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A Biographical Memoir by

MAURICE JACOB

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GIAN-CARLO WICK

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BY MAURICE JACOB

GIAN-CARLO WICK WAS a renowned theoretical physicist of this century. His name is explicitly attached to a very important theorem, the Wick theorem, which played a substantial role in the early perturbative use of quantum field theory. It quickly made its way to textbooks on particles and fields and found later a great use in nuclear and condensed matter physics. Gian-Carlo Wick's name is also associated with the Wick rotation, a theoretical technique using imaginary time, which had an notable impact on the development of fruitful relations between field theory and statistical mechanics.

Gian-Carlo Wick is also well known for the insight and clarity that he brought to several questions at a key time in their development, in particular in meson theory and in the many applications of symmetry principles in particle physics. There are also many properties that are not associated explicitly with his name simply because they have since become part of the common knowledge of physicists. Yet, they were first due to the clarity of his mind and to his sharp insight for physical phenomena. One may mention, for instance, the extension of the then new Fermi theory of beta decay to positron emission and also the relation between the range of a force and the mass of the exchanged particle, which is at the origin of that force. There are also the famous papers by Wick, Wightman, and Wigner on the intrinsic parity of elementary particles and on the question of superselection rules. There is the Lee-Wick approach to spontaneously broken symmetry, which paved the way to present developments on the transition between hadronic matter and the quark gluon plasma occurring at very high temperature and/or very high density. I had the privilege to be associated with his name in the Jacob-Wick expansion, which has long provided a handy formalism for the description of relativistic collisions between particles of arbitrary spins and in the spin-parity determination of the many particles discovered in the sixties.

This list of important and original achievements is long. To find a common thread, one may say that Wick was always fascinated by the mathematical structure of physical theory. In particular, he was a great expert in the application of group theory, something that he extensively used in his works on symmetries. But, together with this great mathematical expertise, he had a deep physical intuition and a strong desire for his contributions to be of direct use in topical matters and thus be expressed with clarity and rigor but still with the minimum amount of technicalities. He never lost sight of the physics. Three eminent qualities—mathematical expertise, physics insight, and a deep concern for practical use by others—appear over and over in his different and important contributions to physics.

Altogether, Gian-Carlo Wick made many fundamental contributions to nuclear and particle physics from the 1930s, when he was a close associate of Enrico Fermi in Rome, to the 1970s, when he worked with Tsung Dao Lee at Columbia. Indeed, in an address about Gian-Carlo Wick to the Accademia dei Lincei in 1994, Luigi Radicati, who was director of Scuola Normale when Wick was there, said, "To speak about the life and science of Gian-Carlo Wick is to recall the evolution of physics over forty years, a period that starts in the thirties and ends in the seventies."

Gian-Carlo Wick died of cancer in 1992 at eighty-two years of age in his hometown of Turin, Italy. He had returned there after a long and productive career that began in Rome before and during World War II, continued in the United States at Notre Dame, Berkeley, Carnegie Tech, Brookhaven, and Columbia, and concluded at the Scuola Normale in Pisa, which he had joined after retiring from Columbia.

In his talk on the occasion of the symposium marking the retirement of Gian-Carlo Wick from Scuola Normale in 1984, Tsung Dao Lee recalled how he first heard about Wick in 1947 in Fermi's class at the University of Chicago. Fermi was discussing some problem connected with the slowing down of neutrons, when he said, "This was solved by Wick," and then he immediately added, "Wick is a very good physicist." Conversely, Wick considered Fermi his "principale maestro" and, as he once said, "Fermi's advice over many years, but first of all the example set by Fermi were my essential guidances as a young researcher." In his 1984 talk, T. D. Lee presented several of Wick's achievements in physics and also said with emphasis, "Gian-Carlo Wick is a gentleman." He was a great physicist. He was a wonderful man.

