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Profiles in Science: Stephen Hawking

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While Stephen Hawking's early academic career lacked focus, the development of motor neuron disease straining against his hopes for a fulfilling life pulled the young scientist's work together. He has since become the world's most famous scientist due, in part, to his strong belief that science should be accessible to the general public. Hawking has published frequently for the academic community but has also published for the lay reader. His life has been recorded and examined by several biographers. This paper gives an overview of Hawking's early life, academic career, his academic and popular publications, as well as a few of the works written about Hawking.

KEYWORDS: Stephen Hawking, Biography, Cosmology, Mathematical Physics, Astrophysics, General Relativity,

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INTRODUCTION

A physics student during the early 1960s studying at Oxford would have been given solid instruction in both general relativity, which deals with the science of the universe, and quantum physics, which deals with the science of atoms and even smaller particles (White and Gribbin 2002). One such student, Stephen Hawking, has since devoted his life to bringing these seemingly distinct fields closer and closer to unity. Hawking, a British cosmologist, is not only a prominent scientist in the academic community but has also found considerable success in presenting and explaining science to the general public.

LIFE AND EARLY EDUCATION

Stephen Hawking's birthdate, January 8, 1942, is 300 years after the famous Galileo Galilei's death, a coincidence which is made less impressive, perhaps, by Hawking's own estimation that 200,000 other babies were also born that very same day (Hawking 1993). Hawking's parents, Frank and Isobel, had both attended the University of Oxford in the years prior to World War II. Frank studied medicine and specialized in tropical diseases but graduated before Isobel began her own studies there (White and Gribbin 2002). That Isobel studied at Oxford at all was remarkable since at that time few women attended college (Hawking 1993). Neither Isobel, who was one of seven children, nor Frank came from wealthy families and yet higher education was valued within their families and, consequently, was valued for their own children (White and Gribbin 2002). Following the outbreak of World War II, Frank returned to England from East Africa where he had been doing research. Upon being told that he would be more useful as a researcher than a soldier, Frank began working at a medical research institute.

It was there that Frank and Isobel met. Isobel was working at the institute as a secretary, "a job for which she was ridiculously overqualified" (White and Gribbin 2002, 6).

Frank and Isobel lived in Highgate, a northern suburb of London (Cropper 2001). At the time of Hawking's birth, London and its surroundings were being frequently attacked by the German forces, so Isobel traveled to Oxford for Stephen's birth (White and Gribbin 2002). Oxford, in contrast to London, was considered safe since an agreement had been made between the British and Germany armies that Oxford and Cambridge would be spared if the same was done for Heidelberg and Gottingen. In the years following his birth, two sisters, Mary and Philippa, and a brother, Edward were born (Hawking 1993).

Hawking's earliest schooling began around the age of four at Byron House school (Hawking 1993). Byron was a progressive school which did not explicitly teach its students basic skills, believing, instead, that learning to read was a natural process where students "were supposed to learn to read without realizing you were being taught" (Hawking 1993, 3). Because of this approach, Hawking did not read until he was eight. By contrast, his sister Philippa was reading by the age of four (Hawking 1993). When the family moved to the northern part of London in 1950, Hawking attended St. Albans High School for Girls, which, in reality, took boys up to age ten.

Since Hawking's father deeply valued education, he hoped to send his first son to the highly prestigious Westminster school (White and Gribbin 2002). It was also an expensive school. Hawking needed to take the exams for scholarship money that was critical for his enrollment in the school, which the family otherwise could not afford. Thirteen old Hawking, however, was sick on the day of the Westminster exams (White and Gribbin 2002). Rather than

attending Westminster, Hawking continued at St. Albans School, which was, nonetheless, a well-respected local school.

Around the age of 14, Hawking decided that he wanted to focus his education and career path on physics and mathematics (White and Gribbin 2002). It was also at this time that his scientific and mathematical capabilities were being noticed by his instructors as well as his peers. In later years, Hawking said he became interested in physics because it is the most fundamental of sciences and yet allows him to ponder the working and depths of the universe (Hawking 1993). Additionally, he believes his interest in cosmology stems from his desire to control things. When he was young, he enjoyed building models of airplanes and boats, which he could control (Hawking 1993). By understanding "how the universe operates, you control it in a way" (Hawking 1993, 5). His father, however, did not share Hawking's interest. Frank pressured his son to pursue medicine, for he believed that studying mathematics was preparation that was useful only for becoming a teacher (White and Gribbin 2002). He made sure that Hawking also took chemistry, believing this would keep his son's career options open (Hawking 1993).

