Bridging the gap between science and the humanities

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The early days

In the middle of my undergraduate tenure, I transferred into an engineering program that promised to blend technical problem solving skills with a broader humanistic awareness. Through small, discussion-based liberal arts courses and an engineering curriculum that emphasized application and real-world problem solving, the program intended to foster a social conscience in engineering students, avoiding the proficient-yet-unthinking automata supposedly churned out by technical universities. After all, talent is ultimately wasted if directed toward the unscrupulous ends of capitalists and defense companies—or so the thinking goes. I remember being deeply inspired by this interdisciplinary vision of education and citizenship. It was clear to me that an engineer without a social conscience was as likely to create problems as to solve them. I had been off social media for years at that point, realizing soon after trying it that this was an engineered technology that actually created the problem it claimed to solve. Here, the issue at hand was not a lack of technical proficiency, rather a misdirection of it. Yet, I thought that idle philosophical musing—pure as its intentions may be—was powerless on its own to seriously confront the world's problems. It made sense to me that the marriage of the technical and humanistic offered a way forward. Notably, I was comfortable with dividing the world into these two halves—on one side, there were scientific questions about force, energy, and motion. On the other, there were humanistic questions about people, values, and experience. I felt no pressure to close this rift.

I graduated college with enough social conscience to avoid the finance or defense industries but insufficient technical skills to do interesting work. My job required a fraction of my allotted 40 hours, and I used the remainder to continue the studies I had begun as an undergraduate. On the humanities side, I read literature, philosophy, religious and spiritual texts. I exercised my scientific thinking with statistics, machine learning, and solid mechanics. Gradually, the initial flickerings of tension between these two worlds began to appear. I saw that the boundary between them was more porous than I had imagined. Questions about guilt and justice could be influenced by ideas from dynamical systems in the setting of industrial safety [5]. Realistic decision-making tasks could be automated by solving optimization problems [2]. Thomas Kuhn showed me that understanding the content and evolution of science is unavoidably sociological [13]. I had always appreciated the beauty of math and physics, but I had never fully appreciated their *strangeness*. How could symbols on paper provide so much power to act in the world? How did we come up with this way of thinking about things? And if science was ultimately a human construct, what did it all mean? Were laws inventions—simply machines to perform calculations—or discoveries of nature's blueprints? The strangeness of science also pointed to its flexibility, to the fact that it was developed by particular people, at particular times, for particular reasons. If a model was nothing more than an "interpretative description of a phenomenon that facilitates access to that phenomenon" [1], what stopped them from being used to think about social problems? This suggested a complex exchange across the boundary dividing science and the humanities—a boundary which I had previously imagined to be impermeable. But if this boundary was fluid, in what exactly did it consist? Was there even a boundary at all? More concretely, why did the question *should I go to graduate school or find a new job?* appear of a different sort than *what is the maximum stress in a structure under two different loading configurations?* Both seemed to be questions about a response in two hypothetical scenarios, yet the latter was obviously scientific and the former felt unanswerably complex. Was there a way to explain this disparity, perhaps finding a larger framework inside which both sorts of questions fit?

Having found no mathematical model to make my choice for me, I rolled the dice and decided to go to graduate school. Alongside my engineering courses, I continued to read philosophy and literature. In particular, I developed a taste for the philosophy of science, as I found further deconstructing the divide between science and the humanities to be thrilling. Seeing how models and the "facts" they produce were social and political objects felt like a forbidden glimpse into the halls of power of our hard-nosed, technocratic society. I came to see the endless discussion of "evidence-based" this or "data-driven" that as techniques to conceal agendas which could not be rationally defended. Such appeal to the well-recognized authority of the scientific method was especially irksome in contexts which I saw as obviously outside the purview of science. Could you really make a scientific argument about the qualities of a good leader [3] or the veracity of a religion [20]? I had not mapped the contours of the science-humanities divide, but I had at this point an intuitive sense when one intruded on the other. And the more I learned about the humble origins of scientific models, the more concerned I became that quantitative approaches had been falsely advertised as the lingua franca of all truth-seekers.

