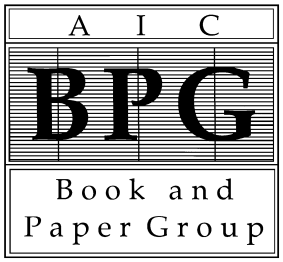

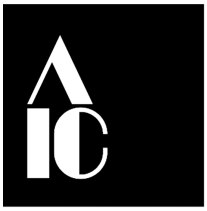

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KATHARINE WAGNER, KRISTI WRIGHT, HOLLY HERRO, AND WILLIAM MINTER
PANEL DISCUSSION ORGANIZERS

Leather Selection and Use: A Panel Discussion on the Impact of Conservators' Choices

INTRODUCTION

The Leather Discussion Group (LDG) was initially formed in 2016 by the four authors of this article, all book conservators, who seek to acquire a better understanding of leather and leather dyes used in conservation. Today, the LDG is working with experts in fields such as zooarchaeology, tanning, and scientific analysis. Ongoing conversations with these experts, conservation colleagues across disciplines, and other leather users continue to provide valuable feedback to move the research forward.

PROJECT BACKGROUND

The LDG goal is to identify factors that contribute to good quality leather and to evaluate currently available conservation leathers. Over time, there have been many changes to leather production and use. Some known problems have been remedied through advances in the production process. Are there still contributing factors that would reduce leather's longevity that conservators are not aware of?

The group has surveyed conservators and tanners regarding their observations on leather. According to the survey results, leather use in modern conservation appears to be declining. Why? And is the decline in use likely to reverse itself? Perhaps it is due to a lack of trust in the material, a shift in conservation philosophy, a lack of training in working with leather, or even due to personal ethics.

The group is in regular communication with several of the primary producers of leather for conservation. From their experience, the tanners are interested in working with conservators to achieve a quality product that is suitable for our needs.

To make research results accessible, the LDG is working with information technology experts at the National Library of Medicine (NLM) to combine historic and modern data into an online, geospatial resource to demonstrate trends in leather production that link use, availability, and quality over the centuries.

Many leather research projects have preceded this one, and the group is summarizing them on the AIC wiki. There are many avenues to consider when assessing leather's longevity, and this warranted research into changes in animal husbandry to determine the effects the mechanization and chemical changes in the tanning and finishing industries may have had on leather quality. Additionally, the group has a collection of discarded leather covered book boards that span several centuries and has partnered with the Smithsonian Museum Conservation Institute (MCI) to conduct a series of tests on them.

The group's current focus is on evaluating the relationship between the tanning process and leather's microbiome. Mr. Jesse Meyer, of Pergamena Parchments & Leathers Incorporated, is collaborating with the LDG to tan several locally sourced hides with known diets using both modern drum and traditional pit tanning methods. At every stage in the process, he is taking samples for analysis. Dr. Laura Weyrich, at the Pennsylvania State University Ancient DNA Laboratory, will then evaluate the microbial characteristics of the samples at different stages in the tanning process. Other Penn State labs will be analyzing the isotopes present to help with diet characterization of unknown leathers.

THE 2021 AIC PRE-SESSION PANEL DISCUSSION

The LDG hosted this panel discussion during the preconference session of the virtual 2021 AIC annual meeting. The panelists consisted of conservators across disciplines, other leather users, tanners, and scientists who focus on leather

This panel discussion took place *virtually* on May 5, 2021, during AIC's 49th annual meeting. The panel discussion organizers planned and led the discussion and recorded notes. Readers are reminded that the panel discussion organizers do not necessarily endorse all comments recorded, and although every effort was made to record proceedings accurately, further evaluation or research is advised before incorporating any observations into practice.

research. Katharine Wagner moderated the overall panel, and Kristi Wright moderated the discussion portions.

The panelists were grouped into three sections: leather users, tanners, and researchers. Each panelist gave a short presentation, and each section had a dedicated discussion portion for those panelists. At the end of the three sections, an overall discussion took place between the panelists.

SUMMARY OF PANEL 1: LEATHER USERS

The panel started with short presentations from a range of leather users in multiple disciplines. Many panelists currently use leather for projects that require its aesthetic and mechanical properties. These panelists prefer to use leather because of the way it can be molded over irregular surfaces, and because it is a traditional material. Some panelists discussed the use of alternate materials such as spunbond polyester or synthetic textured fills. One panelist prefers alternate materials over leather. There was discussion about the need for additional training and a lack of demand for leather use from curators or clients. All panelists agreed that there are some situations where leather is the only suitable material. Attendees surveyed throughout the panel corroborated the panelists' experiences, stating that more leather training, assurances of leather quality, and greater demand for leather use in treatment is needed to ensure the future use of leather in conservation.

WILLIAM MINTER

LDG member and book conservator William "Bill" Minter was the first panelist in this section. Mr. Minter started his book conservation practice in 1978 after a formal apprenticeship and has been using leather for many years. He is currently the senior book conservator at Pennsylvania State University Libraries. He emphasized how book and paper conservators have examined paper and all its nuances, but have not done the same with leather. Rather, conservators examine it and choose it for its aesthetic properties and perhaps thickness, leaving quality to the reputation of the tanner. Conservators rely on tanners for quality assurances but can see that this was not the case 100 years ago. How and what do conservators know about today's leather? More than 100 years ago. TJ Cobden-Sanderson tasted his leather to test it for acidity. and this seemed to have satisfactory results. What can conservators take away from the taste test?

Some earlier binders tested leather in a door hinge to determine its longevity, and Mr. Minter once replicated that earlier experiment (fig. 1). He also discussed the PIRA test and its rejection in the 1970s, stating that conservators need to know if today's leather will last as long as the leather from earlier centuries, and need a reliable test for today's leather.

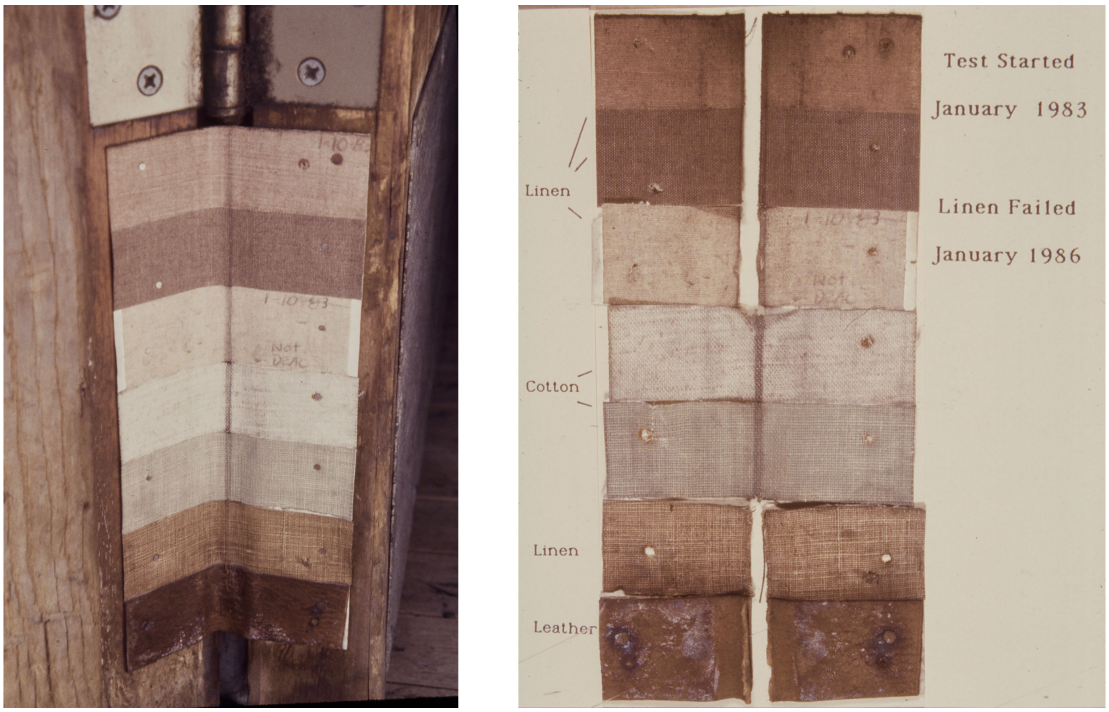

Fig. 1. Bill Minter, an example of testing leather in a door hinge.

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PATRICIA ENGEL
EUROPEAN RESEARCH CENTRE FOR BOOK AND PAPER CONSERVATION-RESTORATION RESEARCH IDEAS

Patricia Engel is a senior researcher at Donau University in Krems, Austria, and currently heads the European Research Centre for Book and Paper Conservation-Restoration. Dr. Engel gave an overview of the European Research Centre (ERC) and discussed two leather research ideas. She also provided a wealth of resources to help conservators interested in accessing the most recent research.

