Arthur William Galston (1920–2008) [1]

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Arthur W. Galston studied plant hormones [3] in the United States during the late-twentieth century. His dissertation on the flowering process of soybean plants led others to develop Agent Orange, the most widely employed herbicide during the Vietnam War, used to defoliate forests and eliminate enemy cover and food sources. Galston protested the spraying of those defoliants in Vietnam, as they could be harmful to humans [4], animals, and the environment. Toxicological research conducted in 1967 revealed that Agent Orange contained a synthetic compound called dioxin, an accidental pollutant that caused birth defects [5], which led to the discontinuation of Agent Orange in Vietnam in 1971. Galston's predictions of Agent Orange's toxicity were confirmed in the 1980s when studies linked Agent Orange to the illnesses of Vietnam veterans and to their children.

Galston was born on 21 April 1920 in Brooklyn, New York, to Freda and Hyman Galston. Galston planned to pursue a career in medicine, citing his motivation as his parents' expectations and his reading of Paul de Kruif's *Microbe Hunters*, a 1926 book on scientists and physicians of the early twentieth century. However, when Galston's father lost his job in the Great Depression, Galston instead chose to study in Ithaca, New York, at the veterinary and agriculture schools at Cornell University [6], which provided free tuition for in-state residents. Galston later credited Loren Petry, his botany professor, as the man who influenced him to change his career path from veterinary medicine to botany. Galston stated that Petry's teaching style, lifestyle, and academic career were very appealing, and when he received an offer letter from the School of Veterinary Medicine, he declined it to major in botany. In 1940, Galston graduated from Cornell University [6] with a Bachelor's of Science degree in botany.

Galston continued his graduate studies in botany and biochemistry at the University of Illinois [7] in Champaign-Urbana, Illinois, where he worked with plant physiologist Harry Fuller. However, Fuller was sent to South America after the Japanese captured Malaysia during World War II. The conquest resulted in a rubber shortage in the US, and the government assigned scientists like Fuller to develop alternative sources of rubber. Additionally, the US government mandated that young men finish school early and become available for military service, so Galston finished his degree program in three years.

Despite having a distant advisor, Galston worked every summer to finish his dissertation on the flowering mechanism of certain strains of soybeans, which many considered economically and agriculturally significant. According to Galston, farmers in Illinois struggled to produce soybeans because soybean plants did not flower early enough before the onset of winter. Through his work, Galston discovered that low concentrations of the compound 2,3,5-triiodobenzoic acid, or TIBA, quickened the flowering process in soybean plants. He also found that high concentrations of TIBA caused the plants to shed their leaves and buds, a process called abscission, which killed the plants. In 1942, Galston married Dale Judith Kuntz, whom he had met at Cornell University [6].

While working toward his joint degree in botany and biochemistry, Galston connected with plant biologist James Bonner at the California Institute of Technology [8] in Pasadena, California. When Galston finished his PhD in 1943, he and his wife moved to Pasadena after Bonner invited him to work on a war-related project to convert the Mexican shrub, called guayule, into a rubber-producing plant. The project aimed to provide rubber for the military. While the project succeeded, the guayule plant became unnecessary when chemists discovered how to produce synthetic rubber around the same time.

In July of 1944, the US draft board sent Galston to Okinawa, Japan, to serve in the US Navy Reserve. During his time abroad, the John Simon Guggenheim Memorial Foundation awarded Galston a scholarship for people who left their academic careers to enter military service. Galston deferred the fellowship until he returned to an academic institution in the US. By the time Galston was discharged from the navy in the spring of 1946, Galston's wife had given birth their first child, William. Galston and his family returned to New York City so that they would be closer to both his and his wife's parents. Galston then spent a year as an instructor at Yale University [9] in New Haven, Connecticut.

Despite being close to his extended family, within a year, Galston returned to Caltech with his wife and son. He cited long hours and poor salary as reasons that he left New Haven. His daughter, Beth, was born shortly after his family moved to Pasadena. From 1947 to 1950, Galston taught plant biology and researched photobiology, or the effects of light on plants. At the time, many plant biologists argued that pro-vitamin A or carotene was responsible for absorbing light in plants, but Galston hypothesized and provided evidence that the responsible molecule was actually vitamin B2 or riboflavin, a hypothesis later confirmed. Galston later reflected that discovery his greatest research contribution.

In 1950, Galston used his Guggenheim fellowship to spend a year at the Karolinska Institute [10] in Stockholm, Sweden. Upon his return, Galston received tenure as a Caltech professor of biology in 1951. In 1952, due to his complaint that there was no adequate textbook with which to teach his plant biology course, Galston co-wrote a textbook, *Principles of Plant Physiology*, with fellow Caltech professor James Bonner. When the book was published, other US biologists claimed that it met a long unfulfilled

need for an elementary plant physiology textbook.

Galston began to engage with politics while at Caltech. With the onset of the Cold War in the late 1940s, US government investigated US citizens who might be sympathetic to communism or the Soviet Union. Galston was a member of the Hollywood Independent Citizens' Committee for the Arts, Sciences, and Professions, a group that protested the US government's practice of blacklisting academics and artists who refused to denounce communism. The US government also expected faculty members at public universities to give loyalty oaths. Galston said that though he was not a communist, he advocated for Caltech's decision not to adopt such a loyalty oath.

