a voice narrating stories about the *molecular practices of cells*. In these stories protein molecules become dynamic, vibrating bodies that act as springs, clamps, locks and twisting motors. Cells become bustling cities jostling with life as tightly packed molecules play off each other in relay races that activate and transduce signals within and among cells. The dance that ensues on the microscope stage propagates the excitability of these stories. The *scientist becomes molecule becoming machine becoming living system*, and the scene unfolds as a lively animation of intracellular life.

In this last scene, the microscopist becomes anthropologist. She hitches a ride on the gestures of the dancing scientist, tracking and amplifying movements with her camera. Like the specimen on the microscope stage, the scientist's body has become an *excitable tissue*. The performance comes to a close as the microscope zooms in on the pulsing hands of the scientist articulating the forms and movements of the very molecules she lovingly models.

*****

One of the performers was Clementine Cummer, a video artist and dancer who had recently graduated with an MA from MIT's programme in Visual Studies. Her thesis and art practice investigated relations among bodies and technologies in biological imaging (Cummer, 2005). I was the other dancer. At that time, I was a PhD student in MIT's programme in Science, Technology, and Society. Before then I had trained for over 20 years in classical ballet and contemporary dance, and laboured for several years as a researcher in life science laboratories.

This choreography articulated a shared set of questions into the life of images, models, and simulations in the biological sciences. My contributions to this joint project drew on archival texts and several years of ethnographic research to animate a range of phenomena I had encountered in the field. This research was finding that structural biologists and biological engineers who build and use models of protein molecules are intimately entangled with the objects of their inquiry. They use their bodies to *figure out* the forms, functions and movements of the molecules that they arduously model. Their conversations at the laboratory bench, in professional meetings and in classroom pedagogy are animated by gestures and affects that articulate their intimate knowledge of molecules. This body-work allows practitioners to performatively materialize models for their colleagues and students. They also use their bodies to feel through the tensions, forces and affinities of their molecular models, and in the process they gain significant kinaesthetic knowledge about the structures and intra-cellular activities of these molecules (Myers, 2006, 2008). The nuanced textures and tones of the ethnographic data I was gathering demanded livelier media than the formal research paper. Clementine and I spent a year collaborating to *dance* our inquiry. And yet apparently we were a little ahead of our time. Little did we know that dancing one's dissertation would become an international craze just two years later.

Dance Your Phd

Zoom ahead to 14 February 2008. The *New York Times* reports the results of the world's first Dance Your PhD contest, held in Vienna, Austria. In his article 'Dancing Dissertations', John Tierney (2008), a science reporter for the *Times*, writes: 'We've been warned that America's lead in science is in jeopardy. Now it looks as though Europe has definitely forged ahead in one field: interpretative dancing of PhD theses':

> You may not be interested in reading a dissertation titled, 'Refitting repasts: a spatial exploration of food processing, sharing, cooking and disposal at the Dunefield Midden campsite, South Africa.' But who could resist the chance to see it danced by the author, Brian Stewart, a graduate student of archaeology at Oxford? (Tierney, 2008)

Indeed, Brian Stewart went on to claim the winning title at this first ever Dance Your PhD contest, held at the Research Institute of Molecular Pathology in Vienna. He performed this short choreography wearing nothing but a loincloth. His colleague, fellow University of Oxford archaeologist Giulia Saltini-Semerari, accompanied him. She was costumed as an antelope. In the course of this one-minute choreography the antelope was hunted, skinned, and feasted on by campfire.

Stewart was in good company. He was among 12 contestants who had responded to a widely distributed call for submissions. *Science* reporter John Bohannon (2008a) had crafted a call for submissions, which read as follows:

The rules are simple

1. The title of your PhD thesis is projected on a screen.
2. We play the music of your choice.
3. You have 5 sec (min) to 60 sec (suggested max) to express this PhD with dance (using no Powerpoint, no pictures, no words).
4. Solo dancers or teams are allowed, but the prize goes to the PhD author.

Prizes
The 3 categories are graduate student, postdoc, and professor.
For each category, the 1st prize is:
... a free 1-year subscription to *Science*
... a gorgeous certificate of achievement
... and cult status for the rest of your life

This contest was hosted by the American Academy for the Advancement of Science (AAAS) and *Science Magazine*. A call for submissions to the second Dance Your PhD contest followed just eight months later and attracted 36 entries from scientists in the US, Canada, Australia, Europe and the UK. In 2010 a third contest ran, this time attracting 45 submissions from PhD students and recent graduates in physics, chemistry, biology and the social sciences (see Bohannon, 2010). 2011 saw the fourth annual competition with 55 submissions.[1] The submissions, uploaded first as YouTube and later as Vimeo videos, were widely accessible on the internet and caused a serious stir in the blogosphere as well as in print and radio news. In addition to the sheer novelty of dancing scientists, much of the commentary circulating around these contests has focused predominantly on three themes: dance as a medium for communicating science; the contests as a mode for public engagement with science; and the function of dance as an effective distraction for overworked researchers.

This essay argues for a deeper reading of this phenomenon. For example, if the Dance Your PhD entries were to be evaluated for their ability to communicate scientific concepts legibly, they would, for the most part, fail. Rather than reading the entries as good or bad representations that either succeed or fail in communicating scientific concepts, this article explores what these dances reveal about the relationship between movement and research. Why might scientists be moved to dance their research? Why dance? Why are they called to movement? To understand the role of movement in research, this article looks at the Dance Your PhD contests in the context of a rich history of dynamic *animations* of scientific concepts. It directs attention to modes of 'body-work' in life science research and teaching, and offers an ethnographic account of embodied animations among practitioners who build and use intricate, atomic resolution models of biological molecules (see also Myers, 2006, 2007, 2008).[2] Indeed, these scientists rely on their bodies to animate otherwise invisible biological phenomena and they conduct *body experiments* to work through hypotheses about how molecules interact. Elsewhere I examine how students submit themselves to intensive training to cultivate the affective and kinaesthetic dexterities they need in order to perform such *embodied animations* effectively (Myers, forthcoming). Here I show how practitioners' bodies become effective media for articulating the forms, forces and energetics of molecular worlds, and for propagating these insights among students and colleagues.

The Dance Your PhD contests expand and extend what it is possible for scientific researchers to see, say, imagine and feel. As such, it is clear that ethnographies of science must keep pace and attend to the modes of body-work and play involved in scientific training and research. This article argues that the Dance Your PhD contest entries must also be appreciated within the larger context of the visual and performance cultures of the contemporary life sciences. In particular, this article pays careful attention to the range of animating media (filmic, computer graphic and embodied) that practitioners use to bring their objects to life. It raises important questions about the epistemic status of these various kinds of animations and examines their relationship to other modes of representation in the sciences. This analysis aims to reorient theories of scientific representation in a way that can account for the affectively and kinaesthetically charged *rendering* practices so prominent among contemporary life scientists. Crucially, this account pays close attention the forces that constrain and enable these lively forms of body-work in laboratories and classrooms, focusing attention on ways that risky affinities are policed in pedagogical contexts and in spaces torqued by differential relations of gender and power.

