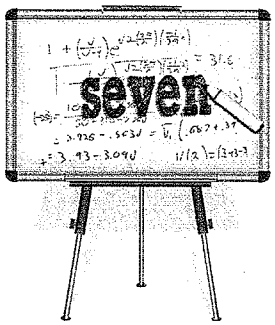

GETTING FUNDAMENTAL ABOUT DOING PHYSICS IN *THE BIG BANG*

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> You tell people I'm a rocket scientist?! . . . I'm a theoretical physicist! . . . My God! Why don't you just tell them I'm a toll-taker at the Golden Gate Bridge! Rocket scientist! How humiliating!
>
> —Sheldon Cooper, Ph.D.,
> "The Pork Chop Indeterminacy"

As a theoretical physicist, Sheldon considers himself above getting his hands dirty to experimentally validate his work—unless it's dirt from the residue of a dry-erase marker. He scoffs at the more applied work of Leonard and Raj, and he finds Howard beneath contempt, a lowly oompa-loompa of science. Still, Sheldon values engineers over social scientists.

Brain researcher Dr. Beverly Hofstadter echoes Sheldon's sentiments on the hierarchy of knowledge, when she explains that she and her cultural anthropologist husband once did papers on the same topic, and hers was the only one worth reading. And oh, the humanities! They simply do not deserve funding.

Scientism is the view that the scientific project occupies a privileged position among human endeavors, and *fundamentalist scientism*, the more specific position that Sheldon often expresses, is the view that all human endeavors form a kind of inverted pyramid, with fundamental physics as the load-bearing point on which everything else rests. Science, in this view, is the most important thing that humans have ever done, and fundamental physics is the most important part of science, justifying Sheldon's "haughty derision" of other disciplines.

Although *fundamentalist scientism* is tempting, it can and probably should be resisted without doing any damage to the structure of the scientific project. If only Sheldon could see this, he would be able to deal better with Amy, Leonard, Raj, and even Howard.

Studies in Sheldonology

In what sense is fundamental physics *fundamental*? In "The Codpiece Topology," Sheldon and his nemesis Leslie Winkle argue over whether string theory or loop quantum gravity theory is correct. What, exactly, are they fighting about? On one level, they're arguing over who is the bigger "dumbass," but on a deeper level, they're arguing about which theory best describes the world as it actually is. Regardless of whether Sheldon or Leslie has the better of that debate, we cannot overlook the fact that these two scientists have the same goal.

That goal, not surprisingly, is tied to what scientists do. On a very general level, scientists make predictions about the world, specifically about how it behaves. Sheldon predicts the existence of magnetic monopoles. Leslie predicts that

there are minute differences in the speed of light for different colors. Leonard predicts the existence of "supersolids," a previously unknown state of matter, at temperatures approaching absolute zero. Amy predicts that if she maps Penny's brain as she cries, she can make a monkey cry by exciting similar brain regions. Arguably, the deeper goal of science is to make predictions about what's going to happen in the world from *any* one moment to the next—to make predictions about how the world changes over time. Eventually, debates over which predictions most accurately describe the world will become rather general and abstract. So, we begin to see the nature of the debate between Sheldon and Leslie. In the most general, abstract, and fundamental sense, does the string theorist or the loop quantum gravity theorist make better predictions about the world and its behavior?

To better appreciate how scientists go about making their predictions, let's invent a novel field of scientific inquiry: "Sheldonology." Clearly, Leonard, Howard, and Raj are the leading experts—thus transforming Howard from an oompa-loompa to a "Willy Wonka" of science! Sheldonologists deal with the study and prediction of Sheldon's deeply unusual behavior; they specialize in predicting what Sheldon is going to do from one moment to another—where he's going to go, what he's going to say, what he's going to have for dinner, where he's going to sit, and so on. So, how might Sheldonologists go about achieving this goal?