The ERC is 11 years old and has approximately 50 volunteers, all being highly educated conservators or scholars in their fields. Research results are disseminated, through the ERC website, to those who preserve cultural heritage and representatives in 40 states. The webpage has many resources, including publications and periodicals and lists of upcoming conferences and courses. Everyone is invited to submit papers for publication to *Conservation Update*, the peer-reviewed periodical of the ERC. Dr. René Larsen, who spoke later in the panel, is one of the founders of ERC and a board member.

Dr. Engel discussed *MuLiBiNe*, a multilingual bibliographic database that searches more than 100 periodicals on conservation literature. One can access any article's abstract via keywords and reach the full article via a long-distance loan (interlibrary loan).

Dr. Engel has been working with leather for many years and presented two research ideas based on her observations and experience. The first is to create a comprehensive survey of leather used on Armenian manuscripts. Dr. Engel's second idea is to compile a history of leather conservation. She has already started a history of parchment conservation, but leather conservation still needs to be done. She is looking for project funding for these two projects, which it is difficult when both U.S. and European researchers are involved. Perhaps a group effort is needed?

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LARA KAPLAN
USING MODERN LEATHER IN CONSERVATION TREATMENTS: AN OBJECT CONSERVATOR'S PERSPECTIVE

Lara Kaplan is an objects conservator at the Winterthur Museum and is an affiliated assistant professor at Winterthur/University of Delaware Art Conservation Program, where she currently teaches the conservation of organic materials. Ms. Kaplan does not often use leather in her practice, in part because of deterioration concerns. She also finds that using other materials works equally well, if not better, in most of her treatments. Not using leather regularly also means that she does not have a ready stash of suitable repair leathers, leatherworking tools, or the highly honed leathercraft skills that would be necessary to use the material in a nuanced way. Despite this, she does feel that modern leather has a place in conservation treatments and is sometimes the best choice for the situation.

Ms. Kaplan gave two examples of times she has used leather in her practice. The first was a hair on hide drum head, where more hair on hide leather was the only material that gave a satisfactory visual match to fill losses. In the second, she used leather to replicate missing parts, in this case the ears from a rope-tension drum, because leather was simpler, faster, and gave good results.

When choosing materials for treatments, Ms. Kaplan is guided by her experience and collaboration with her colleagues at Winterthur, where she co-teaches much of the leather content with Dr. Melissa Tedone. She provided a range of materials that she uses in lieu of leather, making sure they are compatible with leather both visually and chemically, versatile enough to be both structural and aesthetic, and can be easily reversed (fig. 2).

A "go-to" option for her is solvent reactivated Lascaux 498 HV on Asian paper for mending tears. She finds it neat, quick, adaptable, and effective. It both blends in and works well on surfaces that are hard to reach or clamp. Ms. Kaplan has been experimenting with synthetic textured fills using silicone molds and acrylic media. She finds the process engaging and effective, and is interested in seeing how the fills age.

Repair Materials for Skin and Leather

Backings	Adhesives	Application Methods
Asian papers	PVA emulsion (e.g. Jade 403)	Direct
Spunbond synthetics (Hollytex, Cerex, etc.)	PVA emulsion + methyl cellulose or wheat starch paste	Solvent reactivated (vapor, liquid)
Goldbeater's skin	Lascaux 498HV, Lascaux 303HV	Heat reactivated
Synthetic suede (e.g. Ultrasuede)	BEVA film, stock solution, gel	
Hard Tyvek		
Synthetic textured fills		

Fig. 2. Lara Kaplan, repair materials for skin and leather.

In summary, Ms. Kaplan finds that the more tools conservators have accessible, whether leather or not, the better, as every treatment is different and needs to be approached with its specific needs in mind.

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ROSIE BOLTON

Rosie Bolton is the studio manager at the Leather Conservation Centre (LCC) in Northampton, UK. She treats a wide range of leather objects from historic books, furniture, armors, and modern supercar interiors for clients including museums, libraries, and historic houses.

For many objects, Ms. Bolton chooses to use Japanese paper or nonwoven textiles in lieu of leather. She uses these in combination with acrylic paints and mediums, BEVA 371, BEVA film, SC6000, acrylic polymers, wax mixes, klucels, wheat paste, and polyvinyl acetate (PVA).

Some objects, such as car upholstery and furniture, require "heavy-duty repairs" to ensure continued functionality. These repairs often need to be leather patches. Leather is also sometimes the best material to use because of a particular mechanical property it can impart. For example, a tied repair on a leather screen needed a repair using new leather due to the leather's impermeability. Adding a nonpermeable material as a laminate with a nonwoven material in this case could have inhibited the desired qualities and made the treatment more difficult.

When selecting leather, Ms. Bolton takes care to match the type of repair leather to the original leather. For example, for a vegetable-tanned leather object, she would use an unfinished vegetable-tanned leather and finish it herself to match the original object using the same paints, polymers, or coatings that would be applied to nonleather materials. She also noted the importance of having a range of leathers, as this allows her to find a suitable match for any treatment.

When considering longevity, Ms. Bolton referenced leather research indicating that adding aluminum in the tanning process helps to buffer the pH, thereby improving the leather's archival properties. More generally, she prefers to use leathers with hydrolyzable tannins, such as sumac or oak bark.

Ms. Bolton pointed out that selecting leather is more complicated today since a skin is often initially tanned in the country of the animal's origin, generally using mimosa (a condensed, less stable tannin) to preserve the skin for shipping. She expressed concerns that even after stripping the original tanning agent, fibers are ultimately still tanned using the original, typically condensed, tannins. Thus, the sumac or oak bark on these skins is just imparting the final characteristics, not imparting the longevity that is needed in the conservation field.

Other characteristics Ms. Bolton looks for when selecting leather for a treatment are species, surface texture, and handle. She takes care to match the original leather to ensure compatibility both from movement and environmental fluctuations. She also considers which part of the skin to use for the treatment based on what the treatment needs. Stronger treatment needs require the strength from spine leather, whereas more flexible ones might be better taken from the belly area.

For repairs requiring a heavy modern finish, Ms. Bolton does not try to find a leather prefinished to match it. Rather, she will re-create the finish herself on unfinished vegetable-tanned leather using a selection of the adhesives and finishes already described.

She will avoid leathers with unknown tannages or provenance, newer experimental tannages, or those with no known results from aging tests. She also avoids leathers with modern polyurethane finishes because they are unstable and will harden and crack as the plasticizers evaporate.

Ms. Bolton tries to retain knowledge about leathers she has on hand and includes this information in treatment reports. It is also useful to maintain good relationships with nearby tanners and industry experts, which helps ensure that she is considering factors from all angles when choosing leather for repairs.

Ms. Bolton discussed specific treatment techniques such as patching losses from the verso, where she pares the edges of leather to ensure no stray edges that might show through. She also sometimes patches from the recto if access is poor, or if this is necessary for aesthetic purposes. This works best with a more textured leather, such as goat, and requires paring the edges very thinly and then sometimes using pigmented BEVA 371 to secure them and prevent catching.

Alum tawed and oil tanned leathers also have a place in Ms. Bolton's practice. Although she will sometimes use Asian papers for these repairs, she occasionally uses traditionally tawed or tanned leathers to pair "like-with-like." Which repair method to use depends on the context of the object and client requirements. With these treatments, she is more confident that the tannages are stable, and that conservators understand the aging properties. Pre-Industrial Era vegetable tanning fits into this category as well, although the modern processes introduce more uncertainty and require caution.

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LEROY GRAVES

Leroy Graves is the senior upholstery conservator for the Colonial Williamsburg Foundation, where he has been employed for 53 years. He is a pioneer in the field of early American upholstery and devised and implemented a nonintrusive system now known as the "Graves approach."

Mr. Graves works with leather frequently and uses modern leather in his practice in several ways. Most often, he uses it to create reproductions and sometimes uses it to repair historic leather. Upholstery tends to have large sections covered in leather. In some situations, these sections are larger than available hides, so several hides must be stitched together from the underside using a linen support.

Upholstery leather has many of the same issues seen on books and other objects. Cracking, flaking, and red-rot have been observed. Mr. Graves has consolidated and filled losses using layers of toned or painted Japanese paper in the past, but in recent years has chosen instead to add a protective layer in the form of a nylon net slipcover to deter further damage.