Gian-Carlo Wick was born in 1909 in Turin, where he would spend his boyhood and attend the university. His name does not sound typically Italian. His great-grandfather had come to Italy from Switzerland (the St. Gall region). His father was a chemical engineer. His mother was the well-known Italian writer Barbara Allason, who took a very courageous antifascist stand in the 1930s. She brought a very strong intellectual slant to family life.

Physics attracted him early in life and, besides the intellectual inspiration he found in his family, he later paid tribute to one of his college teachers, in mathematics and physics, Professor Artom. He earned a Laurea degree in physics from the University of Turin in 1930, with a thesis on the electronic theory of metals, for which his main mentor was G. Wataghin, who was the first teacher of quantum mechanics in Turin. He then left Italy and worked one year in Germany, sharing the time between Göttingen and Leipzig in the institute of Heisenberg, working on atomic and molecular theory. He met there and became friends with many young physicists, who he later encountered in Copenhagen and the United States.

Wick then returned to Italy and, after one year in Turin, became Fermi's assistant in Rome in 1932. Fermi, the great leader of the Rome group, quickly recognized the talents of his young assistant. The position in Rome was to last until 1937, when Wick was awarded a professorship in theoretical physics, first in Palermo and then in Padova. He came back to Rome in 1940 to take the prestigious chair of theoretical physics, which had been declared vacant after Fermi's departure for the United States. The university actually invited him following the very suggestion of Fermi. He spent the war years in Rome, but he followed Fermi's advice again in deciding to move to the United State in 1946. He first went to Notre Dame to be close to Fermi in Chicago, and then moved to Berkeley.

Before continuing with his career, let us first stop at his Rome period. The achievements of the Rome group in the mid and late 1930s under Fermi's magnificent leadership are world-renowned. This was a fascinating time for physics. Nuclear physics was becoming understood with results that would soon unlock nuclear energy. Gian-Carlo Wick's contributions were important and numerous:

• He showed how to calculate the magnetic moment of the hydrogen molecule, a result that was later used by Stern in his measurement of the magnetic moment of the proton. This was a masterly application of group theory, a tool used by few physicists at that time but the book of Hermann Weyl held no secret for Wick.

• He extended Fermi's theory of beta-decay to positron emission and to electron K-capture by the nucleus. He was thus a precursor for our now familiar substitution of an outgoing particle for an incoming antiparticle or vice versa. I remember Wick recalling Roman café discussions with E. Majorana, who was a great pioneer in the description of particles in terms of quantum fields, with the resulting symmetry between particle and antiparticle.

• He worked on the slowing down of neutrons in materials, the basis of the remark by Fermi mentioned earlier. He developed on his own the basic properties of neutron scattering by crystals, which later was going to find so many important uses in neutron pile research.

• It is also to Wick that we owe the simple relation between range and mass seen as a direct consequence of the Heisenberg uncertainty principle: the heavier the mass of the exchanged particle that is the origin of the force, the shorter the range of that force. As we know today this explains the apparent weakness of the weak interactions. Wick first thought of it as a rather obvious effect, as it indeed looks to many physicists today. It was however not obvious to many at that time. When this caught the interest of Niels Bohr, Wick was very pleased.

• In order to explain the anomalous magnetic moment of the proton, Wick proposed that the physical proton was actually a superposition of a bare proton and of a neutron surrounded by a positron and a neutrino. At that time there was some understanding of weak interactions, but the nature of the nuclear forces with meson exchange was still not known and there were attempts to link them with the weak force. Wick was wrong about the relevance of the weak process, but he was right on the superposition idea, which was later vindicated by meson theory.

In Rome, Gian-Carlo Wick was making his mark as a first class theorist. Perhaps following again the example set by Fermi, Wick also took part in experimental work as a phenomenologist, as one would say today, but also directly. This was in nuclear physics in Rome and later, when he came back to Rome, in cosmic ray research in the Italian Alps. The latter had the advantage of keeping him for weeks in the spectacular mountain settings he loved. Mountaineering was indeed long a strong hobby. He could be easily enticed later to give a long series of lectures on symmetries at the Les Houches summer school in the French Alps, when I was running a session there in 1965. In the 1930s and 1940s, living conditions in the Alps were sometimes still rather rough. I remember him telling that he once complained to an innkeeper about the lack of running water in his room, and was informed, “You know, this is a fashion that will fade away.”

