Mustafa\(^{(pbuh)}\) Prize at a Glance

Mahdi Saffarinia
Secretary of the Mustafa\(^{(pbuh)}\) Prize Policy-Making Council

At the Mustafa\(^{(pbuh)}\) Prize, we are after collaboration and enhancing the science and technology workers in the Islamic world and strive to strengthen the relationship between these countries and important scientific figures in the Islamic world. The missions of the Mustafa\(^{(pbuh)}\) Science and Technology Foundation’s (MSTF) have been defined in terms of networking, capacity-building, discourse-making, and accreditation.

In the evaluation process, 1200 individuals from 32 countries were assessed. The scientific communication has been kept with more than 400 of them.

Noor School Student Competitions is one of the programs developed by the MSTF. Four rounds of this competition have been held so far, in which more than 15,000 people from 7 countries participated. In the coming days, the call for the fifth round of the Noor School Student Competition will be announced.

The KANS (Knowledge Application and Notion for Society) Science Competition is another event of MSTF, of which one round has been held so far.

STEP (Science and Technology Exchange Program) is the other program developed by the MSTF for academics. Seven rounds of STEP have been held so far, in which 400 individuals participated. Now, more than 100 of those eminent scientific figures communicate with each other, and about 910 scientific research institutes are collaborating with the prize.

Over the past two years, the 6th STEP symposium in the field of Water, Energy, and Health was held with the presence of 68 individuals from 28 countries. Moreover, the 7th STEP symposium was held virtually on the theme of Coronavirus challenges with the attendance of 37 scientists from 18 countries.

The 4th EISA (Exposure of Industries to Scientists’ Achievements) summit was held with the presence of 24 technologists from 16 countries and during which more than 80 B2B meetings were held. The 5th EISA summit was held in December 2020 with 44 technologists from 16 countries.

Holding five Science Promotion Meetings of the MSTF aimed to reflect the scientific achievements.

The government of the Islamic Republic of Iran does not finance the Mustafa\(^{(pbuh)}\) Prize. The Prize is financed through the endowments that more than 500 individuals have made to The Mustafa\(^{(pbuh)}\) Prize Investment and Endowment Fund. So far, an overall amount of 3 million dollars of the Prize has been payed.

The Mustafa\(^{(pbuh)}\) Prize has enjoyed a wide international media coverage so far, and well-known credible media like The New York Times and The Guardian have covered its news. Overall, the MSTF communicates with 160 credible media in 23 countries.
Prof. Cumrun Vafa

The 2021 Mustafa\(^{(pbuh)}\) Prize Laureate

Designation: Hollis Professor of Mathematicks and Natural Philosophy, Harvard University
Date of birth: 1960
Place of birth: Iran
Work: F-theory
Field of the Prize: Theoretical Physics
Einstein spent the last four decades of his life pursuing the dream of uniting the general theory of relativity with quantum mechanics without any success. "The intellect seeking after an integrated theory cannot rest content with the assumption that there exist two distinct fields totally independent of each other by their nature," he said in his Nobel lecture in 1923.

The dream has been the Holy Grail of physics, an ‘everything theory’ or ‘final theory’ as some physicists prefer, that brings all the foundations of physics under one umbrella. However, today more or less, the situation is as was, but many physicists believe now they know the right approach: string theory. "This is the only theory which has resolved the inconsistency of Einstein’s theory of general relativity with the microscopic world of quantum mechanics," Cumran Vafa says.

Vafa, a leading physicist world-renowned for his groundbreaking works in string theory, has pursued the dream just as long as Einstein did. "I have worked on string theory beginning in my graduate studies in Princeton University in the mid-1980s, and I have continued it non-stop till today," he says. He believes string theory is "the most fundamental theory of the universe. Whether it is the ‘final theory’ or even that there is a ‘final theory’ at all, remains to be seen."

2500 years ago, the Greek philosopher Empedocles in his great work, On Nature, postulated that everything is composed of four elements: earth, water, air, and fire. He believed these elements or roots, as he said, are moved by two opposing forces: love and strife. Everything was explained by the four elements and two forces back then. How cool was that? However, it seems that was the last time we had a theory of everything.

The theory did not last much, and only one century later, it could not explain the variety of elementary substances found by alchemists. The pursuit for elementary substances went on to the point that in the eighteen-century chemists drew a table of near 100 elements. However, by discovering the atom and its internal structure, the modern age of reductionism began.

At the end of the nineteenth century, physicists developed quantum mechanics to explain why atoms absorb and emit light only by specific wavelengths. Then, Einstein came up with special relativity to combine space and time in 1905. A decade later, he introduced general relativity to merge special relativity with gravity. Trying to remove the contradiction between quantum mechanics and special relativity led to the successful quantization of electrodynamics.

By the emergence of particle colliders with high energy enough to probe the nuclear force, physicists opened up the gate of a subatomic particle zoo, which was a minor drawback. However, they soon realized most of the particles were composite, made up of 25 elementary particles ruled by three fundamental interactions: electromagnetic, weak nuclear, and strong nuclear. The unification was on fire.

The real climax was when physicists successfully merged the weak nuclear force, responsible for radioactive decay, with electromagnetism through a glamorous unification called electroweak interaction. The unification was so brilliant that all were convinced
the next reasonable step should be a grand unified theory (GUT) consisting of all three fundamental interactions.

Through all those victorious years till now, the general relativity has been an almighty nuisance. The theory refuses to consistently combine with the standard model of elementary particles. In the last 80 years, physicists couldn’t even develop a quantized version of gravity, let alone merge it with other fundamental interactions to make a theory of everything. Now, at the bottommost of the foundations of physics, we have two extremely successful but contrary theories: the standard model describing the microscopic world and the general relativity describing the universe at the largest scales.

String theory was initially developed to describe the strong nuclear interaction, but another theory - quantum chromodynamics – did the job perfectly. In the mid-1970s, physicists noticed that the strings, despite the inglorious birth, have an exciting feature resembling an exchanging force just like gravity. So the strings were revived as a promising idea for a theory of everything.

String theory “postulates that the basic entities of matter are not just point-like particles like electrons, but also extended objects like strings,” Vafa says. However, the string-like substructures have to inhabit a world that has way more than three dimensions. Do not look around for those extra dimensions; they are of a finite size or so “compactified” we cannot see them. For mathematical consistency, early string theories required a space-time of 26 dimensions which then, by introducing the supersymmetry, the number reduced to 10. “String theory is best understood in situations where we have a symmetry called `supersymmetry` which posits that particles come in pairs: for every boson, there is a fermion,” Vafa says.

In the mid-1980s, there were five string theories, all in 10 dimensions, all supersymmetric, and all including gravitation. Then in the mid-1990s, a number of physicists, in particular Edward Witten, one of the greatest names in the history of string theory who was Vafa’s thesis supervisor in 1985 at Princeton University, introduced an 11-dimensional theory, called M-theory, encompassing all early string theories. However, M-theory was ill-defined and has not lived up to the expectations, prompting Vafa to develop new compactifications of string theory, such as F-theory (originally in 1996). However, F-theory was not to fix a problem of M-theory. By introducing F-theory, Vafa described a different corner of string landscape from M-theory that has proven to be rather important.

In string theory, different compactifications lead to different solutions; each describes a unique universe with a unique set of elementary particles and fundamental interactions. The collection of the possible solutions, which is called “landscape,” is immensely huge. The number of solutions is commonly thought to be $10^{500}$ but could be insanely higher ($10^{5000}$).

Some string theorists tried to tackle the problem by connecting the theory to our universe’s known properties – elementary particles and fundamental interactions. However, in the past two decades, F-theory has allowed physicists to try a different approach. Vafa has shown “how topological and geometric properties of extra dimensions in string theory can translate to physical properties in observed dimensions.” F-theory helped researchers to describe everything very geometrically. Now they can use algebraic techniques to tackle geometric problems—to analyze the various ways of compactifying extra dimensions in F-theory and to find solutions. The geometry ‘language’ is the key feature of F-theory and turned it into a very powerful framework.

