



Professor Chen Ning Yang

FOREWORD

The career of Chen Ning Yang, extending from wartime China of the nineteen forties into this century, is one of the great stories of modern science. His arrival in Chicago in 1946, to study with Fermi, with Teller and other historic figures there was part of a new era of science, passing from Europe, through America, to the world. In a lifetime of research contributions, he has transformed the way in which scientists think of matter and energy. A pioneer in physics, his great achievements and international stature have served as an inspiration for generations of young scientists, especially from developing nations.

Chen Ning Yang's contributions to physics are unsurpassed in the latter half of the Twentieth Century in their scope and depth. The story of his analysis of parity nonconservation in the weak interactions with T. D. Lee is the stuff of scientific legend: their deciphering of then puzzling features of particle decay, the publication of their solution, and the thunderbolt of its confirmation leading to the Nobel Prize just a year later. This brought them to the world stage as the first Chinese to win that award.

Yang's development with R. L. Mills of the concept of non-abelian gauge invariance and of the class of Yang-Mills theories was another such landmark event. In this case, it took two decades for the concepts that they introduced to flower into the contemporary Standard Model of elementary particle physics. Even beyond the successes of the Standard Model, however, the work of Yang and Mills set physics on a road that it still travels today. They did this by introducing the concept that symmetry principles are a guide to as-yet undiscovered particles and forces. This instinct for the role of symmetry, for the identification of the most essential features, is also reflected in his many contributions to statistical mechanics crowned perhaps by the development of what is now known as the Yang-Baxter equation. That discovery first unravelled the structure of a basic many-body problem, but has echoed again and again in physics and mathematics over the succeeding years.

Frank (the English name he chose in admiration of Benjamin Franklin) served as Einstein Professor and Director of the Institute for Theoretical Physics at Stony Brook University for thirty-two years, from 1966 until 1998, by far his longest-held professional position. As a Nobel Laureate at the height of his creative powers he boldly accepted a position at a then new and nearly unknown university, thereby instantly bringing Stony Brook international attention. As Director, he created and guided a new institute. He set a research style that continues here today, and helped to launch numerous careers of the junior faculty, postdocs and students who passed through the Institute, each of whom came away with memories of encounters with

one of the leaders of Twentieth Century science.

When Frank Yang announced his intention to retire from these positions, it was clear that the closing of this era would provide a unique opportunity to celebrate his unexcelled contributions to physics. It also quickly became clear that representing those fields of physics in which he had worked or that had been influenced by his work, would result in a symposium that transcended the boundaries of any specialization and indeed the separations between theoretical and experimental physics and between physics and mathematics. At the same time by tapping the admiration that Frank Yang has commanded and the reservoirs of visionary encouragement he has sown worldwide, this same effort resulted in the gathering of a superlative list of participants and speakers. Each of these distinguished careers had intersected with Frank's, some speakers having encountered him as a brilliant graduate student, some as the renowned statesman of science that he remains today.

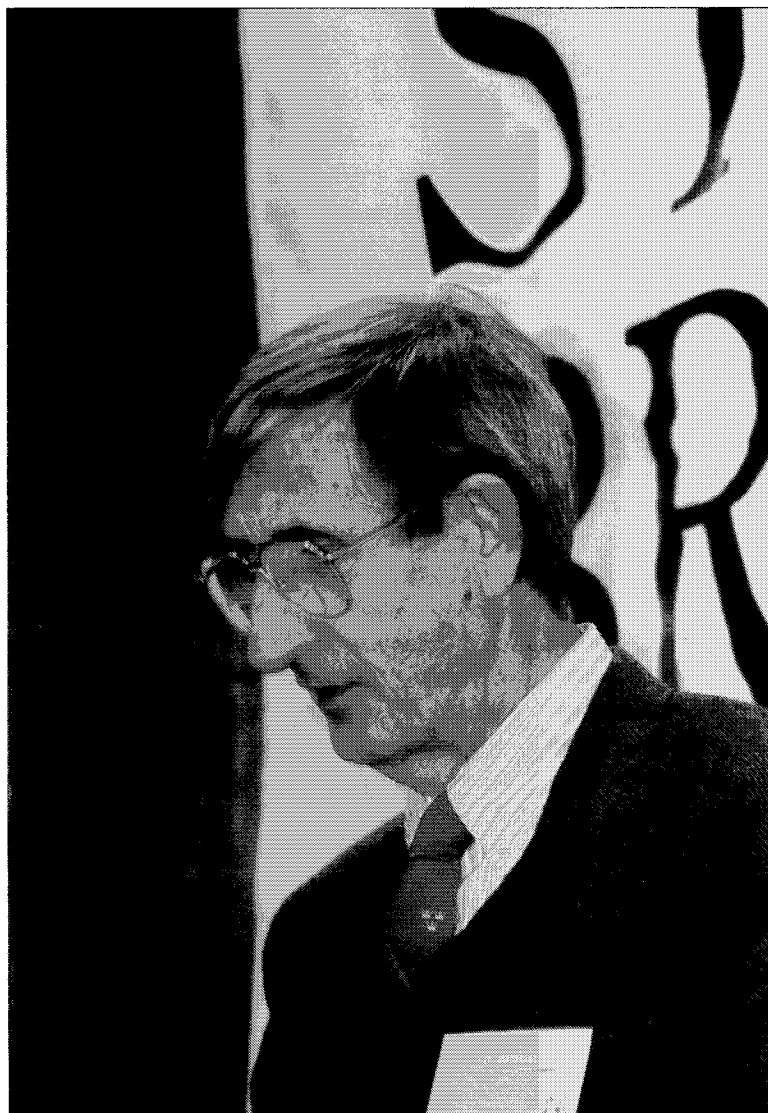
The Symposium "Symmetries and Reflections" was held at Stony Brook on May 21–22, 1999. The list of participants speaks for itself. For those of us involved in the organization, there was a special reward in the participation of so many returning colleagues, those who had passed through C. N. Yang's Institute as the first, or nearly first, step on their personal paths in research. By returning at this season they helped celebrate not only Frank's career but their own as well, and the collaborative venture that is science. In retrospect, the presence of Robert L. Mills (1927–1999) who chaired the opening session and who engaged in an inspiring discussion with students during his visit, was particularly meaningful.