Any aspiring Sheldonologist (such as Penny) will immediately note that her subject of study is—putting it rather mildly—a creature of habit: Sheldon has very particular routines and invariably becomes "disquieted" when those routines are disturbed. This fact is incredibly useful for Sheldonologists because it means that his behavior is consistently nonrandom; their job of *predicting* what he's going to do is made easier in virtue of this fact. Consider, for instance, that for every location where he spends any amount of time, Sheldon seems to

have a particular "spot" where he prefers to sit, and he gets rather upset if he can't sit there: call this the *Sheldon Parking Principle* (SPP). In his and Leonard's apartment, Sheldon's spot is the edge of the couch. Given the SPP, we can make fairly reliable predictions about Sheldon's behavior across a wide variety of circumstances. For example, we know (with a high degree of certainty) that if a newcomer to the apartment sits on Sheldon's preferred cushion, Sheldon will ask him (or her) to move. This explains Leonard's warning to Penny in the pilot episode not to sit on the right end of the couch. Penny is a quick study, and in "The Gorilla Experiment," she shares her knowledge with Bernadette during her first visit. When Bernadette asks why Sheldon can't sit somewhere else, Penny articulates the SPP in great detail:

> Oh no, no, you see, in the winter, that seat is close enough to the radiator so that he's warm, yet not so close that he sweats. In the summer, it's directly in the path of a cross-breeze created by opening windows there and there. It faces the television at an angle that isn't direct, so he can still talk to everybody, yet not so wide that the picture looks distorted.[1]

Sheldon, mildly surprised, nods in approval, saying, "Perhaps there's hope for you after all."

With the SPP in hand, Sheldonologists can predict Sheldon's behavior in a wide variety of novel circumstances. They know that if there's some sort of *damage* to that spot—such as that caused by Penny (or anyone, really) accidentally firing a paintball gun at the cushion—Sheldon will be unable to comfortably sit *anywhere* in the apartment. Moreover, the SPP allows for predictions across a range of *unobserved* or *hypothetical* circumstances. When Sheldon first visits Penny's apartment in "The Tangerine Factor," he spends a long time deliberating about where to sit (outlining the SPP again to a bemused Penny—no wonder she learned it so well). Once he makes

this decision, the SPP allows even amateur Sheldonologists to predict with very high confidence that he will return to that spot every time he visits Penny's apartment (which he does, of course). Generalizing on this instance allows us to predict that Sheldon would behave similarly in any new locale. In fact, if we think about it, we can tell a great deal about how the Sheldon-containing parts of the world are going to change from one moment to the next, given the SPP and a very small amount of information about the world (where Sheldon sits the first time he visits a location).

Of course, Sheldonology includes much more than just the SPP. In "The Cooper-Nowitzki Theorem," for example, Sheldon outlines his eating schedule day by day, explaining that he rotates through seven dinners from seven restaurants, one for each day of the week. Given this piece of information and an arbitrary date, Sheldonologists can predict (with great confidence!) what Sheldon will have for dinner on a given day. There are many other predictable scenarios as well: what happens when he attempts to drive a car, when he gets sick, and when he interacts with his mother. All predictions would be grounded in the observation that there are very stable patterns to be identified in Sheldon's behavior. So, the business of Sheldonology consists of three tasks: observing regions of the world that contain Sheldon, identifying patterns in how those regions change over time, and using those patterns to predict how *other* Sheldon-containing regions might change in various circumstances. This goes a long way toward describing how nonimaginary scientists do science.

A Unified Theory of Sheldon?

Penny's description of the mechanics behind the SPP might seem to appeal to general psychological principles. Yet Sheldonologists are not psychologists specializing in Sheldon's unusual mind or trying to divine the underlying psychological *reasons* for his

behavior. They're more like physicists. For Sheldonologists, then, Sheldon exists as a kind of basic atomic unit or particle. That's not to say that he's small or round or looks like a billiard ball, but only that he's an unanalyzed object in Sheldonologist theory, just as (say) electrons are in particle physics or *strings* are in Sheldon's own field of string theory. That is, Sheldonologists aren't concerned with what's going on inside Sheldon's mind as he makes his way through his day. Rather, they treat him as a *simple*—as an atomic unit—and just try to discern patterns in his (outward) behavior.

