

The Institute at Fifty Five

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Abstract: I review a little of the history of the C. N. Yang Institute for Theoretical Physics at Stony Brook University, the YITP.

1 The Dawn of an Institute

1.1 A New University

Stony Brook University is nearly sixty years old at its current location, which is an intermediate age for universities worldwide, still young, but by no means among the youngest. The State University of New York, its parent organization, is about fifteen years older¹. Although Stony Brook is young compared to the founding institutions of higher education in the United States, like Yale, Harvard and Pennsylvania, and indeed to the “old-line” Land Grant state universities like Illinois, Michigan, and in New York State, Cornell, it is among the first of the post-World War II public universities. Spurred on by population growth and, equally important, a population that felt a growing need for higher education, new universities were founded in many US states. Some are quite large, and while most do not aim for the status of “research universities,” they often encourage their faculty to undertake research in their fields of study. In China, higher education experienced a similar expansive growth. Nevertheless, Stony

Brook was, and remains in many ways, a young university, still striving to reach its full potential, yet celebrating its grand successes, among which is the C. N. Yang Institute for Theoretical Physics.

Stony Brook is a pioneer institution among these new universities, with the ambitious goal of reaching the first rank of universities worldwide. From the start, an Institute for Theoretical Physics was envisioned as a key part of this effort². The idea developed when the new university President, John Toll, was about to join, and when the Department of Physics was led by the very able and energetic Alec Pond. At that time, physics was perhaps the most prestigious of the natural sciences, and a strong physics program was a natural part of the early planning. This surely led to the recruitment of John Toll, who had created a thriving physics program at the University of Maryland almost from scratch. He was an exceptionally young department chair at Maryland, and then a very young president at Stony Brook, but he had a vision for the university, with physics at the fore, yet extending far beyond it. He had a sense of conviction, a level of energy, and an ability to persuade that left an indelible mark on the university.

1.2 C. N. Yang Goes to Stony Brook

Certainly, the highest-profile initiative that Toll undertook, even before he officially assumed office, was to work toward luring Chen Ning Yang, then at the ivory tower and manicured lawns of the Institute for Advanced Study, in storied Princeton, New Jersey, to the muddy ground of an institution whose physical construction was just beginning. Stony Brook had no established traditions, its graduate programs were only recently approved, and its expanding budget was still dependent on the whims of the state government. Joining in this effort with Toll and Pond was one of Pond's senior faculty, Max Dresden. We can only assume that Toll used his personal charm and a preexisting friendship, which must have dated from

the time he was a graduate student at Princeton, and Yang was a rising star at the Institute*.

Looking back, we may still ask why Toll, Pond and Dresden could hope to succeed. C. N. Yang has addressed aspects of this question in the first volume of his collected papers³, and like any historic development, it surely has many sides. We may conjecture that, with the strong personalities that often go along with creative ability, politics at the ivory tower might not have been simple, all the more so with its long-time director, Robert Oppenheimer, preparing to step down. Yang has written that he was approached by Oppenheimer to assume the directorship himself. For Oppenheimer to have asked one of his faculty who was at the peak of his creative productivity to take the mantle of director was, it seems to me, a great compliment on the one hand, but a sign of difficulties on the other. I believe that the world is richer for the time that C. N. Yang saved by accepting the job at Stony Brook, serving as director of the ITP, a much smaller and more focused unit, and from the beginning, one of his own creation. I shall try and say a bit more about what that unit was like when he was director, and what it has become in the years since. To anticipate, though, I shall from here on refer to C. N. Yang as Frank, his adopted American name, by which he was universally known among his colleagues at Stony Brook. It might seem a bit informal in an essay such as this, but at Stony Brook it was a name that carried a deep respect, and sometimes awe.

