

The story of a chess set – a scientific detective story for Holocaust Remembrance Day

<https://doi.org/10.51167/ice000019>

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I learned to play chess at the age of five. My father wanted a partner to play with him, and he started to train me as soon as he thought it was possible. We played with an impressive chess set that had survived tens of years and eventually joined my chess set collection (see Figures 1 and 2). At age 14, I started studying chemistry, and soon I was wondering what the figurines were made of. They seemed to be made of plastic but, in the 1950s, the only abundant plastic

materials in Czechoslovakia were PVC and Bakelite, polymers substantially different from the half-transparent and layered material of our chess set.

The question remained open for decades, until I realized that an instrument, which we purchased for our demonstration lab in Bargal Analytical Instruments, could easily give me an answer. A Fourier-transform infrared (FTIR) spectrometer

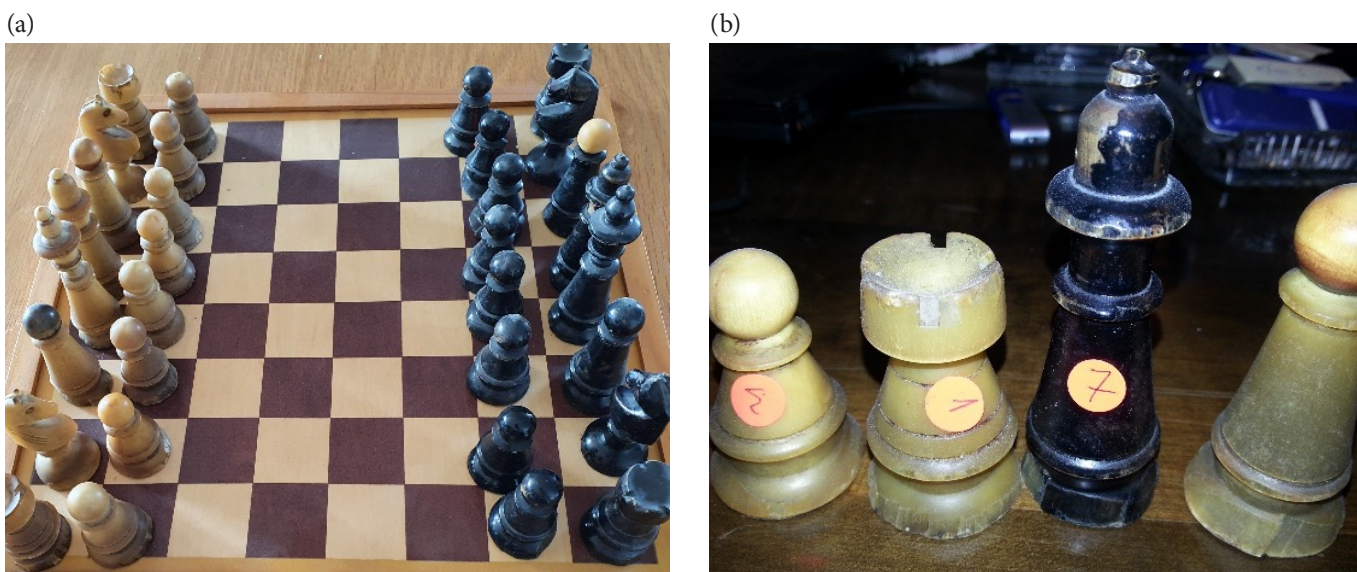


Figure 1. (a) The chess set, (b) some of the chess pieces.

Arie Gillon started studying chemistry at the age of 14, at the High School of Chemical Technology in Prague, Czechoslovakia. He completed his academic degrees in organic chemistry at the Technion, under the supervision of Eli Loewenthal, Shlomo Been and Dan Becker. His post-doc mentor was Yitzhak Apeloig. During his DSc studies, he acted as the chairman of the Technion Junior Staff Association. In 1988, he established Bargal Analytical Instruments Ltd., which now has over 40 employees and is one of the major suppliers of scientific instruments in Israel.



with attenuated total reflectance (ATR) diamond accessory (Thermo Nicolet iS5 with iD5) allows a non-destructive measurement of the IR spectra of solids. The software includes a library of reference spectra that can be used to identify compounds. The library includes a large number of polymers, so I thought it should be simple to identify the material from which my chess set is made.

