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Reginald Sutcliffe and the Invention of Modern Weather Systems Science

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All four of my grandparents—Thomas and Charity (Madison) Kingston and Leo and Eugenie (Levesque) Martin—were denied an education as a result of circumstances beyond their control. The impact of its absence on their lives was substantial, and yet they celebrated the opportunities enjoyed by their children and grandchildren. This book is dedicated to them.

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PREFACE

ON MONDAY, FEBRUARY 4, 1924, Milwaukee, Wisconsin, suffered its greatest twenty-four-hour snowfall event ever as 20.3 inches accumulated beginning late on Sunday night. Having had only the minimal warning available through reports of where it was snowing heavily on Sunday, the city was immobilized by Monday morning as the heavy snow, combined with strong northeasterly winds, piled ten-foot drifts throughout the area. Schools and businesses were closed for days as the streets remained impassable long after the snow finally stopped falling.

Just shy of a century later, on January 28, 2019, the forecast of another significant snowstorm prompted municipal officials to close schools before a single flake had even fallen, prepare roads for snow and ice, and expand emergency services in anticipation of the storm. The city and its 500,000 citizens consequently navigated the ensuing seven-inch snowfall with considerably less disruption to daily life and commerce, and were quickly able to ready themselves for the next weather challenge, the most intense cold wave in nearly a quarter century that came on the heels of the snow. That impactful meteorological event was also forecasted well in advance, and so its arrival, severity, and duration were not at all surprising to the winter-weary citizenry. Clearly, a revolution had occurred in the intervening century.

The revolution, of course, has been in our ability to predict the weather. As recently as the early 1950s, the notion of a reasonably accurate two-day forecast existed only in the minds of fabulists and the very few research scientists who were actively working on the problem. The remarkable advance in predictive ability since that time is arguably one of the most unheralded scientific advances of

the second half of the twentieth century. It was propelled by a predecessor revolution in understanding borne of the development of meteorological science as a true branch of physics. That development, in turn, was at least partly a function of innovations that arose in the urgent struggle against fascism during World War II. The intellectually nimble, critically thinking, and adaptable populace that powered the western democracies to victory was, itself, the end result of a series of slowly mobilized social reforms enacted throughout the nineteenth century that had gradually replaced child labor with access to education.

Though contributions to the development of modern meteorology were made by a large number of scientists in the first half of the twentieth century, an argument can be made that the operational and theoretical innovations produced by one man, Reginald C. Sutcliffe, laid the foundation for the transformation of weather science that has fundamentally reshaped the world in which we live. What follows is the story of his life, his times, and his scientific contributions. Along the way the reader will be introduced to a number of people, places, events, ideas, and social movements that exerted a substantial influence on Sutcliffe's life and on his science. In many ways, his life was unusually illustrative of the progress often associated with the century in which it was lived. His was the first generation in his family's history to trade the socioeconomic suffocation imposed by field or factory labor for the promise of a professional career through comprehensive education. Global economic depression robbed him of the choices his hard work should have secured for him. Long service in World War II interrupted a blossoming career that he resurrected through a combination of necessity and intestinal fortitude. National investments in basic scientific research and expanded access to university education in the aftermath of the war afforded him important leadership opportunities that he ably wielded to forge crucial elements of present-day research and higher education infrastructure.

It seems particularly appropriate, and important, that Sutcliffe's story be told today as civilization finds itself faced with the existential threat imposed by a changing climate. Understanding of the essential physical dimensions of this threat is rooted in the modern weather systems science that his creative genius helped to establish. In fact, the same advances that have led directly to the maturation of weather forecasting now inform the climate debate through the provision of computer model projections of the future behavior of the system. These powerful predictive tools have become so deeply incorporated into our daily lives and our collective sense of the prospects for the future

that they risk being taken for granted. It is my hope that shining a light on Sutcliffe's life and work will, in some way, reduce that risk and inspire instead a renewed appreciation for the human dimension in progress and the rich legacy bequeathed to societies wise enough to fully embrace investments in education and basic research.

INTRODUCTION

The Waiting

THE DULLNESS AND COLD of winter had lingered for nearly all of the early summer in 1922 as the school year raced to its close. Perhaps it was for the best as such weather severely limited the distractions most likely to appeal to a young sportsman like Reggie Sutcliffe, and thus assisted him in maintaining his focus going into the two weeks of Certificate Examinations which had begun on Monday, July 3. After such a prolonged dreary spell, the early afternoon sunshine on July 25 was the perfect complement to the lightness and sense of triumph that filled young Reggie's heart as he walked home down the hill from school that Tuesday. The summer holiday was at hand; he would never attend the Whitcliffe Mount School again. He felt confident that he had done well in the examinations and so held out reasonable hope of securing a coveted County Major Scholarship. Unfortunately, announcement of the results was not promised until late August. Such a delay, and the uncertainty it imposed on his immediate future, was a source of percolating anxiety. Nonetheless, he took deep, satisfied breaths as he slowly wound his way down Whitcliffe Road to Prospect Road and then along the shortcut passage between the homes fronting it that led directly to his own home at 9 Prospect Terrace.