At 17, Hawking took his examinations for entrance into Oxford. Exams, which lasted twelve and a half hours, were spread over two days, and were followed by interviews (White and Gribbin 2002.) Hawking did well on these initial exams and interviews, and, a little over a week later, was invited back for a second interview. Ultimately, he received a scholarship, "the highest award offered by the university" to an incoming student, which paid for a portion of his schooling and offered other benefits such as priority student housing (White and Gribbin 2002, 41-42).

ACADEMIC LIFE

In 1959 Hawking began school at Oxford's University College, his father's alma mater, which is known for being the oldest college of the University and for its academically high standards (University of Oxford 2010; Cropper 2001). What Hawking found at Oxford, however, was not a community of intense academic pursuit and study. Rather he was confronted with the attitude of that time which was that one ought to be smart without trying (Cropper 2001). Having to study to excel was considered shameful. Grades were based solely on final exams so the stress of doing well on weekly assignments did not occupy the students. While he did put forth slight effort in math, Hawking's skills in physics were strikingly intuitive. He completed homework problems with ease and became distrustful of his textbooks, in which he noted frequent errors (White and Gribbin 2002). In general, Hawking found himself in the company of other highly intelligent but bored students. One activity Hawking found to help fill his time was the sport of rowing (Cropper 2001). He participated on the team as a coxswain, who is the in-boat coach and the athlete responsible for steering. Hawking was light and loud, the perfect combination for a coxswain, but he was also reckless. His risk-taking-steering often led to damaged boats and oars (White and Gribbin 2002). In addition to relieving boredom, rowing provided a social outlet for Hawking.

At the end of his time at Oxford, Hawking's academic standing was borderline between a "first-class" degree and a "second-class" degree (Cropper 2001). He told the members of the examination board, those who were responsible for determining Hawking's degree level, that he intended to do research: if awarded a second-class degree, he would stay at Oxford. If, however, he was awarded a first-class degree, he would pursue research at Cambridge (Hawking 1993). The examination board granted him a first-class degree.

The University of Cambridge was originally founded in the 1200s following a dispute between townspeople in Oxford and the University (University of Cambridge 2010). It was here, at Cambridge, that Hawking chose to study theoretical astrophysics and cosmology (Cropper 2001). He had considered researching either elementary particles (the very small) or cosmology (the very large), but was more drawn to cosmology because of Einstein's well-defined theory of general relativity (Hawking 1993). In contrast, the field of elementary particles lacked a solid theory. Hawking hoped to study with the famous cosmologist Fred Hoyle, but he was instead assigned Dennis Sciama (Cropper 2001). Having never heard of Sciama, Hawking was rather disappointed. In hindsight, however, Hawking has stated that he believes he was fortunate to be placed with Sciama, an intensely curious cosmologist whose research environment helped foster the development of his research students (Hawking 1993; Cropper 2001). The only publication that Hawking and Sciama co-authored is "Singularities in collapsing stars and universes" from *Comments on Astrophysics and Space Science* in 1969, but Hawking was able to benefit greatly from Sciama's general guidance.

Soon after Hawking started at Cambridge, it was discovered that he had Lou Gehrig's disease (also known as motor neuron disease or amyotrophic lateral sclerosis), which causes muscles to atrophy and become useless but leaves the mind unaffected (Cropper 2001; White and Gribbin 2002). The doctor estimated that Hawking had two years to live. Devastated by the diagnosis and seemly hopeless outlook, Hawking felt there was little reason to continue work pursing his PhD since it appeared he would not have time to finish it (Cropper 2001). A combination of several factors, including his own strength of will, brought Hawking out of this mindset. During a visit to the hospital for tests, Hawking saw a young boy die of leukemia (Cropper 2001). About this experience, Hawking said, "Clearly there were people who were

worse off than me…Whenever I feel inclined to be sorry for myself, I remember that boy" (Cropper 2001, 454). He also found help from his father, who eventually began serving as his doctor, and from Jane Wilde, a woman he met slightly before the diagnosis in 1963 at a New Year's party (Cropper 2001; Hawking 2007).

Wilde, an undergraduate student at Westfield College, and Hawking slowly began spending time together (Hawking 1993; Hawking 2007). There was tension in their early relationship as Hawking spoke little about his illness, while both he and Wilde suspected he would not live long. Eventually, however, Hawking and Wilde became engaged, and Hawking realized that if he planned on getting married, he needed to finish his thesis and get a job. It was with this new purpose that Hawking began working and researching in earnest and found that he enjoyed it (Cropper 2001).