The Contests

Where did *Science Magazine* journalist John Bohannon come up with the idea to host a Dance Your PhD Contest? Bohannon's radio interview with Andrea Seabrook on the National Public Radio (NPR) program *All Things Considered*, offers some insight:

> I was drunk. Honestly. I just want you to know the reality. You can also use this answer: There was a big party to happen in Vienna with a molecular biologist DJ. He made music that was based on samples of noise taken from molecular biology labs. So DNA sequencers, the mating dances of fruit flies. . . . There are a lot of bizarre noises in the laboratory. He was going to have this DJ event and it was going to be piled high with scientists. I proposed, let's add something to warm them up to get the dancing going. So that's when I proposed that we should do a Dance Your PhD contest.[3]

In this interview and several others Bohannon confesses that he conjured up the idea for this contest one night after a few too many drinks. A self-proclaimed 'Gonzo Scientist', Bohannon couldn't just sit back and watch other scientists perform their PhD dances, he would have to participate. In this NPR interview, he refers to his contribution as a 'surreal break-dance interpretation of a genetic network'. Bohannon filmed the entire event and uploaded the video to his blog on the *Science* website. According to him, after that 'the story just kind of became a runaway hit':

> It was covered by the *New York Times*; I was interviewed by *CNN* and *The Guardian*. And emails just started pouring in from all over the world from scientists, saying: 'When's the next PhD dance?' And of course there was no other PhD Dance. So, eventually, I think by the third dozen email, I realized I had to organize one fast. And since these scientists were all over the world, including Australia it couldn't be a real live event; it had to be on YouTube.[4]

With mounting enthusiasm from scientists around the world, and sponsorship from the Executive Office of the American Association for the Advancement of Science (AAAS) and the journal *Science*, Bohannon went on to mount contests in 2009, 2010, and 2011. Submissions to the 2009 contest were adjudicated by a panel of nine judges, including past winners of the first Dance Your PhD contest, three Harvard University scientists and three members of the world-renowned dance company Pilobolus. The dances were scored for their scientific creativity, artistic creativity and what the judges referred to as 'idea translation'. Four winners, one in each category of graduate student, postdoc and professor, as well as the 'popular choice winner' (the video with the most number of views on YouTube), were later paired with professional choreographers, who took up the challenge of interpreting recent research by these scientists to develop choreographies for a live performance called 'This Is Science' at the 2009 AAAS meeting in Chicago, Illinois. Since then, John Bohannon (2008b) has gone on to sponsor 'live experiments' on his *Science Magazine* website, and in lecture theatres at universities and science museums across North America and Europe. Each dance was evaluated for its ability to communicate scientific concepts in experiments where viewers were asked to match the professional choreographies with abstracts from the published scientific papers that had served as their inspiration.[5]

Distracted Scientists?

How has the media interpreted this phenomenon of dancing scientists? And how have the organizers and contestants made sense of their dances? The numerous press clippings, online videos and radio interviews suggest that the Dance Your PhD contest is interpreted by participants and reporters in three ways: as a challenge to conventional stereotypes about scientists; as an avenue for public engagement in science; and as a means of distraction for over-worked scientists.

As Bohannon figures it, his contest is a bold challenge to anyone who says that 'scientists are awkward and ungraceful' (quoted in Wagenseil, 2008). According to him, the contest serves to contest 'the stereotype of the scientist as the dry, nerdy pencil neck'. His aim was 'to demonstrate to the world that scientists can really dance' (quoted in Evans, 2008). This pitch worked perfectly to propagate the story in a media frenzy, which invariably narrated the contest in the comedic registers of astonishment and surprise. If Bohannon initiated this contest as a means to 'shatter the image' of scientists as 'dull and humourless geek[s]' (ibid.) who don't have rhythm, he also found a way to put dance to work:

> I have to admit my primary motivation was just the hilarity of it. And I was surprised and delighted to see that at least half the dances are rather moving. They are serious stuff. And so the idea is that the public will be engaged with science at a level that they usually don't encounter it.[6]

It is in hindsight that the contest is framed as a large-scale project for public engagement with science. The dances are charged with the responsibility to communicate science to the public. In an NPR radio interview with Bohannon, Bill Littlefield, host of the show *It's Only a Game*, questions whether there can be any scientific merit to the dances. In defence, Bohannon explains:

> If you watch every single dance and read the accompanying text that each of the scientists wrote, you actually you learn a lot of science. So I think a lot of people think this is okay because it falls under public outreach.[7]

In this frame, the dance is deployed as an instrument for science communication. The dances are purportedly translations that make science more legible for the public. Bohannon challenges contestants to 'just use your body and music to explain your science': 'What better way to cut through the problem of jargon than to completely cut out language?' (quoted in Heussner and Sandell, 2008). The idiom of dance becomes an accessible medium for public outreach, such that the winners each become, in Bohannon's (2008b) words, 'a kind of science diplomat'. In this move, art is instrumentalized in service of science education and communication.

As the buzz of these two contests circulated over the radio, in newspapers and, most prominently, through the blogosphere, they were also pitched as a light-hearted, fun-loving means for hard-working scientists to distract themselves from their heady work in the sterile medium of the lab. Bohannon, 'clad in a white disco leisure suit' at the finale event of the second Dance Your PhD contest, exclaimed to a reporter from the *Chicago Tribune*: 'How amazing that scientists around the world busy with lab work took a break to do something as bizarre as this. I love that' (quoted in Mitchum, 2009). This suggestion that the dances were opportunities for scientists to ease up on their hard work was reiterated in several scenarios. For example, the graduate student winner of the second Dance Your PhD contest, Sue Lynn Lau, then a PhD candidate at Garvan Institute of Medical Research in Sydney, Australia, choreographed a dance titled 'The Role of Vitamin D in Beta-cell Function.' Her choreography was accompanied by an alarmingly eclectic soundtrack that included both Buster Poindexter's 'Hot, Hot, Hot' and segments from the *Nutcracker Suite*.[8] Dr Lau apparently loves to dance, though she has never done it seriously.[9] In her experience:

> Doing the PhD is the really hard part and dancing for it was just a bit of fun. I'm finding it very difficult actually to work in the lab. The techniques require a lot of patience and perseverance so it's been a little bit more motivation to get back to the lab actually.[10]

And so, according to the media, the contest 'gives stressed students a bit of a chance to relax and distract their minds from what can be a long, arduous project'.[11]

Participation in the contest is repeatedly read as a diversion from more serious work. As discussions about the contest propagate through the media, what becomes clear is that ideas about what scientists are supposed to be up to in their laboratories are rather constrained. Apparently, there is a moral imperative for scientists to engage in rigorous, disciplined labour, and this must take the form of a kind of disembodied cognition. This imperative is not just policed from inside the laboratory, but also from the public. One of Bohannon's interviews on NPR makes this clear:

> *Bill Littlefield:* You gave grad students post docs and professors six weeks to create and film a dance based on their scientific research, and since scientists are pretty busy people and not known for their dancing ability, you couldn't have gotten more than, what, two three entries?
>
> *John Bohannon:* Well, that's what I feared. The amazing thing is that in the end about a hundred scientists took part producing three-dozen dances.
>
> *Bill Littlefield:* Well obviously our scientists are not busy enough doing science! [Laughter].[12]

Such responses reveal that what counts as scientific productivity is rather narrowly defined. Dance – figured in this context as leisure – is seen as an inappropriate distraction for busy scientists. Moreover, it is

