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WHAT I LEARNED FROM BRITTON CHANCE*

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In this personal and reflective article, I honor the memory of Britton Chance and explain how his mentorship during my tenure at the Johnson Research Foundation greatly impacted my scientific career. I emphasize the critical role of mentors on the development of scientists and present some wonderful and remarkable attributes that characterized Britton Chance's scientific and personal style.

Keywords: Britton Chance; mentorship; scientific attributes and style.

1. Introduction

It was an honor to work with Britton Chance, the Eldridge Reeves Johnson Emeritus Professor of Biophysics, Physical Chemistry, and Radiologic Physics at the University of Pennsylvania. Today, I am again honored to write about his role as my mentor and about his scientific and personal style. While others will write on the multitudes of colleagues and collaborators of Britton Chance and of his creative ideas, studies, instruments, publications, lectures, awards, and global achievements in the advancement of worldwide science, I will write on a more personal and reflective nature of what I learned from Britton Chance.

2. The Role of Mentors

Science is a social phenomenon as evidenced by mentoring and collaboration. A mentor plays a critical role in the development of a creative scientist. Although intelligence is not spread as contagion by proximity and interaction with your mentor, much else is. For example, the scientific style, ethics, and the character of a mentor are often respected and emulated by those in the laboratory social group. Mentors are for life. Therefore, when selecting a research topic of great significance and strong personal interest, it is crucial to consider both the character and the ethics of your mentor as well as

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the institution and its research resources. A good mentor will promote collaborative research that is dependent on the qualities of cooperation, trust, fairness, collegiality, and accountability. Implicit in collegiality is respect. Destructive behaviors such as verbal abuse, jealousy, dishonesty, harassment, and discrimination are to be actively discouraged.

Mentors function in a multitude of roles; they cover the spectrum from how to perform research to how to grow and develop as a social human being. They help us to identify significant research problems. They guide us in formulating a research plan to investigate the problem and they encourage and criticize us in its long and arduous execution. They teach us research ethics; in fact, studies have demonstrated that the mentor−student relationship is the most important factor in formulating the student's ethical behavior. Mentors are critical in our career advancement, often providing us with advice and letters of recommendation as well as social networking. And at appropriate times, they fulfill multifaceted personal roles as guides, advisers, and friends. The mentor−student relationship is by nature a very asymmetrical one; the mentors possess power that derives from experience, knowledge, and expertise as well as status in the institution. Sometimes the mentor−student relationship is exploited for the benefit of one party. For me, Britton Chance was an exemplary mentor and it was a pleasure to work with him.

3. How to Thank Mentors

I think that the best way to thank our mentors is to develop into a creative and productive researcher who produces significant scientific research and publishes in high-impact peer-reviewed journals. I think of mentoring as a tree; our mentors are the roots, and our students and colleagues are the branches. In addition, the mentoring of a new generation of students will ensure the continuance of scientists with a sound knowledge of procedures that are consistent with the sound principles of responsible conduct of research. So we thank and respect our mentors by performing independent research and maintaining the high ethical, social, and scientific standards that were part of their character, scientific style, and laboratory practices. Recently when I and Professor Peter So completed our new textbook, *Handbook of Biomedical Nonlinear Optical Microscopy*, published by Oxford University Press, we gave Britton Chance an autographed copy that included our personal dedications to our mentors; my dedication was to Britton Chance, and Peter's dedication was to Enrico Gratton.

To honor and respect my mentor and friend Britton Chance, I have attempted to promote, protect, and promulgate the process of science in the United States and abroad, to strive for scientific excellence in my work, to be a good mentor of others who aspire to become productive scientists, and to try to emulate some of the seminal characteristics of Britton Chance's scientific and personal style.

4. How I Came to Work with Britton Chance

While I was a research associate in the medical school at the University of California, San Diego, I was using fluorescence techniques to investigate hormone-initiated water flow in kidney tubules. A colleague shared with me a research proposal that was a collaborative effort between Britton Chance and a principal investigator in the Department of Ophthalmology of the medical school of Boston University. The goal of the study was to use the spectroscopic techniques and the unique instrumentation that were developed in Britton Chance's laboratory at the Johnson Research Foundation in the University of Pennsylvania to investigate the oxidative metabolism of the various cell layers that comprise the living rabbit cornea. While the research would mainly take place in Boston, there was the opportunity to spend some weeks each year in the Johnson Research Foundation under the guidance and mentorship of Britton Chance. Since my colleague in San Diego was not able to take the research associate position in Boston, she advised me to apply for the position. I was familiar with the publications and the worldwide reputation of Britton Chance. I immediately applied and was soon after working on the research project in Boston with the great expectation to work a few weeks with Britton Chance in Philadelphia.