When necessary, he will fill losses and large tears using modern leather. An example of this is Lord Dunmore's side chair from the late 1700s, which had a large loss in the middle of the seat (fig. 3). Modern leather was toned and manipulated to match the historic leather and applied to the underside of the original leather. In this case, Mr. Graves chose to use buffalo hide because of its rigidity, which matched the project's needs. Mr. Graves' treatments focus on retaining the historic materials in their original locations, so the leather being repaired remain in situ whenever possible.

Mr. Graves most often creates reproduction seat covers using modern leather. One example he showed during the panel included a 1790 side chair with original under upholstery. Mr. Graves used the technique he devised to create a nonintrusive cover for the original chair using modern leather. The new cover fits perfectly over the original frame. He pares leather using a razor blade. Paring focuses on the areas that must be folded, such as the corners, and most of the leather is left at its original thickness.

Many of the reproduction objects at Colonial Williamsburg are also accessioned objects that are used and handled by guests. Thus, the lab also repairs these reproductions when needed. Modern leather is chosen for these repairs when the situation requires it.

Modern leather is selected based on its durability and how well it matches the project needs. Heated rollers are used for impressing patterns; skivers, razors, and knives are used for paring; and spirit-based Orasol dyes mixed with ethanol and acetone are used for toning. The lab prefers to purchase leather predyed for overall reproductions, but for patches the leather is purchased undyed and toned in-house. To obtain an ideal aesthetic match for original leather, the new leather may be heated and "worn" to visually age it.

Fig. 3. Leroy Graves, Dunmore side chair with leather repair.

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SUMMARY OF PANEL 2: TANNERS

The tanners on the panel demonstrated their approaches to leather manufacture. Three of the four presenting groups specialize in leather marketed for conservation use. The fourth specializes in producing accurate leather using prehistoric tanning methods. This provided both modern and traditional perspectives. The tanners discussed hide sources, tannin selection, and process determination. As with so many of our suppliers, today's specialist conservation tanners are working within an industry with suppliers that market products to much larger producers for economic purposes, making it difficult to fully return to traditional production methods. However, they are all open to discussions with conservators and scientists and are actively working to meet conservators' needs from both a workability standpoint and longevity.

STEVEN SIEGEL AND ERIC THEMMEN
SULFUR- AND METAL-FREE FULL VEGETABLE-TANNED AND SUSTAINABLE CALF LEATHER FOR BOOKBINDING AND RESTORATION

Steven Siegel has been in his family's leather business since childhood, and Eric Themmen is a tanning specialist and export manager with Gruppo Biokimica in Italy. Mr. Siegel and Mr. Themmen gave a joint presentation on a new product, Sulfur Free Calf, which they are developing in collaboration with Dr. René Larsen who spoke later in the panel (fig. 4). Siegel Leather is dedicated to producing a historically accurate chemical representation of bookbinding leather and aims to find a long-lasting solution to the deteriorating bookbinding leather of the past couple of centuries.

The new product is a sulfur- and metal-free 100% vegetable-tanned calf leather, which they started producing a few years ago and continue to develop. The substances used in producing the leather are all naturally occurring (except the fungicide) and sulfur free. Thus, there are no synthetic, sulfited, sulfated, or sulfonated oils or tanning agents. The substances that are used in the process were chosen to avoid potential oxidation, which would result in degradation.

Fig. 4. Steven Siegel and Eric Themmen, Sulfur Free Calf Project.

Mr. Themmen described the tanning process, pointing out that Sulfur Free Calf avoids typical unhairing chemicals, focusing on hair removal rather than hair destruction. It is a pyrogallol/hydrolysable vegetable-tanned leather with no grain manipulation. The skins are drum tanned. The end result is a leather with good organoleptic properties that tools well. The decision to avoid using certain materials is based on recommendations from mid-20th century research. The team classifies this leather as "theoretically archival" and durable long-term. They hesitate to apply the term *archival* to any leather, yet they believe this leather will last longer than any other vegetable-tanned leather currently available.

The team carried out a variety of tests on the completed leather, both fresh and after aging. These include quantitative analysis of organic sulfur, heavy metal analysis, dry fiber coherence assessment, tensile strength, tear load, distortion, and grain strength via ball burst, flex resistance, and the internal tropical test. The results of the latter are available on YouTube in a video titled *Tropical Testing Popular Bookbinding Leathers!* (note 1). The results from the tests showed that the leather's sulfur content is below the detection limits and is completely metal free.

Determining what to use for this engineering project was difficult and complicated, requiring the team to expend a lot of time and resources. The project is deeply personal for Mr. Siegel, and he will continue to support it until it is complete. The end goal for the team is to make sure the science behind this leather is correct and results in the best product possible. This is an open-ended project, and the team is seeking collaborators and feedback.

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DAVID LANNING
GOING L4 LEATHER FOR AIC

David Lanning is the sales director for J. Hewit & Sons, a specialist tannery for bookbinding leather. He discussed sourcing hides, which varies by leather type depending on how the hide will be used. The hides are sourced from the Indian subcontinent, New Zealand, and Northern Europe. The leathers marketed for conservation are "naked," meaning they have no finish to the grain layer. To provide the skins without a finish, they source the best-quality skins possible, finding hides with few marks, holes, or blemishes. To select these skins, they have spent many years developing relationships with the hide suppliers, which ensures that Hewit is provided with the best-quality skins possible.

Skins are purchased in one of two ways. The first is pickled. For this, the hair is removed and the skins limed in their country of origin. They arrive at Hewit in a mild pickling solution that is not much different from that used for pickling vegetables. These skins can move directly into Hewit's tanning process, which allows Hewit to retain complete control over the tannins and chemicals used (fig. 5). However, the skins are expensive to ship this way because they are wet and heavy. The other method is purchasing the skins native tanned. The initial tannins used in this method are condensed/catechol or synthetic and not ideal for bookbinding leather. The tannins are stripped out prior to retanning at Hewit. These skins are dry, easier to ship, and do not risk degrading during the shipping.

Tanning at Hewit is done using quality pyrogallol tannins such as sumac and tara, which yield leather that is stable and not prone to oxidation. Chestnut and synthetic tans may also be added in certain situations to impart a specific desired characteristic into the leather.

J. Hewit & Sons was an integral part of the CRAFT project conducted in the early 2000s. Their report on this project, titled "The Development of Archival Quality Leather" is published in the *Skin Deep* periodical and is also found as a direct download on their website (note 2). The CRAFT project was a pan-European consortium that included tanners, bookbinders, conservators, and scientists. The project built on the already established 1991 British Standard for archival bookbinding leather, as well as two other pan-European projects: the STEP and Environment projects. The CRAFT project goals were to develop an archival leather that retained the organoleptic properties and ease of use important to bookbinders and conservators. Additionally, it showed that the use of aluminum sulfate as a retanning agent improved leather's longevity, a component that researchers had already shown to be effective prior to the establishment of the 1991 British Standard, which recommends it. As a result of this research, Hewit now adds aluminum sulphate to several of its archival tannages.

Hewit provides both undyed and dyed skins. The dyed skins are drum dyed and air-dried using water-soluble acid dyes. The actual recipes and concentrations of the dyes are tailored to the particular leather in question, as different concentrations and types of tannages require different combinations of dyes. When undyed leather is tanned using pyrogallol tannins, such as sumac and tara, it results in a creamy color. This leather is also strong and easy to manipulate. After dyeing, it is difficult to tell for certain how a

Fig. 5. David Lanning, pickled skins sorted, stacked, and ready for tanning.

leather was tanned. Hewit supplies leather unfinished (aniline) and with a casein finish, both which are suitable for tooling.

Mr. Lanning also addressed the thickness of the leather, indicating that the perception that a strong leather ought to be thick is not necessarily the truth. Rather, the more important factor is the ratio of grain to corium after the skin is shaved down to the substance that a conservator or bookbinder can use. This allows the leather to be "fit for its purpose."

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JESSE MEYER

Jesse Meyer is the current owner and president of Pergamena Parchments & Leathers Incorporated. His family has been in the tanning business for more than 470 years, first in Europe and, since the early 1800s, in New York State. They specialize in leather and parchment for bookbinding and conservation, book and manuscript production, leather goods, and interior design.

Mr. Meyer is always researching methods and techniques to improve Pergamena's leather and parchment offerings, keeping a focus on traditional processes while also trying to adapt to modern applications and aesthetics. He started working with the Guild of Bookworkers in the late 1990s and encourages feedback from leather users. Mr. Meyer emphasized that he utilizes both newer information from user feedback and research developments, as well as older information from traditional recipes and processes, to guide changes to his tanning process.

Pergamena uses mainly vegetable tannins for bookbinding leathers but also employs other tannins for different purposes such as leather goods and furniture. When considering leather, Mr. Meyer referenced Tolstoy, quoting "All happy families are alike, but every unhappy family is unhappy in its own way." He extrapolated this to postulate that all leather that is good has "checked all the boxes" that make it good leather, but leather that is not good could be due to any number of issues that contributed to its poor quality at some stage of the process.

