Trends in
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Recognizing pioneering Black plant scientists in our schools and society

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We highlight the achievements of four pioneering Black plant scientists to raise awareness of the importance of diversity, equity, and inclusion in science. Their stories come alive at Historically Black Colleges and Universities through exhibits of science and art and classroom activities (https://www.plantcellatlas.org/pca-art-exhibit.html).

For centuries, the scientific community has maintained racial barriers to entry. Even today, Black Americans comprise only ~ 7% of the scientific community in the USA[i]. Furthermore, the scientists able to overcome these barriers have not been given proper credit for their achievements and remain generally unknown[ii]. Black and Indigenous People of Color (BIPOC) have pioneered scientific advances that have fundamentally shaped modern life. The stories of these innovators are a crucial part of our scientific history and should be told to help break down barriers, celebrate the achievements of BIPOC scientists, and highlight the importance of diversity in science.

To address this goal, we developed a science and art exhibit series in which the inaugural exhibit features the lives and accomplishments of Black scientists in plant biology.[xii] We aim to stage these exhibits at colleges and universities and work with faculty at those schools to incorporate the exhibit into their classes. Here, we summarize the achievements of four historical and pioneering Black plant scientists and illustrate how this exhibit can be incorporated into the classroom using examples from three Historically Black Colleges and Universities: Bowie State University, Howard University, and Morgan State University.

Edmond Albius, a prodigy of pollination

Vanillin, the compound responsible for the taste of desserts around the globe, comes from an orchid native to Mexico: *Vanilla planifolia*. In its native habitat, it is pollinated by the specialized beaks of hummingbirds, and the flowers last only for 1 day[iii]. That, combined with the multi-year process it takes to produce one vanilla bean, makes vanilla difficult to cultivate. Before 1840, it was only grown in select places in Mexico. Today, vanilla beans come mainly from Madagascar, with over 70 000 farmers involved in vanilla agronomy. This change is all thanks to Edmond Albius.

Edmond Albius (Figure 1) was born a slave in 1829 in St Suzanne, Réunion, a French island near Madagascar. Sent to assist the botanist Fereol Bellier-Beaumont as a child, Edmond was taught how to care for Beaumont's many plants. Edmond became skilled in seed collection, plant propagation, and hand pollination[iv]. By then, vanilla had been cultivated globally, but it would not bear fruit without native pollinators able to fertilize the flowers. Curious, Edmond closely examined the blossoms, searching for the stigma, the pollen-receiving organ of the plant. He discovered a leafy lid, the anther cap, encapsulating the pollen and preventing self-fertilization. Edmond opened the flap using blades of grass and deposited pollen into the flower. Weeks later, as vanilla beans hung from the vines, Edmond's discovery launched the modern vanilla industry. 'It is entirely due to him,' quoted Fereol, that Réunion became a prosperous country[v].

Edmond was freed for his discovery and given the last name Albius, but he never received any profits from his legacy. A century later, a statue of Albius was built in Réunion that honors his contribution to science and his country[iv].

Marie Clark Taylor, an education trailblazer

If you ever used a microscope in a class, it is because of the education reform spearheaded by Marie Clark Taylor (Figure 1). Marie Clark Taylor was born in Pennsylvania on February 16, 1911, when the USA was still highly segregated. Yet, she would go on to become one of the most influential figures in US education reform and to demonstrate how BIPOC women shape the world. She was the first woman to earn a PhD in science from Fordham University, the first Black woman to earn a PhD in botany from any American university, and one of the world's most prominent Black educators in science. President Lyndon B. Johnson even requested that Taylor expand her teaching internationally[vi].

Throughout her career, Taylor studied photomorphogenesis: the study of how light influences plant development. Her experiments investigated how photoperiods (precise lengths of light exposure) affected the development of floral buds [1]. After finishing her doctoral studies at Fordham, Taylor served 2 years in the Red Cross in New Guinea. She joined the botany department of Howard University in 1945 to become an assistant professor, became chair of the department soon after, and held that position until she retired in 1976[vii].

