



An Anesthesiologist in the Space Race: The Life and Career of Dr. Clويد D. Green

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ABSTRACT

The space race began in the summer of 1955 when the United States and the Soviet Union pledged to launch artificial satellites. The race culminated in 1969 when the United States landed the first humans on the moon. After completing his training in anesthesiology, Dr. Clويد Green forged his career as one of the physician-scientists who played an integral role by evaluating the effects of space flight on human physiology. Family members of Dr. Green were interviewed and university and society archives, literature and periodicals were reviewed.

Dr. Clويد Green received his medical training at the University of Minnesota. He earned his MD in 1946 before moving to South Dakota and working as a general practitioner. A combination of professional curiosity and the military's request for further service led Dr. Green to complete an anesthesia residency at the University of Iowa. After training, he was assigned as the physician in charge of a bomber wing at a base near Austin, Texas, in 1957. Due to his research on the effects of high altitude on pilots, he was recruited to the Brooks Air Force Base. Dr. Green was the ranking medical official overseeing early space flights involving monkeys. After leaving the USAF, Dr. Green practiced anesthesiology at the University of Virginia before moving to Newfoundland, Canada. He became the first chair of Anesthesiology at the Memorial University of Newfoundland in 1969.

Dr. Clويد Green's career grew alongside the specialty of anesthesiology in the 1950s. His training in anesthesiology proved to be a versatile and profoundly useful skill set as the specialty became fully recognized. Dr. Green's long and fruitful career is the perfect example of the diverse opportunities afforded by anesthesiology training.

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Clويد Darryl Green, MD, used his physiology and anesthesiology skills to bring about the biopack, a self-contained life-support system, which is essential to space travel. He seemingly followed a quote he hung in his childhood room: "Plan for more than you can do, then do it. Bite off more than you can chew, and chew it. Hitch your wagon to a star. Keep your seat and there you are. Go to it."¹ Thanks to his specialization in anesthesiology and involvement in the US military, Dr. Green was able to bridge the gap between space travel and anesthesiology.

Dr. Green was born in Sheldon, IA, to parents Archie and Kathryn Green. He moved several times as a young child and ultimately settled in Sioux Falls, SD. He described it as a "small town neighborhood. Everybody knew each other. Everybody didn't necessarily like everybody else, but we made allowances. Nobody had any

money so there was no jealousy there. Lots of vacant fields for play."¹ He remembered living during the Dustbowl and specifically that his "family was luckier than some, we never went hungry, but there were never any non-essentials."¹ His childhood was largely spent outdoors, particularly hunting with both his parents on a Sunday. As a child, he contracted polio but did not suffer any disability, although he did lose two friends to the epidemic. He also was exposed to a typhoid epidemic but was likely spared due to vaccination and meticulous boiling of water for drinking and washing by his mother. In his senior year, he was a semifinalist in the South Dakota state debate competition. Dr. Green graduated from Washington High School in 1939, and World War II began in Europe that summer; many of his classmates would be killed in the war.

Dr. Green received a \$1000 scholarship which encouraged him to enroll at DePauw University in Greencastle, IN, in the fall of 1939.¹ It sometimes would take as long as 48 hours to hitchhike from Sioux Falls to Greencastle. He participated on the debate team, wrote for

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the school paper, and joined the Sigma Chi fraternity. Dr. Green likely transferred to the University of Minnesota to complete his undergraduate and medical degrees under an accelerated program with the US Army Medical Corps. He was admitted to medical school

“on Friday, December 5, 1941 ... This changed my whole life. If I had not been admitted, I would probably have been in the active fighting. A good chance that my children would never have been born. December 7, 1941 started World War 2. I heard about it first when I was eating a noon meal in a restaurant with five other boys. We planned to study together. Over the radio came news of Pearl Harbor. A woman whose son was on the Arizona began to cry.”¹

In 1943, Dr. Green married his lifelong partner, Margaret Moulton. That same year, 1943, Dr. Green completed his Bachelors of Science degree which was consistent with the plan in Minnesota.² Students could complete a minimum of 18 months of undergrad and 36 months of medical school as long as they fulfilled their BS and MD requirements.³ He graduated from medical school in 1945 but would not earn a Doctorate of Medicine until he completed his internship over the next year.^{3,4} Because Dr. Green enlisted in the Army Medical Corps, he was able to defer active military service until after completing his internship.⁶ He practiced his intern year at Harper Hospital in Detroit, MI, and had a typical experience. He noted in his remembrance of VJ day. “I worked in the emergency room, and operating rooms, and went 36 hours without sleep. We took care of drinking, fighting, car accidents, and stabbings, shootings, etc. kept us busy.”¹ His first two children Patricia and Kathryn were born during his time in Detroit. With the end of World War II, Dr. Green was able to return to South Dakota instead of immediately fulfilling his military commitment.