In that modest rowhouse, his mother, Jessie, was waiting for her boys, Reggie and his younger brother, Alfred, to return. Their father, Ormerod, a grocery manager at the Cleckheaton Cooperative on Market Street, would be occupied at work until just past 6 p.m. Ormerod, though possessed of a love of learning manifest in his modest collection of books, was, like so many of his generation, denied a formal education by the meager circumstances of his youth. Over the years the Sutcliffe boys had observed that their father's true vocation was the

constant attention he gave to his books and his beloved microscope. In fact, less than a week earlier at a meeting of the Workers' Educational Association (WEA), he had proposed that the organization feature a course of study in biology for the coming fall and winter. His name had even appeared in the July 21 edition of the *Cleckheaton-Spenborough Guardian*, where it was said that he "confessed to having received invaluable benefit . . . benefit he valued beyond any amount of gold or silver" from his prior WEA courses in biology. In what would be the proud apex of his academic experiences, Ormerod Sutcliffe would serve as lead instructor in the coming course.

At the moment, Reggie had a few hours of rare summer sunshine to occupy. Greeting his mother at home, he informed her that he was off to meet his mates for the afternoon. Expecting exactly that, Jessie suggested only that he be back promptly for dinner at 7. In reality, he had no particular plans at all for the afternoon. Taking the shortcut passage back to Prospect Street, he crossed the railroad bridge on Whitcliffe Road and headed right down the aptly named Serpentine Road that wound about two-tenths of a mile down toward the town center where it became Horncastle Street. He passed the Market Hall before walking by the Picture Palace at the corner of Bradford Road. Occasionally, one or another of the Sutclifffes would find themselves at the motion pictures, but it was not a common pastime for them. With Mary Massart in the *Knave of Diamonds* and Helen Chadwick in Jack London's *Godless Men* as the offerings of the week, Reggie's latent lack of interest in the movies crossed the line into utter disinterest.

Turning right onto Bradford Road he walked past the magnificent Cleckheaton Town Hall to his left. The Queen Anne–style building with its enormous and ornately decorated concert hall had opened just thirty years before, on February 10, 1892, and had been an enduring source of pride for the community ever since. In fact, in the intervening three decades, only one other event provoked a similar swell of civic pride in the working-class populace of Cleckheaton—the opening of the Whitcliffe Mount School, now his alma mater, just twelve years earlier. The merchants fronting the Cleckheaton Town Hall were familiar to Reggie: Townsend's Boots and Shoes, Wadam's Coats, and F. Stansfield Optician, where his father tended to his eyeglass needs. Further down the street to the south were more shoe shops: Public Benefit Boot Company, along with Kelsall's Boots and Gloves. He stopped into Kelsall's at his mother's request to buy some new socks for him and Alfred as they were about to leave for the annual Whitcliffe Mount scouting trip. At the corner of

Bradford Road and Market Street was one of Reggie's favorite shops, J. Oade Bicycles. Being near his father's grocery on Market Street, Reggie had been a frequent visitor to the shop over the past several years, always interested in looking at the beautiful new bicycles and occasionally purchasing a patch kit or chain oil for his own basic model.

After an idle half hour or so of fantasizing over the bicycles, he headed up Market Street to the Cleckheaton Cooperative to visit with his father and to pick up an apple to sate his hunger until dinner. He had always enjoyed watching his father interact with the customers at the grocery and had developed a deep respect for his friendly, diplomatic manner. Ormerod offered Reggie an enthusiastic congratulations on the end of his successful grammar school career while silently yearning for more for his talented boy. Knowing that his son had already completed more education than anyone in Sutcliffe family history, Ormerod was well aware that more was possibly on the immediate horizon, and he suffered with his son in their mutual uncertainty. He was far too wise to let any of that anxiety show as he discussed the possibility that Reggie could work in the coop after returning from the scout trip in mid-August.

Informing his father he would be back shortly to walk home with him, Reggie was off around the corner to Taylor's Chemists at 51 Northgate to do another errand for his mother. While waiting for his prescription to be filled he may have glanced at copies of the *Cleckheaton and Spenborough Guardian*. Buried in its pages on that day was news of the collapse of the German mark and the acceleration of the calamitous hyperinflation that was plaguing Germany in the wake of the reparations demanded at Versailles. He could not know that these distant rumblings represented the leading links in a chain of events that would eventually play an outsized role in shaping his life, his life's work, and the world at large.