Wick worked with the group led by Gilberto Bernardini in the laboratory of Testa Grigia near the Matterhorn. The group, which included many physicists who became well known, obtained in particular the first measurement of the mean life of the muon. Also known from his cosmic ray work are the Wick’s curves, which have been much used to study the penetrating component of cosmic rays.

The brilliant young Rome theorist also quickly became well known for the quality of his lecturing, which combined rigor with clarity in the most perfect way. His gift, patience, and talent for clarifying complicated matters for the benefit of his fellow physicists has been indeed a constant element of Gian-Carlo Wick's style of work and led to some of his important contributions. He is the author of several well-known and long-used review articles and lecture notes, in particular on meson theory and symmetries. His great talent as a lecturer remained intact throughout his entire life. Near the end of his professional life at Scuola Normale in the late 1970s and early 1980s, he taught a course on general relativity. The students found his lectures inspiring, because he always stressed the important points without getting involved in lengthy calculations. This was not for lack of technical mathematical expertise! He had an impressive mathematical knowledge that covered both classical and modern mathematics, but he had, most of all, the sharp insight to know where the key physics questions were.

In connection with that I must mention an episode reported to me by Luigi Radicati. Once at the European Laboratory for Particle Physics (CERN), two well-known American colleagues came to lunch with a problem of Euclidean geometry they had failed to solve despite much effort the previous night. They even offered a bet to anyone who could solve it. Gian-Carlo sat quietly through the presentation of the problem. As they later took coffee, he offered a simple solution based on projective geometry. The two well-known colleagues had probably never heard of projective geometry, and the reported story does not say whether they paid their bet. Recalling the event, Gian-Carlo Wick said, " When I was in college, Artom had made projective geometry look so beautiful to me that I remembered it perfectly all through my life."

Gian-Carlo Wick's interest for mathematics came back strongly late in life. The librarian of the Scuola Normale still remembers the old gentleman sitting quietly for hours in the library, surrounded by piles of mathematics books.

We now come back where we first stopped, to 1946, when Wick moved to America, first to Notre Dame to benefit from the vicinity of Fermi. Arriving in the United States, Wick found a stimulating research atmosphere and was fascinated by all the activities originating from the results obtained with accelerators that could produce π mesons. His interests in field theory and in the origin of nuclear forces were quickly and strongly revived and he soon accepted the offer from Berkeley to take the chair left by Oppenheimer. He offered his assistant position to Jack Steinberger, who came from the Institute for Advanced Study. They wrote a paper together on neutron polarization, but, when Steinberger became enticed by the experimental possibilities offered by the machine there, Wick let him go to do what he liked best and thus to start his brilliant career as an experimentalist.

The Berkeley period is that of the famous Wick theorem. This landmark paper, entitled "Evaluation of the collision matrix" (1950), shows how to conduct explicit practical calculations starting from the formal relations of relativistic quantum field theory through expression of the chronological product of quantum fields in terms of a sum of normal products. This leads to a direct derivation of the Feynman rules in the calculation of a reaction amplitude.

Wick also worked with Geoffrey Chew on the impulse approximation. His important work on meson theory came out explicitly only later, in 1955, in his famous review article "Introduction to some recent work in meson theory." This very informative paper is a masterpiece of rigor and clarity.

