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First successful substitutes for ivory billiard balls were made with celluloid reinforced with ground cattle bone

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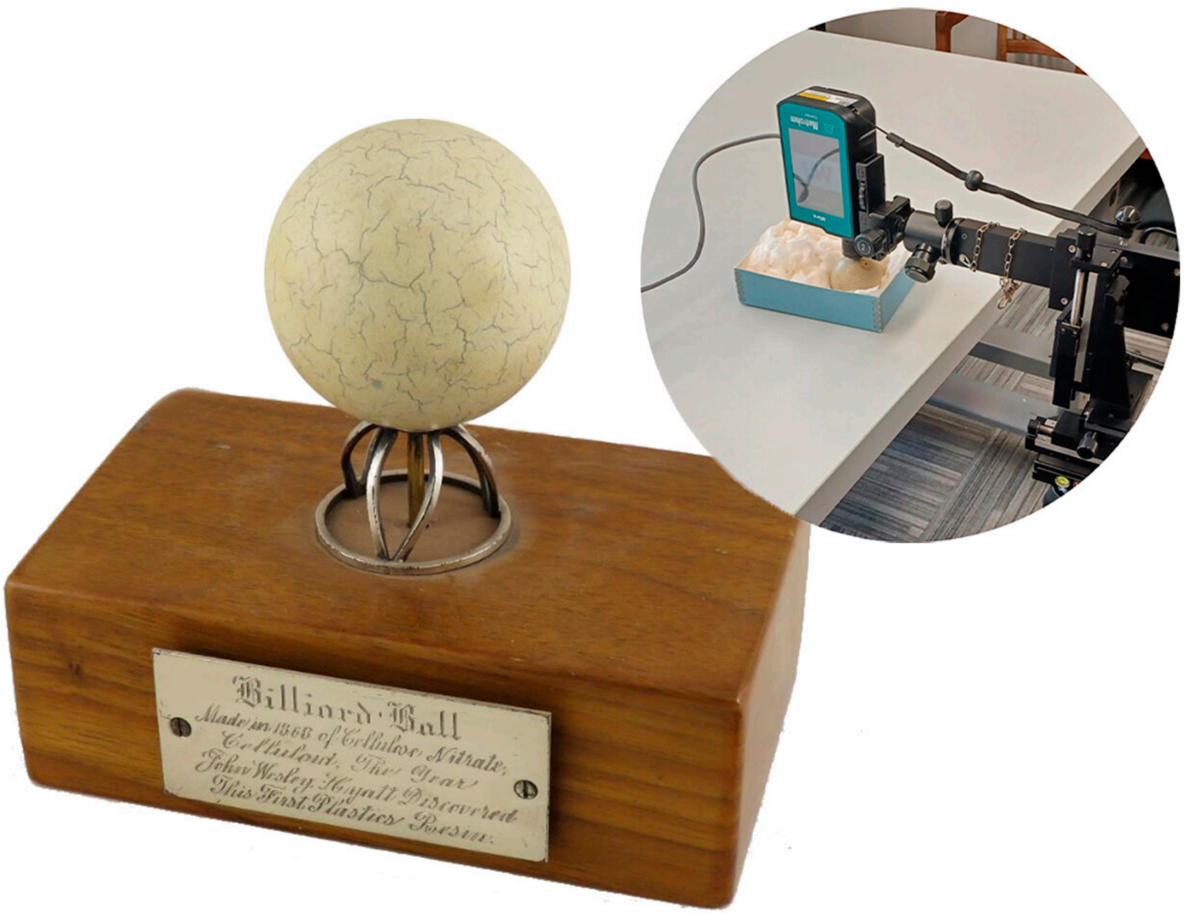

John Wesley Hyatt's original 1868 billiard ball and its in-situ analysis by handheld Raman spectroscopy. Credit: Smithsonian Institution

In the 19th century, the market for ivory products increased to an alarming point. This high demand led to the search for artificial substitutes, but ivory properties were nearly impossible to replicate. The most important substitutes came from Alexander Parkes and John Wesley Hyatt, inventors of the first artificial plastics: Parkesine and celluloid.

These early plastics were made using cellulose nitrate and camphor. The significance of Parkesine and celluloid objects in the history of plastics is well understood; for that reason, they have been collected by prominent museums worldwide.

Hyatt's original goal was to substitute ivory billiard balls. Ivory's properties were highly valued, especially in the game of billiards, which utterly depended on the mechanics of this material. However, difficulties in the acquisition of ivory, its selection and transformation, and its susceptibility to relative humidity and temperature fluctuations that lead to cracking and breaking were not ideal.

