A Case Study on the Relationship between Communication and Productivity

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Francis Crick said that if he had a flawed idea, "**[James] Watson** would tell me in no uncertain terms this was nonsense, and vice-versa. If he would have some idea that I didn't like, and I would say so, this would shake his thinking." Crick believed it essential to be "perfectly candid, one might almost say rude, to the person you're working with." The death knell to real collaboration, he said, is "politeness".

What's striking about Watson and Crick is that being unsparing with each other served their work, while a second pair of scientists, who were by all accounts in a better position than Watson and Crick to crack the problem of DNA, were stymied by a power dynamic that kept them from engaging at all.

In January 1951, the physicist **Maurice Wilkins** returned from vacation to King's College in London, one of the centres for budding DNA research, and found a young scientist named **Rosalind Franklin** working in the x-ray lab. Assuming she was his new assistant, he asked her how her research was progressing. "And she just said, 'Go back to your microscopes,' which bewildered me," Wilkins remembered.

Unbeknownst to Wilkins, Franklin had been given space in the lab he had been using (and given his PhD student as an assistant) so she could do her own DNA research, not a subset of his. The lab's director, J.T. Randall, hadn't even mentioned Wilkins to Franklin when he hired her. She was a star researcher – she made the crucial discovery that there was not just one but two forms of DNA. But she and Wilkins were in a cold war.

Sixty miles north, in Cambridge, Watson and Crick were heating each other up. "We had evolved unstated but fruitful methods of collaboration," Crick wrote, "something that was quite missing in the London group. If either of us suggested a new idea the other, while taking it seriously, would attempt to demolish it in a candid but non-hostile manner. This turned out to be quite crucial."

In January 1953, Watson visited Wilkins's office, and Wilkins showed him a critical photograph of Franklin's. "The instant I saw the picture my mouth fell open," Watson said. Known as Photo 51, it was an x-ray image of the "B" form of DNA. Watson and Crick had surmised that the DNA structure might form a helix but had no data to confirm it. Photo 51 not only showed a helical pattern but showed it clearly enough to reveal the distance between each helical twist.

The question remained: How did the four basis, those molecular building blocks of DNA – adenine, thymine, guanine, and cytosine (or A, T, G, and C) – align within the helix? As late as February 19, 1953, Watson leaned toward matching each base with a like base to form the structure (that is, A with A, T with T, and so on), while Crick advocated for complementary pairings (A with T, and G with C), in part because the amount of adenine always equal the amount of thymine, and the amount of guanine always equalled the amount of cystosine. "When one of us got on the wrong track, the other one got [us] out of it," remembered Crick.

In late February 1953, a visiting scientist suggested that the rules of hydrogen bonding would make the complementary pairings work within a helical structure, allowing A to bond to T, and C to G. Then, on the evening of February, Watson fiddled with the model of DNA and crabbed about the difficulty of making the helical structure work when the sugar-phosphate backbone was on the inside. As Watson told me, "Francis, I think, aware how hard it was to build a structure, any structure, just said, 'Build it [the phosphate] on the outside.' And I gave the flippant reply, 'It'd be too easy.'"

"Then why don't you do it?" Crick responded.

An elegant double-helix structure resulted the next morning, with each base arranged so that it naturally attracted its mate. Further, the model could "unzip" and make copies of itself, which provided insight into how DNA might replicate. Though it would take another week to finalize the model, Watson wrote that very day, at lunch, "Francis winged into the Eagle to tell everyone within hearing distance that we had found the secret of life."

It's poignant that although Rosalind Franklin and Maurice Wilkins didn't fight, they didn't talk either.
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James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin

In 1962 James Watson (b. 1928), Francis Crick (1916–2004), and Maurice Wilkins (1916–2004) jointly received the Nobel Prize in physiology or medicine for their 1953 determination of the structure of deoxyribonucleic acid (DNA). Wilkins's colleague Rosalind Franklin (1920–1958), who died of cancer at the age of 37, was not so honored because the Nobel Prize can only be shared by three scientists.

The molecule that is the basis for heredity, DNA, contains the patterns for constructing proteins in the body, including the various enzymes. A new understanding of heredity and hereditary disease was possible once it was determined that DNA consists of two chains twisted around each other, or double helixes, of alternating phosphate and sugar groups, and that the two chains are held together by hydrogen bonds between pairs of organic bases—adenine (A) with thymine (T), and guanine (G) with cytosine (C). Modern biotechnology also has its basis in the structural knowledge of DNA—in this case the scientist's ability to modify the DNA of host cells that will then produce a desired product, for example, insulin.

The background for the work of the four scientists was formed by several scientific breakthroughs: the progress made by X-ray crystallographers in studying organic macromolecules; the growing evidence supplied by geneticists that it was DNA, not protein, in chromosomes that was responsible for heredity; Erwin Chargaff's experimental finding that there are equal numbers of A and T bases and of G and C bases in DNA; and Linus Pauling's discovery that the molecules of some proteins have helical shapes—arrived at through the use of atomic models and a keen knowledge of the possible disposition of various atoms.