About a year before Toll, Pond and Dresden initiated their discussions with Frank, the State of New York had initiated a program of Einstein

* Much of this story, and indeed much else in this document, comes from a collection of materials, including personal recollections, assembled by the late Professor Peter B. Kahn, the long-time chair of the Department of Physics, in Endnote 2. His materials complement C. N. Yang's accounts given in Endnote 3. I am grateful to Peter for sharing this labor of love on his part with the Institute and Stony Brook University. Certainly, significant omissions of important events and research contributions are inevitable in a brief history like this, and I offer regrets for them to my colleagues past and present.

Professorships, designed to lure distinguished natural scientists to positions at universities of the state. These were open to both public or private universities if a strong case could be made, and indeed the presumption of the well-established private universities was that they would succeed in filling these positions. It takes, however, a special chemistry to move leading scholars, and not every effort was successful. Personal chemistry was part of the success that Toll, Pond and Dresden achieved. Perhaps it was as well the very challenge Frank felt of joining a new university, with the highest of hopes, and the chance to help guide its development. This was an opportunity that no Ivy League university, with set traditions, could offer. His remarks at a university of similar age, The Chinese University of Hong Kong, reflect such a viewpoint⁴.

It was well recognized among the Stony Brook administration and senior faculty that an old mansion overlooking Long Island Sound, known as Sunwood, was a wonderful recruiting tool⁵. And indeed, in his *Collected Papers*⁶, Frank refers to a sunset, shared with his family on a visit, that helped seal the deal.

But there is more than that to the geography surrounding Stony Brook. About twenty miles to the Southeast of Stony Brook, accessible by somewhat winding roads at the time, is Brookhaven National Laboratory. Since the early 1950s, Frank had spent substantial time there. Those visits were at the times of some of his most famous discoveries. In 1954, his work with Robert L. Mills was done there, and there is a connection to the discovery of parity nonconservation as well. There was the excitement of new experiments and new results happening in real time right next door. There were also great scientists who had become personal friends, especially the Brookhaven Director, Maurice Goldhaber and the accelerator theorist, Ernie Courant. Courant, in particular, joined the Institute for some years, helping to initiate outstanding careers in accelerator physics, such as Alex Chao's.

Among the documents I've seen at Stony Brook was one predating Frank's arrival, which identified three areas of special opportunity in theoretical physics: elementary particles, statistical mechanics and gravity. Although I do not know the author of this document, I believe it reflects the judgement of Max Dresden. In any case, the scientific development of the ITP can be understood in these terms over its many decades to the present day.

In a tribute to Frank on his sixtieth birthday, John Toll wrote⁷, "His talent is so unique that wherever he located would almost inevitably become an international Center of Theoretical Physics." And thus it came to be, not only for the ITP, but for Stony Brook in its entirety, about which Toll goes on to write that it "has been infused with his example." His first task, however, was bringing together a faculty for his new Institute.

1.3 Assembling a Faculty

Leading up to his arrival in the fall of 1966, Frank assembled the original faculty of the Institute, which included Dresden as Executive Vice Director, and Ernest Courant, whose appointment was a joint one with Brookhaven. Surely the biggest original "catch" was Benjamin Lee, who moved from the University of Pennsylvania, where he was a young full professor. Rudy Hwa and Boris Kayser rounded out the original faculty. Among those who formed the core senior faculty of the Institute for the next few decades, Alfred (Fred) Goldhaber joined in 1967, Gerald (Jerry) Brown, Hwa-Tung Nieh and Daniel (Dan) Z. Freedman in 1968, Barry McCoy and John (Jack) Smith in 1969, William (Bill) Weisberger in 1972 and Peter van Nieuwenhuizen in 1975.

Quite naturally, not everyone stayed, and in particular Ben Lee moved on to become the director of the theory group at Fermilab, where his stellar leadership and research showed Frank's judgement in bringing him to the ITP in the first place. Dan Freedman moved on to MIT in 1981. But both

Lee and Freedman made signature discoveries while at the Institute. For example, Freedman's proposal of coherent neutrino-nucleus scattering has now been realized in the laboratory. Hwa and Kasler also moved on, Hwa for an outstanding career at Oregon, and Boris Kayser to important service and research at the National Science Foundation, continuing at Fermilab.