In 1955, the chairman of the botany department at Yale, Oswald Tippo, invited Galston to return to Yale as a full professor. Galston accepted partly because his wife and both sets of parents wanted their family to return to New York. Galston took on more administrative responsibilities at Yale, focusing less on his experiments and more on running laboratories, teaching courses, and overseeing graduate student research. He chaired the department of botany from 1961 to 1962 and directed the division of biological sciences from 1965 to 1966. In 1962 and 1968, Galston served as president of the American Society of Plant Physiologists and, during the period from 1956 to 1978, he served both as president of the Botanical Society of America and as a consultant to DuPont, an chemical company in Wilmington, Delaware. Galston later said that he considered leaving Yale to work solely in industry, but he stayed in academia because he said he loved to teach and to interact with students.

Galston again became politically involved in the 1960s, during the US's involvement in Vietnam. A decade earlier, military leaders first reported that US soldiers were ill equipped for the jungle-fighting tactics of the National Liberation Front, the Vietnamese communist army, and the dense jungle foliage that they used for cover. As a result, those leaders asked scientists to develop herbicides to eliminate forest cover and potential enemy food sources. During that time, two senior plant physiologists from Fort Detrick in Frederick, Maryland, informed Galston that his dissertation on TIBA, the soybean flowering compound, had led to their investigation of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid. Like TIBA, those compounds affected plant hormones [3] and were the active components of Agent Orange, named for the orange stripe on its steel drum containers. While the US military used other herbicides, including Agent White, Agent Blue, and Agent Pink, Agent Orange was the most widely used defoliant in the Vietnam War, accounting for approximately 11.2 million gallons of the estimated 19 million gallons of herbicides dispersed between 1962 and 1971. In 1969, Galston recorded that the visit from the Fort Detrick scientists and later media coverage of herbicide use in Vietnam led to his personal convictions about the misuse of science and his subsequent opposition to US military policy.

In the mid-1960s, Galston joined a growing group of scientists who protested the use of chemical warfare and the unforeseeable consequences of using untested herbicides in massive quantities. At the August 1966 annual meeting of the American Association of Plant Physiologists, Galston prepared a resolution that was subsequently sent as a petition to President Lyndon Johnson in Washington, D.C. The letter warned of the defoliants' immediate and long-term danger to the ecology of the area, and to humans [4] and animals. The letter's authors reasoned that destruction of food crops inevitably affected the civilian population, namely Vietnamese women and children, who were not actively involved in the war. The petition failed, but Galston and other scientists continued to lobby for the US military to stop using defoliants in Vietnam, and for toxicological studies of Agent Orange and its ilk.

As the US public began to question the Vietnam War's lack of progress and protest the US's military tactics, the US Department of Defense, headquartered in Washington D.C., ordered an investigation of the sprayed defoliants and their possible links to mutations, cancer, and birth defects [5]. In 1966, Bionetics Laboratories, headquartered in Los Angeles, California, reported to the US Surgeon General's office in Washington, D.C., that one of the active components in Agent Orange, 2,4,5-T, contained a pollutant called 2,3,7,8-tetrachloro-dibenzo-para-dioxin, or TCDD. In studies conducted on pregnant rodents, small doses of TCDD caused birth defects, while large doses resulted in stillborn or mutated infants. Later research showed TCDD to be an extremely toxic organic compound, linked to severe cancers, skin diseases, and birth defects. Through his connections at Caltech, Galston presented that information alongside researcher Matthew Meselson, to Lee A. DuBridge, a former colleague from Caltech who was the science advisor to US President Richard Nixon. President Nixon subsequently terminated the US military policy of developing and using herbicides, called Operation Ranch Hand, in 1970. He fully discontinued spraying of Agent Orange in 1971.

Following his involvement in the Vietnam War, Galston visited Vietnam in the middle of the war with virus expert Ethan Signer to investigate the consequences of Agent Orange exposure. In April of 1971, the pair toured North and South Vietnam and interviewed Pham Van Dong, the prime minister of North Vietnam, and other leaders. They also visited the People's Republic of China, the first US scientists to do so in greater than twenty years. The pair met several dignitaries on their trip, including China's prime minister Chou En-Lai. Galston returned to China with his wife and daughter the following year on a two-month long trip, working two weeks on an agriculture commune, then a requirement for Chinese scientists. He detailed his experiences in his 1973 book, *Daily Life in People's China*. Throughout the 1970s, Galston maintained an interest in US Vietnam relations, writing newspaper articles and letters to the editor in the *Hartford Courant*, and lecturing about the topic at local universities.

Over the next two decades, Galston continued to teach and conduct extensive research on plant development, much of which was published in the international journal Plant Physiology. He also filled administrative positions at Yale University [9], acting as chair of the department of biology from 1985 to 1988. Galston remained active in research and the Yale community after his retirement in 1990. In 1994 he wrote *Life Processes of Plants*, a comprehensive review of plant physiology, including plant

reproduction, developmental processes, and hormones [3]. During that time Galston also helped found Yale's Interdisciplinary Center for Bioethics. He credited his earlier involvement with the Vietnam War as factors that sparked his interest in the social and ethical consequences of scientific research. Galston organized events and taught undergraduate bioethics seminars. Galston co-edited with ethicists Emily Shurr and Christiana Peppard.

Galston received numerous honors for his accomplishments in plant physiology and his contributions to Yale University [9], including Guggenheim, Fulbright, and Senior National Science Fellowships, and two honorary degrees. Aside from his academic achievements, Galston described himself as an amateur saxophonist and jazz aficionado. By the time of his death in 2008, Galston had authored several books on plant physiology and bioethics, and greater than 300 papers. On 15 June 2008, Galston died of congestive heart failure in Hamden, Connecticut, where he lived with his wife.

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