Ronan Ferro
HONR 298J - Section 0201
Timothy Koeth
21 May, 2019

The Life and Work of Sheldon Lee Glashow

Introduction

Sheldon Lee Glashow at Harvard in 2011 [A].

Sheldon Lee Glashow is an American theoretical physicist, best known for his prediction of a fourth quark, the charm quark, at a time when only three had been proposed, as well as proposing the first grand unified theory of particle physics, which would go on to influence all future work in unifying the standard model of particle physics. While not strictly an accelerator scientist himself, much of his work was proven through the use of accelerators, and modern accelerator science owes much of its foundational knowledge about particles to him. Glashow has also been awarded a Nobel Prize in Physics, and a Robert Oppenheimer Memorial Prize, for his work with electroweak interactions. Despite his impressive resume, however, Glashow is a humanist at heart, and sees value in thinking of science as a humanity itself, making him somewhat unique among physicists, who have a reputation for being disinterested in the subjectivity of the humanities. In this paper, we will explore the work and life of Glashow, to bring more attention to such an influential and fascinating scientist.

Early Life

Glashow was born on December 5, 1932, in New York, New York. He is the son of two Jewish Immigrants from Russia: Bella née Rubin and Lewis Glukhovsky, who immigrated to the United States from Bobruisk in order to seek freedom from Tsarist Russia [1]. After struggling through the Great Depression, Lewis became a successful plumber, enabling his family to live comfortably, but he and Bella were unfortunately unable to attend a university themselves. As such, they were determined to send their children through university, which, ultimately, they all did.

Glashow himself was the youngest of three boys, as when he was born, his brothers Samuel and Jules were eighteen and fourteen years old, respectively. While they went on to pursue careers in dentistry and medicine, Glashow was more interested in being a scientist, which he attributes to Samuel, who got him interested in mechanics at a young age and helped install a chemistry lab in their family's basement [1]. In this lab, Glashow became adept at synthesizing selenium halides, and has said, "never again would I do such dangerous research[1]" [1]. Considering the potential danger, and that Glashow was only fifteen when his chemistry lab was installed, it is probably for the best that he never did work like this again, and he is lucky he didn't accidentally poison his whole family when he did. Despite all that, Glashow's parents were very supportive of his scientific aspirations, apart from the occasional suggestions he become a doctor and take up science as a hobby. Presumably, he either never told them how dangerous halogens are, or they had the utmost confidence in their son's abilities.

Interestingly, encounters with dangerous chemicals appear to run in the family, as before Glashow was born, his father fell into a vat of molten lead, and emerged unharmed [2]. When he fell in, there was a layer of air that insulated him for long enough to get out without any of the lead sticking to him. Glashow's father liked to tell this story a lot, which might have also played a role in his love of science from a young age.

When he wasn't flirting with death in his basement, Glashow attended Bronx High School of Science, where he became good friends with Gary Fienberg and Steven Weinberg, with whom he studied physics on their commute to school, and Dan Greenberger, who taught him calculus in the school cafeteria [1]. While this might seem strange today, at the time, high school math ended with geometry, so if students wanted to learn calculus before college, they would have to teach it to themselves. Additionally, by coincidence, Steven Weinberg would go on to share the 1979 Nobel Prize in Physics with Glashow and Pakistani theoretical physicist Abdus Salam, despite all three of them conducting their research on electroweak unification theory independently of each other [4].

After graduating high school, Glashow attended Cornell University, alongside Steven Weinberg and mathematician Daniel Kleitman, who would go on to become his brother-in-law. Glashow has said that throughout his education, he learned just as much from his peers as he did from his teachers, which seems pretty likely, given his impressive circle of friends [1]. After receiving a Bachelor of Arts degree from Cornell in 1954, he went to graduate school at Harvard University, where he studied under Professor Julian Schwinger. Schwinger, incidentally,

Cornell University [B].

