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PROFESSOR BRITTON CHANCE AND THE EARLY TIMES HE LIVED

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1. Introduction

Professor Britton Chance passed away on November 16, 2010. Born on July 24, 1913, he was 97 years old when he died.

I was honored to have had the opportunity to meet Professor Chance and have friendly conversation at the early conferences of the Society of Magnetic Resonance in Medicine (SMRM). Among the participants at these exciting and energetic conferences was a tall and quiet British gentleman with good posture. One day he spoke to me, and that started our long-term friendship.

I would like to reflect on my interactions with Chance, the times in which he lived and the historical backdrop.[1–3]

2. Early Maturation of Genius

2.1. *A boy's great invention*

Britton Chance (hereafter "B.C.", which was his nickname) was recognized as a genius as early as age 13 (in 1926). Using electronic circuits, he produced a wireless machine on his own. At the age of 17, he invented feedback control-based automatic steering equipment for marine vessels using electronic circuits and a servomechanism. When B.C. was a university student, General Electric in the United Kingdom tested his automatic steering equipment in a large-scale ship sailing from London to New Zealand and Australia.

Norbert Wiener (1894–1964), who was also called a prodigy, entered university at the age of 11 (in 1906). Beginning with mathematics, his research covered many areas extending to biology and philosophy. Wiener's representative research was cybernetics. His publication of *Cybernetics* in 1948 saw the formulation of this concept. The origin of cybernetics was the ancient Greek *kybernetes*, meaning steering. B.C. achieved the practical use of feedback loop-based automatic steering equipment when he was a child — more than 20 years before Wiener formulated the concept of cybernetics. B.C.'s strong interest in marine vessels from childhood led to his winning a gold medal at the Helsinki Olympics in 1952. (He was part of the winning US yacht racing team in the 5.5-meter class.) The concept of automatic steering was linked to the invention of the precision-guided bombs that were used in World War II.

2.2. *B.C.'s travels between the United Kingdom and United States and his encounters with Glenn Millikan*

B.C. acquired a Ph.D. in physical chemistry at the University of Pennsylvania in the United States in 1940, followed by his acquisition of a Ph.D. in biology and physiology at the University of Cambridge in the United Kingdom in 1942. When he was a graduate student at the University of Pennsylvania, he introduced the stopped-flow method in a microflow channel and researched the kinetics in the chemical reactions of enzymes related to mitochondria. He met Glenn Millikan (1906–1947), who devised another innovative stopped flow analyzer. B.C. was a research student in Millikan's lab at the University of Cambridge. The encounter with Millikan may have deeply influenced B.C.'s subsequent biophysical and medical research.

Glenn Millikan was the son of Robert Millikan (1868–1953), who had received the Nobel Prize in Physics in 1923 for measuring an electrical charge with an oil drop experiment. Glenn married Clare Mallory (1916–), the beautiful daughter of George Mallory (1886–1924), a renowned mountaineer. Glenn Millikan also loved mountain climbing. However, he slipped and fell from Millikan's Overlook while climbing and died at the age of 41.

3. High-Altitude and Aviation Medicine

Glenn Millikan always loved physics and towering mountains. That combination may have led to his inventing the oximeter, which contributed significantly to the high-altitude and aviation medicine that blossomed during World War II. The term *oximeter* was also coined by Millikan. During the war, there were many high-altitude aerial battles. Being a physicist, Millikan conducted noninvasive measurement of the light absorption of oxidized hemoglobin and deoxidized hemoglobin by permeating light through human earlobes using a mercury emission line spectrum. In 1942, he made the oximeter mobile by using an incandescent bulb and filters. The device was embedded in a fighter pilot's headgear to automatically supply oxygen when the oxygen concentration in the bloodstream declined at high elevations, thus incorporating the concept of the feedback loop including human metabolism.[4–6]

In 1940, when the German Air Force started large-scale air raids against the United Kingdom, Millikan returned to the United States almost concurrently with B.C. and continued his research at the University of Pennsylvania. During this period, some treatises were issued under both their names.[7] In 1947, Millikan died at the age of 41 in a climbing accident at Millikan's Overlook in Tennessee.

Due to the outbreak of World War II, B.C. was summoned to the MIT Radiation Laboratory (the so-called Rad Lab) in 1940 and developed electronic circuits. After Millikan died in 1947, when the war was already over, B.C. devoted himself to physiologic and medical research at the University of Pennsylvania as director of the Johnson Foundation (1949–1983). Although the double-wavelength measurement method was Millikan's patented invention, B.C. further developed the principle and almost completed it. He produced much excellent research in physiology and medicine using the so-called Chance machine.

