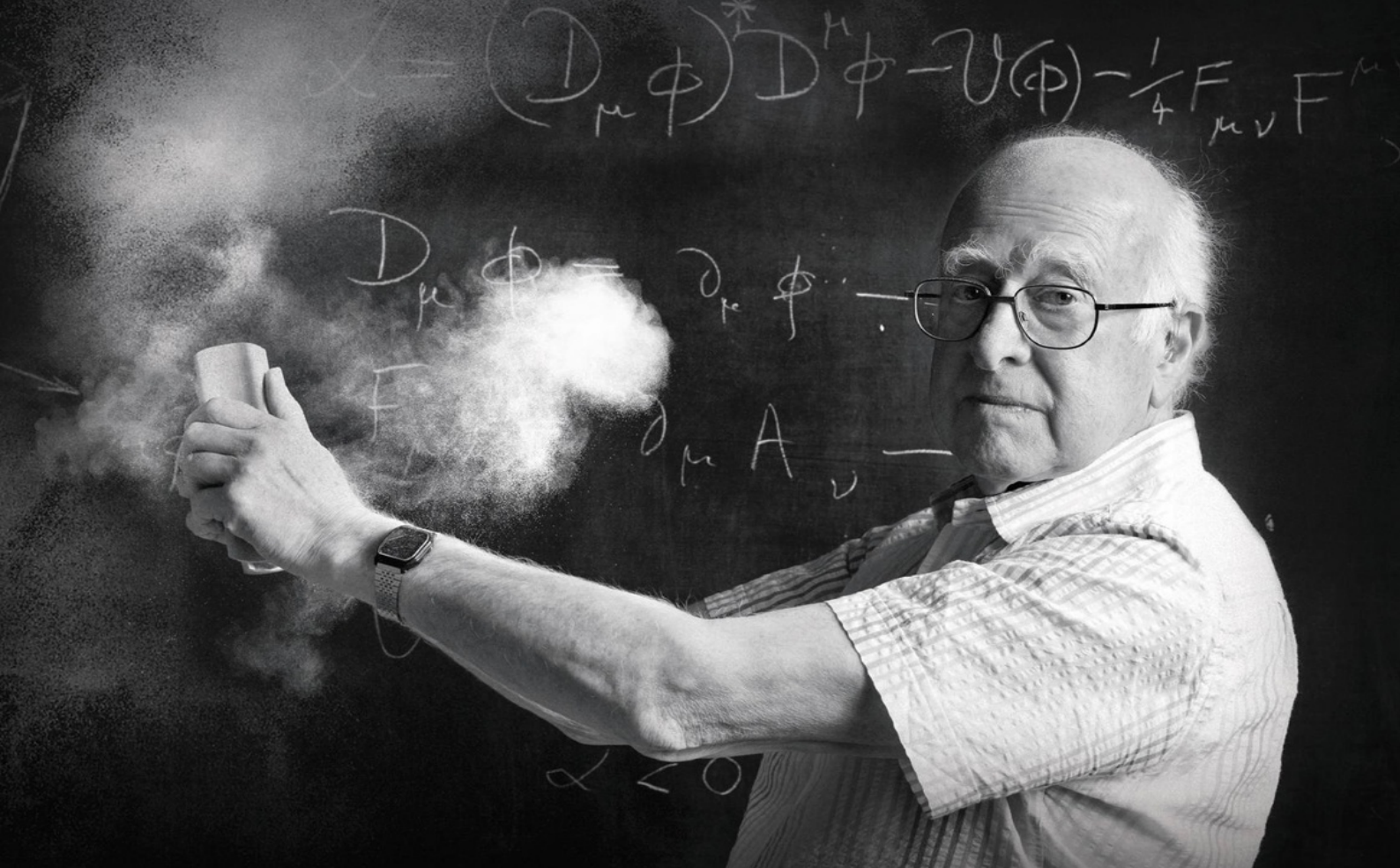
FRANK CLOSE

ELUSIVE

HOW PETER HIGGS SOLVED THE MYSTERY OF MASS



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BASIC BOOKS

New York

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Basic Books
Hachette Book Group
1290 Avenue of the Americas, New York, NY 10104
www.basicbooks.com

First Edition: June 2022

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Library of Congress Cataloging-in-Publication Data
Names: Close, F. E., author.

