TRIPLY FORMULATED NITROCELLULOSE: CELLULOID, VISCOSE AND CELLOPHANE

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Introduction

Is it perhaps too early in this century to single out a material, or a class of materials, as the most popular. During the twentieth century, nylon and plastics were contenders. In the nineteenth century, nitrocellulose had such a role, at first as an explosive, often termed guncotton or, in French, *fulmicoton*; and as collodion, a nitrocellulose gel used to dress wounds.

In 1845, the German chemist Christian-Friedrich Schönbein (1799-1868) had inadvertently nitrated cellulose. He found the ensuing product to be highly explosive. In 1846, he supplied Michael Faraday with a sample (1).

Nitrocellulose, under these two formulations, became much written about. The novels by Jules Verne featured it prominently. In *From the Earth to the Moon* (1865), guncotton is the explosive used to hurl the explorers. In the same novel, an American named Maynard is credited tongue-in-cheek with the devising of collodion—when in fact the French Louis Ménard had devised it in 1846 (2). Jules Verne was deriding what his French readership perceived as American one-upmanship. In *Journey to the Center of the Earth* (1864), the heroes blow up with guncotton a mountain of granite blocking their progress (3).

These examples show that nitrocellulose, in either formulation, was very much part of the popular culture—to such an extent that it spawned other inventions, which I shall now chronicle.

Antecedents

During much of the nineteenth century, American billiard balls were made of ivory, a precious material that was already becoming rare (4). It became so ruinously expensive that a company manufacturing these balls, Phelan & Collander, in 1860 launched a competition for a substitute product (5). The selected inventor would win a $10,000 prize, hefty at that time (6).

Alexander Parkes (1813-1890), an Englishman, son of a locksmith, was a prolific inventor (7). He worked for the Elkington's Company in Birmingham, where he developed a technique of fine electroplating. In 1856, he came up with a replacement material for ivory, which he named parkesine (8, 9). It consisted in cellulose treated by nitric acid—such an ester was then named a collodion (10)—which the incorporation of ethanol rendered plastic (11). This artificial ivory rewarded Parkes with a bronze medal at the Universal Exhibition in London in 1862, in addition to a flattering reputation (12).

Daniel Spill (1832-1887), an Englishman who made raincoats in his brother George's company, became interested in the waterproofing properties of parkesine. The George Spill & Co., in Stepney Green near London, thus started manufacturing it. However, it was an expensive material, on account of the ethanol component. Moreover, it tended to lose its shape and to show cracks after a relatively short time.

The American John Wesley Hyatt (1837-1920) then entered the scene. Born in Starkey, in the state of New York, he had become apprenticed in a printing shop in Illinois aged only 16, and found a similar job subsequently in Albany, New York. When Phelan & Collander made their prize public, he sought also to make an artificial ivory. Like his predecessors Spill and Parkes, Hyatt modified collodion; Hyatt's modification was to add camphor to it (13, 14). He had the astute idea, in order to obviate the need for ethanol, to do this under heating and pressure. As a consequence, his product did not suffer, as parkesine did, from premature ageing (15). He patented the new material , a cellulose derivative that he named celluloid, in 1863. Hyatt convinced his brother Isaiah Smith Hyatt to join him, and they started a company. Hyatt was gifted not only in chemistry, but also in mechanics and industrialization. He built machines for molding celluloid pieces by injection. The first artificial plastic material in the modern era was born (16). It was the scion of two natural products, wood pulp and camphor. Parkesine failed to sustain the competition with the newer material. Its manufacture stopped in 1868; later on, during the 1880s, the British Company Xylonite of Daniel Spill would merge with Hyatt's Celluloid Manufacturing Company, as it was named by then.

By 1870, the Hyatt brothers had their own business, the Albany Dental Plate Company. Indeed, their main production was not billiard balls but dental plates (17, 18). These prosthetic devices made out of celluloid had some problems, however: they were poorly compatible with hot drinks, for heat made them soft, and one's tea left a taste of camphor in the mouth. As early as 1871, the Hyatts' company moved to Newark, New Jersey, close to New York City, and took a new name, the Celluloid Manufacturing Company. It would remain active there until 1949, for a total of 77 years. The Hyatt brothers diversified their production into haberdashery items such as buttons, detachable collars and stays for shirt collars and for corsets. These stays superseded the earlier metallic battens, that rusted on contact with sweat and thus stained clothing.

Celluloid was also turned into large combs for elegant ladies to plant in their hair. The Celluloid Manufacturing Company also produced shirtfronts, referred to under the affectionate and rather vulgar name, dickies. Compared to shirts, they had the advantages not to shrink upon washing and to be cleaned easily, with just the brush of a sponge. They met therefore with huge commercial success.

What are the factors in the adoption of a new material such as celluloid? Its already mentioned low production cost. The three inventors referred to above, Parkes, Spill and Hyatt, did not attempt a frontal attack on the problem posed—to come up with a substitute material for ivory with the assets of whiteness, hardness, mechanical resistance, and ability at undergoing elastic collisions (billiard balls). Nurtured in the Industrial Revolution, they knew to start their research by choosing their raw material. They all opted for cellulose, i.e., wood pulp. This answer surely was assisted by the great contemporary vogue of cotton powder, aka fulmicoton. It was made initially from cotton dipped into a nitric acid bath, which after drying yielded an explosive.

The next question these inventors faced was how to render plastic the derivatized celluloses. How, once they had been functionalized by nitric or sulfuric acids, to have them be shaped or molded? The rather obvious answer was by adding a solvent. Indeed, mankind has for millennia known how to evolve a malleable, plastic material such as playdough or its predecessor, fuller's earth, from the parent dry powder, simply by adding water. Parkes and Spill did not go beyond this second step. Hyatt conversely did. He was inventive enough to conceive of the operational procedure of camphor incorporation. In addition, he was able to mechanize the molding step, thus gaining access to reproduction of the identical object in as many copies as necessary.

As early as the 1870s, in the US, at the instigation of Leland Stanford—the founder of the university bearing his name—Eadweard Muybridge was photographing at regular intervals running horses. This technique enabled him to analyze the detailed motions of their various strides, the step, the amble, trot and gallop.

