

Nine Lessons of my Teacher, Arthur Strong Wightman A Talk at Princeton University, 10 March 2013

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Preamble.

All of us here today have been students of Arthur Wightman. But his thirty-six formal doctoral students form a very special club, which I represent on this part of today's program. A few members appear in this 1965 snapshot of Arthur Wightman's seminar in Palmer 301, with Arthur smiling benevolently in the center.



Postdoctoral fellows and other visitors to Princeton surround the students during those exciting times some 48 years ago. To the best of my knowledge, here is the complete, wide-ranging list of graduate students:

Arthur Wightman's student club

Silvan Samuel Schweber 1952	Gerald Goldin 1969
Richard Ferrell 1952	Eugene Speer 1969
Douglas Hall 1957	George Svetlichny 1969
Oscar W. Greenberg 1957	Barry Simon 1970
Huzihiro Araki 1960	Charles Newman 1971
John S. Lew 1960	Stephen Fulling 1972
William Stanley Brown 1961	Robert Baumel 1979
James McKenna 1961	Alan Sokal 1981
Peter Nicholas Burgoyne 1961	Vincent Rivasseau 1982
E. James Woods 1962	Rafael de la Llave Canosa 1983
John Dollard 1963	Steven Bottone 1984
Eduard Prugovecki 1964	Thea Pignataro 1984
David Shelupsky 1965	Jan Segert 1987
Arthur Jaffe 1966	Jay Epperson 1988
Oscar Lanford, III 1966	Marek Radzikowski 1992
Anton Capri 1967	Jan Westerholm 1996
Robert Powers 1967	
Lawrence Schulman 1967	
Christian Gruber 1968	
Jerrold Marsden 1968	

Pictures amplify words, so I passed through Cambridge for one day while travelling from Basel and Zürich (where I am currently on sabbatical) to Princeton. Most of Thursday I waded into the piles of boxes in my attic. This mining operation yielded a random and quite incomplete sample of images—for life provides too little time for the things we want to do. The photos are not all from Princeton, nor do they all include Arthur Wightman. Important periods, places, and people remain temporarily buried in my attic. But I did turn up a few gems—including this seminar image—that relate in some way to our beloved, departed friend. I project them independently from my talk, and you can view some 100 other images, including a few courtesy of Ludmilla. Eventually these photos can be viewed on the Princeton physics department web site.

Let me proceed with a very personal story, woven between those photographs that provide some interesting glimpses into the past. My remarks reflect a student's perspective, and are entitled Nine Lessons of my Teacher, Arthur Strong Wightman. Some lessons

are quotes; others are inferences. These lessons frustrate a humble student's attempt at emulation. Hopefully these remarks will resonate with others here.

Lesson I. Modesty.

In retrospect it seems quite improbable that a science undergraduate in the 1950's could spend four years at Princeton without ever encountering—or even hearing the name—Arthur Wightman. Yet that happened. Even though those years were spent mainly in Frick Laboratory, all my roommates, and many other friends were in physics or mathematics. I attribute this to Arthur's lack of self-promotion or self-aggrandizement. In today's world filled with primadonnas, such modesty is extraordinary—and very special. Arthur was always speaking of the work of others—rarely of his own. Luckily Arthur had many advocates who admired what he achieved.

My first impression of Arthur came as a student in Cambridge. I had gone to learn mathematics and physics—British style—with the encouragement of my undergraduate mentors Donald Spencer and Charles Coulston Gillispie. In spite of Cambridge being a hotbed of analyticity and S-Matrix theory in perturbation theory, a couple of my friends (including John Challifour) recommended reading Arthur's paper on the axioms. And someone there had an early copy of the 1960 Les Houches lectures. The refreshing appeal of Arthur's approach lit my desire to return to Princeton as a graduate student, and I was not alone. Thus began my personal encounter with Arthur Wightman's scientific adventures.