His association with Berkeley was, however, to be rather short. Wick's deep attachment to freedom led him to resign rather than sign the loyalty oath that the regents of the University of California had imposed. Yet one cannot say that he had any strong allegiance in politics. He cared deeply about the status of the world, and he would observe with accuracy and comment with clarity and precision on political events. However, he would repeat that "anyone who claims to predict the future is a fool." He was first of all very deeply attached to freedom and his opposition to fascism in Italy, which he shared with his mother and many friends in Turin, had warned him of the great dangers of witch hunting. In the same way that he was critical of fascist ideas in Italy in the 1930s and 1940s—when many around him accepted the state of affairs not so much with enthusiasm but as an inescapable condition at that particular time—Wick could not accept the limitation to the liberty of opinion that McCarthy was trying to impose. Wick was not at all a Communist (he considered Communists fanatical). Yet he refused to swear in that loyalty oath that he had never been a member of the Communist party, considering that the question brought an intolerable limitation to the liberty of thought. That he put his profound conviction above the benefit of obvious working conditions and career advantages still commands respect. As he once said to Radicati, "I had once to take such an oath in Italy for mere survival reasons and I always regretted it. I did not want to repeat an act that repelled me as being so much against my liberal principles." Wick left Berkeley and moved to Carnegie Tech in Pittsburgh in 1951.

During his tenure at Carnegie Tech, which was to last until 1957, Wick spent a year at the Institute for Advanced Study in Princeton, collaborating with Wightman and Wigner on the paper on the intrinsic parity of elementary particles. It was to be followed by another collaborative effort, in 1970 this time, on "Superselection rule for charge." He also spent a year at CERN in Geneva, a place he visited many times. He was there for another year in the early 1970s during his tenure at Columbia, and after he moved to Scuola Normale, he became a regular summer visitor for one month. Of particular importance during his time at Carnegie Tech was his work on the Bethe-Salpeter equation, where the Wick rotation appears. The analytical properties of the scattering amplitude are studied using imaginary time, with an eventual continuation to real time. We already noted that this technique finds many applications in the fruitful interplay between field theory and statistical mechanics.

Gian-Carlo Wick moved to Brookhaven National Laboratory in the fall of 1957 to head the Theory Division. An important contribution at this time was the development of the helicity formalism for the description of collisions between particles of arbitrary spin. It soon became a basic tool for the analysis of the many particles discovered in the 1960s, and the paper I wrote with him quickly became a citation classic. I had come to Brookhaven at the same time. I was a very green young physicist at that time and I did not yet have a Ph.D. As a student at Ecole Normale in Paris, I had benefited from the teaching at Saclay and at the Les Houches summer school, but I was merely a beginner. Feeling at first lost at Brookhaven and alone in an office where I was supposed to do research on my own, I turned to Saclay for advice. The answer came loud and clear: “Hang on to Wick; he is highly worth it.” Gian-Carlo was kind enough to tutor me as his student. The research on the helicity formalism eventually became my thesis work. My association with him was to mark me for life.

In 1967, Gian-Carlo Wick was awarded the Dannie Heineman Prize for Mathematical Physics by the American Physical Society “for contributions to quantum field theory, for the investigation of the theory of scattering of particles with spin, and his deep analysis of the symmetry principles in physics.”

Wick became a tenured professor at Columbia in 1965, having had an association with the university since 1958. His research at Columbia was done mainly in collaboration with T. D. Lee. Among its highlights was their work on discrete symmetries, the study of indefinite metric and unitarity, and their introduction in 1971 of the idea that, in quantum field theory, the vacuum could show a special structure that disappeared at high temperature. The title of the paper is "Vacuum stability and vacuum excitation in a spin 0 field theory." This new resulting form of matter was proposed long before the same general idea emerged in describing the structure of matter at the quark level, with an expected transition between hadronic matter and a quark gluon plasma. Since the 1980s, this has been an important field of research, bringing together nuclear and particle physicists. There is already good evidence that the transition takes place, but we are still struggling to study its properties. Early work at CERN and Brookhaven, which already has yielded a very interesting crop of results, will soon continue in a dedicated way at Brookhaven with RHIC and at CERN on the Alice detector at the LHC.