Independently from Muybridge, the Frenchman Etienne-Jules Marey invented in 1892 what he named chronophotography, an identical photographic technique for decomposing movements. Marcel Duchamp became interested in the chronophotographs by both Muybridge and Marey, to such an extent that he labeled "chronophotograph" his great 1912 canvas, *Nu descendant un escalier*. Thus, things were ripe in the 1890s for the appearance of cinematography. Persistence of images on the retina was a well-known phenomenon, due in part to stroboscopy.

It only remained to find a suitable support. Celluloid answered that need: it had the hoped-for characteristics, which were rather numerous. One had to scroll photographic images in sequence, in linear temporal sequence. The support thus had to be linear, enabling each image in turn to have the light of a projector shine on it. A projector was also needed. To evoke motion for the viewers, many images were required. This called for their miniaturization, and thus for enlargement as they were displayed. Even if each image had dimensions of the order of a centimeter, a projection time of only five minutes translated into a ribbon several meters long. Hence, a reel. Moreover, there was a need for that support to be transparent.

Indeed, yet another criterion was the recording of this cinematographic sequence. A possibility, by analogy with the stacking of the pieces of perforated cardboard used in a mechanical organ or pianola, would have been to use equal length strips, vertically superimposed on one another. In that case, the chosen support would have needed to be rather rigid. However, as you know, the prevailing solution was winding the strip of images cylindrically, in the manner of Edison's original phonographic recordings, or around a pulley. Since storage was by winding, the tape had to be a pliable and flexible film.

Last but not least, the material had to be inexpensive. This was all the more important because the fast, exponential growth of the Seventh Art—it becoming a novel, lucrative industry—quickly made multiple copies a necessity. In the early twentieth century the number of existing plastic materials was limited to bakelite, galalithe and celluloid. Bakelite had liabilities: it was opaque and unwieldy to condition into strips of film with a thickness of the order of a tenth of a millimeter. Moreover, it was a late invention, occurring only about 1909. As for galalithe, a polymer devised from casein in 1889, the raw material would have made it too expensive.

Vinyl might have been an option. However, it was deemed useless until the 1920s. Polyvinyl chloride (PVC) was first made by the German chemist Eugen Baumann in 1872. He never applied for a patent. PVC was patented in 1913 only when another German, Friedrich Klatte polymerized vinyl chloride using sunlight. Klatte was the first inventor to obtain a patent for PVC. But no useful application of PVC existed until Waldo L. Semon made it into a better product. Semon has been quoted as saying, "People thought of PVC as worthless back then [circa 1926]. They'd throw it in the trash" (19).

All of which explains the choice of celluloid, in existence and in commercial availability since 1870—with the added asset of being made in the United States, which rapidly became the seat of the movies industry (20). As early as 1856, Parkes had proposed substituting parkesine for glass in photography. Daniel Spill followed suit and pushed his xylonite in 1870. After David and Fortier used celluloid as a support for gelatin emulsion in the 1880s, John Carbutt, of the Keystone Dry Plate Company in Philadelphia, made it commercial in 1888. He purchased the celluloid sheets from the Hyatt brothers. Celluloid had the assets of transparency, being unbreakable and light. In the West Orange laboratory of Thomas Edison, W. K. L. Dickson experimented on the Kinetoscope—a cylinder device—the following year. Magic lanterns were also experimenting with celluloid slides, less heavy to carry around than slides made of glass. An important step in the transition from photography to cinematography, was the celluloid film band proposed by Walter Poyner Adams in 1888. Another crucial step was a change in the formulation of celluloid, making it into thin and flexible films (John H. Stevens, 1882). This was the time when George Eastman stepped in, decisively. Together with William H. Walker, he marketed a roll film holder in 1885. Roll film allowed shooting photographic sequences. Production of celluloid-backed roll film began in 1889. It met with considerable commercial success. Thomas Henry Blair, who had founded a company in Boston, competed with the Eastman company, located in Rochester, NY. The Blair company proposed a full range of photographic products. The Edison-Dickson Kinetoscope was ideally suited for the Blair celluloid films. Such projections happened until nearly the end of the nineteenth century. Ousted from the American company he had started, Blair moved to England. The European Blair Camera Company supplied raw film stock for the pioneering experiments in cinematography of the Lumière brothers, in Lyon, France. All that explains the strong, durable association of celluloid and the movies (21, 22). At the turn of the twentieth century, there were simply no alternatives to celluloid in devising motion pictures. It had one major drawback, though, its flammability (23).

Even today, more than a century later, a search on the Web shows that the majority of sites elicited by the word "celluloid" relate to the movies. Production of the first cinematographic films increased even further the wealth accruing to the Newark-based Celluloid Manufacturing Company. It even indirectly increased the faraway camphor production from Taiwan. Gradually, films made from cellulose acetate started competing with those made out of celluloid, the latter having the twin drawbacks of being flammable and explosive.

Devising Artificial Silk

I have sketched out briefly the history of celluloid, for its obvious parallel with the history of rayon. Ivory in the former, silk in the latter were precious, natural luxury materials for chemists to imitate and for the chemical industry to produce in large amounts. These novel artificial goods, celluloid and rayon (24), had a social impact; they—together with their retail outlets, department stores starting towards the end of the nineteenth century—were a significant factor in the rise of the middle class in Western countries.

There are enough accounts of the inventions by Chardonnet, and by Cross and Bevan, that I shall content myself by taking note of the main features; and I shall give prominence to some of the less well-known parts of the story, for the interesting questions they raise. Comte Hilaire de Chardonnet (1839-1924) was a rather idiosyncratic character, as well as an inventor of the edisonian type. He was independently wealthy and a *polytechnicien*. Having set-up a laboratory in his home, he devoted himself to scientific research, investigating, for instance, ultraviolet absorption by organic substances and the mechanism of vision. After long and careful observation of silkworms—Louis Pasteur was then similarly engaged—in a biomimetic spirit (25), Chardonnet threaded collodion (26) through a glass spinneret, and thus managed to mimic filaments of natural silk.