---

[1] Fluorine and chlorine, the two halogens that bond most readily with selenium to form selenium halides, are both incredibly toxic and volatile gasses, as are the selenium halides they form, particularly selenium hexafluoride [3].

won the 1965 Nobel Prize in Physics for his work with quantum electrodynamics, and is considered one of the greatest physicists of the twentieth century [5]. Unsurprisingly, Glashow did very well under Schwinger, and received a Ph.D. in physics in 1959. It was also during his time at Harvard that Glashow first became committed to electroweak synthesis, for which he would eventually become famous, and de and Schwinger had even planned to write a paper on it together. Unfortunately, one of them lost their first manuscript of it and the project was called off [1].

Professional Life

Having finished graduate school, Glashow had planned to work at the Lebedev Institute in Moscow, Russia, with Igor Tamm, a Russian physicist who had taken interest in his work. Looking back, it's interesting that Glashow would want to work in Russia, considering his parents history with the country, and the United States' hatred for it in the 1950s. In any case, he never ended up going to Russia, as he never received the required Russian visa, so he instead spent his fellowship at the Niels Bohr Institute and at CERN in Copenhagen [1]. It was during this time that he discovered the SU(2) x U(1) structure, a critical component of the electroweak theory. To clarify, The electroweak theory is a description of how electromagnetism and the weak force, two of the fundamental forces in nature, are actually different aspects of the same force. According to the theory, above the unification energy, above 246 GeV, they would actually merge into one force. However, the required temperature to reach such energies (10^{15} K) has not been exceeded since the Big Bang, so the two forces have been separate for most of time [6].It was also during his time in Europe that he met Murray Gell-Mann, the American physicist who created the "Eightfold Way" to describe how elementary particles interacted with one another[2] [4]. Glashow worked with Gell-Mann at Caltech, alongside fellow physicist Sidney Coleman, for many years. He would also later describe the Eightfold Way as "distracting", and wonders at how he and Coleman were able to miss the discoveries of the Gell-Mann-Okubo formula and the Cabibbo current, despite working with one of the people who discovered them [1]. Ironically, Glashow's later work with the standard model of particle physics would

---

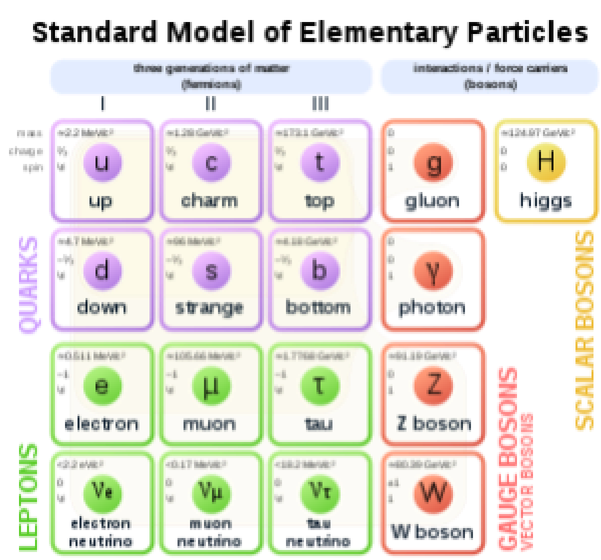
[2] At the time, thanks to advances in particle accelerator capabilities, there was a huge influx of new elementary particles being discovered, and it was becoming increasingly difficult to organize and classify them, so the Eightfold Way was a method to sort them by properties. It worked by arranging particles into lattices with different properties on each side.

re-contextualize the Eightfold Way as a consequence of flavor symmetries[3] between different types of quarks.