The collected articles that follow represent the breadth and depth of the Symposium. The reader will find both the excitement of discovery and the pleasure of recollection. There are numerous anecdotes and fond memories, some strongly-held opinions in physics and beyond, but most of all the kinds of concepts and questions that make science an adventure. The major themes of contemporary physics, and the major discoveries of recent decades are well represented. Some of these articles contain material that has been updated since the Symposium. We believe that this collection can serve as a snapshot of the frontiers of physics at the close of the Twentieth and the opening of the Twenty-first Century. We are delighted as well to present a complete list of Chen Ning Yang's publications up to the end of 2002.

As with any significant event involving so much travel, and so removed from the normal routine, the Symposium could not have happened without a dedicated group, sharing a common goal and vision. It was also made possible by a generous and skilled support staff, including Ms. Elizabeth Gasparino and Ms. Doreen Matesich. The organizers are grateful for the support of Stony Brook University, including its Provost Robert L. McGrath and President Shirley Kenny and of the Department of Physics and Astronomy including past Chairs Peter Kahn, Peter Paul and Janos Kirz. This volume would not have been possible without the energetic efforts of K.K. Phua of World Scientific Publishing, and we greatly appreciate this chance to preserve the record of the Symposium. We also thank Ms. Judy Wong

of Hong Kong University for the list of the publications of C. N. Yang including titles in Chinese. Finally, we thank our colleagues, both present and former, from what is now, since the time of this Symposium, the C. N. Yang Institute for Theoretical Physics of Stony Brook University, for their support and for continuing the tradition set by Frank.

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Freeman Dyson

A CONSERVATIVE REVOLUTIONARY*

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I am delighted to have this opportunity to sing the praises of my old friend and colleague Frank Yang. The title of my talk is “A Conservative Revolutionary”. The meaning of the title will become clear at the end of the talk.

One of my favorite books is Frank’s “Selected Papers 1945–1980 with Commentary”, published in 1983 to celebrate his sixtieth birthday. This is an anthology of Frank’s writings, with a commentary written by him to explain the circumstances in which they were written. There was room in the book for only one third of his writings. He chose which papers to include, and his choices give a far truer picture of his mind and character than one would derive from a collection chosen by a committee of experts. Some of the chosen papers are important and others are unimportant. Some are technical and others are popular. Every one of them is a gem. Frank was not trying to cram as much hard science as possible into five hundred pages. He was trying to show us in five hundred pages the spirit of a great scientist, and he magnificently succeeded. The papers that he chose show us his personal struggles as well as his scientific achievements. They show us the deep sources of his achievements, his pride in the Chinese culture that raised him, his reverence for his teachers in China and in America, his love of formal mathematical beauty, his ability to bridge the gap between the mundane world of experimental physics and the abstract world of groups and fiber bundles. He wisely placed the eighty pages of commentaries together at the beginning of the book instead of attaching them to the individual papers. As a result, the commentaries can be read consecutively. They give us the story of Frank’s life in the form of an intellectual autobiography. The autobiography is a classic. It describes the facts of his life in clear and simple words. It quietly reveals the intense feelings and loyalties that inspired his work and made him what he is.