Vafa’s contribution to the field is not limited to F-theory; he worked on formal aspects of the theory, including the discovery of duality symmetries and its elucidation. In the mid-1990s, Vafa and his colleague, Andy Strominger, showed that the entropy of black holes predicted by Bekenstein and Hawking can be derived from a deeper perspective in string theory as extended objects wrapped around extra dimensions of space. The result was considered the first clear demonstration of the principle of holography in a competing theory of quantum gravity. “This was one of the first non-trivial confirmations of string theory which showed the importance of both the extra dimensions as well as the extended nature of fundamental objects in string theory,” he says.

Vafa has initiated the Swampland program in recent years, showing how quantum gravitational consistency puts severe restrictions on consistent quantum theories. The term “swampland,” which he coined in 2005, refers to those physical theories that are not compatible with string theory. He proposed swampland as a way for physicists to wade into the immense landscape of solutions and rule some large acreage of the landscape as physically inconsistent.

Vafa believes despite the immensity of the landscape of solutions, there is a unique solution that matches our universe. “I bet there is exactly one, but to pinpoint this is not going to be easy,” he says.

String theory has often been criticized for just providing abstract mathematical results and making no measurable predictions. Vafa admits that the magnitude of technological difficulty to overcome in connecting string theory to experiments is currently beyond resolution, but “this should not be viewed as a weakness in the development of string theory,” he says. “The theoretical progress we have made in string theory is one of the most remarkable achievements in the history of science,” he believes. “Of course, we still need to understand more deeply what string theory is, and this will require many more decades to develop. When the dust settles, we would likely end up revolutionizing many branches of physics and mathematics.”
Legend has it that an apple fall on Newton’s head inspired him to formulate the laws of gravity. Regardless of the truth behind it, this is more a story of being curious than a story of being lucky. As Albert Einstein once said, “The important thing is not to stop questioning. Curiosity has its own reason for existence.” After all, such a moment has probably happened to everybody as it happened to Cumrun Vafa, Hollis Professor of Mathematics and Natural Philosophy at Harvard University. “When I was 7 or 8 years old, I was wondering why the moon doesn’t fall on the ground,” he remembers. No one answered the question for him, but he says that was not important. “What bothered me was not that I couldn’t get a good answer but that it didn’t bother anyone else.” Perhaps, because of his appreciation for wonderer spirits, Vafa decided to donate the monetary award of Mustafa (pbuh) Prize to help those who do bother by such questions. He asked the Mustafa Science and Technology Foundation (MSTF) to direct the entire financial reward of his prize to form the seed fund to create an International Research Institute for Fundamental Physics located in Iran.

He, of course, is one of the few who kept his sense of curiosity and wonder alive all through his life. He never stopped asking hard questions about the nature of the universe and remained curious as he was in childhood. “Where do we come from? What are the fundamental laws of nature? What is everything made of? Can we have a simple description of everything? These are the kind of questions which drew me to science,” he says.

Now, in the fourth decade of his career, Vafa is wrestling with the most challenging questions about the foundations of reality, questions about the nature of gravity and matter at the most fundamental level. Somehow, as a leading string theorist, he is still pursuing his childhood questions about moon with an approach that also has roots in his childhood and early education.

Vafa vividly remembers when his teacher, Mrs. Sadighi, taught them the concepts of height, width, and depth for the first time in the third grade in primary school. “I remember asking myself why do we have exactly three of these things? Why not more or less than three? In other words, in my primitive way, I was wondering why the space is three-dimensional.” It seems just three dimensions were never enough for Vafa, neither in childhood nor now. Many years later, he just happened to be the founder of F-theory, a branch of string theory with 12 dimensions.

The most critical feature of the F-theory is its geometrical language that turned it into a very powerful framework. F-theory helped researchers to describe everything very geometrically. It seems the geometry is Vafa’s personal niche, a hometown that he knows all its backdoors and shortcuts.
high school, he got really excited about studying geometry. The idea that simple logical deduction from Euclidean axioms can shed light on the properties of circles and triangles was satisfying for him. “That one could draw an auxiliary line to solve an otherwise difficult geometry problem was like a fun game to play. I had a lot of pleasant hours with my friends in high school where we spent on proving geometry statements,” he says. However, as a high school student, he never thought of his future as a scientist. “At the time, trying to become a scientist was not viewed as a very ambitious career objective! It was only later, in university, where my love for science led me to decide to focus on mathematics and physics and finally in graduate work mainly on physics,” he says.

Vafa’s enthusiasm for science came about in the early years of his high school education when he saw one of his cousins doing his physics in the last year of high school. “He was doing calculations on a piece of paper, and I asked him what he was trying to accomplish. He explained to me that by the calculation, he is trying to find out if you throw a ball in the air at a given angle with a given speed where it will hit the ground,” he remembers. He was shocked that it was possible to use mathematics to answer such a question. That one can predict what will happen to things moving around us by logical reasoning. “This connection between pure thought, in the form of mathematics, and its application in explaining reality was what made a long-lasting impression in my mind,” he says.

Vafa attended the prestigious Alborz High School in Tehran. It was the part of his life that his associates had a significant role in the path he finally chose for his career. “Alborz high school classmates, Principal, Dr. Mojtahedi, and other teachers had an important influence on me as I grew up while learning new subjects,” he says.

Vafa is world-renowned for his groundbreaking works in string theory and the mathematical technology needed to explore this field. He is one of the founders of the duality revolution in string theory, which has reshaped our understanding of the universe’s fundamental laws.

However, reaching such a position needs more than just curiosity and passion. Vafa always has been a hardworking person. Later in high school, he started to study his own aspects of Maxwell’s theory of electricity and magnetism. Then he studied Einstein’s theory of special relativity which he found beyond belief at the time. “Phenomena predicted by Einstein’s theory, such as contraction of lengths or dilation of time, were, on the one hand, mind-boggling and on the other quite magical,” he says. In fact, many of the ideas of special relativity could be illustrated using Euclidean geometry. Those fascinating thoughts played very nicely with his enthusiasm for geometry.

In 1977 Vafa went to the USA as an undergraduate at the Massachusetts Institute of Technology (MIT), where he got his bachelor’s degree in math and physics as a double major. For graduate work, he went to Princeton, where he earned his Ph.D. in Physics in 1985. He then became a junior fellow at Harvard, where he has been a professor of physics for more than three decades. In 2018, he was officially appointed the Hollis Professor of Mathematics and Natural Philosophy in the Physics Department at Harvard University. This endowed professorship, established in 1712, is the second oldest chair at Harvard and the oldest chair in science in all of the United States. Vafa is the 15th incumbent of the chair through its history of more than 300 years.

Vafa enjoys art, music, poetry, culture, and philosophy when he is not doing physics. “Listening to music and especially Persian music is very relaxing and inspiring for me,” he says. His daily swim is also a source of balance for him as an occasion to float freely as if in outer space and think freely about everything or maybe a “theory of everything.” However, he says, above all, he enjoys spending time with his family and friends. He believes humanity, kindness, and bonds with his family and friends are those aspects of life he cherishes most. “I was fortunate to be living in a family compound in Shemiran, surrounded by relatives, nature, tall trees, and a peaceful environment. I remember the interesting stories my grandmother would share with us while running around in our compound — Baagh-e Vafa. The beautiful sight of the Alborz Mountain is imprinted in my mind from my viewing of it when I was a child, and thinking of it still brings back good memories,” he says. “I have been very fortunate to have had a very happy childhood. Raised by kind and caring parents, with two protective and fun brothers, one older and one younger.”

Vafa believes many people, from his parents to and friends to his teachers and professors played key roles in his life and career. “But perhaps, if I were to single out one person, it would be my wife, Afarin Sadr, who has had the most impact on who I am today. And of course, our children - Farzan, Keyon, and Neekon - who have been an inspiration for me.”
Prof. M. Zahid Hasan
The 2021 Mustafa\textsuperscript{(pbuh)} Prize Laureate

Designation: Eugene Higgins Professor of Physics, Princeton University
Date of birth: 1971
Place of birth: Bangladesh
Work: Weyl fermion semimetals
Field of the Prize: Quantum Physics
For so many years, topology was considered to have no or little practical value. Even mathematicians did not apply it to any serious problems in a serious way for a long time. For most of us, topology is nothing more than mind-boggling games with exotic geometrical objects like the Möbius strip – a loop made by twisting a ribbon once and gluing the ends together – which has only one surface and one edge. If you cut the Möbius strip lengthwise, you will get one larger loop instead of two loops of the same size. In other words, if you start to walk on a Möbius strip, after a $360^\circ$ turn, you will find yourself on the opposite side of the start point, so it takes another $360^\circ$ turn to return to where you start.

