“Hey, Bill! How are you doing lately? I haven’t seen you in the pub for a while now. What are you up to these days? You said a while back that you were going to put together a paper about for submission. How is that going?” Phil asked when he saw his friend Bill, who is pursuing grad studies in the field of biology.

“It’s going all right, I guess. There’re a few experiments that I still need to repeat to get better blots, but I just finished the draft for the paper in the lab so I headed straight here for some cold refreshment. How about you? How goes your philosophy research?” Bill replied.

“Same-old stuff. I’m going to do some TAing this year to satisfy my Ph.D. requirement in philosophy. Hey, is that your draft there? Mind if I read it?”

“Nuh, go ahead. Knock yourself out”. Bill reached out and gave Phil the manuscript.

“Mmmm…that’s interesting. I couldn’t help noticing the way that you biologists make statements such as “demonstrating this”, “determining the underlying mechanisms”, or “finding the cause”, etc. It all makes it seem like you really believe you can prove your hypotheses, when in fact what you should be doing is to try to falsify them. You probably have heard in the past that you can never prove things right with empirical sciences; you can only eliminate the possibilities,” Phil said.

“Yes, I know that, but it doesn’t mean my results cannot demonstrate anything. I carry out my experiments very carefully to ensure that it’s safe for me to draw valid conclusions. For example, if I want to show that there is binding between two proteins, I would run very well controlled experiments to show this interaction. Afterwards, if I do indeed see the binding of these two proteins in all my experiments, I would then conclude that the results demonstrate such interaction! It’s rather straight-forward, isn’t it?” Bill asked.

“Ha! Not really! You still can’t “prove” it. How can you be sure that your experiments truly lead to your conclusion?” Phil asked.

“Well, I repeat my experiments many times and I’m always checking to make sure that the results are reliable. Besides, I do statistics to back me up and to tell me mathematically what the chances are that I’m making a mistake in my final statement”, Bill explained.

“Yeah, but are you sure that your experiments would yield the same results if they were done elsewhere in the universe?” Phil asked.

“Ah, now I know what you’re getting at…obviously I won’t be sure until I repeat my experiments ‘everywhere’. That’s just impossible. However, at least I can suggest that’s how things work in the system of my choice. We’re usually pretty careful about that. We usually describe our experimental system in good detail so that it becomes clear exactly “where” in the universe we run our tests,” Bill said frankly.

“Still not good enough though. Did you run your experiments over and over again? If not, how can you be so sure that you’ll be getting the same results the next time around? We all believe that we’ll see the sun rising from the east every dawn, but how can you be certain that the good old sun will be there the east tomorrow morning? If you want to say that you’ve proved something, you should have done the experiments in every system possible in the whole universe and then get the same results every single instance! Obviously that’s not going to be feasible, and that’s the reason why you can never prove things in experimental sciences. You can, however, propose more predictions from your results and then try to falsify them. This is the whole basis behind the hypothetico-deductive method put forth by one of the greatest philosophers of science, Karl Popper, whose idea has been very influential in science,” Phil said.

After a sip of the refreshing amber nectar, Phil continued: “According to Popper’s hypothetico-deductive
method, the best way of doing science is to falsify your hypothesis instead of verifying it, in what is called the scientific method, which I’m sure you know”.

“Of course!” Bill voiced his reply emphatically.

Sensing that Bill may be getting edgy, Phil felt the need to explain himself further: “The whole idea behind the scientific method is that you formulate your hypothesis and then draw conclusions from it by applying logical deduction, a process that derives conclusions about particular instances from general observations. You can also use logical induction which goes from particular to general, but, as you would expect, this is often dismissed in science since it defeats somewhat the purpose behind the process…you will see in a second. The point I’m trying to make is that the conclusions you draw become your predictions for you to test through experiments. For example, you can hypothesize “all diamonds are colourless”. By logical deduction, any pieces of stones you grab and say “this is a diamond” should, according to your hypothesis, be colourless. The problem is that you can do that with so many diamonds, but it would be impossible to verify your hypothesis by checking every diamond in the world. On the other hand, finding just one diamond with some colour such as the pink one sported by J.Lo will falsify your hypothesis. Therefore, it’s much easier to falsify than to verify. In contrast, logical induction will most likely get you nowhere since you are reasoning from particular instances to make general propositions - you can never conclude that all diamonds are colourless no matter how many colourless diamonds you see. For that reason, logical induction is not favoured in science”.

“Judging from what you’ve just told me in the last few minutes, it sounds to me that it’s practically impossible for us to prove anything in experimental science then!!” Bill protested.

“Exactly!” Phil agreed.

“No, that’s got to be wrong. How about Newton’s laws then? It certainly applies well to what we observe in our ordinary life,” Bill countered.

“Newton’s laws certainly have stood the test of time in some systems, but no one can say they’ve tested them in every corner of the universe, or that they’re going to work from the beginning till the end of time. We have indeed used the laws on many, many occasions but you can’t be sure that they’re always going to be universally applicable forever. Besides, Newton’s laws are not always applicable.”