He had been at it for 30 years. He chose a derivative of cellulose, since silkworms fed on mulberry leaves, i.e., on cellulose—to gross first approximation. Little did he know that silk is another type of biopolymer, a polypeptide. After a long search, he selected, as the most promising natural form of cellulose, linters, i.e., the short hair on cotton seeds, with a maximum length of 25 mm (27). He patented his artificial silk in 1884 and proudly displayed samples at the two Paris exhibitions, in 1889 and 1900. He built and started in 1892 his first factory for producing artificial silk in Besançon, his hometown. He set up other factories outside France, in Sárvár (Hungary)—to which I shall return later—Tubize (Belgium) and Padova (Italy), among others.

The Chardonnet nitrocellulose process was rather quickly superseded. For one main reason, Chardonnet's Besançon factory did not have well-organized research (28). Also, about the time it opened, two British inventors, Charles Cross (29) and Edward Bevan, found in 1891 a significantly better procedure, the viscose process (30). They discovered that cellulose, for instance from spruce paper pulp, after treatment with strong caustic soda, can be treated by carbon disulfide and turned into a viscous, molasses-like solution. A cellulose ester—a xanthate, technically—is formed. After suitable ripening, this viscous solution is extruded through the fine holes of a spinneret, a constellation of hair-like openings in a platinum plate. The resulting fine filaments are led into an acid coagulating bath and thence wound onto reels, washed, and dried. The xanthate ester being thus decomposed, a continuous bundle of filaments of regenerated cellulose results (31).

Before continuing to spin the yarn of this story—an unavoidable metaphor, with such a subject matter—a feature of the Chardonnet episode deserves amplification. He turned to collodion, i.e., nitrocellulose, because this product had been much explored and used as a panacea by many other inventors and scientists. The chemical had been discovered by Pelouze in 1838. Under the French name *fulmicoton*, it had become an explosive, with an attractive weight-to-detonating power ratio. Fulmicoton led Alfred Nobel to the invention of dynamite. As a varnish, collodion was used to dress wounds—it was still in use during World War I.

To return to artificial silks, in 1904, Courtaulds acquired the Cross and Bevan 1892 patents to the viscose process, manufacturing artificial silks from wood pulp. They established an American subsidiary, the American Viscose Corporation (AVC) in 1909 (32). Other processes for turning cellulose into artificial fibers were devised, but the viscose process remained dominant (about 80%) throughout the first half of the twentieth century. In 1930, production of artificial silk (33)—it was named rayon in 1924, a point I shall return to—was led by the US (60 kt), followed by Italy (30 kt), Great-Britain (23 kt), Germany (20 kt), and France (18.5 kt) in fifth position only (34).

Devising Cellophane

Jacques Edwin Brandenberger (1872-1954) was a Swiss engineer, employed in France in a succession of companies: in 1903, he was in charge of dyeing in a cleaning outfit. He was experimenting already with application of layers of viscose onto fabrics, to improve their aspect. In 1905, he was managing a branch of *Blanchisserie et Teinturerie de Thaon* (BTT) in Gisors (département of the Eure). He continued his experimentation with viscose cellulose silk there. In 1907, he transferred to the mother company in Thaon (Vosges), and he continued in his attempts to affix viscose artificial silk onto fabrics. Being frustrated with other techniques, he looked into the possibility of applying thin films of viscose.

This very real history has become replaced, in some quarters, by a picturesque but fallacious anecdote: "Brandenberger was seated at a restaurant when a customer spilt wine onto the tablecloth. As the waiter replaced the cloth, Brandenberger decided that he should invent a clear flexible film that could be applied to cloth, making it waterproof" (35). The truth of the anecdote is that Brandenberger was indeed trying to apply such a viscose coating to cotton fabrics.

By the end of 1908, Brandenberger had succeeded, and patented the application of cellulosic films on various supports. He mentioned explicitly in the patent applications the analogy to photographic and cinematographic film (36). The president of BTT, Paul Lederlin, granted him a subsidy and approached *Société Française de la Viscose*, with which a collaboration agreement was signed. By 1908 Brandenberger devised also the first machine for manufacturing transparent sheets of regenerated cellulose, at the rate of 10-15 meters per minute. The early results were rather disappointing though. Brandenberger failed to come up with films of uniform, reproducible thickness. Finally, during the spring of 1909, he was able to produce films weighing only 25 g per square meter, i.e., with a thickness of only 0.016 mm (37). By 1912, he was making a saleable thin flexible film, used in gas masks. Would they come handy just a few years hence!

The viscose films produced by Brandenberger did not fail to attract the attention of the movie-making industry, of companies such as Eastman-Kodak and Pathé, for these viscose films were much less flammable than celluloid. Brandenberger named his invention "cellophane" and trademarked it in 1912. He foresaw a possible realm of applications in the wrapping of goods (38). The same year (1912), the American Chemical Society validated cellophane for food-wrapping. The BTT company did not prove itself equal, however, to the task of marketing this new material. It sold its cellophane-producing branch to *Comptoir des textiles artificiels* (CTA), which already included *Société française de la Viscose*.

An independent company *La Cellophane* was incorporated in 1913. It started production in Bezons (Oise) during the war, in 1915. By the end of the war, in 1919, 40% of the production was already being shipped to the United States. The same percentage applied in 1923: 160 t of cellophane were produced in Bezons for the American market—which explains DuPont de Nemours becoming interested, as we shall see further on.

A vividly interesting part of the cellophane story, which we owe in part to World War I, is the feedback from technology to science. At the Rockefeller Institute, starting in 1915, Alexis Carrel and the young mathematician he had hired as an assistant, Pierre Lecomte du Nouy, measured war wounds by planimetry, after they had traced the outline of the wound onto cellophane (39). A considerably more important application to science was use of cellophane as the semi-permeable membrane in dialysis studies, it became standard just a few years later (40).

New Words, New Brands

We live in an era of relatively new brand names, such as Apple, Amazon, Google or Yahoo. Names for their popular commercial products do not lag behind: Macintosh, iPhone, iPad, Kindle or Word. Some such names have already entered the language.

Neologisms coined by corporations have thus entered the common language. This particular development was ushered in much earlier, at the turn of the twentieth century, at least for the products I am focusing on. The names of the commercial products based on the same cellulose-derived chemical product, rayon and cellophane, for the fiber and for the transparent film respectively, have also entered the language, to such an extent as to no longer require a capital initial letter. The viscose process by which the former used to be—and continues to be, to a minor extent—manufactured has nearly achieved a similar status.