Pergamena selects hides from local sources to ensure they are well preserved. The tannery has a working relationship with local farmers and hunters, which helps ensure that the animals were well treated, humanely slaughtered, and expertly processed creating a hide free of cuts, holes, or

grain abrasions. The proximity of the hide sources allows them to receive hides raw and salt them quickly for initial preservation.

Salting the hides must be done properly, however. Receiving the hides in a raw or salted state also allows Mr. Meyer to see their true initial condition when choosing which ones to tan for which purposes. He showed an example of bugs present on a raw deerskin that was not initially processed correctly by the hunters. Although evidence of the bugs would not be seen after the tanning process, the damage they did before tanning could create problems later. Mr. Meyer showed another example of a pile of salted goat skins exhibiting "red-heat," which demonstrated how salting is not an indefinite preservative for skins. In warmer weather, the salting effectiveness decreases and red-heat results, which is halophilic bacteria establishing itself on the hide. Red-heat can sometimes appear later as purple spots on the leather. To avoid this, Pergamena moves salted hides into the next phase of tanning as quickly as possible.

Pergamena uses both vegetable and synthetic tannins on leathers. However, Mr. Meyer emphasized that the company works with users to determine the preferred tannins, and this practice will continue. The vegetable tannins they use are pyrogallol, such as chestnut, and they formulate their tanning process to avoid catechol tannins entirely.

Mr. Meyer pointed out that they have started marking leather to make it possible to trace it back to its point of origin (fig. 6). This is especially useful for customers who wish to know more about the animal itself, such as where it was raised, why it was raised, and what it was fed.

The end goal for Pergamena is to make quality leathers that meet clients' needs. They strive to maintain sustainability and traceability, and to make it archival.

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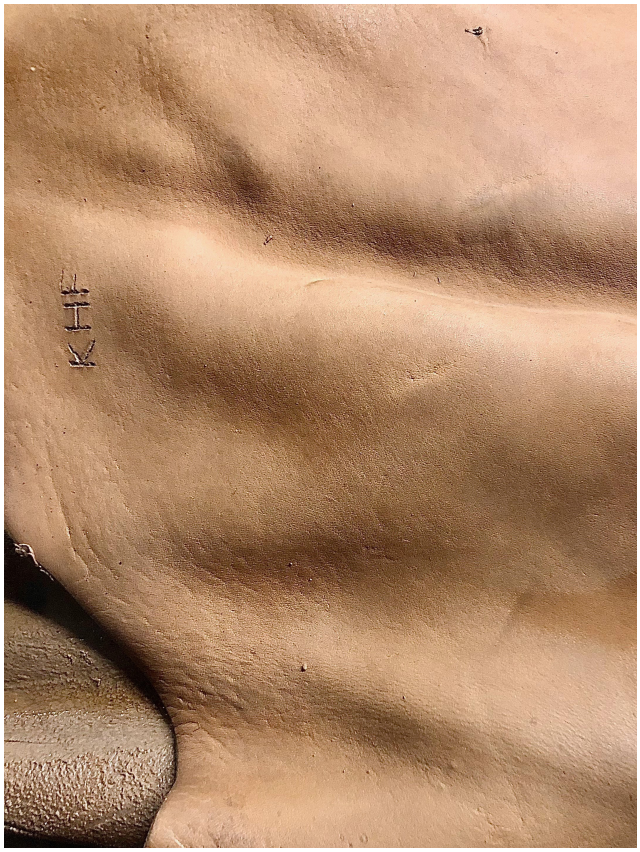

Fig. 6. Jesse Meyer, marking allows the leather to be traced back to its point of origin.

THERESA EMMERICH KAMPER

Theresa Emmerich Kamper has a PhD in experimental archaeology and more than 25 years of experience in prehistoric skin tanning. She researches, tans, and tailors skins in a traditional manner for replicas for museums, period-appropriate television clothing, reenactment items, and modern fashion commissions. She does a significant amount of research on archaeological leather, analyzing tannage, manufacturing methods, and end-of-life use characteristics. She uses this research to create a "biography" for the artifacts she studies. Dr. Emmerich Kamper also teaches hands-on tanning courses and gives demonstrations for open-air museums (fig. 7).

Dr. Emmerich Kamper selects hides based on the time period of the artifact. This must take into account what types of animals were in the area at the time, either based on evidence of use or analysis results from DNA or proteomics studies. She matches the breed or variety from domesticated animals, selecting heritage breeds from the appropriate area. Because the time period starting around 10,000 BP has no extant evidence, Dr. Emmerich Kamper selects hides based on the type of animals likely present, the environment in the area during the time period, and the product's end use.

Most of the skins are locally sourced in the UK. Some of the animals are sourced from other locations based on availability. For example, she receives reindeer from Finland and other fur-bearing species from North America via the fur harvesters' association in Canada.

Although she does do some vegetable tanning, her primary focus is on rawhide or fat tanning because those were the primary processes used on prehistoric leathers. She aims to create a wide variety of qualities using a single tannage

Fig. 7. Theresa Emmerich Kamper, tanning and working leather using historic processes.

type to replicate what was available to the people originally implementing these processes. Her decision making is based on the extant qualities of the artifact, as well as the functional requirements for its use. As for durability, Dr. Emmerich Kamper emphasized that when one item wore out, the remaining good parts of the leather were recycled into another item. This means that parts of the leather might wear out, whereas other parts remained usable for future purposes.

She occasionally dyes leather but most often leaves it the color imparted by the tannin, which can be quite dark. This is partially due to a lack of archaeological evidence regarding dyes. However, there are ethnographic samples that demonstrate dye use. Therefore, the client has the option of a minimalist replica using only scientifically verifiable information or a dyed replica using colorants inferred from what would have been available at the time. In all cases, Dr. Emmerich Kamper only uses naturally available dyes that she collects herself. Some of these dyes are very colorfast because they contain tannins, which act as a mordant, like black walnut hull (brown), bracken fern root (yellow), and willow bark (pale brown or rose). Others contain no tannins, and some are more fugitive. Some examples include lichens (multiple colors), fungi (multiple colors), and cochineal (red), woad and other indigotin-containing plants (blue), and berry stains (pinks and purples).

Leather use in prehistory conveyed many things about the creator and owner, such as skill, status, identity, or wealth. Leather was used to create functional items that ran the gamut of everyday life. Leather was not expected to last for generations; however, it was ideal for its initial purpose and reusable for patches or items requiring smaller pieces.

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SUMMARY OF PANEL 3: RESEARCHERS

Several leather experts presented their research, covering ancient DNA analysis, proteomics, fiber and sulfur analysis, and nanocellular analysis. Many of the research projects are ongoing, yet they did have recommendations for conservators to consider when treating, selecting, and storing leather.

They suggested that conservators use either the micro hot table (MHT) method or a fiber coherence test to assess the current state of leather deterioration. Nanoclays may help with consolidation. The use of sulfur, which is especially common in the dehairing process, may be detrimental to the longevity of the skin. The LDG is still assessing the impact of the microbiome on leather. Proteomics are useful for determining not only the type of skin but also some of the other proteins present from adhesives and consolidants.

LAURA WEYRICH
TRACING THE HISTORY OF BUGS IN OUR BOOKS

Laura Weyrich, director of the Ancient Biomolecules Research Laboratory and associate professor of anthropology at Pennsylvania State University, specializes in reconstructing ancient microbial communities, or microbiomes, present on humans, animals, and in the environment. Dr. Weyrich is a microbiologist by training and is enthusiastic about bacteria, fungi, virus, parasites, and other micro-organisms. She emphasized that the entire world, including human bodies, is completely coated in micro-organisms and everything has its own microbial signature, referred to as microbiota, which can be analyzed using metagenomics. Her talk challenged listeners to consider all of the microbes that might be living on the surface of our books. The microbiota of the book can lend information such as where the book has been, who handled it, what it is made from, whether it is breaking down, and its age (fig. 9). Ancient DNA analysis can help recover the information about the previous microbiome for a book. This technique has already been applied to archaeological leathers and to analyze how different tanning processes influence the recovery of ancient DNA. However, successfully recovering micro-organisms from ancient leathers has yet to be accomplished. Using these techniques on bookbindings can help us understand the sources of the leathers, as well as the sources of damages to the leathers.