Complexity science

I was first exposed to complexity science and the Santa Fe Institute (SFI) after reading Douglas Hofstadter's *Godel, Escher, Bach* [8]. I soon followed up with John Holland [9, 10], Stephen Wolfram [19], Harold Morowitz [14], and assorted online courses on Complexity Explorer. I admired the ability of complexity scientists to think as humanists, philosophers, and scientists all at once. Evidently, these were people who, like me, felt that the answers to interesting questions lied at the intersection of fields. Though my youthful commitment to "solving the world's problems" often wavered, I was steadfast in believing that the most imaginative work synthesized disparate ideas, rather than tunneling deeper into the minutia of existing ones. Freeman Dyson illustrated this sort of taste with the analogy of frogs and birds:

> Some mathematicians are birds, others are frogs. Birds fly high in the air and survey broad vistas of mathematics out to the far horizon. They delight in concepts that unify our thinking and bring together diverse problems from different parts of the landscape. Frogs live in the mud below and see only the flowers that grow nearby. They delight in the details of particular objects, and they solve problems one at a time [6].

Though by no means a mathematician, I definitely saw myself as a bird. I enjoyed my PhD course work, but I struggled to find research topics which I thought warranted serious time. I bounced from one thing to the next, learning as much as I could but never settling. I spent probably half my time on topics outside of engineering, and considered pursuing an MA in philosophy alongside my engineering PhD. At one point, I put together a final project for a class that I was auditing on the various means of talking about weather phenomena—from myth, to history, to statistics, to physics. True to my initial interest in integrating science and the humanities, I was intrigued that there were so many ways to talk about the same thing. I began to imagine how social problems—designing incentives in academia to maximize innovation, perhaps—might be translated into technical problems. This was especially true as I learned about control theory and model-constrained optimization in the context of engineering, topics with obvious political reverberations. I day-dreamed that the Santa Fe Institute offered a home for someone as broadly curious and unfocused as me. The first time I applied for the Complex Systems Summer School, I wrote in my application statement about grasping the structure of "wicked" problems with analogies from math and physics. Nonlinear dynamics opened up the possibility of deterministic chaos, high-dimensional problems required lossy compression to be tractable, optimizing systems required predictive models and their gradients, which the real world did not readily provide. To me, the pulling back of some complex real world problem to a mathematical one represented a genuine increase in understanding, even if it did not result in a solution. Doing so would at least reveal the structure of the problem, showing clearly why it was so hard to solve. I did not get in to the program that summer. I was probably not ready, anyway.

I had begun to understand that some social problems genuinely resembled technical ones. I also felt that I came to conclusions about what laws and explanations in science were. A law was simply a compressed representation of data. The more profound the law, the more circumstances in which it could be used. Often, the law required some massaging to apply to the problem of interest. Conservation of energy can be used to determine the speed of a ball rolling downhill, and also to predict the evolution of temperature in a heated body. It acts as a "zipping up" of all data on these systems, but non-trivial work is required in the unzipping. In particular, the discipline of continuum mechanics is simply the application of energy and momentum conservation to matter. It develops elaborate theoretical machinery to unzip fundamental laws to produce data on the thermal and mechanical behavior of solids and fluids. Along these lines, scientific explanations consists in showing how disparate phenomena are all the consequence of a small set of known laws. This is Kitcher's concept of unification in science [12]. An explanation is simply the act of unzipping the law to produce data. The governing partial differential equations of solid mechanics are "explained" by showing them to be consequences of momentum conservation. Fundamental Laws themselves are not explained, they are empirical observations of certain kinds of regularity in the universe. With these ideas in mind, understanding became a matter of pulling phenomena back to fundamentals. The science-humanities tension then boiled down to the following question: could scientific and humanistic discourses be pulled back to something more fundamental than either of them? If the heat equation and the square root dependence of the rolling velocity were both consequences of energy conservation, could an analogous statement be made about these two ways of understanding the world?

I think it is fair to say that—roughly speaking—the humanities talk about minds, and science talks about matter. In other words, they each treat separate aspects of the world, and evidently use different methods to do so. The concept of emergence first illustrated to me that the laws a system appeared to obey depended on the perspective from which it was viewed. The canonical example is statistical mechanics, which shows that a collection of gas particles can be random at the level of position/momentum microstates, yet rule-bound at the level temperature/pressure/volume microstates. Similarly, a computer follows certain rules at the level of file directories, yet this behavior emerges entirely from electromagnetic microphysics that knows nothing of files or folders. Such examples begin to sketch how mind and matter need not be ontologically distinct, though of course no one has succeeded in making the journey between the two. Thus, emergence further closed the gap between science and the humanities. Realistically, my questions were simpler than this. For me, it was not necessary to argue that mind could be reduced to matter. I primarily wanted to know why we have such different ways of talking about the two phenomena. Why did physics exclusively rely on mathematical models, and the humanities rely on natural language? Why were there laws of physics, but not laws of social systems?

