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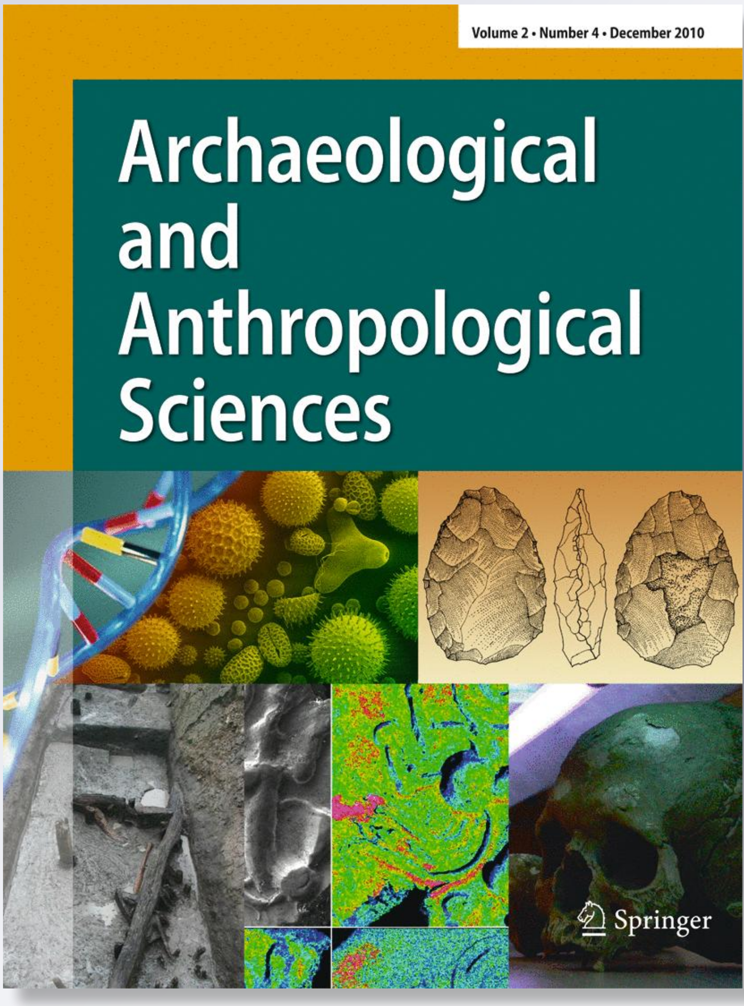

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ORIGINAL PAPER

A Fisk patent metallic burial case from Western Missouri: an interdisciplinary and comprehensive effort to reconstruct the history of an early settler of Lexington, Missouri

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Abstract In 2006 a cast-iron coffin was discovered in an unmarked burial plot in Lexington, Missouri. A multifaceted investigation was conducted to provide historical documentation and possible identification of the individual. The coffin is an early Fisk Patent Metallic Burial Case. Osteological analyses indicate that the skeletal remains belong to a 20 to 30 year old white female who consistently ate an omnivorous diet with significant amounts of C4 plants or seafood. Rib morphology and her burial garments suggest she frequently wore restrictive clothing. No gross skeletal pathological lesions or trauma were observed except for a patch of reactive bone and an atypical pattern of bone remodeling on the visceral surface of the sixth rib. Subsequent bacterial DNA analysis of the ribs and sternum indicate the presence of tuberculosis infection. Although not conclusive, multiple lines of evidence are consistent with the skeletal remains representing Elizabeth (Triplett) Stewart who died in 1854 of pulmonary tuberculosis. This multidisciplinary research significantly contributes to the local history of Lexington, Missouri and provides a likely identification of the deceased individual for the Stewart Family.

Keywords Historic archaeology · Stable isotope · Tuberculosis · Corset · Fisk coffin · Paleopathology

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Introduction

Accidental discovery of historical cemeteries and graves are not uncommon in modern urban areas, and the information gleaned by studying the human remains and artifacts can offer significant insights into the health, lifestyles, and mortuary practices of the people of the times (Lee and Magilton 1989; Jamieson 1995; Allen IV 2002; Katzenberg et al. 2005; Kjellström 2005; Owsley et al. 2006). The study of cemeteries and burials also appeal to the public and allow anthropologists to showcase the kinds of information that can be attained from such studies (Mytum 2007). In addition, studying historical cemeteries and graves can provide researchers with a tool for evaluating analytical methods.

During excavation of a grave plot for a recently deceased patron in November 2006, workers at the Machpelah Cemetery in Lexington, Missouri discovered an unmarked grave containing an ornately designed cast-iron coffin. The grave plot had been purchased by John Shotwell Stewart in 1850, but the plot was not marked with a head or foot stone. The Stewart family descendants and the Machpelah Cemetery Board requested the coffin be removed and the skeletal remains analyzed to help identify the individual inside. The coffin was transported to the Human Skeletal Identification Laboratory (HSIL) at the University of Missouri and opened under the observation of an audience that included members of the Stewart family and the Machpelah Cemetery Board, students, and local media (Sewall 2007; Stonacek 2007). A multifaceted and multi-disciplinary study was then undertaken to derive as much historical information as feasible and to facilitate identification of the deceased individual. The relatively rare cast-iron coffin is documented and the results of multiple analyses of the skeletal remains and associated historical artifacts are presented. The discovery and analysis of the coffin and its contents provides a unique opportunity to document and obtain historical information that contributes to our knowledge of mortuary practices, social customs, dress, diet, health, lifestyle, and commodity in mid-19th-century Missouri. In addition, the study provides a possible identification of the deceased individual for the Stewart Family.

Historical background

Lexington, Missouri is platted on the south bank of the Missouri River in Lafayette County. Established in 1822, Lexington was largely settled by Kentuckians. It became the seat of Lafayette County in 1823. Lexington is also the site of several prominent historical events including the tragic Saluda steamboat accident in 1852 that killed an estimated 75 people (Hartley and Woods 2002; Lloyd 2002), and the major Civil War Battle of the Hemp Bales (Monaghan 1984). More importantly, because of its proximity to the Missouri River and emphasis on trade and agriculture (primarily cattle, tobacco, and hemp), Lexington attracted a great deal of steamboat traffic and became one of the most populous and prosperous cities west of St. Louis from the 1830s through the 1850s (Lexington Chamber of Commerce (LCC) 2008). In the 1840s, the Russell, Majors and Waddell trading firm was established in Lexington, making the city one of the major settlements outfitting wagons for explorers and settlers traveling west on the Santa Fe, Oregon, Mormon, and California Trails.

The Machpelah Cemetery in Lexington, Missouri was established in 1849. The cemetery contains the remains of numerous settlers, Civil War soldiers, and the victims of the Saluda steamboat accident. John Shotwell Stewart purchased lot C-41 in the Machpelah Cemetery on 15 October 1850 for 20 dollars (Missouri Record of Deeds 1850). Today many of Mr. Stewart's descendants are buried in this section. The cast-iron coffin discovered in 2006 was in plot two of lot C-41.

John Shotwell Stewart was born on March 22, 1820 in Mason County, Kentucky to William N. and Abigail Stewart. He grew up in Mason County where he is recorded in the 1820, 1830, and 1840 U.S. Census. On May 9, 1844, he signed a contract with his father to purchase carpentry tools and some household items under a mortgage (Mason County Mortgage Books 1844: Book 53). On December 2, 1844, he married Elizabeth Triplett in Mason County, Kentucky (Mason County Kentucky Marriage Bonds 1844 to 1845). Shortly afterwards John and Elizabeth migrated to Lexington, Missouri. Lafayette County Deed Records indicate that John purchased three lots in Lexington at 12th and South Street in 1847. The 1850 U.S. Census lists John Stewart as living in Lexington and employed as a carpenter. Living in the household was also his wife Elizabeth, who was 22 years of age at the time, his 6 month old son John W.H. Stewart, his cousin Christopher M. Stewart (age 22 years) and Ezra Boyen (22 years old). Christopher Stewart and Ezra Boyen were both listed as carpenters in 1850 Census, and Christopher is buried in the Machpelah Cemetery near the Stewart plot. Elizabeth and John W.H. both died in the early 1850s and most likely were buried in the Machpelah Cemetery. Elizabeth's obituary indicates she died of pulmonary consumption (*Lexington Weekly Express* 1854:3), known today as tuberculosis. Approximately 6 months after Elizabeth's death, John married Georgia Ann Williams in Lexington, Missouri. John and Georgia moved to a farm in Lafayette County in 1858 and raised nine children. Many of the descendents of John and Georgia Stewart still live in the

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area. On August 23, 1858, Abigail Stewart (John Shotwell's mother) died in Lexington, Missouri at the age of 64 years. She too most likely was buried in the Machpelah Cemetery but there are no clear records of this event. In 1867, John Stewart is listed as a farmer in the militia enrollment papers but he was exempted from the militia based on his advanced age (Post-Civil War Militia Enrollment Papers 1867). As a carpenter in Lexington he built the staircase and some of the cabinets for the famous Oliver Anderson House and the William Limrick or Linwood Lawn mansion, both today listed on the National Register of Historic Places. John Stewart died on November 3, 1885 on his farm and was buried in the Machpelah Cemetery. At the time of his death he owned approximately 400 acres of land, 35 acres of corn and cattle, sheep, hogs, and mules. He left his nine living children $264.27 each.

Materials and methods

The coffin and its contents were examined by a multidisciplinary team of specialists generally following the analytic protocol outlined by Owsley et al. (2006). The collection of computed tomography scans of the body and associated artifacts in the coffin prior to its opening was not possible due to the lack of appropriate facilities. The protocol employed includes 1) describing and measuring the coffin, 2) recording taphonomic observations, 3) identifying and analyzing the clothing and other artifacts, 4) cleaning and preserving the skeletal remains and associated artifacts, 5) conducting an osteological analysis (metric and nonmetric) to develop a biological profile and to observe indicators of health and lifestyle, 6) photographing the coffin and its contents, and 7) conducting stable isotope, histological, and ancient DNA analyses of the bone. In addition, historical research was conducted to facilitate personal identification of the skeletal remains and to help identify the coffin availability.

Examination of the coffin

The coffin was transported to the HSIL at the University of Missouri in Columbia, Missouri by members of the Machpelah Cemetery Board. The external surface of the coffin was cleaned with a paint scraper and metal-wire brush to remove as much soil and rust as possible. A commercial water-displacing spray with viscous oil was used to clean oxidation from around the bolts and seam. The external surface of the coffin was then measured, photographed, and sketched. To open the coffin, the lid bolts were cut and drilled out and the seam between the upper and lower shells was loosened. A small hole was also drilled into the base of the coffin near the feet to drain water that had collected. Soil in the coffin was then removed with hand-held archaeological equipment following standard archaeological procedures. The location of human remains and artifacts was recorded and then the items were removed. Soil removed from the coffin was then sieved through a fine screen to trap any small artifacts or bones missed during excavation.

Examination of textiles and artifacts

All artifacts discovered within the coffin were cleaned and attempts were made to identify them. One piece of flat, ribbon-like cording, discovered above and below the skeletal remains, was further investigated to determine the identity of the fibers used in its manufacturing. The cording probably served as a stiffener for a negligee corset (Brinsko 2009). The initial exam of the cording was carried out using a Leica MZ16 stereomicroscope, capable of between 7X and 115X total magnification. Both transmitted and reflected light was used. Photographs and measurements were taken using the Olympus DP-70 digital camera with DP Controller software.