After his work with Gell-Mann at Caltech, Glashow became an assistant professor at Stanford, and then an NSF fellow at the Nordic Institute for Theoretical Physics (NORDITA[4]) before becoming an associate professor at University of California, Berkeley, where he stayed from 1962 to 1966 [2]. In 1966, he finally settled at Harvard University, where he went to graduate school, Where he has mostly stayed ever since, with the exception of a few brief breaks to CERN, MIT, and the University of Marseilles. At Harvard, he was named the Eugene Higgins Professor of Physics (a prestigious title for professors at several Ivy League universities) in 1979, and became emeritus in 2000, at which point he moved to Brown University. According to him, he intentionally chose Brown because it was not quite as prestigious as Harvard, so he thought he could have more of an impact there, and indeed, strengthen its ties to Harvard, as well as MIT. Additionally, the Harvard physics department was becoming more and more saturated with string theorists, which bothered Glashow due to his disdain for String Theory as a concept due to its lack of testable predictions.

Work with the Standard Model of Particle Physics

In 1961, Glashow extended Schwinger's original electroweak theory by including the Z0, a short range neutral current. Z0 is short for the Z boson, an elementary particle that mediate the weak force along with the W boson. It is called Z0 because its flavor quantum numbers and charges are all zero, thus making it its own antiparticle. Interestingly, the Z boson would not actually be discovered until 1983, at the Super Proton Synchrotron at CERN, but originally was proposed in 1958 by physicist Sidney Bludman [8]. Neutral currents, meanwhile, are one of the ways particles can



[C]

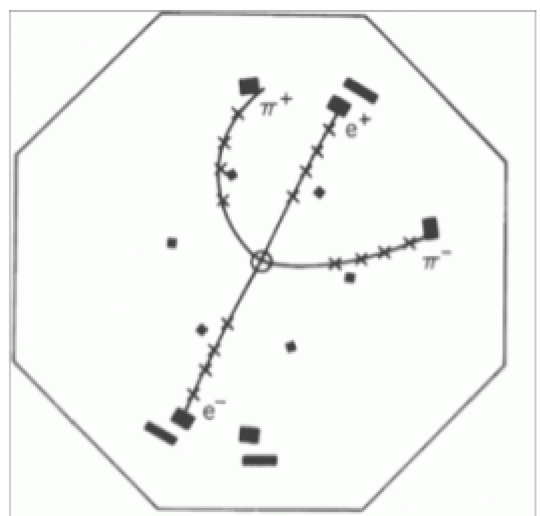
[3] Flavor symmetries refer to the three pairs of quarks: up and down, strange and charm, and top and bottom. The strange nomenclature of particle physics is largely a consequence of the fact that subatomic particles do not have properties that are analogous to macroscopic properties, and thus are given unusual names like "charm" and "strange" so that they are not accidentally compared or associated with macroscopic concepts that seem like they could apply to them, but don't.

[4] From Danish: Nordisk Institut for Teoretisk Atomfysik [7].

interact via the weak force, and play an important role in nuclear decay. They are mediated by Z bosons. By integrating the neutral current into previous electroweak unification models, Glashow was able to propose the SU(2) × U(1) symmetry structure. This structure, would go on to form the matrix structure of the standard model of particle physics, as well as be the basis for the now accepted theory of electroweak interactions. For this, Glashow was awarded the 1979 Nobel Prize in Physics, alongside Steven Weinberg and Abdus Salam, who coincidentally were working with electroweak theory around the same time.

In 1964, meanwhile, Glashow was working with American theoretical physicist James Bjorken, and was the first to predict the existence of a fourth quark. While this was technically the first proposal of such a particle, it was not formally predicted until 1970, when Glashow, along with Greek physicist John Iliopoulos and Sammarinese physicist Luciano Maiani proposed the aptly named Glashow-Iliopoulos-Maiani mechanism (or GIM mechanism), which is the mechanism by which flavor changing neutral currents are suppressed. This mechanism required the existence of a fourth quark in order to function, as it showed that two quark pairs would cancel out the flavor changing neutral currents. The mechanism also removed an anomaly where classical theory symmetries would not carry over to quantum theory correctly with an unequal number of quarks and leptons [4]. Thus the prediction of the fourth quark is credited to this team. The quark was called the charm quark, because, as Glashow put it, “We [he and Bjorken] called our construct the 'charmed quark', for we were fascinated and pleased by the symmetry it brought to the subnuclear world’ [7].