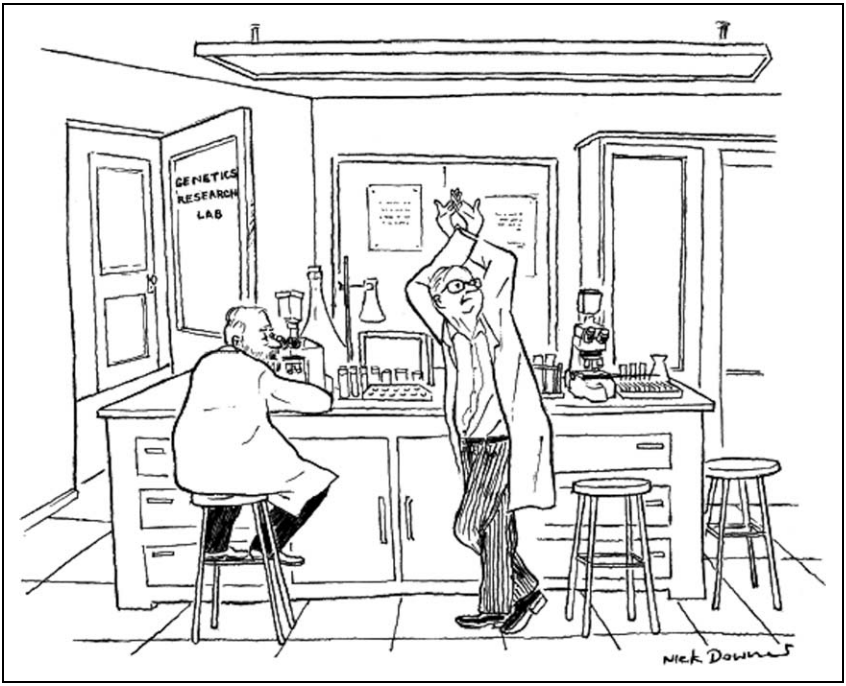

Figure 1. 'Very good, Michaels – you're a DNA molecule. Now get back to work.'
Source: Cartoon by Nick Downes. From Nick Downes, *Big Science* (AAAS Press, Washington D.C. 1992). Reprinted with permission from the artist.

not only the scientists who are chastised for getting distracted from their important work. The science reporters who cover this story are, apparently, equally culpable. In the comment section of his online article, *New York Times* reporter John Tierney (2008) is lambasted by one of his readers for taking up space to report on the contest. In this reader's mind, the contest is clearly a grand waste of time:

> So instead of John Tierney writing about something worthwhile like America's lost power in the sciences, he showcases something completely irrelevant. I used to believe John Tierney cared about science. His last two articles, on this and NASCAR physics, has [*sic*] proven otherwise.[13]

This reader taps right into the assumption that science is all work and no play, and that play itself has no proper place in the lab.

Body Experiments

Nick Downes' cartoon (Figure 1) speaks directly to anxieties about what counts as proper conduct in the laboratory. This cartoon figures two male scientists in a lab. One is seated at the laboratory bench with his instruments and test tubes, apparently busy at work, while the other has twisted his body into the shape of a double helix. As narrated through the caption, the seated scientist gestures to the contorted one: 'Very good, Michaels – you're a DNA molecule. Now get back to work.'

It would be easy to read the cartoon in the same register as the media reports on the Dance Your PhD contests; that is, by laughing at the scientist whose playful contortions are distracting him from his work. Yet, there's another way to read this cartoon: perhaps the joke is on the scientist who thinks that he's getting his work done by sitting at the laboratory bench? Could it be that the helically wound-up scientist is doing the important experiment? In my reading, he is conducting a crucial *body experiment* (a twist on the well-known thought experiment) in order to *figure out* the molecular structure of a complex biological molecule. Ethnographic research among structural biologists and biological engineers who build models of biological molecules has shown that body experiments like this are a widespread phenomenon (Myers, 2007). Indeed, Downe's cartoon perfectly inscribes the iteratative and performative 'body work' involved in molecular model making (Myers, 2008).

The Dance Your PhD submissions need not be interpreted as failed art projects. They also need not be assessed as to whether they communicate science coherently. Rather, these dances can tell us about *forms of knowing* and experimental inquiry in the life sciences. While it is true that the Dance Your PhD contest submissions inhabit a carnivalesque modality that explicitly breaks from the mundane context of day-to-day research practice (see Bakhtin, 2009), they do gesture at the kinaesthetic and affective entanglements of inquiry that are crucial to laboratory research. In what follows these dances are examined in the context of a history of other performative modalities and situated among an array of everyday gestures and movements. These contexts show how scientists use their bodies as experimental media. This essay argues that if scientists' moving bodies can generate both new forms of knowing and things known, then the stakes are high for ensuring that these forms of body-work are fostered in research and teaching contexts.[14] But first, let's go back in time.

Molecular Happenings

> Only rarely is there an opportunity to participate in a molecular happening. You are going to have that opportunity, for this film attempts to portray symbolically, yet in a dynamic and joyful way, one of nature's fundamental processes: the linking together of amino acids to form a protein. (Paul Berg)

Science is no stranger to dance. The Dance Your PhD contests remember earlier encounters between dance and science. In 1971, for example, a football field at Stanford University bore witness to a large-scale 'molecular happening' that gathered up over 100 dancers and musicians. This 'happening' was recorded on film and has since circulated widely, entertaining undergraduate biology classrooms across the US for decades. More recently it has become a major hit on YouTube.[15]

'Protein Synthesis: An Epic on the Cellular Level' is a massively amplified *animation* of the intricate molecular interactions involved in protein synthesis. This *re-enactment* of protein synthesis was directed by Robert Allan Weiss, choreographed by Jackie Bennington and accompanied by a molecularly inspired revision of Lewis Carroll's 'Jabberwocky'. The film opens with a mini-lecture by Nobel Laureate Paul Berg. In his 'Protein Primer', Berg addresses his audience from within a classroom. He stands in front of a blackboard diagram that indexes the molecular pathways involved in protein synthesis (see Figure 2). Before him is a colourful ball and stick model of a protein. His sweeping gestures instruct his audience how to make sense of this model (Figure 2).

> We know now that the three-dimensional structure and the function of a protein is determined by the order of the amino acids along the backbone of the molecule. So protein synthesis involves programming and assembly. And this film – with people portraying molecules using the dance idiom – tries to animate these two processes: the programming and assembly of a protein.
>
> Our genes carry the instructions for ordering the amino acids of each protein. Those instructions are encoded in a messenger

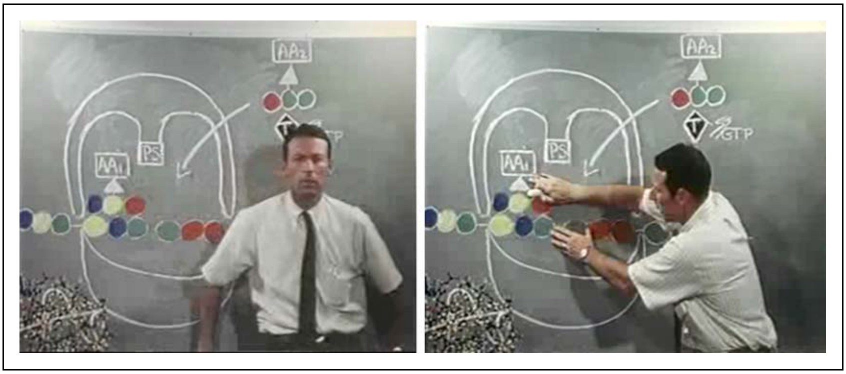

Figure 2. A 'Protein Primer': Paul Berg uses his blackboard diagram to index the sequence of molecular interactions involved in protein synthesis. Screenshots from 'Protein Synthesis: An Epic on the Cellular Level.'

> molecule, RNA, depicted in this film as a long snaking chain. Each of the message units is played by three adjacent people in the chain. Coloured head balloons indicate the bases. Green for Guanine, blue for Uracil, yellow for Adenine.
>
> If there is a message, there must be a way to translate that message. And that's the job of the ribosome and the transfer RNAs. The ribosome is composed of a large and a small sub-unit and these are depicted in the film as tumbling, rolling clusters of body, amorphous by themselves, but organized and structured in the act of translating the message ...