Of the four DNA researchers, only Rosalind Franklin had any degrees in chemistry. She was born into a prominent London banking family, where all the children—girls and boys—were encouraged to develop their individual aptitudes. She attended Newnham College, one of the women's colleges at Cambridge University. She completed her degree in 1941 in the middle of World War II and undertook graduate work at Cambridge with Ronald Norrish, a future Nobel Prize winner. She resigned her research scholarship in just one year to contribute to the war effort at the British Coal Utilization Research Association. There she performed fundamental investigations on the properties of coal and graphite. She returned briefly to Cambridge, where she presented a dissertation based on this work and was granted a Ph.D. in physical chemistry. After the war, through a French friend, she gained an appointment at the Laboratoire Centrale des Services Chimiques de l'Etat in Paris, where she was introduced to the technique of X-ray crystallography (see video below) and rapidly became a respected authority in this field. In 1951 she returned to England to King's College London, where her charge was to upgrade the X-ray crystallographic laboratory there for work with DNA.

Already at work at King's College was Maurice Wilkins, a New Zealand–born but Cambridge-educated physicist. As a new Ph.D. he worked during World War II on the improvement of cathode-ray tube screens for use in radar and then was shipped out to the United States to work on the Manhattan Project. Like many other nuclear physicists, he became disillusioned with his subject when it was applied to the creation of the atomic bomb; he turned instead to biophysics, working with his Cambridge mentor, John T. Randall—who had undergone a similar conversion—first at the University of St. Andrews in Scotland and then at King's College London. It was Wilkins's idea to study DNA by X-ray crystallographic techniques, which he had already begun to implement when Franklin was appointed by Randall. **The relationship between Wilkins and Franklin was unfortunately a poor one and probably slowed their progress**.

Meanwhile, in 1951, 23-year-old James Watson, a Chicago-born American, arrived at the Cavendish Laboratory in Cambridge. Watson had two degrees in zoology: a bachelor's degree from the University of Chicago and a doctorate from Indiana University, where he became interested in genetics. He had worked under Salvador E. Luria at Indiana on bacteriophages, the viruses that invade bacteria in order to reproduce—a topic for which Luria received a Nobel Prize in physiology or medicine in 1969. Watson went to Denmark for postdoctoral work, to continue studying viruses and to remedy his relative ignorance of chemistry. At a conference in the spring of 1951 at the Zoological Station at Naples, Watson heard Wilkins talk on the molecular structure of DNA and saw his recent X-ray crystallographic photographs of DNA. He was hooked.

Watson soon moved to the Cavendish Laboratory, where several important X-ray crystallographic projects were in progress. Under the leadership of William Lawrence Bragg, Max Perutz was investigating hemoglobin and John Kendrew was studying myoglobin, a protein in muscle tissue that stores oxygen. (Perutz and Kendrew received the Nobel Prize in chemistry for their work in the same year that the prize was awarded to the DNA researchers—1962.) Working under Perutz was Francis Crick, who had earned a bachelor's degree in physics from University College London and had helped develop radar and magnetic mines during World War II. Crick, another physicist in biology, was supposed to be writing a dissertation on the X-ray crystallography of hemoglobin when Watson arrived, eager to recruit a colleague for work on DNA. Inspired by Pauling's success in working with molecular models, Watson and Crick rapidly put together several models of DNA and attempted to incorporate all the evidence they could gather. Franklin's excellent X-ray photographs, to which they had gained access without her permission, were critical to the correct solution. The four scientists announced the structure of DNA in articles that appeared together in the same issue of *Nature*.

Then they moved off in different directions. Franklin went to Birkbeck College, London, to work in J. D. Bernal's laboratory, a much more congenial setting for her than King's College. Before her untimely death from cancer, she made important contributions to the X-ray crystallographic analysis of the structure of the tobacco mosaic virus, a landmark in the field. By the end of her life, she had become friends with Francis Crick and his wife and had moved her laboratory to Cambridge, where she undertook dangerous work on the poliovirus. Wilkins applied X-ray techniques to the structural determination of nerve cell membranes and of ribonucleic acid (RNA)—a molecule that is associated with chemical synthesis in the living cell—while rising in rank and responsibility at King's College. Watson's subsequent career eventually took him to the Cold Spring Harbor Laboratory (CSHL) of Quantitative Biology on Long Island, New York, where as director from 1968 onward he led it to new heights as a center of research in molecular biology. From 1988 to 1992 he headed the National Center for Human Genome Research at the National Institutes of Health. Afterwards he returned to CSHL, from which he retired in 2007. During Crick's long tenure at Cambridge, he made fundamental contributions to unlocking the genetic code. He and Sydney Brenner demonstrated that each group of three adjacent bases on a single DNA strand codes for one specific amino acid. He also correctly hypothesized the existence of "transfer" RNA, which mediates between "messenger" RNA and amino acids. After 20 years at Cambridge, with several visiting professorships in the United States, Crick joined the Salk Institute for Biological Studies in La Jolla, California.