Title: Elusive : how Peter Higgs solved the mystery of mass / Frank Close.
Description: First edition. | New York : Basic Books, 2022. | Includes bibliographical references and index.
Identifiers: LCCN 2021050657 | ISBN 9781541620803 (hardcover) | ISBN 9781541620797 (ebook)
Subjects: LCSH: Higgs, Peter, 1929– | Physicists—Great Britain—Biography. | Higgs bosons. | Quantum theory.
Classification: LCC QC16.H53 C56 2022 | DDC 539/.092 [B]—dc23/eng/20211216
LC record available at https://lccn.loc.gov/2021050657

ISBNs: 9781541620803 (hardcover), 9781541620797 (ebook)

E3-20220427-JV-NF-ORI

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BASIC
BOOKS

PREFACE

To many, the Large Hadron Collider (LHC) at CERN in Geneva is synonymous with Peter Higgs, the physicist after whom the particle accelerator's primary target—the Higgs boson—is named. But what is the Higgs boson, and why is it so singular to have been dubbed in media headlines the God Particle? And not least, who is Higgs?

This breakthrough goes back to 1964 when the thirty-five-year-old physicist seeded a theory about the nature of matter and the fundamental forces of nature that had remarkable consequences. This theory assumes that even if space were to be emptied completely of matter and all known sources of energy, it would still be filled by a ghostlike field that cannot be shut down. Immersed in this essence forever, we have nonetheless been unaware of it. The concept of an elusive elixir is so revolutionary, and so removed from our normal senses, that it took half a century to prove it, leading to Higgs' Nobel Prize in 2013.

I have known Peter Higgs for many years, as a colleague in the scientific community and as a friend. After publication in 2011 of my history of particle physics in the late twentieth century, *The Infinity Puzzle*, Higgs agreed to join me in conversations at several science and literary festivals to help explain the universe and promote public understanding of his work. *Elusive* draws on those and other discussions, supplemented by a series of lengthy weekly phone conversations held during the COVID-19 lockdown, by letters, and by interviews of other leading actors in the decades-long quest for the Higgs boson. Memories of events that happened in the distant past are easily conflated, and wherever possible I have cross-checked the recollections of Higgs and other interviewees with documentary records, failing which, with one another's knowledge of the events. If anyone has archived information that would lead to corrections, please let me know.

Originally, I had envisaged a detailed biography of Higgs with some personal memories of reactions to his theory and the path to its experimental proof. All projects evolve, and this one did especially. The

unforeseen arrival of the COVID pandemic prevented access not just to Higgs and his papers but also to libraries and other tools of the trade, which we have often taken for granted until they suddenly went out of reach. Thanks to the internet, much of the research I wanted to undertake remained possible, though not access to Higgs himself. Peter Higgs has managed to avoid much of the pace of modern life. In addition to having no television in his Edinburgh apartment, he does not use the internet and is not accessible by email—historically emails sent to him at Edinburgh University would be administered by departmental assistants. He has no public mobile phone contact. Other than personal visits, Higgs has been accessible only by me first leaving messages on a landline answerphone to agree on times for a conversation, or by sending letters through the post.

I am a trained physicist, not a psychologist or social scientist, but as well as describing how the effort to confirm Higgs' theory appeared to scientists at large for half a century, I wanted to explore the human side of science, not least to reveal the emotional roller coaster that Higgs experienced as the saga consumed his later years to such an extent that he told me it had "ruined my life".[1] The result is not so much a biography of the man but of the boson named after him, from conception through gestation to birth, and its creator's feelings during the half-century saga that culminated in its discovery in 2012.