The charm quark was later proven to exist in 1974 when the J/ψ meson (the first particle containing a charm quark) was discovered independently by Burton Richter’s team at the Stanford Linear Accelerator Center (SLAC) and Samuel Ting’s team at Brookhaven National Laboratory (BNL). Because the two teams discovered it so close to each other, the J/ψ meson is the only particle with a two letter name. It was named “psi” by Richter’s team because it was one of the only remaining Greek letters, and resembles the particle’s spark chamber pictures, and named “J” by Ting’s team because it was one letter away from K, the name of the already-known and opposing strange meson.

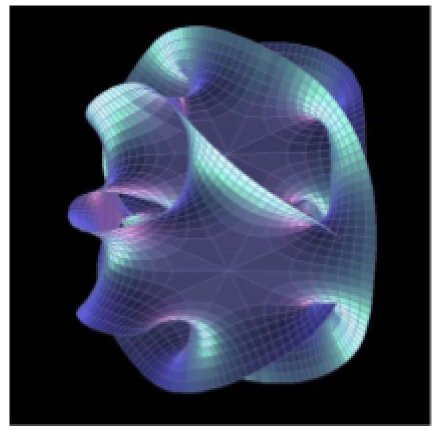


The psi-shaped decay of the J/psi meson [D].

In 1973, Glashow and American theoretical physicist Howard Georgi proposed the first grand unified theory, a model of particle physics that further merges the electroweak force with the strong force into one super force. While such a force’s existence has yet to be proven experimentally, due to the astronomically high energy that would be required to merge all three forces together, its existence is plausible through Glashow and Georgi's theory, and would suggest that, at some point early in the Universe's life, there was a moment where all three forces were yet to separate [9]. They also discovered how to fit the gauge forces, or forces that were mathematically formalized to regulate redundant degrees of freedom, into the standard model as an SU(5) group. Their theory predicted the mass ratios between third generation leptons and quarks, and showed that the law of Baryon numbers was inexact, and laid the groundwork for all unifying work since.

Superstring Theory

Superstring Theory, or just String Theory, is a relatively recent development in physics, dating back to the late 1960s. It is an attempt to unite all of the four fundamental forces into one singular theory by way of what are called strings. According to String Theory, all particles in the Universe, including those that conduct the forces like bosons, are actually just tiny vibrating strings[5], with each vibration frequency corresponding to a different particle [10]. String Theory also operates in many dimensions - Superstring Theory uses ten, while Bosonic String Theory operates in twenty-six. Because of this, String Theory is fundamentally impossible to visualize, and so far has proven impossible to prove or find evidence for [10].



An attempt at visualizing String Theory [E].

String Theory is relevant to Glashow's story because he absolutely hates it, largely due to its lack of experimental evidence and testability, as well as its lack of unification - there is not currently one "String Theory", but rather many theories that present the idea of such a theory [10]. Glashow - who coincidentally was one of the last Nobel Prize in Physics laureates before String Theory was introduced - is on record as describing it both as a "new version of medieval theology," and as "a tumor," and has campaigned to keep String Theorists out of the Harvard physics department, though this campaign failed [11][12]. This comparison to theology is oddly appropriate, as String Theory and religion both attempt to answer very fundamental questions about the Universe in a beautiful, consistent way, but cannot be proven or disproven experimentally. To this end, Glashow has, in an interview with Nova, said, "The string theorists have a theory that appears to be consistent and is very beautiful, very complex, and I don't

---

[5] The "strings" would not actually resemble strings we encounter in our world, but rather are one-dimensional objects that interact with each other moving. The term "string" was chosen as it is the English word that comes closest to actually describing them. At the extreme edges of science, when concepts get further and further from our familiar world, our everyday language becomes less and less equipped to describe them.

understand it… there ain't no experiment that could be done nor is there any observation that could be made that would say, 'You guys are wrong.' The theory is safe, permanently safe. I ask you, is that a theory of physics or a philosophy?" [11].