In the summer of 1965 Hawking earned a research fellowship at Gonville and Caius College of the University of Cambridge (Cropper 2001). Gonville and Caius College is currently one of the largest and wealthiest of the Cambridge colleges and has produced the second greatest number of Nobel Prize recipients out of all the Cambridge and Oxford colleges (Gonville and Caius College 2010). The same summer that Hawking began his work at Gonville and Cauis, he and Wilde were married; two years later their son, Robert, was born. Their second child, Lucy came in 1970, and in 1979, their third child, Timothy arrived (Hawking 1993; Hawking 2007).

HAWKING'S WORKS FOR ACADEMIA

A search conducted in Thomas Reuters ISI Web of Knowledge[sm] supplies a results list of 144 publications by "Hawking, SW". In another search, and after excluding what are determined to be interviews or reprints, an additional 14 articles are found by searching for "Hawking, S".

These publications account for another 614 citations. (This set of publications excludes other authors who are "Hawking, S", most notably a scientist in the medical field from Canada.) On his own website, Hawking lists 194 publications through November 28, 2008 (http://www.hawking.org.uk/). This more complete list includes items such as books, significant lectures, and award essays. Hawking's first published paper is "On the Hoyle-Narlikar theory of gravitation" in *Proceedings of the Royal Society of London Series A: Mathematical and Physical sciences* (1965). In it he disproves the steady state theory of the universe which Hoyle (the professor with whom he originally wanted to work for his PhD) and Narlikar (the graduate student whose office was next door to his own) had developed (White and Gribbin 2002). This paper, which according to a Thomas Reuters ISI Web of Knowledge[sm] citation analysis has been cited only eight times, began Hawking's highly active publication life.

Thomas Reuters ISI Web of Knowledge[sm] results show Hawking's most active years as 1978, 1984, 1996, and 1999 when he produced seven publications each year, but his most active decade was the 1990s, during which Hawking had 47 publications. Hawking's own website, which includes a number of publications which Thomas Reuters ISI Web of Knowledge[sm] does not, shows his single most productive year as 1984, with ten publications. He also lists the 1990s as his most active decade with 52 publications. The 2000s (including the current year, 2010) have found the scientist relatively inactive in the publication arena with only 18 publications listed on the Thomas Reuters ISI Web of Knowledge[sm] and 22 on the Hawking's website (a list which is only updated through November 2008). This has not meant that other researchers are not still reading and using Hawking's publications. Hawking's five publications from 18 publications from the 2000s have already been cited a combined 927 times.

The articles retrieved for this study have been published in 33 different journals. One third of these host over three quarters of Hawking's publications and are journals which have been identified in *Journals of the century* (Stankus 2002). The journal *Physical Review D* has been host to the greatest number of Hawking's articles (45 out of the retrieved 158) and has also been the journal in which Hawking has been cited most often (responsible for 8,386 out of 26,044 total citations). Hawking's single most cited paper is an article he wrote in 1975 and published in *Communications in Mathematical Physics*. "Particle creation by black-holes" has been cited 3,629, which is an average of just under 101 citations per year since its publication. The years with the highest number of citation occurrences for "Particle creation" are 2008 and 2009 with 301 and 263 citations respectively.

Throughout his career Hawking's research has been cosmology. Up until around 1970 Hawking specifically focused on singularities (Hawking 1993). During this time, Hawking worked with another cosmologist, Roger Penrose, who was at Birkbeck College. Together they determined that according to the principles of the general theory of relativity, the universe must have been a point of infinite density at some time in the past, which is termed the big bang singularity (Hawking 1993). Hawking realized that the work they were doing to prove singularities, could also be applied to the study of black holes. (Black holes are created when stars run out of fuel and begin to collapse under their own gravity. They continue to collapse until all the matter within a certain range has been crushed into a single point.) In 1970, Hawking began focusing more completely on black holes (Hawking 1993). In 1974, Hawking wrote the article "Black-hole explosions", in which he describes how a black hole may emit particles, or evaporate, and eventually "explode" due to the high rate of particle emission that the black hole would experience at the end of its lifetime. This article, which appeared in the journal

Nature, is Hawking's second most cited paper: 1,458 citations according to Web of Science citation analysis.