After completing his internship, Dr. Green moved his family back to South Dakota. First, they lived in Parker but, after 2 years, relocated to Canton where Dr. Green worked at Canton-Inwood Hospital, a larger facility with a shorter commute.^{5–7} Dr. Green was a dedicated small-town general practitioner. His family recounted stories of Dr. Green delivering babies in barns, being called in the middle of the night, and setting out with his black doctor's bag.⁵ After a particularly difficult miscarriage by a family friend, Dr. Green began to consider specialties outside of general practice mostly due to his desire to become an expert in a specific area where he could perfect his skills.^{5,7} This coincided with a US military request that he serve his time for the deferment granted during medical school. Dr. Green indicated that he would be of more use if trained in anesthesiology. The US Air Force agreed, and Dr. Green was accepted into the Anesthesia residency program at the University of Iowa.

Dr. Green and his family relocated to Iowa City in 1955, and he enrolled in the Graduate Course of Anesthesiology at University of Iowa. In the University of Iowa course catalogue, a “Graduate course in Anesthesiology” was listed as an “An intensive course covering two years' work in lectures, conferences, seminars, and laboratory practice including experience in anesthetic agents and technics, pneumatology, diagnostic and therapeutic nerve blocks, and resuscitative measures.”⁸ The course was limited to physicians who completed an internship and the approval of the staff. The University of Iowa was a significant center for research into the underlying pharmacology and physiology of anesthesia under the direction of Dr. Stewart Cullen. Dr. Cullen, an academic “grandson” of Ralph Waters, MD, trained under Dr. Rovenstine, corresponded with Dr. Waters and molded his program after the Wisconsin model.⁹ He balanced the residency training between clinical, teaching, and research foci. Although there was no formal research requirement, Dr. Cullen developed strong relationships with other research departments through his own projects and encouraged his residents to follow. Dr. Green

was a quintessential candidate for Dr. Cullen's program as he recruited those physicians who had general practice experience prior to enrolling in anesthesia residency. Other residency classmates included Dr. John Severinghaus and Dr. Edmond “Ted” Eger II, who went on to have distinguished careers.

Following graduation from University of Iowa, Dr. Green was assigned to the Lockbourne Air Force Base outside of Columbus, OH, in 1957. He was the commander of the base hospital and was a flight surgeon for Strategic Air Force Command wings.¹⁰ During the cold war, the units stationed at Lockbourne flew Boeing B-47 Stratojets on reconnaissance missions over the North Pole to monitor the Soviet Union. The activities of the base seemingly coincided with the Soviet Union's rejection of the Open Skies proposal. The Open Skies agreement proposed by President Eisenhower was a program where the United States, Britain, France, and the Soviet Union would exchange maps of exact military bases to allow aerial surveillance and ensure compliance with arms control agreements. Although rejected by the Soviet Union, Eisenhower was determined to gather intelligence on Russian bases and missile capabilities. Dr. Green flew with the bomber wings and studied their physiologic responses to changes in atmospheric gas concentrations during long flights. This may have been the first time data of this type were collected in the United States.¹⁰

On October 4, 1957, Sputnik, the first artificial satellite, was launched by the Soviet Union. The American public was surprised and frightened by the achievement, fearing the Soviets could also launch missiles at the United States. In response, the US government formed the National Aeronautics and Space Administration (NASA) to accelerate their space program. Because of his experience and training, Dr. Green was a prime candidate when the government needed a physician to construct a survivable environment for animals and, ultimately, humans on spaceflights. He was transferred to the School of Aviation Medicine at Brooks Air Force Base, Texas, in 1958. He took the position of senior medical officer in the Department of Physiology that required an additional 2-year commitment to the Air Force.¹⁰ This was no small sacrifice for a family with six children living on a military salary. His appointment coincided with the creation of NASA in October of 1958. He was the project officer in charge of design and construction of a life support system for the first two animal space flights of Project Mercury.^{11–16} Project Mercury was the mission that eventually put



Fig. 1. Dr. Green with rhesus monkey (used with permission from Dr. Green's family).