This insight begins to capture another important aspect of doing science: it is conducted in distinct domains. Think of the common experiment, conducted in many elementary school classrooms, to determine whether sugar cubes dissolve more quickly in warm or cold water. Here the basic atomic unit is the sugar cube, and water temperature is the variable. This is akin to Sheldonologists studying Sheldon in a new locale in which he sits. After some experimentation, fledgling scientists will be able to make reliable predictions about sugar cubes in water and Sheldon in new places. So, there are "sugarologists" and "Sheldonologists," and these represent distinct fields of inquiry. Distinct fields of scientific inquiry are often called the "special sciences" because each attempts predictions only about its subject matter (that is, *especially* about its topic).

Yet we could ask: what is going on inside sugar cubes or Sheldon that explains their respective behaviors? The former requires us to (rather literally) dig deeper into the nature of sugar. The latter requires us to (more metaphorically) dig deeper into Sheldon. Consequently, we no longer take sugar cubes or Sheldon as a basic unit; we begin to analyze our subject more deeply. This might occur to us once we have learned a great deal from our "sugarology" or "Sheldonology" endeavors. What explains why sugar dissolves the way it does? What explains why Sheldon acts the way he does? This, in turn, suggests that there is a scientific mode of inquiry that is more

fundamental than "sugarology" or "Sheldonology" because it provides deeper or more profound information about the subject matter. This subsequent level of scientific inquiry—the next special science—would be more fundamental to explaining its subject matter. It seems "sugarologists" will eventually reach the special science of chemistry. Chemistry presumably can explain everything sugarologists study, but not vice versa. This is another way to understand how it is more fundamental, but also explains why scientists would probably say that chemistry is theoretically more general than "sugarology." It's tempting to argue that the special science of physics is more fundamental than chemistry. If so, then physics can explain everything chemistry can, but not vice versa. This explains why some scientists hold that physics is more general than chemistry; its scope includes more than only chemistry. Clearly, the most fundamental of the special sciences would also be the most general; its scope would include everything.

What about Sheldon, though? Where is the next stop for Sheldonologists? Some scholars might contend it's sociology or anthropology. From there, it's a short step to psychology. Yet if Dr. Beverly Hofstadter is correct, neurobiology is more fundamental to cognitive systems than is psychology. If so, then neurobiology explains everything psychology does but not vice versa. This makes neurobiology more general, because its scope includes more than only psychology. Amy Farrah Fowler would no doubt agree. But is there a field of inquiry about Sheldon (or anyone, I suppose) more fundamental than neurobiology? Biology, perhaps? It's tempting to argue that just as physics is more fundamental than chemistry, it is also more fundamental than neurobiology or biology. Sheldon Cooper (and Leslie Winkle) would agree. Sheldon holds that because the world is made of matter, physics is the most fundamental of the special sciences, and whatever is the most fundamental to physics would explain everything. In "The Zazzy Substitution," however, Amy staunchly disagrees with

Sheldon's assessment, signaling one of the more memorable "non-breakups" in sitcom history.

> Amy: Absolutely not. My colleagues and I are mapping the neurological substrates that subserve global information processing, which is required for all cognitive reasoning, including scientific inquiry, making my research *ipso facto* prior in the *ordo cognoscendi.* That means it's better than his research, and [to everyone else at the table] by extension, of course, yours.
> Sheldon: Excuse me, but a grand unified theory, insofar as it explains everything, will *ipso facto* explain neurobiology.
> Amy: Yes, but if I'm successful, I will be able to map and reproduce your thought processes in deriving a grand unified theory, and therefore, subsume your conclusions under my paradigm.

Sheldon accuses her of "rank pyschologism," and they nonacrimoniously agree to "terminate their non-relationship immediately," which mysteriously occasions Sheldon's becoming a cat lover.

In any event, Sheldon's quarrel with Amy harkens back to his spat with Leslie: what mode of scientific inquiry is most fundamental to understanding the world in terms of predicting its behavior from one moment to the next? Sheldon and Leslie agree that it's (fundamental) physics but disagree about which specific theory it is. Amy, though, disagrees with Sheldon, arguing that theoretical physics—even in its attempt at a grand unified theory—is not fundamental in the way Sheldon believes.