Berg continues with his description, indicating how 'puffs of smoke' in the performance indicate the use of energy. He concludes with this proviso: 'My diagram is of necessity static. But protein synthesis is a dynamic process. This movie tries to bring those dynamic interactions to life ... ' The phenomenon of protein synthesis defies the flat or static representational conventions Berg has available in his classroom (see Figure 3). In his narration, moving bodies are the ideal animating media for visualizing molecular dynamics. The 'dance idiom' enables participants to collectively articulate[16] the 'programming' and 'assembly' of a polypeptide chain. Molecular structures and interactions are brought to life through 'tumbling, rolling clusters of bodies' that weave across the field. This 'epic' 13-minute re-enactment is full of life: joyful, excitable bodies laugh

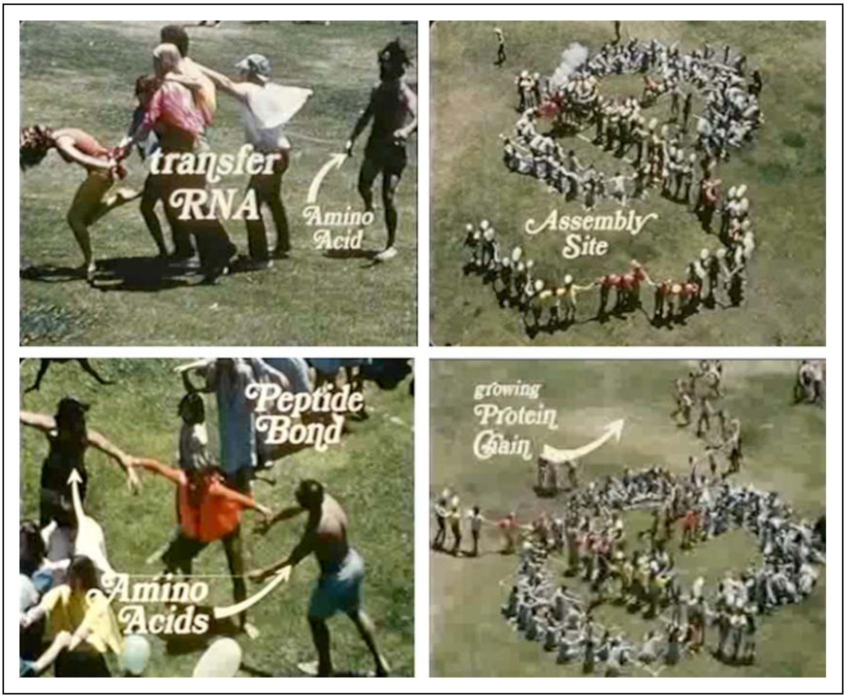

Figure 3. Screenshots from Robert Allen Weiss's 1971 staging of 'Protein Synthesis: An Epic at the Cellular Level'.

and shout, careening and cartwheeling across the field. If this is indeed a re-enactment of the cybernetic machine metaphors of code and information flow, it is at least cybernetics on LSD.[17]

In this large-scale re-enactment of protein synthesis, dancers' bodies stand in as proxies for individual molecules. These bodies-cum-molecules coalesce and converge across the massive surface of a football field, forming higher-order aggregates and molecular assemblages. This 'molecular happening' thus animates and amplifies Berg's two-dimensional blackboard diagram of protein synthesis, allowing him to play his diagram forward in time.

One of the winning entries for the second annual Dance Your PhD contest offers a 21st-century example of a 'molecular happening', if on a smaller scale. This one engages four dancers to animate and amplify the multidimensional movements of a single haemoglobin molecule as it binds and releases oxygen. Vince LiCata, a tenured professor in the Department of Biological Sciences at Louisiana State University won in the category of 'Professor'. His well-staged

Figure 4. Screenshots from 'A Molecular Dance in the Blood, Observed', winner of the 2009 Dance Your PhD contest in the category of Professor.

choreography, 'A Molecular Dance in the Blood, Observed', is set to Laurie Anderson's 'Born, Never Asked' (see Figure 4).[18]

Haemoglobin is a protein that transports oxygen in the blood. It is made up of two pairs of identical sub-units that interact with one another to endow the protein with structure and chemical function. In LiCata's staging, two pairs of dancers wear red T-shirts and light blue jeans. One pair dons purple gloves and matching goggles, while the other set is clad in white gloves and goggles. The two pairs rotate around a single axis in tight formation, curving, swaying and reaching out into the space. They rotate as an aggregate, and as they move, they keep two small white balls of oxygen in play among them.[19]

One of the compelling features of this choreography is that the movements of this animated molecule resonate with a set of movements that come alive among practitioners in research and teaching contexts. More specifically, LiCata's dance re-members a well-rehearsed gesture that has propagated widely among structural biologists since Nobel Prize Laureate Max Perutz solved the structure of haemoglobin in 1962.[20] Haemoglobin is one of the primary structures that life science students must learn, almost as a rite of passage, early on in their studies of biochemistry. Because its conformation changes each time it binds and releases oxygen, it is often imagined and performed as a 'breathing molecule'. Biochemistry students often re-enact this breathing molecule by making a gesture as if they were holding a pulsing substance breathing with life in their hands. Such movements allow students and practitioners at all levels to use their bodies to lean into their data and feel through the kinetics of molecular motion. These forms of body-work are resonant with those performed by Michaels, the helically wound-up geneticist featured in the cartoon in Figure 1. If the 'Epic' protein synthesis performance and LiCata's staging of haemoglobin are choreographed forms of *embodied animation*, then these more mundane, everyday gestures are improvised *body experiments*. The following sections take a closer look at some key differences in these forms of animation and examine epistemic concerns about the representational status of animations, computer graphic, embodied and otherwise. Later, the article turns to examine some of the forces that constrain and enable *body experiments* in laboratories and classrooms, with a particular emphasis on the ways that they are policed in contexts of differential relations of gender and power.

Rending Time

A wide range of animating media have been deployed in the history of the life sciences (Keller, 2002). Time-lapse film, as used in microcinematography and confocal microscopy, for example, can pull fast- or slow-moving cellular phenomena into time frames that makes sense to human perception (Cartwright, 1995; Keller, 2002; Landecker, 2005; Myers and Dumit, 2011). Most recently, life scientists have turned to computer graphic media to animate the molecular practices of cells (Kelty and Landecker, 2004). Digital media forms allow researchers to integrate static data forms, such as freeze-frame biochemical data and crystallographic snapshots of proteins and compose moving-image sequences that narrate the temporal flow of a process. Major initiatives are under way to develop animations that can support pedagogical efforts to bring cellular processes to life in the classroom. At Harvard University, for example, educators with the BioVisions project have formed partnerships with professional character animators.[21] These animators make use of some of the film industry's most sophisticated technologies. In efforts to render molecular forms and movements with empirical accuracy they build on known protein structures and biochemical data. This, of course, does not stop them from exercising their artistic licence to inflect their action-packed, fly-through scenes with highly stylized textures, tones and caricatured rhythms. It is precisely because they are so expressive that these highly produced animations are such generative resources for insight into the visual cultures of the life sciences. They express the aesthetics of contemporary biological imaginaries, demonstrating the range of affective registers and elaborate figural vocabularies that scientists use to amplify otherwise sub-visible processes.