He continued his wandering down Cheapside and back up Albion Street, perhaps hoping to run into his many friends, but really just to let the moment, the culmination of his hard work at Whitcliffe Mount, sink in. He wondered how a university education might influence the trajectory of his life, for he had no proximate model. In fact, the closest such models he had were those of his headmaster and physics master at school. They seemed to lead exciting, fulfilling lives and enjoyed enormous respect from their students and the larger community. What would he do with an education in mathematics? Even now, and in spite of his affection for his own teachers, he knew he did not want to be a schoolteacher. Perhaps a man of business? Such enterprises require able minds armed with powerful analysis skills in order to ensure success. Though

he struggled to free his mind of thoughts of his hypothetical university education, he could not resist and found himself imagining the daily round trip he hoped soon to be making to Leeds. When should he leave to get to class and when would he come home? How easy would it be to make new friends? What would it be like to attend college classes? His physics master, William Pearson, had attended Leeds and had spent the last two years filling young Reggie's head with expectations. As he aimlessly wandered through town consumed with his thoughts, he spied some of his schoolmates seemingly in the same trance while on missions of their own. Uncharacteristically, for he was a very popular lad, he purposefully avoided them all in order to maintain focus on his internal dialogue.

Mercifully, the 6 o'clock hour finally arrived, and Reggie reconnected with his father at work as planned. Together they walked up Market Street to Westgate and turned left onto Tofts Road. They were leisurely in their pace to allow continued conversation and to ensure the uphill grade was not unduly challenging to Ormerod who had a weak heart. It was a short walk, and in ten minutes they were greeted by the familiar warmth of the Sutcliffe home filled with the aroma of dinner on a sunny summer evening. The conversation turned to Reggie and Alfred's camping trip to Tal-y-bont, a few miles inland from the mouth of the River Conwy in North Wales, to be led by the headmaster at Whitcliffe Mount, Herbert Clayborn. They were leaving on Friday and returning two weeks later on August 11. Both Reggie and Alfred had taken part in prior camping trips, usually to some remote spot in Wales. Reggie was particularly susceptible to the spell that the stark, foreboding grandeur of the Welsh countryside can cast upon one's soul as these first exposures to the country sparked a love affair with Wales that would burn throughout his life. This year's trip would be a particularly welcome diversion from ruminations regarding his future that he knew would increasingly occupy him as the month wore on. As he would do throughout the rest of his life, on the trip he found refreshment and renewal in the water.

On Wednesday, August 23, nearly two weeks after returning from Wales and enduring a maddening, unrequited desire to finally know what his immediate future might hold, word arrived in a letter from the West Riding Council that Reggie had won a County Major Scholarship. The annual award of £70 would be sufficient to send him to the University of Leeds at the end of the following month. As luck would have it, he had come home that afternoon for lunch, leaving his father at the coop. When Jessie proudly greeted him at the door with a hug and the news, Reggie nearly fainted from the instantaneous relief of weeks of anxiety. He was elated! In their excitement, Reggie and Jessie decided

to withhold the news from Ormerod until the family sat down to dinner that evening. Reggie, about to head back to work at the coop, would be the vessel of this benevolent conspiracy.

Returning to work, he found that the pressures of the past few weeks were nearly matched by the difficulty of keeping his fabulous secret for a few short hours. Would 6 o'clock never arrive? When it did, Reggie and his father began their short walk up the hill toward home with hardly a word between them, a rare enough circumstance that Reggie worried the cat was, somehow, already out of the bag. Jessie had dinner ready upon their arrival, and after a brief wash and change of clothes, they were all seated. Realizing he and his mother had not thought about precisely how the news would be divulged, Reggie just blurted it out once his family had begun to eat. Alfred already knew and had been sworn to secrecy by his mother as part of the plan. His older brother, Robert, along with his father were, as he had hoped, caught completely by surprise. Dining ceased as an interval of stunned silence enveloped the crowded house. As if responding to a signal only they could see or hear, Robert and his parents reigned serial hails of congratulations on Reggie in what became a boisterous scene of familial pride, complete with backslapping and long embraces. Ormerod was so deeply moved by the sudden reality that a Sutcliffe was going to be university educated that he was the first of the congratulants to withdraw back into his own thoughts. All the labor, all the challenges of child-rearing, all the moving that he and Jessie had done over the last twenty years had, in fact, secured for their son the chance at a better life than the one they had lived. When he had again collected himself after a few moments, Ormerod embraced his son and rejoined the celebration full of eagerness at what the future might now hold for his boy.