Glashow goes on to say that, in the physics community, there is a divide between physicists and String Theorists, and that neither group are talking or listening to the other [11]. This, he feels, is a problem because it distracts physicists from the questions that can be answered experimentally, and might cause experimental physics to fall by the wayside in favor of something closer to philosophy, hence the "tumor" analogy from earlier. He has also said that if String Theory could answer questions about the Universe in general, like why are there six quarks, then he would take it more seriously, but so far, it has not been able to [11]. Glashow is also not alone in his disdain for String Theory, as American theoretical physicist Richard Feynman has described it as "crazy," "nonsense," and "the wrong direction" for physics, and even some physicists who were involved quite heavily with String Theory, such as Lee Smolin and Peter Woit, have called it a "tragedy" and a "disaster" [12].

Glashow even has an article in the May 1986 issue of the journal *Physics Today* with physicist Paul Ginsparg called "Desperately Seeking Superstrings?" With a title parodying the old classified ad phrase, the article is unsurprisingly critical of Superstring Theory, stating, "the theory depends for its existence upon magical coincidences, miraculous cancellations and elations among seemingly unrelated (and possibly undiscovered) fields of mathematics" [13]. In particular, they point out that even though String Theory has failed to encompass or address the standard model, or even produce verifiable predictions in any meaningful way, it still has attracted many of the world's leading physicists into an almost cult-like school of thought, with sentiments that "eerily recall 'arguments from design' for the existence of a supreme being", which is more reminiscent of religion than science [13].

Of course, all this is not to say that String Theory has no value. As Glashow points out, "it leads to many interesting ideas" and "is important to mathematics" [11]. He even admits that it might one day be useful to mathematics in the same way that number theory, an otherwise useless area of mathematics, eventually gave rise to cryptography [11]. However, as of yet, it has not incorporated existing knowledge into a unified theory the way it intended, but has instead just generated more theories about itself. And this, Glashow argues, is doing more harm than good to physics as a whole.

Humanism

Humanism, as defined by the American Humanist Association, is "a progressive philosophy of life that, without theism or other supernatural beliefs, affirms our ability and responsibility to lead ethical lives of personal fulfillment that aspire to the greater good" [14]. It is a

AMERICAN HUMANIST ASSOCIATION
GOOD WITHOUT A GOD

AHA logo [F].

philosophy that one should do good because it is the right thing to do, rather than because they fear some divine punishment.

Glashow is very big on humanist ideals, so much so that, in 2003, he signed the third Humanist Manifesto: Humanism and Its Aspirations, which features themes like "Knowledge of the world is derived by observation, experimentation, and rational analysis" and "Working to benefit society maximizes individual happiness" [14]. Many of the ideas expressed are, to an extent, core principles of the sciences, so it's little wonder why Glashow was drawn to them. Additionally, in an interview with the magazine *La Vanguardia,* he has expanded on his ideology. He draws many comparisons to the arts, citing Shakespeare as one of the scientists who has inspired him the most, stating, "There is no good science without conscience, or without a profound knowledge of the human soul. And Shakespeare is the best when it comes to that" [15]. He also says that the other two most inspirational scientists to him were Albert Einstein, for being brilliant enough to launch three different groundbreaking theories in the same year, and Galileo, for sticking to his empirical observations despite the threats of the church [15]. He goes on to say that all good scientists are humanists, and that " We are only civilised if we manage to combine art and science. A scientist who has no knowledge of the humanities will be a bad scientist" [15].

Coming from this perspective, Glashow has written a book called *From Alchemy to Quarks: The Study of Physics as a Liberal Art*, which attempts to bridge the gap between science and humanities [18]. In it, he traces the history of physics and chemistry from medieval ages through today (or 1994, when the book was written) in a style geared towards liberal arts students. Originally, the book was written for a core-curriculum course at Harvard, which Glashow describes as "aimed at bright students of law, language, or letters… physics for poets who can count," highlighting its intended cross-disciplinary appeal [18]. Unfortunately, the course proved very hit-or-miss with students, as the students that want to be scientists love it, and those that don't think it is a waste of time. Glashow believes this is partially because the non-science students didn't have the math to understand it properly, specifically plane geometry. He claims "If you've gotten somebody who didn't take plane geometry, then they are never going to learn any science" [2].