So even as a student, I discerned that Arthur Wightman's work received wider recognition and appreciation in Europe, than it did at home—a familiar theme of heroes not being recognized in their own back yard. For in Europe, Arthur Wightman was a well-deserved super-star. He remains so in our memories.

Interlude.

During the summer of 1961, before returning to Princeton at age 23, I made my way as an official “observer” to a summer school in Hercegnovi, not far from Dubrovnik. My main goal motivating that trip was to encounter another personal hero, Kurt Symanzik. Also Tullio Regge was there as well, and complex angular momentum was a concept I had been trying to understand. The physicist B. Jakšić organized that remarkable meeting. Exhausted from the train from London to Paris, I made my way through the crowded hallway of the Simplon-Orient Express with great despair, as there seemed to be no remaining seat. Finally I spotted what must have been the last open place in the train; what a pleasure to discover that I was sitting next to Maurice Jacob, who in fact was heading to the same place. Our resulting conversation led to a lifetime friendship.

The Hercegnovi lectures were outside in the warm climate, with the help of a small, portable blackboard. Many informal discussions took place in an open coffee area shielded from the sun by trees and an arbor; many more developed over dinner in one of the local restaurants. There I met and became friends with several other students, including Klaus Hepp, David Ruelle, Derek Robinson, Angus Hurst from Adelaide, and Edward Prugovecki from Belgrade (who like me was about to make his way to Princeton to study with Arthur Wightman). I became familiar with some of the teachers as well:

not only Jacob, Symanzik and Regge, but also André Martin, Walter Thirring, and the experimentalists Jack Steinberger and Valentine Telegdi.

The Zürich theorists in Hercegnovi were emissaries of their mentor Res Jost. This lineage continued when Hepp became an ETH professor. His students: Robert Schrader, Konrad Osterwalder, and Jürg Fröhlich, along with some of their students, became four generations of mathematical physicists who, along with Edward Nelson and Barry Simon, continued the Princeton-ETH and eventually Harvard connection.

Lesson II. Work on Big Problems.

Arthur Wightman's modesty was personal. It had nothing to do with scientific direction. Arthur towered over problems by his physique, and also by his persistence and strength—in science as well as in his middle name. He bent over backward to avoid the pedestrian. Arthur extolled work he held in high esteem, and his private evaluations of others could be severe. He aspired to think about perplexing things. So it was natural that Arthur suggested problems to his students that were important, but often they were impossible to solve.

What could be more fundamental than to understand the compatibility of relativity with quantum theory? They were the two most fruitful advances in 20th century physics. During the 40's, physicists developed rules for predicting consequences of the quantum field equations of Maxwell and Dirac. Today the measurements and calculations have evolved to 14-decimal place accuracy, with 23 Nobel laureates along that path. So one of the most fundamental questions in 1950 was: does it all make sense?

At the time, most physicists thought that a non-perturbative, mathematical theory of non-linear fields was impossible. But Arthur took up the challenge resulting in the Wightman axioms embodying quantum theory, covariance, stability, and locality. Pauli, Schwinger, Lüders, and Zumino understood spin and statistics and PCT in certain contexts. It appeared amazing that both results were simply consequences of the fundamental Wightman axioms, the latter work relying on the Bargmann-Hall-Wightman theorem and work of Res Jost.

The full proof of this, as well as studying further consequences of the axioms, led to much new mathematics, including Arthur's collaboration with Lars Gårding. These gave insights into the theory of several complex variables, domains of holomorphy, representation theory, linear and non-linear analysis, operator algebras, the theory of distributions, and partial differential equations. And I was lucky to arrive in Princeton about the time that Ray Streater came for a year to write together with Arthur their famous exposition, "*PCT, Spin and Statistics, and All That.*"

Arthur wanted to find examples of field theories satisfying the axioms. As an early attempt, he began the herculean program of analyzing representations of an infinite-dimensional Weyl algebra, and the corresponding anti-commutation algebra. Perhaps that would lead to insight into possible interactions. Arthur's students Schweber, Lew, Araki, Woods, and later Powers (and others) made major advances in understanding the representations. Again it led to new frontiers both in mathematics and in statistical physics. But the multiplicity of possibilities clouded the original goal of giving insight into relativistic interactions, their equations of motion, or their Lagrangians.