Having arrived

I applied to the summer school again the following year, this time offering a clearer vision of how complexity science fit into my academic trajectory. In my statement, I had more to say about the connections between emergence and so-called "multiscale" problems in engineering mechanics, but mostly I talked about complexity as a bridge between philosophy and engineering. I saw a need for establishing stronger connections between these disciplines in a world where the social and political dimensions of technology are unmistakable. That year, I had participated in an engineering ethics seminar and a philosophy of technology reading group, and I felt that studying complex systems would show that the ethical and technical dimensions of engineering could be integrated. I was put on the wait list for the summer program, an improvement over the previous year's performance, though an outcome I still considered a defeat. This was frustrating, given that I was carrying out my PhD in accordance with principles that I thought SFI would recognize. To my surprise, I received an email many weeks later, indicating that I had been admitted to the program. In the lead up to that summer, I packed my mind full of all the nifty nonlinear dynamical systems I could find, emotionally prepared myself to not be the smartest person in the room, and set off south to New Mexico.

I started a set of notes specifically devoted to the summer school. The first entry reads: "Day 1: I have the feeling that this is the first place I have ever belonged." I was immediately blown away by how interesting everyone was. How excited they were to talk about ideas. How fluently they switched between technical and philosophical topics. I had never encountered so many people like this in one place—and this was not for lack of trying, believe me. Notes from the first week are filled with entries on model construction, intelligence, coarse-graining, etc. I quickly found the physics people and picked their brains about thermodynamics and renormalization. Furthermore, I wanted to know what topics the probability aficionados were working on.

Personally, I shared on partial differential equations, scientific machine learning, the philosophy of science, and some neat examples I had accumulated over the years of coarse-graining in mechanics. Our cohort enjoyed lectures on information theory, dynamical systems, fractals, network science, artificial intelligence, computational linguistics, mathematical biology, and so on. All of this was very stimulating, and very exhausting.

A week of frenzied discussion of technical questions and a more-or-less constant stream of similarly themed lectures marked an inflection point for me in the program. I felt that the exposure to new topics was beneficial, but if I really wanted to learn about dynamics on networks, Kadanoff block renormalization, or Bayesian inference, I would just need to sit down and do it. Talking about it only took you so far. Furthermore, I started to get the sense that much of the ongoing work at SFI centered on finding new applications for the existing tools of computational science. Though network models of epidemics and dynamical system approaches to ecology were interesting to me, this was but a stone's throw from my "day job" of numerically solving partial differential equations. Plus, I worried that mathematizing rich social and ecological phenomena risked flattening them beyond recognition. I longed to think about something more speculative, and ultimately more human. What emerged to replace mania about technical matters was the question I had now been circling around for years: *how did science relate to other ways of knowing?* In response to the call for group project proposals, I rallied my usual contrarian spirit and set forth the topic "science & spirituality." While the title was perhaps needlessly iconoclastic, it garnered some interest from others who were similarly keen on discussing something other than mathematical models—a group had formed.

After a day or two of nervousness that nothing concrete could come out of this topic, we settled in on recording open-ended conversations with students and faculty about the limitations of science. The title of our project—revealed to the prospective interviewee when scheduling a time to talk—initially put many of the faculty in a defensive position. They probably thought that some new-age crackpots had slipped through the walls of SFI. I quickly learned that the word "spirituality" often has unsavory connotations for the science-inclined. In hindsight, something like "science & other ways of knowing" would have been less controversial while remaining mostly aligned with our intentions. But spirituality had no baggage for me, and I am not sure there is a better word for the exact set of questions it points at. The humanities may study minds, but often in a dispassionate way. Spirituality, on the other hand, has a clear normative dimension. To use a phrase from David Krakauer and Toby Eagan, it concerns itself with what is "good, true, and beautiful." Spirituality takes subjective experience to be a serious object of study. And, as the Buddhists are fond of saying, seeing experience clearly naturally leads to prescriptions for how one ought to act [17]. As much as I wanted to map the science/humanities boundary, I was also not opposed to some guidance on how to move through the world. If science had something to say about this, great. If not, that seemed worthwhile to know. Either way, our topic explored the boundary between the quantitative and qualitative. So we stuck with spirituality, despite the apologetics it often required.