And yet these animations don't just express an aesthetic, they performatively sediment particular ways of seeing and storying the action that plays out in the sub-visible recesses of a cell. This is precisely why computer graphic animations can pose problems for practising scientists. By scripting the direction of action and the temporal flow of a process, animations like these tend to generate what some have called a kind of 'epistemic anxiety' (e.g. Prentice, 2007). While these animations can be used effectively as pedagogical 'lures', many researchers are sceptical about using them as research tools (see Stengers, 2008 on lures; see also Myers, 2009a). A conversation with Lynn and Joanna, two post-doctoral fellows charged with developing an undergraduate curriculum in biology, was illuminating in this regard.[22] In the midst of a wide-ranging discussion on the visual media they use when they teach, I asked Joanna, whose PhD research had examined the phenomenon of protein folding, how she felt about animations, in particular those that describe how proteins fold to acquire their active conformations in the cell. Below is an extended excerpt of her response and the conversation that ensued:

> *Joanna:* I've always hesitated [to make animations of protein folding]. . . . I have always really hesitated trying to put what I see in my head onto paper. I was always the one in the lab who was able to make beautiful models for people. Not 3D models. But I was the one who was easily able to take the data, and make the 2D cartoon to see that, 'Okay this step goes first, then it's got to be this step, then this step.' I could do that very easily. But I always hesitated to actually put anything amorphous, [like] the simulations together. Because from day one of joining the lab, [the head of the lab] was like, 'You can't make a simulation of protein folding. You can't do it! It's not going to be accurate!'

I can give you the steps that I know happen. I have no problem describing or creating representations that make people understand that very easily. But making an animation that goes from one to the other. . . . It's that ingrained . . . thing that says:

'No you can't do that it'll be wrong!'

For instance the molecule I was studying when I was there: It's got two sections. And we – myself and another grad student – we determined that yes, in fact, without a question, what happens is that one section folds before the other. We could see it and we know it happens. And we have lots of data that shows that's how it happens. But I would never try to model a . . .

Lynn: A continuous process?

Joanna: Yes, a continuous process out of that. I could say yes, I can give you a model that shows that 'this guy is solid,' 'this guy is loose'. [She uses her arms and hands as proxies for each section of the protein]. But I would never [animate it]. . . . It's very difficult because so little is known. That's what makes protein folding so hard to describe to people. 'Cause, everyone seems to want to put a time sequence on things, to make a simplified animation. There's so few cases where we can say a simplified animation, 'Oh, that's right.' We just don't know.

Lynn: That's interesting. I just realized that's what irks me about the tRNA [transfer RNA] folding movie that [we] show in class. It's precisely that. You don't know that's what happens.

Joanna: You don't know the directionality, you just don't know . . .

Lynn: . . . that that's the order of the steps.

Joanna: From a protein folding background, to me it's infinitely frustrating when people do that. I've seen more graduate students spend their careers trying to make animations and simulate folding when there's no experimental basis for what they are doing. . . . And it's very difficult as a true protein folder – I can't buy it. I don't believe it. I can see the desire to represent that, or to get at those steps. But there is just not enough data to support [it].

Joanna and Lynn are concerned that animations overdetermine the temporal sequence of what is for them a dynamic process. Joanna 'knows' how a protein folds, and she can 'see' it; she even understands the 'desire to represent' the forms and movements of the folding process. However, she is concerned that animations overdetermine processes she knows to be amorphous, ephemeral and impossible to capture. Joanna is particularly anxious about the ways these animations *rend* time: they impose a tempo and a direction; they put a time stamp on a process. An animation that runs time in a set direction effects a kind of closure by directing how others see and experience a process. A viewer's visual field is flooded with data; and their imagination is saturated with some visions of life and not others. This forecloses other interpretations and other ways of visualizing living processes. It is no surprise that practitioners are uneasy about the ways these time-stamped animations can seduce both lay and professional audiences.[23]

If these forms of animation generate so much anxiety, which forms do practitioners rely on in the context of their daily work? The following section argues that certain forms of embodied animations enable modellers to experiment with molecular motions, and shows how in the process they get entangled affectively and kinaesthetically with their data and their models.

Animate Renderings

If time-lapse imaging and computer graphic animations are two prominent techniques used in contemporary life science imaging, then embodied animations, like LiCata's haemoglobin dance and the 'Epic' re-enactment of protein synthesis offer another option for scientists.[24] What these molecular happenings have in common is that they are all highly produced, choreographed and staged re-enactments of dynamic molecular processes. And while there is nothing inherently limiting about these distinct media forms – each can enable modellers to engage their objects, concepts and data in open-ended explorations – the animations that are produced in these media rend time in the very ways that cause Joanna and Lynn such concern. They put a time-stamp on a process, and set the tempo and the direction of molecular events.

Body experiments might be classified as a different kind of embodied animation. Such experiments include those conducted by the helically wound-up scientist in the cartoon in Figure 1, or students' breath-filled emulations of pulsing haemoglobin molecules. They make explicit the kinaesthetic and affective dimensions of what are normally recognized as 'thought experiments'. These gestures and affects are part of the daily and mundane work of learning and conducting inquiry in science. What sets this form of animation apart from the others is that body experiments are improvised explorations that unfold in the rhythm of hypothesis formation, communication and experimentation. They are not prefabricated, choreographed or fully composed. As improvised articulations they can be re-enacted, revised and refuted mid-gesture. They can be repeated, but always with a difference. What's crucial here is that these animations do not fix the temporal flow of a process: their temporality is elastic.[25] Where an animated movie with a singular story line runs directionally in time, a modeller conducting a body experiment can hesitate and prevaricate. By shifting the rhythm of their movements, they can play with molecular time. They can use their bodies as proxies to test out the attractive and repulsive forces and tensions between atoms in a molecule. This form of body-work helps them to model proteins analogically with their bodies and to hypothesize and work through a range of possible molecular forms and activities. They can do this on their own while they are working through a problem at the bench, or with groups of colleagues and students. These experiments allow practitioners to *reach towards* phenomena and engage kinaesthetically and affectively as if they were somehow inside the process. Such forms of 'haptic creativity' allow practitioners to feel their way through possible forms, tempos and movements (see Myers and Dumit, 2011).

So what can an embodied animation like this accomplish for a scientist? How does it relate to their empirical work of crafting sound models and animations that can represent the molecular world? In what follows I argue that body experiments challenge theories of representation to account for the performativity of model-making.

Protein models and animations are commonly treated as 'representations' of otherwise imperceptible molecular phenomena. 'Representations', in this context, can be taken as what Evelyn Fox Keller (2000: S82) calls 'models as nouns', that is, as 'separate entities' at the 'end of the process' of model building. Yet Keller introduces a crucial distinction that shifts attention to the practice of model building. Rather than focusing on models as end-stage representations of phenomena, she treats models as 'verbs', that is, as actions, doings and enactments. Models and animations are thus not just objects that stand in for knowledge or phenomena. They do more than represent things. They also *enact* them, and in the process produce new forms of knowing for the modeler and new material instantiations for molecules. (see Barad, 2007 and Mol, 2002 on enactment). In the context of protein modelling, scientists turn their bodies into experimental media to generate insight into molecular forms and movements. This appears to be crucial to the labour of crafting sound models and animations. By becoming proxies for a process, researchers can emulate a phenomenon in ways that generate kinaesthetically and affectively charged knowledge. A model or animation is thus not only a representation, but also a performative *form of knowing*.

The concept of *rendering* is generative in this context. As my dictionary reminds me, the term *rendering* is multivalent. A rendering can indeed be a representation of something, as in a translation, a work of art, or a detailed architectural drawing. But a rendering is not just an object that can stand in for something else; 'rendering' as a verb is also the activity of producing these representations. In this active sense of the term, a rendering can be a performance, as in the rendering of a play or musical score. As such, renderings can carry the mark of the artist, such that, as the performer enacts it, a musical score is inflected with unique tones, textures and affects. Another use of the term is in the field of computer modelling, where a rendering is 'the processing of an outline image using colour and shading to make it appear solid and three-dimensional' (*Oxford American Dictionary*). In this sense, a rendering is the modeller's elaboration, addition or augmentation of a simpler thing. To render is also to provide, hand over or submit (as in 'to render up' a verdict or a document), each of which is a performative gesture that passes an object or communication from one person towards another. Heard in a different register, to render is also to tear or rip things apart (see also Shukin, 2009). What holds all of these diverse uses of the term together is that each refers not just to the object that is rendered, but also to the subject, the one who renders, and the activity of rendering.