In addition to his two most cited papers, Hawking's other works have been frequently cited. Twenty of his articles have been cited over 300 times. Of these 20, 13 also appear in the list of top twenty cited papers when considering the average citations per year, an important measure when one considers that new papers will have had less time to be cited than older papers. "Brane-world black holes" from *Physical Review D*, for example, was published in 2000 and has 283 total citations, an average of 25.55 citation per year. "Gravitational multi-instantons" from *Physics Letters B*, which was published 22 years earlier, has 302 total citations, an average of only 9.5 citations per year. In looking over Hawking's most citied articles, several main subject areas, which are all closely related, emerge. In addition to Hawking's work on black holes he also has studied the structure of space and the properties of gravity more generally. Space and time in day-to-day life are seen as separate realties or separate concepts. A person can seemly move in any direction s/he would want in space but can only move forward with respect to time. Space and time instead are woven together into the flexible, dynamic fabric of spacetime (Hawking and Israel 1979). Spacetime is distorted by mass and energy and this distortion is observed as gravity (Hawking 1993). The idea of the "braneworld" is that the universe with which we interact and are able to observe is actually just confined to a single sheet of reality (Cartwright 2007). Gravity, which appears weak compared with the other fundamental forces, may actually be able to act outside of the confines of our brane, or sheet, and interact with other dimensions. Hawking's most recent academic publication from September 2010, "No-boundary measure in the regime of eternal inflation" from *Physical Review D*, continues to consider the structure and history of the universe.

In addition to the scholarly articles which Hawking has written, he has also produced several books for the scientifically minded audience. The first of these academic books was *The large scale structure of space-time* (1973). Many of Hawking's books are collections of academic papers that represent important developments in science on a given topic. *300 years of gravitation* edited by Hawking and Werner Israel, for example, is a collection of papers from various authors which were gathered to mark the 300th anniversary of the publication of Isaac Newton's *Principia* (1987). Hawking and Israel also collaborated on a similar project, *General relativity: An Einstein centenary survey* (1979), which marked the 100 year anniversary of Albert Einstein's birth. While the editors claim that the aim of *General relativity* is to "provide a survey…of research in general relativity, which would be accessible to the non-specialist" (1979, xvi), it is clear that neither this book, nor *300 years* are meant for the "airport stalls" that are the aim of his later books written for the lay audience.

HAWKING'S WORKS FOR THE PUBLIC'

Hawking believes in the importance of having a scientifically informed citizen population. In a 1989 speech, Hawking makes the point that advances in science and technology will continue and that the public must possess a basic understanding of science in order to make informed decisions (Hawking 1993). He continues that the public has both a mistrust and a curiosity about science. He feels it is the curiosity which should be embraced and encouraged by the scientific community (Hawking 1993).

Prior to writing for a public audience, Hawking had published academic books through the Cambridge University Press (Hawking 1993). Overtime, however, his focus changed. In 1983, Hawking began work on a book that was geared toward the general public. His personal

goal was to make enough money to fund his daughter's education (Hawking 1993). Due to this, he envisioned a book that would be accessible enough that it could "sell in airport book stalls" (Hawking 1993, 34). While he missed the mark on being able to finance his daughter's education (she was in her last year by the time the book was published), Hawking certainly met his goal of reaching a public audience (Hawking 1993). *A brief history of time*, which came out in 1988, stayed on the London *Sunday Times* best-seller list for 237 weeks. *A brief history* has sold around nine million copies and is published in nearly forty languages (Garner 2010, Hawking 1996). *Library Journal*, a well-known review source for popular fiction and non-fiction, selected *A brief history* as one of the "Best Books" of 1988 (Rawlinson et al. 1989). *Physics Today,* a widely read professional journal of the American Institute of Physics, is another source of a favorable review. Reviewer James L. Anderson praises Hawking for creating a book that is of interest to the general public as well as to the professional scientist (1988). Hawking credits his editor Peter Guzzardi, for his role in making Hawking's first book for the popular audience such a success. Guzzardi, a non-scientist, was keenly interested in the book and after reading through each of Hawking's drafts would send them back asking many questions and requesting clarification (Hawking 1993). The result, Hawking states, is a book much better than it would have been without Guzzardi guidance and persistence.

Following the success of *A brief history,* Hawking, has produced several other books for the general public. In 1993, he published *Black holes and baby universes and other essays*, a collection of speeches, essays, and an interview on both scientific and personal topics. *The universe in a nutshell* is Hawking's second book written specifically to explain scientific concepts to non-scientists (2001). *Nutshell* covers some of the same topics as *A brief history* but includes many updates and new ideas that developed between the publications of the two books.

It also includes illustrations to help clarify the concepts, a device Hawking used when he republished his first book in 1996 as *The illustrated brief history of time*. Like *A brief history, Nutshell* received favorable reviews, which acknowledge the wit and accessibility of Hawking's writing (Hooper 2001; Beall 2002).

Hawking has also taken his writings for the general public down a different path. In 2007 he published *George's secret key to the universe*, the first of a three-book series, co-written with his daughter Lucy. This fiction chapter book is an adventure story meant for a youth audience. Like Hawking's other popular books, *Secret key* is intended to introduce a new audience to scientific concepts, the point which reviewers acknowledge as a commendable element of the book, while lightly criticizing the plot (Carton 2007; Cox 2008). The series continues in *George's cosmic treasure hunt* and the third book is yet to be released.