Another thing with the fascinating world of topology is that everything could morph into another geometrical object. The fine details of structures don’t matter in this world: a coffee mug morphs into a doughnut, whereas a glass morphs into a ball. This play-doh way of looking at things often has little connection to our daily lives. However, since the last decades of the 20th-century, topology started to appear in surprising places, from digital photographs, bank transactions, and biology to physics. Significantly, the marriage of topology and physics in the 21st century has proven to be highly fruitful. “We are in the middle of a topological revolution in physics, for sure,” Mohammad Zahid Hasan, the Eugene Higgins Professor of Physics at Princeton University, says. Hasan and his team had a key role in the flourishing development of this field.

Some of the most fundamental features of subatomic particles turned to be topological at their heart. Consider the electron spin, which could be pointed up or down. Counter-intuitively, a $360^\circ$ rotation will not return the particle to its original state. In the strange world of quantum physics, an electron is not just a particle and can also be described as a wave function, and a $360^\circ$ rotation just shifts the crests and troughs of the wave. Therefore bringing an electron back to its initial state needs another complete turn. Does it sound familiar? Yes, if you are thinking of a Möbius strip. In fact, this is not just an analogy; it seems each electron does contain a tiny Möbius strip.

In the 1980s, some theorists began to suspect that a surprising newly discovered phenomenon called the quantum Hall effect might have a topological root. According to this effect, the electrical resistance of a single-atom-thick layer of a crystal changes in discrete steps. More importantly, temperature change or the crystal impurities don’t affect the resistance. “Such robustness was unheard of, and it is one of the key attributes of topological states that physicists are now eager to exploit,” Hasan says.

Instead of the Möbius strip in the case of electron’s spin, physicists revealed the topology of the quantum hall effect as the surface of a doughnut. Until the mid-2000s, physicists considered the quantum hall effect and other topological effects peculiar because they have been seen only in the presence of intensive magnetic fields. However, they realized if an insulator is composed of heavy elements, it is
Such as ultrafast transistors or new kinds of quantum electronics and lasers. Breakthroughs in quasiparticles that act like Weyl fermions. Weyl fermion discovery named Top Ten. Quasiparticles, which are massless, including quarks, electrons, and neutrinos, have some mass. However, Hasan calculated that topological effects inside crystals of tantalum arsenide should create massless quasiparticles that act like Weyl fermions. Weyl fermion discovery named Top Ten Breakthrough of 2015 by Physics World. Being massless means this quasiparticle can move through a material faster than ordinary electrical currents and find applications such as ultrafast transistors or new kinds of quantum electronics and lasers. Hasan has also made essential contributions in topological phase transitions, topological magnets, topological superconductors, and Kagome materials. Kagome lattices are formed by a network of corner-sharing triangles. When electrons are placed on such lattices, they exhibit several strange phenomena. The most striking of them is that some electrons behave as if they are massless.

When kagome lattice materials are magnetized, these massless electrons behave as if they are in a topological insulator. This is what makes them very interesting. “We are exploring kagome lattice materials in search of new types of topological insulators, especially looking for the ones that may remain topological at room temperature,” Hasan says. “Superconductivity on kagome lattices may be topological, so such materials may provide a new platform for qubits (quantum computing).” Hasan believes his research field is primarily discovery-driven, not application-driven. “Once we discover something unexpected, we try to explore it for deeper understanding.” However, finding pathways to develop applications of topological materials is always a shorter-term goal. There are two primary directions in this case: One is to discover a topological magnet that may work at room temperature and develop it further to make a low dissipation device. The other direction is to discover a topological superconductor and optimize it for quantum braiding operation for creating a functional topological qubit that is naturally fault-tolerant.

Hasan and his team are currently working on both directions, with some promising results published this year. “I tend to think of the field as primarily discovery-driven, and the biggest breakthrough may and likely will come unexpectedly, as we continue to pursue existing research directions,” he says. However, by exploring kagome lattice materials, it seems they are on the verge of another groundbreaking discovery.

Physicists hope that topological materials could eventually find applications in faster, more efficient computer chips or fanciful quantum computers. But the real reward of topological physics is a deeper understanding of the nature of matter itself. “I have long thought of ways to use topological materials to make analogs of black holes or wormholes in the lab but did not get a chance to dedicate to these ideas,” Hasan says. “Emergent phenomena in topological physics are probably all around us, even in a piece of rock.” He recalls a poet of William Blake which aptly describes his research endeavors:

To see a World in a Grain of Sand
And a Heaven in a Wild Flower
Hold Infinity in the palm of your hand
And Eternity in an hour

Thanks to the unusual mathematics that governs their behavior, in topological material, electrons can form certain states in which they collectively behave as a single elementary particle. These “quasiparticle” states may have properties not present in any known particle or even mimic particles that are not discovered yet. The major excitement was in 2015 when Hasan experimentally discovered one of the most-wanted quasiparticles in a topological semimetal: Weyl fermion, a massless fermion conjectured initially in the 1920s by the mathematician Hermann Weyl.

According to the standard model of elementary particles, all known fermions, including quarks, electrons, and neutrinos, have some mass. However, Hasan calculated that topological effects inside crystals of tantalum arsenide should create massless quasiparticles that act like Weyl fermions. Weyl fermion discovery named Top Ten Breakthrough of 2015 by Physics World. Being massless means this quasiparticle can move through a material faster than ordinary electrical currents and find applications such as ultrafast transistors or new kinds of quantum electronics and lasers.

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While studying a bismuth-containing thermoelectric material by a synchrotron facility at the Department of Energy’s Lawrence Berkeley National Laboratory (Berkeley Lab), physicist M. Zahid Hasan of Princeton University noticed that something was interfering with the electrons’ behavior inside the material. He and his team also noticed that they have observed the same unusual interference more than a decade ago during a similar experiment with the same material.

At first, they saw the interference as a problem. However, around 2007 after doing more experiments and gaining some understanding of the theory related to his team’s observations, Hasan realized that this obstruction was actually a discovery: topological insulator. A groundbreaking discovery that triggered a revolution in quantum material science that continues today and could someday lead to new generations of electronics and technologies.

Trying to get a theoretical insight about the effect, Hasan struck up a conversation with some theoretical physicists, including a fellow professor, Duncan Haldane. “At that point, I was not aware of the theoretical predictions,” he says. Through their discussions about the theoretical works, it turned out some of them date back several decades. However, those theoretical works did not provide many clues in finding the effect in the materials exhibiting this phenomenon. Hasan found out the only way to tackle the problem is by combining the fields of quantum theory, particle physics, and complex mathematics. “I had to translate all of the abstract math into these experiments,” he says. “It was like translating from a foreign language.”

In 2016, Haldane and two other physicists won the Nobel Prize in Physics for their theoretical discoveries of topological phases of matter. At the time Nobel Prize announcement, Haldane said that in his first paper about such materials, he had mentioned: “this is unlikely to be anything anyone could make.” “My work sat around as an interesting toy model for a very long time—no one quite knew what to do with it.” In its supporting materials for the prize, the Nobel Committee had cited early experiments by Hasan’s team on materials exhibiting topological insulator phases.

Hassan was born and brought up in Dhaka, Bangladesh, in 1971. “As a child, I have been curious, adventurous, dreamer, and naturally driven to achieve goals.” He was a voracious reader, but his first wonder about science came about by playing with a navigation compass. “By playing with it, I became interested to learn the way it works. Something invisible pulling compass needle along a line - an invisible force at play,” he says. Trying to figure out the mystery, Hasan broke the compass into pieces. It seems the rule...
of the game remained the same for him today. “There was this mysterious and invariant force at play - and this same sense of mystery and search for the underlying fundamental law of nature seems to continue to drive my research today,” he says.

Growing up, Hasan was nowhere near sure about his passion for science. He was seriously interested in entirely different things like creative writing, poetry, art, and architecture with a drive towards aesthetics. “Over time, I seem to have developed an interest in more abstract arts like mathematics and physics.” However he believes, he is driven by the inner aesthetics of the interplay between physics and mathematics to describe nature. “I had a difficult time choosing between creative writing or arts and fundamental science. He even attended some art school for some time and wrote for magazines.