Usually, microbes in leathers indicate degradation. Some of this degradation can be the result of bacteria on the leather before tanning, whereas degradation of leather after tanning is usually attributed to fungi. Dr. Weyrich hypothesized that this may be why different fungicides are used in various tanning processes. She also mentioned the red-heat that Mr. Meyer showed examples of earlier in the panel. The red-heat is attributable to halophilic bacteria, but thus far it is unknown what type of specific species contribute to this, let alone what they might actually be doing to the leathers.

Only one study so far has taken a metagenomic approach to this sort of analysis. That study demonstrated that different microbial communities are associated with damaged versus undamaged parchment. The study Dr. Weyrich is pursuing in conjunction with the LDG will take this approach to leather at different stages in the tanning process. It will use ancient DNA and different metagenomic approaches to identify the source of the leather, explore the method of tanning, and identify microbes associated with degradation. Using these approaches can help us understand different mechanisms behind deterioration and hopefully lend some insight into techniques to combat it in the preservation and conservation process.

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ELENA BADEA
THE POWER BEHIND MICRO-CALORIMETRY: ABOUT LEATHER MAKING AND ITS PRESERVATION OVER THE MILLENNIA

Elena Badea holds a PhD in engineering chemistry and is the project director for National Textiles and Leather in Bucharest, Romania, where she oversees the Advanced Research for Cultural Heritage (ARCH) Laboratory. She is also an associate professor for the Faculty of Sciences at the University of Craiova, where she teaches chemistry of materials and chemical thermodynamics. She is a specialist in advanced methodologies of the study of ancient and historic collagen-based materials.

The ARCH Research group Dr. Badea heads is doing research on both new and historic leathers and parchments. On historic materials, the team is looking at deterioration patterns and damage quantification, as well as leather consolidation materials and methods. They use a multitechnique approach that allows her team to examine all of the structures within parchment and leather. This approach looks at the formation of damaged intermediate states in parchment and the detanning of leather. This is done on several scales: from molecules to fibrils to solid materials. The leather consolidation research is geared at working with conservators to meet their specific needs.

On modern materials, they are examining and developing tanning and retanning agents, fillers, additives, and the changes to the processes when upscaled in industry. Often this encompasses upholstery, fashion, and automotive leathers and meeting sustainability requirements or a need to impart specific properties, such as hydrothermal highs and lows, to the leather. They also research hydrothermal stability, fire resistance, and hydrophobicity.

With a background in physical chemistry, much of her research implements techniques such as differential scanning calorimetry (DSC) on both the macro and micro scale (DSC and micro DSC). DSC is one of the best techniques for assessing the thermostability of proteins, which is a vital property for the longevity of either leather or parchment. It can be used in combination with other techniques, such as solid-state nuclear magnetic resonance (NMR). Optical microscopy in polarized UV and infrared, SEM, atomic force microscopy, and spectroscopy like Raman and FTIR that target the molecular fingerprint of collagen. Another technique extensively used, especially with historical samples, is the MHT method, which is a thermal microscopy widely used in the past several decades in conservation laboratories.

Dr. Badea suggested using the MHT method to test for the quality of leather in our conservation labs. It works nicely, is quite simple and inexpensive, and is backed by extensive research. It is best to consider the analysis of all shrinkage intervals and temperature and perform it jointly with other

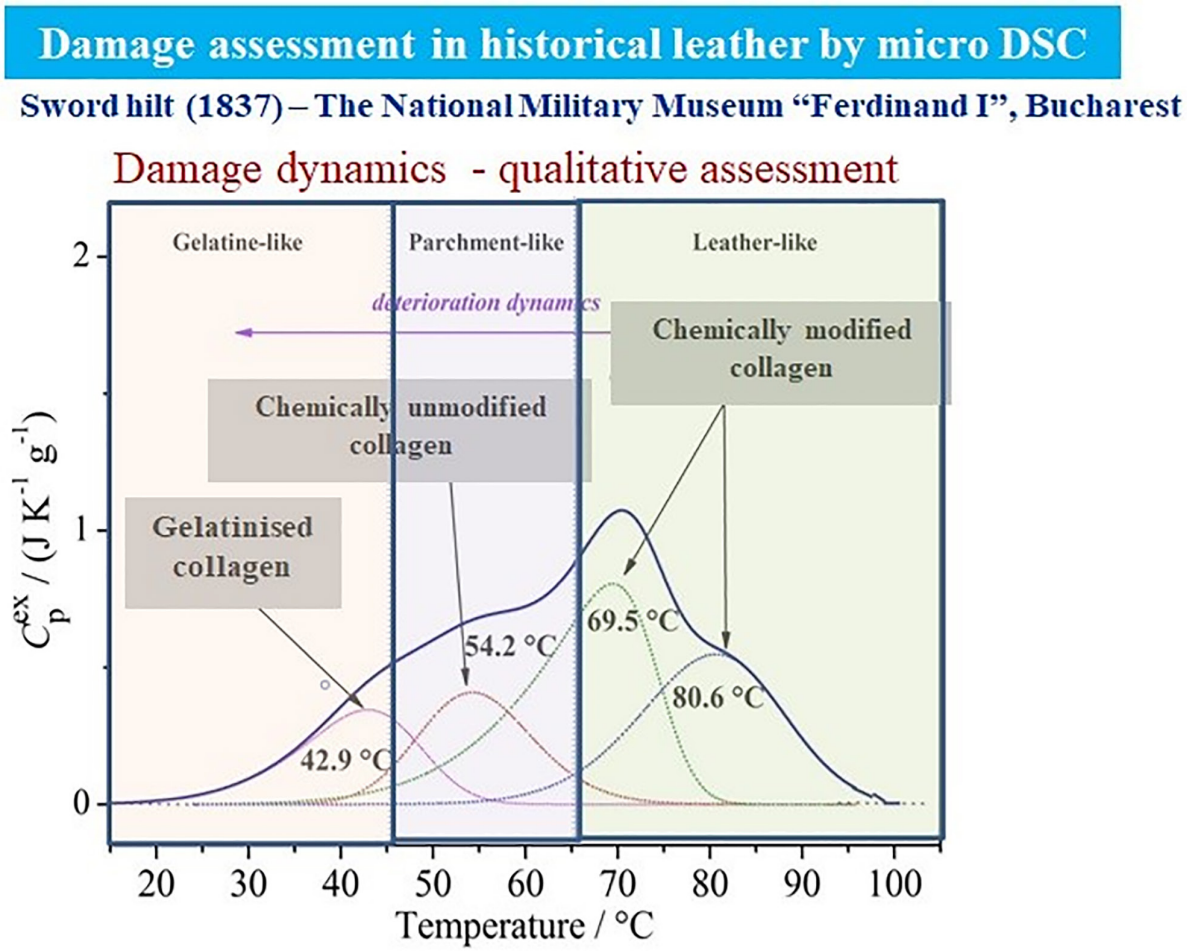

Fig. 8. Elena Badea, qualities contributing to the longevity of skin.

complementary analyses to avoid over- or underestimating the condition of the parchment or leather. MHT has been used in conjunction with other techniques to assess the effect of conservation treatments after artificial aging, and it works very well for that as well.

Concerning what qualities contribute to the longevity of a skin, Dr. Badea postulated that it depends on the skins' thermal stability and tanning homogeneity (fig. 8). She showed figures representing the microcalorimetric signals of collagen denaturation for two different vegetable-tanned leathers exposed to gamma radiation in doses from 10 to 100 kilogray (KGy). A leather tanned with mimosa extract was highly stable even after being exposed to 100 KGy of gamma radiation. This leather had a thermal stability of more than 65°C. The second example, which had a thermal stability below 65°C, showed observable detanning after a dose of 25 KGy of gamma radiation and gelatinization after 100 KGy. This research is published in *Radiation Physics and Chemistry* under the title "Micro-DSC, FTIR-ATR and NMR Mouse study of the dose-dependent effects of

gamma irradiation on vegetable-tanned leather" (note 3). Dr. Badea emphasized that 100-KGy gamma radiation is very harsh, as just 25-KGy exposure renders an environment sterile.

In addition to this, Dr. Badea addressed the effects of leather consolidation treatments, including recent research she has done exploring halloysite nanotubes (HNT) loaded with nanoMgO for the purpose of increasing thermal stability. Even one treatment on historic leather increases the thermal stability and decreases the collagen molecular distribution, contributing to the overall chemical and mechanical stability of the skin.

In summary, the analysis techniques discussed demonstrate why and how collagen survives in parchment and leather, revealed clues as to how leather thermal stability results from hydrogen bonding and covalent cross-linking of collagen with traditional tanning agents, helped find ways to reinforce fragile artifacts, and inspired ways to develop modern leather by reinterpreting ancient technologies.