As Thomas Edison famously said, "Genius is 1 percent inspiration, 99 percent perspiration". What drives an individual to invest that 99 percent without any guarantee that the inspiration will follow? Why was it to Higgs and not some other more star-spangled scientist that the discovery fell? Some, uncharitably, dismiss Higgs' singular success as luck. Without doubt fortune was involved here, as it is in many discoveries, but being in the right place at the right time is not enough; having the preparation to be able to act on serendipity is also important. Higgs' story is a scientific analogue of the wisdom expounded by golfer Gary Player. After he holed a remarkable putt to win a major tournament, someone remarked, "Gary—that was lucky!" Player supposedly replied: "And the more I practice, the luckier I become!"[2] Higgs' one visible triumph was the result of years of practice, in his case of intense scholarship as he deepened his understanding of a profound enigma in theoretical physics and persisted until perfection was achieved.

As a student, Higgs wrote a theoretical physics paper that excited molecular biologists, but apart from that, prediction of the Higgs boson

was his one triumph. There was no previous work by him in particle physics that would have singled him out as midwife of a revolution. Having made the breakthrough, Higgs himself developed no further new pathways; it would be others who built on his creation and drove the quest associated with his name. A shy, modest person, Higgs was fated to be thrust into the limelight when from the late 1980s interest in the boson suddenly blossomed. As the world's media responded to the needs of particle physicists for a totem to promote their construction of the LHC, his life became public property. There are some who revel in fame and public adulation; Higgs is not one of them. On the morning when the Nobel Prize was to be announced, he disappeared, to avoid the media circus.

How did Peter Higgs feel to have been proven correct after waiting so long? Did he ever doubt his theory, or worry that he was wrong as thousands of scientists and engineers devoted years, decades even, of their careers to the pursuit of the boson? And when the eponymous particle was found, how did he react: with relief, or with trepidation that his life would be irrevocably changed? What does the discovery reveal about the cosmos and our place in the universe? These are the questions that I discussed with him over several years, as he lived through the dramatic days that moved a theory from speculation to lore, revealing for all time some of the most profound implications about the nature of the universe. His answers inspired this book.

Frank Close
Oxford, March 2022

PRELUDE

THE CASE OF THE DISAPPEARING PROFESSOR

IN THE WEEKS leading up to the day of the Nobel announcement in 2013, media excitement had grown intense in the expectation that this year the eighty-four-year-old scientist would win. The pressure on Peter Higgs had built over previous years, reporters even occasionally lurking uninvited outside the home of this intensely private man in Edinburgh's New Town. For Higgs, the potential euphoria of winning the Nobel threatened to be overwhelmed by the demands of the media. Worse, if after all the anticipation the award were to go elsewhere, interest would only be magnified. Whatever the result was going to be, Peter Higgs had spent twelve months preparing.

Higgs' apartment at the top of a three-storey Georgian tenement building is reached by a bare staircase of well-worn stone steps. As there are no lifts in the architecturally preserved townhouses of this UNESCO heritage site, Higgs has to climb eighty-four steps every time he returns home. In 2013, that meant one step for each year of his life. Such exercise has kept him fit into his ninth decade, well prepared for the sharp hills of Edinburgh's spectacular volcanic scenery. On that October morning, he planned a stroll of about a mile to Princes Street where he would take a bus to Leith, on the shore of the Firth of Forth. He wanted to be well out of reach when the Nobel Prize was announced.

The view through the two sash windows in Higgs' living room is historic and inspiring. Directly ahead stretch the cobbles of Darnaway Street, at the base of a canyon of sandstone townhouses which leads into Heriot Row and its pleasantly manicured gardens. Fifty metres away, on the left and opposite those gardens, is India Street, where at number 14 in

1831 was born the mathematician and architect of the theory of electromagnetism, James Clerk Maxwell. It was in Maxwell's work that Higgs, back in 1964, had found the key to solving a fundamental problem in physics, and had first made himself a candidate for the Nobel Prize. Between the rooftops of Heriot Row and India Street are visible the River Forth and, on a clear day, the shores of Fife by Kirkcaldy, some thirty miles away.

We can imagine the bespectacled, rosy-faced professor, with his domed bald head and strands of white hair, as he stood at the edge of the window, unseen by any lurking journalist. The coast seemed clear. His disinformation plan—that he was away in the Scottish Highlands—appeared to have worked, so any photographers were seeking their quarry elsewhere. The owners of the ground-floor and first-floor flats had been careful not to allow anyone masquerading as a visitor to pass through the secure outer door from the street to the stairwell, but even so Higgs checked the landing outside his flat before starting down to the main entrance.