Resolving a "Nonlovers" Quarrel (about Science)

Fundamental physics is the enterprise of identifying patterns that will predict the evolution of *any* system we might choose to consider, from Sheldons to dolphins, stars, cloned Leonard

Nimoys, check-engine lights, distant planets, subatomic particles, or "sweaty" stuffed animals (and, by extension, "whores of Omaha"). If successful, a grand unified theory would be fantastically important. No wonder Sheldon believes that there is a Nobel Prize in his future.

In his fight with Amy, Sheldon quite rightly notes that "a grand unified theory, insofar as it explains everything, will *ipso facto* explain neurobiology." There's a rather large nugget of truth here: Sheldon is certainly right that any system that can be studied by neurobiologists—any *cognitive* system—will also be subject to study by fundamental physicists. Any *patterns* identified by neurobiologists will *by definition* be patterns in systems that fundamental physicists are also concerned with; a grand unified theory is neither very grand nor much unified if it has nothing to say about (for instance) the human brain.

It's worth considering this point in greater detail, because this gets at the heart of the question we're concerned with: is Sheldon's arrogant attitude toward other modes of inquiry justified or not? Let's think more carefully about Amy's claim that if her research pans out, she will "be able to map and reproduce your thought processes in deriving a grand unified theory, and therefore, subsume your conclusions under my paradigm." Although Sheldon dismisses this as "rank psychologism," there's surely something to Amy's claim. If she succeeds in discerning *all* of the patterns underlying brains, then, given enough information about the state of a brain-containing system at a particular time, she should be able to predict what that system will be doing at a later time, right? We know, for instance, that Leonard's mother (also a neuroscientist) has a detailed scan of Sheldon's brain on hand from their "date" with the CAT scanner in "The Maternal Capacitance"; might not Amy and the elder Dr. Hofstadter put their heads together (no pun intended), figure out how brains work in general, and then predict every thought (about physics and otherwise) that Sheldon will have in the future?

Perhaps, but it's worth asking what they will have accomplished if they succeed at this task. Would a success here amount, as Amy argues, to "subsuming [Sheldon's] conclusions under [her] paradigm?" Does this prove that neuroscience is *more fundamental* than fundamental physics? Sorry, Amy, but not exactly. If Amy and Leonard's mother were to succeed at cooking up the kind of Sheldon-simulation we've been talking about so far, they would have (in effect) built a system that can *do physics.* This would be a triumph for neuroscience, to be sure, but recognizing this fact still amounts to recognizing that a tremendous number of patterns are outside the purview of Amy's project. Simply put, there are physical things that don't do physics. This point is reminiscent of Sheldon's comment to Penny in "The Gorilla Experiment": "Physics encompasses the entire universe, from quantum particles to supernovas, from spinning electrons to spinning galaxies." Neuroscience cannot make this claim, nor can *any* of the special sciences: a biologist such as Bernadette has no more to say about supernovas than a neuroscientist such as Amy does. Only physicists can make the claim of ultimate generality, and *that's* the sense in which fundamental physics is fundamental.

Yet this falls short of justifying Sheldon's arrogance completely because fundamental physics is far from the *only* project worth pursuing. Although it's true that the patterns of fundamental physics must also apply to brains, the project of identifying patterns that hold *only* in brains might still be fantastically useful. The fact that these patterns hold only in a restricted set of systems might be considered a benefit, rather than a problem: if we're interested only in predicting the behavior of systems that contain brains, then we're allowed to ignore a tremendous amount of extraneous information about how systems that *don't* contain brains behave, especially if it makes our task easier! If we encounter brain-containing systems on a daily basis (as we do), then we have good reason to care a great deal about how those systems behave, even if, in

identifying the relevant patterns, we ignore information about how (for instance) "spinning electrons and spinning galaxies" behave. The business of science is in identifying interesting systems and discerning patterns in how those systems change over time, and it's an inarguable fact that there are tremendously useful patterns to be found that don't hold everywhere in the universe. It is the business of the special sciences to identify those patterns, and Sheldon should recognize that this enterprise is a fantastically important one in its own right.