I brought chess pieces of both colors to the lab, and we made several measurements. The result was shocking: the library search determined with the highest probability that the figurines are made of human skin [see Figures 2(a – c)]. The ATR accessory measures a very thin layer, just about 1 micron (one thousandth of a millimeter) thin, so there was the possibility that what we measured was epithelial cells from our fingers. We therefore washed the figurines thoroughly, but the result gave an even higher probability that they were made of human skin.

My parents lived before WWII in the small town of Chust in Ruthenia, which is known as the Carpathian Ukraine, at that time Czechoslovakia. Following German occupation of Czechia in 1939, Czechoslovakia was dismembered and Ruthenia with over 100,000 Jews, 14% of the population, was annexed to Hungary. The Hungarian Jews, although persecuted, were saved from the Holocaust until March 1944, when Germany occupied Hungary. My family was transported to Auschwitz on the festival of Shavuot, June 1944. When my parents, among the few that survived, were liberated, they had the choice of returning home to Ruthenia, which was now annexed to the Soviet Union, or remaining in Czechoslovakia. The Jews who decided to stay were relocated to the Sudetes region (north-west Bohemia, near the German border), which was half-empty, after the transfer of more than three million Germans to Germany. My parents were accommodated in an apartment left by Germans, and I was born there. Three years later, when we moved to Prague, my