Body experiments are renderings that gather up the modeller and their media, and make tangible the very activity of model building. Rather than focusing on whether a model or animation is a good or bad representation of a phenomenon, this shift to the idiom of rendering foregrounds all the ways in which models and animations are inflected by the affects and sensibilities of those who perform them. These animations are attempts to resonate with, rather than just represent, molecular worlds. Body experiments thus also articulate the *affective entanglements* that tether scientist and specimen in their close encounters in the lab (for more on 'rendering' see Myers, forthcoming).

As renderings, embodied animations are left open to interpretation, and so are inviting for others to *try on* for themselves. This often plays out in a back-and-forth relay of gestures that looks much like an improvised dance between conversing colleagues, or between scientists and their students. These often informal performances appear to leave room for intra-active play, opening up to a kind of exploration that enables the modellers' interlocutors to participate with them in figuring out the nuanced forces, affinities and movements of a molecular interaction (Myers, 2006). In this sense, embodied animations are 'intra-active' (Barad, 2003) and participatory, offering an opportunity for modellers and their colleagues to learn how to *move with and be moved by* (Myers, 2005) the objects they lovingly and arduously model. Seen as 'lures', these embodied animations can 'vectorize' bodily experience to produce new forms of knowing for those actively participating in the intra-active play of embodied modelling (see Stengers, 2008: 96).

Interrupting the Tacit Habitus

For the most part researchers in professional contexts are uninhibited in their body-work. Sometimes subtle, sometimes elaborate, their gestures amplify the structure and movements of molecules in conversations in laboratories, during lab meetings, in offices, hallways and over meals in cafeterias. In interviews, when researchers explain the activities of their proteins, they perform the vibrations of molecules oscillating like conductive media in the cytoplasm and wave their arms about to emulate the floppy ends of polypeptide chains. They also contort their bodies into sometimes-awkward configurations to demonstrate conformational changes, and to show how molecules 'work' mechanically and chemically in the cell. And yet, as an ethnographer-in-training, my first years in the field offered plenty of opportunities to make some crucial mistakes in the ways that I addressed these phenomena with my informants. These mistakes taught me important lessons about the tacit norms that constrain and enable how practitioners can use their bodies. These researchers, it turns out, do not have unlimited degrees of freedom in their molecular expressions. Their body-work is disciplined by a range of forces that impose limits on what it is possible for them to see, to say, to imagine and to feel. Working alongside them I learned about the fraught dynamics of gender and power that constrain body-work in the contexts of laboratory life and classroom pedagogy.

The Dance Your PhD contests and 'Protein Synthesis: An Epic on a Cellular Level' are both explicit in their use of dance as a medium for rendering dynamic phenomena. Rarely, however, did researchers use the idiom of dance to refer to their body-work. In fact, when conducting interviews, I had to be careful to avoid directing a researcher's attention to their own movements. For these reasons I rarely used video to record interviews and scientists at work. I learned quickly that protein modellers' expressive performances depend on a condition in which their body-work remained tacit. What follows is a series of key ethnographic moments that show a range of contexts in which practitioners' body experiments were truncated. My concern here is with the forces that make this lively body-work so risky for practitioners, and thus such a precarious phenomenon.

Most of the time, in both pedagogical and professional settings, practitioners moved their bodies without inhibition. The few times I directly called attention to their elaborate movements, they became self-conscious or froze mid-gesture. During an interview with Lynn and Joanna I asked them to explain how they use their bodies in teaching. Joanna was happy to show me how she moves to teach students about how proteins wiggle through a gel matrix. Yet after reflecting on what it was they were doing in class up in front of their students, Lynn was visibly embarrassed: 'We're making fools of ourselves is what we are doing!' When I asked them to focus on their body movements they became self-conscious. It seems as if, upon reflection, their body-work seemed excessive; a breach of proper conduct. As junior women in science they perhaps felt doubly anxious about over-spilling acceptable bounds.

Andrés, a postdoc at another institution, also experienced discomfort when I drew attention to his body-work. I was attending an annual meeting for structural biologists with anthropologist Michael

Fischer (see Fischer, 2009). I was off looking at student posters when Mike told Andrés that I was studying how structural biologists 'danced' their molecules. Andrés confessed to Mike that he had choreographed 'a little dance' for one of the molecules that he had modelled. When I rushed up to him having just heard the news, he balked: 'I hate dancing, but there was just no other way to communicate the mechanism. I had to dance it.' I asked him to show me his dance. He was mortified. When we first met several months before, I had asked him how his protein worked. At that time he was quite comfortable enlisting my participation to perform his model of a cell adhesion molecule. Indeed, he swept me up into a contact improv choreography that animated the hypothetical strength of molecular interactions by experimenting with various ways to clasp our hands (see Myers, 2006). Given this context, I didn't think twice when I asked him to 'do his dance' right there in the bustling lobby of the conference. Apparently, in so doing, I skipped over the part that was crucial to him. By singling out a researcher's body-work as the focal element of interest I did not properly acknowledge the content of what he was trying to communicate. What I should have asked was: how did this molecule work? What was it about the molecule that demanded he perform the mechanism with his body? While he refused to show me his 'secret' dance as we stood in the bustling lobby at the scientific meeting, he admitted that he had performed it before for a small group of colleagues. In this moment, he taught me that body-work is a crucial, but tacit, part of his practice.

Differential relations of gender and power can also severely constrain modes of body-work. Zeynep, a protein crystallographer conducting postdoctoral research in a lab at the same institute as Andrés, recounted a story that brought these issues to the fore. We were at a cocktail party held by a mutual friend when she told me about an incident that occurred when she was describing a molecular mechanism she had hypothesized to the head of her lab. We were standing in the corner of the kitchen, and she cleared space to show me the elaborate choreography she used to convey this molecular mechanism to her professor. The mechanism involved one part of the protein making an upward, twisting, piston-like movement into another part of the protein. She demonstrated this with zeal, making a large upward gesture with one arm to enact the piston, while using her other arm to show the space occupied by the rest of the protein. Apparently her professor read her molecular dance as an overtly sexual performance. He taunted her and called her out for making such rude gestures in public. This sexualized her body-work and rendered it an excessive and improper expression of knowledge. She took this warning seriously, and told me that she'd become much more self-conscious since then about just how she moved when relating molecular mechanisms. This professor shamed Zeynep and so disciplined such performative 'excesses' out of her practice.[26]

In other contexts, especially in the undergraduate biology classrooms I observed for my study, performative modes of body-work are made explicit and encouraged as pedagogical exercises (Myers, 2009a). However, encounters with these postdocs demonstrate that, at least for practising researchers, such performances depend on a condition in which their body-work remains tacit. To propagate their insights effectively, researchers must keep their molecular gestures alive in discourse and practice. Yet, apparently it is only in 'intra-actions' (see Barad, 2003, 2007) that can tacitly elicit and sustain them that these embodied animations can thrive and propagate as forms of knowing.

This research shows that identifying these performances as forms of dance can all too quickly gender or sexualize a practitioner's body. Yet, this dynamic shifts when scientists appropriate the dance idiom for their own purposes. It seems as though the Dance Your PhD contests, the 'Epic' performance of protein synthesis and numerous other productions have opened up a new space for scientists to stage their body experiments and explicitly engage dance as a medium.[27] What is key here is that in these contexts scientists participate in dance modalities on their own terms, without a curious anthropologist imposing her interpretive schema on their practice. The overwhelming enthusiasm for these performances among scientists suggests that dance may actually offer an effective medium for rendering lively processes.[28] Indeed, practitioners can be seen actively seeking out opportunities to move their bodies. So, why dance? Their participation in these performative modalities is evidence that there is something involved in scientific inquiry that calls their bodies out to play.