In college, Hasan had the chance to take the quantum mechanics lessons from Steven Weinberg, theoretical physicist Nobel Prize laureate, at the University of Texas at Austin. Through those classes, he was fascinated by the beautiful mathematics of the angular momentum of spins. “Much of what I do today is about understanding how electrons move through complex arrays of spins in novel materials using high-energy scattering techniques,” he says. However, his interest in condensed-matter quantum physics grew during his graduate at Stanford University, where he obtained his Ph.D. in 2002.

Despite his theoretical background, he went for an experimentally challenging thesis in high-temperature superconductivity and high-energy accelerator-based spectroscopy. As a fourth-year graduate student at Stanford, he led an international collaboration with researchers from some top research institutions and labs that showed the feasibility of performing a new class of high-energy scattering experiments in condensed-mater physics.

Eventually, in 2002, he joined Princeton University, where he has held the Eugene Higgins endowed professorship since 2017. Throughout his career, Hasan has been working in many top research institutions and labs. “I think a combination of traits made it possible to utilize, operate and collaborate at many top institutions. First, it comes with proposing a great new idea for projects that others get quickly excited about. Second, good work ethics and clarity of expectations from all parties. Third, high level of scientific productivity. All these factors contribute to maintain collaborations and create new opportunities in new environments,” he says.

Hasan describes himself as a curious and adventurous person and, at the same time, reflective and meditative, always searching for more profound and more significant meaning. “What are the quantum laws of nature that govern the physical property of complex materials? This sense of unraveling a mystery - that a tangible universe can be described by invisible forces and abstract rules inspired me to pursue physics.” However, when he is not drowned in physical thoughts, he directs his curiosity toward other subjects like the history of ideas and civilizations, including the history of Abrahamic faiths and cultures and their impacts on the history of the world. Besides exploring art and architecture, he is also into music, especially the Sufi genre.

He says his parents played pivotal roles in becoming the person he is now. He remembers the day his father brought home a fossilized piece of coral when he was 5 or 6 years old. “I was fascinated by the fact that such beautiful creatures grow deep under the ocean, where I have never seen.” Then he tried to learn more about deep-sea corals and creatures by reading books, but he eagerly wanted to see the ocean itself. Imaging the existence of corals under the oceans formed a sense of mystery and an aesthetic drive in him that turned into a passion for adventure.

The following year his father took him to Cox’s Bazar – a beach town by the Bay of Bengal about 200 miles south of Dhaka – on a family vacation. That was an amazing experience – Cox’s Bazar seashore is one of the longest and most beautiful ones in the world, but he was not entirely happy! “I wanted to see a bigger and more powerful ocean. So my father took my mother and me another 100 miles down the beach and rented a high-power speedboat.”

They started heading off towards the Indian Ocean. “I can still vividly recall the waves we were surfing through as we headed south,” Hasan says. Of course, they did not make it to the Indian Ocean, but “it gave me a sense of adventure and a sense that it is worth asking big questions – Is there a bigger ocean? What is beyond the ocean?”

“The event is perhaps my greatest memory with parents. This event shows how my father helped instill a sense of adventure in me and let me pursue and nurture it. That was how I learned to ask big questions and took on real adventures to answer them.” Now, Hasan himself is a father and says he will be happy to support his children in whatever they choose to do later in life, but “I think we’ll definitely get them a fancy compass for their birthday.”
Prof. Mohamed El. Sayegh
The 2021 Mustafa\textsuperscript{(pbug)} Prize Laureate from Islamic countries

Designation: Professor of Medicine and Immunology, American University of Beirut
Date of birth: 1959
Place of birth: Lebanon
Work: Novel Therapies to Improve Renal and Cardiac Allograft Outcomes
Field of the Prize: Medicine
Struggle for Tolerance in a Hostile World

Search for immunologic tolerance to avoid transplant rejection

Some while ago, a friend of Mohamed Sayegh, “a nephrologist, a colleague and a friend of the family,” passed away after the complications of a kidney graft he had received from his wife many years ago. It seems that rejection, acute or chronic, is the final fate of any transplant, and the recipient should expect it sooner or later.

Sayegh is “interested in understanding the mechanism of transplant rejection and how to fool the immune system to accept the transplant, a term called immunologic tolerance.” His team has even used transgenic animals to study the mechanism of rejection and tolerance. Sayegh is mostly focused on promoting research at the regional level nowadays.

Donating one of your kidneys does not shorten your life expectancy, but it may add up to 20 happy years to the lifespan of those with kidney failure. It is the most promising, and most of the time the only, therapeutic measure for a so-called end-stage renal patient with irremediably dysfunctional kidneys.

The American surgeon Joseph Murray (1921-1990) performed the first successful kidney transplant in 1954, which brought him the 1990 Nobel Prize in Physiology or Medicine. In that revolutionary transplant surgery, the recipient received a kidney from his twin brother, which gave him another eight long years to live.

This so-called isograft is a type of transplant in which the donor and the recipient are not the same but are genetically identical. Isograft is technically a kind of allograft, or a graft from another person, but is immunologically similar to autograft, or a graft from the same person, in that it does not trigger an immune response.

However, not everyone has a twin willing to donate a kidney to his/her sibling, let alone for other organs that have no extra copy that could be spared. Limiting the kidney grafts supply to a diminished source of genetically identical twins would not answer the huge demand for organ or tissue transplants.

Today, about 100,000 kidney transplant surgeries are performed worldwide every year, up to %60 of all transplant surgeries followed by liver, heart, and lung, respectively. Though the kidney transplant is the most common transplant surgery, it has the longest waiting list, too, with more than 5 people for each available kidney.

The main hurdle that should be passed somehow is a problem called histocompatibility, or tissue compatibility, having similar genetics for cell surface protein. Immune cells check these proteins to discern if the cells carrying them on their surfaces belong to their own body or an invading
foreign organism. In the latter case, the graft would be rejected by the recipient's immune system.

The rejected graft would be destroyed and lose its function. Routine clinical procedures include testing a potential recipient's compatibility to an available organ and using immunosuppressant drugs.

Let us have a look at the immunology of transplants. The alloresponse -- in which the prefix “allo-” from Greek means other and different -- is the immune system response to different cells and tissues belonging to other individuals. For such a response, the immune system must first recognize the foreign or allogenic molecules by a mechanism called allorecognition, short for alloantigen recognition. An organism defends itself against any potential invader through this phenomenon that has been observed in all vertebrates and other multicellular animals. The recognition is done using molecules called antigens on the surface of the non-self cells.

There is much polymorphism in these surface proteins called the major histocompatibility complex (MHC) molecules. If the molecules are genetically dissimilar, they are immunologically incompatible and will be recognized by the recipient's immune system. As the term histocompatibility implies, MHCs were first discovered in the process of tissue transplantation between individuals with incompatible genetics: The donor cells had MHCs on their surfaces that were incompatible with host cells.

In humans, T-cells or T lymphocytes, a kind of white blood cells, are in charge of distinguishing between self and non-self cells antigen. Allopeptides bound to MHC molecules are displayed on the surface of antigen-presenting cells (APCs) to be recognized by T-cells. In transplantation, T-cells recognize the foreign antigens of the donor's cells and react accordingly. This is where the graft rejection process begins. Even a minor incompatibility may provoke a strong reaction from host T-cells.

Recognition by T-cells takes place directly or indirectly, depending on the allograft characteristics. In the direct pathway, recipient T-cells recognize the allogeneic MHC molecules expressed by APCs of the donor as foreign. These cells that display non-self allogenic antigens -- MHC-peptide complex -- on their surface, exit the grafted organ soon after transplant and reach the host T-cells through the lymphatic system and teach them directly about their potential targets.

However, the recognition may occur indirectly when recipient T-cells recognize a self MHC molecule bound to a peptide with different amino acids. The alloantigens from graft are internalized, after engulfing surface proteins of donor cells by the recipient APCs, and then presenting them in the form of peptides on their MHC molecules. These “wrong” peptides, or allopeptides, will be presented on the recipient APCs, not the donor APCs, as is the case in the direct allorecognition.