The basement of the property is below street level, separated from the pavement by a sunken passage. A small bridge, which crosses the well and links the front door to the street, is adorned with ornamental cast-iron railings and a lamp. Now powered by electricity, the light's casing is the remnant of the gas lamp that illuminated the New Town in Georgian times. After a final glance to left and right he crossed the traverse, descended six steps to street level, and set off eastwards along Heriot Row.

It was a pleasant autumn morning, balmy for October in Scotland, with a gentle breeze from the south-west. Higgs was wearing a green-grey parka jacket, which would have been ideal camouflage had he indeed been in the Scottish Highlands, but still helped him merge anonymously in the streets of Edinburgh. His destination, Leith, was about three miles away. With collar pulled up around his neck, the acclaimed professor made his getaway. It would be another hour before his absence was noticed.

Sixteen months earlier, in June 2012, I had introduced Peter Higgs to the audience at a book festival in Melrose, near Edinburgh. Two hundred people filled a large marquee in the gardens of a mansion adjacent to Melrose's ancient Abbey, at the height of summer. Peter Higgs was relaxed; it was his story, and he knew his lines. I was nervous. Although I have given talks about physics around the world for forty years, both to

specialists and to the public, this was the first time I had taken the role of interlocutor to someone else's tale.

And what a tale. Nearly half a century before, in the space of a few months, Higgs and five other theorists had independently discovered the key to how beauty and order emerged from the chaotic debris of the Big Bang. Their breakthrough underpins modern understanding of why the universe consists of shapes and forms, rather than of massless particles rushing through space at the speed of light, without any possibility of being caught in atoms or molecules. It also explains why the sun barely stays alight, the force converting its hydrogen fuel into helium and liberating energy being so feeble that the sun, instead of burning its fuel fast and expiring almost immediately, has survived billions of years.

All atomic particles belong to one of two families: fermions or bosons. The names honour two scientists, Enrico Fermi and Satyendra Bose, who in the early days of quantum mechanics studied how particles behave when in large groups. Fermions are the basic seeds of matter, such as electrons or quarks, which in quantum mechanics are like cuckoos: two in the same nest are forbidden. Bosons are like penguins: large numbers cooperate as a colony. Bosons can accumulate into the lowest possible energy state—an effect known as Bose-Einstein condensation, after the two scientists whose work explains this phenomenon. This extremely low-energy state is manifested in weird phenomena, such as the superfluid ability of liquid helium to flow through narrow openings without friction; in superconductivity; and, if the six theorists were correct, Higgs bosons condense to produce a weird substance—today known as the Higgs field—that fills the universe.

Two millennia after Aristotle argued that the realisation of "nothing" is untenable, the Higgs field is in effect a physical confirmation of that philosophy. According to Higgs' theory, a truly empty vacuum devoid of all matter would be unstable. Add the Higgs field to this void, however, and it becomes stable. This may be counter-intuitive, but that is part of the theory's magic.

Physics students are taught how in the nineteenth century attempts to find a ubiquitous ether, by sensitive measurements on the behaviour of light-waves as they bounced off mirrors and mingled together, found no evidence for this hypothetical stuff. Moreover, the absence of this ether was presented as a foundation of Albert Einstein's celebrated special relativity theory on the nature of space and time. Yet in 1964 Higgs and

those other theorists had found a loophole in the arguments that had dismissed the ether and, in effect, they resurrected it in the guise of what has become known as the Higgs field. At least, that was the theory; whether nature read their equations remained long unanswered.

At Melrose I began with a light-hearted provocation: “It is easier to be Shakespeare or Mendelssohn than a theoretical physicist.” Being in Scotland, I suggested that changing a few words in *Macbeth*, or a few notes in Mendelssohn’s *Hebrides Overture*, would still leave wonderful works of art; change a mere handful of symbols in Peter Higgs’ equations, however, and they would not work. Higgs’ theory was exciting conceptually, constructed from beautiful mathematical structures. Had this been a symphony or a work of literature, its value would have been recognised decades earlier. However, the ultimate value of a theory in physics is never decided by intrinsic elegance, let alone public opinion, but always by experimental test.