A neologism, by definition, is when a new word enters common parlance. A new brand can be deemed successful if and when its name becomes a common word and enters the dictionaries—as in the above examples. The process of generalized adoption can be likened to an epidemic. It needs a vector. There is an infection phase, when a steady state is achieved: more people per unit time—a week, say—acquire the word than forget or lose it. Infection brings about a process of collective memorization. Infection demands diffusion among a group of people, by the highly effective word of mouth. The neologism process is complete only with mutual contamination between otherwise separate social circles, when the new word, with or without a splash, enters the language. At least, this is what my intuition suggests.

But words seldom exist in isolation. They belong to families. Consider as example the neologism with which this narrative began, parkesine—named after Alexander Parkes. Parkesine begot celluloid, assuredly. But not directly. There was an intermediate: the Hyatt brothers initially named their product Ivorine, since it was an imitation of ivory (41).

The name "cellophane" was coined about 1911 by its inventor, Jacques Brandenberger, as a protected brand name. This name took and held because it is transparently logical, the cellulose primary material lending it the first four letters, while the -phane suffix refers to its diaphanous aspect, *diaphane* in French. As readers will recall, French words are graced with a gender. In the case of cellophane, this gender has become ambiguous. The "e" ending suggests the feminine, "la cellophane." However, this material is shaped as a thin film. The word "film" is masculine in French. Accordingly, one also finds the form "le cellophane". According to Google, the feminine is dominant, but by a mere factor of two, 44,800 versus 23,200.

The name "viscose" for the process by which cellulose is transformed into either artificial silk or cellophane film dates to 1892, to its devising by the British chemists Cross and Bevan. It is a cognate of "viscous" and refers to the syrupy aspect of the mother liquor, after cellulose has been treated with caustic soda. The name "rayon" for the derived artificial silk, is somewhat more difficult to trace. It was coined, apparently, in 1924 at a meeting of the National Retail Dry Goods Association of America (42).

All these words share a transatlantic coloring, hybrids between French and English. There is a long list of such hybrids, going back several centuries; examples include *le weekend*, sport and tennis. In addition to naming, these words served for branding too. The technologies appeared at the time when trademarks started being legally protected as intellectual property and as a consequence of international agreements, such as the Madrid Agreement Concerning the International Registration of Marks of 1891, following upon the Berne Convention of 1886 and the Paris Convention of 1883 (43).

The Role of Advertising

With both rayon and cellophane, it was considerable (44). There were three main features: direct advertising by chemical industry to consumers, targeting of women, and the merging into political propaganda during the Thirties in the fascist countries, Germany and Italy.

Direct advertising from commodity producers in the chemical industry to consumers at the end of the line (45) resulted from innovation of both kinds, product innovation and process innovation, exemplified by both rayon and cellophane. Modern advertising, an industry born with the twentieth century and carried forward by visionaries such as Albert Lasker, had already shown its mettle, with its ability to create novel needs among consumers—orange juice being a prime example, introduced in the aftermath to World War I (46). Advertising could draw upon the novelty of materials such as the cellulose silks and the cellophane film. As wrote an influential designer of the times, the Thirties, primarily (47),

> These new materials are expressive of our own age. They speak in the vernacular of the twentieth century. Theirs is the language of invention, of synthesis. Industrial chemistry today rivals alchemy! Base materials are transmuted into marvels of new beauty.

Inducing new tastes, new needs in customers, social trends can converge with advertising (48). John Wanamaker, a pioneer of the American department store, hired John E. Powers to write the advertising copy, on which he spent lavishly. This may have created the American model for the symbiosis of department stores and advertising agencies. The 20 largest stores in NY and Chicago in 1899 spent about $1.775 million on advertising, an amazing amount, even in aggregate (49).

Advertising sold the new synthetic fabrics. They were applied to sportswear, a trend that originated in Southern Florida. "Beginning in the mid-1930s and culminating in the early 1950s, manmade fibers were first marketed and accepted in clothing that was to be worn for casual purposes" (50).

Some examples: in 1936 the 18th Annual Beaux-Arts Ball, appropriately named *Fête de Rayon-Fantastique*, could boast that all the costumes worn in the pageant were of fabrics made from rayon. A group of rayon manufacturers donated thousands of yards of the stuff for draperies and costumes, and in return Mrs. S. Stanwood Menken wore a rayon costume (The Spirit of Rain) and the famous stripper Gypsy Rose Lee wore a costume (The Eclipse of the Sun). It was all the idea of an advertising man named Reimars, representing the American Enka Corp., one of the main producers of synthetic fabrics at the time (51). The *Ladies' Home Journal* published an ad in 1940 featuring the Hollywood star Rita Hayworth, sponsored by the American Viscose Company, clothed in its Crown rayon brand. *Time* magazine published in 1948 for the American Viscose Corporation an advertisement entitled "Another fitting job for rayon." A lady, seen from the back, combs her hair while looking at herself in the mirror. She could be an actress putting on the finishing touches prior to stepping on the stage. The first sentences of the accompanying text are: " A fitting job vital to most women. Mysterious to most men. Challenging to the rayon engineer."

Turning to cellophane, its advertising is no less interesting. In the 1900s, celluloid still enjoyed an aura of modernity, as a brand-new plastic material, that the then nascent advertising industry embraced as a support for some of its messaging, to the extent of printing on it. In the early 1900s, celluloid thus served as support for much of the promotional items by the Hamilton watch company, of Lancaster, Pennsylvania. Retailers used them as giveaways to their customers. During the period 1917-1923, the Parisian Novelty Company, of Chicago, distributed celluloid vanity cases, serving likewise as supports for advertising. Louis L. Joseph, its founder, had a preference for novelties made of celluloid. Advantages of celluloid for such purposes were, first and foremost, its transparency. Celluloid offered also cheapness, light weight, durability, ease of molding, flexibility and ready availability in a wide range of thicknesses.