Both direct and indirect allorecognition may be involved at the same time in allograft rejection. Direct allorecognition often leads to acute rejection of allografts soon after transplantation, while indirect allorecognition often contributes to chronic rejection in the long-term through damaging the graft with progressive loss of function that leads to graft loss finally.

The indirect pathway of allorecognition leading to chronic allograft rejection is the subject Sayegh and his colleagues have researched thoroughly in the past decades. They have devised, among others, a clinically useful novel assay that shows the occurrence risk of indirect allorecognition and chronic rejection in humans and then developed specific therapeutic strategies to prevent or interrupt this process.

For transplantation to be successful, the human leukocyte antigen (HLA) of the donor and the recipient must be the same, which is seldom the case. Even a minor HLA mismatch, which is actually unavoidable, leads to allorecognition and increases the risk of graft rejection. “We examined the response to incompatible HLA peptides as a predictor of chronic rejection,” Sayegh says.

Immunology is a hostile world; a cell eats cell world, to use Thomas Hobbes analogy. It takes a savior and brilliant approach to bring tolerance to such a milieu. Sayegh believes that the most critical question in the field is “the mechanism of immunologic tolerance and how to fool the immune system to accept a foreign organ without rejection and immunosuppression.” This would revolutionize tissue and organ transplantation. “This is still elusive,” he says.
As Paracelsus, the Swiss medieval physician, said quite rightly, “medicine is not merely a science but an art. The character of the physician may act more powerfully upon the patient than the drugs employed.” This character, or a physician’s influence on the patient or his/her co-workers, makes a huge difference. This is why a medical student should improve his/her leadership skills besides learning the clinical aspects of care.

Mohamed El. Sayegh plans to write a book on leadership. “I spent the last 11 years of my life as dean of medical school and as an executive in healthcare. I learned a lot about leadership,” he says. He is indeed an eminent leader who has served the last decade as the Dean of the Faculty of Medicine and Executive Vice President of Medicine and Global Strategy at the American University of Beirut (AUB), Lebanon. “After spending 22 years of my academic career as a physician-scientist, this senior level leadership role shaped the next phase of my academic career. I was responsible for around 5,000 health care professionals,” he says.

Leaders’ performance comes into focus when the situation is of an emergency, and it’s most common to be stuck in an emergency when you choose medicine as your career. Anyone who witnessed a surgery gone awry in an operating room appreciates the value of an efficient leadership. In medical practice leaders, at any level of the organizational chart, can take the group performance to higher levels of excellence by inspiring the staff and encouraging them. They know how to manage the team to stay on a mission in a stressful situation.

Good leadership is based on the wisdom derived from many years of actual failures and successes in the field. “Good leadership is about team formation, caring, mentoring, and creating future leaders,” Sayegh says. He thinks the most essential skills a leader should possess to maximize group performance include “teamwork, functional working groups rather than rigid hierarchy, and investing in the Human Resources.”

He plans to write a book on medical leadership, with “The One of a Kind Leader” as its title, to emphasize that leadership, first of all, is about creating future leaders. It’s not surprising that he likes a quote from the American writer Ralph Waldo Emerson that “Do not go where the path may lead. Go instead where there is no path and leave a trail.”

Mohamed H. Sayegh is the 10th and the last child of a large family living in Beirut. “I grew up mostly with my nephews and nieces,” he says. He was a city boy accustomed to urban lifestyle but enjoyed picnics and outings with family and friends or through school planning.

Sciences, History, and Arabic literature were his favorite subjects in
school. Arabic poetry is still his favorite pastime. The white medical gown, however, was the future garment he envisage himself in. “I grew up in a family where my older brother was a doctor. When I was young he was in the States and he was our idol. I always knew I wanted to be a physician but was not sure about research and discovery until later.” He says.

Mohamed H. Sayegh, following the example of his elder brother, moved to the United States, after receiving a medical doctorate from the American University of Beirut in 1984. In the United States, he first completed his Internal Medicine residency at Cleveland Clinic Foundation in Ohio by 1987, and then his clinical fellowship in Renal Medicine and Transplantation Immunology at Harvard Medical School and the Brigham and Women’s Hospital in Boston, by 1990. He taught in Harvard Medical School, from 1990 to 2009, where he ascended to Full Professor of Medicine and endowed a chair in Transplantation Medicine.

In the July of 2009, Sayegh returned to his alma mater, the American University of Beirut, as the dean of the Faculty of Medicine and the Vice President for Medical Affairs. Besides this, he holds many executive positions and is serving as a special advisor to several high-profile projects.

Sayegh is the recipient of many prizes, awards, and honors in the past four decades including a mentoring award from the American Society of Transplantation in 2008 and is a member of many learned societies such as the American Society of Transplantation which served as its president from 2000 to 2001.

Sayegh is a prominent researcher and a world-renowned pioneer in fields concerning nephrology, organ transplantation, and transplantation immunology. “When I was doing my internal medicine residency in Cleveland I was intrigued about research. I got interested in transplantation immunology,” he says.

Sayegh, a member of many high-impact medical journals editorial boards, has helped these fields proceed through his contributions such as journal publications, book chapters, and a few textbooks.

Sayegh is pursuing an ambitious plan in the American University of Beirut Medical Center, known as the AUBMC 2020 Vision, which has reversed the brain drain process in the last decade by bringing back more than two hundred Lebanese medical researchers from abroad.

Sayegh names his wife, Samia Khoury, as one of those persons who have the most significant influence on his career. Dr. Khoury is herself a professor at the American University of Beirut and a world expert on multiple sclerosis.

Sayegh thinks he owes much to his mentor at Harvard, the late Dr. Charles B. Carpenter (1921-1993). “Bernie had a big influence on me,” Sayegh says. Dr. Carpenter, or Bernie to those close to him, was a part of the team that performed the world’s first kidney transplant and a founding member of the American Society of Nephrology, and the American Society of Transplantation, among others. Carpenter, who has been described as a “true pathfinder in the field of transplantation and nephrology,” however, is mostly remembered as a great mentor to generations of leaders in the field – a niche Sayegh is determined to occupy.

Sayegh is a credible calm leader, one that listens patiently to those who come for advice. He is all that it takes to be a great mentor and through the years has trained many researchers who are now themselves leaders of renal transplant around the world. “Dr. Sayegh has shown leadership skills very early in his career. His colleagues always sought his advice and guidance. His greatest attribute is his mentorship. He has been a wonderful mentor to many people,” says Dr. Khoury.

Sayegh has made mentorship his trademark. He is the new Dr. Carpenter to the next generations. It seems the mentorship is something that even if can’t be taught, can at least be caught.
Prof. Yahya Tayalati

The 2021 Mustafa (pbuh) Prize Laureate from Islamic countries

Designation: Professor of Physics, University Mohammed V in Rabat
Date of birth: 1971
Place of birth: Morocco
Work: Observation of the Light by Light Scattering and the Search for Magnetic Monopoles
Field of the Prize: Theoretical and Particle Physics
What are we made up of? At the most fundamental level, one can ask the same question as what the universe is made up of. Currently, the standard model of particle physics is our best answer to the fascinating question. According to the standard model, all the matter in the universe, including galaxies, stars, planets, and even you, is made up of 25 elementary particles. The development of the standard model began in the 1960s and was completed mainly by the late 1970s. Besides the fermions and gauge bosons, there is only one more particle in the standard model: the Higgs boson, which gives masses to the other elementary particles.

Higgs boson was the last elementary particle to be discovered. However, it was proposed independently by several researchers in the early 1960s. After nearly half a century of particle-chasing, physicists hunted the elusive particle in 2012 at the Large Hadron Collider (LHC), the largest and by far the most powerful particle accelerator on earth. “By colliding protons at high energy and high luminosity, this powerful accelerator makes it possible to probe the matter on new scales and to thoroughly test the Standard Model,” says Yahya Tayalati, a physicist at University Mohammed V in Rabat, Morocco, who was involved in LHC project for two decades. The discovery slotted into place the final missing keystone of the standard model.

Through the victorious years of particle physics, researchers in other fields of physics have also tried their hands on the foundations of reality. In the 1930s, astrophysicists realized that galaxy clusters contain a lot more mass than all visible matter combined can possibly account for. Apparently, a new type of “dark matter” was needed to explain the observations. Since then, evidence of dark matter has piled up to the point that now no one doubts its existence. Still, no one knows what dark matter is made of. Astrophysicists say it is a type of particle that has no interaction with ordinary matter, a mysterious one that neither absorbs nor emits light. However, the horrifying fact is that dark matter is five times more abundant than visible matter.