4. Work at the MIT Radiation Laboratory

4.1. *MIT Radiation Laboratory*

In 1940, B.C. obtained his first Ph.D. in the United States. In 1942, when B.C. acquired his second Ph. D. in the United Kingdom, the Battle of Stalingrad occurred. B.C. returned to the United States and worked on the development of radar at the Rad Lab. This radar research was as much a key to the Allies' destiny as the Manhattan Project, which developed the atomic bomb.

B.C. was chosen and summoned to the Rad Lab because he had invented automatic steering equipment using electronic circuits as a child. He started his radar research at MIT's old wooden Building 20. However, the reinforced concrete Building 24 was quickly constructed for him. The entire first floor was used by B.C.'s research group of approximately 50 members. Although the old wooden Building 20 (Japanese style) has been demolished, it is historically known as the actual radar development site. Various developments began in this building, including the genesis of NMR that led to MRS, MRI, and fMRI.

4.2. *Wartime radar development*

B.C. first took charge of the signal processing circuit system of microwave radar SCR-584 (single corps radar 584), which was a circuit to precisely measure the delay from the emission of radio waves to hit enemy aircraft until their return. The urgent project completed the SCR-584 — outstanding anti-aircraft radar — and it began to be used worldwide as a powerful tool for victory. The first demonstration experiment was conducted at a military practice site in Virginia. Automatic gunfire equipment interlocked with the radar was activated against a mock target towed by a long cable and the first shot successfully smashed the mock target into pieces. The success was indeed the birth of world's first automatic aircraft-tracking radar, a legendary benefit of the R&D by B.C. and the other experts at the Rad Lab.

B.C.'s second project was the development of a new type of radar called SG-3. The project became urgent when a number of German submarines (U-boats) approached the coastline near New York. Given that submarines surface at night to recharge their batteries from the diesel engines, it was necessary to capture the submarine locations when they surfaced in pitch dark, which required compact radar embeddable in a surveillance aircraft. The third urgent project was the development of the world's first guided radar system for airstrikes — precision-guided bombs that could reach a target regardless of visibility.

B.C. also developed pulse code modulation (PCM) and many computer-related innovative electronic technologies. He issued many electronic circuit-related publications, including *Electronic Time Measurement* and *Waveforms*. Many people in the electronics field view B.C. as a specialist in electronic engineering.

5. War and Peace

5.1. *Sailing*

When I talked with B.C., I often sensed how much he loved electronic circuits. That with which we are really familiar as children seems to retain the attraction even as we grow old. For our collaborative research at the Advanced Research Laboratory of Hitachi, Ltd., B.C. and Dr Shoko Nioka brought measurement equipment from the United States to Japan. B.C. was already in his 80s at the time. Due to turbulence, the screws came off the measurement equipment and flew around the baggage room of the airplane. The equipment arrived in an awful condition. B.C. looked disappointed. But he changed his mood and asked us to get him an oscilloscope and a soldering iron. He worked on the equipment without a circuit diagram until late at night and impressively repaired it so that it could function perfectly. We started to collect various data the following days, among which the data of a windsurfing champion recalling and re-creating a winning race was the most interesting. The brain function at that time was measured by near-infrared spectroscopic brain-function imaging. The prefrontal cortex was significantly activated, whereas no significant activation was seen when the subject was enjoying snowboarding as a hobby.[8]

As an Olympic gold medalist, B.C. was deeply interested in sports medicine and brain function while engaging in sports. He used to say that yacht racing was a "sprint of the brain" as many parameters had to be evaluated instantly. He seemed to want to know about brain function while racing. However, B.C. told me that he did not want to discuss the Helsinki Olympic Games. The 5.5-meter class yacht racing (three racers in a yacht) is a team sport. To win a gold medal, not even a slight mistake is allowed. I suspect that the mental pressure of racing was unimaginably hard on him as a scientist, especially with teammates whose lives were dedicated to yacht racing. I never had an opportunity to hear the details of B.C.'s Olympic Games experience.