Conclusion: The Affective Entanglements of Inquiry

> I was surprised and delighted to see that at least half the dances are rather moving. They are serious stuff. (John Bohannon, NPR Interview, 2008)

Theories of scientific visualization tend to treat imaging technologies as apparatuses that can to 'capture'and contain living phenomena, taming them as objects for scientific inquiry. In this frame, experimental objects are cast as passive captives of the apparatus. However, the apparatuses of capture deployed in the life sciences can never fully contain their objects; the elusive phenomena they try to pin down continually escape and evade attempts to extract clear, clean data. A gestalt shift makes it possible to see that it is not so much the phenomena that are caught, but the scientists themselves: they are the ones arduously entraining their bodies, imaginations and instruments to the rhythms of phenomena they desire to know.[29] Indeed, practitioners can be seen *hitching rides on* and being *pulled in by* the phenomena they struggle to comprehend. This shift to a language of 'hitching onto' and 'getting caught by' signals researchers' capacities to *move with and be moved by* the phenomena that they attempt to draw into view. As this article has attempted to show, practitioners are lured by the liveliness of molecular movements they can intuit but not otherwise see, and so they are caught: *affectively entangled* with the phenomena they model in the lab.

Theories of representation and communication in science must be reconfigured in order to account for the role of embodied animations in the production and propagation of scientific knowledge. Henri Bergson's *Matter and Memory* (1991), which animates a theory of perception based on 19th-century physiology, offers some insight to think through the kinaesthetic and affective entanglements of inquiry in life science laboratories and classrooms. In this work Bergson bundles perception and movement together in the nervous tissue of the body, exploring how affect and responsive action are produced through a 'kind of motor tendency in a sensory nerve' (1991: 55–6). Diffracting Bergson through Deleuze (1986), I've been lured to figure living bodies as fleshy antennae whose physiologies act as a kind of resonating medium that oscillates between conduction and resistance, and manifests energies as perception, affect, and action. In this view, bodies become *excitable tissues*[30] attuning to the energetics and movements of the world. In the context of protein modelling, scientists can be seen attuning their sensoria to subtle molecular forces and affinities and hitching rides on molecular movements. In this sense, their tissues become *excitable media* with the capacity to collect up and relay nuanced molecular affects. Their body experiments, in this sense, are *transductive*; that is, they can propagate forms of knowing through performative articulations that excite others into action.[31] If expert modellers are capable of affecting and being affected by one another's molecular gestures, then students' bodies must first be trained to become responsive and receptive to the subtleties of molecular forms and movements (see also Myers and Dumit, 2011).[32] As they lean into their data and get swept up by the momentum of molecular movements, these researchers become *affectively entangled* with their molecules and their models.

These entanglements are, however, tacit and precarious. As I have shown above, body experiments are subject to severe constraints that make them impossible to sustain in certain power-laden contexts. Documenting these sometimes fleeting and precarious forms of knowing is thus crucial. And yet this task demands that an ethnographer learn how to *move with and be moved by* the energetics, affects and movements of these embodied animations.[33]

I approach the embodied animations as evidence that scientists are pulled into molecular worlds that are as much imagined as palpable. In this sense they produce *conjurings* of the *molecular practices of cells*. Already lured by lively stories of molecular phenomena, these researchers tap into their bodies and imaginations to hypothesize possible molecular forms and movements. This liveliness excites biological imaginations, forms of inquiry and pedagogical interactions. If these performative affects are intrinsic to the conceptual and material work and play required to produce and propagate molecular knowledge, then it is imperative to understand how, when, where and why these risky affinities are policed.

In spite of much effort to discipline their body-work, it is clear that scientists don't always keep their bodies in line. The Dance Your PhD contests appear to defy the normative moral economy of the laboratory, where scientists' cognitive labour is at a premium. The enthusiasm with which scientists have embraced the Dance Your PhD contests suggests that they are on the look-out for ways to resist discursive conventions that limit what is possible for them to see, to say, to imagine and to feel. Perhaps it is through the medium of dance that they are best able to avow, rather than continue to disavow, their richly embodied kinaesthetic knowledge and the affective entanglements that inflect their inquiry.

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Notes

1. See URL (consulted December 31, 2011): http:/news.sciencemag.org/sciencenow/2011/10/dance-your-phd-winner-announced.html.
2. On gesture and body-work in other domains of science see also Prentice (2005), Alač (2009), Vertesi (2009), and Myers and Dumit (2011).
3. Bohannon interviewed on NPR's All Things Considered, 22 November 2008, URL (consulted April 2011): http://www.npr.org/templates/story/story.php?storyId1/497356050
4. Bohannon interviewed on NPR's *All Things Considered*, 22 November 2008.
5. Videos of the professional choreographies produced for 'This Is Science' and results from experiments to match choreographies and scientific research articles can be viewed at URL (consulted April 2011): http://www.sciencemag.org/cgi/content/full/324/5932/1262-b
6. Bohannon interviewed on NPR's, *It's Only a Game*, 6 December 2008, URL (consulted April 2011): http://www.bu.edu/wbur/storage/2008/12/onlyagame_1206_4.mp3
7. Bohannon interviewed on NPR's, It's Only a Game, 6 December 2008.
8. To see Sue Lynn Lau's YouTube submission see URL (consulted April 2011): http://www.youtube.com/watch?v=QiTFBRPFRh8

9. Media release, Garvan Institute, 24 November 2008, URL (consulted April 2011): http://www.garvan.org.au/news-events/news/phd-student-sue-lynn-lau-dances-her-way-to-chicago.html
10. Lau interviewed by Michael Turtle for PM Radio in Australia, 1 December 2008, URL (consulted April 2011): http://www.abc.net.au/pm/content/2008/s2434907.htm
11. ABC News, 1 December 2008, URL (consulted April 2011): http://www.abc.net.au/news/stories/2008/12/01/2434873.htm
12. John Bohannon interviewed on NPR's, *It's Only a Game*, 6 December 2008.
13. See comments on Tierney (2008), URL (consulted April 2011): http://tierneylab.blogs.nytimes.com/2008/02/14/dancingdissertations/
14. In 2011 Bohannon, accompanied by a flock of dancers, gave a TED Talk on the vagaries of powerpoint. He suggested that scientists should give up their mind-numbing slides and enliven their presentations with dance. Yet, he makes it clear that dance offers more than just a savvy means of communication. In the talk he offers dynamic account of one biological engineer who works directly with dancers to brainstorm models of cell movement. This is an excellent example of the explicit use of body experiments. See URL (consulted December 31, 2011): http://www.ted.com/talks/john_bohannon_dance_vs_powerpoint_a_modest_proposal.html
15. As of 30 December 2011, 'Protein Synthesis: An Epic on a Cellular Level' has received over 796,309 views on YouTube, URL: http://www.youtube.com/watch?v=u9dhO0iCLww
16. On modes of 'articulation' see Latour (2004).
17. 'Protein Synthesis: An Epic on a Cellular Level' was remounted in 2006 at Kenyon College in Ohio by students and faculty of the departments of Dance and Drama, and Biology. In place of Paul Berg, this re-enactment was narrated by MIT/Whitehead Institute biochemist Harvey Lodish. See URL (consulted April 2011): http://www.kenyon.edu/x31680.xml
18. To view LiCata's YouTube submission and his explanation of the choreography, see URL (consulted April 2011): http://www.youtube.com/watch?v=2L1UJgYH6bU&feature=channel_page
19. This choreography stages an animation, not only of the haemoglobin movements LiCata was investigating, but of the very techniques he developed to make that phenomenon visible. In the

text that accompanies his YouTube video, LiCata explains that 'low temperature isoelectric focusing' is a technique that 'freezes (literally) and takes a snapshot of the dimer-dimer interactions at different times'. LiCata developed a visualization technique that allowed him to pull freeze-frame images of haemoglobin into time; that is, to animate an otherwise imperceptible process. This visualization process is depicted in the dance by 'old man frost' – complete with white beard and black cloak – who repeatedly appears on the scene and shakes powdered snowflakes on the dancers, while another dancer moves into the frame to snap a photograph of the frozen dancers with a flash camera.