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CAROLINE SOLAZZO
PROTEOMICS ANALYSIS OF LEATHER AT MCI

Dr. Caroline Solazzo is a research scientist in the Proteomics and Biomolecular Mass Spectrometry Laboratory at the Smithsonian's MCI in Washington, DC, with extensive expertise in proteomics of ancient animal fibers.

Dr. Solazzo gave a presentation describing proteomics as a method of analyzing leather. Proteomics is used to characterize and describe all proteins in a system, typically analyzed by mass spectrometry. Collagen, the primary component of animal skin, is a structural protein, which makes leather an ideal candidate for proteomics. Proteomics can identify both the species of animal used to make the leather and proteinaceous additives such as binders, adhesives, and consolidants, as well as assess the level of degradation present in the collagen proteins in the skin.

First, the proteins are extracted and converted into peptides by solubilization and subsequent digestion with trypsin, which cuts the proteins at the amino acids lysine (Lys) and arginine (Arg). The peptides are separated by liquid chromatography and analyzed by mass spectrometry (LC-MS-MS) and further fragmented into their amino acid sequences that are then searched against a protein database.

Collagen, a family of large proteins containing about 1500 amino acids, is the most abundant protein component in skin tissues. Other less abundant proteins are typically removed during the cleaning and scraping of the skin, leaving three major protein chains identified in leather by proteomics: collagen I alpha 1, collagen I alpha 2, and collagen II alpha 1. Tests on modern bovine leather processed with different methods showed that oil tanning and alum tawing resulted in higher percentages of these proteins being recovered than with chrome and vegetable tanning. In the latter, the proteins did not completely solubilize, highlighting the more efficient binding of collagen in these tanning methods.

Dr. Solazzo then discussed the results of the proteomics identification for 18 leather samples from historic bookbindings and modern vegetable-tanned leathers (fig. 9). The historic samples were in a range of conditions, from highly degraded to generally good. About half of the historic samples were cow, five were sheep, two were goat, and one was horse. The goat samples also had bovine markers, but this was probably from hide glue. Hide glue may have been present in the others, too, but can only be positively identified if it comes from a different species. Milk, egg white, and wheat paste were also identified.

To assess the leathers for protein degradation, both rates of hydrolysis and deamidation were determined. Multiple samples were taken from the leathers—one in a more damaged area and one in a less damaged area. Hydrolysis is measured as the breakdown of protein chains at nonenzymatic positions, whereas deamidation is the modification of asparagine and glutamine into aspartic acid and glutamic acid, respectively. Some of the samples had advanced hydrolysis, but all were affected by high levels of deamidation. Deamidation increases as leather ages, so this was expected for the historic leathers. However, deamidation in a modern leather and/or rapid increase with aging may be a useful parameter to indicate a shorter anticipated lifespan for that leather.

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RENÉ LARSEN
SULFUR- AND METAL-FREE FULL VEGETABLE-TANNED AND SUSTAINABLE CALF LEATHER FOR BOOKBINDING AND RESTORATION

René Larsen is a conservator, educator, and biochemist who was the scientific director for the STEP project, as well as several other European Union leather projects. He gave the final talk of the panel.

Dr. Larsen gave a short background history on previous leather projects, starting with the Athenaeum project in

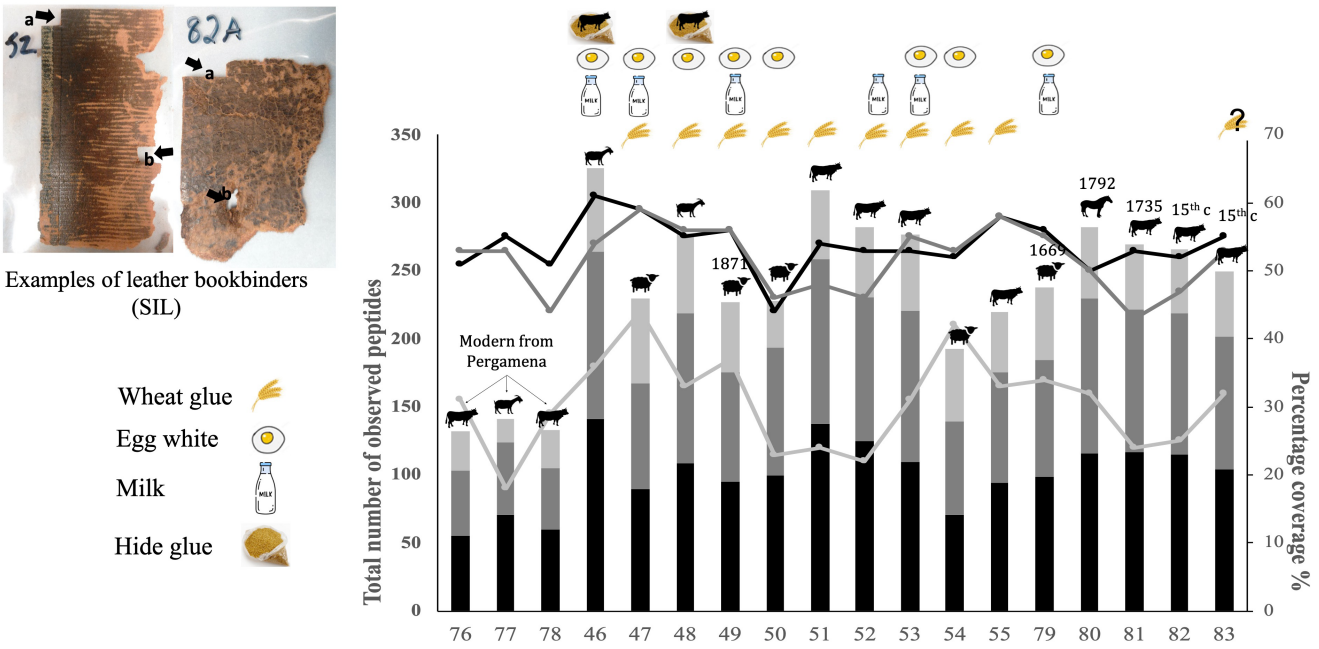

Figure 1: Number of collagen peptides and protein coverage for collagen I alpha 1 (black), collagen I alpha 2 (dark grey) and collagen III alpha 1 (light grey) in all 18 leather samples (15th c. to 21rst c.). Species identification (cow, sheep, goat or horse) of the leather is based on the presence of specific collagen markers. The presence of protein binders is indicated above (with legend on the left).

Fig. 9. Caroline Solazzo, proteomics identification of leather bindings.

1843, the Royal Society of Arts Committee on Leather for Bookbinding at the turn of the 20th century, the British long-term storage trial, and the STEP and ENVIRONMENT European Commission projects. The early projects attributed leather decay to pollution in the environment, as well as the tannins used, and so the long-term storage trial included both hydrolyzable and condensed tannins. It was conducted jointly in polluted London and relatively pristine Aberystwyth, Wales. The European Commission projects also used the leather on these bindings leading to valuable information regarding the deterioration of naturally aged leather in different environments and recommendations regarding a long-term durable archival leather.

In 2019, Dr. Larsen joined the Sulfur Free Calf project. It was originally intended to be a durable vegetable-tanned leather with good organoleptic properties for bookbinding and is now retitled the "Sulfur and Metal Free Vegetable Tanned Archival Calf Leather" to also convey its intended longevity. It was tested by external labs for sulfur content, and the results were under the test detection limits in all cases. Another test, to determine mineral tannins (ISO 17072-2:2019), compared the aluminum, chromium, iron, titanium, and zirconium contents of five leathers including the Sulfur Free Calf. According to UNI EN 15987, to be metal free, the sum of all tannin metals must be less than or equal to 0.1% metals mass/total dry weight of the leather. The Sulfur Free Calf was the only one of five leathers to pass this test.

This leather (SF KLO) was tested along with commercially available conservation leathers in several ways (fig. 10). Dr. Larsen discussed the results of these tests. The first was to assess the coherence of dry fibers before and after aging in dry heat (120°C) for 24, 48, and 96 hours and also after natural aging. He also recommends the coherence of dry fiber assessment to conservators for use on a regular basis. To do this, a very small number of fibers are scratched from the surface and then classified in one of five ways: (1) very coherent, (2) coherent and slightly powdered, (3) equal parts coherent and powdered, (4) slightly coherent and powdered, and (5) completely powdered. SF KLO retained its coherence, reaching only a state of 2 (coherent and slightly powdered) after 96 hours of dry heat aging. The other tested leathers reached a state of 4 (slightly coherent and powdered) in the same amount of time.

Additionally, the test results on the commercial leather showed that this leather, which was from the same East German producer but purchased for different purposes and at different times, clearly will behave differently under different aging/storage conditions.