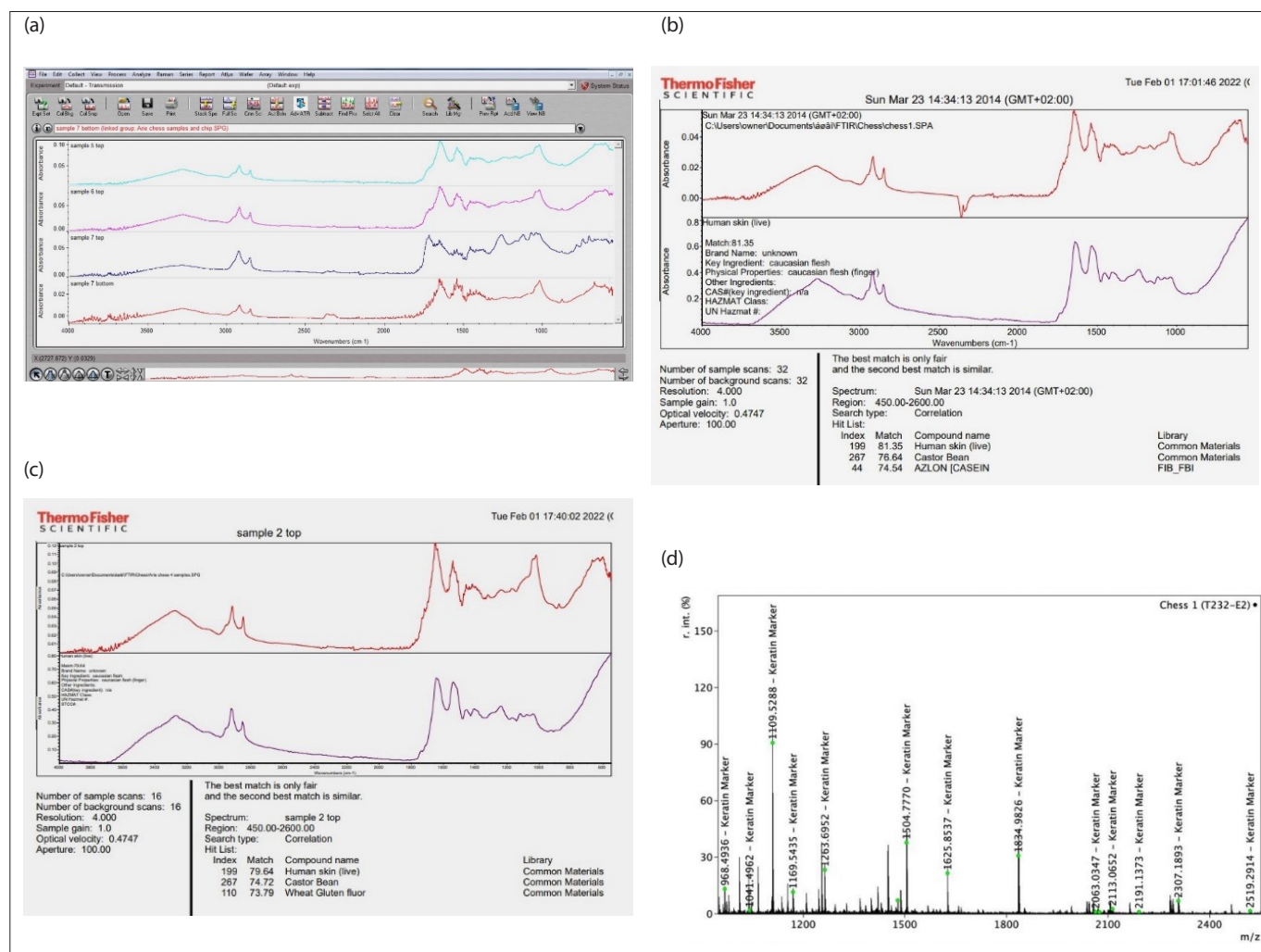


Figure 2. (a) FTIR spectra of several chess pieces, (b,c) typical library search, (d) PMF spectrum with highly conserved keratin ions indicated.

parents again received an apartment in which Germans had lived during the war.

I have no idea whether my father purchased the chess set, or perhaps found it in one of the flats among the gadgets left behind by the Germans. I suppose he found it in one of the flats because, after the war, he could not possibly afford to purchase such an apparently expensive set.

It is known that, during the Holocaust, the Nazis produced artifacts from bodies of Jews they murdered. They made not only soap from human fat, but also “ornamental” objects like lampshades, from human skin. There is no evidence of chess figurines made from human skin, but it could be possible. If so, my chess set should be in Yad Vashem, the Holocaust memorial museum in Jerusalem, and not in my private collection. It became crucial for me to pursue this issue thoroughly.

When identifying compounds by searching a spectral library, it is most advisable not to depend on the computer blindly, but to compare the spectra visually. Inspecting the library spectra revealed that the IR spectra of bovine leather and human skin are almost identical, and that the probability that the chess pieces are made of processed bovine leather is just a few percent lower than that they are made of human skin. The expert opinion of Prof. Stephen Weiner from the Archeology Department of the Weizmann Institute of Science in Rehovot and of Dr. Michael Bradley from Thermo Scientific in Madison, Wisconsin, was that it is impossible to distinguish between human skin and bovine leather by means of IR spectroscopy. They both recommended solving the problem by DNA analysis.

I turned to my friends in the forensic department of the Israeli Police. It was explained to me that the forensic lab in Jerusalem compares human DNAs, but does not have the ability to compare DNA of other species. I was referred to Dr. Gila Bar-Gal (no connection to my company Bargal Analytical Instruments) in the Faculty of Agriculture of the Hebrew University, who deals with the analysis of the origin of DNA. Gila was very responsive. Incidentally, at the same time, she was asked to check a horn smuggled from India, suspected to be ivory, and we could help her by using FTIR/ATR to show that it was a plastic artifact. Gila's staff used a polymerase chain reaction (PCR) replication technique and confirmed that the samples were of human origin.