Fibers which were already loosened or separated from the intact cording were cut away using a Teflon®-coated razor blade. The fiber was mounted on a glass microscope slide using temporary mounting media: Cargille Refractive Index Liquid (R. P. Cargille Laboratories, Inc). The mount was coverslipped and examined using a transmitted polarized light microscope (PLM) equipped with a rotatable analyzer and first order red (530 nm) compensator (100X—1000X magnification). Cross-sections were made across the width of several individual fibers from the cording to produce cross-sections which were thin enough for PLM observations. The cross-sections were mounted dry on a glass slide first, then later in Cargille Refractive Index Liquids® for observations.

To preserve the arrangement of the hairs making up the cording, Norland Optical Adhesive (NOA) #65, $n=1.524$, was used to embed a small part of the whole cording. A 2×3 mm section of the cording was cut. Several layers of NOA, which cures under long wave UV light (350—400 nm), were placed over the cording section on a clean glass slide until it was completely enveloped. The NOA was cured after each new layer addition for approximately 15 min using a hand-held UV light source. Once the medium was satisfactorily cured, and the cording was entirely embedded, a Teflon®-coated razor blade was used in hand-sectioning the whole cording piece in the same manner as described above for individual fibers. Observations were made using both the stereomicroscope and PLM.

Scale casts were performed on several individual hairs as follows: a thin layer of clear nail enamel was painted on a clean glass slide and allowed to partially set for approxi-

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mately 30 s. A fiber was then gently placed on the nail enamel until the enamel hardened. Once hard, the fiber was pulled up from the nail enamel. If scales are present, their imprint will remain in the nail enamel and can be viewed using transmitted light microscopy.

In order to determine if any binder was present in the cording, a small piece of cording (approximately 10×3 mm) was placed in a Pyrex® test tube and immersed in approximately 1 mL of room temperature chloroform. Chloroform will extract most organic binders, if present, into solution, and the cording would be expected to break up (Skip Palenik 2008, pers. comm.).. The chloroform supernatant was then spotted onto a KBr salt plate for transmitted FTIR microspectoscopy, using a Mattson Galaxy 5020 equipped with a Quantμm Infrared Microscope. Any spectra obtained were searched against an extensive IR library.

Multiple individual fibers from the cording were removed and mounted for polarized light observations. Several other fibers were also detached from the cording and scale casts were attempted. A thin coat of clear nail lacquer was applied to a clean glass slide. After it had thickened slightly, the hair was laid on the nail lacquer while it hardened. Once dry, the hair was gently pulled out of the nail lacquer, and the imprint was examined microscopically to determine if scales were present or absent. Cross-sections of several fibers were produced by hand and examined under a microscope to determine cross-sectional morphology of the fiber.

Examination of the skeletal remains

The human skeletal remains were inventoried and standard osteometric dimensions of the skull and postcranium were recorded following Buikstra and Ubelaker (1994). The skeleton was also grossly analyzed to develop a biological profile and to record any indicators of disease, trauma, diet, and habitual behavior evident on the bones.

A biological profile was established using standard osteological methods for the estimation of sex, age, ancestry, stature, and body mass. Metric and nonmetric traits of the pelvis, cranium, and long bones were used to determine sex (Bass 1995; Buikstra and Ubelaker 1994; Moore-Jansen et al. 1994; Ousley and Jantz 2006). Age-at-death was estimated by examining age-related morphological changes in the long bone epiphyses (Bass 1995), pubic symphysis (Katz and Suchey 1986), auricular surface (Lovejoy et al. 1985), sternal rib ends (Işcan et al. 1984), and cranial sutures (Meindl and Lovejoy 1985). Ancestry was estimated using nonmetric traits of the skeleton (Gill and Rhine 1990) and comparing the morphometric data from the cranium with selected 19th and 20th century reference samples using Fordisc 3.0 (Ousley and Jantz 2006). Stature was estimated using long bone regression equations for 19th century white females in Fordisc 3.0 (Ousley and Jantz 2006).

Each bone was examined macroscopically for evidence of traumatic injury, disease, and abnormal morphological variation (Buikstra and Ubelaker 1994; Ortner 2003). The dentition and jaw bones were also examined for dental caries, antemortem tooth loss, abcesses, periodontal disease, calculus formation, and linear enamel hypoplasia (Buikstra and Ubelaker 1994).

To help reconstruct the lifestyle of the individual in the coffin, muscle attachment locations, bone dimensions and femoral cross-sectional structural properties were examined. Structural properties of long bones (cortical area and moments of area) can be used to reconstruct the loading forces placed on bone during life due to activity patterns and intensity. Cortical area (CA) provides information on the bone's strength in compression and tension loads, while bending and torsional rigidity of the bone is estimated using the second moments of area (I) and polar moments of area (J), respectively (Ruff 2008). Several variables were calculated from the external dimensions of the long bones to provide a proxy for the biomechanical properties (Wescott 2001). A bone shaft shape index was obtained for the following areas: femoral midshaft and subtrochanteric, tibial nutrient foramen, and humeral midshaft. Shape was calculated for the femur and tibia as the ratio of the anteroposterior (AP) and mediolateral (ML) diaphyseal diameters. The ratio of the maximum and minimum shaft diameters was used for the humerus. The shape index provides a proxy for the second moment of area ratios (I_x/I_y and I_{max}/I_{min}) obtained from diaphyseal cross sections (Pearson et al. 2006; Ruff 1987; Stock and Shaw 2007; Wescott 2001, 2006). An estimate of the polar second moment of area (J) was calculated at femur subtrochanteric and midshaft using the equations provided by Pearson and colleagues (Pearson et al. 2006). Due to the relationship between body size and bone shaft strength, the cross-sectional properties were divided by the product of body mass and bone length (Ruff 2000). Body mass was calculated using femora head diameter with Ruff et al.'s (1991) female regression equation, which is based on a population from Baltimore, MD. European American females born in the mid-19th and early 20th centuries and living in St. Louis, Missouri at death were used for comparison. The sample included skeletal dimensions for 52 women from St. Louis with an average age of 47 years. The skeletal remains used for comparison are part of the Robert J. Terry collection housed at the Smithsonian National Museum of Natural History.

Histological analysis

A left sixth rib and a midshaft femoral section were prepared for histological age-at-death estimation. A visual

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inspection of the rib cortex revealed the presence of an approximately one inch patch of reactive bone on the periosteal surface of the pleural cortex (surface near the lungs). No sign of pathology was observed on the femoral section. To ensure the integrity of the bone during sectioning and grinding, the two bone samples were embedded in a resin medium, Epo Thin® (Buehler Ltd., Lake Bluff, IL). Three transverse wafers, each approximately 100 µm thick, were removed from each bone using a low speed Isomet metallurgic wafering saw (Buehler Instruments, Evanston, IL). The resulting wafers were then manually ground to a thickness of approximately 80 µm using 400 grit carbon embedded paper following the method developed by Frost (1958). The thin sections were then mounted on glass microscope slides and cover slipped using Permount®. The cortical sections were examined with a standard research microscope under both transmitted and polarized light.

Ancient DNA analysis

Bones of the thoracic cage were examined for the presence of tuberculosis bacterial DNA because of suspicion based on historical documentation and histological analyses of the rib. DNA was recovered from four bones of the same individual—the manubrium and body of the sternum and the first and second left ribs. The analyses were performed using facilities strictly dedicated to ancient DNA (aDNA) research, physically separated from the post-PCR working area and from the analysis of modern DNA samples. Furthermore, DNA extraction and PCR amplification procedures were performed in two different UV-irradiated hoods, located in two physically separated rooms, using different sets of pipettes. Only ultrapure reagents dedicated to aDNA analysis, sterile disposables and filtered tips were used while disposable protective clothing (gloves, coats, masks, and hair coverings) were worn throughout. Blank extraction (containing no bone material) and blank PCR (containing no DNA extract) controls were included in each set of the experiments to monitor possible contamination from non-relevant DNA and/or cross contamination between the samples.

Ancient DNA extraction was performed using a modified GuSCN-based method (Boom et al. 1990) and further analyzed for the presence of the IS6110 sequence of the *Mycobacterium tuberculosis* DNA complex using PCR. The DNA from the first rib was extracted in a separate procedure than DNA from the second rib, the manubrium and sternum. To reduce the risk of contamination from previous handling the cortical layer of the examined area was removed using a sterile blade. Bone powder was obtained by scraping of the freshly uncovered area and approximately 30 mg of it were collected into the 1.5 ml Eppendor tube containing 500 µl GuSCN-solution (4 M GuSCN; 0.1 M Tris-HCl, pH 6.4; 0.002 M EDTA, pH 8.0; 1.3% Triton). The tubes were mixed manually and then incubated with a slight agitation at 56°C over night. On the next day, DNA was extracted by binding to 10 µl of the in-house made silica suspension in the presence of 1 ml 6 M NaI, which was performed on ice for an hour, washed twice with 0.5 ml 70% ethanol, air-dried and then eluted in 100 µl of sterile PCR water at 56°C for an hour.

The insertion sequence IS6110 of the *Mycobacterium tuberculosis* DNA complex, which is present in 10-20 copies per bacterium (Thierry et al. 1990), was first targeted using primers INS1 and INS2 with an expected 245-bp amplicon (Van Sooligen et al. 1994). The DNA complex was then targeted with the primers P1 and P2, which amplify a 123-bp fragment (Eisenach et al. 1990). In order to increase the sensitivity and specificity of the reaction a semi-nested PCR was performed using IS-3 and P2 primers, resulting in the amplification of a 107-bp fragment. The primers oxyR1 and oxyR2 were used to amplify a 150-bp sequence of the single-copy *oxyR* pseudogene in an attempt to differentiate between *M. tuberculosis* and *M. bovis* (Fletcher et al. 2003). Primer sequences and PCR conditions are given in Table 1.

Ten µl of each aDNA extract were subjected to hot-start PCR amplification in a 25 µl reaction containing 1× buffer, 10 pmol of each primer, 0.2 mM of each dNTP, 1.5–2.0 mM MgCl2 and 1 unit of AmpliTaq Gold DNA polymerase (Perkin Elmer, Oak Brook, IL). Bovine serum albumin (BSA) was added to each tube at a final

Table 1 Primer sequences and PCR details

Target	Primer name	Primer sequence	Primer concentration	$T_{annealing}$	$MgCl_2$	Primer pair / Amplicon size
IS6110	INS1	5′-cgtgagggcatcgaggtggc-3′	25 ng/µl	68°C	2 mM	INS1+INS2 / 245 bp
	INS2	5′-gacgtaggcgtcggtgacaaa-3′	25 ng/µl		2 mM	
	P1	5′-ctcgtccagcgccgcttcgg-3′	10 pmol	68°C	1.5 mM	P1+P2 / 123 bp
	P2	5′-cctgcgagcgtaggcgtcgg-3′	10 pmol		1.5 mM	
	IS-3	5′-ttcggaccaccagcacctaa-3′	10 pmol	58°C	1.5 mM	+ P2 / 107 bp
oxyR	oxyR1	5′-cgcgctgtcagagctgacttt-3′	10 pmol	62°C	2 mM	oxyR1+oxyR2 / 150 bp
	oxyR2	5′-tctgcggaatcagtgtcacc-3′	10 pmol		2 mM	

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concentration of 0.8 mg/ml in order to overcome possible inhibition of the reaction. Five microliters of the first-round PCR products were used in the semi-nested amplification performed for 25 cycles. Fifteen microliters of aliquots of the PCR products were verified on the 2% agarose gels stained with ethidium bromide. Bands of the expected size were cut from the gels and PCR products were cleaned using QIAquick Gel Extraction Kit (QIAGEN) following the manufacturer's instructions except for that PCR products were finally eluted in 30 µl. Automated sequencing was performed at the DNA Analysis Centre of the Hebrew University of Jerusalem.