Starting in the 1930s, celluloid advertising targeted women especially, with ads in three of the most popular magazines among housewives: the *Ladies' Home Journal*, *Good Housekeeping*, and the *Saturday Evening Post*. Magazines were not the only media though. The Cellophane Radio Program, hosted by Emily Post, broadcast every Monday and Thursday morning in most major cities and addressed topics of interest pertaining to the home and daily social life. To give an idea of the ads, one placed by DuPont Cellophane in a 1934 issue of the *Saturday Evening Post* introduces housewives to the novel concept of the meat counter in supermarkets. It is entitled "New self-service meats make shopping quicker, easier." In France, the early advertising of cellophane was in the style of *bandes dessinées*, i.e., comic books. One issued in 1930 by the cellophane factory in Bezons is interesting in terms of gender studies: in half the frames, a handsomely dressed man uses cellophane. As for housewives, they wear an apron as their distinctive feature!

American-style advertising (52) pushing cellophane as partaking of the new shopping style (supermarkets), arrived in France rather late, only in the years following World War II. The advertising campaigns, such as the *Paris Match* weekly featured in 1954, were carbon copies of the pre-war American ones. The rhetorical question by Fohlen and Abrams (1962), "Can the French Be Americanized?" was to be answered, in the ensuing years, with a resounding YES (53).

Was the advertising effective? Enormously. In the case of cellophane (54)

> A national grocery store chain reported a 2,100 percent increase in doughnut sales in two weeks after wrapping its doughnuts in cellophane. Market surveys confirmed that housewives felt no compelling urge to buy doughnuts before walking into the store but snapped them up strictly on impulse "because they looked so inviting in transparent packages."

With all the advertising pushing rayon and other cellulose-derived fabrics, cellophane as well, into the shopping bags of American ladies, was a backlash inevitable? At least one person, the great American writer E. B. White—too easily discarded as a humorist—took issue with the underlying consumerism, with the Keynesian notion—as it would become known—of jump-starting the economy by inducing people to purchase goods. In a series of three articles in *The New Yorker*, he reiterated the very American belief in the good, simple life, as had been advocated by Thoreau—a set of beliefs that periodically re-emerge, as later shown for instance in the writings by Jack Kerouac. White wrote (55):

> … it is only on the surface that [nature's] variety is baffling. At the core it is a simple ideal. You feel it when lying stretched on warm rocks, letting the sun in. It is just possible that in our zeal to manufacture sunlamps at a profit, we have lost forever the privilege of sitting in the sun.

He railed against the new consumerism: "The revolution began with cellophane," people are "intrigued with its new transparencies," and driven to accumulate, egged on by advertising. White advocated instead "a society based on the assumption that nobody is going to buy anything, ever again." White even advocated an upended pay-scale, with the goal of decreasing consumption, paying the highest executives the lowest wages and the lowest-ranking employees the highest salaries.

Totalitarian states were prompt to seize upon the new synthetic materials, as both symbolical of the new man their governments purported to nurture, and making them autarchic, independent of imports from foreign countries. Fascist Italy, a major player in rayon production (SNIA Viscosa), took the lead. A rayon truck convoy took to the Italian roads in 1934, publicizing the multitudinous merits of the new fabric (56). Rayon found its bard in

Marinetti, the poet who founded the Futurist movement (*Poem of Viscose Tower*, 1937-38). A whole new fascist city, Torviscosa, was built for viscose process work. The fiber itself became based on *Arunda donax* reeds from reclaimed Italian marshes, obviating a reliance for cellulose on Scandinavian firs. Nazi Germany and Stalinist USSR followed similar autarchic paths; for them too advertising artificial silks from cellulose became material for political propaganda (57, 58).

The historian faces a nagging question: did the propaganda for rayon and cellophane in totalitarian countries differ from their advertising in democracies in essence, or only in extent? I won't attempt to answer it here. To close this section on a jollier note, a hit song from those times, of the American New Deal, when the economy was starting to recover from the Depression, between the two World Wars, was Cole Porter's 1934 hit "You're the Top":

> You're the purple light of a summer night in Spain
> You're the National Gallery
> You're Garbo's salary
> You're cellophane!

Selling Artificial Silks: Department Stores

At the turn of the twentieth century, a retail institution already existed to sell artificial silks to customers, Chardonnet's at first, viscose silk a few years later (59). Chambers of Commerce in all big cities of the Western world prided themselves in their department stores (60). They had been in existence for a generation already. These were palaces of shopping, grandiose buildings devoted to luring the burgeoning middle class into spending money on splendidly displayed items of every description (61, 62).

They made women especially, but men also, come to visit them out of curiosity, out of idleness too—female members of the bourgeoisie as a rule stayed at home and did not work. Once they had entered a department store, they were captives. All kinds of selling tricks were used. Each client was made to feel special. The interior architecture was museum-like. It harbored luxury items that acted as motors of sales more indirectly than directly: customers who could not afford their high prices had the option of turning to less expensive substitutes, mere imitations of such luxury items—but worthwhile imitations. Artificial silks, for instance. Likewise, novelties coexisted with classics. Fashion dictated to women the purchase of dresses, and of many other pieces of clothing, which one had to be seen in, since their predecessors had been made obsolete. These temples of consumerism were made to look like aggregates of small boutiques, rather than like the huge emporiums they were. The new middle class flocked to them; all its tastes were attended to there. Department stores not only catered to the middle class, they pampered it (63).

The French novelist Emile Zola devoted his Au Bonheur des Dames (published in 1883) to one such store (64). It is a fictionalized account of how Aristide Boucicaut's Au Bon Marché worked. I quote here from that novel, because it is relevant to commercialization of artificial silks. It is a description of some of the (natural) silk fabrics, made both in the Far East and in Lyon, and sold in that Parisian department store. I beg to be forgiven for doing it in the original French, out of respect for the lyricism (65):

> Au milieu du rayon, une exposition des soieries d'été éclairait le hall d'un éclat d'aurore, comme un lever d'astre dans les teintes les plus délicates de la lumière, le rose pâle, le jaune tendre, le bleu limpide, toute l'écharpe flottante d'Iris. C'étaient des foulards d'une finesse de nuée, des surahs plus légers que les duvets envolés des arbres, des pékins satinés à la peau souple de vierge chinoise. Et il y avait encore les pongées du Japon, les tussors et les corahs des Indes, sans compter nos soies légères, les mille raies, les petits damiers, les semis de fleurs, tous les dessins de la fantaisie, qui faisaient songer à des dames en falbalas, se promenant par les matinées de mai, sous les grands arbres d'un parc.