Taylor revolutionized science education by adopting a hands-on approach to learning. She advocated for using living plant cells to study life in real-time using light microscopes. Given that the cross-sections

Figure 1. Edmond Albius (top left). Marie Clark Taylor (top right). George Washington Carver (lower left). Percy Lavon Julian (lower right).

of cells were still living, students could watch the processes that made life possible. To her dismay, live imaging using microscopy was not common in American science classrooms. If microscopes were even available, dead tissue samples were typically used. Grants from the National Science Foundation allowed her to disseminate her methods, and the use of live plant tissue became the educational standard. Taylor died in December 1990, leaving a legacy that inspires students to this day.

George Washington Carver, an agricultural transformer

Although he is commonly known as 'The Peanut Man' in American history, George Washington Carver's true legacy extends far beyond peanuts; he revolutionized agriculture by introducing and demonstrating the value of crop rotation.

George Washington Carver (Figure 1) was born in Missouri circa 1864. He took an interest in plants at a young age and was nicknamed 'the plant doctor' by neighbors. As a teenager, Carver decided to put himself through school, funding his education through domestic work. He was initially accepted to Simpson college to study art but was rejected once they discovered that he was Black. However, he persevered and switched to the sciences, earning a Bachelor's degree from Iowa State University in 1894[viii].

Carver studied fungal infections of soybeans to great success and pursued a graduate degree after encouragement from his professors. After earning his Master's degree in agriculture in 1896, he was recruited to Tuskegee University by Booker T. Washington, a highly influential Black educator. Carver founded the Agricultural Experiment Station at Tuskegee and managed the two farms at the school. He also sat on numerous councils and was an adored professor[ix]. His efforts at Tuskegee focused on rehabilitating the South: centuries of cotton farming had destroyed the soil and ecology of the region, leaving farmers both financially and physically malnourished. Carver taught farmers inexpensive methods to sustainably live off the land, like using swamp muck instead of commercial fertilizer, and acorns as pig feed. Moreover, Carver independently invented crop rotation for peanuts, soybeans, and sweet potatoes, in a similar fashion to the Three Sisters of First Nation agricultural practices[viii]. These practices restored the nitrogen content of the soil while providing a nutritious diet for the farmers[ix].

Carver's most famous success was with peanuts, inventing a use for every part of the plant [2]. Some of his peanut-derived creations included nitroglycerin, laundry soap, and a treatment for goiter[ix]. The initial market for peanut products was very small. Thus, Carver met with the House of Representatives in 1921 to argue for a tariff on peanuts, where he impressed the representatives so much that he earned a standing ovation as well as his tariff. Peanuts became a major cash crop in the South soon after due to the success of the tariff. His work went on to gain worldwide recognition[ix]. In 1916, Carver was elected to the UK's Society for the Encouragement of Arts, Manufactures, and Commerce. He later received the Spingarn Medal in 1923. Posthumously, Carver was inducted into the National Inventors Hall of Fame and was given a national monument, the first dedicated to a Black American[viii].

Percy Lavon Julian, a botanical chemist

Glaucoma, arthritis, infertility in women: these conditions are treatable with modern medicine because of the work of Percy Lavon Julian (Figure 1).

Born in 1899 and living under the oppression of Jim Crow laws, Julian's primary education was inadequate. He was accepted to DePauw University in Indiana, contingent on taking both high school and college courses simultaneously. He excelled and was named valedictorian of his class in 1920, going on to earn a Master's degree in organic chemistry from Harvard University in 1923[x]. Despite his successes, securing a teaching position was arduous because of the presumption that a white student body would refuse to learn from a Black educator[xi] [3].

In 1929, Julian began pursuit of a PhD at the University of Vienna, Austria, developing an interest in medicinal plants. He earned his PhD in 1931 with flying colors and a network of colleagues in biochemistry. After graduating, Julian returned to DePauw with one of his colleagues, Dr Josef Pikl, where he began working on the synthesis of physostigmine, a compound used in the treatment of glaucoma[x]. Physostigmine is sourced from the African Calabar bean, and its production was limited by agricultural restraints. Julian was able to synthesize the compound and earned international acclaim for his success[xi] [4]. He also discovered that stigmasterol, a reaction intermediate of physostigmine synthesis, could be used as a precursor to the synthesis of several hormones, including progesterone. Progesterone is used to increase fertility in women and prevent complications in childbirth, but was difficult to procure and was in high demand. Excited about his discovery, he contacted the Glidden company to order soybean oil for his research but ended up working for the company as a chemist instead. An accidental spill of water into a tank of soybean oil yielded white solid, which, upon Julian's examination, contained stigmasterol: Julian had just discovered a method to mass produce the coveted precursor[x]. Using this method, he industrialized the production of progesterone, helping millions of women around the globe deliver children successfully. In 1949, Julian also used his knowledge of plant sterols and organic chemistry to produce cortisone and hydrocortisone from plant precursors on a mass scale[xi].