The beginnings of an answer

Once we got talking, any initial suspicions the interviewee had about quackery on our part subsided. It was clear that our interest in the limitations of science was curious, open-minded, and sober. These conversations took on an intimate tone, which was refreshing in contrast to the usual circumspection of academics talking about technical matters. It was gratifying to see researchers roll up their sleeves a bit, feeling free to share on personal opinions, beliefs, and experiences that inform their work. In total, we interviewed Brandon Ogbunu, David Krakauer, Melanie Mitchell, Cris Moore, David Feldman, Mary O'Connor, Thalia Wheatley, Toby Eagan, Ted Chiang, Marina Dubova, Simon DeDeo, Jacob Foster, and Sean Carroll. For me, these conversations were energizing, as it felt that we were getting at questions that were on everyone's mind, but that no one had had permission to talk about. *What can we know? What does knowing consist of? What does science leave out? Why does this matter?* It was an incredible luxury to spend weeks among a diverse group of intelligent people discussing these topics, free from the stifling pressures of most of our home environments.

Personally, the three salient takeaways from the discussions and the personal reflections that accompanied them were the following: 1) regularity is what makes knowledge possible, 2) different languages are required for different kinds of regularity, 3) science should be seen not as a static collection of beliefs, but rather as a dynamic approach to knowledge generation. I will expand upon each of these points below. I am sure there is an extensive literature on each of these topics. I have probably read some of it, but I do not care to read more of at this time. The following are the conclusions I have come to personally. One can read endlessly—it becomes so tiresome. There comes a time when you must trust that you can figure some things out on your own. To my group members: if the following feels like a disenchantment of the wonderful world of particularity and mystery we encountered, this is not intentional. For better or worse, the analytical version of me still has the upper hand.

Regularity: There are two types of understanding: descriptive and predictive. A phenomenon of interest is well-described when its state can be approximately or exactly specified with a small number of descriptors. The nature of a state is context-specific and usually ambiguous. The state of a gas is the position and momenta of the molecules. The state of the government may have something to do with what elected officials throughout the country are up to, or perhaps the motion through phase space of the particles they comprise. A mental state is the collection of beliefs, attitudes, ideas, stories, and feelings which are currently top of mind. A description of each of these states is informative when the state can be compressed with minimal loss of relevant information. There are many states of a gas that correspond to "hot," but the differences between them are irrelevant. There are many ways for the government to be considered "shut down," but the differences are irrelevant if the only thing you care about is whether the trash is taken away at a national park (for example). Furthermore, there are a multiplicity of mental states which correspond to "frustrated," but this descriptor still provides some useful insight to a sympathetic friend. As such, these are informative descriptions. Descriptions are possible when systems repeatedly visit "macrostates," by which I mean a collection of microstates that share a property of interest. I can effectively describe my moods with words like "frustrated," "excited," or "bored" because these words summarize more fine-grained mental states, and these mental microstates with equivalent summaries recur often. But, to be clear, there are many ways to be frustrated or bored. A system must be regular in the sense that it tends to visit only a small number of macrostates in order to admit compressed descriptions. Otherwise, the dictionary of descriptors of macrostates would be just as unwieldy as specifying microstates. As Confucius said: "the beginning of wisdom is calling things by their proper name." Recognizing regularity and supplying descriptors for recurring macrostates is descriptive understanding.

Predictive understanding is obtained when descriptors of a system can be evolved in time. Having a good description of a system does not suffice to predict its dynamics, though it is a prerequisite. I can *describe* a gas with pressure, volume, and temperature, without knowing anything how they are related. I can *describe* mental states without understanding how they interact with one another and the outside world. The possibility of prediction arises not just from regularity in the macrostates that are visited, but in their time dynamics. When one macrostate tends to precede another, one can use the former to predict the latter. Descriptions are possible when a system preferentially visits certain regions of its phase space, prediction is possible when such movement through phase space has non-random structure. These are two different kinds of regularity. Knowing about a system consists in being able to describe it and in using these descriptions to make predictions.