CHAPTER 1

Background

THE PENNINES ARE the topographical spine of Great Britain, running northward from just northwest of Nottingham to just south of the English border with Scotland. Though even the highest points along the range are less than three thousand feet, such modest relief is sufficient to render a substantial influence on local weather and climate. The high hills are wetter, colder, and windier than the surrounding areas and can be characterized by rather severe winters. The eastern edge of the range is notably drier than the western edge, a consequence of the hills acting as a rain shadow. The net effect of these orographic influences is that the Pennines form the main watershed in northern England and divide the region's drainage into a set of rivers flowing westward toward the Irish Sea (the Eden, Ribble, Irwell, and Mersey) from a set flowing eastward to the North Sea (the Tyne, Tees, Wear, Swale, Ure, Nidd, Calder, Wharfe, Aire, Don, and Trent). Embedded in a steep and narrow portion of the Calder Valley is the village of Hebden Bridge, the site of the confluence of the Calder with the River Hebden. The consistent rainfall of the region, coupled with the steep hills, ensures a steady flow in both. The water from these rivers powered some of the first mills as the water frame technology invented by Richard Arkwright in 1769, and first implemented at the Cromford Mill at the southern foot of the Pennines in 1775, spread quickly through the region, sparking the Industrial Revolution. In fact, at one time Hebden Bridge was known as "Trouser Town" for its substantial clothing manufacturing industry. The larger cities of Manchester and Leeds, at the western and eastern foot of the hills, respectively, became centers of the wool and cloth trade, housing some of the first large factories of the Industrial Era.

By the dawn of the nineteenth century, West Yorkshire had been transformed from a remote, pastoral region with a mining and small manufactures economy into the very heart of the factory-based economy of the Industrial Revolution. The boom of industry was accompanied by a decline in living conditions as overcrowding in the factory towns heightened the risk of waterborne diseases such as cholera, which erupted in both 1832 and 1848 in the region. In addition, factories of the time often employed a large number of women and children, cheap labor available at very low wages. Many of the children were pauper children from London and other southern cities: boys and girls between the ages of seven and twenty-one who were dependent on the Poor Law Guardians, local property owners elected annually to oversee the administration of the Poor Laws, including operation of the notorious union workhouses. Mill owners would contract with these guardians for large numbers of such children to be "apprenticed" as factory labor. Living conditions were poor in the so-called "prentice houses," and the children were often paid two pence a day (~$1.25 in today's US dollars) for fifteen-hour shifts and hot bedding (i.e., serially sharing a single bed) with children in the opposing shift. In England and Scotland in 1788, two-thirds of the workers in 143 water-powered cotton mills were children.[1] Workhouses would sell orphans and abandoned children as "pauper apprentices," who worked without wages for board and lodging. Children employed as mule scavengers by cotton mills would work fourteen hour days, six days each week, crawling under machinery to pick up cotton. Devastating injuries, including loss of hands or other limbs, and even death by decapitation or by crushing beneath the machines were among the terrible fates suffered by some of these unfortunates.

Of course, such labor conditions left child employees of the factories completely without an education. These abuses were addressed by Parliament in a series of Factory Acts designed to regulate the conditions of industrial employment. The first such legislation, the Health and Morals of Apprentices Act of 1802, introduced by Sir Robert Peel, was motivated by the concerns of medical experts regarding the health and welfare of children employed in the cotton mills of Manchester. Since the act was largely concerned with the employment of apprentices, it offered no regulation of "free" (non-indentured) children. Additionally, as it *permitted* local magistrates to enforce compliance but did *not require* them to do so, it was largely unenforced. The act specified that, in addition to meeting some basic hygienic conditions, factories could not employ apprentices during the evening (9 p.m. to 6 a.m.) and their working day

could not exceed twelve hours, exclusive of the time taken for breaks. In addition, apprentices were to be educated in reading, writing, and arithmetic for the first four years of their apprenticeship. This was directed to occur during every working day within usual working hours, but the act did not specify how much time should be set aside for learning. The classes were to be held in a section of the mill or factory specifically designed for the purpose. Every Sunday apprentices were to be given one hour of instruction in Christianity, every other Sunday a service was mandated in the factory, and once a month the apprentices were to visit a church. Furthermore, each apprentice was to be examined by a clergyman at least once each year. Male and female apprentices would sleep separately with not more than two per bed.[2]

The local magistrates were charged with appointing two inspectors, known as visitors, who were to make sure that the factories and mills were complying with the specifics of the act. One inspector would be a member of the clergy, the other a justice of the peace, and neither was to have any vested interest in the mill or factory. The visitor had the authority to assess fines for noncompliance, and the right to visit and inspect the facility at any time of day. A written copy of the act was to be displayed in two places in a given mill or factory and owners who refused to comply with any provision of the act could be fined between 2 and 5 GBP ($250–$615 equivalent today). The act took effect in June 1804.