As T. D. Lee has said of Wick, "Gian-Carlo was a person of gentle disposition and deep thoughts. Throughout his career, he immersed himself in the fundamental problems of physics, invariably motivated by their challenge and importance. His solutions were always characterized by a special clarity of mathematical analysis." This summarizes perfectly the memory that he leaves with those of us who had the privilege to know him.

The last part of Wick's career was spent at Scuola Normale after he retired from Columbia. This was a quiet and serene period for him, with much reading in the library. But people recall his beautiful lectures, his pertinent interventions in seminars, and many wonderful conversations.

His work in physics was rewarded many times. In addition to the Heineman Prize of 1967, Wick was the first recipient of the Ettore Majorana Prize in 1968. He received the Medaglia Matteucci of the Academia del XL in 1981. He was a member of the National Academy of Sciences, Academia Nazionale dei Lincei in Rome, Academy of Sciences of Torino, and the Ligurian Academy.

When he turned seventy-five, Wick summarized his life as a physicist in a talk titled "Ricordi di una fisica diversa" at the symposium that marked his retirement in Pisa. In his research he could be abstract in a subtle and deep manner, but he always remained close to the physics in a very concrete way. Never imposing himself, he was at the same time very generous of his time and effort for those who approached him for advice and guidance. As he once said, "I cannot boast of having created a school, but I derive much satisfaction in having known as my students younger physicists who later, developing further their talents, have become well known for their own contributions." I would add that the teacher here shows far too much modesty. His impact was certainly profound and quickly felt. Everyone who approached him was impressed by his knowledge of physics, by the clarity of his ideas, and by the depth of his understanding of any phenomenon. He carried this rigor and clarity of ideas well outside the domain of physics. He assessed political problems with the same uncompromising attitude as he did physics. He was a man of extreme intellectual honesty, whose ethical judgment came before material advantages, qualities demonstrated by some hard choices he had to make. He shared with his mother a very wide culture well above any particular ambition or national pride. Fluent in four languages, Wick was a humanist as well as a physicist. He had a great span of intellectual interests. As a young man he took inspiration from the breadth of interest of Niels

Bohr and Arnold Sommerfeld, who both much impressed him.

Gian-Carlo Wick was deeply concerned about the special responsibility of physicists in society and the more so throughout the long Cold War years. He once allegorically compared the physics community to adults who left their children in a log cabin during their absence, giving them a box of matches so that they could have fun with them, but later deeply regretting having done such a thing! He did not think that physicists could be better than others at solving the problems of the world, but he repeatedly stressed their strong responsibility to inform and advise. Being to the left in the Italy of the late 1930s and a liberal in the America of the late 1940s, Wick was often and almost systematically against the prevailing current, and often anxious about the future of the world. Yet it is people like him who give hope for humanity.

Near the end of his life Wick was honored by the "la Stampa" club of Turin, which awarded him its Silver Plate for 1991. This is a prestigious prize, which every year since 1980 honors three Piedmontese for achievements that have contributed to the international renown of Piemonte, the province of Turin. He shared the 1991 prize with actress Caterina Boratto and publisher Giulio Einaudi. He felt strongly this sign of gratitude from his own city at a time when his illness was already well advanced.

Wick is survived by his wife Vanna of Turin and two sons from a first marriage, Lionel of Forest Hills, New York, and Julian, of Tokyo. Gian-Carlo Wick has left us. However some of the works of the young Rome theorist—the Wick theorem, the Wick rotation, the Jacob-Wick expansion, the Lee-Wick approach to the vacuum, and his important contributions to meson theory and to symmetry properties—will all long remain in physics textbooks. And, for some time, there will also be the wonderful memory that is kept preciously by all those who had the privilege to know him.

THIS MEMOIR IS A much enlarged and edited version of a note that I wrote in 1992 as an obituary for *Physics Today*. Bringing it to its present form, I benefited from information and editorial help of L. Radicati from Pisa and J. D. Jackson from Berkeley.

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