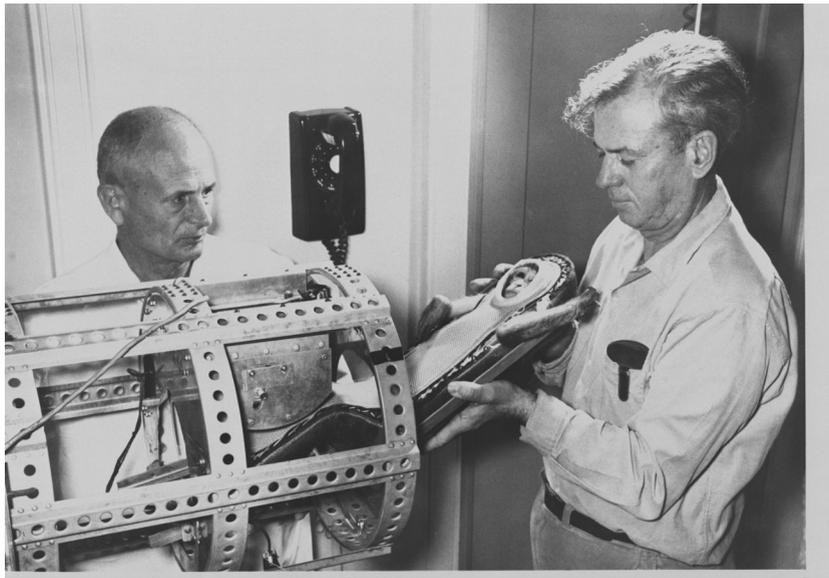


Fig. 2. Insertion of rhesus monkey Sam into biopack 1959 (NASA).

two US astronauts on the moon. Dr. Green commented in his memoirs that “I designed the life support system for the space capsule; the ideas came from the literature and research at the National Institute of Health in Bethesda, Maryland.”¹

Building the life support system, or biopack, was a unique project but one well suited for an anesthesiologist. In one of his papers, Dr. Green reflected on the novelty of his assignment: “It is not often that one goes into the laboratory specifically to design a new instrument. A biopack is a new type of scientific instrument, designed to be used at a certain time and for a specific purpose. Since commercial models of new instruments are not available, the investigator has the privilege, pleasure, and challenge of building his own.”¹² The design included limited and specific size restrictions, as the biopack was an added feature once the rocket

mechanisms were designed. The pack itself was 30” long and 18” in diameter. The external shell was airtight and made of a fiberglass reinforced polyester resin which could withstand 20 psi of internal and external hydraulic pressure changes. The interior consisted of an aluminum alloy frame, biological sensors, power supply, and a movie camera. Within the frame was a fiberglass “couch” where the monkey was restrained¹² [Figures 1 and 2].

Perhaps one of the aspects of the biopack most related to anesthesia was the creation of an efficient but safe atmosphere inside the hermetically sealed capsule. The biopack was flushed with 100% oxygen at 760 mm Hg. To eliminate excess carbon dioxide and water vapor build up in the capsule, lithium hydroxide was used as an absorber. Because there was not room or sufficient power supply for a true forced air system, a small fan was installed to allow for air circulation. Other



Fig. 3. Assembling Little Joe capsules in 1959 (NASA).

toxic gasses such as ammonia was managed by using an absorbent diaper to contain the urine and using potassium peroxide as an oxygen source to minimize the carbon monoxide excreted. In addition, the closed system required a heat sink to prevent overheating of the unit. A block of ice was used because it allowed for the greatest heat capacity for weight and volume for about 36 hours.¹²

Perhaps monitored better than their human counterparts, astronaut primates had vital signs recorded throughout the flight. Dr. Green commented on the specific data collected, "Experience has shown the pulse rate, respiratory rate, temperature, and biopack oxygen tension are minimal requirement for an intelligent interpretation of the condition of the animal which has been sealed in a capsule for hours or days."¹²

Having discussed the environment in which the monkeys would travel, selection of the primate astronauts was another task; rhesus monkeys were chosen for their size and availability. Both Sam and Miss Sam used in Dr. Green's test flights were chosen for their attentive and industrious natures.¹⁵ Specifically, they were noted to be unfazed by distractions and stressors and were in top physical shape. The primates were named after the School of Aviation Medicine where the project was based.¹⁵

The first test flight occurred at Wallops Island, VA, on December 4, 1959, using the Little Joe space craft [Figure 3], a model for the Apollo vehicle to be used for human astronauts.^{14,16} The flight was successful, with the capsule reaching over 280,000 ft. The goals of the mission were to observe the physiologic effects of acceleration on a small primate and to check the safety of the project Mercury flight equipment, especially the launch abort system. This experiment verified the adequacy of flight equipment to be used in Project Mercury and showed the biomedical effects of acceleration experienced during the abort of a Mercury flight after liftoff not to be adverse.^{14,16}