The future test regime will include three accelerated aging systems, six standard physical and chemical tests for leather, and the tropical test with slightly elevated

SAMPLE	HOURS	COHERENCE	TANNAGE
KLO ref	0	1	Hydrolysable
KLO 24	24	1	"
KLO 48	48	1,5	"
KLO 96	96	2	"
IFV ref	0	1	Condensed
IFV 24	24	2	"
IFV 48	48	3,5	"
IFV 96	96	4	"
NAT. AGED	YEAR		
HW7	≈ 1995	2	Metal / condensed/ hydrolysable
HW6C	≈ 1995	2,5	"
HW6B	≈ 1997	3	"
LEF8A	≤ 1989	4	Condensed

Fig. 10. Rene Larson, artificial aging test results of the new sulfur-free leather versus commercially available conservation leather.

temperature and nitrogen oxide pollution. There will be five micro analytical methods developed for conservation laboratories—including the dry fiber coherence test and the hydrothermal stability test presented by Dr. Badea. Once these methods are completed, he intends to publish a comprehensive guide to them.

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DISCUSSIONS

Leather Users

The discussion began with a question about the decision to use leather versus alternative materials. Generally, the panelists feel that leather is desirable due to its mechanical properties, which are difficult to replicate using other materials. Alternate materials, however, have properties that leather cannot replicate. Mr. Minter noted that leather is easily moldable into whatever shape is needed. Ms. Bolton agreed and noted that the strength and flexibility of leather and the ability to pare it up to the edge are key benefits to using leather as a repair material. At the LCC, she noted that leather is used when repairing furniture that is still in use due to the ability to thin the leather at the edges so the leather repairs will not lift when the furniture is in use. For furniture that will not be used, BEVA applied around the edges of the repair can reduce the step at the junction of the original leather and the repair leather. Ms. Kaplan finds that the decision to use leather is a practical one based on the specific item being treated and tends to treat objects that are decorative or no longer functional. As a result, the demands on the repair material are less. Usually, she does not need the mechanical properties of leather. If she needs a structural repair, then leather is sometimes the better option, although she also uses Tyvek and spunbond polyester because they give enough strength for her needs. Ms. Bolton agreed that spunbond polyester, which is thin and strong, can be useful for repairs where it is necessary to add as little bulk as possible.

This line of thought led to a question about determining the desired thickness of leather to use as a repair material. Some leather users prefer to thin the leather significantly, whereas others prefer to use a thicker, stronger leather. Mr. Siegel interjected to say the hide type is important. If making gloves, one needs a thin leather such as Ethiopian hair sheep that is strong but thin, at 0.4 mm, whereas when making Western saddles, steer leather, which is much thicker at 7 to 8 mm, is used. However, paring down the steer leather to 0.4 mm would leave it with no strength due to the intertwined construction of leather. Shaving it down 50% equates to the loss of 70% to 80% of the strength of the leather. Leather should be used at as full a thickness as possible when strength is an issue. In the repair process, choosing a leather of the same thickness as the original leather is the best course of action. With bookbinding leather, if the ideal thickness is 0.6 to 0.8 mm, one should start with a smaller skin from a younger animal. Mr. Minter agrees that using leather as close to the original thickness as possible is preferable. Dr. Larsen added that the full thickness of the leather allows the highest physical strength, which is in the middle of the corium.

A member of the audience asked whether any of the panelists have used other, nonmammal leather, such as fish leather. Ms. Bolton responded that at the LCC, one of the primary characteristics they look for is visual appearance. As a result, they match the repair leather species to the species of the original leather, which is not often fish skin. She pares the edges of repair leather to a thin edge, but the area where the actual area of loss is located will be left to as full a thickness as possible. If thinness is the goal, then Japanese tissue, a nonwoven material, or a laminate of Japanese tissue and Remay (to double the strength) is used. Ms. Kaplan agreed with Ms. Bolton and added that even when she is repairing fish skin, she will quite often create a substitute that mimics the original material. Despite appearances, it may not move and flex in the same manner as the original material. An audience member commented, and Ms. Kaplan agreed, that training strongly influences whether one is comfortable working with leather, and this influences decision making.

Ms. Wright then asked the panelists whether they are using leather as often as they did at the beginning of their careers and whether the philosophy behind using leather has changed. Mr. Minter answered that during his apprenticeship, rebacking or rebinding were common practice, whereas now the philosophy is to save as much of the original binding as possible. Many curators prefer less intrusive treatments. Ms. Bolton reiterated that the materials they use are dependent on the client. Generally, museums prefer leather alternatives, whereas private clients prefer leather. Dr. Engel noted that conservators who use a lot of leather are probably not experimenting with other materials. She tends to use leather in her private practice due to her training. Ethically, she feels it is the best match for leather repairs. She works closely with the tanneries on specifications for the skins she uses. She does not use synthetic adhesives, choosing glue or paste instead. For adhering leather, she uses wheat starch paste that is cooked for 20 minutes, as it has strong adhesive forces. In rare cases, she uses isinglass or parchment glue.

Tanners

The tanner discussion started with a question about using tannin-based dyes for color fastness, economy, and their environmental friendliness. Can these dyes still be applied in lieu of aniline dyes? At Hewit, Mr. Lanning stated that Hewit uses dyes that work in an acid environment. Many steps in the tanning process occur in an acidic environment including dye application as the acid environment fixes the dye to the leather. He does not believe that Hewit's process would work well with natural dyes. Dr. Emmerich Kamper explained that there would be no benefit to using tannins as a mordant on vegetable-tanned leather, as that would overtan the leather, applying one tannin over another. However, using tannin-based dyes on fat-tanned leather is beneficial because the skins become less stretchy. Mr. Meyer has used vegetable dyes in parchment with different tannins providing different coloration. In the process, he noted that if care is not taken, the parchment will

be tanned instead of dyed, creating an undesirable velvety surface. He has conducted a trial using cochineal dye, and the result was so light that it was barely discernible. Mr. Lanning added that shades of brown are relatively simple to achieve with tannins but that any of the brighter colors, such as blues, yellows, greens, and bright reds, are much more difficult. Mr. Siegel does use vegetable dyes for tanning hides in Nigeria that have been used for hundreds of years and produce very bright colors. There is a wide range of dyes available, but he is unsure if they are archival.

Ms. Wright then asked whether the market for dyed or undyed skins is greater. Mr. Themmen said that the Sulfur Free Calf has a natural, undyed color. Opinions vary, but generally clients purchase it undyed and dye the leather to their specifications after purchase. Dr. Emmerich Kamper generally does not use dyes, producing 80% of her leathers in natural colors from cream to smoke, depending on the tannins used. Mr. Lanning noted that most of the calf they sell is dyed, yet most of the goat they sell is undyed. Mr. Themmen added that the sulfur calf is dehaired in a nondestructive way, creating a white base for the tannins and resulting in a cream-colored skin that the client would find easy to dye.

An audience member asked about the practicality of making leather with the current market processes, using pre-1830 materials, wondering whether those materials are even available. Mr. Siegel described previous research into leather degradation, which concluded that using sulfur compounds in the dehairing process is detrimental. The chemistry of dehairing a hide in the modern age without using sodium sulfide is difficult, as is tanning leather without using a sulfide tanning agent. Mr. Themmen added that modern leather production is based on speeding up the processing time. The solution is to research how tanning was done in the past and find a modern way to replicate it. Artificial aging, to mimic the lifespan of 200 to 300 years, is key to see how well the leather ages. Mr. Siegel stated that the sulfur-free leather they are making in Nigeria is archival and even takes no more than four weeks to produce using techniques that have existed for hundreds of years.

Researchers

Ms. Wright asked the researchers to recommend how best to translate the testing results into practical use when treating historic objects and selecting modern leathers for treatments. Dr. Larsen responded that it is important to note that many of these research methods look at similar mechanisms but from different angles. It is up to the scientists to analyze the data and translate the results so that they can be used by the conservation community. It is also key to develop simple testing methods that can be conducted in conservation labs. Dr. Weyrich agreed, noting that many of the methods discussed today cost hundreds of dollars per sample and often require an advanced degree to interpret. What researchers can do is take the information and translate it back into simple techniques. Better yet would be for researchers to work on the same materials so they can combine all of these efforts and understand how the results from different testing methods overlap, ultimately telling more of the story.

Ms. Wright then asked if the researchers think conservation treatments (e.g., dyeing leather or applying consolidants and leather dressings) are affecting leather longevity. Dr. Larsen says that extensive studies of the Domesday Books and the Codex Sinaiticus show that the treatments conservators are doing are accelerating the deterioration of leather and parchment. Dr. Weyrich added that from an ancient DNA perspective, conservation may alter or create a new DNA signal making the recovery of the original DNA impossible. She praised Dr. Solazzo's study highlighting that leather is not the only animal material used in bookbinding. There are layers of animal and plant materials, and when a book is conserved, further layers may be added. Molecular methods may be able to shed information on the original DNA signatures.