His most recent publication for the public is *The grand design*, co-authored with Caltech physicist Leonard Mlodinow. On September 7, 2010, *The grand design* was number one on Amazon.com's bestseller list (Garner 2010). As of this writing, the book is number 54 and has been within the top 100 for 65 days. While *The grand design* focuses on the newest and currently most likely candidate for a unified theory, M-theory, reviewers and responders have tended to focus instead on the authors' claim that the universe does not require a god for its existence (Garner 2010; *Targeted New Series* 2010; Gundy 2010). M-theory suggests that the universe of which we are aware is not that only one, but, in fact, multiple unique universes exist (Hawking 2010). The idea of multiple universes or realities is not new, but the details specific to M-theory are relatively new developments. While the religious community may be unhappy with Hawking's suggestions, one reviewer using the words "condescending" and impenetrable",

another reviewer calls *The grand design* "accessible", and another points out that the focus of the book is M-theory, not religion (Garner 2010; Kluger 2010; *New Scientist* 2010).

WORKS ABOUT HAWKING

Hawking does not dwell on his physical difficulties. He has been supported by family as well as medical care-givers (Hawking 1993). Up until 1985, Hawking was still able to communicate with his own voice, though at that time only those people who knew him very well were able to understand his extremely slurred speech. Even that ended when Hawking caught pneumonia and had to have a tracheostomy operation (Hawking 1993). For a while the only way he communicated was by raising his eyebrows when someone would point to the correct letter on an alphabet card. Then Walt Woltosz, a computer expert from California, sent Hawking a computer program which allowed him to select words using small movements of a switch controlled by his hand, or by small movements of his head or eyes (Hawking 1993). This information is then sent to a speech synthesizer, a voice which is now famous and widely associated with Hawking. It is the startling contrast between Hawking's physical limitations and extraordinarily able intellect, however, which seems to make his life story particularly interesting. Beyond this contrast, Hawking has attracted public attention with his efforts in increasing the scientific awareness of the general public. The public, in turn, has had an interest in Hawking himself.

Stephen Hawking: A life in science by White and Gribbin was first published in 1992 and republished in an updated version in 2002. This biography skillfully meshes together Hawking's private life with his life in science to create a clear, personal picture of the famous scientist. The Cambridge University Press publisher and St. Edmund's College fellow Simon Mitton, writing

in *Nature* (one of the most important general science journals), however, criticizes the heavy use of previously published materials for information on Hawking's personal life, questions the validity of many anecdotes, and points out the books has "many" factual errors (1992). Mitton, according to White and Gribbin, was the head of the Institute of Astronomy, where Hawking became a staff member in the late 1960s. Other reviewers, who may not be as personally familiar with Hawking's story, have praised *A life in science* for being highly readable and an "inspiring account" of Hawking' s life (Sapp 1992; Dixon 1992).

Jane Hawking (Wilde) describes her life with Hawking and their marriage of 25 years in *Travelling to infinity: My life with Stephen* (2007). This book is as much a memoir as it is a biography as she relates both her life as well as Hawking's. *Travelling to infinity* focuses on Wilde's romantic involvement with Hawking, the growth of their family, the strain of their life together as Hawking's condition worsened and his fame grew, and their eventual separation and divorce. While she does write some about physics and Hawking's academic life, her view is less technical and more personal than are found in other accounts of the scientist.

Other less widely read biographies have also been written. *Stephen Hawking: A quest for the theory of everything* (1992) and *Stephen Hawking: A biography* (2007) attempt to give overviews of the scientist's life for a general audience while a great number of books such as *Stephen Hawking (Great achievers)* (1995), *The importance of Stephen Hawking* (1995), and *Hawking and black holes: The big idea* (1998) aim to introduce the scientist to a school-aged audience. Additionally, brief biographical pieces can be found in collections such as *Great physicists: The life and times of leading physicists from Galileo to Hawking* (2001) or, for younger readers, in *Great scientists* (2007).

CONCLUSION

In his early teen years, Hawking's friends made a bet as to his fate. One friend bet another that Hawking would never amount to anything. Hawking has stated, "I don't know if this bet was ever settled and, if so, which way it was decided" (Hawking 1993, 9). Even if Hawking claims to not know the outcome of the bet, his influence in the world of cosmology and his impact on popularizing science has been profound. He has written extensively for academia and has been cited widely. His success in writing for the lay audience has ignited interest in learning more about physics and about the scientist's life. From what may have been an unfocused beginning, Hawking has become today's most famous scientist.