In order to bring nonindentured children under the regulatory protection of the government, the Cotton Mills and Factories Act of 1819 was carried through Parliament again by Peel. This act prohibited employment of any child under the age of nine and further mandated a maximum twelve-hour workday for children ages nine to sixteen. Though it did apply to all children, as the name suggests, this act regulated only the cotton industry. It originated in a draft prepared by the reformer Robert Owen in 1815, but emerged four years later in a substantially weaker form and shared the fatal flaw of its predecessor: it was effectively unenforceable. Specifically, enforcement was left to local magistrates who could only inspect a mill if two witnesses had given sworn statements concerning a given mill's noncompliance.[3]

After these initial attempts to regulate the growing cotton milling industry and safeguard the health and well-being of children, Parliament wrestled with the competing demands of burgeoning capitalism and social welfare in a series of additional measures in 1825, 1829, and 1831. The Factory Act of 1833 (known also as Althorp's Act) provided that children under the age of nine could not be employed in textile manufacturing (except in silk mills), children under the

age of eighteen could not work between 8:30 p.m. and 5:30 a.m., and children ages nine to thirteen must not work more than eight hours each day, must have a one-hour lunch break, and must have two hours of education each day. The workday extended to a maximum of twelve hours each day for children ages fourteen to eighteen. Importantly, a Factory Inspectorate (with authority from the Home Office) was established to carry out routine inspections with magisterial authority and a right to demand entry.[4] Further acts in 1844, 1847 (the Ten Hours Act), and 1850 represented a tug-of-war between the magnates and the social reformers, and left the condition of child laborers effectively unchanged from 1833. In fact, the lack of what would today be judged progress on protecting children in this regard was at least partially an artifact of a prevailing attitude of the day among opponents of such protections—namely, that the life of a mill child was preferable to that of many other children (child miners, for example), as other industries were more labor-intensive, more dangerous, more unhealthy, required longer hours, involved more unpleasant working conditions, or were more conducive to lax morals. Interestingly, once it became established that the enactment of these reforms in the textile industry, weak though they were compared to modern standards, had not adversely affected the prosperity of either the industry as a whole or of the industrial millworkers, the very same argument was inverted and used to bring the textile trades within the scope of the Factories Acts, including bleaching and dyeworks (1860), lacework (1864), calendaring (1863), and finishing (1864). In 1864 the Factories Extension Act was passed, expanding the original act to a number of additional, nontextile occupations (i.e., pottery, match making, cartridge making, and paper staining). The Factories and Workshop Act of 1878 consolidated all of the provisions of the previous acts together to ensure that no child under the age of ten was to be employed anywhere, education was compulsory for children up to ten years old, ten- to fourteen-year-olds could only be employed for half days, and women could not be employed for more than fifty-six hours each week.[5] Another thirteen years passed before the Factory Act of 1891 raised the minimum working age to eleven. After another ten years, the Factory and Workshop Act of 1901 raised the minimum age to twelve while further addressing the education of children, mealtimes while at work, and the provision of fire escapes from commercial buildings. In total, just over a century had passed since the first Factory Act of 1802 and, looking back in 1910, Sidney Webb (who had years before helped establish the London School of Economics) felt compelled to opine:

> The system of regulation which began with the protection of the tiny class of pauper apprentices in textile mills now includes within its scope every manual worker in every manufacturing industry. From hours of labour and sanitation, the Law has extended to the age of commencing work, protection against accidents, mealtimes and holidays, the methods of remuneration, and in the United Kingdom as well as in most progressive English-speaking communities, to the rate of wages itself. . . . It has even . . . converted the economists themselves . . . to a "legal minimum wage"—and the advantage of Factory Legislation is now as soundly "orthodox" among the present generation of English, German, and American professors as "laissez-faire" was to their predecessors[6]

He also could not refrain from analysis of the manner by which this transformation had been wrought:

> This century of experiment in Factory Legislation affords a typical example of English practical empiricism. We began with no abstract theory of social justice or the rights of man. We seem always to have been incapable even of taking a general view of the subject we were legislating upon. Each successive statute aimed at remedying a single ascertained evil. . . . Neither logic nor consistency, neither the over-nice consideration of even-handed justice nor the Quixotic appeal of a general humanitarianism, was permitted to stand in the way of a practical remedy for a proved wrong. That this purely empirical method of dealing with industrial evils made progress slow is scarcely an objection to it. With the 19th century House of Commons no other method would have secured any progress at all.[7]

A parallel abuse of workers exacerbated in the Industrial Era in Britain was the long-standing operation of truck systems (equivalently, company store systems). In such a system employees of a mill or factory were paid, not in legal tender, but in vouchers or token coins, which could only be spent at the company—or truck—store. The potential for abuse in such a closed economic system was widely exploited by factory owners who were able to set artificially high prices for consumer goods or provide only the lowest quality of such goods, or both. As the number of employees connected to manufacturing rapidly grew with industrialization, so too did the fraction of total capital (in the form of wages) that became sequestered from the regional and national economy. Thus, the truck system was not only unfair to the industrial worker, but also was damaging to the broader

economy as it explicitly prohibited market competition for the wages of factory workers. Under this system, it was easy for a worker to become so indebted to an employer as to be powerless to legally leave his employ.