One of the smallest and brightest of the gems in Frank’s book is a two-page description of Fermi, written as an introduction to a paper by Fermi and Yang that

*Talk at the banquet of the C. N. Yang retirement symposium, May 21–22, 1999, Stony Brook.

was included in a volume of Fermi's collected papers. Frank studied with Fermi in Chicago from 1946 to 1949. He learned more physics from Fermi than from anybody else, and Fermi's way of thinking left an indelible impression in his mind. Frank writes, "We learned that physics should not be a specialist's subject. Physics is to be built from the ground up, brick by brick, layer by layer. We learned that abstractions come after detailed foundation work, not before". Fermi's practical spirit can be seen in the title of the great Yang-Mills paper published in 1954. Anyone speaking about the paper today would call it the paper that introduced non-Abelian gauge fields. But the title does not mention non-Abelian gauge fields. The title is "Conservation of isotopic spin and isotopic gauge invariance". The physical question, how to understand the conservation of isotopic spin, came first, and the mathematical abstraction, non-Abelian gauge fields, came second. That was the way Fermi would have approached the problem, and that was the way Frank approached it too. Fermi was great because he knew how to do calculations and also knew how to listen to what nature had to say. All through his life, Frank has balanced his own gift for mathematical abstraction with Fermi's down-to-earth attention to physical details.

Please let me digress here briefly to tell a story about Fermi that has nothing to do with Frank. I was not a student of Fermi, but I had the good luck to spend 20 minutes with Fermi at a crucial point in my career. I learned more from Fermi in 20 minutes than I learned from Oppenheimer in 20 years. In 1952 I thought I had a good theory of strong interactions. I had organized an army of Cornell students and post-docs to do calculations of meson-proton scattering with the new theory. Our calculations agreed pretty well with the cross-sections that Fermi was then measuring with the Chicago cyclotron. So I proudly traveled from Ithaca to Chicago to show him our results. Fermi was polite and friendly but was not impressed. He said, "There are two ways to do calculations. The first way, which I prefer, is to have a clear physical picture. The second way is to have a rigorous mathematical formalism. You have neither". That was the end of the conversation and of our theory. It turned out later that our theory could not have been right because it took no account of vector interactions. Fermi saw intuitively that it had to be wrong. In 20 minutes, his common sense saved us from several years of fruitless calculations. This was a lesson that Frank did not need to learn, since he had already absorbed Fermi's common sense during his years as a student in Chicago.

Frank has not been idle during the 15 years since his selected papers were published. Another book was published in 1995, this time not written by Frank but by his friends, a festschrift to celebrate his seventieth birthday, with the title "Chen Ning Yang, a great physicist of the twentieth century". This book contains, hidden among the technical contributions, a number of personal tributes and recollections. It describes Frank's active involvement, continuing up to the present day, helping science to grow and flourish in three Chinese communities, in the People's Republic

of China, in Taiwan and in Hong Kong. Frank is happy to be able to pay back the debt that he owes to his native land and culture.

Not included in either of the two books is a paper written by Frank two years ago with the title "My father and I". This is a tribute to his father, who was a professor of mathematics and died in 1973. It is a wonderfully sensitive account of his relationship to his father and of the pain that each of them suffered as a result of their separation. His father stayed in China through the hard years while Frank grew to greatness in America. Both of them knew that it was better so. Without America, Frank could not have become a world-class scientist. Exiled from China, his father would have been a tree without roots. And yet, the separation hurt both of them deeply. For Frank, his personal separation from his father and the political separation of America from China were two parts of a single tragedy. Luckily, President Nixon decided to recognize the People's Republic just in time, so that Frank was able to visit China twice before his father died and to sit by his bedside during his last illness. In the commentary to his *Selected Papers*, Frank describes the difficult decision that he made in 1964 to become a citizen of the United States. This was a formal recognition of his separation from China and from his father. He writes, "My father ... had earned a Ph.D. degree from the University of Chicago in 1928. He was well traveled. Yet I know, in one corner of his heart, he did not forgive me to his dying day for having renounced my country of birth".