5. Some Attributes of Britton Chance's Scientific and Personal Style

5.1. *Perseverance*

Once I arrived in Boston and began my work on constructing the instrumentation, I telephoned

Britton Chance (known as BC to his colleagues) to describe my progress and to seek advice on the design modifications and the electronics. I was shocked when he told me that just before I arrived in Boston, the NIH grant proposal was funded; and at that point the principal investigator in Boston University (my boss) decided that he no longer needed the help and advice of BC and therefore terminated BC's subcontract. The principal investigator never disclosed this to me. Nevertheless, in the next months I frequently telephoned BC and he generously shared his ideas and suggestions with me. The principal investigator in Boston accused me of giving BC important information; however, this never occurred, and in fact the flow of information was always from BC to me.

Britton Chance was a fierce competitor, an Olympic Gold medalist, and a prolific achiever. As soon as BC learned of the dastardly deed of his former collaborator, in fact on the same day, he began to write a new grant proposal that was soon to be submitted to the NIH. While others may have become angry, depressed, or stopped in their tracks, BC rose to the occasion, and with vigor and creative energy, he composed a grant proposal with new experimental designs and shortly thereafter had it submitted, reviewed, and fully funded within a few months.

Perseverance is one of the strengths that BC showed throughout his life. He taught me to stay on the course, to stay focused, to suppress petty anger at the weakness of character in colleagues, and to move on and to move forward with the important things — the advancement of science and learning and the generation of knowledge. Within a few months, I made the ethical decision to join BC as a research associate in the Johnson Research Foundation at the University of Pennsylvania. The perseverance and the ability to prioritize goals and to focus on the key objectives, all these things that BC taught me, remained with me and are extremely beneficial to me in my professional and private lives.

5.2. *Interdisciplinary approaches to research*

Britton Chance also taught me the value of interdisciplinary approaches to research. Many of the exciting and fascinating problems in science are at the boundaries of traditional disciplines. Solutions to these problems require a deep understanding of disparate fields of science and engineering. BC was a master of this broad approach to research. Often it is the design, construction, and the appropriate modification of new instrumentation that results in significant discovery in science. BC was highly skilled in many fields, including instrument design, electronics, optics, biochemistry, cell biology, and physics. His fundamental mastery of these fields not only supported his broad knowledge of how molecules, cells, tissues, and organisms behave, but also was joined with his creative genius as master instrument developer. BC easily moved across traditional research boundaries and that part of his scientific style contributed to his success in research. In my career I attempted to follow his leadership in interdisciplinary approaches to research. I am grateful to BC for his mentorship that stressed broad thinking across disciplines.

5.3. *Collaborative approaches to research*

BC had a fantastic ability to intuitively sense the outcome of an experiment, typically before the experiment was performed. Of course this ability was not foolproof; if it were, there would be no need to do experiments. However, this great physical intuition is helpful in the planning of experiments. This physical intuition was combined with BC's correct assessment of the intrinsic value of collaborative research. When BC learned of a new development in science or engineering, he immediately thought of how he could apply the new knowledge to the solution of problems. BC was the source of generations of collaborators who were mentored by BC and then formed their independent research groups or returned to their host institutions. I learned from BC the value of collaborative approaches to research and that methodology was critical to my approach to the solution of scientific problems. In particular, my collaboration with clinicians permitted me to work in the clinic and to develop noninvasive diagnostic instrumentation for the fields of ophthalmology and dermatology.

I also learned from BC the necessity to obtain a solid knowledge base and expertise in the terminology, techniques, and research strategies of the fields that straddle the collaboration such that the collaboration is not strongly asymmetrical. In my case for example, I worked in the eye clinic, assisted in eye surgeries, and studied many basic science and

clinical aspects of ophthalmology and dermatology. This preparation was a necessary step to a stronger collaboration with my medical colleagues. All too often the collaboration between a scientist or engineer and a clinician is too asymmetrical; the result is a less-than-optimal collaboration and working relationship. BC showed me the way, and I tried to emulate his collaborative strategies in research.

5.4. *International aspects of science*

BC was an active proponent of the international aspects and the universality of science. He welcomed scientists and engineers in his laboratory, and this rich culture of diversity was a prominent aspect of the Johnson Research Foundation. There was a daily influx of guests who visited BC and presented lunch-time seminars. BC would always sit in the front row in the library where the seminar took place. After BC ate his sandwich, one may assume that he was asleep, which was not the case; he will be thinking and at the end of the seminar, during the question period, BC would awaken (he was never really not awake) and present the nonplussed speaker with a brilliant question that went directly to the heart of the speaker's research presentation. Both the speaker and the audience would be typically in awe.

In summary, Britton Chance was the dominant figure in the modern development of the field of biomedical optics and the interdisciplinary areas of biology and medicine. His diligence, creativity, friendly disposition, and deep physical insights powered the biomedical optical revolution that today continues in the research and mentorship of his students and colleagues. In my opinion, the best memorial to Britton Chance is to pick significant research problems, to formulate a research plan, and to dive into the hard work of research, teaching, and mentoring the next generation of researchers. Above all, I learned from Britton Chance to do research with enthusiasm, perseverance, joy, kindness, justice, friendship, and appropriate ethical behavior.