In 1998, cosmologists surprisingly discovered that the expansion of the universe is accelerating. They can mathematically show that the mysterious accelerator, called “dark energy,” is nothing but the energy carried by empty space. Besides that, there is one more thing we know about dark energy for sure: 68 percent of the total matter-energy content of the universe consists of dark energy. In other words, we are living in a universe with a composition of 68% dark energy, 27% dark matter, and only 5% ordinary matter. All our knowledge about the building blocks of the matter is limited to that 5% ordinary matter.

Despite its enormous success, the standard model leaves several fundamental questions unanswered. “A major problem with the standard model is related to the origin of dark matter and dark energy, constituting nearly 95% of the energy density of the universe, remained totally unexplained, and the standard model fails at providing a viable candidate for the observed abundance of dark matter in the universe,” Tayalati says. However, this is not the only problem with the standard model. One of the most
fundamental questions left open by this model is the gravitational interaction, which is
totally ignored in the description of fundamental interactions. “All this and many other
arguments suggest that this model is only an effective theory of a more fundamental
model manifesting itself at higher energy,” he says.

Tayalati involvement with ATLAS, the largest general-purpose particle detector
experiment at LHC, goes back to the project’s early days. He spent twenty years of his
career in ATLAS, covering many topics ranging from hardware projects and detector
operations to software development and physics analysis and measurements. His first
involvement was the ATLAS Liquid Argon Presampler, in which he has contributed to
all steps related to the construction, commissioning, and operation of this subsystem.
The Presampler, which is used for photons and electrons detection, has proven to be very
efficient and it is now widely used in many ATLAS physics measurements.

One of the recent achievements of Tayalati and his colleagues in ATLAS collaboration
was the observation of Light-by-light (LbyL) scattering for the first time in 2019. This
process is completely forbidden in classical electrodynamics but appears in quantum
electrodynamics. The LbyL scattering is an extremely rare process which makes its
measurement very difficult and inaccessible. Many attempts with other devices have been
proposed without any success.

Regarding the ultra-peripheral high energy heavy-ion collisions at the LHC, the
probability of this process gets enhanced, and researchers found an excellent opportunity
to observe that. They hoped to detect the telltale signal with a simple topology of two
scattered photons at the final state while the heavy ions escape the collisions. Eventually,
using data collected by ATLAS, Tayalati and his colleagues reported 59 events while they
expected only 12 from the background, and this was interpreted as the first observation
of the LbyL scattering of photons.

They have also measured the probability of this process and what they obtained is
very close to the theoretical predictions. It was a clear demonstration of how LHC can
perfectly work as a photons collider. What makes this process very interesting is the fact
that scattered photons could couple to any new particle, providing a promising way to
probe physics beyond the standard model. “We in ATLAS explored the LbyL scattering
to search for axion-like particles, which is a great candidate to dark matter. The study
provides the most stringent limits to date on axion-like particle production,” Tayalati says.

Another fundamental question left unanswered by the standard model is about the
mass of neutrinos. Besides their unique properties, what makes them the favored particle
for many physicists, Tayalati is no exception, are their implications on cosmology and
astrophysics. Neutrinos are the messengers transmitting information from the early stages
of the universe. Detection of these long-time travelers could help in the understanding
of the evolution of the universe. Furthermore, measurements from neutrino telescopes
coupled to gravitation waves and photons detections have opened a new area of Multi-
Messengers astrophysics in recent years.

Tayalati started his career as an experimental high-energy physicist with a Ph.D.
degree from the University of Mohammed First, Oujda, Morocco. At that time, he
proposed a solution to one of the problems in neutrinos physics, which was the observed
deficit of neutrinos coming from the sun. Later he pursued the field by involvement in the
ANTARES project, a neutrino detector residing 2.5 km under the Mediterranean Sea. “I
have been involved in the early preparation and deployment of the ANTARES telescope,”
he says. Due to his efforts, Morocco officially joined this international collaboration
in 2011. Since then several students graduated with the ANTARES project. “I was the
convener of the exotic physics group and with the Moroccan students we derived the
strongest experimental limits on the existence of Magnetic Monopoles,” he says.

In recent years, Tayalati has started a new collaboration with KM3NeT, which is a
large research infrastructure, in construction with the technology and the knowledge
acquired from its predecessor ANTARES. “I convinced three universities in Morocco
to join this international effort and to form an Astroparticle cluster in Morocco,” he says.
This cluster allowed launching a pilot project, M1, to set up and operate a production line
of optical modules for the KM3NeT neutrino telescope in Morocco.

Before the LHC first run, many physicists hoped that this fascinating machine would
reveal some clues about what might lie beyond the standard model. However, everything
seems standard so far. Tayalati believes events beyond the standard model are quite rare,
so isolating and investigating those events needs a massive amount of data.

“Up to now, we have collected only 10% of data planned for the LHC program; this
was sufficient to constraint or to reject many exciting theoretical models that introduce
physics beyond the standard model. Certain versions of supersymmetry, for example, are
less and less plausible,” he says. However, he thinks it is very early to judge the situation,
and we have to wait for the subsequent runs.”

Tayalati believes the breakthrough will be “detecting a signal that can be interpreted
as a candidate for dark matter or graviton. This will open a huge challenge for both
experimenters and theorists to confirm such a discovery and interpret it within a
universal model.”
In the realm of experimental particle physics or high-energy physics, everything is oversized, sophisticated, and of course, expensive. A handful of countries can afford such large-scale infrastructures needed for running experiments in this field. Usually, developed countries or a consortium of them participate in the construction of the research infrastructure.

However, in 2017, thanks to the efforts of a dedicated physicist Morocco found a place among the leading countries that have a vital role in a large-scale international project: Cubic Kilometer Neutrino Telescope (KM3NeT). The contribution of the Moroccan team, led by Prof. Yahya Tayalati from the University Mohammed V in Rabat, is not only for the scientific exploitation but also for the project construction, which is entirely new. That was for the first time that a Moroccan - and even African - team contributed to constructing a particle detector.

This unprecedented cooperation with the Moroccan team was partly due to Tayalati’s background with Antoine Kouchner, spokesperson for the ANTARES Collaboration and coordinator of the ORCA-KM3NeT project in the 2000s. “I have known Prof. Tayalati for a very long time since he had come to France to do part of his studies during his doctoral thesis. This is how we met. We were both in the thesis together,” says Kouchner. The other reason behind this success was Tayalati’s doctoral thesis which he did on the ANTARES project – the KM3NeT predecessor – at the same time with Kouchner. Then afterward, they parted ways, and each lived their own scientific adventures. However, they remained in contact, and the idea of this cooperation came to life through their connection.

Tayalati already had the right expertise on the ANTARES project that he had acquired during his doctoral stay in France. “I have started my career as an experimental high-energy physicist with a Ph.D. degree from the University of Mohammed First, Oujda, Morocco,” he says. At the time, he proposed a solution to one of the problems in neutrinos physics. The first group of Oujda that joined the collaboration did not participate in constructing the first ANTARES project. But they participated in analyzing data in a specific sector related to the research of new physics. “I have been involved in the early preparation and deployment of the ANTARES telescope, and my effort allowed Morocco to join this international collaboration in 2011 officially. Since then, several students graduated with the ANTARES project,” Tayalati says.

The under-construction KM3NeT research infrastructure, which will be deployed at the bottom of the Mediterranean Sea at a depth of 3 kilometers, will host the next generation of neutrino detectors as part of a world effort to detect dark matter. This is the most important scientific collaboration in which Morocco was involved. “I convinced three universities in Morocco – The University Mohammed First in Oujda, The Cadi Ayyad University in Marrakesh, and my University in

An Unflagging Collaborator
YahYa Tayalati; an Intimate Profile
Rabat – to join KM3NeT collaboration and to form an Astroparticle cluster in Morocco,” Tayalaty says.