I did check the Olympic records. The photos of the Helsinki Olympic Games 5.5-meter class yacht racing gold medalists — the four members of the US team and their boat, *Complex II* — are part of the official record. The team won three of seven races, winning the overall gold, beating the Swedish and Norwegian teams.[9]

5.2. *Dilemma between humanitarianism and military research*

B.C. loved electronic circuits, mechanical equipment, and ships sailing on a vast ocean, and he was also a true humanitarian. He raised many children including adopted children. He was also a feminist. For example, although the historic American Philosophical Society, which was founded by Benjamin Franklin (1706–1790), was a males-only society, when B.C. served as its chancellor, the organization began to accept female members, according to what I heard from the members of the American Philosophical Society at its annual party.

B.C. served as a highly responsible Steering Committee member at the Rad Lab during wartime. That prompted me to ask him a straightforward and perhaps discourteous question: "What did you think of the atomic bombing of Japan, being in a position whereby you knew all the confidential information?" B.C. offered a sincere response.

B.C. devoted himself to the development of radar in wartime because he believed that would be a key to self-defense and interception. In fact, he declined to join the Manhattan Project to develop a mass murder weapon. Most of B.C.'s close friends also declined. He said that he suffered intolerable agony when the R&D cost to kill one enemy soldier was discussed during Steering Committee meetings. Although the development of radar may have determined the winners and losers of the war, it was true that radar actually helped to protect citizens as pointed out by B.C.

Immediately after the invasion of Normandy (1944), a large volume of German V-1 bombs, a predecessor of cruise missiles, were fired at London. The V-1s, explosive-loaded flying objects propelled by a pulse jet engine, created a living hell for Londoners. Given that the V-1 flight velocity was 640 km/h, whereas combat aircraft at the time flew at 670 km/h, it was difficult to destroy the V-1 without prior knowledge of its flight course. Therefore, the new type of radar developed in close cooperation between the United States and the United Kingdom proved really useful.

B.C. thought that precisely targeting military facilities using precision-guided bombs would help reduce the number of citizens being victimized. B.C. was against the use of the atomic bomb as a mass murder weapon and tried to dissuade his associates from using it. He even suggested that, if the bomb had to be used, the entry to Tokyo Bay be closed to force the Japanese to give up fighting. At that time, development of a turbocharger had enabled an air raid of Tokyo using B-29 bombers. Because the B-29 could fly at ultrahigh altitude with low oxygen concentration, gunfire from the ground did not reach the B-29 and Japanese combat aircraft could not approach it. A few weeks before the atomic bombing, B.C.'s development team completed special radar (Radar-X). B.C. said that he was devastated to hear that Hiroshima was actually hit by an atomic bomb.

I understood B.C.'s deep agony when I saw him working with his students and fellow researchers. B.C. never judged people by nationality, race, or gender. He often showed up at the lab even on his days off to support enthusiastic students and researchers.

6. Conclusion

B.C. was kind to me both officially and privately. He stayed in a Japanese-style room at my modest home. Although he was always a British gentleman, he liked sweets and sometimes hidden chocolate fell out of his briefcase. At one time, hearing a noise in the night, I hurried to see what was going on only to find him secretly eating chocolate that had been left on the dining table. I remember his naughty look at that time. He also let me stay at his home in Philadelphia many times. I have never stayed at a hotel when I visited him. When I served as a guest lecturer on the progression of research in Japan at Philadelphia University, he would often take me to his seaside villa on weekends. Attached to the yard at his villa was a waterfront bank that he made by piling up stones, where a cruiser and a motorboat that B.C. was crazy about were anchored. B.C. walked on the floating pier in a remarkably well-balanced way to take care of his cruiser. When it was clear and sunny and not windy, B.C. was not happy. When a hurricane approached, the sky became cloudy and white waves started to appear, B.C. got revitalized. "The weather is getting good. Let's sail!" I struggled to pull a rope of the jib (a triangular sail in front of the mast), sprayed by droplets from the high waves. On the boat, B.C. was really strict, almost like a different person. When I made a mistake in boat operation, he would scold me, which I suspect was a result of his strict ship handling from his yacht racing days.

Although we sailed into a strong wind, B.C. was always vigilant. Morse code transmissions could be heard early in the morning when it was still dark. Communicating with ships sailing nearby, he would directly obtain weather information far more accurate than the weather forecasts. And, of course, B.C. had no problem in handling wireless equipment and an antenna.

In this paper, I have described B.C. and the historical backdrop of the times he lived, mainly focusing on episodes that other people may not write much about. I would be pleased if this paper gives you some insight into how wonderful Britton Chance was, apart from his eminence and prestige.

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