20. In a video interview accessible online, Max Perutz can be seen animating the mechanism of haemoglobin, demonstrating with delight the form and movements of the molecular structure as it captures and releases oxygen. See video interviews with Max Perutz online: 'Face to Face with Max Perutz', Vega Science Trust, URL (consulted April 2011): http://www.vega.org.uk/video/programme/1
21. See Myers (2006, forthcoming) for a discussion of the 'Inner Life of the Cell'. This animation employed character animators and state-of-the-art computer graphic animation systems. It was produced by Biovisions, a collaboration between Harvard University and the Howard Hughes Medical Institute Biological Sciences Multimedia Project. Currently clips of this video are widely circulated on YouTube. The original animation is available to view online; URL (consulted April 2011): http://www.studiodaily.com/main/technique/tprojects/6850.html
22. These are pseudonyms. The names of all the people I interviewed for this study have been changed.
23. On the theme of the seduction of simulations and computer graphic animations, see Turkle et al.'s (2005) report to the National Science Foundation, 'Information Technologies and Professional Identity: A Comparative Study of the Effects of Virtuality'. Turkle's *Simulation and its Discontents* (2009) builds largely on this report.
24. These media forms (filmic, computer graphic and embodied) are of course quite distinct from one another. For one thing, they afford different relations among modellers and their objects, instruments and data. For instance, time-lapse film is used to

capture static images of objects at equidistant points in time. When these still images are run in sequence forward in time they can produce a moving image that records the physical changes of an object or phenomenon (see for example, Landecker, 2005). Time-lapse can speed up or slow down a process to make change perceptible as movement (see Deleuze, 1986). Computer animations, on the other hand, don't always rely on the same kind of visual access to their objects. They have a different 'growth logic', one that sets algorithms in motion to direct movement (Kelty and Landecker, 2004).

25. Marcinku Khedzior (an architect, experimental musician and break dancer based in Toronto) has helped me to think through the elasticity of time (personal communication). He invokes the musical term 'tempo rubato'. Translated directly as 'stolen time', it indicates where a musician can play with the tempo of a musical score. Rather than thinking of it as 'robbed time', Khedzior treats rubato as a way of 'rubbing' or 'massaging time'. I'm interested in how such modes of rending and pulling at time allow a performer to rework and transform the flow of time, and so inflect the performance with their own affects. Dancers also experiment with the elasticity of time as they generate their own renderings of the tempos and rhythms of music.
26. On the function of 'shame' as an affect in pedagogical performance see Sedgwick (2003), Werry and O'Gorman (2007), and Myers (2010).
27. For example, Timothy Springer, a principal investigator at Harvard Medical School, commissioned a local Boston dance company, Snappy Dance Theatre, to choreograph and perform interactions among the molecules that he studies. He showed a video of the resulting choreography, 'Turning on Integrins', at a lecture in Sweden where he was receiving an award. His address to the Crafoord Society included a justification and explanation of the dance:

    > I am now facing one of the greatest challenges of my life – explaining what I do to a lay audience. I am not too good at doing this in words, so I am going to use movies, and even a modern dance, to bring the cells and molecules I work with to life. . . . I have collaborated on a modern dance in which two integrins are the stars.

Later in the lecture he narrates the choreography as it plays out on a screen, identifying each dancer as a specific molecule. The video from this choreography opens with highly skilled dancers holding placards to identify themselves as particular molecules. Two male dancers clad in white pants with bare chests and bald heads are the 'integrins'. Two, sprightly female dancers wearing glittery skin-coloured body suits with bare legs and little fairy-like wings are the 'activation signals'. A third female dancer, in a skimpy white dress with bare shoulders and sultry moves, is introduced as the 'ligand'. Springer narrates the scene with subtle sexual innuendos:

> We also see two activation signals, and a ligand, to which the integrins will stick when they get activated. . . . The ligand wants to adhere, but the integrins are not sufficiently aroused. Suddenly activation signals arrive on the scene, meaning something bad is happening offstage, like a blood vessel rupture or an infection. These signals travel through the blood and alert the cells. Now, the activation signals enter the cells, and excite the integrins to become interested in binding ligand. The integrins change into a different, highly active shape that is specialized for ligand binding. (Springer, 2004)

Other examples of scientific choreography can be found online. YouTube hosts a wide array of videos produced by science and medical students performing their own choreographies of biological and chemical phenomena. Some of these are posted as 'responses' to the 'Epic' protein synthesis re-enactment. Other uploaded videos include those that students have captured with their cell-phones as their science and math teachers dance key concepts in the classroom.

28. The dances submitted to the contest draw from a wide repertoire of familiar dance techniques, including jazz, Latin and modern dance. Highland dancing, Indian classical dance, belly dance, and tango have been featured among the winning dances. But many of these dance forms are often highly gendered and severely constrained. For example, many of the women scientists gravitate to the gendered idiom of classical ballet or expressive modern dance. They costume themselves in flowing skirts and choreograph highly feminized emotive gestures. There is

often a literalism to these choreographies that aims toward a direct communication of facts and phenomena. As such, they tend to lack the more sophistication of contemporary and experimental approaches to dance. For example, contemporary practitioners and theorists approach dance as more than a medium for communication or expression. They shift focus away from the epic narratives of classical ballet to consider dance forms that don't attempt to convey coherent stories or express feelings. See for example Foster (1996) and Kozel (2007).

29. Kohler's (1994) *Lords of the Fly* is a wonderful example of such a shifting perspective. Isabelle Stengers' (2010) 'cosmopolitical' concept of 'reciprocal capture' is evocative of the modes through which a scientist is also made captive by her own apparatus.
30. The history of life science abounds with the language of 'excitation', 'irritability' and 'sensitivity'. These are terms deployed in cell biology and neuroscience in the 19th century. In *Matter and Memory*, Bergson writes: 'living matter, even as a simple mass of protoplasm, is already irritable and contractile . . . it is open to the influence of external stimulation, and answers to it by mechanical, physical and chemical reactions' (1991: 28). See Gieson (1969) for a taste of the language of irritability and excitation in history of the protoplasmic theory of the cell and studies of muscle tissue.
31. For ways of thinking through the concept of transduction see Helmreich (2007). See Myers (2006) for more on the transduction and propagation of affects among protein modellers.
32. On affect see also Deleuze (1988), Massumi (2002), Stewart (2007), Manning (2009) and Featherstone (2010).
33. What ethnographic modes of attention would be needed to keep pace with dancing scientists? The Dance Your PhD contests provoked me to re-evaluate my ethnographic methods. My response was to launch a 365-day ethnographic methods research project on movement, affect and gesture (URL: http://adanceaday.wordpress.com). I used the form of a daily movement practice as an experimental medium for crafting new methods for anthropological research. In this project, I approached ethnography as a practice of learning how to move with and be moved by other moving bodies. The aim was to cultivate dexterities for sensing and transducing movement and affect through a variety of

media, including textual and graphic forms. The project hinged on refining techniques for recording movements and affects in the field using the most basic tools of pencil and paper to generate gestic diagrams and graphematic traces. Once tuned in to moving phenomena, this ethnographer could become a transducer in a field of affects (Myers, 2009b).

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