Since department stores were such a sensational innovation, monumental additions to the cityscape in France, England, the United States, and elsewhere, contemporary accounts abound. An early short essay described this novel metropolitan feature (66). Major cities all had their department stores, Paris (67), London (68). New York (63), Philadelphia, Chicago, San Francisco, (69) … Department stores duplicated as exhibition halls for merchandise and as vehicles for its throughput—to express it crudely (70). Since they were meant and designed to manipulate the minds and the bodies of women, their main customers, department stores have become choice items in gender studies (71).

The middle class became a reality about the time (1889) when its name appeared in a dictionary, according to someone who researched the topic (72). This was the time, when Comte de Chardonnet invented his artificial silk, for the emergence indeed of the middle class. That it was contemporary with the flourishing of the first department stores is not a mere coincidence: there is a definite correlation. One may go further, and assert a cause-effect relationship. Department stores could not have long survived, had it not been for the existence of a middle class—their prime market. This rising middle class needed to prove to itself its rising social status, which it signaled with luxury items—such as garments made of silks and, since genuine silks were extremely expensive, imitation silks would do (73).

To compare this mentality (74) with our times, nowadays the middle class shops worldwide by slavishly imitating the behavior of trendsetters—or so it is led to believe. The so-called jet set, as featured in people magazines, advertises items such as Rolex watches, Armani or Ralph Lauren clothes, Gucci shoes, Chanel perfumes, Louis Vuitton luggage, single malts, etc.—in brief the articles offered in so-called duty-free shops in airports. Members of the middle class have been brainwashed into compliance and routinely turn these into status symbols.

The Sprouting of Factories

Both rayon and cellophane were commercial success stories. Customers rushed to buy them. Manufactures were built to accommodate the high demand. What did they look like? Where were they built? What kind of workforce did they host? I shall answer these questions for the rayon case, since it amounts to a lesson in economic geography.

Their aspect was both characteristic and peculiar: huge plants covering very large areas. For one thing, they associated two distinct functions, chemical production and a textile plant, in which the newly made viscose silk was turned into fabrics. These two manufacturing functions differed also in the (wo)manpower necessary. The former needed very few people, was near-automatic. The latter demanded a numerous personnel, in order to look after the individual mills which, collectively, occupied such a vast ground space. A whole article by a French geographer at the end of the Thirties expresses his admiring surprise at such industrial and architectural behemoths (75).

These viscose factories were set, typically, in areas already engaged in production of textiles. In France, production of artificial silks occupied the area of the former production of natural silk, around the city of Lyon (34, 76). In the United States (31, 77), to refer only to the plants erected by the American Viscose Company and active during the 1930s, they were located in Lewistown, Pennsylvania (PA) and Marcus Hook PA, to the northwest and southwest of Philadelphia, respectively; in Meadville PA, in the north of the state near Lake Erie; in the appropriately-named Nitro, in West Virginia (WV), near Charleston, and in Parkersburg, WV, west of Morgantown; and in Roanoke, Virginia, west of Richmond.

These implantations sought female labor both inexpensive and qualified, with prior experience in textile manufacturing. All the above locations were in the textile belt, at the boundary between the industrial North and the cotton-growing South, straddling the Mason-Dixon line. One may question also, noting such a geographic distribution of their plants, if the British corporation Courtaulds was not, deliberately or unconsciously, guilty of a neo-colonial mentality in setting-up factories in former British colonial territories, with the American Viscose Company as their subsidiary (78).

As for the workforce, it was overwhelmingly female, on account of the textile part of a viscose plant. It needed to be rather highly qualified, in addition, because the viscose process was such a complicated and capricious one. There had to be mastery, which only know-how from long habit could impart. This was required to such an extent that when a viscose plant was set up in my hometown of Grenoble, in southeastern France, a significant part of the workforce consisted of Hungarian women, transferred from a viscose plant in Hungary—as readers will recall, one of the original offshoots of Chardonnet's Besançon factory (79, 80).

DuPont and the French Connection

Part of this story involves the DuPont de Nemours Corporation, as it decided during the 1920s to start producing both artificial silk and cellophane (81). In both instances, this company drew on French know-how. And those were not the only such cases. The DuPonts also exploited a license to the synthesis of ammonia using the process invented by Georges Claude and exploited by his *Société anonyme de l'Air Liquide*—a company still existing nowadays. From yet other French companies, DuPont de Nemours purchased rights for titanium pigments, for acetate flake, cellulose and the cellulose acetate yarn process (82).

To return to artificial silk and cellophane, DuPont de Nemours purchased the license for the viscose rayon technology in 1919 from *Comptoir des Textiles artificiels*, and that for the manufacture of cellophane in 1923 from *La Cellophane Société Anonyme*. The DuPont rayon plant started production in 1921. Their cellophane plant started production in 1924. Their production of rayon expanded markedly and it caught up with that of the American Viscose Company (83)—but only until the Depression hit in 1929. Just like other manufacturers exploiting the viscose process, the DuPont managers and scientists had to contend with its complications and idiosyncrasies, some of which they were able to master (28). The DuPont scientists sought other outlets than garments and hosiery for rayon. They found it, in 1936, in tire cords. This new outlet expanded greatly during World War II, for not only was rubber a strategic material, but synthetic rubber tires also came into their own during that period.

As for cellophane, DuPont remedied a major drawback by waterproofing it, as a result of the R&D by a clever young scientist, William Hale Church. Moisture-proof cellophane started being produced in 1927. It proved to be not only an industrial, but also a commercial bonanza as well, contributing heavily to the benefits of the corporation until the advent of World War II.

The likely factors in the cooperation of the American with the French companies were, in the aftermath of World War I, sympathy for the French side and the will to help France regain its economic footing and re-industrialize. One might deem Francophilia natural on the part of the DuPont de Nemours family, descendants of a Frenchman who emigrated to the US at the end of the eighteenth century—and during the 1920s, this was still a company run by them. Besides, they likely appreciated the technological breakthroughs embodied in these inventions, those of artificial silk, cellophane and nitrogen fixation primarily.