The earliest postdoc appointments were equally impressive in hindsight: William (Bill) Bardeen, Michael Nieto, Wu-Ki Tung and York-Peng (Ed) Yao. Each of them made significant contributions over long careers. We may note that Bill Bardeen and Wu-Ki Tung returned to Stony Brook for the YITPs 40th anniversary symposium.

2 The Sweep of Time

2.1 Early Milestones

Frank ensured that the Institute would be a place of discovery with his early papers (1966 and 1967) in solvable models, including the one that introduced the Yang–Baxter equation. He has identified this as one of his three greatest achievements, alongside the papers bringing to light non-Abelian gauge theories and parity non-conservation. It's worth mentioning that both of the latter papers list Frank's affiliation as Brookhaven National Laboratory. On a visit Frank made to Stony Brook in 2010, I was called upon to make a short presentation at a ceremony at which he was in the audience. I said that these papers showed there was “something in the air of Long Island that was good for theoretical physics”, and he indulged me with a smile.

Another early contribution of Frank's, which began a long-time collaboration with T. T. Chao, a postdoc brought by Max Dresden, was the concept of limiting fragmentation in the collisions of nucleons and other strongly-interacting particles. It is worth noting a feature of Institute

work that we will see again. This is the persistence of the influence of fundamental insights. The concept of limiting fragmentation, developed to understand proton-proton collisions proved its relevance and usefulness forty years later, in the description of nucleus-nucleus collisions at the Relativistic Heavy Ion Collider at Brookhaven.

It was during those early days that the quantization of Yang–Mills theories was achieved, and Ben Lee’s work with Jean Zinn-Justin played an important role in bringing this ground-shaking development to maturity. The landmark review, *Gauge Theories*, by Abers and Lee served as a standard introduction to these modern developments for many years. Nieh’s work with Ben Lee and M. L. Yan covered both gauge and gravity theories, while McCoy, with T. T. Wu of Harvard pushed forward studies of correlation functions in solvable models.

2.2 Illuminations of the Mid-1970’s

In particle physics, the years of 1974 and 1975 were exciting ones at the Institute, no less than everywhere else with an interest in elementary particles. The discovery of the J/Ψ meson, and the increasing evidence of a fourth quark, had the effect of bringing quantum field theory back to center stage. Coupled with data on high energy electron-positron scattering from a few years earlier and evidence for neutral currents in the weak interactions, our contemporary Standard Model, began to present itself in the laboratory, echoing previous theoretical proposals, most famously those of Glashow, Salam and Weinberg.

The resulting Standard Model, is fully confirmed as the correct “effective theory” for fundamental forces in the energy and luminosity ranges explored up until now. The Standard Model famously includes the unification, or more accurately mixing, of weak and electromagnetic interactions. Although the strong interactions are not part of this mixing/

unification, the electroweak interactions of strongly-interacting matter are described perfectly. The Standard Model is a triumph of the concept of Yang–Mills non-Abelian gauge field theories, but leaves unanswered the question of “why these gauge theories?” Two nearly-simultaneous advances at the Institute created new perspectives on how such questions might be answered.

In 1975, a parallel development, seemed to have the potential to address such questions, and hence carried its own excitement. This was the discovery of Supergravity at the Institute, by Peter van Nieuwenhuizen and Daniel Freedman, with coworker Sergio Ferrara. Supergravity opened a new breadth in the applicability of symmetry concepts within quantum fields, and demonstrated for the first time, a formalism capacious enough to encompass all four of the fundamental forces.