Of that sextet of theorists who had variously stumbled on the same idea —known by colleagues as the Gang of Six—Higgs alone had identified a means of testing the theory by direct experiment. To do so, he drew attention to an exceptionally ephemeral particle, now known as the Higgs boson, which the theory implies must exist. Find it, confirm that it behaves as the theory predicts, and you will have made a profound breakthrough in understanding nature.

On stage in Melrose, I explained that Higgs’ scribbled equations on a sheet of paper half a century ago had inspired CERN—the particle physics laboratory in Geneva—to build a vast machine capable of simulating the conditions of extreme heat that occurred in the aftermath of the Big Bang itself. Some of the smartest brains on the planet—more than ten thousand scientists, engineers, and technicians from around the world—had combined their expertise to collaborate in the quest.

The machine—an engineering marvel—is as large as can be fitted into the stable geology surrounding CERN, between Lake Geneva and the Jura Mountains. It was also at the limit of what could be afforded—about €10 billion. Even then, the combined efforts of many nations, and of the CERN management focusing its resources on this single enterprise for several years, were needed to bring the LHC to fruition. The purpose of all this in the public perception was to find Higgs’ boson. That was not wholly the case (as we shall see), but the amount of publicity which the gigantic venture excited had thrust him into the limelight.

If this huge weight of responsibility weighed on him, he did not show it. So, my first question at Melrose was this: “Peter, if tomorrow you found a mistake in your arithmetic, would you tell anybody?” It was a rhetorical question to help break the ice. There were no mistakes, of course. Over the decades many other mathematicians have checked and verified Higgs’ algebra, its basic ideas used like pieces of Lego to build other theories that have been tested experimentally. Hints of the boson’s existence had been seen and had given clues, like the footprints of some exotic creature in the snow might be used to puzzle out its identity. Forty-eight years previously, in 1964, no one could have foreseen the implications of the equations which Higgs had written on his sheet of paper in his office one July afternoon. One of his colleagues returned from summer vacation to find a note from Higgs on his desk: “This summer I had the only really original idea I’ve *ever* had.”[1]

PART 1

CHAPTER 1

A NAME ON THE BOARD

PETER WARE HIGGS was born on 29 May 1929, in Newcastle upon Tyne. When Higgs first came to public notice in the 1980s, his Edinburgh professorship caused some media to describe him as Scottish, or even "Scotch". He was in fact one-quarter Scottish. His parents came from Bristol, and his father's family, who were descended from Saxon peasants, had lived in the west of England for generations.[1]

Peter's grandfather, Albert Higgs, was in his late forties when he died suddenly, in 1911, after losing all his money. The cause of his death was probably suicide following ruin from gambling, but the truth remained a family secret. None of them would tell Peter the reason, and he clearly got the message: "Don't ask!" Albert's widow, Charlotte, now penniless and facing destitution, was left to care for Tom, their only child.

Charlotte and Tom joined forces with her widowed sister-in-law, Nelly, and her son, John, Tom's cousin; the two families lived communally in the Redland area of Bristol. Charlotte contributed to the finances by working as a shop assistant, while Nelly looked after the boys' welfare at home. Peter's father, Tom, then age thirteen, was a high-flying classics scholar at Bristol Grammar School and was offered a bursary to cover his fees. With his interest in classics and influenced at home by Aunt Nelly, who was "disgustingly pious", Tom expected to go into the church as a career. But World War I changed everything.[2]

In November 1916 Tom reached eighteen years of age and was conscripted. The first Battle of the Somme had been raging for four months. He was sent to fight in the trenches of northern France for what became two years of abomination and was "absolutely disgusted by the Church of England padres who exhorted the troops to go over the top and kill Germans". As a child he had been fed Christian dogma, whose

representatives in the trenches acted hypocritically, and he had also been instructed to follow the Ten Commandments, whose interpretation appeared now to be negotiable. These experiences established in Tom a sceptical attitude to religion, while the relegation of his colleagues to mere cannon fodder at the whims of remote generals encouraged a hatred of war which his son later inherited.