With such a strong humanist ideology, it should come as no surprise that Glashow is not religious, despite coming from a Jewish family. He specifically describes himself as "a practising atheist," which is a somewhat ironic turn of phrase as atheists, by definition, do not practice [15]. He could arguably be considered a practising humanist, though this comes with little in the way of practice other than simply being a good person.

Later in the interview, he also mentions that none of his work matters now, because climate change is such a pressing, urgent issue that those in power are not doing enough about. He concludes the interview by calling everyone to "free ourselves of this idiot Trump right now, and save our planet!" [15]. He also mentions how he was inspired by Galileo, who stood true to his observations and theories despite the dogma of the church. While he does not draw this comparison himself, the current struggle between scientists and politicians on climate change is very similar in nature, with one side arguing based on evidence and empirical observations, and the other ignoring such evidence in favor of their own distorted world-view.

Other Details

In the same interview, the interviewer points out that Glashow shares his first name with Sheldon Cooper, one of the physicist characters on the TV show *The Big Bang Theory*. According to Glashow, he actually inspired the character, and shares some physical traits with him, such as being tall and lanky, and tucking one thumb into his belt as he walks [15]. Glashow says he has no objections to being the inspiration for the character, despite how badly stereotyped the character is. However, he does make clear that all of Sheldon Cooper's other characteristics are completely fictional. Notably, Glashow has neither Asperger's syndrome[6] nor a reputation for being irritating.

Jim Parsons as Sheldon Cooper [G].

In 1972, he married Joan Shirley Alexander, whom he lives with along with their four children in Brookline, Massachusetts. Interestingly, Lynn Margulis, the famous evolutionary biologist and proponent for symbiosis, was Joan's sister, and thus Glashow's sister-in-law, which then makes Carl Sagan, who was Lynn's husband in the early 1960s, Glashow's former brother-in-law. Through Joan's other sister, Sharon, Glashow is also brothers-in-law with Daniel Kleitman, who was also a doctorate student of Julian Schwinger.

In 1979, the year he received his Nobel Prize, Glashow participated in the inauguration of the Harvard Core Curriculum Program, which was Harvard's general education program at the time that focused on interdisciplinary learning, before being replaced by their current system [1][17]. As a result, for many years, Glashow taught his course "From Alchemy to Quarks" to students who were decidedly not scientists, and were never planning on being scientists, who nonetheless took great interest in physics and the history behind it. Glashow himself is a huge proponent of interdisciplinary knowledge, so this class suited him perfectly.

In addition to being critical of Superstring Theory, Glashow is also critical of the concept of a theory of everything, though for different reasons. Whereas Superstring Theory is trying to

---

[6] While the character of Sheldon Cooper has not been confirmed to have Asperger's syndrome, his behavior is remarkably consistent with that of people who do, so much so that even the actor who plays him, Jim Parsons, has stated that Sheldon "couldn't display more" traits of Aspergers [16].

explain fundamental forces in a way that cannot be tested, a theory of everything is simply unrealistic in Glashow's eyes, as he thinks the concept is "foolish" [11]. In his view, there is no way for a human theory to perfectly encapsulate everything, because there is no way humans could possibly know everything. The Universe is simply too large and too complicated for anything we do perfectly describe all of it. He thinks it arrogant to believe otherwise [11]. In Glashow's mind, scientists, and humanity as a whole, are not seeking perfection, but rather simply improvement. As he says, "the theories we have today of life and chemistry and physics are much better than they were ten years ago. And ten years from now they will be better still," so science will always improve, and our understanding will always grow, but we will never understand everything perfectly, because we are not perfect [11].