Arthur then asked whether mathematical analysis could be used to find solutions to certain specific Lagrangian field theories, using perturbative or non-perturbative analysis. This effort came to be known as constructive quantum field theory. Oscar Lanford and I had problems in this domain as thesis topics. The three of us wrote a joint paper on our early work. But it took almost ten additional years after we received our degrees, before complete examples of interacting quantum fields in two and in three-dimensional space-time were shown to exist, to satisfy all the Wightman axioms, and more. In the two-dimensional case, one also proved that the fields describe particles and their scattering. This follows from the existence of isolated single particle states, and using Haag-Ruelle theory to obtain the existence of an S-matrix.

Arthur Wightman was the spirit behind this effort, which had major contributions from many persons here today, including my teacher Ed Nelson in its early stages. I am extremely grateful for my long and fruitful collaboration on these problems with Jim Glimm, as well as work with many students, postdoctoral fellows, and collaborators. To list at this point the names of all those persons whose work was crucial for establishing Arthur's dream about this topic would take too long—so I only mention Jürg Fröhlich, Barry Simon, and Tom Spencer who are here today.

Lesson III. Distinguish ‘What you Know’ from ‘What you Think you Know’.

In his lecture on Hilbert's sixth problem, Arthur insisted, “A great physical theory is not mature until it has been put in a precise mathematical form.” Physics based on mathematics had been the norm for Newton, Maxwell, and Einstein. This attitude can be traced through the history of modern physics, including the history of statistical physics and non-relativistic quantum theory.

Arthur was among a small minority of scientists who insisted that in spite of its difficulty, relativistic quantum physics (and specifically quantum field theory) should be put on the same solid footing! Arthur spread this view with missionary zeal. Arthur was a fanatic about detail. This is necessary if one wants everything to be correct, and Arthur did just that. But detail is not enough, and unfortunately we still do not know the complete answer.

Arthur was fascinated by Polynesian head-shrinkers, for which he found an analog in our world. Arthur sometimes joked that the ‘world's greatest head-shrinkers are the publishers of books.’ When he received the galleys of the Streater-Wightman book, he gave copies to Oscar Lanford and me; we then competed to see who could find more typos (or other small problems). Arthur relished every one we found.

Lesson IV. Do not ignore what physicists think.

This was Arthur's mantra. He constantly emphasized that mathematical physics is a part of both physics and mathematics. If physicists believe they understand something, one should get to the bottom of it. Ignore it at your peril, even if at first sight it appears to be nonsense. And you need to look in all mathematical directions. For example: if you work in constructive quantum field theory, you need to incorporate whatever is known from the perturbative analysis of renormalization, renormalization group flows, or the mathematics of phase-cell analysis or of functional integrals.

I took that lesson to heart, and always tried to have contact with persons outside mathematical physics—both in physics and in mathematics. The natural interchange brought about by casual conversation had a profound effect on my own scientific direction. Curt Callan once joked that ‘mathematical physicists try to solve difficult problems, while particle physicists try to avoid them.’ But in my mind ‘avoiding’ a problem is the first step to solving that problem.

Lesson V. Do not ignore the past.

Arthur was also adamant about careful citation of the work of others. He taught us to read the literature and to understand it. We have heard of his great knowledge; Arthur appreciated the history of his subject, and he respected it.