Stable isotope analysis of bone and teeth

Stable isotope analysis of human bone has been widely utilized in archaeological reconstructions of prehistoric diets since skeletal tissues are a product of the diet and there are some major differences in isotope values for different food groups (Tykot 2006). Carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotope ratios can be used to reconstruct diet in ancient human remains due to differential fractionation of atmospheric carbon dioxide by certain plant groups during photosynthesis and differential fractionation of nitrogen during fixation or absorption. Specifically, plants with the C4 (Hatch-Slack) photosynthetic pathway, including maize and sugar cane, stand out since they have enriched carbon isotope values relative to C3 plants (Calvin-Benson photosynthetic pathway), which include all trees and bushes and most wild grasses in northern latitudes. Plants that follow the crassulacean acid metabolism (CAM) photosynthetic pathway (mainly cacti) may also have relatively enriched $\delta^{13}C$ values, but CAM plants are very unlikely to have been important in this study. Nitrogen isotope values are also enriched through each trophic level so that the importance of meat and/or fish in the diet can be estimated.

There are important differences between skeletal tissues in how they reflect diet and over what length of time. Stable carbon and nitrogen isotope values derived from bone collagen reflect the average intake of dietary protein throughout the final years of an individual's lifespan (Ambrose 1993), at least when protein was a significant percentage of the total diet, while carbon isotope values in bone apatite and tooth enamel reflect the whole diet (protein, fats, and carbohydrates). Tooth enamel (and dentin), however, does not turn over, and thus represents diet at the age of formation, with isotope changes between certain teeth associated with age at weaning (Wright and Schwarcz 1998). Analysis of all three tissues thus provides information on the whole diet, as well as protein sources in particular, and changes over an individual's lifetime, such as migration or culture change.

All isotope measurements are reported using delta notation ($\delta^{13}C$, $\delta^{15}N$) and, following internationally recognized standards, are expressed in parts per thousand or per mil (‰). C3 plants have average values of about −26‰ and C4 plants such as maize have values about −10‰, but these values can vary among the particular species in a given geographic area. In ideal cases, values for the plants most likely to have been consumed are tested so as to be more precise in the interpretation of the results. The carbon in bone collagen is typically enriched +5‰ relative to the plants consumed, while the carbon in bone apatite or tooth enamel is enriched about +12‰. Nitrogen (only in collagen) is typically enriched about 3‰ relative to dietary protein for each trophic level.

Carbon isotopes were measured on bone collagen, bone apatite, and tooth enamel from the unknown individual. The location of Lexington, Missouri makes it unlikely that there were any native C4 plants, so that higher carbon isotope values would most likely be the result of maize and/or seafood in the diet. High nitrogen isotope values would reflect consumption of aquatic resources rather than maize, especially if the apatite carbon isotope values were proportionally less towards C4 plants than the collagen carbon isotope values (since maize only has about 10% protein).

Bone collagen and apatite samples were derived from the proximal end of the right fibula, while first and second molar teeth were taken from the mandible. Bone collagen, apatite, and tooth enamel samples were extracted using well-established, standardized laboratory methods, and prepared using procedures designed to remove non-biogenic carbon without altering the biogenic carbon isotopic values (Tykot 2004; 2006). The preservation of these samples was excellent, with a very high bone collagen yield, and consistent yields at each stage of the preparation process for the bone apatite and tooth enamel samples. All sample preparation and the subsequent analyses were conducted at the University of South Florida, with samples analyzed (along with standard reference materials) on dedicated Finnegan-MAT Delta Plus XL mass spectrometers, one equipped with a CHN analyzer (for organic collagen samples), and the other equipped with a Kiel III device (for inorganic apatite/enamel samples). For collagen, the reliability of the results obtained are supported by the sample processing yields, the mass spectrometer signal strength of the C and N signals produced, and their C:N ratios.

Facial reconstruction

Artistic renderings developed from an unidentified human skull provide a visual representation of unknown individuals and can aid with postmortem identification. Two-

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dimensional facial reconstruction is a process of recreating a facial image using information extracted from a human skull. There are two phases in this process, the technical and artistic. Information on sex, age, and unique facial characteristics were obtained from the skeletal analyses.

In order to conduct the facial reconstruction, the mandible was first mounted in anatomical position and cranial and mandibular landmarks were marked on the bone. Facial tissue depth markers corresponding to the soft tissue thicknesses for white females (Taylor 2001) were attached to the appropriate landmark on the skull (Taylor 2001). Next, the skull was photographed on the Frankfort Horizontal Plane (FHP) utilizing a 50 mm lens mounted on a Pentax SLR 35 mm digital camera and with the barrel of the camera lens perpendicular to the FHP. The skull was photographed with and without a calibrated scale since scaling the image to a 1:1 ratio was necessary before the drawing process could begin. A calibrated scale allows for accurate print enlargement as long as the barrel of the camera lens is perpendicular to the scale. Images were taken of both the frontal and lateral views of the skull.

Once the images were enlarged to a 1:1 ratio, the frontal and lateral view photographs were placed side-by-side on the drawing board to begin the artistic phase. Vellum paper was used for the drawing surface. The placement of the eyes and ears and width of the nose and mouth were determined using skeletal and dental landmarks following guidelines in Taylor (2001). The recovery of the intact hair mat facilitated drawing the hair, which was brown, naturally wavy, and twisted into a bun. Research was conducted to observe hair styles for women during the early to mid-1800s. The hair mat was also placed on the skull using a female model to determine the most likely position of the bun. Adding additional facial details and clothing was the last step. Facial features were drawn to depict a woman slightly older looking than a person in her mid to late twenties based on today's standards. The lifestyle of women during that era was often physically demanding and they were often exposed to the elements for prolonged periods of time. Prolonged skin exposure to sun and wind promoted premature aging. After refining the face and neck, clothing was added. The collar design was obtained from clothing examples women wore during that era. Upon completion of the rendering, the image was scanned into Photoshop® and several contrast adjustments were completed.

Toxicology of hair and nails

Finger nail and head hair samples were sent to the St. Louis University Toxicology Laboratory and examined for the presence of narcotic alkaloids and derivatives of opium (*Papaver sominiferum*) and coca (*Erythroxylum coca*) plants. Morphine, codeine, and cocaine were commonly available and used for pain management of diseases in the 19th century (Meldrum 2003). Two samples of finger nail and two samples of head hair were digested using concentrated nitric and perchloric acids. The samples were then analyzed on a flameless atomic absorption using the Zeeman technique.

Results

Examination of coffin

The coffin is a Fisk Patent Metallic Burial Case in the style manufactured from 1848 to 1853 (Boffey 1980; Fisk and Raymond Company 1850; Habenstein and Lamers 1955). It is a mummy-shaped cast-iron case and approximately 181 cm (71 in.) long and 50 cm (20 in.) wide at its widest point on its shoulders (Fig. 1). The coffin consists of two shells (upper and lower) of nearly equal height joined with a flanged seam and secured with nine slotted-head bolts on each side. There are three ornately decorated swing-bail handles (Fig. 2) on each side; one near the head, one at the hip region and one near the feet. After cleaning the handles swiveled. The lower shell or base of the coffin is decorated

Fig. 1 Photograph of the Fisk Patent Metallic Burial Case from the Macpelah Cemetery in Lexington, Missouri (**a**) and an illustration of the upper shell design (Photograph by Daniel Wescott, 2007; Drawing by Marc Oliver, 2007)

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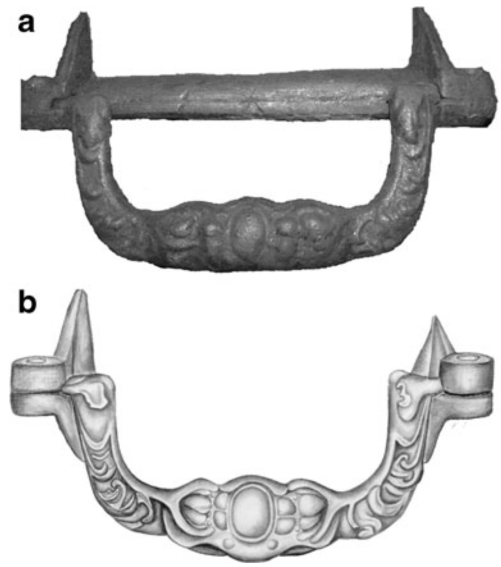

Fig. 2 Photograph of the rear handle (**a**) and illustration of the handle design (**b**) (Photo by Daniel Wescott, 2007; Drawing by Marc Oliver, 2007)

with parallel grooves spaced approximately 2 cm or 3/4 in. apart running perpendicular to the long axis. The upper shell or lid is ornately decorated as a person draped with a cloth (Fig. 1).

At the head end of the upper shell is an oval glass viewing plate and removable metallic cover (Fig. 3). The metallic cover is decorated with an oak leaf and acorn design surrounded by an oval of leaves and berries. The viewing window cover hinges cranially and is secured with a single slotted-head bolt caudally. Paint (possibly white) was still apparent on portions of the viewing window cover, and the viewing window is intact but no longer transparent (Fig. 3).

The chest region of the lid was damaged by heavy machinery during discovery of the coffin, but reconstruction was possible. The chest region is designed to resemble a cloak draped over the shoulders with a smooth rectangle area with no apparent design. The rectangular area was for an inscription or placement of a plate (Fisk and Raymond Company 1850). Commonly the plates were made of thin metal adhered to the coffin and were not durable (Boffey 1980).

At the foot of the coffin is an oval with a thistle flower design (Fig. 4). The thistle flower was a common mortuary symbol for remembrance and sorrow and pain in Christianity (Hall 1994). At the most caudal end of the burial case is a circular patent seal (Fig. 5) indicating the coffin design was patented by A.D. Fisk on 14 November 1848 in New York. Cross-marks in the shape of an X were etched across the seal between the upper and lower shells near the foot end (Fig. 6). This marking may have been used to match upper and lower cases that were fitted.

Taphonomy and mortuary practices

Upon arriving at the University of Missouri, the coffin contained a dark soil over the body in the damaged chest area. The cranium was visible when looking into the damaged area but the lower extremities were covered with reddish-brown water. After the water was drained, 5 to 10 cm of reddish-brown soil covered the bottom of the coffin indicating that the coffin seal had probably been compromised. Contamination of the coffin soil by dirt that fell into the damaged area of the coffin lid made microbiological examination of the soil pointless.