Also at the Institute, and around the same time, a series of intimate lunchtime lectures by the then-Mathematics Chair, James (Jim) Simons opened the door to a new understanding of gauge theories. Frank speaks in an interview of how, while teaching Einstein’s General Relativity, he realized strong parallels with non-Abelian gauge theories⁸. As developed by Einstein, general relativity is all about the geometry of space-time. So where is the geometry of Yang–Mills theories? Well, the Mathematics Department at Stony Brook had become, under Simons leadership, a powerhouse in geometry. What better way to find out than to consult with the Chair himself? Both Frank and Jim have recounted both the halting pace of their discussions, and how in time their mutual understanding flowered, and led to new insights. These insights in turn inspired some of the great names of mathematics, including Isadore Singer and Michael Atiyah, and shortly after, Simon Donaldson.

The geometrical connection also provided physics with a new perspective on the fundamental fields of the Standard Model, and of the

deeper theories that might be at its origin. At the Institute, it helped motivate influential work by Fred Goldhaber, independently and with Frank, on magnetic monopoles.

2.3 When I Arrived

I personally arrived at the YITP in 1976 as a postdoc and stayed for two of the pivotal years of my scientific career. Then after a year away at the Institute for Advanced Study, I followed Frank's path back to the Institute. I was lucky enough to have a choice, but, based on what I had experienced as a postdoc and what I'd learned about my other choices, I felt that my future at the Institute would be judged primarily on the advances in physics I was able to make. My experience confirmed my expectations.

When the Institute was being planned, the teaching responsibilities of Institute faculty were left for Frank to define. Indeed, some early documents suggest that Institute faculty would have no teaching duties at all. Starting early, however, that changed, and Institute faculty taught first advanced, and then over time introductory undergraduate courses, a practice that continues to this day.

I first visited the Institute in 1976, arriving by car after a rather long, rainy ride on the Long Island Expressway. I recall Frank in the audience as I gave my interview seminar. Seeing him react with approval to the central idea of my talk was a thrill. Of course, in very typical Frank style, his verbal comments began with something like "if you have proven this, it is important...". I also remember the clear positive reaction of my long-time colleague, Fred Goldhaber, at the talk. Others of my colleagues to be surely understood as well, but Fred was in the front row, and his warm sign of appreciation is also a memory I cherish all these years later.

I can remember around that time a brief chat I had with Frank in his office, across a table that remains today in just about the same place.

I saw a very attractive bronze vessel in the style of the early Chinese dynasties, and asked if it were an “original”. Of course not, Frank replied, “if it were real it would be in a museum.” Another memory, perhaps from some years later is representative of the lunchtime conversations of early years. We were discussing computers, the conversation having begun with Frank mentioning that his son, Franklin I believe, was taking a course on computer programming, and had encountered the problem of programs that never stop running. The conversation led to the question of whether there could be a test (a program itself presumably) of whether or not any program would end. This led to the realization that if such a test could be made, it would allow one to solve many, perhaps most, theorems in number theory. I recall that another postdoc, David Wilkinson, made that observation, after I asked “could we tell whether a program that looked for ten thousand sixes in a row in the expansion of pi would ever end?”.

Although Ben Lee had left for Fermilab before I arrived, I was pleased to find in the acknowledgement section of the Abers and Lee review on gauge theories, an appreciation of the memorable Hannah Schlowsky, for her expert help in typing and assembling the manuscript. I too worked with Hannah quite a lot.

It is perhaps at this point that I should mention the continuity of administrative assistants at the ITP. To my knowledge, there have been only four Assistants to the Director over the entire lifetime of the Institute, only one more than the number of Directors. The very capable Jeri Schoof was the first, who went on to a career in Stony Brook’s Provost Office. The others are Kitty Turpin, who retired with Frank in 1999, Betty Gasparino, who retired in 2018, and currently Dawn Huether. Frank set a tone and expectations for how to interact with faculty, visitors, postdocs, students and staff, which each of these capable and understanding administrators have honored and extended over the years.