Gila used her remarkable scientific insight and compared the DNA of the chess pieces with that of her students. It was identical to one of them, indicating that they had contaminated the samples with their fingers. They resampled the chess figurines several times, but did not succeed in

producing DNA pure enough to get a meaningful result. In the case of ancient tissues, this is a prevailing problem and Gila's recommendation was to send the samples to a lab specializing in ancient DNA sequencing. Genetic sequencing is done in Israel on modern DNA only, so the samples had to be sent abroad. This did not happen, so the issue was postponed for some time.

Several years later, I saw on TV news a report that included an interview with Prof. Oded ReHAVI of the Neurobiology Department in Tel Aviv University, in which it was mentioned that he deals with ancient DNA. Oded referred me to Prof. Christopher Mason of Cornell University, who collaborates with him and whose lab performs the DNA sequencing for him. Chris volunteered to run the DNA analysis of the chess pieces free of charge, but requested samples of bovine and human skin as a reference. There was no problem with bovine skin; I simply cut a piece out of one of my leather belts. Regarding human skin, I turned to my friend Prof. Juri Kopolovic, the head of the Pathology Department of Hadassah Ein Karem Hospital in Jerusalem. Juri explained that it is illegal to supply human samples, but generously offered to provide a piece of his own skin after some minor surgery he planned to undergo.

In the meantime, I asked Chris why he needs references, as the human and bovine DNA sequences are known. Instead of replying, he referred me to a forensic lab in Texas, that specializes in ancient genome sequencing. The manager of the lab ruled out any possibility of performing DNA sequencing on skin that had been treated chemically. End of story; there was no need any more for Juri's altruistic donation of his own skin.

Oded ReHAVI mentioned to me that there are works negating the conjecture that the infamous lampshades were made of human skin. A due search led me to Mark Jacobson's book [1]. The book describes a lampshade found in the USA, whose DNA sequencing revealed human origin. Several years later, in repeated testing, human contamination of the sample was detected, and the lampshade was determined as being most probably made of parchment. This was published in 2012 in National Geographic's TV movie *Human Lampshade: A Holocaust Mystery*.

To my surprise, the program featured Prof. Chris Mason from Cornell with whom I had been in touch, as the scientist who performed both the original and the following corrective analysis. He testified that the correction was facilitated by advanced technology, that had improved between the analyses. Why then was it impossible to perform DNA sequencing of the tanned leather/skin of my chess set, while

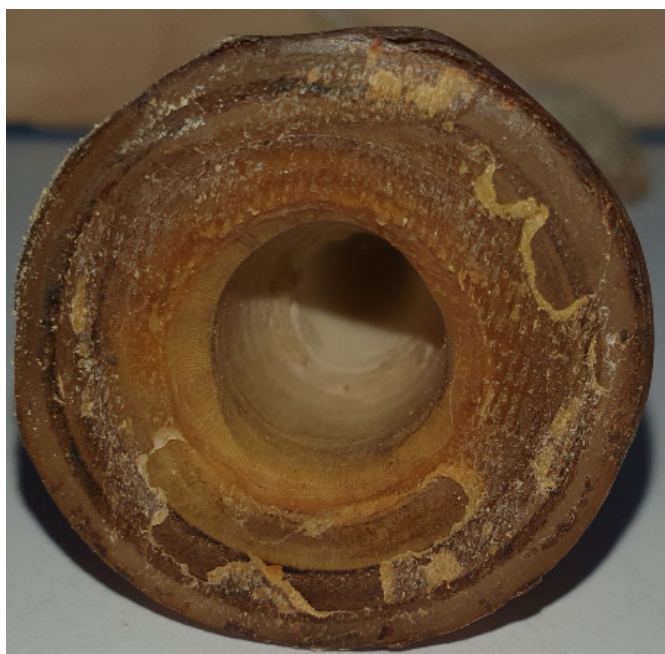


Figure 3. Pawn interior.

it could be done on parchment, which is virtually the same material? This question remained unanswered.

