

Higgs Boson: Chapel Hill, CERN, QUB

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INTRODUCTION

Professor Sir Peter W. Higgs was born in Elswick, Newcastle-upon-Tyne in 1929. I¹ was born nearby in Jesmond, near Newcastle University, a few years later.

For schooling, Higgs with his parents, was moved to Bristol. His father was employed as a BBC engineer^{1,2}. At Bristol, Higgs's left arm was broken by a fall into a crater left by a German bomb^{1,2}. Higgs read Physics at Imperial College, London, where he progressed to a Ph.D. in Physics with Distinction. This led to Higgs's appointment at Edinburgh University in the Physics Faculty^{1,2}. From its Tait Institute of Mathematical Physics, in October 1964, Higgs published a brief communication, "Broken Symmetries and the Masses of Gauge Bosons"³.

In 1965-1966 Higgs spent a sabbatical year at the University of North Carolina, Chapel Hill^{1,2,4}. Higgs expanded upon his 1964 publication³, and in November 1965 from Chapel Hill submitted his paper, "Spontaneous Symmetry Breakdown without Massless Bosons" to *Physical Review*⁵. Higgs sent simultaneous copies to colleagues he thought would be interested in a pre-publication reading^{1,4}.

CERN: HIGGS FIELD AND THE HIGGS BOSON:

The Conseil Européen pour la Recherche Nucléaire, European Organization for Nuclear Research, known as CERN, was established with an initial Resolution at a December 1951 meeting of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris. In June 1953 the CERN Convention was signed by twelve Member States, and in 1955 construction of CERN's Geneva Research Facility began⁶. At present membership has grown to twenty-three Member States along with Associate Members and Observers⁷.

The Higgs field causes elementary particles to attain mass⁸. CERN originally defined the Higgs boson as "a particle predicted by theory. It is linked with the mechanism by which physicists think particles acquire mass"⁹. Proof of the predicted particle, it was thought, would complete the Standard Model of Particle Physics developed during the second half of the last century^{8,9,10,11,12}. Higgs' 1966



Figure 1. Sir Peter Higgs (1929-) by Victoria Crowe, OBE, DHC, FRESE, MA (RCA), RSA, RSW (1945-). Oil on canvas, 2014, 127 x 140.5 cm. Reproduced by permission of the Royal Society of Edinburgh.

paper⁵ and what followed was a crucial turning point in understanding this model for all matter^{1,4, 8,10,11,12}.

Forty-seven years after publication of his 1966 paper, submitted from Chapel Hill, Peter Higgs (Fig. 1) was awarded the 2013 Nobel Prize in Physics, shared with

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Professor François Englert of the Free University of Brussels. The Nobel Citation states: “For the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS [A Toroidal LHC Apparatus] and CMS [Compact Muon Solenoid] experiments at CERN’s Large Hadron Collider”^{13,14,15}.

GEORDIES VISIT UNIVERSITY OF NORTH CAROLINA, CHAPEL HILL

In March 1966, while a Clinical Associate in Anaesthesia at Harvard University, I was invited to the University of North Carolina, Chapel Hill to advise changes needed in the leadership of Surgical Departments. Welcomed with Southern hospitality, I was introduced to my “fellow Geordie”, Peter Higgs. Our dinner host told me that ‘Wykehamist’ Professor Freeman J. Dyson^{16,17,18} at the Institute for Advanced Study (IAS) in Princeton, New Jersey had insisted that the following week, on March 15, 1966¹⁴, there should be a Higgs lecture at IAS on the acquisition of mass by subatomic particles.

FREEMAN J. DYSON: IAS, PRINCETON

Freeman J. Dyson was born at Crowthorne, Berkshire, in 1923, the son of Sir George Dyson, Composer, and Director of Music at Winchester College from 1924, and his lawyer wife, the former Mildred Atkey^{16,17,18,19,20}. He was elected a “Scholar” at Winchester College. These select seventy boys lived within the College¹⁸. Freeman Dyson was awarded prizes in Mathematics and Science. He also distinguished himself in Athletics and became a Shakespearean Scholar¹⁸.