For this Arthur relied heavily on the wonderful Princeton library. This torus-shaped domain on the top of Fine Hall was replete with wood paneling, book cases built into appealing nooks, and files where one could even find copies of unpublished reports or notes available nowhere else. Arthur loved that library, which was the charge of a remarkable woman Ann Kenny, who had been originally trained as a mathematician. Arthur and Ann got along famously; he often told coworkers and students how he argued to protect the library from budget cuts or other administrative problems.

Lesson VI. Teach Well.

Arthur told us that in a lecture you should, “tell them what you are going to do; do it; then tell them what you have done.” Yes, Arthur’s lectures were wonderful from a student’s point of view. But Arthur’s legacy as a teacher extends far beyond pedagogy.

Arthur’s interests were so broad. They spanned quantum mechanics, the foundation of quantum fields, representation theory, renormalization, symmetry and symmetry breaking, the physics of higher spin particles, continuum mechanics, statistical physics, ergodic theory, dynamical systems, transport theory; the list goes on and on. Arthur put many of these topics into his courses. Others appeared in summer schools or workshops that he organized.

But beyond conveying knowledge of the past, Arthur was so generous with his ideas about research directions and the future. Arthur inspired thirty-six students, countless collaborators, and many colleagues. Perhaps the most important knowledge a teacher can impart on a student is to explain what others know and what they do not know—and to tell which research questions are really important. Arthur did that so splendidly!

As a student I recall being interrupted while in Arthur’s office by a string of telephone calls and other visitors to his open door. Everyone seemed to desire Arthur’s wisdom or guidance. I recall thinking to myself how selfless he was; perhaps Arthur should make himself less available to others, in order to keep more time to work on his own research.

Lesson VII. Create a Congenial Working Atmosphere.

I could talk at length about the atmosphere in the department for students, or Arthur and Anna-Greta’s sociable evenings at their home. But your eyes see the whole story in the expressions on people’s faces in the 1965 photo of Arthur’s seminar, the first of the photos in the collection. (I believe the speaker was Klaus Hepp.) People and the quality of their personal interaction meant a great deal to Arthur. It stimulated good work.

When Arthur went to Madison for the summer, he included a bevy of students in his party. When Arthur spent his 1963–64 sabbatical starting the mathematical physics program in Bures, he took Oscar Lanford and me along.

At Princeton, life in the department was unbureaucratic. Courses were to enjoy and not to be graded. Administrators were to be conversed with and not to be bombarded with forms. And Arthur's door was always open. Where can one find that simple life now?

Lesson VIII. Be a Good Citizen.

Arthur also worked in so many ways to improve Princeton and the world. He argued for a rational policy for the admission of science undergraduates. He spent countless hours working for the Princeton Press. He encouraged the founding of *Communications in Mathematical Physics* and later served for years as an editor there and with other journals. He helped found the Department of Applied Mathematics at Princeton, and recruit its original members. He was involved in the transition from Palmer and Fine to Jadwin and the New Fine Hall. The list is endless, and Arthur showed his students that unusual citizenship should be the norm.

Lesson IX. What Next?

Being Arthur's student could be frustrating. After meeting with Arthur to discuss a successful new idea or result, inevitably Arthur moved the conversation from achievements (for they were the past) to ask about the future. Predictably, out would come the exclamation and question, "What Next?" (Like the Elliott Carter opera with that title.) Arthur seemed never satisfied with knowledge; Arthur always wanted more.

Today we still do not know the answer to many of Arthur's simple questions. Does four-dimensional quantum field theory makes sense? Abdus Salam remarked privately in 1969 that one could not hope to find the answer in the 20th century. And he was right! Hopefully the 21st century will provide insight into that conundrum.

Moreover, to understand confinement in QCD, or the mass gap in Yang-Mills theory, one will need new insights both into physics as well as into mathematics. And who will supply those ideas? Certainly Arthur would be overjoyed if both the physics advances and the mathematics advances originated from the same mathematical physicist!

In any case, I am sure that whenever any big problems in mathematical physics like these are solved, Arthur will be with us in spirit—smiling benevolently from heaven.