None of what we've said so far gives us a reason to prefer Sheldonology, neuroscience, microbiology, or fundamental physics *full stop*. Although it's certainly true that any Sheldon-containing system is *also* a brain-containing system (and thus that any system that can be studied by Sheldonologists can *also* be studied by neuroscientists), or that any brain-containing system is *also* a living thing–containing system (and thus that any system that can be studied by neuroscientists can *also* be studied by biologists), there might still be circumstances in which we'd prefer Sheldonology to neuroscience or neuroscience to biology. In particular, it might be the case that we have compelling reasons to *care* about patterns that hold only in Sheldon-containing systems more than we care about patterns that hold in *all* brain-containing systems (for example, if we encounter Sheldon far more than we encounter most other people). In that case, we might well be willing to trade the generality of neuroscience for the relative simplicity of Sheldonology, even if it means working with a special science that holds in a smaller set of possible systems. When Leonard and the gang attempt to work out the optimal restaurant/theater pairing at the beginning of "The Financial Permeability," they (quite reasonably) choose to do it in terms of Sheldonology. The relevant problem, as Leonard puts it, is finding "a Sheldon-approved restaurant proximate to a Sheldon-approved theater." It would be possible, of course, to work out this problem in terms of (say) fundamental physics—Sheldons, restaurants, and theaters

are all within the province of fundamental physics. There's a far easier way to go about it, however. Given the principles of Sheldonology, the gang can hone in on *just* the relevant patterns (which contain facts about things such as Red Vines and Ice-ee machines) and exclude all of the irrelevant patterns about supernovas and galaxies. Expressing the problem as a problem in Sheldonology makes their lives *easier*, so why not go about things that way?

The Pragmatics of the Special Sciences

This brings us to another important aspect of doing science, no less important than the others: in many cases, the choice of which special science to appeal to is a highly pragmatic one. That is, science contains a pragmatic element that sometimes gets overlooked. For instance, it makes little sense to object to Amy that in studying human brains she's wasting her time, because the patterns she identifies are ones that couldn't possibly hold in the interior of the sun. Why not? For exactly the same reason that Leonard might well specialize in Sheldonology, rather than in something more general: we encounter conditions such as the ones in which the generalizations of neurobiology hold far more often than we encounter conditions such as those of the interior of the sun. We have good reason to care about the patterns that neurobiologists identify, because there are a lot of systems displaying those patterns around here. If our goal is to predict the behavior of those systems, we don't necessarily care whether those predictions would break down in certain extreme conditions—that is, if there are possible systems in which the patterns identified by neurobiology wouldn't apply.

So, where does this leave Sheldon and his disdain for sciences other than fundamental physics? In some sense, he's correct in his belief that his project of finding the patterns that underlie everything is special. If he's successful, he'll be

able to claim that he's succeeded in articulating a set of patterns that has a level of generality beyond those of any other science. In another sense, though, this isn't the only project worth pursuing. It might also be useful to point out, in closing, that it isn't even clear that Sheldon actually *thinks* it is. Though he claims to be humiliated when his sister implies he is a rocket scientist, rather than a theoretical physicist, he nevertheless shows what can only be described as loving reverence for Leonard's mother, a brain researcher, calling her a "remarkable woman." It's also worth noticing his dedication to physics isn't absolute. When Ramona Nowitzki takes over his life in "The Cooper-Nowitzki Theorem," he eventually tries to enlist Leonard's help to destroy her (invoking the "Skynet clause" of their friendship), despite the fact that she is pushing him toward greatness. Sheldon values things other than physics—Red Vines, *Halo*, comic books, good Thai food, and (perhaps) even Amy's companionship. He values all of these things because they help him live the life he wants to live—he values them for *pragmatic* reasons. Ultimately, he should have a similar appreciation for biology, neuroscience, and the other special sciences.[2]

NOTES

1. I offer my sincere thanks to the webmaster at <http://bigbangtrans.wordpress.com> for episode dialogue here and throughout.

2. Thanks go to Dr. Dean Kowalski for his helpful feedback, comments, and editorial suggestions.