Even before the ANTARES KM3NeT, Tayalati had a great experience in working with extensive collaborations. After his thesis work, he began his career in ATLAS, one of the most significant collaborative efforts ever attempted in science, with over 5500 members, including physicists, engineers, technicians, students, and support staff worldwide. “My involvement with the ATLAS experiment at CERN (European Organization for Nuclear Research) includes more than 20 years of my career,” he says. The complexity of the underground ATLAS detector requires a tremendous amount of effort from all members of the collaboration. Operating the apparatus, collecting the data, and analyzing them involve almost everybody in this collaboration to different degrees. Each member in ATLAS has a direct or indirect contribution to every scientific publication, which has nearly 3000 scientific authors. “In the end, you feel you are always contributing to the overall ATLAS achievements,” he says.

What Tayalati has been doing through his career is much different from his childhood dream about his future profession. “I was fascinated by airplanes; I dreamed of being a pilot one day,” he says. “Like all Moroccans from my generation, I used to spend all weekend playing with my friends until late hours outside my parents’ home.” With no internet, computer games, and smartphones, they have to invent proper games with basic tools. “Some concepts of physics have a major role in those games,” he remembers. His education started in a Quranic School where he learned the first basics of rigor and discipline, two essential qualities for being successful in science as a collective enterprise. Later, in primary school, he got drawn to scientific subjects, while he was mostly interested in mathematics in high school.

Tayalati comes from a working-class family in Morocco. His father was a miner in a coal mine. “It is a tough job. He pushed my siblings and me to work hard for a better job than he had. He was illiterate but very aware of the importance of education in self-promoting. My father and the nature of his job had a big impact on me,” he says. The first time Tayalati left the country was to attend a school at ICTP (Abdus Salam International center of theoretical Physics in Trieste).

The journey had a significant impact on his life and career. It happened during the preparation of his master’s degree in one of the prestigious laboratories of theoretical physics in Morocco, which was officially connected to the ICTP. “I was very impressed by both the work of Prof. Abdus Salam on the standard model and deeply influenced by his personality,” he says. Abdus Salam’s efforts in developing sciences in the Muslim world through the different mobility programs he established at ICTP were really inspirational to him. “This was one of the major motivations that pushed me to this field.” Abdus Salam (1996-1926), a Pakistani theoretical physicist, was the only Muslim scientist who won a Nobel Prize in physics.

Tayalati describes his efforts in teaching different aspects of high-energy physics to get more students interested in this field as his most important contribution. “I’m someone that as scientist, researcher, teacher, and parent likes to combine all challenges and move and share my knowledge with my community for a better life,” he says. He decided to spend the monetary award of the Mustafa Prize helping his colleagues and student. “This award will come at the right time in my career to help me to get access to some materials that will be needed by the members of my group. And they will be proud to see it is going to be used for such purpose supporting the mobility of our Ph.D. students.”

In recent years, he participated in a global effort called “International Masterclasses,” aiming to prepare the next generation of researchers in high-energy physics. “Given that there is not enough information about research in the high-energy physics field. The Master classes usually present the first opportunity for high school students to be in direct contact with our activities,” he says. The program consists of an international day during which the more than 13 thousand 19-15 years old high school students in 60 countries come to one of about 225 nearby universities or research centers to learn what it is like being a particle physicist. “We have found that international Masterclasses usually raise a huge amount of interest among them, and many decide in the end to pursue this field,” he says.

Tayalati says once he is done with research, he wants to spend time with his family. “I am proud and grateful for my family, my wife, and my kids who always support me spending hours on my research. They understand my challenges in this field and the time I devote to research and traveling outside the country. I’m grateful for their patience and support.” When it comes to his bucket list, the top priority is initiating a new collaboration. “I wish I had time to get together many scientists – theorists and experimentalists – in different fields of high-energy and Astroparticle physics to set common goals for fundamental research.”
Prof. Muhammad Iqbal Choudhary

The 2021 Mustafa\(^{(p_buh)}\) Prize Laureate from Islamic countries

Designation: Director of ICCBS, University of Karachi
Date of birth: 1959
Place of birth: Pakistan
Work: Discovery of fascinating molecules with therapeutic applications
Field of the Prize: Bio-organic Chemistry
Are the plants called medicinal medicinally effective? Well, the market is full of all kinds of ‘medicinal’ plants material with glossy packages and charming brand names. But do they actually work? “Medicinal plants have been the basis of traditional medicines since antiquity, and in contemporary era have played a central role as sources of new drugs,” says Muhammad Iqbal Choudhary, a biochemist of International Center for Chemical and Biological Sciences (ICCBS) at the University Of Karachi, Pakistan.

Choudhary has tested many medicinal plants for their effectiveness. “As a chemist, I have been truly fascinated by the immense chemical diversity present in plants,” he says. With the modern tools of science, combined with traditional knowledge of their uses, medicinal plants can serve as a sustainable and rich source of new drugs against prevailing and emerging diseases.

With all of its romanticist elements, getting back to nature has become a lifestyle in recent decades throughout the world. Using traditional herbal formulations instead of so-called ‘chemical’ pharmaceuticals, which many consider a product of modern civilization depravities, is a conspicuous aspect of this movement that is not confined to the East; the herbal drugs are widely consumed in many developed countries.

There are between 50,000 and 80,000 flowering plant species used for their medicinal properties worldwide. Medicinal plants are generally prescribed for a wide range of health benefits, from breaking up the bladder stones and lowering blood pressure to reducing the risk of diverse cancers and even curing depression.

How do these claims stand the test of science? There are several valid techniques developed by phytochemists and pharmacologists to ascertain the efficacy of such herbal formulations. Have traditional herbal remedies in general stand to the claims of traditional medicine? Are these plants more promising than any other random plant for pharmaceutical research? Are herbal drugs safe? Are they effective? What is the optimal dosage? How about their side effects and/or interactions with other drugs?

“Our work and work of other scientists have firmly established the importance of medicinal plants as the most important source of new drug entities, and in many cases scientifically substantiated their traditional uses,” says Choudhary. “It is interesting that not all medicinal plants, used in traditional medicines, pass through the strict scientific criteria of safety, efficacy, and consistency. However, the success rate of finding ‘drug-like molecules’ from medicinal plants is disproportionately higher than the random screening of plant extracts or chemical libraries.”

Choudhary’s team has worked on many medicinal plants used in traditional medicines, and isolated several bioactive lead compounds or potential drugs. For example, they used pygmy groundcherry (Physalis minima) against Leishmaniasis, a tropical disease caused by a protozoan parasite that affects over 12 million people in 97 countries. They have also discovered potent antiepileptic natural products from a species of larkspur (Delphinium denudatum). They have then synthesized it in

Hunting Therapeutic Molecules in the Jungles of Traditional Medicine
Muhammad Iqbal Choudhary
tests herbal extracts at the crucible of modern science
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entire machinery of life. Their overexpression leads to the onset of innumerable
diseases. Enzymes must bind to a specific molecule, called substrate, to begin or
accelerate a chemical reaction. Then to decrease or even stop an enzyme activity, you
have to use a molecule that binds to the enzyme and prevents it from binding to the
substrate. This is called the enzyme inhibition process. These molecules, known as
enzyme inhibitors, work through several mechanisms, including a competition with
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equally important enzymes, which can be used to halt the molecular cascade involved in
the enzyme-related disorders, such as Alzheimer's diseases, diabetes, and ER+ breast
cancer," says Choudhary. As a result, several new classes of lead molecules were
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The goal is to reduce as much as possible the final product that would otherwise
be produced. And when the final product of the reaction facilitated by the enzyme is
an unwanted detrimental compound leading to a physiological condition, its inhibitor
may be called a drug. Many molecules considered as a drug, such as erythromycin
antibiotic, are actually enzyme inhibitors blocking an enzyme's activity to destroy a
pathogen or tip a physiological balance to our favor.

One of the internationally recognized discoveries of Choudhary's research group
is urease inhibitors. The inhibitors of the enzyme urease, for example, have been used
as anti-ulcer drugs. The urease, produced profusely by the bacterium Helicobacter
pylori in the human stomach, increase the acidity of the stomach mucosal lining by
breaking down the urea molecule (its substrate). The increased acidity cut through the
lining and develop to gastritis or stomach ulcer which in some cases may progress to
cancer. Anything that can block the urease is thus a potential drug for ulcers.