There is a follow-up to this active sympathy from DuPont for French companies. In the late 1930s, prior to the onset of World War II, the French Rhône-Poulenc company and DuPont de Nemours started collaborating in the production of synthetic fibers. There was an exchange of technologies. DuPont acquired the rights to cellulose acetate from the French. They, in turn, bought a license for nylon 6,6 in 1939. During the war years, when Rhône-Poulenc was forced to collaborate with the German chemical industry and France was occupied, the collaboration with DuPont de Nemours was only put on hold, not jettisoned. Once the war was over, not only was it renewed, the DuPont de Nemours company had carefully put aside the royalties it owed the French company for exploiting the cellulose acetate license. In exchange, it gave Rhône-Poulenc the French rights to nylon production. The ensuing sudden affluence greatly assisted the rebirth of Rhône-Poulenc as a major player in French industrial chemistry during the post-war period (84).

The Sprouting of Supermarkets

In like manner to artificial silks being sold like hot cakes by department stores in major cities, starting in the 1880s, cellophane wrappings helped in making supermarkets—also known at the time as *self-service* grocery stores—become ubiquitous, starting in the early Thirties (85). The exact date of birth is disputed. Mike Cullen, nicknamed King Kullen, opened his store in Jamaica, close to New York City, in 1930. The first prototype is said to have opened at the end of 1927 (86). This novel retail institution (73) came about as the convergence of three forces, the individual automobile, refrigeration and plastic packaging (87).

Refrigeration, viz. use of an heat-exchanging fluid—freons came to be the universal vectors—and a pump, started becoming a ubiquitous feature of American life during the 1920s, at the very time when Du Pont entered the cellophane business (88). Clarence Birdseye invented the "Quick Freeze Machine" in 1926, that enabled on-the-spot food preservation. Dr. Mary Engle Pennington, refrigeration expert, private consultant to packing houses, shipping firms and warehouses, had been the first chief of the Food Research Laboratory, established in 1907 by the Department of Agriculture to help implement the Food and Drug Act. A pioneer of strict hygiene in handling food, she was instrumental during the Thirties in bringing refrigeration to American grocery stores and the newly established supermarkets (89).

Cellophane food-wrapping, as an application of the new material, was present at its birth: it was advocated in that function as early as 1912 (90). The association of cellophane packaging and refrigeration was also urged early on (91). It became the norm (92). Design was called upon to make the cellophane wraps attractive (93), and to induce impulse buying by customers (94, 95). Supermarkets sprouted everywhere in the United States during World War II when American women were needed for war production. To shop for groceries once weekly, instead of daily, freed them for the war effort (96). Supermarkets had become by 1945 as much a part of the American landscape as gasoline pumps, located likewise within easy access of highways and freeways. The Eisenhower era development of a network of interstate highways, for strategic reasons, had for its main result the spread of suburbs, made all the more widespread by cheap fuel for the cars, and by the ready availability of a nearby shopping center, with a supermarket at its core.

Conclusions

Chameleon-like, wood pulp was turned into three different—widely different in terms of their uses—new materials. One would not construe celluloid, rayon and cellophane as identical, even though their chemical constitution is basically the same—a difference being that celluloid retains the nitrate, largely absent from the other two.

A first lesson from their story is the importance of playful pursuits to the devising of new materials. Are games and play of as much of importance to mankind as health and nutrition? One gathers so from television viewers watching nowadays professional sports, soccer in most of the world, baseball and football in the US.

What is obvious today was already the case at the turn of the twentieth century. In 1901, a decade after the British invented table tennis, an Englishman named James W. Gibb discovered celluloid during a visit to the US. As a consequence, celluloid served as the material for ping-pong balls—ping-pong is the other name of the game—until 2014, when other synthetic polymers started to replace celluloid, in the official description by the international federation running that sport (ITTF) and by the Olympics organization.

Another robust finding from the devising of novel materials from nitrocellulose is the relative insignificance of chemistry to their story. Nitrocellulose, as guncotton or collodion, was a predominant material during the second half of the nineteenth century. The inventors I have referred to selected it as their starting material for that overwhelming reason. By trial-and-error, not on the basis of chemical knowledge and reasoning, they experimented with a variety of adjuncts in order for the resulting formulations to offer satisfactory results.

What kind of results? Mechanical engineering properties predominantly, such as satisfactory plasticity for molding or extrusion (97). The visual aspect had also great importance, the artefacts made from these new materials had to look like the natural objects they were meant to substitute: billiard balls made of celluloid, aka ivorine, were imitations of the ivory-made items, garments made of rayon had to look as if they were made of silk. At no point did the inventors base themselves on the chemical make-up of the natural stuff, whether calcium and magnesium phosphate for ivory or a polypeptide for silk. Their simulacra were made from an inexpensive raw material such as cotton or wood pulp, they looked fine and were pliable enough for industrial machinery, to them inventors that was sufficient.

Rayon and cellophane were both offsprings of viscose. The writer and humorist Liebling (98) knew it, he must have been well briefed by a professional chemist (99).

Taken together, the stories of rayon and cellophane point to a gap in our view of the past. Obviously, history of science is inseparable from history of technology or corporate history. But other strands need to be woven in: social history; history of mentalities; history of games and play; literary history—exemplified here by Zola, by Marinetti and Futurism; imperial history—without which the American Viscose venture of Courtaulds loses meaning; history of language and of its nurturing of neologisms as above documented; history of advertising and of its appearance at the turn of the twentieth century in the United States; history of ideologies, such as Communism and Fascism; economic history; that of design and fashions …

In short, a total history (100) is called for.

Acknowledgments

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2. J. Verne, *De la Terre à la Lune*, J. Hetzel, Paris, 1865, p 97. Curiously, Maynard is absent from 19th-century English translations of *From the Earth to the Moon*.
3. J. Verne, *Voyage au Centre de la Terre*, J. Hetzel, Paris, 1864, pp 296ff.
4. It would be tedious to list all the uses ivory was put to in the 1880s, say. To mention just a few: billiard balls, buttons for clothing, combs, false teeth, jewelry, knife handles, piano keys, umbrella handles, … . No wonder if elephants were being hunted relentlessly, to the extinction we are currently witnessing.
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6. *Homo ludens*—to use Huizinga's term—endures across the centuries: rubber was used originally, after the conquistadors brought back the first samples to Europe, for ball games at the Spanish court. One wishes for a history

of materials focused on their applications to *play* of all kinds.