Various Parliamentary attempts to restrict the abuses of the truck system had been enacted from as early as 1464.[8] The various enactments were first applied to one type of manufacturing enterprise and then others in succession. In this systematic way, a series of Truck Acts gradually came to regulate the practice in nearly all fabrication industries in England. These various measures were collected and consolidated in the Truck Act of 1831, which provided "that the entire amount of wages earned by or payable to any artificer in any of the trades . . . in respect of any labour by him done in any such trade, shall be actually paid to such artificer in the current coin of the realm, and not otherwise."[9] Later, specific expansions to this provision, such as the Hosiery Manufacture (Wages) Act of 1874, were made to protect workers in the hosiery trade from abuses arising from rental charges for the equipment they used in the factory.

Legislative remedies were not, however, the only response to the abuses of the truck system at the dawn of the Industrial Era. The Fenwick Weavers' Society was a professional guild founded in 1761 in the village of Fenwick, East Ayrshire, Scotland, to collectively foster and maintain high standards in the weaving craft. By 1769 the society's activities had grown to include collective purchasing of bulk food items and books through the pooling of member resources. This institution of collective commerce for the benefit of members argues for consideration of the Fenwick Weavers' Society as the first Industrial Era consumer cooperative. The first incorporation of this concept to an industrial factory setting is attributed to Welshman Robert Owen.

Owen was born in the small market town of Newtown, in Montgomeryshire, Wales, in 1771, the sixth of seven children. He received formal education until the age of ten, at which point he was sent to London with his brother William. He apprenticed in the drapery business in Stamford for three years and then returned to London in the employ of another draper.[10] These experiences prepared him to take a position, in 1787, in the wholesale and retail drapery business in Manchester, a city poised to become the capital of the English Industrial Revolution. Near the end of 1790, he borrowed 100 GBP (approximately $16,000) from his brother William and became a clothing manufacturer in the shadow of the new spinning mills.[11] In 1792 he became manager at the new Piccadilly Mill where a reputation for production of fine yarns was quickly acquired. In the wake of a business relationship thwarted by marital politics,

Owen left Piccadilly Mill in 1795. The next year, along with three partners, he opened a new mill, the Chorlton Twist Company. During a visit to Glasgow, Owen met David Dale, proprietor of the New Lanark Cotton Spinning Mill. Immediately interested in Dale's daughter Caroline, Owen discovered that Dale was looking to sell New Lanark to someone who would continue his progressive approach to industrial manufacturing, especially his humane policy toward children. Owen's willingness to oblige was likely a substantial factor in Dale's decision to sell New Lanark to the Chorlton Twist Company, as well as to approve his daughter's marriage to Owen, in September 1799.[12]

The New Lanark Mill was, in 1800, the largest cotton spinning complex in England, employing nearly two thousand people (five hundred of whom were children, some only five or six years old, brought from the poorhouses of Edinburgh and Glasgow). Owen created more living space in the village and enforced higher hygienic standards. For the times, Owen was revolutionary in prohibiting the employment of children under the age of ten in the mill as well as for the promise of appropriate breaks for meals for older children. In addition, New Lanark provided access to educational opportunities for both children and adults. Notably, Owen's opening of a store in which employees could buy high-quality food and other necessities at nearly wholesale prices arguably established him as the father of the cooperative movement. These innovations at New Lanark gained high public profile when it became clear that improving the lives of his workers and their families resulted in increased productivity and profit for his business.

By the time he left Britain for the United States to oversee the establishment of what was eventually a failed utopian community in New Harmony, Indiana, in 1825, Owen's ideas, coupled with their apparent success at New Lanark, spawned the establishment of a large number of cooperatives, the vast majority of which had failed by 1840.[13] Determined to incorporate lessons learned from the numerous failures of consumer cooperatives, the Rochdale Society of Equitable Pioneers a group of twenty-eight tradesmen (roughly half of them weavers), organized in Rochdale, Lancashire, in 1844. Over a period of four months, they managed to amass 28 GBP of capital (1 GBP per person) for the purpose of opening their own cooperative filled with food items, bought wholesale, that none of them could otherwise have afforded. On December 21, 1844, the store opened, carrying a limited selection of butter, flour, sugar, oatmeal, and candles. By the following February the store had added a selection of tea and tobacco, and was soon known for providing high-quality goods.[14]

Central to the success of the store was the society's development of the famous Rochdale Principles, which pronounce a set of ideals for the operation of a consumer cooperative. Viewed from the present day, the Rochdale Principles remain conceptually appealing and fundamental: (1) open membership, (2) democratic control through a one person/one vote system, (3) distribution of surplus to members in proportion to that member's trade with the cooperative, (4) payment of limited interest on capital, (5) political and religious neutrality, (6) cash trading only without extension of credit, and (7) promotion of education. The principles form the operational basis upon which consumer cooperatives around the globe operate to this day.