Fortunately, various compounds could be used as urease inhibitors, but should we
prescribe them as oral agents to patients with stomach ulcers? Does it matter that these
substances are of plant or bacterial origin or have been synthesized? What about side
effects? Is it specific enough to not bind to proteins other than the target enzyme? What
factors make an enzyme inhibitor an effective drug? These are questions Choudhary's
research addresses.

Choudhary's research interest has been centered on finding the biological activities of
natural and synthetic compounds. His team's research projects are focused on
metabolic and neurological disorders. “We aim to find solutions to the unsolved
and prevailing health challenges,” he says. They have successfully employed a deep
understanding of chemical principles and biological processes in discovering a large
number of fascinating molecules with potential therapeutic applications. The quality
of their research is internationally recognized and has also attracted the attention of
leading pharmaceutical industries.

One of the most fascinating groups of molecules is enzymes that modulate the
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“Our research group has studied and discovered novel inhibitors of clinically
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The biological activity of a plant is based on the phytochemicals it possesses. These
chemicals are biosynthesized by plants in response to biotic and abiotic stresses, and
thus the same plant collected in different seasons and from different regions may have
huge differences in its phytochemical profile and biological effects. This makes the
entire field of botanicals and phytopharmaceuticals rather complex and uncertain.

"How to ensure that we correctly measure the quantities of thousands of these
chemicals in plant extracts is one of the most enduring questions in my field of
research. Despite major advances in spectroscopy, genomics, and metabolomics,
the answer to this question is yet to be found," says Choudhary. The answer to this
problem will indeed be a breakthrough in the field. "Our group plan to develop rapid
untargeted metabolomic methods which can compare the metabolomes of control
plant (proven to be biologically active) with test plant," he says.

Choudhary has a dream: to establish a multidisciplinary International Center for
Tropical and Neglected Diseases. He wishes to have the time and energy to complete
this mission soon. "This center will fulfill my dream of creating a world-class research
facility with sustainable funding and global network of satellite laboratories to study
the causes and treatment of innumerable tropical and neglected diseases," he says.
Neglected because these poor man diseases are "not in the priorities" of the global
pharmaceutical business, even though they affect the lives of billions of people in the
most impoverished regions of the world.
That everything in the world, living or not, is made of the same material makes a huge difference in your worldview. When you realize that absolutely everything, from the humble mold to higher mammals like us, is constituted of not but the same molecules and atoms, the world looks a lot more meaningful. After all, it seems our body has no difficulty ingesting and digests other organisms and turns them into flesh.

This view of the world pushes you toward a sense of integration; it puts rationality against mysticism. “Rational beliefs bring us closer to getting good results in the real world,” as said by Albert Ellis, the American psychologist. And good results are what could be found in profusion among the plenty of works that have been done by Muhammad Iqbal Choudhary, 62 years old Pakistani organic chemist.

“Chemistry has been my interest since my school days. Even at a tender age, I had a profound appreciation that everything around us is a manifestation of tiny molecules. From complexion to thoughts, aging to diseases are all due to biochemicals our bodies produce,” he says.

During his Master’s studies, he was one curious soul, always looking for an explanation of everything in chemistry. His obsession with chemistry guided him towards Prof. Atta-ur-Rahman FRS, who provided him with high-quality research supervision. Rahman, the renowned Pakistani organic chemist, whom Choudhary describes as “my dear mentor, great teacher, and friend,” played an essential role in shaping his career as a scientist.

“Long association with great teacher Prof. Atta-ur-Rahman FRS and unique and thought-provoking discussion with him has helped me to develop critical thinking and analytical approach, essential for scientific research,” says Choudhary. “I was fortunate to get the opportunity of learning from his long experience in research, his tremendous knowledge in organic chemistry, and his unwavering passion for serving. He is certainly the greatest influence in shaping my career as an organic chemist, deeply interested in the chemistry of life.”

Choudhary remembers his childhood as “definitely the most special time which shaped who I am today.” He was raised in a family where education and religion were strongly valued. Being the eldest among five siblings, he was taught to be responsible and develop a sense of empathy, care, and comprehension of things in a logical way.

Muhammad Iqbal was blessed with a large library in their home, which he was always fond of reading from. His father often asked him to deliver little speeches to social and political gatherings even at the young age of three. He used to regularly take part in debates and speech competitions held in their school and region.

He was a regular visitor of their neighborhood mosque. “It is interesting that I
was given the responsibility of supervising the construction of a large building of
the mosque at a young age. There I spent a lot of time with elders and developed a
great deal of seriousness and respect," he says.

Choudhary recalls then being "his mother’s child, spending hours with her
in the evenings and listening stories of prophets. I remember I used to help my
mother in house chores too." He recalls those days when he used to play football
in the evening with his friends and brothers in a vast playground near their home.

Choudhary thinks of his parents as those who had the most influence on him
becoming the person he is now. "Indeed, first and foremost, my beloved mother
Nisar Begum inculcated in me a great sense of responsibility, truthfulness, and
eagerness to learn. She shaped me as a person of a clean heart and satisfied soul," he says. "Secondly, my father, Ghulam Hussain Choudhary, who was a social
worker, taught me to serve people selflessly. He taught me to appreciate diversity
and respect everyone regardless of race and religion."

He attended a school near their home, one of the many free for all schools
which his father established for children of migrant families. His favorite subjects
were science and geography in school, representing his inquisitiveness to learn
about the unknowns. "These subjects gave me a great appreciation of cultural
diversity, nature, and knowledge-based development in different regions and
countries of the world," he says.

Choudhary thinks his interest in science and research is embedded in early
education. "Most importantly, interpretation of the Quranic verses about studying
and pondering about the universe and creations of Allah SWT had inspired me
towards inquiry and inquisitiveness," he says. He was very keen and proud of the
contributions made by Muslim scientists in the medieval world. "My readings
about great Muslim scholars of the medieval era, who laid the foundation of
modern science, have helped me to shape my interest in science."

Choudhary was also fond of reading about tremendous developments in
other countries too. That gave him keenness to travel and enthusiasm to study
science. Hands-on experiments, which he was able to perform in the excellent
science labs of his secondary school, further fueled his interest in natural
sciences.

His in-built eagerness to learn and his strong reading habits finally guided him
to become a researcher and a scientist. "I still remember my curiosity of why my
grandparents were aging and developing various illnesses, and why aging cannot
be stopped or reversed," he says. He then developed tremendous interest in the
chemistry of life as his profession and passion.

Choudhary got his Ph.D. in organic chemistry from H. E. J. Research Institute
of Chemistry located at Karachi University, Pakistan. He is now one of the most
prolific authors and among the world leaders in the field of natural product
chemistry. He has tremendously affected the field with his research, like his
mentor Dr. Atta-ur-Rahman. A natural product is one that is produced by plants,
animals, and microorganisms; metabolites such as carbohydrates, proteins, lipids,
and nucleic acids.

Natural products chemistry aims to know the products that evolved in living
organisms under various tensions during many million years. These chemists
try to extract this ancient wisdom of nature and exploit it for the benefit of man.
Many of these chemicals have been demonstrated to have medicinal properties by
Choudhary and other natural products chemists.

Choudhary is a professor of bioorganic and natural product chemistry and,
since 2002, has served as the director of the International Center for Chemical
and Biological Sciences (ICCBS) that has been called the developing world’s
finest research center of chemical and biomedical sciences. His efforts have
been instrumental in setting up several research institutes both domestically and
abroad.

Choudhary’s contribution includes more than a thousand publications along
with 57 international patents. He has written 68 books and 40 chapters in other
books. "Apart from my scientific contributions, I draw great satisfaction on
opportunities I was able to create for hundreds of young scholars of Afro-Asian
world to get advanced training in research at the ICCBS and at various other
institutions of the world," he says. He has guided up to one hundred international
Ph.D. students, many of them women.

"With the passage of time, I realized that my family values, excellent scientific
training in top institutions of U.S.A., extensive traveling abroad, and my association
with ICCBS have equipped me with skills and vision to lead and excel both
academically and professionally," he says. He feels he has been given a mission to
serve both his country and humanity as a whole.

It is hard for him to find any extra time nowadays, but traveling has always
been his passion. "Diversity of cultures, people, nature, landscape, and history
fascinate me," he says.
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