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Figure 1. Hawking's Timeline

Year	Life Event
1942	January 8th – Stephen Hawking is born
1959	Awarded scholarship to attend the University of Oxford
1962	Begins graduate work at the University of Cambridge
1963	Diagnosed with Lou Gehrig's disease
1965	Publishes first academic paper "On Hoyle-Narlikar theory of gravitation"
	Awarded research fellowship at Gonville and Caius
	Jane Wilde and Hawking are married
1967	First child, Robert, is born
1970	Second child, Lucy, is born
1974	Publishes "Black-hole explosions"; second most cited paper
	Honored as a Fellow of the Royal Society
1975	Publishes "Particle creation by black-holes"; most cited paper
	Awarded Eddington Medal from the Royal Astronomical Society in London
	Awarded the Pius XI Medal from the Pontifical Academy of Science at the Vatican
1976	Awarded the Hopkins Prize
	Awarded the Dannie Heinemann Prize
	Awarded the Maxwell Prize
	Awarded the Royal Society's Hughes Medal
1979	Third child, Timothy, is born
	Received the Albert Einstein Award
1980	Inaugurated as Lucasian Professor of Mathematics at Cambridge
1988	Publishes bestselling *A Brief History of Time*
	Awarded Israeli Wolf Foundation Prize in physics
1989	Companion of Honor
1990	Separates from wife Jane Wilde
1993	Makes cameo appearance on *Star Trek The Next Generation*
1999	Awarded Julius Edgar Lilienfeld Prize from the American Physical Society
2006	Awarded the Copley Medal by the Royal Society
2007	Experiences weightlessness at NASA's Kennedy Space Center
2009	Received Presidential Freedom Award
2010	Received Cosmos Award

Figure 2.

Top 20 Most Cited Hawking Papers – Total Citations
(Source: Thomson Reuters ISI Web of Knowledge)
Data gathered on October 15, 2010

Title	Source Title	Year	Total Citations
Particle creation by black-holes	*Commun. Math Phys.*	1975	3629
Black-hole explosions	*Nature*	1974	1458
Wavefunction of the universe	*Physical Review D*	1983	1409
Action integrals and parition-functions in quantum gravity	*Physical Review D*	1977	1251
Cosmological event horisons, thermodynamics, and particle creation	*Physical Review D*	1977	1092
The development of irregularitites in a single bubble inflationary universe	*Physics letters B*	1982	937
Zeta function regularization of path integrals in curved spacetime	*Commun. Math Phys.*	1977	836
4 laws of black hole mechanics	*Commun. Math Phys.*	1973	702
Breakdown of predictability in gravitational collapse	*Physical Review D*	1976	623
Thermodynamics of black-holes in anti-desitter space	*Commun. Math Phys.*	1983	529
Singularities of gravitational collapse and cosmology	*Proc. Roy. Soc.*	1970	477
Supercooled phase-transitions in the very early universe	*Physics letters B*	1982	440
Black holes in general relativity	*Commun. Math Phys.*	1972	433
The quantum state of the universe	*Nuclear Physics B*	1984	418
Black-holes and thermodynamics	*Physical Review D*	1976	409
The unpredictability of quantum-gravity	*Commun. Math Phys.*	1982	326
Origin of structure in the universe	*Physical Review D*	1985	305
Path integrals and indefiniteness of gravitational action	*Nuclear Physics B*	1978	304
Chronology protection on conjecture	*Physical Review D*	1992	303
Gravitational multi-instantons	*Physics letters B*	1978	302