I continued to search. I found out that the infamous Buchenwald human skin lampshade, which was photographed by the US army when liberating the Buchenwald concentration camp, had disappeared. Another lampshade, claimed to be made of human skin in one of the USA museums, was found to be made of cellulose. The conclusion is that if the Nazis used Jewish corpses as a raw material, this was not a systematic effort but a local initiative.

From Jacobson's book [1], I learned that Yad Vashem, the holocaust museum in Jerusalem, is not allowed to keep human remains, and that holocaust museums in general are not interested in artifacts of this kind, which in their opinion distract public attention from the main issue of the Holocaust to side issues and controversial legends.

The conclusion was that I have to keep the chess set in my possession. What is it made of? This question remained unanswered. But this was not the end of the story.

When I submitted this story to all the people mentioned in it with a request for permission to mention their names, I received updated and interesting information. First, Chris Mason answered that he would be willing to analyze the sample after all, if it would arrive with the requested reference material. Further, Gila Kahila Bar-Gal had advanced in her



Figure 4. Vietnamese horn chess figures.

research and was now able to deal with ancient samples. She sent a detailed report of the work performed on mitochondrial DNA sequencing of the white chess piece, which provided inconclusive results. The DNA quality did not allow the identification of the source reliably, but the results hinted at domestic sheep (*Ovis aries*), breed Awassi. This breed is in fact abundant in the Middle East but not in Europe, which was supposedly the origin of the chess set. Gila suggested submitting an additional, cleaner sample.

Finally, Steve Weiner turned my attention to an article on zooarchaeology by mass spectrometry (ZooMS) by Matthew Collins [2], professor of Palaeoproteomics in the Department of Archeology in Cambridge University, and also in the University of Copenhagen. This novel method establishes the source of bones found in archeological sites by identifying proteins by means of high-resolution mass spectrometry (MALDI-TOF). I turned to Matthew and he referred me to Dan Kirby from Dan Kirby Analytical Services in Milton, Massachusetts. This is the lab that performs the ZooMS testing, which was in the meantime renamed PMF (peptide mass fingerprint) analysis.

I responded by opening the bottom cover of one of the hollow pieces (Figure 3) and grinding its inner part with a new grindstone fitted on a drill. I divided the resulting powder into three samples. I brought one of them to the Faculty of Agriculture, and sent one to Chris Mason with a sample of human skin that I got from a plastic surgeon. The third I sent to Dan Kirby, who sent me a prompt and surprising report: The PMF spectrum clearly shows that the sample does not include collagen, the protein found in skin and hide, but

keratin, the protein found in hair, feathers, nails, horns and hooves [see Figure 2(d)]. The method used by Dan could not point at a specific animal, except to establish that it was a mammal. From the size of the chess pieces, Dan suggested that their source was either equine or bovine hooves.

From a literature search I learned that hooves are built of several layers and are far from being homogenous, as they seem to be from the outside. Their only use is grounding them to powder for fertilizers and animal feed. However, chess sets made of horns were on sale in the mid-20th century, mainly in the USSR. Today, copies are manufactured in Vietnam from buffalo horns. Among the photos of the Vietnamese products on sale, I found sets similar to mine, but obviously more shiny and not peeling (Figure 4). I informed Dan of this and he promised to repeat the analysis with a method he was currently developing, that would establish the horn origin more precisely. A week later I received the second answer: The existing databases negated equine origin, but still could not distinguish between bovine and ovine origin.

The bottom line is that I can relax. My chess set is almost certainly made of sheep horn.

References

- [1] Mark Jacobson, *The Lampshade: A Holocaust Detective Story from Buchenwald to New Orleans*, Simon & Schuster, USA, 2010.
- [2] Matthew Collins *et al.*, *Spectroscopy Europe*, 2010, **22**, 6–10.

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