Furthermore, the number of players was increasing, and the industry knew that the supply was not inexhaustible. In the National Museum of American History resides the original billiard ball developed by Hyatt. Putatively, it is the first celluloid object ever created, dated to 1868, and is the founding object of the plastics industry. However, its composition was unknown.

Historians and scientists have written about Hyatt's billiard balls due to their significance in the history of plastics. However, because they did not know their composition, they could not determine to what extent substitute materials had been used. For decades, several designs were proposed, such as billiard balls made of pure celluloid or billiard balls made of shellac compositions coated with a cellulose nitrate solution.

The common interpretation was that Hyatt's original billiard ball failed because the properties of celluloid, or any other alleged materials, could not approach the mechanical properties of ivory. In a recent study published in *PNAS Nexus*, we determined the composition of Hyatt's billiard balls and proposed a different interpretation.

John Wesley Hyatt's premier composite

To determine the composition of the Hyatt's original 1868 billiard ball, we required the support of the Smithsonian Institution, their permission to acquire micro samples, that is, samples invisible to the naked eye, and modern analytical techniques, namely elemental and molecular spectroscopies and protein mass fingerprint.

The results were surprising: Hyatt's early experiments with billiard balls resulted in the development of a premier example of a reinforced polymer composite material made with cellulose nitrate, a cellulose derivative polymer holding the ball together; camphor, a plant-based material working as cellulose nitrate plasticizer; and ground cattle bone, an animal by-product conveying the necessary mechanical properties to the system.

We quantified the proportions of ground bone to celluloid with micro-Fourier transformed infrared spectroscopy and found a correlation with a formulation patented by Hyatt on May 4, 1869, of 75% ground bone to 25% cellulose nitrate by weight. We proposed this composite be called reinforced celluloid. However, had it been successful?

A money ball made of reinforced celluloid

By looking carefully at the written records related to the world of billiards, we found references to tradenames of billiard balls sold from the 1880s to the 1960s, clearly different from ivory, but whose compositions were also enigmatic: Bonzoline, Crystalate and Ivorylene. All these billiard balls were directly or indirectly related to the Albany Billiard Ball Company, established by Hyatt in 1868 in Albany, New York, U.S. We analyzed these billiard balls and found that their compositions were unexpectedly consistent with Hyatt's reinforced celluloid composite.

The realization that reinforced celluloid was sold for almost 90 years proved the commercial success of Hyatt's 1868 composite. Looking at the stories surrounding professional players and their material choices allowed us to understand how this material entered commerce and culture.

Initially, there was prejudice against the use of the artificial substitute. The game between Charles Dawson and John Roberts Jr. in 1899, known as the match of the century, epitomized this problem. Roberts Jr. wanted to play with Bonzoline, and Dawson contested, "Whoever heard of a money match of any importance being played with Bonzoline balls?"

However, reinforced celluloid billiard balls were more uniform than their ivory counterparts. This advantage led to improved performances by Roberts Jr. and other influential players. In time, even Dawson was publicizing the Bonzoline billiard balls. Reinforced celluloid performed well and cost half the price of ivory, which promoted the growth of the game of billiards throughout the world and contributed to the survival of elephants. Hyatt made a money ball with his inventive shoot toward an ivory substitute.

An inspiration for the future?

Look at a contemporary billiard ball from the macroscale to the microscale. It is likely composed of a phenol-formaldehyde matrix, a filler, and other additives—a very similar system to reinforced celluloid. Although the qualities of phenol-formaldehyde plastics were crucial in surpassing earlier billiard ball materials, nowadays, environmental questions have been raised about this material as a plastic pollutant.

If a young engineer, much like John Wesley Hyatt did 155 years ago, aspires to develop an innovative and environmentally sustainable alternative to contemporary billiard ball materials by utilizing raw materials derived from bioresources, there is a rich source of inspiration in the example set by Hyatt's composition. Not only because it demonstrates the feasibility of such an endeavor but also because it illustrates the challenges that must be overcome to accomplish a transformative invention.

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More information: Artur Neves et al, Best billiard ball in the 19th century: Composite materials made of celluloid and bone as substitutes for ivory, *PNAS Nexus* (2023). DOI: 10.1093/pnasnexus/pgad360

Artur Neves has a PhD in Conservation and Restoration of Cultural Heritage granted by NOVA University of Lisbon, Portugal, in 2023. In 2022, he was awarded a Fulbright research fellowship. Hosted by the Department of History of the University of Maryland, he worked with cultural institutions for the interdisciplinary study of celluloid heritage, including the Smithsonian Institution’s National Museum of American History. He is now a postdoctoral research fellow in the project “Plastics Metamarphoses: reality and multiple approaches to a material” working on plastics material culture in Portugal.