In 1941, Dyson proceeded as Scholar to Trinity, Cambridge^{16,18,19,20}. Paul Dirac was Dyson’s Physics Professor²¹, as was Arthur Eddington²². Dirac was a Fellow of St. John’s College and winner of the 1933 Nobel Prize in Physics for “the discovery of new productive forms of atomic theory”²¹. He was also Lucasian Professor of

Mathematics (1932-1967), the chair held by Newton (1663-1696), and Stephen Hawking (1979-2009)²³. Dyson studied Mathematics with the legendary G.H. Hardy²⁴. World War II interrupted Dyson’s Cambridge education and from 1943-45 he was Civilian Scientist for the R.A.F.^{17,19,20,25}. He later elucidated his rationale for civilian scientific work in critiques of nuclear and other warfare²⁶. He returned to Cambridge to complete his B.A. in the Mathematics Tripos in 1945. Dyson entered Cornell University’s Physics Department under future 1967 Physics Nobelist Hans Bethe in 1946²⁷. At Cornell Dyson developed a collegial friendship with Richard P. Feynman, Professor of Theoretical Physics, and 1965 Winner of the Nobel Prize in Physics^{1,19,28,29}. While Dyson contributed to the mathematics of theories of quantum electrodynamics, he did not share Feynman’s Nobel Prize^{17,19}.

While Dyson never received his Doctorate, he taught at Cornell from 1949-1952¹⁷. Professor Dyson accepted a Permanent Position offered by Director J. Robert Oppenheimer³⁰(Table

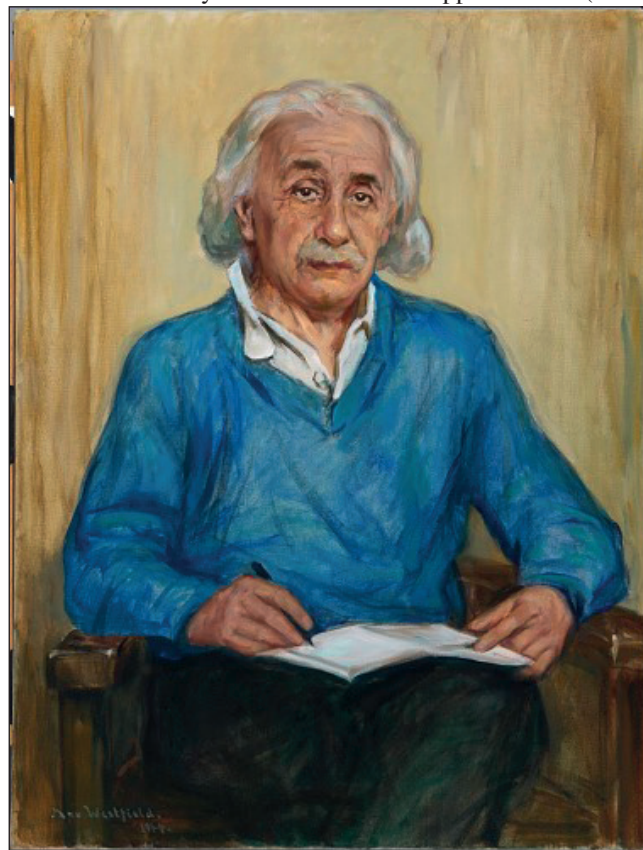


Figure. 2. Albert Einstein (1879-1955). Oil-on-canvas, 1944 by Max Westfield (1882-1971), 40.5 x 30.5 inches.

Catalog no. NPG.67.16, National Portrait Gallery, Smithsonian Institution, Washington, DC. Gift of the artist; ©Estate of Max Westfield, and reproduced with permission.

1), at the (IAS), Princeton, New Jersey, as a colleague of Einstein¹⁹ (Fig. 2). Dyson was elected Fellow of the Royal Society in 1952²⁰. Dyson held his Professorship at IAS for the remainder of J. Robert Oppenheimer’s directorship (1947-1966) and throughout Dyson’s career^{17,19,25} (Table 1). Dyson’s original contributions to mathematics, physics and

**TABLE 1. DIRECTORS,
INSTITUTE FOR ADVANCED
STUDY, PRINCETON, NJ³⁰**

Director	In Office
Abraham Flexner	1930-1939
Frank Aydelotte	1939-1947
J. Robert Oppenheimer	1947-1966
Carl Kaysen	1966-1976
Harry Woolf	1976-1987
Marvin L. Goldberger	1987-1991
Phillip A. Griffiths	1991-2003
Peter Goddard	2004-2012
Robbert Dijkgraaf	2012-2022
David Nirenberg	2022-

cosmology led to a long list of publications^{19,31,32,33}. While he was never awarded the Nobel Prize, he received many honours including the Max Planck Medal (1969), the Harvey Prize³⁴(1977), the Wolf Prize in Physics (1981), and twenty-one honorary doctorates²⁰.