Plurality of languages: As the examples of governments and mental states already suggest, descriptions and predictions need not be quantitative. Mental states are described with natural language to much avail, as are states of the government ("shut down," "democratic," "fascist," etc.). After all, numbers and words are both just symbols used by humans to represent states of affairs in the world. I could encode natural language descriptions in numbers by defining a codebook mapping words and punctuation to numbers. I suppose this requires some additional information theoretic properties like uniquely decodability, but this is besides the point. Quantitative descriptions shine when states are continuous (position $\mathbf{x}$ of a particle) and when the system has sufficient regularity to make precise predictions ($\mathbf{F} = m\ddot{\mathbf{x}}$). The majority of examples of systems which permit precise quantitative predictions come from physics. *This is because physics deals with the simplest things in the universe.* For example, few things are so easily described and predicted as the motion of planets exerting gravitational forces on one another. The planets can be treated as point masses, so each of their positions is described by three numbers. The system is insensitive to all happenings in the universe except for forces. The planets' color, temperature, and chemical composition are all unimportant. The dynamics are independent of the history of their motion. Their motion obeys a simple and exceptionless mathematical rule. It really does not get any simpler than this!

Contrast orbital mechanics with the dynamics of mental states. There is no small set of numbers I can use to locate myself in the space of "mental states." It is tricky business even positioning a given mental state on a spectrum. It is not clear what it means to be 3 out of 10 frustrated. This is definitely not straightforward to measure. Unlike the insensitivity of the planets' to their context, mental states are influenced by any and all sensory data—the weather you observe through the window upon waking up, the temperature of your room, new emails in your inbox, how much gas is in your car, the content of the daily news, the day of the week, and so on. Furthermore, occurrences from long ago are stored in memory, and may play causal roles in conditioning mental states as much as real-time sensory data. Therapists will surely agree that the way in which your parent responded when you scored a goal in a soccer game in kindergarten may be just as relevant to determining the dynamics of your daily frustration as the actual events of the day. This immense sensitivity to the environment and history suggests that mental states are a very different kind of system than the orbiting planets, which stupidly continue on in their motion, oblivious to anything but net forces.

While quantitative descriptions are appropriate for simple physical systems, natural language seems better-suited to capture the richness of systems involving minds. Minds exhibit significantly more complex kinds of regularity than physical systems. Though the social world would be completely unintelligible to us if there were no regularity, it is not the sort that quantitative models handle well. Consider an example: you walk into a coffee shop and the barista smiles at you.... *What just happened?* Suppose that you have been developing a very sophisticated probabilistic model of human behavior for the purposes of avoiding embarrassment and rejection. You are curious about this barista, but unsure of how to proceed. Numbers were invented to ease the deeply human fear of uncertainty and losing control, after all [15]. Accordingly, you query your model:

$$P(\text{attraction}|\text{smile}) = 0.9$$

This is really good news! But wait, things are not so simple. Consider the fact that you smiled first. Maybe this response was just an attempt to be polite? Your model query is updated to read

$$P(\text{attraction}|\text{smile}, \text{you smiled first}) = 0.75$$

Things are still looking pretty good. But note that an infectiously catchy song just come on at the coffee shop. Perhaps this plays some role in explaining the smile? Thankfully, the model can handle this nuance. It now predicts

$$P(\text{attraction}|\text{smile}, \text{you smiled first}, \text{catchy song}) = 0.70$$

Fortunately, the confounding variable of the catchy song doesn't change your odds too much. What about the fact that, after an especially long bout of cold and rain, the weather today is quite warm and sunny? Everyone seems to be smiling, come to think of it. Also, you happen to be wearing a silly T-shirt (it is a picture of cartoon goose with no text). Maybe this is relevant? Upon further reflection, it is not 100% clear that the smile was even directed at you. Furthermore, this particular barista might smile all the time. In fact, the coffee shop may even instruct the employees to smile in an attempt to cultivate a warm and welcoming customer experience. Plus, there was some potentially lively banter among other employees behind the bar which could account for the smile. Your model query is now

$$\begin{gathered}P(\text{attraction}|\text{smile}, \text{you smiled first}, \text{catchy song}, \text{nice weather}, \text{goose shirt},\\ \text{uncertain recipient}, \text{chronic smiler}, \text{employer-enforced smiling}, \text{mid-banter})\end{gathered}$$