“What do you suggest for us experimental scientists, then? I thought the hypothetico-deductive method is the only systematic, logical way that allows scientists to discover the truth about phenomena”, Bill asked. “I understand it takes time, but to say that we would never get to the truth, isn’t that a bit too much?”

“Well, the hypothetico-deductive method is just a logical way of advancing your empirical observations further. If you treat your hypothesis as a true premise, you can then design experiments in an effort to falsify your premise based on logical deduction. If you fail in doing so, you know your experiments have been unsuccessful in falsifying your idea, and you can keep going forward knowing that your experiments could not prove you wrong yet. Afterwards, you can base more predictions on the results that you have obtained,” Phil explained.

“That’s not how biology works though; biology is not mathematics in which you can construct true premises. We’re basing our hypotheses on observations which in actuality should not really be considered as true premises”, Bill argued.

“Actually, that dilemma applies to all experimental sciences, not just biology. Nevertheless, you should still be able to apply the hypothetico-deductive method. It goes like this: you assume for a second that your observations are indeed self-evident axioms and then you try to falsify your hypothesis through your experiments. The good thing about deductive reasoning is that if you can prove your conclusion wrong or ‘false’, you can then safely say that one of your premises was false as well. That is, of course, assuming that you’re using sound logical deductions throughout”, Phil clarified.

“You’re confusing me here. You told me earlier that we can’t prove things in science! By the same token, you can’t “prove” your conclusion wrong either. You just said that if you “prove” your conclusions wrong, you falsified your premise. How can you ever prove anything wrong if you cannot prove things in science at all? Your argument is coming back to bite your rear end, my friend”, Bill responded with a grin on his face.

“Ha, you got me there. It’s true that you have to base on experiments to ‘prove’ your conclusion wrong, but you’re absolutely right when you said that you can never prove in science. However, the beauty of the hypothetico-deductive method is the way in which it deals with observations. As human beings, we have to rely on what we observe, especially when we make predictions in science. What the scientific method allows you to do is to take your empirical observations together and test them in such a way that you can safely say whether your ideas are wrong. It’s true that since it’s all based on observations, one cannot possibly ascertain things either way. However, if you use the deductive scientific method, at least you would be confident that your observations or experiments can indeed falsify your ideas. They’re still observations but you now have a sound logical system to back you up in saying that they falsify your original premise. You still can’t escape the inherent uncertainty of empirical observations but you would know that your interpretation is at least logically right. Let’s put it this way: strip your observations of uncertainty and, for the sake of the argument, imagine for a second that your observations are indeed true. That truth you’ve just found can be used to falsify premises but not to prove them true; it’s just a glitch of the logical deduction. At the end of the day, there is no logical way of proving your premises true using logical deduction - you will never be able to prove things, you can only falsify. Now, on top of that, add the uncertainty of experimentation…” Phil confessed.
“Ahh, I think you’re just being picky. Don’t you think it’s just semantic whether we prove or disprove our hypothesis? It’s the same thing whether I demonstrate my hypothesis or I falsify the alternative hypothesis. For example, wouldn’t falsifying the hypothesis “protein X does not bind protein Y” be the same as proving “protein X binds protein Y”? In fact, the experiments performed to prove the hypothesis would be exactly the same as the ones that try to falsify it! Besides, you would still be using the hypothetico-deductive method just fine, only this time you are dealing with the reverse hypothesis”, Bill argued.

“Hold on there! You’ve just committed some logical fallacy. Even if you hypothesize that protein X doesn’t bind protein Y but, later on, your experiment falsifies this hypothesis and finds that they do indeed associate with each other, you cannot say for sure that they bind to each other every single time, which is what “protein X binds protein Y” entails. The real alternative hypothesis to “protein X does not bind protein Y” is that “protein X can bind to protein Y”, as opposed to “protein X always binds protein Y”. What you are doing just now is simply providing some evidence supporting that protein X binds to protein Y in some instances. Since biology is based mostly on observations, you can never prove anything but to suggest that some possible explanations are likely to be wrong. Try thinking of the path to the absolute truth as an infinite maze. What Popper said in a way is that you will never reach the end point, but you can obtain useful information along the way and get closer to the absolute truth by making conscious efforts in trying to avoid taking the wrong turns at every fork in your journey. That’s what the scientific method allows you to do when based on observations. Surely, it’s still based on observations that can be flawed and subject to experimental error; but the important thing here is that when your observations tell you a given turn is wrong, at least now logic is on your side”, Phil elaborated. “Whenever you think that an experiment points to the right turn…well, my friend, logic just abandoned you.”

“Are you saying that we’re stuck? It seems that what I’m doing is quite futile then! What’s the meaning of all my work?” Bill seemed to be dejected at this time.

“Lighten up, pal. You don’t need to wait till you reach the ultimate truth to reap its benefits. If you apply the hypothetico-deductive method in your science, you’ll be on the right path to the ultimate truth, and that can be more than enough to put your knowledge to good use. You’ll be able to smell the roses every step of your way.” Phil tried to console Bill.