FOUNDING AND DIRECTORSHIP OF IAS IN PRINCETON, NEW JERSEY

The IAS was founded in 1930 with an initial endowment of five million dollars (just over one million pounds, or 62.5 million pounds in 2019³⁵), the gift of renowned Newark, New Jersey Department Store innovator and philanthropist, Baltimore-born Louis Bamberger and his sister, Mrs. Felix (“Carrie”) Fuld³⁶. Bamberger was acquainted with Harry Gordon Selfridge from Selfridge’s early career at Chicago’s Marshall Field’s. They corresponded for many years³⁷. After selling his sixteen-story department store to the owners of Macy’s at peak before the October 1929 Stock Market Crash, Bamberger and his sister considered endowment of a medical school in Newark. They consulted their legal and financial advisors, Herbert Maass and Samuel Leidesdorf, to select the individual they considered most astute and knowledgeable: Dr. Abraham Flexner, author of the eponymous 1910 Report on Medical Education^{36,37,38}. Dr. Abraham Flexner was a brother of Dr. Simon Flexner who served as the first Director of the Rockefeller Institute for Medical Research, later renamed Rockefeller University, from 1911-1935³⁹. The Flexners were acquainted with and assisted by President Theodore Roosevelt^{37,39}. Louis Bamberger and Carrie Fuld met with Dr. Abraham Flexner in New York City³⁷.

Abraham Flexner advised against establishing a medical school in Newark, New Jersey. Abraham Flexner advocated instead for the foundation of an independent educational institution to support and encourage creative scholarship in multiple disciplines. The Bamberger siblings were inspired by the potential of Abraham Flexner’s proposal and agreed, with the stipulation that Flexner serve as the new Institute’s first Director^{30,37}. Dr. Flexner served from 1930-1939 (Table 1). Bamberger and Flexner’s appointees to the initial 1930 Board of Trustees included 1912 Nobel Prize Winner in Physiology and Medicine Alexis Carrel⁴⁰, Johns Hopkins Professor of Pathology and Bamberger cousin Florence R. Sabin, and former Johns Hopkins Medical School Dean Lewis Weed³⁷. A suitable site was acquired in Princeton, New Jersey, and Fuld Hall, named for Bamberger’s late business partner and brother-in-law Felix Fuld, was built^{36,37,41} (Fig. 3). Louis Bamberger supported the lease of Princeton University space for the new Institute until separate facilities were available³⁷. Abraham Flexner developed a close and collegial friendship with Louis Bamberger, who maintained an active role in the academic and administrative affairs of the (IAS), and continued his financial support. Upon Bamberger’s death in 1944, IAS was the beneficiary of the greater part of his estate³⁷.

In October 1932 the Institute announced the appointment of its first two Professors of Mathematics, Oswald Veblen and



Figure 3. Cornerstone-laying ceremony, Fuld Hall, IAS, May 22, 1939; Photographer unknown.

Attendees shown left to right: Alanson B. Houghton (IAS Trustee), C. Lavinia Bamberger (sister of IAS founders and benefactors, Louis Bamberger and Caroline (Carrie) Bamberger Frank Fuld), Albert Einstein, Anne Crawford Flexner (wife of Abraham Flexner), Abraham Flexner (IAS Director), John R. Hardin (IAS Trustee), Herbert Maass (IAS Trustee), Harold W. Dodds (President, Princeton University). Louis Bamberger and Mrs. Fuld did not attend and were represented by their sister. From the collections of the Shelby White and Leon Levy Archives Center, Institute for Advanced Study, Princeton, NJ, USA, no. E-36, and reproduced with permission.

Albert Einstein³⁶ (Fig. 2). In 1933, Einstein surrendered his German passport at the German Consulate in Antwerp. He proceeded to England where he considered other offers of academic positions. In October 1933, while still a “Research Student” at Oxford⁴¹ Einstein arrived in Princeton, New Jersey to begin what would become a lifetime tenure^{36,42}.

In February 1966, shortly before Peter Higgs’ March 15, 1966 guest lecture at Professor Dyson’s invitation, the IAS publicly announced the upcoming retirement of its director, J. Robert Oppenheimer who would be succeeded by Harvard’s Littauer Professor of Economics, Carl Kaysen^{43,44,45} (Table 1).