Glashow is known for his wit and sense of humor, particularly in interviews, where he will often crack jokes with the interviewer. For instance, in an interview with the American Institute of Physics, he makes a joke about how his chair position at Harvard, the Mellon Chair of the Sciences, "was a wonderful honor, but it was a folding chair; it lasted only a few years", and goes on to talk about his association with the Ig Nobel Prize [2]. The Ig Nobel Prize is a parody of the prestigious Nobel Prize that is awarded every year by the scientific humor magazine *Annals of Improbable Research* (AIR) [19]. It is intended to honor "achievements that make people laugh, and then think" [19].

The Stinker, the mascot of the Ig Nobel Prize and parody of the statue The Thinker [H].

Later in the interview, Glashow discusses how when he first proposed the charm quark, most people didn't believe him, until 1976 when it was found at SLAC and BNL simultaneously. Glashow had a challenge of sorts going in which he would eat his hat (as well as his shoes and socks) if the charm quark was not found, which he was willing to wager because he was so confident that it would be found. When it was, he felt vindicated, and admits, "it's an awfully nice feeling to know you're right and be surrounding by all these apparently brilliant people who don't agree with you" [2]. The physicists he was betting against were given symbolic candy hats to eat, which Glashow jokingly laments was not really much of a punishment, even though, technically, they did eat their hats. He also notes that he was never good at experiments, as when he was at Cornell, he accidentally dropped bricks onto delicate little glass tubes for a lab, destroying them, after which he was asked to take a passing grade and never set foot in the laboratory again [2]. With this in mind, it is astonishing that he survived his childhood experiments with halogens without any adverse effects on his health.

Glashow has also talked about how, due to the lack of support from Congress for particle accelerators[7], particle physicists in America often shift their focus to astronomy, and have, in his words, "revolutionized astronomy" [2]. He credits the discovery that the Universe is expanding faster the further away you get to both "real astronomy types and real particle types," and is very interested himself in questions about the larger Universe, such as whether it is finite or infinite, or what dark matter, the Universe's "chef's specialty" in his words, actually is [2].

Conclusion

Sheldon Glashow is one of the most important lesser known scientists in the last century. Not only has his work with the standard model redefined how particle physics operate, he proves that science and humanity are not separate, but rather one and the same. While not as famous as more public scientists like Carl Sagan or Neil DeGrasse Tyson, his lighthearted, exaggerated personality helps to bring a very human side to a body of work that could otherwise feel cold, and distancing. In fact, his books, *Interactions: A Journey Through the Mind of a Particle Physicist and the Matter of This World, From Alchemy to Quarks: The Study of Physics as a Liberal Art,* and *The Charm of Physics* have all been widely acclaimed for strongly featuring his wit and personality, which bring a lot of flavor, so to speak, to books that, based on their subject matter, could have been very dry and uninteresting.

Glashow supposedly also has another book, titled *1001 Mechanical Delights*, that is in the works, which he describes as "crazy, kooky problems for kids who are interested in mechanics" [2]. He mentioned this book in his interview with the American Institute of Physics, in which he mentions that he didn't realize how big a number 1001 actually is (which is ironic for a particle physicist who routinely works with literally astronomically large numbers), and was up to about 500 at the time of the interview [2]. Of course, this interview was from 1998, so it is unlikely that this book is still in the works. However, given the absurdity of some mechanics problems in contemporary textbooks, such as busses racing around 45 degree inclined tracks and children sliding down forty-meter-tall ice hemispheres, it's concept might have still proven influential.

In any case, Glashow is a fascinating man, whose work has been instrumental in the development of particle physics and our understanding of the Universe as a whole. Beyond that, however, he is still just a human, like any of us. I hope that, throughout this paper, I have given you not only an appreciation for the kind of work Glashow has done, but also shown you who he is as a person, and shown the more human side of his work. After all, that is what he is all about.