2.4 The years that followed

The founding concept of the YITP is not a single scientific or technological development, but the conviction that theoretical physics will remain a focus of human interest and a magnet for the finest intellects into the indefinite future. By maintaining an outstanding and creative faculty and an open spirit of discussion and collaboration, the YITP also serves as an ideal environment for the training of future leaders in science. From the illuminations of the mid-1970's followed repeated instances that "a greater chance of significant work" can come from entering "a promising field" even, or perhaps especially, for a researcher who is "young and inexperienced" ⁹. In the years that followed, the Institute added junior faculty to explore the potential of particle physics through the 1980s and '90s (Robert Shock, George Sterman) and the potential of supergravity and supersymmetry (Martin Roček and Warren Siegel). In Statistical Mechanics, the tradition was continued with the hiring of Jacques Perk in 1980 and Vladimir Korepin in 1990. In 1987, Jacques moved to Oklahoma State University.

The very significance of the developments of the mid-1970s can be found, and became clear, with discoveries extending to the end of the Twentieth Century. The Particle Physics of the 1980s and 90s may be described as a Journey Toward the Standard Model. One key landmark was the discovery of the top quark at Fermilab, announced in 1995 (a development in which the Stony Brook group in High Energy, led by Paul Grannis, played a central role). The careful analyses of data in the light of theory would not have been possible at the necessary level of precision without the advances in fundamental concepts in the strong interactions at high energy, many developed at the Institute (Sterman). The same can be said for the discovery of the Higgs Particle, with key calculations carried out at the YITP (Smith). Similarly, the development of experiments to

observe neutrino masses, and of guidelines of leptonic flavor violation were pioneered here (Shrock). These high-precision observations guided the increasing confidence in the Standard Model as the century came to a close.

In the closing decades of the Twentieth Century, Supergravity became a key component of String Theory, and with the clarification of concepts of duality and holography, it took a position of center stage in many fields. Supersymmetry became a widely-studied formalism for extensions of the Standard Model, often relying on the supergravity formalism to limit the astounding variety of models. At the YITP, research continued at what seems to me a more fundamental level, often finding links to contemporary mathematics (Roček) and to string theory (Siegel).

In statistical mechanics, solvable models were studied at a new level, with derivations of exact correlation functions for the Ising Model (McCoy, with former YITP student, Craig Tracy). These developments, along with the work of C. N. Yang at the ITP, influenced some of the groundbreaking theoretical advances of Alexander Zamolodchikov, who later joined the Institute as the first C. N. Yang–Wei Deng Professor of Theoretical Physics. Later new solvable models were found here (McCoy with Perk and Au-Yang). Advances in solvable models made possible new results on the Hubbard Model, and to a review of methods in solvable models that is as influential as the Abers-Lee review of gauge theories (Korepin).

An era ended for the Institute with Frank's retirement. His retirement symposium was exciting both for the science and the sense of community in the broad range of fields where Frank's work was held in the highest esteem. The program was rich in former Nobelists, and Nobelists to be. The proceedings were published in *Symmetry & Modern Physics: Yang Retirement Symposium*¹⁰.

2.5 The Institute Pivots to the Future

It is a testament to Frank's unequalled status in creating an identity for Stony Brook that there was no serious talk of reorganizing or repositioning the ITP within the university at the time of his retirement. (At least none that I, as a senior faculty member at the time heard.) At the banquet of the retirement symposium, it was announced that henceforth the ITP would be known as the C. N. Yang Institute for Theoretical Physics. Afterwards, I was told that Frank said that we shouldn't have done this, but should rather have used the name as an attraction for a wealthy patron. In retrospect, however, it was the right move; with Frank's name aloft as our flag. In this way, the Institute was reaffirmed as an organic part of Stony Brook University's enduring structure.

In the years approaching his retirement, Frank relied on Peter van Nieuwenhuizen to take on many of the responsibilities of Director, and it was natural for Peter, himself a prize-winner and natural leader, to take over the reins. In time, however, Peter gravitated to his natural role as Professor, teaching far more than the average faculty member, and developing a wide range of courses. Peter went on to be recognized with a university-wide award in teaching, which he described at the time as the formal recognition of which he was most proud (this from a co-winner of the Dirac and Heineman Prizes and later the Breakthrough Prize in Fundamental Physics). In September of 2001, the author of these notes became the YITP Director.