This can go on and on, ad infinitum. Forget the preposterously large amount of data required to calibrate a model of this sort, which already disqualifies it as viable. If we are honest, we have no idea when to stop conditioning the model on additional variables. The barista themself may not know why they smiled. Even if it could be built, a mathematical model of this sort would be mind-bogglingly complex. Furthermore, such a model would necessarily be probabilistic. I don't believe that human behavior could be predicted deterministically in even the most circumscribed situations, let alone "out in the wild." So despite its complexity, such a model would not provide certainty. If you are a gambler or advertiser, perhaps fine-grained knowledge of probabilities of social outcomes is a boon, but for most of us, outsourcing our choices to a gargantuan computational model seems like a hefty price to pay for probably marginal improvements. Plus, we already have amazingly fine-tuned instinctual machinery for reading and interpreting social situations of exactly this sort. I suspect its a lot easier to use natural language and gut feelings than quantitative models to navigate these situations. In short: quantitative methods work well to talk about systems with very simple regularities. Systems which have simple regularities are insensitive to context and history. Most systems involving minds do not respect these two properties. For these, we use qualitative methods and our own intuitive machinery, which has evolved to identify and interpret the relevant features of social situations. We can share about experience through conversation, stories, and art. These media have unique abilities to store and transmit information about human experience.

Unlike the states of physical systems, experiences of the world are difficult to compress. In my thinking, recurring experiences are given words (frustration, excitement, boredom, jealousy, relaxation, etc.). This allows us to pretty effectively report on our journey through life. But this journey would be pretty drab if it did not allow for complex mixtures of these basic named experiences. We turn to linear algebra to make some sense of such combinations, and their connection to incompressibility and art. We think of these named mental states as basis vectors. The set of experiences we can describe with our basis is given by

$$\text{span}\Big\{\text{frustration}, \text{excitement}, \text{boredom}, \dots\Big\}$$

I suspect one function of good art is to introduce us to experiences which are difficult to describe in our existing basis of mental states. For example, the most recent novel I read is *Stoner* by John Williams. In it, the author paints the picture of a humble farm boy turned mediocre academic who persists in a loveless marriage but ultimately finds peace [18]. The reader feels pity for Stoner's hardships, but also admiration of his acceptance of them. Good novels leave us feeling that we lack the conceptual tools to make sense of the experience they provided. Call the experience of reading Stoner a vector $\mathbf{s}$ and our basis of concepts $\{\hat{\mathbf{v}}_i\}_{i=1}^N$. If the book is interesting and/or surprising in some way, we probably have that

$$\mathbf{s} = \sum_{i=1}^{N} (\mathbf{s} \cdot \hat{\mathbf{v}}_i)\hat{\mathbf{v}}_i + \mathbf{e}_\perp$$

where $\mathbf{e}_\perp$ is an "error vector" orthogonal to the space spanned by the basis of states. This measures the extent to which the experience of the novel cannot be explained by experiences that we have currently named. There is really no simpler way to get an understanding of $\mathbf{e}_\perp$ without having an experience similar to that of *Stoner* or reading the book in its entirety. While everyone is guaranteed to encounter frustration, excitement, and boredom in their life, the emotional experience of a novel is often more complex and exotic. The only reason that compressing mental states with words succeeds is because we can agree on what they mean. Put differently, our life directly provides knowledge of how to "decode" words to their corresponding internal states (or distributions of internal states). The Stoner state $\mathbf{s}$ is incompressible in the sense that there is no simpler description of it than the book itself. However, once we are familiar with the book, we can name the experience, perhaps using it as a basis for future descriptions. We might augment our basis set with $\mathbf{v}_{N+1} = \mathbf{e}_\perp$. This is what happens when we use analogies to characters in novels and movies to make sense of our own lives.