The coffin contained a moderately well preserved skeleton in anatomical position (Fig. 7). The majority of soft tissue had decomposed but head and pubic hair along with many of the finger and toe nails were discovered in their proper anatomical locations. While the coffin seal had been compromised allowing water into the case, it does not appear to have caused any significant movement of the bones or artifacts. The body lay supine in an extended position. The arms were at the side with the right forearm and hand bent so the hand rested over the lower chest, and the left forearm was turned so the left hand lay on the left hip. It is possible however, that postmortem movement of the limbs resulted in the placement of the upper limbs. The

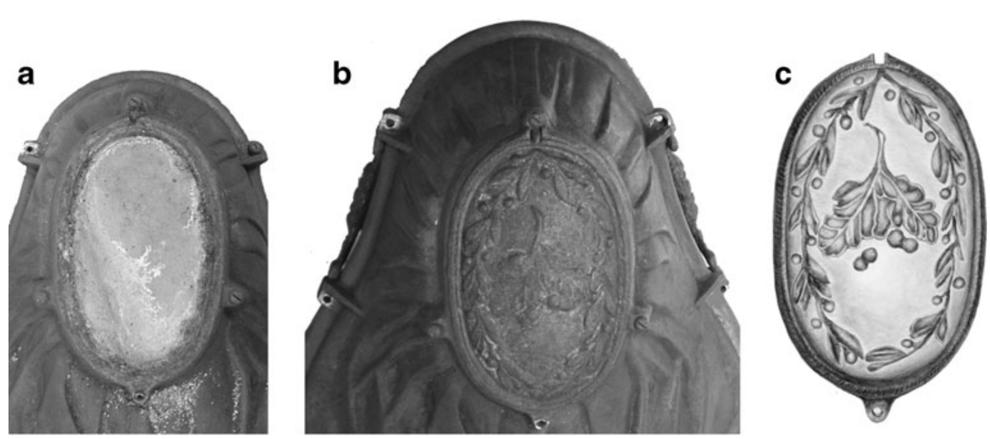

Fig. 3 Viewing window (**a**) and metallic cover (**b**) with artistic illustration (**c**) of the floral design of the viewing window cover (Photos by Daniel Wescott, 2007; Drawing by Marc Oliver, 2007)

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Fig. 4 Thistle floral design on foot of the burial case (Photo by Daniel Wescott, 2007)

Fig. 5 Fisk Patent Stamp located at the foot end of the Fisk Case that reads "A.D. Fisk Patent, New York, Nov 14, '48" (Photo by Daniel Wescott, 2007)

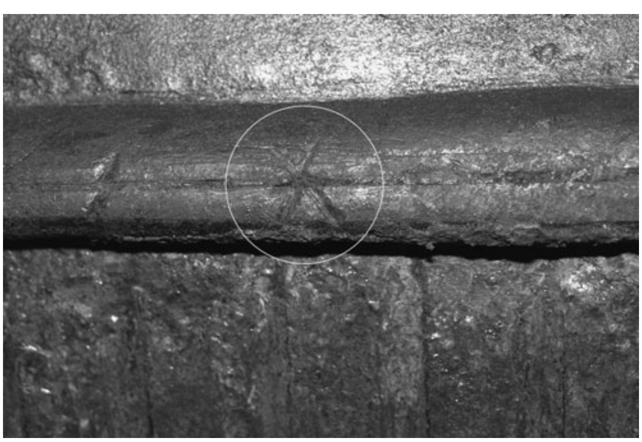

Fig. 6 Cross-marks etched (*within circled area*) across the seal between the upper and lower shells near the foot end likely to indicate fit between the upper and lower shell (Photo by Daniel Wescott, 2007)

Fig. 7 Lower shell of coffin containing skeletal remains and artifacts as observed upon opening (Photograph by Jeff Nichols, 2007)

thigh and legs were extended but the right femur and tibia were laterally rotated. This is probably the result of postmortem movement. The body appears to have been fully clothed, including shoes and a veil on the face, but deterioration of many of the textiles prevents complete reconstruction of the individual's burial attire.

Examination of textiles and artifacts

All of the artifacts discovered within the coffin are associated with clothing or coffin lining. A light color weave textile of linen, cotton, hemp, or similar natural fibers that was probably part of a chemise was discovered over the ribs, pelvis, and the proximal thighs (Fig. 8). Large fragments of a tightly woven black fabric were discovered that appears to have covered from at least the shoulders to below the knees (Fig. 9). The black textile is clearly external to the light colored chemise fabric and is adhered to the coffin sides and bottom in several places. It is likely this textile was part of a dress. Fisk Cases were generally lined only around the head so it is unlikely the fabric is part of the coffin lining (Boffey 1980). A light colored tulle material was found near the cranium and was probably a face veil. During removal of soil in the coffin several long (~8 in), narrow (1/4 in.), and thin rectangular cords were found running parallel to the long axis of the body in the abdominal region external to the chemise material. Upon

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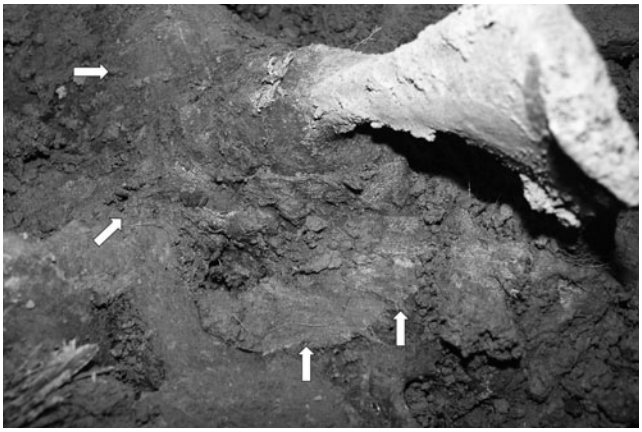

Fig. 8 Light color weave textile (*indicated with arrows*) coving left hip region that is likely part of a chemise (Photo by Daniel Wescott, 2007)

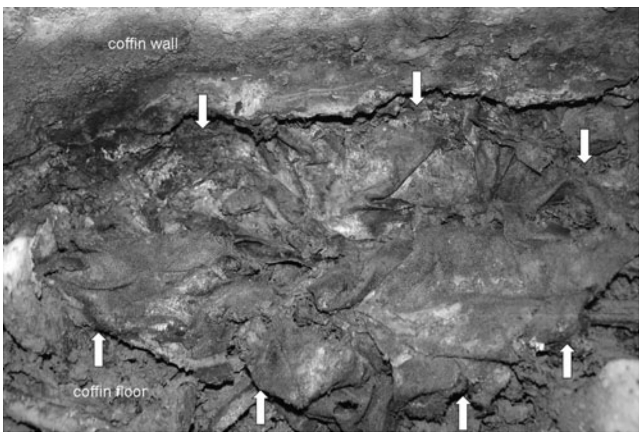

Fig. 9 Black fine weave textile (*outline indicated by arrows*) under left side of skeleton that is likely part of a dress (Photo by Daniel Wescott, 2007)

removal of the skeleton, six more cords were found. The length and width of the cords and their pattern of distribution within the coffin is consistent with cords stitched into a corset. Specifically, these cords resemble the pattern and length of cording seen in a "two breast, two hip gusset corset" often referred to as a negligee corset (Grimble 2004). The individual was also wearing a pair of black leather shoes. Leather heels and fragments of the leather shoe back were present (Fig. 10). The only other artifacts discovered were three white shell buttons. One was 3/8 in. diameter with four holes and two are 1/4 in. diameter with 3 holes. Based on the textiles present, it appears the woman was wearing a chemise and corset under a black dress. She also wore black leather shoes on her feet and a veil over her face.

Microscopic analysis of possible corset cording

One of the cords thought to be associated with the gusset corset was examined to determine how it was manufac-

Fig. 10 Leather shoe heals (Photo by Daniel Wescott, 2007)

tured. The cording dimensions measure approximately 105 mm long, 7 mm wide, and 1 mm thick. The cording is generally flattened and rather stiff, but not perfectly straight; it is bent or curved in several places. The cording appears dark brown by reflected light, with some regions of golden brown or rust-colored adherent particles. One side of the cording shows texture, and individual fibers can be visualized and followed along the length of the cording (Fig. 11a). Together these fibers form the cording, and run straight and roughly parallel to each other. In some areas several individual fibers are beginning to separate from the main body of the cording. A close look at the textured side of the cording reveals the presence of a second type of fiber laying atop the straight parallel fibers, much smaller in diameter and with a much more twisted and irregular morphology (Fig. 11b). These fibers were picked off and mounted for polarized light microscopy. The fibers are natural fibers, presumably textile fibers given the context of the corset cording, and a cursory examination indicates they may possibly be flax (linen) or hemp. On the untextured side of the cording appears very smooth, and while slight longitudinal striations are evident, individual fibers cannot be seen (Fig. 12a). This side of the cording is very flat and even and also contains the majority of golden brown and rust-colored adherent particles (Fig. 12b).

A small piece of an individual fiber of the cording (already beginning to separate from the rest of the cording) was removed and mounted for polarized light observations (Fig. 13a). By transmitted light the fiber was dark brown to tan in color, appearing more darkly colored where it was thicker. More importantly, brown pigment granules (melanin) were visible, indicating that this fiber is a mammalian hair. The fiber's birefringence and sign of elongation are also consistent with hair. The diameter for all hairs that were observed ranged from 150–250 μm, indicating that this hair was not of human origin (typical human hair diameters have a range of about 40–120 μm). Microscopical exam of the cross section also shows that the sides of

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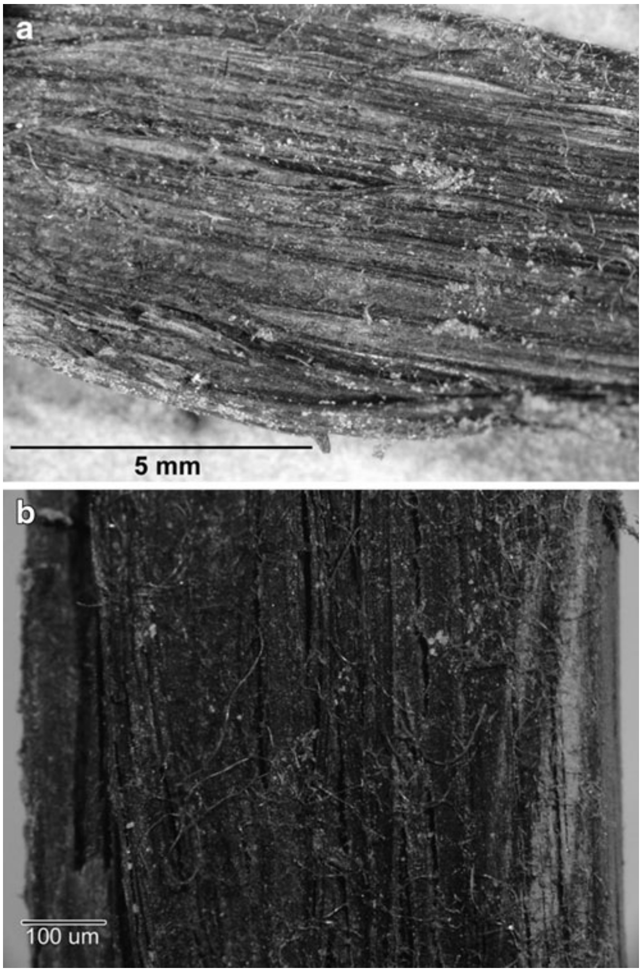

Fig. 11 Texture side of corset cording showing the primary parallel fibers (**a**) and secondary fibers atop (**b**) (Photos by Kelly Brinsko, 2008)