Starting in 2003, the Institute, along with the Department of Mathematics, took the leading role in organizing a series of Simons Summer Workshops, reinvigorating the mathematics-physics tradition that began with the conversations between Jim Simons and Frank decades before. These workshops have continued until the present day, under the inspired leadership of Cumrun Vafa of Harvard and Martin Roček.

The preparation for the first workshops was uncharted ground, and the Institute staff, Elizabeth Gasparino and Doreen Matesich, worked heroically alongside faculty, especially Martin and George, to find lodging, organize lunches, and process reimbursements for dozens of participants. These included senior leaders in the field and junior scientists of all levels, and revolved around discussion, with limited formal presentations. This tradition has continued. The workshops established Stony Brook as a destination, offering a unique ground for the interplay between theoretical physics and mathematics.

The history of the Simons Center for Geometry and Physics will be written elsewhere, but suffice it to say that the resounding success of the Simons Summer Workshops helped pave the way to its establishment. The first news, electrifying to the Stony Brook community, came in 2006, with the announcement of a major gift by Jim and Marilyn Simons, and the planning and construction continued until a grand opening in 2010. There was a sense of a new beginning as members of the Institute and the Departments of Physics and Astronomy and of Mathematics saw the new building rise from what had been a long-neglected open field. In the academic year of 2009–10, the Institute served as a base for the first postdocs and faculty of the Center, until the doors were ready to open. Permanent physics faculty of the Center are members of the Institute, and this stellar list has included Michael Douglas (until 2015), Nikita Nekrasov and Zohar Komargodski, who joined permanent members in mathematics, the renowned Kenji Fukaya and Simon Donaldson. The Center quickly grew to international stature under the leadership of Directors John Morgan and Luis Alvarez-Gaumé. In this growth, and in many Center activities, Institute faculty have played and continue to play an ongoing role.

The years following Frank's retirement have brought a new round of faculty to the Institute, whose work continues organically the development

of the enduring Institute themes of gravity, elementary particles and statistical mechanics. The first two decades of the Twenty-first Century have seen what is perhaps a refocussing of attention in Theoretical Physics, pulling back from the search for a “theory of everything”, and finding the richness available in realizable models and materials, all the while developing ideas that extend our current knowledge of elementary particles and quantum cosmology.

In this development, we may recall the words of caution Frank offered long ago at the Centenary Conference for the Massachusetts Institute of Technology¹¹. This took place in 1960, which was, Frank reports in his talk, a time when hopes were high for a new “overarching” theory that could encompass all natural phenomena in a newly-discovered formalism. Certainly, progress was made at that time, but the horizon of a “final theory” receded, only to reappear in the 1980s, after the triumph of non-Abelian gauge theories and the very advances in String Theory that brought Supergravity back to the fore.

By now, however, String Theory and Quantum Field Theory have moved closer together, a process enabled in large part by arguments based on holography and duality. Their applicability is also now broadened, and a new sense of shared interests, methods and aims is found between theoreticians in elementary particle, condensed matter, and nuclear physics, including a growing interest in quantum information. These are once again heady times, reflecting the belief that Theoretical Physics will remain at the forefront, and indeed will help create frontiers, not necessarily bounded by a final theory, at least not yet.

The Institute is proud to characterize all of its appointments in the Twenty-first Century as significant contributions to its tradition. Working in particle phenomenology, Maria Concepcion Gonzalez-Garcia, who joined in 2001, is an established world leader in the determination of

neutrino masses and mixing parameters from the world's evolving data, and also in testing the Standard Model in collider physics. Patrick Meade's (2009) close examination of data from the Large Hadron Collider has influenced searches for anomalies that might be signs of new physics, and he has identified influential models that demand reevaluations of the way data is analyzed. Rouven Essig (2011) is one of the originators of search techniques for light dark matter. He has a breadth of interests from collider searches to dark matter direct detection in the laboratory, where, although a theorist, he is co-spokesperson for several important experiments.

