GEORGE GREEN, APPLIED MATHEMATICIAN

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Consider the typical characteristics of the lives of many of the mathematicians we now consider historically significant: having educated parents, attending the best schools, winning a mathematical contest, or holding an endowed chair at a university. In contrast, there is George Green, the man for whom Green's Theorem of Multivariate Calculus is named. He made revolutionary advances in mathematics despite lacking all the above named academic advantages. The July 1993 bicentennial of Green's birth was the occasion of several events celebrating his life and work. In fact, only recently have the fascinating details of that life been fully understood. This short summary is offered with the aim of lifting some of the obscurity surrounding Green; much more information is available in the references.

George Green, Jr. was born into the family of a Nottingham, England baker and his wife. His schooling was minimal — lasting only about 14 months, beginning at age 8. In 1807 the senior George Green built a 50 foot tall brick windmill in Sneinton, just outside of Nottingham, to insure a more reliable source of flour for baking. George, Jr. worked in the mill from his fourteenth to his fortieth year and studied mathematics and physics in his spare time. Meanwhile, he became close to Jane Smith, the daughter of the man hired to operate the mill. Their relationship led to a total of seven children, but they never married.

Green's greatest mathematical work was his first, *An Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism.* He published this privately in 1828 due to the fact that he was a miller — a common man, and not a member of any academic organization. In this work we find the proof of Green's Identity in three dimensions (but not the two–dimensional version in calculus texts!), the first use of the term "potential function," a discussion of the existence and uses of Green's functions, and extensive use of the idea of reciprocity. All of these have become important tools in the field now known as Potential Theory.

Unfortunately, the fact that the Essay was published privately meant that the learned societies of the day had no reliable way of finding out about it, and it was completely ignored by them. However, one of the purchasers of the Essay was Sir

Edward Ffrench Bromhead, an influential public administrator who lived in nearby Thurlby, Lincolnshire. He was a mathematics graduate of Caius College, Cambridge, and was astounded by what he saw in the Essay. Actually, he may have been the only subscriber who was able to understand it.

After a two–year interruption, Green and Bromhead corresponded regularly and met a few times. Bromhead's encouragement led the late–blooming mathematician to continue with further researches, and his influence with friends still in Cambridge allowed these papers to be published there.

With letters of reference from Bromhead, Green entered Caius College in October of 1833, at age 40, despite the brevity of his previous formal schooling. Green was soon noted by his professors to be the top mathematician of his year and was expected to place first in the Mathematical Tripos, the competitive exam given to graduating seniors from all colleges of Cambridge. However, in January 1837 Green finished the exam in fourth place, becoming Fourth Wrangler, instead of placing first and being Senior Wrangler. Of the three students placing ahead of him, only J. J. Sylvester later achieved some measure of renown in mathematics.

Green stayed on in Cambridge and continued his mathematical investigations, all of which were concerned with mathematical physics. Some of the problems he studied involved the motion of fluids in a canal, the motions of a pendulum, and the propagation of sound and light. Finally, in November of 1839, Green received what he had been waiting over two years for — a fellowship at Caius College. This paid him a small salary and gave more legitimacy to the work he was doing there. With his health failing, Green left Cambridge in the spring of 1840 and returned to Sneinton to live with Jane Smith and their children. He died of pneumonia in May 1841, at age 47.

Green's premature death probably kept him from completing more original research and achieving a moderate level of notoriety in his lifetime. As it was, he died a near unknown and only later was given full credit for what he had accomplished.

The rediscovery of George Green's work was done by William Thomson, who entered St. Peter's College, Cambridge in the fall of 1841, just a few months after Green died. He saw a reference to the Essay, but could not find a copy anywhere in Cambridge. After graduation and a Second Wrangler placing in the January 1845 Mathematical Tripos, Thomson planned to go to France to do some experimental

work. On the night before leaving, he saw his tutor William Hopkins by pure coincidence and discovered that Hopkins had three copies of the Essay! Thomson took two of the copies and read the Essay while sailing to France. Astonished by what he found, Thomson passed it on to some of the important mathematicians on the European continent and was able to get it published in well–known German and British journals. William Thomson is now better known as Lord Kelvin. At the age of 22 he was appointed to the Chair of Natural Philosophy at the University of Edinburgh, Scotland, a post he held for 53 years. Kelvin listed his great heroes of science as Green, Faraday, and Fourier.

What about the mill in which George Green labored for the majority of his life? It was used into the 1860s, when steam power put most of the windmills out of business, then sat idle until 1919. At that time, Green's youngest daughter died nearly destitute and the Crown took over the mill to pay her debts. The purchaser leased it to a shoe and floor polish manufacturer, who used the structure until it was heavily damaged in a 1947 fire. Again the mill sat idle until the mid 1970s, when rumors that a new highway would require the mill to be razed prompted a group from the University of Nottingham to begin working to restore it. Their efforts were highly successful, resulting in a complete renovation of the exterior and interior. In fact, the mill now grinds grain into flour just as it did 150 years ago. Also, added onto the mill was a Science Center containing educational displays about applications of Green's mathematics. Special thanks are due to Mr. Denny Plowman, Keeper of Green's Mill and Science Center, for his assistance with my research into George Green's life and work.

There were several celebrations held in 1993 in Green's honor. One of these included the placing of a plaque with Green's name in Westminster Abbey, London. It is near the statue of Isaac Newton and the plaques for Kelvin, Faraday, and Maxwell. This fulfills a wish of Green himself. In April 1833, Edward Bromhead wrote to Green and invited him to go to Cambridge to meet Bromhead's friends, those whom he called the "chivalry of British science." Green's response was, "I think I have no right to go there, and must defer that pleasure until I shall have become a tolerably respectable man of science, should that day ever arrive."

That day has certainly arrived, although it took 160 years for proper recognition to be given to Green's work. Finally, he has taken his rightful place among the great names of nineteenth–century British mathematics and science.

References

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