---

[7] This lack of support stems largely from the fact that while accelerators are vitally important to understanding particle physics and the Universe, they don't have many practical applications the way something like medical research or material science does. As Glashow puts it, "when a congressman comes and says, 'Is this stuff going to do anything?' and the answer is, 'No, it won't.' It's like grand opera" [2].

Bibliography

[1] Sheldon Glashow – Biographical. NobelPrize.org. Nobel Media AB 2019. Wed. 15 May 2019. www.nobelprize.org/prizes/physics/1979/glashow/biographical/.

[2] "Sheldon Glashow." *Sheldon Glashow | American Institute of Physics*, 26 May 2015, www.aip.org/history-programs/niels-bohr-library/oral-histories/5905.

[3] Proctor, Nick H.; Hathaway, Gloria J. (2004). James P. Hughes (ed.). Proctor and Hughes' chemical hazards of the workplace (5th ed.). Wiley-IEEE. p. 625. ISBN 978-0-471-26883-3.

[4] "'Sheldon Lee Glashow' on Revolvy.com." Revolvy, www.revolvy.com/page/Sheldon-Lee-Glashow.

[5] "Julian Schwinger Bio." *Julian Schwinger Foundation*, schwingerfoundation.org/biography.php.

[6] Sutton, Christine. "Electroweak Theory." Encyclopædia Britannica, Encyclopædia Britannica, Inc., 20 July 2006, www.britannica.com/science/electroweak-theory.

[7] Mühlen, Hans. "NORDITA." *NORDITA*, www.nordita.org/.

[8] "The Z Boson." *CERN*, home.cern/science/physics/z-boson.

[9] "'Grand Unified Theory' on Revolvy.com." *Revolvy*, LLC Revolvry, www.revolvy.com/page/Grand-Unified-Theory.

[10] Whitwell, Tim. "What Is String Theory?" *Physics.org*, www.physics.org/article-questions.asp?id=47.

[11] "Nova Interview." *PBS*, Public Broadcasting Service, www.pbs.org/wgbh/nova/elegant/view-glashow.html.

[12] Holt, Jim. "Unstrung." *The New Yorker*, The New Yorker, 20 June 2017, www.newyorker.com/magazine/2006/10/02/unstrung-2.

[13] Ginsparg, Paul, and Sheldon Glashow. "Desperately Seeking Superstrings?" *Physics Today*, vol. 39, no. 5, May 1986, pp. 7–9., doi:10.1063/1.2814991.

[14] *American Humanist Association*, americanhumanist.org/.

[15] "Sheldon Glashow, Nobel Prize in Physics for the Electroweak Theory". La Vanguardia, 20 June 2017, raed.academy/wp-content/uploads/2017/06/Sheldon-Lee-Glashow-contraLVeng.pdf.

[16] Collins, Paul. "Must-Geek TVIs the World Ready for an Asperger's Sitcom?" *Is the World Ready for an Asperger's Sitcom? - By Paul Collins - Slate Magazine*, web.archive.org/web/20090210061649/http://www.slate.com/id/2210635/pagenum/all/.

[17] Faculty of Arts and Sciences Harvard College. "The Core Curriculum Requirement." *Core Curriculum Requirement*, static.fas.harvard.edu/registrar/ugrad_handbook/2009_2010/chapter2/core02.html.

[18] Glashow, Sheldon L. *From Alchemy to Quarks: the Study of Physics as a Liberal Art*. Brooks/Cole Pub., 1994. ISBN 0-534-16656-3.

[19] "Ig Nobel Prizes." *Improbable Research*, 26 July 2018, www.improbable.com/ig/.

Image Credits

[A] https://en.wikipedia.org/wiki/File:Sheldon_Glashow_at_Harvard_cropped.jpg

[B] https://en.wikipedia.org/wiki/Cornell_University

[C] https://en.wikipedia.org/wiki/Standard_Model

[D] https://www.quantumdiaries.org/2014/08/06/jpsi/

[E] https://www.crystalinks.com/stringtheory.html

[F] https://americanhumanist.org/

[H] https://www.improbable.com/ig/