In France Tom was befriended by a fellow Bristolian, Charles Coghill, who after demobilisation in 1919 introduced Tom to his sister Gertrude, Peter's mother. Gertrude had been born in 1895 in Shropshire close to the Welsh border, where her father was a physician. It was through her father's side that Scotland could claim its quarter of Peter Higgs' ancestry.

Her grandparents, Higgs' great-grandparents, John and Alexandrina Coghill, came from Thurso, the northernmost town on the British mainland. They had two sons. The elder, John George Sinclair Coghill, Peter Higgs' great-uncle, himself had scientific distinction, collaborating at the University of Edinburgh in 1869 with James Simpson on pioneering work in anaesthesia. Peter's grandfather was the younger brother, James Davidson McKay Coghill, who was born in Edinburgh in 1839.[3]

James also studied medicine, though at a less rarefied level than his brother. A general practitioner (GP) interested in tropical diseases, he spent twenty years in Ceylon (now known as Sri Lanka) until in 1891 he returned to the United Kingdom, divorced his wife, and took a post at the General Hospital in Birmingham. There he met and married a nurse—Peter Higgs' free-spirited maternal grandmother Emily Margaret, known to everyone as Maggie, who memorably spoke with a pronounced "Brummie" accent. Maggie's background was a Victorian classic. She was one of nineteen children, few of whom survived childhood. Her mother had given birth to her first child at age nineteen, followed by one every year until she herself died, age thirty-eight, in childbirth.[4]

James and Maggie had three children: James, Charles, and their elder sister, Gertrude—Peter Higgs' mother. Their father appears to have been a typical remote Victorian patrician, leaving the children's upbringing to Maggie. He teased her about her Brummie accent, so much so that Gertrude feared lest any child of her own one day might speak that way, or indeed with anything other than good elocution. Two of Maggie's sisters lived in Bristol, so when her husband James died in 1906, she and the three children moved to that city to be near them.

A SOLITARY CHILD

Like many others who had experienced the horrors of the trenches, on demobilisation Tom Higgs returned home to Bristol deeply traumatised. His thoughts of the church gone, an interest in radio steered Tom towards electrical engineering. Born with natural curiosity and an enquiring mind, he was among the one in a hundred who entered university in those days. In his opinion, Oxford and Cambridge "were for the sons of the idle rich to waste their time and also that of their tutors", so he enrolled in his hometown at Bristol University. After graduation, in 1922 he joined the nascent BBC in Newcastle upon Tyne, as deputy chief engineer for the north-east region.

Tom and Gertrude married at Christ Church in the Clifton area of Bristol in 1924 and settled in Newcastle. Seriously depressed by the trauma of fighting on the Western Front, and convinced that humankind had no future, Tom didn't want to add to human misery by producing children. After five years of marriage, however, Gertrude managed to "sabotage their traditional method of contraception",[5] fortunately for Peter, who would be their only child.

A few months after Peter was born, the family moved to Birmingham, where they lived for the next decade. If the child is father of the man, then Peter Higgs' tendency to be a loner who would go his own way, never mind what other people think, was the product of his early years. Peter was a sickly boy. He was born with severe eczema, so bad that at night he wore cardboard tubes encasing his forearms to prevent him from scratching the rash in bed. After a time, the eczema disappeared only to be replaced with chronic asthma. As the asthma seemed to be brought on by vigorous exercise, his parents banned him from playing with other children. This quarantine carried on beyond his fifth birthday and prevented him starting primary school in September 1934.

His father was uncomfortable with children and left Peter's upbringing to his mother. Gertrude was now haunted by memories of her own maternal upbringing, and of her mother's distinct elocution. Because Peter's family had moved away from Newcastle while he was still a baby, he had escaped speaking like a Geordie—a native of that city—but only by the irony of the family ending up in Birmingham, the locus of Maggie's fear. Her son was now "at risk of speaking Brummie English!" She insisted that Peter have private schooling to ensure that he learned "received pronunciation".[6]