“See??!! I knew it - there’s got to be some meaning as to why my work and I exist in this universe. I may not be phrasing my conclusions as carefully as you philosophers would like them to be, but it turns out I’m doing just the right thing. Now, leave my manuscript alone! It’s all good”. Bill continued: “You’re just giving me a hard time. People can interpret my results any way they want without having to believe any of my comments, however strong or radical they might be. In the end, data speak for themselves! Besides, I think biologists understand pretty well what I really mean even if I do make bold statements”. Bill tried a last ditch effort to save himself some grace.

“I don’t think that’s true at all. You have to be very careful about what you say. You and I may be on the same page when it comes to how science should be practiced in theory and where it can lead us in the future. But remember how this conversation started? I just had some objections on how bold experimental scientists sometimes can be in communicating their findings. Some scientists may know that you are full of it when you are saying too much, but it would not be so clear to others if your comments are worded careless with false confidence. I wonder to what extent this has hindered and still does hinder our scientific progress such as the development of drugs and the clinical trials, which are not as successful as people would either normally anticipate or are led to believe”, Phil disagreed.

“Come on, stop it. Scientists do this but they don’t mean any harm by it. If you don’t do it but everyone else does, you would be at a disadvantage right from the start. I’d like to think that we’re being assertive in presenting our data. You have to understand that it’s to publish or to perish in our savage little world! Despite this boldness in how scientists communicate their findings, mankind has been doing just fine. Think about it: would we be able to drive our cars and run over some stinky Philly steak sandwiches if science didn’t exist? We’ve certainly come a long way since our ancient cave days”, Bill said energetically.

“Well, all I’m saying is that sometimes people go overboard. I wonder if we would have done even better were it not for the illusion that science can uncover the truth. Take for example one of the biggest if not THE biggest discovery in your field. When Watson and Crick proposed the structure for DNA, they were a lot more careful. They said: “We wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.)”. Had you written the proposal, you would have probably said your data “clearly and unambiguously demonstrate the structure of DNA”. Instead, they were “suggesting” their finding instead of saying outright that they were proving it left, right and center”, Phil refuted.

“It’s just some people who like to make bold statements. Having said that, sometimes you can’t help but to draw your conclusions or sensationalize your research a little bit so that it sells better and gets much-needed attention by attaining its maximum impact. It’s the way things work in science, I think. After all, data are data – how far can you stray away from it? Incidentally, in case you are interested, Watson himself also said that cancer was going to be cured in two years back in 1998 based on findings published by Folkman,” Bill said.

“No, he said that he was misquoted. This is a perfect example of how when the findings get misconstrued, the lay public will still swallow it hook, line and sinker. And that is exactly what I’m trying to tell you. Society at large has given scientists a great deal of freedom in finding out how things work, but at the same time scientists carry with them a tremendous social responsibility in presenting scientific findings in a most clear and objective way, not only to each other in their research community but to the entire society. I understand there is no point in
communicating the nitty-gritty of your research to the lay public, but my point is that if the experimental scientists themselves feed this collective perception that science leads to discovering the truth by “selling” each other their findings, then we’re screwed because the same feeling can only leak out and reinforce the public’s blind faith in science. I was reading this article¹ in The Scientist the other day, and the author goes: “As a proposition about history, Wallace’s hypothesis ultimately cannot be proved.” There! The author is suggesting the hypothesis cannot be proved because you can’t go back in time and run tests, but otherwise hypotheses can be proved just fine. And the guy is writing for scientists presumably. I just think you should be more aware and careful of the way you conduct science and conclude from your experiments. As a graduate student in science, you should learn to appreciate the philosophy behind how you carry out your experiments in your quest to logically and truthfully advance scientific knowledge. Surely the data are important, and surely science has done tremendous things for us; but again I wonder if the way other scientists in your field think and what they say about science has any impact on the eventual outcome of our scientific progress. Would their strong, over-the-edge comments have got in the way of how we would have advanced over the years? You said it’s the pressure to excel in a tough, competitive environment. I don’t know, man, perhaps it’s just nature to do so for human beings,” Phil pondered.

At this point, both Bill and Phil realized that the bar was about to close. They quickly paid for their drinks and briskly walked into the street to start a whole new discussion on human nature in the cold early morning.

References

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Love the Rock.

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If you are familiar with the many stories told in Greek mythology you would know that the ancient gods, while sometimes caring and compassionate, were mostly a cruel and nasty lot. Dare cross these folk and, like Atlas (condemned to hold the world on his shoulders) and Prometheus (chained to a cliff and eaten by a bird), their wrath upon you was likely to be swift, brutal, and in many cases, eternal. The story of Sisyphus, whose suffering was popularized by the famous French philosopher Albert Camus, is no exception. Influenced by other existentialist¹ writers, Camus was of the rather dreary opinion that humans fundamentally lack definition and that life was without meaning. The paradox, he explains, is that despite this meaninglessness we still struggle to find meaning in our lives. Camus calls this absurd. In his book The Myth of Sisyphus, he defines the absurd and uses