AROUND THE TIME the first store opened, and just fourteen miles northeast of Rochdale, in and around the village of Hebden Bridge, John and Hannah Sutcliffe (née Ormerod) welcomed a son, William, into their family. It is not known what John Sutcliffe did for a living, though, having been born around 1810, it is quite possible that he worked in some capacity in a shop, in farming (including livestock), or in one of the growing number of mills that sprung up in the Calder Valley as the Industrial Revolution transformed the region. Whatever it was that provided sustenance to the Sutcliffes, it did not make them rich as later they moved to Horsehold, on the edge of the moor above Hebden Bridge, about seven miles from Todmorden where William sold secondhand clothes in the market. William Sutcliffe married Mary Jagger, the daughter of Thomas and Sarah (née Greenwood) Jagger, who was born in Heptonstall in 1842. Mary was also from meager means, and she and William raised their family of four in Horsehold: the eldest a son, Ormerod Greenwood Sutcliffe (whose name joined the surnames of his two grandmothers), and three daughters. During a single snowy week in December 1878, one month into what would be a particularly snowy winter, tragedy struck the Sutcliffe family as first John Sutcliffe died (December 7), followed a week later by the death of his son William (December 13) of typhus. This left Mary with four children, the oldest only eight years old, with no viable means of making a living. How she and her orphans survived at Horsehold is not known, but Ormerod, her eldest son, left school to work in a factory at age ten. He was a slight boy and, after "not having grown an inch" after three years of working in the factory, Mary, fearing that his stunted growth

was a function of the factory environment and not wanting to further compromise her son's future, took him out of the factory in 1883. Ormerod next took up work as a shop assistant in a local cooperative society, thus beginning an affiliation with the cooperative movement that endured, almost without interruption, for the rest of his life.

On November 22, 1834, Robert Cockcroft was born in Erringdon, one of seven sons of Thomas and Martha Cockcroft. In their youth, the Cockcroft brothers traveled as a team doing contract woodcutting all over the country with a sister, Peggy, who traveled with them as cook. Little additional detail exists surrounding this interesting story, though it suggests a steady living along with an unusually high level of camaraderie derived from this coordinated enterprise. Perhaps at some point in his travels as a woodcutter, Robert met Mary Sutcliffe, who was one of many children of a different William Sutcliffe, a factory manager in Hardcastle Craggs near Heptonstall. Robert and Mary were married in Heptonstall on February 20, 1864, and he became manager of the Dyers Department at his father-in-law's woolen factory, a factory driven by waterpower. Jessie Cockcroft was the third of four daughters (and a son) raised by Robert and Mary. Robert Cockcroft died a relatively young man at the age of fifty-six (on March 18, 1891), leaving five children but not at particularly young ages. The family's life after Robert's death was difficult, but they were not destitute, and work was available in the growing number of factories and workshops that had moved down from the hills into the Calder Valley in the years leading to the turn of the century.

Sometime during the 1890s Ormerod Sutcliffe and Jessie Cockcroft crossed paths and began a courtship that culminated in their wedding on February 26, 1900. As the couple were both at or near thirty, quite old for marriage at the time, they wasted little time in starting a family, welcoming their firstborn, William, into the world late in 1900, followed by Robert near the end of the next year. On November 16, 1904, Reginald Cockcroft Sutcliffe was born in the modest Sutcliffe home at 88 Bradley Road in Wrexham, Wales. In late October 1906, Willie contracted diphtheria and died, at age five, on November 3. He was buried at Lumbutts, outside of Todmorden, in the same grave as his grandparents, William and Mary, and his aunt, Alice. This tragedy, coupled with Ormerod's protracted struggle to conduct business in the Welsh language, compelled the family to leave Wales and move to the Yorkshire town of Cleckheaton where Ormerod took a job managing the grocery store at the Cleckheaton Cooperative, the identical position he had held in Wrexham. The despair that surely gripped

both parents as they marshaled the energy for the move was at least partially alleviated not long after when the last of the Sutcliffe boys, Alfred Ormerod, was born on January 10, 1908.

The Sutcliffe home was, as recalled by Reggie, a warm and congenial one. The relationships among the brothers were always amicable but never particularly close. They, like all of their relatives, had no wealth or property and lived on the "better end" of the working-class wages earned by Ormerod. Though his father had been a lay preacher in his younger days, and along with his own father had walked the hills around Hebden Bridge on Sundays to deliver their messages at various chapels, Ormerod had lost the faith in his early manhood. Jessie liked to go to church from time to time, and there was no militant anticlericalism, but organized religion played no part in the Sutcliffe home.