Professor Kaysen had been President J.F. Kennedy’s Deputy Special Assistant for National Security Affairs from 1961-1963, including the Cuban Missile Crisis, before his appointment to the Economics Faculty at Harvard. During World War II, Kaysen had served the U.S. Air Force as an Intelligence Officer at High Wycombe, where officers were quartered in Wycombe Abbey, a school for young ladies. At IAS, Kaysen and Dyson became close colleagues and friends who shared reminiscences of their wartime experiences^{17,45,46}. J. Robert Oppenheimer died of throat cancer on February 18, 1967^{19,43}. Kaysen continued as Director of IAS until 1976, when he returned to Cambridge, Massachusetts to accept a Professorship at the Massachusetts Institute of Technology. Here he served as David F. Skinner Professor of Political Economy⁴⁶.



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PETER HIGGS AT HARVARD

Early in the morning after being dined with Peter Higgs at Chapel Hill, I phoned Prof. Fred Mosteller^{47,48,49,50,51,52} with whom my Harvard boss Henry K. Beecher^{53,54} (Fig. 4) had me working on non-parametric statistical problems^{47,51}. I recounted my meeting with Peter Higgs. I learned that Fred Mosteller, who had received his Ph.D. from Princeton in 1946 and maintained strong academic ties throughout his career, was acquainted with Professor Dyson, as well as with Harvard's Professor Kaysen (Table 1). After my telephone call to Professor Mosteller, Peter Higgs was invited to speak



Figure 4. Henry K. Beecher (1904-1976), Henry Isaiah Dorr Professor of Anaesthesia Research, Harvard University. Oil on canvas, 1962, 48 x 31 inches, by Jean-Pierre Alaux (1925-2020). From the collections of the Massachusetts General Hospital, No. 81. Beecher was mentored by Harvard Professor of Surgery Edward Delos Churchill and Danish Nobel Laureate August Krogh of the University of Copenhagen. Henrik Bendixen and I continued the research of Professor Lorraine Smith, Musgrave Professor of Pathology at QUB.

at Harvard on March 16, 1966, the day after his visit to the IAS^{1,2,4}. Peter Higgs gave his lecture and then by request was asked to continue in symposium mode. The reported attendees included future 1979 Nobel Prize Winner Sheldon Glashow of Harvard and later University Professor at Boston University⁵⁵, long-time distinguished Harvard Professor of Physics Sidney Coleman⁵⁶, Harvard Associate Professor of Biophysics Walter Gilbert, later Winner of the 1980 Nobel Prize in Chemistry⁵⁷, and Professor Fred Mosteller of Harvard, best known at that time for establishing the authorship of the *Federalist Papers*⁵⁸. In his 2013 Nobel Prize Acceptance

Lecture, Higgs credited his 1966 Harvard invitation to Stanley Deser of nearby Brandeis University, who became Ancell Professor of Physics and later Visiting Professor at the California Institute of Technology, Pasadena^{59,60}.

CERN

The proofs for validation of Higgs' work came from two parallel experiments of CMS and ATLAS at CERN's Large Hadron Collider (LHC) beneath Geneva, Switzerland^{2,10,12,61,62,63}. Geordie Peter Higgs' 2013 Nobel Prize was shared with Professor François Englert of the Free University of Brussels^{13,64}. Higgs' brief communication to *Physical Review Letters*, received on 31 August 1964 and published on 19 October 1964³ had, at the request of the Editor^{4,59} referenced Englert and Brout's similar communication to the same journal published on 31 August 1964⁶⁴. Englert's colleague, Robert Brout, had predeceased⁶⁵.

At the July 4, 2012 CERN press conference honouring Peter Higgs, Queen's University Belfast-educated Director of Accelerators and Technology, Stephen Myers was among the CERN leadership⁶². Also present were Professors Gerald Guralnik of Brown University, Providence, RI^{66,67}, and Carl R. Hagen^{66,67} of the University of Rochester, New York State, whose parallel efforts⁴, along with those of Thomas Kibble, FRS 1980, Knighted 2014^{68,69}, had contributed to understanding of the Higgs mechanism and boson characteristics. After the CERN Press conference, Peter Higgs took the next flight back to Edinburgh with colleague Alan Walker².