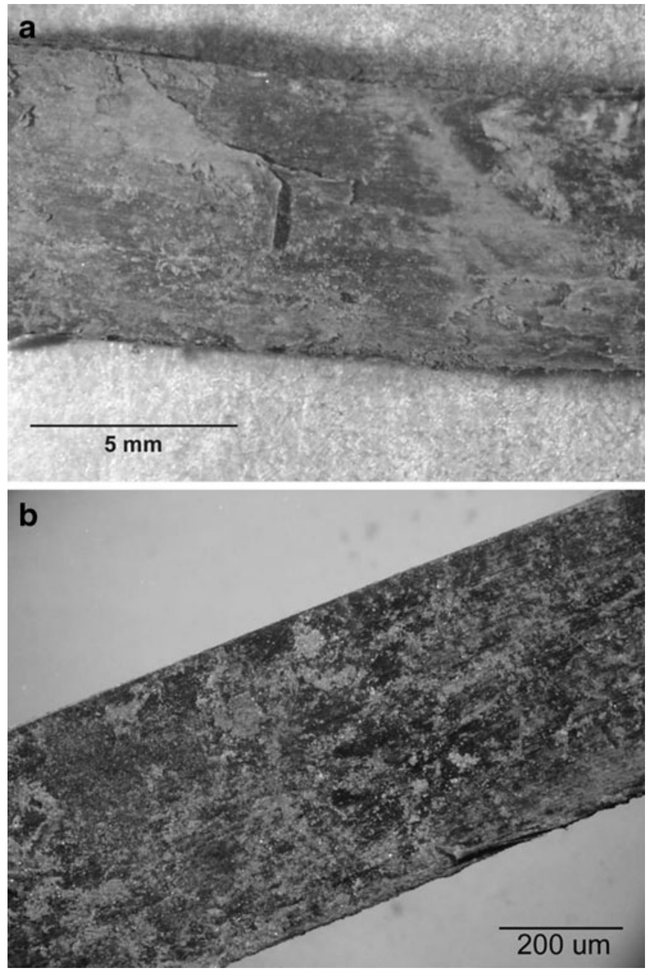

Fig. 12 Smooth untextured side of corset cording which is flat and even (Photos by Kelly Brinsko, 2008)

some of the hair fibers (Fig. 13b) are somewhat uneven and appear to show evidence of degradation or injury to the hair. Other hairs, however, appeared to be smooth, with no obvious damage. There was no evidence of fungal attack or growth on any of the hairs observed.

The cross-sectional shape of individual hairs ranged from circular to completely flat. Severe degradation of the cuticle and some areas of the cortex were noted. Cuticle scales were detached or beginning to detach. Cortical cells showed signs of separation, and, interestingly, the melanin pigment granules appeared to form concentric rings around the medulla (Fig. 13b).

Transverse cross sections were also made on the cording as a whole (Fig. 14), rather than just individual fibers. Results were surprising, showing some hairs that appeared to have softened and flattened into the ribbon-like shape of the cording. Some individual hairs had medullary canals, but other, more flattened hairs, did not. Note that only on one side of the cording are the hairs flattened. This side is the smooth side seen on the intact cording, and explains why individual hairs could not be visualized. The textured side shows hairs that have a nearly circular cross-section and are easily individualized, which was clearly seen macroscopically and with the stereomicroscope on the intact cording. The flattening and distortion of the fibers on one side of the cording is possibly an artifact of the degradation of the hairs, perhaps from contact with the immediate environment within the coffin. Another cause may be the use of the cording as the corset boning and the hairs may have simply become flattened from continued use in the corset (Fig. 14).

Species determination is typically based on the shape and arrangement of the cuticle scales, as well as the morphology of the medullary cells and relative size of the medulla. Scale casts that were performed on several hairs indicated that scales were no longer present or intact. Because of the advanced state of degradation of the medulla, cell morphology could not be observed and the medullary ratio (defined as the diameter of medulla divided by the diameter of the hair, and often used to distinguish

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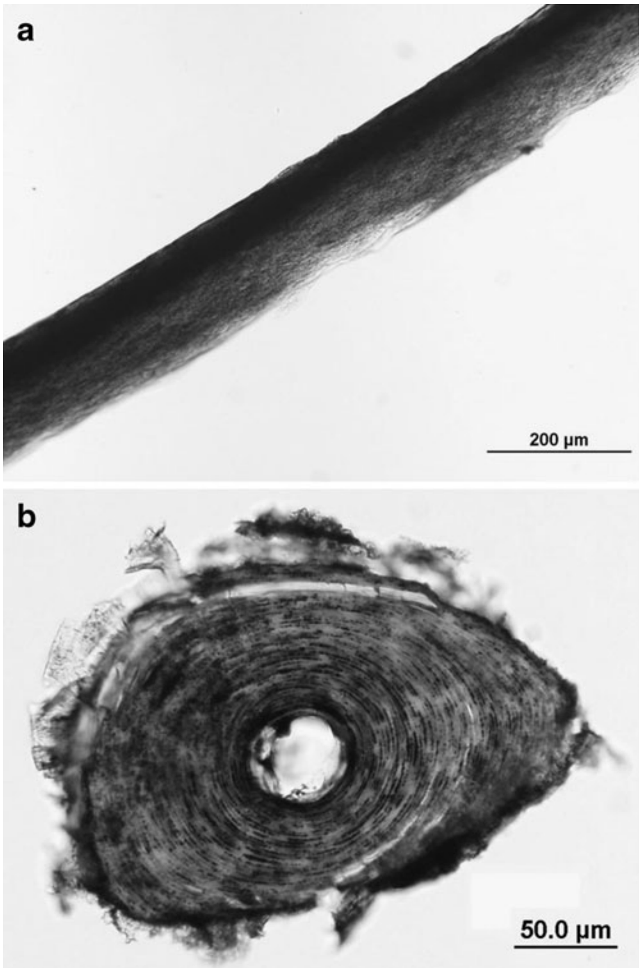

Fig. 13 Corset cording fiber (**a**) and cross-section (**b**) (Photos by Kelly Brinsko, 2008)

between human or non-human hairs) could not be measured reliably. Therefore, an accurate species determination is impossible. Based on thickness alone, however, the hair is non-human. Horse hair (tail or mane) was a very common textile fiber during the mid-1800s, and has a thickness consistent with that of the cording fibers. This is therefore the likely source, but it is not the only possibility.

Chloroform was used in an attempt to extract any binder that might be present in the cording. A small piece of cording was placed in a bath of chloroform, and did not break up in either room temperature or gently heated chloroform, indicating that binder was not present. Nonetheless, the supernatant was spotted onto a KBr salt plate for transmitted FTIR microspectroscopy. No spectra were obtained, signifying the absence of binder in the cording.

Examination of skeletal remains

Biological profile

Osteological analysis indicates the individual in the coffin was a 20 to 30 year-old white female. She was approximately 159.3 cm (62.7 in.) tall and weighed between 55.7 and 59.2 kg (122.5 to 130.3 lbs.). Head hair present indicates that she had relatively long brown wavy hair.

Age was estimated using multiple criteria. All the epiphyses exhibit complete closure except the medial epiphyses of the clavicles which are partially fused. Ectocranial suture closure had not commenced indicating an age of less than 30 years (Meindl and Lovejoy 1985). Morphological features of the sternal rib end suggest an age range of 20 to 24 years (Işcan et al. 1984), histological analysis of the femur provides an estimate of approximately 21 years of age (see below), and age-related morphological features of the auricular surface (Lovejoy et al. 1985) and pubic symphysis (Katz and Suchey 1986) are consistent with an age of 20 to 30 years.

Sex was estimated based on metric and nonmetric traits of the pelvis, long bones, and skull. Female traits in the pelvis include a wide subpubic angle, wide greater sciatic notch, long pubic bone with a ventral arc, subpubic concavity, and a narrow and ridged ischiopubic ramus. The postcranium is small and relatively gracile. The skull is gracile with no prominent mastoid processes, nuchal ridge, or supraorbital ridges. Craniometric analysis also clearly indicates the sex as female. In a comparison of white males and females using FORDISC 3.0, the cranium from the cast-iron coffin classifies as female with a posterior probability of 0.998 and a typicality of 0.999. This indicates the skull is very typical of a white female.

Ancestry was estimated by examining metric and nonmetric traits of the cranium. Discriminant function analysis was conducted using 17 cranial measurements and comparing

Fig. 14 Cross-section of the whole corset cording showing flattened hairs with no medullary cavity on the untextured surface and less flattened hairs with clear medullary cavities on the textured surface (Photo by Kelly Brinsko, 2008)

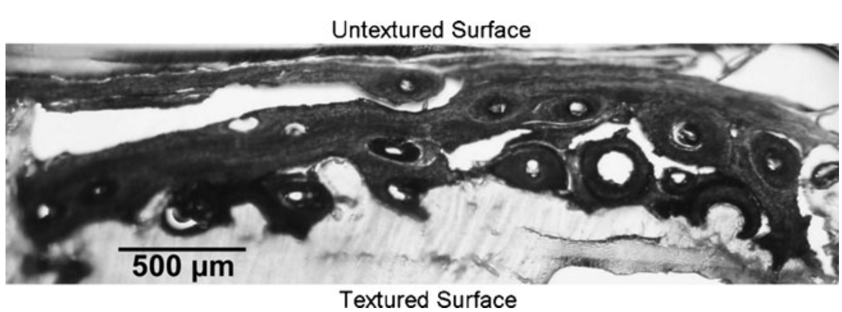

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Table 2 Femur shape and strength for Lexington female and St. Louis females

Variable	Lexington female	St. Louis females[a]
Stature (mm)	1593	1596
Body mass (kg)	59	61.6
Femur maximum length (mm)	425	427.1
Femur subtrochanteric AP diameter (mm)	25	26.8
Femur subtrochanteric ML diameter (mm)	29	27.2
Femur midshaft AP diameter (mm)	26	26.2
Femur midshaft ML diameter (mm)	22	25.3
Femur head diameter (mm)	42	42.7
Femur subtrochanteric AP/ML index[b]	89.3	99.3
Femur midshaft AP/ML index[b]	118.2	104.6
Femur subtrochanteric polar moment (J)	1659.4	1709.7
Femur midshaft polar moment (J)	1010.2	1405.6
Femur subtrochanteric section modulus (Z)[c]	95.1	95.9
Femur midshaft section modulus (Z)[c]	65	81.5

[a] mean value

[b] AP diameter divided by ML diameter multiplied by 100

[c] Polar section modulus which provides an estimation of bone strength

the measurements of the woman from the coffin to those of Native American, black American, white American, and Asian (Japanese) females using FORDISC 3.0. The woman classified as a white female with a posterior probability of 0.917 and a typicality probability of 0.992.

Stature was estimated using femur length (42.5 cm) at approximately 159.3 cm (5 ft. 3 in.) with a 90% range of 152.4 cm to 168.7 cm (5 ft. 0 in. to 5 ft. 5 1/2 in.). Femoral head diameter was used to estimate body mass and was found to be 122 to 130 lbs., a normal weight for a woman of her height and robustness. Her stature and estimated body weight are also near average for 19th century women from St. Louis (Table 2). The average stature and body mass estimates for the 52 women from St. Louis were 159.6 cm (~5 ft. 3 in.) and 61.6 kg (~135 lbs.).

Thoracic cage morphology

Visual examination of the skeleton revealed several abnormal morphological features of the thoracic cage, including flattening of the ribs and spinous processes of the vertebrae. Right ribs 6 through 12 and left ribs 7 through 12 exhibit anterior projection or flattening when compared to anatomical specimens (Fig. 15). Medial twisting of the inferior border (Fig. 15), which would result in lateral compression of the ribcage, was observed on ribs 8 through 11 on the right side and ribs 9, 10, and 11 on the left side. Minor flattening of the lower thoracic and upper lumbar spinous processes was also noted.