On the "formal" side in quantum field and string theory, Leonardo Rastelli, a doctoral student of Dan Freedman, joined in 2006. Working broadly in string and quantum field theory, Rastelli has become a leader in deriving exact, nonperturbative results in field theories, and serves as the leader of the Simons Collaboration on the Nonperturbative Bootstrap. The presence of Christopher P. Herzog (who left for King's College in 2019) and Shu-Heng Shao (starting this year) further strengthened the Institute's efforts in string and quantum field theory. Shu-Heng brings pioneering work in new areas, with shared high energy and condensed matter physics implications. In quantum information, Tzu-Chieh Wei (2011) is widening Institute connections to the Department of Physics and Astronomy, as is Vladimir Korepin, who is bringing the methods of solvable models to quantum information. With Marilena LoVerde in 2015, the Institute branched into the exciting field of cosmology, in concert with the Department of Physics and Astronomy. Marilena has departed for the University of Washington, but cosmology at the Institute will continue with Vivian Miranda, who has special interests in the investigation of dark energy.

By the end of this period, the original senior faculty have retired, but it is a pleasure to report that Peter van Nieuwenhuizen, Barry McCoy

and Fred Goldhaber kept active involvement with the Institute, through the university post-retirement program of Toll Professorships. Peter, in particular, has become the first C. N. Yang Lecturer, continuing to lecture in retirement in advanced courses, some of his own creation, to a new generation of graduate students.

In 2013, the Institute received its first endowed chair, made possible by a donation in honor of Chen Ning Yang, by Wei Deng, a Beijing-based industrialist. The donation was transferred in a ceremony at his headquarters, attended by Frank and other dignitaries, along with Stony Brook President Samuel Stanley and Institute Director George Sterman. An international search for this position brought one of the pioneers of contemporary quantum field theory, Alexander Zamolodchikov to Stony Brook. This appointment had a special resonance at and beyond the Institute, for the importance of Frank's work of the 1960s to Sasha's ground-breaking advances. At his installation, Sasha warmly recounted the pinnacles of Frank's work mentioned above, and placed his own achievements with pride within the current of the Yang–Baxter tradition. A particularly satisfying connection is the way in which the work of Zamolodchikov laid the groundwork for Rastelli's non-perturbative bootstrap program. Fittingly enough, just a few years after the establishment of the Yang–Deng Professorship, a donation from Renaissance Technology personnel made possible the first Renaissance Professor of Theoretical Physics, which was awarded to Leonardo.

Our newer faculty have done well in research in the opening decades of the Twenty-First Century. For example, last year Rouven Essig received a New Horizon Prize and became a Fellow of the American Physical Society, and Leonardo Rastelli was named a Simons Investigator.

Along with research, teaching and mentorship are key missions of the Institute. In the summer of 2020, for example, seven students graduated,

all going on to top postdoctoral positions (Berkeley, Edinburgh, Harvard, Hopkins-Maryland, Rutgers, UC Davis and UCLA). Graduating student Samuel Homiller (Patrick Meade, advisor) was awarded the 2021 J. J. & Noriko Sakurai Dissertation Award by the American Physical Society. This level of training success is a sign of the continuation of another great tradition at the YITP.

As this snapshot illustrates, former YITP graduate students and research associates alike have spread the influence of the YITP throughout the world. They have served as directors for theory programs at international laboratories, such as Luis Alvarez-Gaumé at CERN and Eric Laenen at NIKEF, and as national scientific advisors (José Labastida in Spain). They are Fellows of scholarly societies, including the Royal Society (Ashoke Sen) and the National Academy of Sciences (Bill Bardeen) and have won international prizes, including the Heineman Prize (Bill Bardeen and Barry McCoy) and Breakthrough Prizes (Sen and the late Shucheng Zhang). They are well represented in the faculties of leading institutions in North and South America, Europe, Asia and Australia. Recent former YITP students who have attained tenured positions within the past few years include students Elli Pomoni at DESY and Abajit Gadde at Princeton.