An attendee posed the question of whether conservators should be concerned with new repair material corrupting DNA, mass peptide fingerprinting, or proteomic tests. Dr. Weyrich stated it is a concern and is writing a paper considering whether these treatments affect trace recovery by adding DNA or destroying existing DNA. Dr. Badea responded that added leather or parchment can usually be identified using the normal physical, chemical, and analytical methods. She gave an example of using PVA in Marco Polo's will, where there is definite interaction between the collagen in the parchment and the added PVA. Conservators need to ensure that there will be no interaction between the leather and added compounds. The problem is that some of these reactions do not become visible for 10, 20 or even 30 years. From analysis that Dr. Badea has conducted, it is clear that for most items, be it books or furniture, that treatment was not favorable to the artifact. Dr. Larsen added that, if possible, conservators should retain original samples of untreated leather or parchment before treatment is started for future analysis.

When asked how those samples should be stored, Dr. Weyrich stated that for DNA and protein preservation, it is ideal if the samples can be frozen, which she realizes is untenable. Other techniques require different storage solutions, so this should be further explored to determine a feasible solution.

All Panelists

Ms. Wright then opened up the discussion of the ways in which conservation treatments affect the longevity of the historic objects to the entire panel. Dr. Engel noted that the approach of the owners of the objects has changed. In the past, conservators were asked to make items look "new" again, clean, and flat. This necessitated treatments such as humidifying parchment and leather to flatten them. She feels

it was not only the materials that conservators added to the items that caused damage but also some of the treatments themselves.

Mr. Lanning countered with a question about long-term storage of leather for future testing. He understands the theoretical need for this, but in the case of tanneries, the environment itself is dirty with chemicals in the air and the warehouse where different leathers come into contact with one another. In this working environment, how is one expected to ensure no cross contamination occurs? Dr. Weyrich stated that it was eye opening for her to see the differences between the conditions in a tannery and the conditions in a microbiome lab. In her work with Mr. Meyer to try and trace different microbial signatures through the tanning process, they are intentionally trying to avoid cross contamination where possible even though this is not feasible in a typical tannery environment. In her testing, she will be able to ascertain the number of microbes that are maintained across all skins versus those specific to individual skins. Tracking this information will be valuable. Does the information shift according to season, the type of animal hide, or in industrialized versus nonindustrialized environments? The answer to these questions might be important in explaining how leathers are preserved over time.

An attendee asked whether microbes are still viable and whether conservators should be concerned. Dr. Weyrich explained that many of these microbes are not adapted to living in the human body and are not present in high enough quantities to cause concern. This is compounded by the fact that the goal of tanning is to stop microbial growth. Mr. Siegel added that all modern tanning is done with biocides. Mr. Meyer added that experiments could be done to tan without biocides. Mr. Siegel postulated that fatliquor purchased from a chemical company already has added biocides. Mr. Meyer countered that in his experience, if they do not add biocides after fatliquoring there will be mold growth, indicating that there may be biocides in the fatliquor but not in sufficient quantities to inhibit mold growth. Mr. Themmen added that there are laws that govern the amount of preservation agents that can be added to chemicals, and that the key is to change the biocides and bactericides used as the microbes build resistance to the formulas. Mr. Lanning stated that there is no choice but to use biocides and fungicides and to switch the ones used for this reason. He also added that some pathogens, such as anthrax, can survive the tanning process. Dr. Weyrich finds this fascinating when thinking about preindustrial tanning. Now tanners know to add biocides and fungicides to control mold growth, but what were people doing before to inhibit this growth?

An audience member asked whether smoke tanning or other indigenous tanning methods acted as a biocide or fungicide. Dr. Emmerich Kamper responded that the small batches tanned in the pre-Industrial Era were tanned in pits that were periodically drained. The balance of the acidity and alkalinity in the pits inhibited bacterial growth. In the smoke-tanning method, smoke is filled with formaldehyde and oleic compounds that act as fungicides. However, even a well-brain-tanned leather will rot if left in water for a prolonged period of time. As a result, researchers do not have many leather samples from ancient times, although some Roman-era leather survives, as well as other ancient leathers from dry sites.

A question was posed to Dr. Badea, from an audience member, about using confocal microscopy for evaluating degradation in historic skins. She responded that atomic microscopy can be used, but because the surfaces of leathers and parchments are not smooth, it is difficult to produce clear images. It is also expensive testing to undertake. However, it does work to measure the distance in between the fibers, which can help determine damage. There are easier and cheaper tests that can be performed that are more realistic in a conservation lab. Dr. Larsen added that wet parchment testing using a transmission microscope provides the same general results as with SEM. Researchers need to take these findings that use advanced testing techniques and find a way to obtain the same results with less complicated techniques.

Ms. Wright then asked whether the many changes to the tanning process made after the extensive leather research in the 19th and 20th centuries resulted in significantly improved leather quality. Has modern leather achieved similar characteristics to medieval leather? Mr. Lanning says, from the tanner's perspective, that they are all trying to produce the best leather they can. Tanners can only work with available research results. For example, Dr. Larsen was very involved in the STEP project, Mr. Lanning was involved with the CRAFT project, and Mr. Siegel is researching and testing his sulfur-free leather. Mr. Siegel added that what is being produced today is certainly better than what was being produced 100 years ago. What he does not know is whether the leather being produced today is as good as leather produced 500 years ago. Perhaps further testing will be enlightening. He suggested that researching what has gone on in the past to help guide future choices is complicated by proprietary formulas. It would be helpful if tanners producing leather for scientific and conservation use would share those formulas. At least writing these formulas down now would allow researchers in the future to have access to the knowledge of what worked and what did not work. Mr. Lanning noted that all of Hewit's processes are recorded but are commercially sensitive. In 50 years, he can share those formulas but cannot share current proprietary formulas. Mr. Themmen added that the practice and science are far apart, and Dr. Larsen noted that having scientists involved in research projects means that their test results will be made available even when the formulas remain proprietary. This gives conservators insights into the durability of the leather and the main types of tannages that were

used. It also offers assurance as to the quality of the final product.

Ms. Wagner followed up asking the tanners if they retained their historic recipes. Hewit has an archive, but there were two fires, one in the late 1800s and one in the 1950s, that destroyed many of the records. They do have records from 1950 onward. Pergamena also has detailed records going back 50 years, but they reference many chemicals that are no longer used (because they are carcinogenic or no longer produced for other reasons). Their older records typically contain recipes that are very general, such as "use a bunch of bran" or "use a barrel of cod liver oil," making it difficult to re-create a viable recipe. Mr. Lanning encountered the same vagueness in the older Hewitt recipes, which sometimes have baffling instructions like "a yoghurt pot of this." In producing leather, the formulas also change frequently, even yearly, due to the availability of chemicals. They are frequently dropped and replaced in the UK. As small users of these chemicals, they do not have much ability to influence the industry.

Ms. Wright asked whether the leather users are currently performing any of the recommended tests in their conservation labs. Ms. Kaplan said that Winterthur uses the MHT method. The audience asked what inexpensive tests can be incorporated in the conservation lab—for example, what is another option for a leather shrinkage test? Dr. Badea stated that the MHT results are all open source and can be used with microscopic observation. She said it is not too difficult to access DSC testing, but it is a test that is not used in tanneries. However, the test is important because it sheds light on the bonding of tannins to collagen. This can assist in the understanding of the mechanism of deterioration. DSC is important for historic leather but also when designing a new product. For tanners, measuring leather shrinkage is not enough when designing and producing high-quality leather. There are many more chemicals in modern leather than there were in ancient leather because of the need to produce the leather more quickly and in a cost-effective manner. Producing archival leather is more expensive than producing chrome-tanned leather, but one can only charge so much for the archival, vegetable-tanned leather.

The panel was well received and led to enlightening and engaging discussion. Attendees indicated that leather, as a topic, is important in the current conservation climate. Panelists expressed interest in continuing the discussions in the future, and the group is already planning periodic virtual meetings. Research, both previous and current, will be summarized on the Leather Research page of the AIC BPG wiki. Furthermore, the group is open to discussions during future AIC annual meetings.

NOTES

1. Siegel Leather, *Tropical Testing Popular Bookbinding Leathers!* Uploaded November 2020 at YouTube.com. Video, 03:57. https://youtu.be/M20eeDusJIc.
2. https://www.hewit.com/download/fs-craft.pdf
3. https://doi.org/10.1016/j.radphyschem.2021.109712

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