Skeletal and dental pathology

A macroscopic examination of each bone failed to uncover any indications of healed or unhealed trauma or lesions associated with disease, except for a patch of reactive bone on the pleural surface of one rib. No indications of osteoarthritis or other degenerative changes were observed.

The dentition, however, shows significant pathology. Positioning of the maxillae and mandible indicates she had a moderate overbite, a common orthodontic condition. The lower anterior teeth also exhibit slight crowding, dentine exposure, and significant plaque buildup on the lingual surface (Fig. 16). Resorption of the maxillary and mandibular alveolar bone indicates active periodontal (gingivitis) disease at death. In the maxillae, all 16 permanent teeth were present at death, but the left 2nd lower or mandibular

Fig. 15 Comparison of rib 8 morphology of the woman from Lexington (*right*) and an anatomical specimen (*left*) showing anterior projection or flattening and medial twisting (Photo by Stephanie Golda, 2008)

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Fig. 16 Lingual surface of mandibular teeth showing crowding, heavy plaque formation, and alveolar bone resorption (Photo by Daniel Wescott, 2007)

molar was absent antemortem with complete modeling of the socket. The maxillary left lateral incisor socket suggests that the tooth was present at death but the tooth was not recovered. The woman also suffered from significant tooth decay. A large carious lesion is present on the maxillary right 3rd molar causing destruction of the mesiobuccal quarter of the crown. A moderately large interproximal carious lesion is also present on the right maxillary 3rd premolar (Fig. 17a). On the left maxilla, the premolar crowns are completely destroyed by carious lesions (Fig. 17b), the 1st molar shows a small interproximal cavity on the mesial crown surface, and the 3rd molar exhibits several small occlusal caries. The lower dentition exhibits less decay but there is an occlusal carious lesion near the center of the left 2nd molar crown and an interproximal cavity between the left premolars.

Long bone functional analysis

Long bone shape and strength for the Lexington woman and females from the 19th century St. Louis sample are

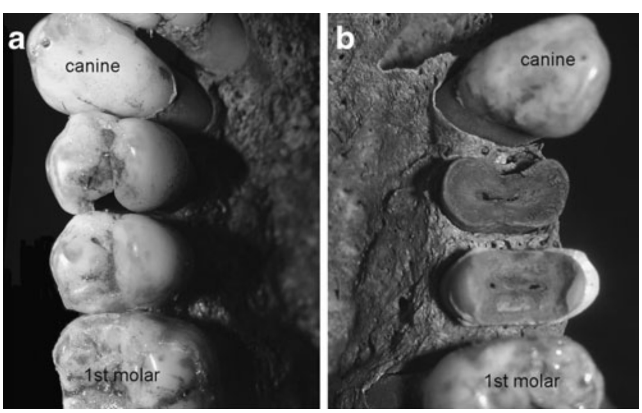

Fig. 17 Maxillary teeth showing interproximal carious lesion between right premolars (a) and crown destruction of left premolars (b) (Photos by Daniel Wescott, 2007)

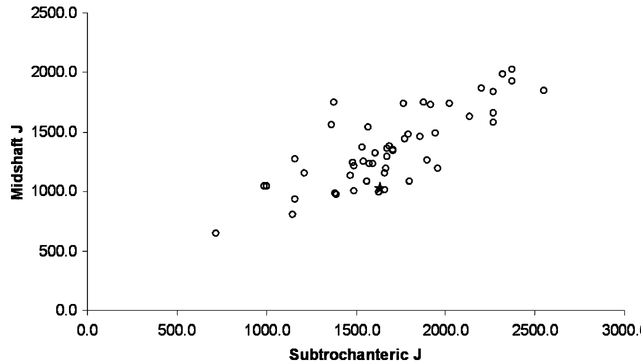

Fig. 18 Femur strength of the Lexington woman (*star*) compared to 19th century white females from St. Louis (*circles*)

provided in Table 2. Her standardized femur subtrochanteric and midshaft strength is within the normal range for adult 19th century females although femoral midshaft rigidity is relatively low (Fig. 18). Femur subtrochanteric strength is highly correlated with body mass, and the Lexington woman's bone rigidity is near the expected value for her body size. The reduced femoral midshaft rigidity, however, suggests she may not have been as active as expected for a 19th century female. The reduced femoral midshaft strength is primarily associated with a reduced mediolateral dimension (Fig. 19).

Histological analysis

Two histological aging methods were use to estimate the age of the Lexington woman. The Kerley and Ubelaker (1978) method, which was used to assess age from the femur, resulted in an age of 21.1±9.19 years. The Stout and Paine (1992) method was used to assess age from a rib cross section. The Stout and Paine (1992) method requires the quantification of osteon population density (OPD) or the number of intact and fragmentary osteons/mm^2. An age estimate of only 13.0 years was obtained

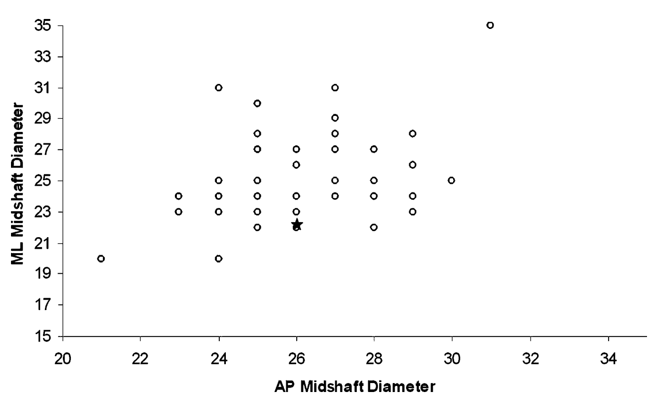

Fig. 19 Femur midshaft AP and ML diameters of the Lexington woman (*star*) compared to 19th century white females from St. Louis (*circles*)

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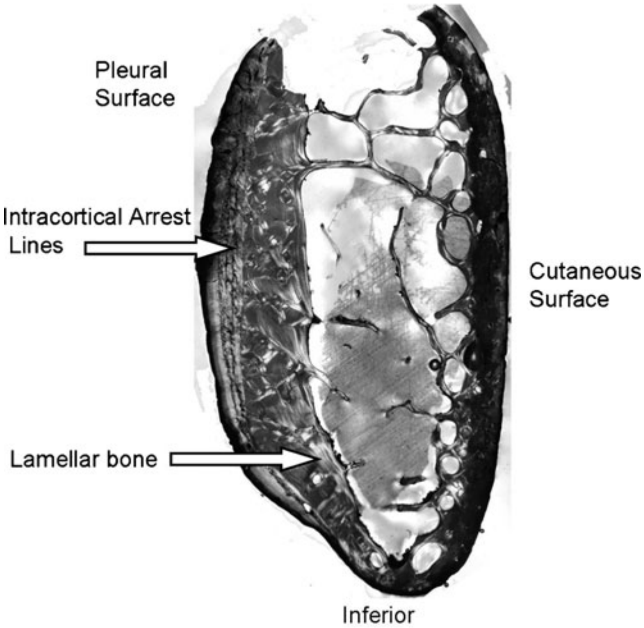

Fig. 20 Rib cross-section illustrating pathological changes on the pleural surface (Photo by Margaret Streeter, 2008)

using the Stout and Paine (1992) formula, but the overall histomorphological appearance of the rib cortex deviated from the typical adult pattern. The outer or periosteal half of the pleural cortex was composed of unremodeled lamellar bone. Haversian systems were sparsely distributed on the pleural cortex and there were many primary vascular and Volkmann's canals (Fig. 20). The inside or endosteal half of the pleural cortex was sharply differentiated from the periosteal half by three distinct intracortical arrest lines and sparsely remodeled with the drifting type of osteons. The cutaneous rib cortex also had few osteons, the majority of which were drifting. The overall morphology of the rib cortex appears pathological, and most closely resembles the pattern seen in the rib cortical bone of young children and is not consistent with the micromorphology of an individual in her twenties (Streeter and Stout 2006).

Ancient DNA analysis

Ancient DNA methodologies are frequently used in paleopathological studies in search of molecular evidence of a disease underlying certain bone pathology (Baron et al. 1996; Faerman et al. 1997; Fletcher et al. 2003; Donoghue et al. 2005; Taylor et al. 2005; Hershkovitz et al. 2008). Historic records indicate the individual died of tuberculosis and the histological examination of the sixth rib indicated pathological changes in bone. Therefore, evidence was sought at the DNA level by analyzing DNA recovered directly from the thoracic bones for the presence of *M. tuberculosis* DNA complex.

The DNA extractions were performed from the four bones (manubrium, sternal body, ribs 1 and 2), and the obtained aDNA extracts were subjected to PCR amplification using primers specific to the *M. tuberculosis* DNA complex. Amplification of the 123-bp fragment resulted in the PCR products of the expected size (Fig. 21a) and was followed by a semi-nested PCR which provided the expected 107-bp long amplicon (Fig. 21b). Altogether, 24 PCR reactions produced 11 positive results in three out of four aDNA extracts—1st rib, sternal body, and manubrium. The results of the sequence analysis confirmed the presence of the tuberculosis infection in this individual by showing sequences identical to those of the *M. tuberculosis* DNA complex. Failure to amplify a 245-bp fragment of the IS6110 insertion sequence and a 150-bp fragment of the *oxyR* psuedogene attested to the poor state of DNA preservation.

The authenticity of the findings is supported by several lines of evidence. The DNA extraction and PCR amplification procedures were performed using the facilities dedicated to ancient DNA analysis only, physically separated from modern DNA and post-PCR working areas. Four bones of the same individual were analyzed in two sets of

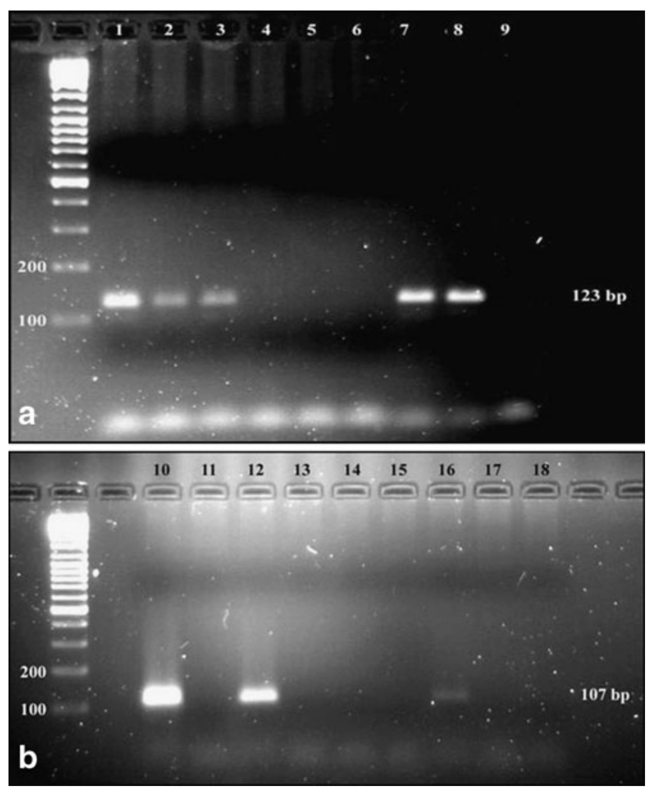

Fig. 21 PCR amplication and sequencing showing (**a**) first-round PCR with primers for a 123 bp fragment (lanes: 1—1st rib, 2—2nd rib, 3—manubrium, 4, sternum) and (**b**) semi-nested PCR for a 107 bp fragment (lanes: 10—1st rib, 11—2nd rib, 12—manubrium, 13—sternum) (Photo by Ljuba Zamstein, 2008)

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the experiment separated in time and performed with freshly prepared reagents. The results are consistent with three of them found positive for tuberculosis (see post-script). No PCR products were observed in the numerous blank DNA extractions and blank PCR controls. Although amplification of a larger fragment was unsuccessful, both 123-bp and 107-bp amplicons were repeatedly amplified from three out of four aDNA extracts. The observed inverse correlation between the amplification efficiency and the length of PCR products reflect poor DNA preservation. It is generally agreed that the state of DNA preservation is not related to the age of the specimen. Furthermore, single-copy sequences survive less commonly than multi-copy ones and shorter DNA fragments are more likely to be retrieved (Paabo et al. 2004). Altogether, DNA recovered from these relatively recent bones demonstrated the same properties as those commonly found in archaeological specimens. Finally, the results of the sequence analysis confirmed the specificity of the obtained sequences to the *M. tuberculosis* DNA complex. The identification of the *M. tuberculosis* DNA in the skeletal remains under study was consistent with the results of the histological examination of the sixth rib and historical information, suggesting the presence of an infection.