2.6 What Research Will Survive for Ten Years? For Fifty?

In 2016, the Institute held a Fiftieth Anniversary Symposium. A highlight was Frank's video greeting, in which he saw ahead fifty more years of discovery, much of it in concert with the Simons Center for Geometry and Physics. As noted above, Frank pointed out that young people are fortunate to work in a new field, making discoveries as they bring it to maturity¹². On the other hand, Frank has commented more than once that most of our efforts will be forgotten in ten years, and indeed it

must be that way, to open room for progress. Yet, foundational insights have a way of resurfacing repeatedly over time

In many cases, those very discoveries open new methods that may find application in other fields. Frank's own research portfolio shows so many examples of this phenomenon. In my brief talk at the conclusion of Frank's retirement symposium¹³, I thanked him on behalf of my colleagues for making discoveries that allowed us, "in our finest moments, to make discoveries and creations of our own, on which we may look back with pride." In this light I look with pride, and sometimes even awe, at the scientific output of my colleagues, from those who were there when I arrived, to those who joined in the present century. Much of this work has, and will continue to make, an impact after ten, and in some cases, fifty years. We have seen it, in some of the examples given above. But more than that, it is the process itself, building on what we inherit, of carrying on in parallel or in collaboration with a stable set of colleagues over decades that makes scientific research at a place like the C. N. Yang Institute for Theoretical Physics so rewarding.

In summary, looking back over the fifty-five years of the Institute so far, through his leadership and example, Frank Yang created an environment where the air is good for theoretical physics, as he had found it on Long Island many years ago. Someday, in a term of years comparable to a single, full professional life in science, the Institute itself may celebrate its one hundredth birthday, at which participants will look back on this celebration for Frank's 100th birthday as one of the milestone in its history.

Acknowledgements

This brief sketch of the YITP is an expression of appreciation and gratitude for all Frank's contributions, and for the chance to build my

career within the tradition he created. Thanks are due as well to all my colleagues, who have made my time as director so satisfying, in their many and deep contributions to that tradition. This work was supported in part by the National Science Foundation, through award PHY-1915903, itself the continuation of a connection founded by C. N. Yang.

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- 1 Sidney Gelber, *Politics and Public Higher Education in New York State: Stony Brook — A Case History* (Peter Lang Press, 2001).
 - 2 Sidney Gelber (2001); *C. N. Yang and the ITP*, written and compiled by Peter B. Kahn. Three volumes, unpublished.
 - 3 C. N. Yang, *Selected Papers 1945–1980 with Commentary* (W. H. Freeman and Company, 1983).
 - 4 C. N. Yang, “Forty Years of Study and Teaching,” based on a speech delivered at The Chinese University of Hong Kong. Reproduced in Endnote 2, Peter B. Kahn, volume 3.
 - 5 Sidney Gelber (2001).
 - 6 C. N. Yang (1983).
 - 7 See Endnote 2, Peter B. Kahn.
 - 8 See Endnote 2, Peter B. Kahn.
 - 9 See Endnote 4.
 - 10 George Stermann, Alfred Scharf Goldhaber, Robert Shrock, Peter van Nieuwenhuizen and William Weisberger, eds., *Symmetry & Modern Physics: Yang Retirement Symposium* (World Scientific, 2003).
 - 11 “The Future of Physics,” based on remarks delivered at a Panel Discussion, M.I.T. Centennial Celebration (8 April, 1961). Reproduced in Endnote 2, Peter B. Kahn, volume 3.
 - 12 See Endnote 4.
 - 13 George Stermann et al., eds. (2003).