The memoir "My father and I" ends on a happier note. It ends with a glorious moment of reunion. Frank describes how he stood at midnight on July 1, 1997, at the Hong Kong Convention and Exhibition Center, to watch the Union Jack being lowered and the flag of the People's Republic being slowly raised, while the band played "Arise, you who would not be enslaved". Frank writes, "Had father observed this historical ceremony marking the renaissance of the Chinese people, he would have been even more moved than I. ... The intellectuals of his generation had to personally experience the humiliating exploitations in the Foreign Concessions ... and countless other rampant foreign oppressions. ... How they had looked forward to the day when a prosperous China could stand up, when the British Empire had to lower the Union Jack and withdraw troops, when they can see for themselves the Chinese flag proudly announce to the world: This is Chinese Territory! That day, July the first, 1997, is the day their generation had dreamed of throughout their lives".

We can all rejoice that Frank was standing there to give his blessing and his father's blessing to the reunion. For me, that pride and that feeling of fulfilment that Frank expresses have a special resonance. I too belong to a great and ancient civilization. My home-town in England was also the home-town of Alfred the scholar king, who made our town into a great center of learning eleven hundred years ago, while the Tang dynasty was establishing the system of government by scholars that endured for a thousand years in China. Our king Alfred was translating scholarly texts from Latin into English, soon after the Tang poet Tu Fu wrote the poem

that Frank quotes at the beginning of his *Selected Papers*: "A piece of literature is meant for the millennium. But its ups and downs are known already in the author's heart".

Like Frank, I too left my homeland and became an American citizen. I still remember the humiliation of that day in Trenton when I took the oath of allegiance to the United States, and the ignoramus who performed the ceremony congratulated me for having escaped from the land of slavery to the land of freedom. With great difficulty I restrained myself from shouting out loud that my ancestors freed our slaves long before his ancestors freed theirs. I share Frank's ambivalent feelings toward the United States, this country that has treated us both with so much generosity and has treated our ancient civilizations with so little understanding. And I share Frank's pride in the peaceful lowering of the Union Jack and raising of the Chinese flag that he witnessed in Hong Kong, the place where our two ancient civilizations briefly came together and gave birth to something new.

Five years ago, I had the honor of speaking at the ceremony in Philadelphia, when the Franklin Medal was awarded to Frank Yang by the American Philosophical Society. We were assembled in the historic meeting-room of the society, with the portraits of Benjamin Franklin, the founder of the society, and Thomas Jefferson, one of its most active members, looking down at us. It was self-evident that Franklin and Jefferson approved of the award. We know that Frank Yang feels a special admiration for Franklin, since he gave the name of Franklin to his elder son. I would like to end this little talk with the same words that I used to praise Frank on that happy occasion.

Professor Yang is, after Einstein and Dirac, the preeminent stylist of the 20th century physics. From his early days as a student in China to his later years as the sage of Stony Brook, he has always been guided in his thinking by a love of exact analysis and formal mathematical beauty. This love led him to his most profound and original contribution to physics, the discovery with Robert Mills of non-Abelian gauge fields. With the passage of time, his discovery of non-Abelian gauge fields is gradually emerging as a greater and more important event than the spectacular discovery of parity non-conservation which earned him the Nobel Prize. The discovery of parity non-conservation, the discovery that left-handed and right-handed gloves do not behave in all respects symmetrically, was a brilliant act of demolition, a breaking-down of intellectual barriers that had stood in the way of progress. In contrast, the discovery of non-Abelian gauge fields was a laying of foundations for new intellectual structures that have taken 30 years to build. The nature of matter as described in modern theories and confirmed by modern experiments is a soup of non-Abelian gauge fields, held together by the mathematical symmetries that Yang first conjectured 45 years ago.

In science, as in urban renewal and international politics, it is easier to demolish old structures than to build enduring new ones. Revolutionary leaders may be divided into two kinds, those like Robespierre and Lenin who demolished more than they built, and those like Benjamin Franklin and George Washington who

built more than they demolished. There is no doubt that Yang belongs to the second kind of revolutionary. He is a conservative revolutionary. Like his fellow-revolutionaries Franklin and Washington, he cherished the past and demolishes as little as possible. He cherishes with equal reverence the great intellectual traditions of Western science and the great cultural traditions of his ancestors in China.

Yang likes to quote the words of Einstein, "The creative principle lies in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed". On another occasion Yang said, "That taste and style have so much to do with one's contribution in physics may sound strange at first, since physics is supposed to deal objectively with the physical universe. But the physical universe has structure, and one's perceptions of this structure, one's partiality to some of its characteristics and aversion to others, are precisely the elements that make up one's taste. Thus it is not surprising that taste and style are so important in scientific research, as they are in literature, art and music". Yang's taste for mathematical beauty shines through all his work. It turns his least important calculations into miniature works of art, and turns his deeper speculations into masterpieces. It enables him, as it enabled Einstein and Dirac, to see a little further than other people into the mysterious workings of nature.