They were working class but were never compelled to sacrifice necessities, only luxuries. There was never a shortage of food—house-baked bread was a staple—never a need to compromise fires (Ormerod was fond of a roaring fire), and the boys were always adequately clothed. Ormerod, too, was always smartly dressed, with a bowler hat and umbrella and a tall silk hat for funerals. The secret of this apparently comfortable life given limited resources was, according to Reggie, that Ormerod was a home-loving, sober man—a rigid teetotaler throughout his life—and a nonsmoker except once each year when he indulged in a Christmas cigar. He also had a roving intellect and, though having been denied an education by the familial and social circumstances of the time, he had accumulated a library of a hundred or more books, including a bible concordance and sermons from his younger days, a presentation copy of Shakespeare in two handsome volumes (a gift from the staff at a prior position), works by Ruskin, books on socialism, and even some books in mathematics with which he had evidently struggled at some time.

Politically he was a socialist and supporter of the Labour Party, but with no particularly partisan ardor as he took little active interest in politics. He was a passionate gardener, an avocation he passed to his third son, and grew most of the family's vegetables from the onset of the World War I onward. He was heavily involved in the local Workers' Educational Association (WEA) and attended evening classes on biology at the Cleckheaton Technical School, working with his microscope and taking copious notes. Toward the end of his life he was recruited as an instructor to deliver courses himself. One can easily imagine the great pride and satisfaction that might be engendered in a keen intellect, deprived in youth of the opportunity to pursue ideas, when finally allowed to follow such

passions and rise to the level of instructor. Above all, Reggie remembered him as a nurturing father who was loved and respected as a natural response to his devotion to his wife and sons and not as a reflex to a menacing dominance.

A lifelong heart condition, which was ultimately the cause of his early death at age fifty-nine, classified him C3 in World War I and he was excused from war service. For the family this was, of course, extremely good fortune as the fathers of many of the boys' friends were conscripted and not a small number were killed. Thus, for the Sutcliffes, the war years passed without the losses borne by so many others. There was never any serious friction between Ormerod and Jessie, and Reggie recalled that his mother was "what I am sure I thought of as the norm—a reliable housekeeper who was always there to meet our needs."

Ormerod and Jessie's concern for the education of their boys, though clearly a high priority, apparently was not manifest in a dictatorial oversight of their studies. The elementary school attended by the Sutcliffe boys, the Whitcliffe Road School, was a short five-minute walk from their modest home at 9 Prospect Terrace. Reggie's memories of elementary school were vague but centered on a recollection that the schoolwork was taken in stride by all three of them, particularly so by Robert. In fact, the headmaster of the Whitcliffe Road School, Mr. Hugh Patchett, considered Robert to easily be the smartest of the three. There may well have been a recognition by their parents that Robert and Reggie were "bright," which pleased them to no end. Indeed, Robert earned a scholarship to the newly opened Whitcliffe Mount School, entering in 1913. Among the various motivations for the family's move to Cleckheaton, the story surrounding the creation of the Whitcliffe Mount Secondary School may well have been a factor. In any event, this school would make a remarkably positive influence on the Sutcliffe boys and set Reggie on a path that would eventually contribute to the construction of modern synoptic/dynamic meteorology.

Professor Sutcliffe with his ever-present globe at the University of Reading sometime in the late 1960s. Courtesy of Mrs. Elin Bowes.

ABOUT THE AUTHOR

JONATHAN E. MARTIN is a native of northeastern Massachusetts where the drama of battling the region's famous winter storms as a morning paperboy sparked a lifelong passion for the phenomenology and science of weather systems. He received his BS in meteorology at St. Louis University, his PhD in atmospheric science at the University of Washington, and has been a professor in the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin–Madison since 1994. He has earned recognition for his teaching, including the Underkofler Excellence in Teaching Award, a fellowship in UW's Teaching Academy, the Mark H. Ingraham Distinguished Faculty Award, and the UW Vilas Distinguished Achievement Professorship. He was named by the Princeton Review as one of the nation's "Top 300 Professors" and was honored by the American Meteorological Society in 2016 as the society's recipient of the Edward N. Lorenz Teaching Excellence Award for "outstanding teaching and mentoring that combines boundless enthusiasm with consummate skill to educate and inspire a generation of undergraduate and graduate students." His research expertise is in midlatitude weather systems, and he has authored over seventy scientific papers. He also has authored two textbooks; one a leading undergraduate/graduate textbook—*Mid-Latitude Atmospheric Dynamics: A First Course*—and the other an introductory text—*Introduction to Weather and Climate Science*. His scholarship includes substantial engagement with the public as he and colleague Steve Ackerman ("The Weather Guys") write a weekly column on weather and climate science for the *Wisconsin State Journal* and appear regularly on Wisconsin Public Radio.