Stable isotope analysis of bone and teeth

Sample yields for this individual were more than acceptable and reliable C:N ratios were obtained for the collagen samples on the fibula and the tooth roots of the first and second molars (Table 3). The differences between bone and tooth values for both collagen and apatite/enamel (5.6, 5.2, and 6.0) are consistent with the carbon isotope values for the first molar but significantly more positive. This is consistent with breast feeding after birth. Overall, the carbon isotope values indicate a significant amount of C4 and/or seafood in the diet, at least 40% (collagen value of about −15 is +6‰ from pure C3 plant diet, with the most positive value possible estimated at about −5, or +16‰; 6/16=40%). The N values suggest an omnivorous diet, unless agricultural products had artificially elevated N values due to use of fertilizers. Potentially some freshwater or marine fish in the diet could also have produced these $\delta^{15}N$ values, but comparison with local plant/animal values would need to be made before making such an interpretation. The general similarity in values for the bone (representing the last several years of life) and the teeth (representing the diet at time of tooth formation) supports the possibility that this individual lived in the same area or at least had consistently similar dietary patterns from birth to death.

Facial reconstruction

Anterior and lateral two-dimensional reconstructions of the face (Fig. 22) were conducted to facilitate identification if pictures or drawings are found in the future and to give a human face to the Lexington woman (Fig. 22c). Figure 22a illustrates the landmarks and tissue thickness markers on the skull and the positioning of the eyes, while Fig. 22b shows the relationship of the skull and soft tissue features of the face.

Toxicology of hair and nails

Hair and nail samples were negative for opiates, cocaine, or cocaine metabolites. Although no drugs were detected, medicinal use of morphine or cocaine cannot be completely ruled out because the negative results could be associated with poor preservation (Owsley et al. 2006).

Discussion

Fisk patent metallic burial case and mortuary practices

The cast-iron coffin discovered at the Machpelah Cemetery in Lexington, Missouri is an early Fisk Patent Metallic Burial Case (Fisk Case) and was probably manufactured between 1849 and 1853. Metallic coffins were being made as early as 1836 (Habenstein and Lamers 1955), but in 1848 Almond Dunbar Fisk received a patent (US Patent No. 5920) for "an air-tight coffin of cast or raised metal." The mold design shown in the patent, however, was probably never produced. In fact, Fisk states in the patent application that the design had "not anything to do with the construction of the coffin, and may be used or omitted at pleasure." The Fisk Case was advertised as being able to protect the deceased from water seepage and vermin and to safeguard the public from contagious diseases (Habenstein and Lamers 1955). Advertisements also claimed the Fisk

Table 3 Stable isotope results

Sample	Lab #	$^{*13}C_{co}$	$^{*15}N_{co}$	C:N	Lab #	$^{*13}C_{ap/en}$	$^{*18}O$
Fibula	8753	−14.9	11.3	3.0	8756	−9.3	−8.6
M1	8754	−13.1	11.1	3.0	8757	−7.9	−6.5
M2	8755	−14.1	12.9	3.0	8758	−8.1	−7.1

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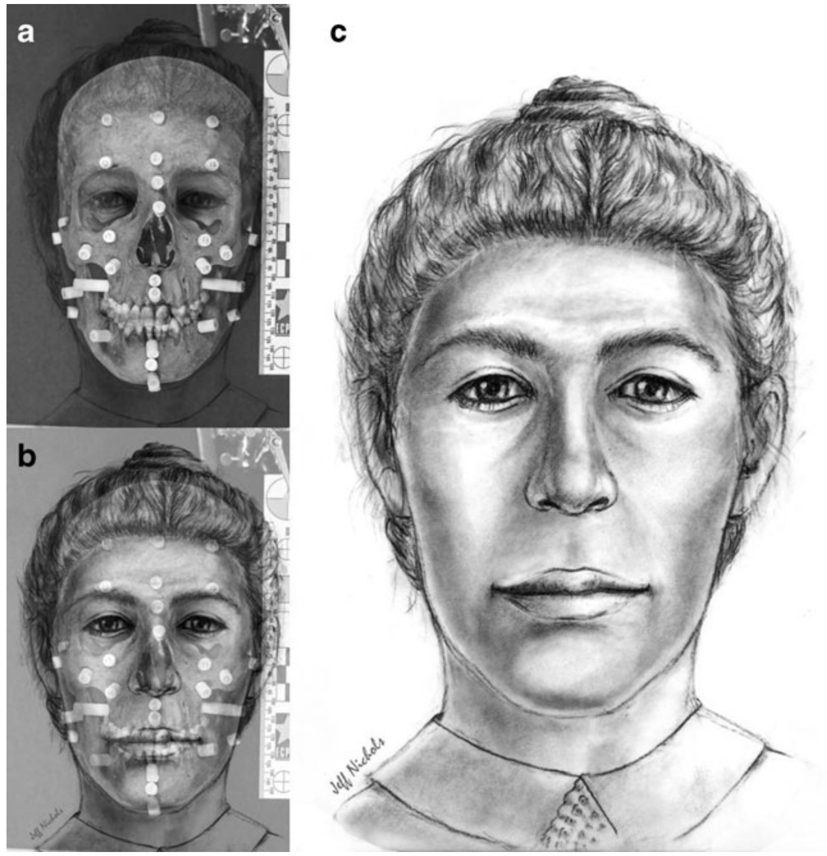

Fig. 22 Facial approximation of Lexington woman illustrating the reconstruction process (**a** and **b**) and final approximation (**c**) (Photos and drawings by Jeff Nichols, 2008)

Case was able to preserve the body of the dead for months or years giving ample time for the body to be shipped long distances or for distant loved ones to travel to the funeral and still view the body.

The Fisk Case was a very successful product fulfilling the practical, aesthetic, and emotional needs of mid-19th century Americans (Tharp 2003) as well as the recent technological advancements allowing for the standardization, mass production, and large scale distribution in the eastern United States (Habenstein and Lamers 1955). Production of the Fisk Case commenced in 1849 at Fisk's foundry in Long Island, NY until the foundry was destroyed by fire the same year. Production of the Fisk Case resumed in 1850 at the Fisk and Raymond Company in New York City (Fisk and Raymond Company 1850). The Fisk and Raymond Company printed a lengthy advertisement in 1850 describing the Fisk Case and providing testimonials to its excellence. According to the 1850 advertisement, the price of the coffin ranged from 7 to 40 dollars based on size and style of finish. Also in 1850, the A.C. Barstow Company of Providence, RI and the W.C. Davis and Company of Cincinnati, OH were licensed by Fisk to manufacture the Fisk Case (Habenstein and Lamers 1955). Fisk, however, died late in 1850 due to health complications resulting from the fire in his foundry and his patent was surrendered to John G. Forbes and Horace White of Syracuse, NY (Couchbuilt 2008; Saulsbury 1863)

The Fisk Case continued to be successful after Fisk's death, and production must have become even more extensive. Advertisements for the Fisk Case can be found in mid-19th century newspapers from nearly every town in the United States with railroad connections or steamboat access. As early as 1851 the W.T. Woodson and Company, an undertaking business in Chicago, IL, advertised in the *Chicago Daily Journal* (August 18, October 7, and November 2) that they had a large assortment of Fisk Cases available. In 1852, the W.C. Davis Company advertised in the *Cincinnati Daily Non-Pareil* that they had made arrangements with the patentee for the manufacture and sale of the Fisk Case in the west (Coachbuilt 2008). In July, 1853 a St. Louis undertaker, Geo N. Lynch and Company, was advertising the Fisk Case in the *Lexington Weekly Express*. One of their advertisements (*Lexington Weekly Express* 1853a:3) stated that "Agents for the sale of Patent Metallic Burial Cases are now in receipt of a full supply, and are prepared to furnish them on liberal terms. Orders solicited." The picture in the *Lexington Weekly Express* mortuary is identical to the Fisk Case discovered at the Machpelah Cemetery.

The coffin manufacturing portion of the W.C. Davis Company was sold to Crane, Barnes, and Company on

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August 15, 1853, which became the Crane, Breed and Company of Cincinnati 5 months later (Habenstein and Lamers 1955). The 1853 Fisk Case by Crane, Breed and Company was similar to the original mummy shaped Fisk Case but with "simplification of line and design" (Habenstein and Lamers 1955:267). Photographs of the 1853 Fisk Case by Crane, Breed and Company suggest that it may have differed in minor details from the coffin discovered at the Machpelah Cemetery. In 1854, Crane, Breed and Company released several new patterns of the Metallic Case with important improvements and finish. The 1854 "Bronzed Case," while still mummy shaped, was stylistically very distinct from the Fisk Case manufactured between 1849 and 1853 (Habenstein and Lamers 1955). In 1855, Martin Crane produced a new coffin design that eliminated the mummy shape and simplified the decorations. One of the new patterns is known as the Plain or Octagon pattern cast-iron burial case and it was finished in imitation rosewood or bronze (Habenstein and Lamers 1955).

An historical review of the Fisk Case indicates that the style found at the Machpelah Cemetery was manufactured between 1849 and 1853, an extremely narrow temporal span in historic archaeological terms. It is impossible to know, however, how long it took for all of the early Fisk Cases to be sold and used. The strategic location of Lexington on the Missouri River suggests that coffins manufactured in Cincinnati, OH by W.C. Davis and Company could have been easily transported to Lexington, MO via St. Louis. Furthermore, newspaper advertisements suggest the Fisk Case was readily available to citizens of Lexington, MO by 1853.

Personal identification

One of the goals of this project was to identify the individual buried in the Fisk Case discovered in Lexington. In medicolegal investigations, positive identification is achieved by comparing ante- and postmortem physical information. Ideally the genetic assets or DNA of the unknown individual can be compared with those of a presumed relative to make a personal identification. When DNA comparisons are not possible, anthropological methods that examine unique features of the bone and teeth, especially when combined with circumstantial evidence, are a valid alternative (Katzenberg et al. 2005). To provide personal identification in historical archaeology cases it is necessary for the biological, genealogical, and artifactual data to concur (Owsley et al. 2006). In this investigation, multiple lines of evidence were used in an attempt to identify the individual from the cast-iron coffin including the biological profile developed from the skeletal remains, cause of death, genealogical and historical records provided by the Stewart family, historical newspapers, and government records.