The second test flight, also on Wallops Island, VA, launched on January 21, 1960. Many of the goals were similar to the previous flight. They were also interested in the physiologic effects of rapid-onset reverse acceleration.^{14,16} In addition to recording physiologic data, the test flight included psychomotor effects of a stressful environment. Monkeys were trained to respond to a cue light. When the light was on, they performed a task, and if they failed to execute the task, they received a mild electric shock. Although the team felt no final conclusions could be drawn, they did record significant nystagmus during the initial 30 seconds following escape from the vehicle.¹³ The report concluded that "this period comprised of the uncontrolled near weightless portion of the flight and during the time the only complete failure of psychomotor performance training occurred."¹³

The news of the successful flights was broadcast nationwide.¹⁷ Although this was not the first successful animal or primate space flight, it was the United States' first test of an unanesthetized primate. It also was a successful early test of the spacecraft for Project Mercury. This news captivated the public during the cold war, especially considering the successful launch of Sputnik I and II by the Soviets about 2 years earlier in the Fall of 1957.

His 2-year commitment completed, Dr. Green was recruited by the University of Virginia and joined their department of anesthesiology in 1960. He remained a productive academician. He published papers describing the effects of nitrous oxide on white blood cell production. This work appeared as case reports in the *New England Journal of Medicine* and as animal studies in *Anesthesiology* in 1963.^{18–20} Other papers he authored included the toxic effects of ether on the liver nucleic acid metabolism, the use of cervical epidurals for carotid endarterectomies, and a comparison of the effects of anesthetic agents on bone marrow.^{21–23} Because of his academic prowess, he was recruited to the Memorial University of Newfoundland in St. John's, Newfoundland, Canada, in 1969 and was the founding chair of the Department of Anesthesiology. He continued to publish on varied topics such as sympathetic blockade in epidurals and evaluating myocardial

contractility.^{24,25} By 1974, he was appointed the Associate Dean for Clinical Affairs.²⁶ He instituted a universal start time for the operating rooms, which was not a popular or common notion then but one routinely practiced today. In addition, he was chaired the committee developing a national curriculum for anesthesiology residency in Canada.²⁷

Dr. Green suffered a heart attack at the age of 55 and required a quadruple bypass surgery performed at the Cleveland Clinic.² Although he stepped down from his administrative responsibilities, he remained on staff at Memorial University until taking a position at the University of Nebraska in Omaha.²⁸ He continued to teach and pursue research until his retirement in 1977, when he moved to Bradenton, FL. He died in 2001.

The trajectory of Dr. Clويد Green's career was a consequence of the scientific and political environment of the day combined with his own intellectual curiosity and motivation. Born into a middle-class family of small business owners, he did not have a life of privilege, but his intellect and hard work saw him successfully through college and medical school. The 1950s were a time of rapid advancement in anesthesiology which provided many opportunities to scientists. Based on some estimates, this decade also saw a doubling of US physicians dedicated to a career in anesthesiology.²⁹

Dr. Green was fortunate to train under Dr. Cullen at the University of Iowa. They were leading the research into muscle relaxants and inhalational anesthetics. His fellow residents were investigating monitoring equipment. It was here he made a significant transition from a clinical GP to an academic anesthesiologist. Specializing in anesthesiology changed the trajectory of Dr. Green's career due to the basic anesthesia skills and the training in the scientific method. He is the quintessential example of how a curious mind and a strong work ethic molded by a rigorous academic environment forms an intellectual leader.

In addition, the trajectory of Dr. Green's career and life was significantly changed by his military service. Although frustrated by the lack of treatment options for patients as a small town general practitioner, it was not until the military requested further service that he was motivated to acquire more training. It was his work with pilots flying at high altitude for prolonged periods that attracted NASA's attention. His data provided early insight into building a survivable environment for its astronauts in space.

Anesthesiology influenced Dr. Green's career, and he used anesthesiology to make contributions to aerospace medicine. His knowledge about physiology and anesthesia circuits aided his ability to create the biopacks for the Project Mercury test flights. Monitors used to measure the physiologic response to the flights were more advanced than those used on a human undergoing anesthesia. Both the history of anesthesiology and the history of space travel are ones of creative problem solving. Dr. Green's story demonstrates how the two complement each other and how each pushed the other forward.

To this day, both space and unconsciousness remain great scientific frontiers. Dr. Green wrote some advice for his grandchildren which represents his personality and accomplishments well: "Approach each problem as a challenge to be won by ingenuity. Someone once told me, 'Green you are not unusually smart, but you are the most ingenious person I have even known.' I took this as a compliment and have always tried to find new solutions, new ways to approach old problems. A dose of ingenuity and a bit of luck has done wonders for me."¹

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