Science as process: The last takeaway from the project was that science is not a static entity. The collection of all published research is not science. Science is the process by which this knowledge is generated. To be fair, philosophers of science have debated the reality of the scientific method. Chief among which is Paul Feyerabend, famous for his provocative claim that "anything goes," meaning that there is nothing standardized about how scientists conduct research [7]. This is a bit extreme—there is obviously something unique about the scientific approach to knowledge generation, even if it is not algorithmic. Compared to religious belief, science adapts to new data more effectively. Though imperfectly realized, this efficacy comes from the scientific ideal of comparing predictions to the outside world. To me, the scientific process is a bizarre two step process of descent into Feyerabend's dream world of intuition, aesthetics, metaphysical commitments, and irrationality, followed by a reemergence into the physical world of experiments and measurements. The dreams need to cash out in something practical that can be replicated by others. Perhaps this latter stage demarcates a scientific approach to knowledge. But if science is a process, it can be applied to any question one has. Thus, I can be scientific about spirituality. I have some dreams, I generate some hunches about how to live life, and I try them out. Religious or spiritual authority of texts or teachers is not recognized in the "scientific" view, as the source of authority is the "outside world," which here means one's own experience. If a certain strategy works to accomplish your goals, it is valid. In the words of William James:

> In the history of Christian mysticism the problem how to discriminate between such messages and experiences as were really divine miracles . . . has always been a difficult one to solve, needing all the sagacity and experience of the best directors of conscience. In the end it had to come to our empiricist criterion: By their fruits ye shall know them, not by their roots [11].

One can adopt a scientific attitude to aspects of life which are not cast in the language of math. In my account, science and the humanities differ not in their fundamental approach to knowledge generation, but only in the language they use to report their findings.

Conclusion

I was inspired to write this long-winded intellectual history to eulogize my interest in the science/humanities question. Given that I have not worried about the question much since the summer school, I suspect that I feel satisfied with the understanding I have built up. My understanding is simply this: there is no fundamental difference between science and the humanities. Both try to understand the world. Understanding requires talking about the world. Saying anything sensible requires regularity. Quantitative models are good for the simple stuff. Natural language is as good as we can do for the rest. Applying quantitative models to complex phenomena risks distorting such phenomena beyond recognition. When this happens, we end up talking more about the properties of the model than the behavior of the phenomenon itself. Sometimes we discover new ways to quantify, and this brings about a transition from natural language to quantitative descriptions. A clear-headed approach to knowledge acquisition is epistemological pluralism. Any and all strategies are fair game, but depending on the problem, some may be more useful than others. If you are lucky, the weakness of one strategy is the strength of another. In *The Big Picture*, Sean Carroll summarizes his philosophy of poetic naturalism with three tenets: 1) there are many ways of talking about the world, 2) all good ways of talking must be consistent with one another and with the world, and 3) our purposes in the moment determine the best way of talking [4]. This summarizes my personal conclusions pretty well, though it is not clear how to verify that different ways of talking are consistent with one another. Religious creation stories often conflict with scientific accounts of the Universe's early days—in this case, the inconsistency is plain to see. But things are less clear-cut in the case of spiritual questions. Are Jung's archetypes consistent with biology? Are mystical experiences of Truth and Beauty consistent with the picture of an indifferent physical world painted by particle physics? I don't think anyone knows the answers to these questions at this time. So maybe we opt to wave the emergence wand, saying that the "is" of microphysics provides a rich enough substrate to support the "ought" we often feel when turning our attention inward to experience. By abandoning the pipe dream of mathematical precision, a scientific approach to spirituality finds something infinitely more vast, working empirically with experience in its own terms.

Postscript: on studying minds

I am always curious what the state of brain research is—not that I really know anything about it. The brain is the ur-complex system, so naturally it came up at SFI. We had some lectures from researchers working on the brain, and there were plenty of summer school students from cognitive and neuro-science. I didn't get the impression that anyone was close to cracking the consciousness question. I heard a lot of "X part of the brain lights up when you do Y, which might mean something!" One book that had been repeatedly recommended to me was Anil Seth's *Being You*. I bought this after returning from SFI, wondering if it might make progress on the consciousness question sound more exciting to me. This was not the effect. The book begins with grandiose claims about a breakthrough new paradigm for understanding consciousness, then talks about a vague connection to Bayes Theorem as tool to understand perception for the remaining 300 pages [16]. The conclusion that I have come to is that the best way to learn about the brain—in the particular way that I am most interested in knowing about it, to be clear—is through contemplative practice. In one's own mind, all the cognitive biases, energy-saving heuristics, and perceptual distortions are on full display, with no need for expensive scanning machines. Plus, you might learn something about how to live your life.

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