STEPHEN MYERS: BELFAST AND GENEVA

Physics Review published Peter Higgs' landmark paper submitted from Chapel Hill on May 27, 1966⁵. Higgs returned from Chapel Hill to Edinburgh in the autumn of 1966^{1,2,4}. Belfast-born Stephen Myers was then a student at QUB. He received his BSc Degree in Electrical and Electronics Engineering with First Class Honours in 1968 and his PhD in 1972⁷⁰. Late in 1972, he began his career at CERN as Engineer-in-Charge for the operation of the Intersecting Storage Rings (ISR)⁷⁰. In 1983 he coauthored preliminary performance predictions for a Large Electron-Positron Collider (LEP)⁷⁰. Myers was given responsibility for commissioning the LEP, and oversaw its preparation. During the 1990s Myers was appointed Project Leader of the LEP upgrade. QUB awarded Myers an Honourary DSc (Eng) in 2003^{70,71}.

CERN released the details of the September 19, 2008 incident which disabled the LHC. Reports state that "...a fault occurred in the electrical bus connection in the region between a dipole and a quadrupole, resulting in mechanical damage and release of helium from the magnet and cold mass into the tunnel. Proper safety measures were in force, the safety systems performed as expected and no-one was put at risk"^{72,73}.

In October 2008, Myers was nominated CERN's Director of Accelerators and Technology. In the aftermath of the



Figure 5. CERN, July 4, 2012; Announcement of the proof of the Higgs boson. Co-Nobel Prize winners in Physics 2013, Englert and Higgs are shown.

The central physicists, CERN management and officers: Front row, left to right: Physicist Francois Englert, Physicist Peter Higgs, ATLAS spokeswoman Fabiola Gianotti, CERN Director Steve Myers. Second row, left to right: CERN Director Sergio Bertolucci, CERN Director- General Rolf Heuer, CMS spokesman Joe Incandela, Physicist Carl Hagen, Physicist Gerald Guralnik. From the Photograph Collection of CERN, Geneva, Switzerland, and reproduced with permission.

September 19, 2008 incident, Myers organized the repair of the LHC and directed its continued operation from 2010 through 2012. Under his direction, in 2012, the LHC received approval for two large experiments, ATLAS and CMS, to confirm the Higgs boson^{74,75}. Myers was named Head of CERN's Office of Medical Applications from January 1, 2014^{74,76}.

On April 2, 2014, Myers returned to QUB to lecture on "The Large Hadron Collider and the Discovery of the Higgs Boson"^{77,78}.

Work continues at QUB with the development of new particle accelerators. Dr. Gianluca Sarri, who received his Ph.D. from QUB in 2010, has reported on proposals to build a powerful yet compact particle accelerator at QUB as part of ongoing work by the European Strategy Forum on Research Infrastructures^{79,80}. Plasma, ionised gas broken down to its basic components, can provide much higher accelerating power than a solid-state accelerator. The proposed accelerator is designed to use lasers to move the plasma particles in waves. Dr. Sarri reports that the space required for a plasma-based particle accelerator will be reduced ten-fold from 400 by 400 meters to 40 by 40 meters. Potential medical applications include enhanced images of biological samples and early detection of tiny cracks or defects in medical instrumentation⁷⁹.

The proposed accelerator at QUB would be used to produce accelerated particles used for radiotherapy and nuclear medicine. The European Strategy Forum on Research Infrastructures is expected to shortly reach their decision on the report^{79,80,81}.

CERN AND MEDICAL PROGRESS

The history of subatomic particle therapy goes back at least a century^{82,83,84,85}. In recent years, investigators at CERN and with affiliations to many universities and hospitals worldwide have investigated a broad array of technologies and applications. CERN's medical endeavors continue^{76,86,87}.

EPILOGUE

Shortly after my return from Chapel Hill to Harvard, on March 17, 1966, Fred Mosteller told me that, "Peter Higgs' lecture-cum-symposium was convincing and well-received. A Nobel Prize will follow." That award, and others, did follow. On November 15, 2013, the City of Edinburgh, granted its Freedom of the City to Professor Peter Higgs⁸⁸. Geordie Higgs' birthplace, as well as mine, granted Freedom of Newcastle-upon-Tyne on April 2, 2014⁸⁹.

On April 17, 2014, Higgs' Nobel Prize co-winner, Professor François Englert, delivered the David M. Lee Historical Lecture in Physics at Harvard. He recounted the formulation of the theory known as the Brout-Englert-Higgs mechanism^{3,64}. Professor Englert discussed the role of the ATLAS and CMS detectors at CERN, and "the implications for unknown universal structures that might be revealed at even higher energies"⁹⁰.

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