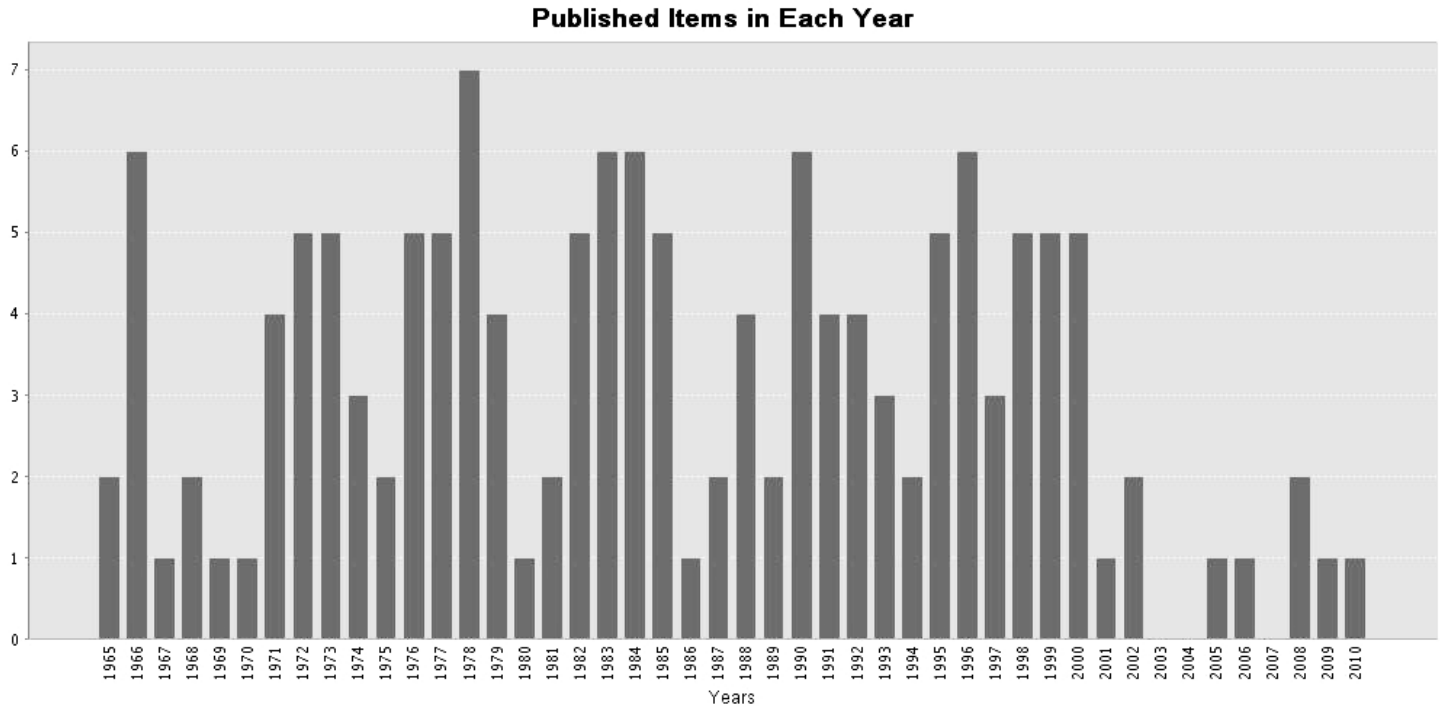
Figure 3.

Top 20 Hawking Papers – Average Citations per Year
(Source: Thomson Reuters ISI Web of Knowledge)
Data gathered on October 15, 2010

Title	Source Title	Year	Average per Year
Particle creation by black-holes	*Commun. Math Phys.*	1975	100.81
Wavefunction of the universe	*Physical Review D*	1983	50.32
Black-hole explosions	*Nature*	1974	39.41
Action integrals and parition-functions in quantum gravity	*Physical Review D*	1977	36.79
The development of irregularitites in a single bubble inflationary universe	*Physics letters B*	1982	32.31
Cosmological event horisons, thermodynamics, and particle creation	*Physical Review D*	1977	32.12
Brane-world black holes	*Physical Review D*	2000	25.55
Zeta function regularization of path integrals in curved spacetime	*Commun. Math Phys.*	1977	24.59
Thermodynamics of black-holes in anti-desitter space	*Commun. Math Phys.*	1983	18.89
Rotation and the ADS-CFT correspondence	*Physical Review D*	1999	18.58
Information loss in black holes	*Physical Review D*	2005	18.5
4 laws of black hole mechanics	*Commun. Math Phys.*	1973	18.47
The gravitational Hamiltonian, action, entropy and surface terms	*Class. Quant. Grav.*	1996	18
Breakdown of predictability in gravitational collapse	*Physical Review D*	1976	17.8
Entropy, area, and black-hole pairs	*Physical Review D*	1995	16.88
Brane new world	*Physical Review D*	2000	16.27
Chrolonogy protection conjecture	*Physical Review D*	1992	15.95
The quantum state of the universe	*Nuclear Physics B*	1984	15.48
Supercooled phase-transitions in the very early universe	*Physics letters B*	1982	15.17
Wormholes in spacetime	*Physical Review D*	1988	12.04

Figure 4.