7. The reason why inventors do not form social groups, differentiating them from scientists, is their restrictive means for communicating knowledge: patents are meant more for protection of ownership, of know-how and trade secrets, than for the advancement of learning. While discovery thrives on the not-for-profit competition for priority, invention is very much the province of egomaniacs engaged in the occasional wild goose chase or, more prosaically, aiming for a windfall—such as the memorable Balthazar Claës portrayed by Balzac in *La Recherche de l'Absolu* [*Quest for the Absolute*] or the many idiosyncratic inventors portrayed by Jules Verne. Inventors were very much individuals, definitely not members of a group. They resist later and thus anachronistic categorizations. They are closer to engineering than to science, to mechanical engineering more specifically. Their goals are extremely diverse: to benefit mankind; to seek fame; one-upmanship; to emulate, better to outdo nature; to reap major profit; entrepreneurship; starting a company that might outlast them … On invention and discovery, see for instance C. Piscopo, and M. Birattari, "Invention Versus Discovery," in E. G. Carayannis, Ed., *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship,* Springer, 2013, pp 1139-1146; N. R. Lamoreaux and K. L. Sokoloff, "Inventors, Firms, and the Market for Technology in the Late Nineteenth and early Twentieth Centuries," in N. R. Lamoreaux, D. M. G. Raff and P. Temin, Eds., *Learning by Doing in Markets, Firms, and Countries*, University of Chicago Press, Chicago, 1999, pp 19-60; T. Nicholas, *J. Econ. Hist.*, **2010**, *70*, 57-82.
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9. The natural-artificial dichotomy, much anterior to man-made plastics, goes back to *daidala* in Greek Antiquity and, of course, to alchemical work. It is such an overworked point that I need not elaborate on it further. An outstanding discussion is that by Roald Hoffmann ("Natural/Unnatural," *New England Review and Bread Loaf Quarterly.* **1990**, *12*, 322-335).
10. The first commercial use was in 1851. Schönbein had patented cellulose nitrate in the US in 1846.
11. Is there a connexion between the Age of Plastics, that began during the second half of the nineteenth century and the Second Industrialization? Probably, through the rise of the middle class. See below.
12. Parkes started commercial manufacture of parkesine in 1866.
13. Camphor is a globular molecule. In the solid state, it is a plastic crystal: the spherically-shaped molecules spin on their lattice sites with little hindrance. This fact about camphor, reached in the mid-twentieth century, is an *a posteriori* justification for the empirical use of camphor, by nineteenth-century inventors, as a plasticizer. See P. Laszlo and E. M. Engler, "New Description of Nuclear Magnetic Resonance Solvent Shifts for Polar Solutes in Weakly Associating Aromatic Solvents," *J. Am. Chem. Soc.*, **1971**, *93*, 1317-1327.
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80. This is the part of the story that connects with my family history. My parents left Hungary in 1930 because of the Depression. The three of us settled in Grenoble in March 1940, just a few weeks before the Phony War flared up into real war. My parents, François and Magda Laszlo, got in touch with the small local Hungarian community—the worldwide Hungarian diaspora to this day is closely knit, if anything because of the unique Hungarian language they share. Grenoble, initially in the Free Zone, became occupied, first by Italian troops, later by German troops. François Laszlo became active in the Resistance network led by the famous Abbé Pierre, which helped numerous Jews, children in particular, cross the nearby border to escape into Switzerland. These highly dangerous Resistance activities were recorded in his application for French citizenship, that was quickly granted him in 1946. Magda Laszlo also engaged in an underground activity: she organized the Hungarian workers into a union, overwhelmingly female as I have pointed out, in the Grenoble viscose plant. It is perhaps no coincidence if Resistance activities flourished in this plant as a whole, as moreover its director at the time, Mr. Fries, tolerated them instead of cracking down as he might have. I am unable to offer any written document in support of these assertions of the political activities of my mother during World War II, when I was a young child. They are part of the family tradition, just hearsay to the strict historian. I hope they won't be dismissed out of hand.

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About the Author

Pierre Laszlo enjoyed a transatlantic professional academic career, as a physical organic chemist. It led him, early on to history of chemistry which became his main activity after he formally retired in 1999.

2020 HIST Award to Lawrence M. Principe

The recipient of the 2020 HIST Award of the Division of the History of Chemistry of the American Chemical Society is Dr. Lawrence M. Principe. This award is the successor to the Dexter Award (1956-2001) and the Sydney M. Edelstein Award (2002-2009), also administered by the Division of the History of Chemistry.

Lawrence (Larry) M. Principe was born in northern New Jersey in 1962. He fell in love with alchemy while studying chemistry at the University of Delaware (B.S. Chemistry, B.A. Liberal Studies, 1983). A "dual approach" to the history of chemistry has characterized his work ever since. He obtained a Ph.D. in Organic Chemistry from Indiana University in 1988, but his interests in the History and Philosophy of Science motivated him to earn a second Ph.D. at Johns Hopkins University in History of Science, from which he graduated in 1996. His dissertation became the acclaimed book, *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (Princeton, 1998).

Meanwhile, the Chemistry Department at Johns Hopkins took advantage of Principe's talents in organic chemistry by hiring him as a Laboratory Instructor. When a tenure-track position in the History of Science opened, he was chosen in 1997 for a joint appointment between Chemistry and History of Science. In 2006 he was honored as the endowed Drew Professor of the Humanities, with Chairs in both Chemistry and the History of Science.

Principe continued his Boyle scholarship and joined with Michael Hunter and Antonio Clericuzio to produce the six volume complete *Correspondence of Robert Boyle* (Pickering and Chatto, 1999-2001). Principe's collaboration with William Newman (Indiana University, 2013 HIST award) examined the laboratory notebooks of George Starkey and Robert Boyle and discovered the actual chemistry they contained. This project produced *Alchemy Tried in the Fire* (Chicago, 2002), which won the History of Science Society's Pfizer Prize (2005), given for the best book in the History of Science in the prior three year period.

Principe has served both adepts in the discipline of history of chemistry and *chymistry* and a broader audience. The 2006 conference on alchemy at the Chemical Heritage Foundation, for which Principe was organizer and editor of its proceedings, *Chymists and Chymistry* (Science History Publications, 2007) is one example of his service to scholarship. His *The Secrets of Alchemy* (Chicago, 2013) delivers exceptional scholarship to a wider audience.