Later in life, Julian founded his own company, Julian Laboratories, making him one of the first Black millionaires in American history. He was the first Black chemist to be accepted to the National Academy of Sciences and was also elected to the National Inventors Hall of Fame. After he sold his company, he founded the Julian Research Institute, a non-profit organization, which he ran until his death in 1975[x]. Percy Lavon Julian was one of the most prominent chemists in American history, using his knowledge of plants to make effective medicines that were globally accessible.

Concluding remarks

The work of these monumental Black plant scientists is an ode to the power of BIPOC individuals, and it is important they are properly recognized for their accomplishments in our society. Toward this goal, we have initiated an exhibit featuring artwork memorializing the lives and achievements of these scientists.[xii] These exhibits can be used as a source for discussion in the classroom. We list example use cases of how the achievements of these scientists and the importance of diversity can be incorporated into the classroom (Box 1). By remembering the names, lives, and achievements of these scientists, the intellectual vibrancy of Black history can be, in part, unerased. Embracing diversity will lead to new

Box 1. Approaches to incorporate this art exhibit and BIPOC scientists into undergraduate classrooms

- Create a course project asking students to summarize the contribution and impact of one Black scientist in the field of the subject of the course. Students may work in a group and present in the class.
- Develop course lab modules based on the applications of the scientists' inventions: role of stigmasterol in plant physiology; functions of different phytochemicals in peanuts; anatomical dissection of vanilla flower; or growth of plants towards directional light.
- Design small science projects investigating any potential applications of phytochemicals.
- Dedicate a whole lecture time to the life and inventions of the scientists and their relevance to science and society.
- Design a case study based on artificial pollination for flowers to produce vanilla seeds: students can discuss the topic on a web-based blog. Teachers can evaluate the students on the strength of their arguments for a solution to the problem.
- Discuss the Black scientists' contributions while lecturing about the intricate functional anatomy of flowers and pollination (Edmond Albius), photomorphogenesis (Marie Clarke Taylor), and phytochemicals, phytomedicine, and chemistry (George Washington Carver and Percy Lavon Julian).
- Encourage course term papers on topics such as effects of crop rotation in the era of climate change or plant-based medicines, such as physostigmine or progesterone.
- Enable student-led multimedia presentations to the class about each of the scientists' contributions and accomplishments.

questions and new ideas that keep research moving forward [5].

Resources

[i]https://ncses.nsf.gov/pubs/nsf21321/data-tables

[ii]www.pbs.org/wgbh/nova/article/barriers-black-scientists/

[iii]www.encyclopedia.com/social-sciences/applied-and-social-sciences-magazines/vanilla-industry

[iv]www.blackpast.org/african-american-history/edmond-albius-1829-1880/

[v]https://www.nationalgeographic.com/science/article/the-little-boy-who-shouldve-vanished-but-didnt

[vi]www.womeninhorticulture.com/post/woman-of-firsts-marie-clark-taylor

[vii]https://thefordhamram.com/56782/culture/fordhams-first-female-ph-d/

[viii]www.history.com/topics/black-history/george-washington-carver

[ix]www.smithsonianmag.com/history/search-george-washington-carvers-true-legacy-180971538/

[x]www.sciencehistory.org/historical-profile/percy-lavon-julian

[xi]www.acs.org/content/acs/en/education/whatischemistry/landmarks/julian.html

[xii]www.plantcellatlas.org/pca-art-exhibit.html

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Authors' contributions

Conceptualization: S.Y.R., M.E., S.L.R.; Methodology: M.E.; Investigation: M.E.; Visualization: M.E.; Funding acquisition: S.Y.R.; Project administration: S.L.R.; Supervision: S.L.R., S.Y.R.; Writing – original draft: M.E.; Writing – review & editing: M.E., S.L.R., A.O., J.P., H.U., S.Y.R.

Declaration of interests

The authors declare that they have no competing interests.

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