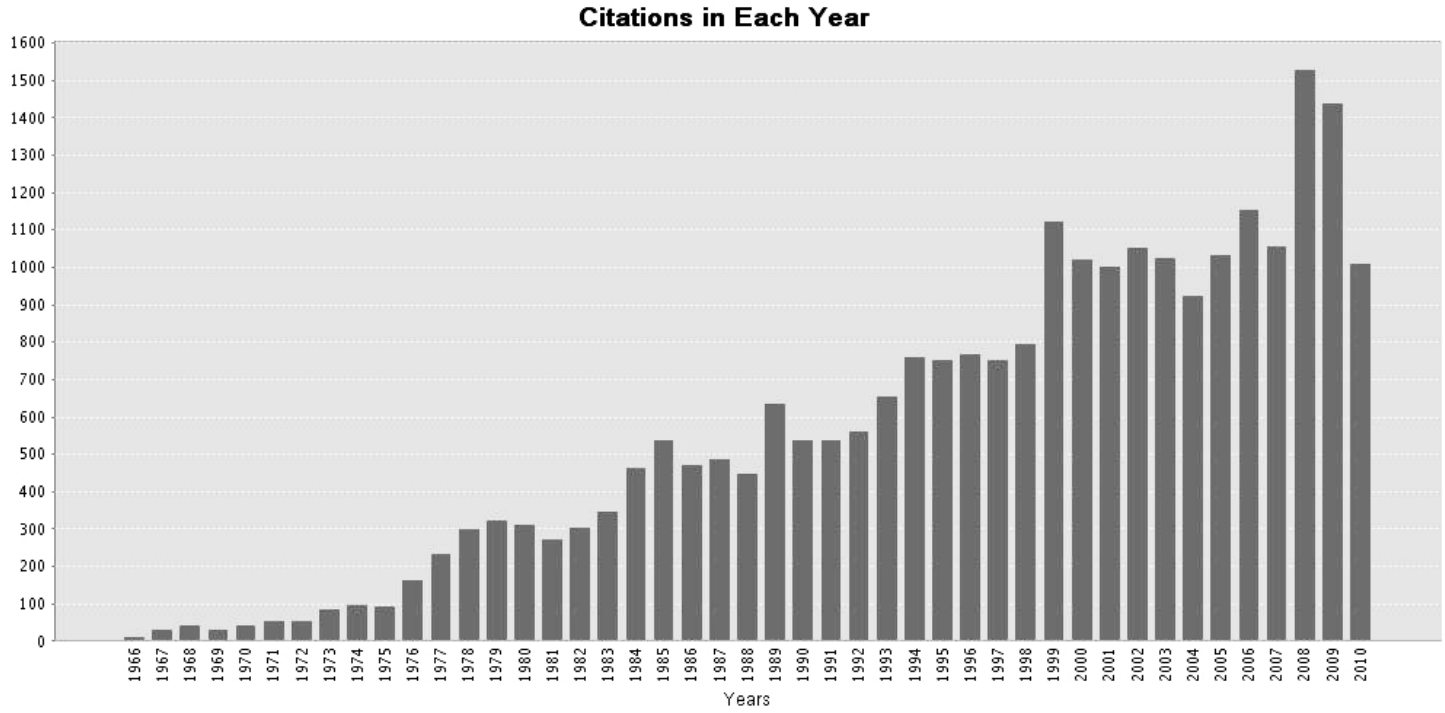
Hawking's Publications by Year
(Source: Thomson Reuters ISI Web of Knowledge)
Graph generated on October 15, 2010



This graph only shows the 144 publications retrieved in the author search "Hawking, SW" and exclude the 14 publications that were found by analyzing the results of the author search "Hawking, S".

Figure 5.

Number of Citations of Hawking Publications by Year
(Source: Thomson Reuters ISI Web of Knowledge)
Graph generated on October 15, 2010



This graph only shows the 144 publications retrieved in the author search “Hawking, SW” and exclude the 14 publications that were found by analyzing the results of the author search “Hawking, S”.

Figure 6.

Hawking's Books
(with Hawking as a primary author or editor)

Pub Year	Audience	Title Publisher
1973	Academic	*The large scale structure of space-time* Cambridge University Press
1979	Academic	*General relativity: An Einstein centenary survey* Cambridge University Press
1979	Academic	*The limits of space and time* Great Ideas Today
1981	Academic	*Superspace and supergravity* Cambridge University Press
1986	Academic	*Supersymmetry and its applications: Superstrings, anomalies, and supergravity* Cambridge University Press
1988	Popular	*A brief history of time* Bantam
1989	Academic	*Three hundred years of gravitation* Cambridge University Press
1993	Academic	*Euclidean quantum gravity* World Scientific Pub Co Inc
1993	Academic	*Hawking on the big bang and black holes* [collected papers] World Scientific Pub Co Inc
1993	Popular	*Black holes and baby universes* Bantam
2001	Popular	*The universe in a nutshell* Bantam
2003	Academic	*On the shoulders of giants* Running Press
2005	Popular	*A briefer history of time* Bantam
2005	Academic	*God created the integers* Running Press
2007	Youth	*George's secret key to the universe* Simon & Schuster
2007	Academic	*A stubbornly persistent illusion: The essential scientific works of Albert Einstein* Running Press
2009	Youth	*George's cosmic treasure hunt* Simon & Schuster
2010	Popular	*The grand design* Bantam