Based on historical information and genealogical records it is highly probable that a member of the John Shotwell Stewart family would have occupied the burial plot since he purchased this section in 1850. It is unlikely that a Fisk Case would have been used in Missouri prior to 1850 due to lack of availability. An examination of the Stewart family genealogy and death announcements in local papers indicate four women related to the Stewart family who died or may have died in Lexington, Missouri during the 1850s. John Stewart's wife Elizabeth C. (Triplett) Stewart died on May 5, 1854 at the age of 26 years of pulmonary tuberculosis. Abigail (Shotwell) Stewart, John's mother, died on August 23, 1858 at the age of 64 years of unknown causes. An obituary listed in the *Lexington Weekly Express* indicates that Mary Triplett died on June 3, 1853 at John Stewart's residence (*Lexington Weekly Express* 1853b). The notice was also copied in the *Maysville Eagle* printed in Maysville, KY. Mary is presumably Elizabeth's mother or sister (most likely her sister), but no information was found that confirmed her relationship, her age, or her cause of death. Finally, John Stewart had three sisters: Charlotte born in 1830, Abigail born in 1833 and Elvira born in 1836. The Stewart family has records of the burial locations for Abigail and Elvira, but little information is known about Charlotte except that she was in Mason County Kentucky in 1850. To sum up, based on historical records, it is likely that the Lexington woman in the Fisk case is Elizabeth, Abigail, or Charlotte Stewart or Mary Triplett.

Mitochondrial DNA was obtained from the bones and sequence analysis of the hypervariable segment I (HVS-I) of the control region was performed. Since no maternal relatives of Elizabeth Stewart, Mary Triplett, or Charlotte Stewart were identified there is no possibility for an individual identification at this time. Historical records were searched to find individuals buried in the cemetery that fit the biological profile. The Machpelah Cemetery has two information sheets provided by Stewart Family members about the locations of graves in C-41. One information sheet that was completed in 1951 by Charles and Cecil Stewart indicates that "Grandma Stewart and Daughter" were buried in plots No. 1 and No. 2 of Lot 41, Block C. Another information sheet completed by Cecil Stewart in 1962 notes that John Shotwell Stewart's son John W.H. is buried in plot No. 1 and Elizabeth C. Stewart is buried in plot No. 2.

The grandmother of Charles and Cecil was Georgia Ann, John Shotwell's second wife. Georgia Ann is known to be buried in a different plot at Macphelah. If Charles and Cecil were referring to their great grandmother on the information sheet, this would imply that Abigail Stewart and one of her

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daughters, presumably Charlotte, are buried in the plot. However, Abigail died at 64 years of age so she does not fit the biological profile of the woman in the coffin. While Charlotte Stewart cannot be ruled out, it is unlikely that she would have been buried in the Machpelah Cemetery even if she died in the 1850s. United State Census records indicate that Charlotte was living with her mother and father in Mason County, KY in 1850. Charlotte's father died around 1855 in Mason County and her mother appears to have moved to Lexington, MO following his death. There are no records indicating Charlotte, who would have been 25 years old at the time, moved to Lexington, MO. It is very likely that records of her end because she married and changed her surname.

Mary Triplett also cannot be ruled out as the woman in the coffin since no biological data on her is available. If Mary is Elizabeth's mother then she does not fit the biological profile of the woman in the coffin. However, if Mary is Elizabeth's sibling she would be expected to be of similar age. One of the primary purposes of the Fisk Case was to preserve the body while being shipped long distances to relatives, and Fisk Cases were possibly available in Lexington, MO by the early summer of 1853. Mary Triplett may have died unexpectedly and been placed in a Fisk Case for transportation to Kentucky, but this event was prevented for an unknown reason. Mary's obituary was copied to the Maysville, KY newspaper, but it states that she was formerly of Kentucky—possibly implying that she had moved to Lexington, MO.

Multiple lines of evidence (both biological and historical) suggest that the woman in the Fisk Case was Elizabeth C. (Triplett) Stewart who died in 1854 of pulmonary tuberculosis. The most significant circumstantial evidence is that the woman in the coffin and Elizabeth Stewart were the same age and had the same cause of death. The availability of the early Fisk Patent Metallic Burial Case in Lexington, MO corresponds well to Elizabeth's death date. In addition, it seems logical that Elizabeth and her son would be buried in the first two plots of the cemetery section purchased by John Shotwell. One of the burial information sheets for the Machpelah Cemetery specifically states that Elizabeth Stewart was buried in C-41 Plot No. 2 and her baby son in Plot No. 1. The baby, John W.H. most likely died 24 September 1850 and John Stewart purchased the plots in October 1850. While not conclusive, the available information strongly suggests that the woman in the Fisk Case is Elizabeth Stewart.

Diet, health, and lifestyle

Diet

The investigation of human skeletal remains and mortuary objects can provide a wealth of information regarding diet, health, and lifestyle. Dietary information can be obtained from skeletal remains by the gross examination of the dentition and chemical analyses of the teeth and bone. This woman had heavy calculus or plaque buildup on the incisors, significant tooth decay, especially of the molars and premolars, and substantial resorption of the alveolar bone due to periodontal disease. There are indications of dental attrition on the mandibular incisors, but the level of wear is not great for her age. All of these characteristics together suggest she ate relatively nonabrasive and cariogenic foods. Stable carbon and nitrogen isotope analysis of the bone and teeth provides further evidence for diet, although local plant and animal values are necessary to obtain more precise evidence. Carbon and nitrogen values obtained from bone and teeth of the woman indicate an omnivorous diet that remained relatively consistent throughout her life. It is likely that protein in her diet primarily came from freshwater fish, deer and other animals, while a high percentage of dietary carbohydrates were obtained from plant foods such as corn and sugar that use the C4 photosynthesis pathway. Corn was probably a dietary staple in western Missouri and would have resulted in the isotope signature observed and contributed to the dental decay and plaque buildup. Freshwater fish would have also been readily available in river towns like Lexington.

Health

Skeletal remains and historical documents also indicate that Elizabeth Stewart died of pulmonary tuberculosis. There was a small patch of reactive bone visible on the pleural surface and an atypical pattern of remodeling observed histologically on the same surface. While expected for a person that died of tuberculosis, these bony changes are not diagnostic. However, the aDNA results clearly demonstrate that she had tuberculosis. This case study is an excellent example of the need to conduct microbiological examinations of skeletal remains when possible. The majority of tuberculosis infections affect the lungs while skeletal manifestations are observed in 5% to 7% of the cases (Ortner and Putchar 1985). Interestingly, Elizabeth Stewart's obituary indicates that she suffered a great deal from the tuberculosis, but drug tests of her hair and nails revealed no indication that she took morphine or other narcotics to relieve the pain. Other than a rib, the general condition of the bones indicates that the woman had good skeletal health. There are no apparent fractures or evidence of bone loss.

The restrictive clothing worn by the woman and recent pregnancy could have aggravated the tuberculosis infection. The tight clothing and pregnancy would have likely interfered with movement of the diaphragm and reduced blood and lymph flow to the lungs (McLean 1902; Viswanathan 1936). Tuberculosis infection primarily occurs

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in areas with restricted ventilation or blood circulation, and external interferences such as constrictive clothing can increase an individual's vulnerability to the disease and aggravate symptoms (Viswanathan 1936). McLean (1902:380) stated that women wearing tight clothing for social conventionalism were literally 'dressed to kill'.

Tooth decay and calculus formation are good indicators of diet, but also provide information about dental care. None of the cavities were filled. In addition, the plaque buildup and dental decay indicate that she did not receive professional dental care and had relatively poor dental hygiene.

The skeleton can also provide significant information about habitual activity. The long bones of the Lexington woman are generally gracile and muscle markers are not robust. This indicates that she did not regularly participate in strenuous physical activities. This is probably not surprising given her health. Interestingly, while her femoral subtrochanteric strength is normal for her body weight and size, her femoral midshaft strength is slightly low primarily due to a decrease in the mediolateral strength. Individuals with long term illness that result in reduced mobility often exhibit a reduced midshaft ML bending strength (Wescott and Child 2009).

Lifestyle

One of the most revealing aspects of the Lexington woman's anatomy is that it provides information about her clothing. Flattening and medial twisting of the inferior rib borders are likely to have resulted in lateral compression of the ribcage. Angel et al. (1985) described similar characteristics in Terry Collection females from St. Louis and attributed them to corset wearing. Most girls began wearing a corset at about 12 years of age (Grimble 2004). The compression on the lower ribcage due to restrictive clothing during growth and development is responsible for the morphological deformities. The most likely explanation for the thoracic deformity seen in the woman from Lexington is also that it resulted from wearing restrictive clothing, especially wearing a corset from an early age. Complex forms of tight lacing were in fashion during the mid-19th century. American women during this time period typically wore ankle length dresses of wool, cotton, or silk. Skirts were very full and sometimes shaped by bustles, which during the mid-1850s were small down-stuffed pads that extended the woman's backside (Ewing 1972). Under the dress some women and girls wore a chemise for underwear. Over the chemise they wore a corset or stay.

Tight-lacing of clothing became extreme after 1830 with the invention of the metal eyelet, which allowed corsets to be laced tightly with greater ease (Ewing 1972; Groves et al. 2003). Richardson and Kroeber (1973) found that women's waistlines were at the smallest between 1841 and 1870. Women that practiced tight-lacing endured many physical restrictions including constipation, indigestion, headaches, backaches, respiratory problems, fainting, anemia, nausea, vomiting, and abscesses (Davies 1982). It is possible that the woman from Lexington did not frequently wear tight-laced clothing because of difficulties with tuberculosis and her lifestyle on the frontier. However, if she is Elizabeth Stewart, she would have been 12 years of age in 1840 and therefore would have grown up during this period of extreme corset tightening. In addition, evidence indicates that she was most likely wearing a gusset or negligee corset when buried.

Other less likely factors may have caused the abnormal rib shape, including postmortem flattening, occupational hazards, developmental abnormality, or disease (Groves et al. 2003). It is unlikely that the deformation in the ribs of the Lexington woman were associated with postmortem changes since the cast-iron coffin would have prevented pressure from the overlying soil from deforming the chest. Occupational hazards can also be ruled out as the likely cause for the deformities since Elizabeth Stewart was unlikely a shoemaker, one of the only occupations that have been linked to thoracic deformities (Groves et al. 2003). Furthermore, deformities resulting from shoemaking are primarily associated with sternal morphology (Groves et al. 2003). Some developmental abnormalities such as "pigeon chest" are corrected with a corset, but the morphological changes observed in the woman from Lexington are not consistent with reported cases (Groves et al. 2003).

Mortuary objects often communicate the social status and power of the deceased, and burial in a metallic coffin is typically thought to indicate relatively high socioeconomic status (Allen IV 2002; Owsley et al. 2006). By inference, the burial of Lexington woman in a Fisk coffin would indicate that she or her family were relatively wealthy considering Fisk Cases were substantially more expensive than traditional wooden coffins used during this time (Tharp 2003). This is especially true since John Stewart was a carpenter who possessed the skills and equipment to manufacture wooden coffins. While a Fisk Case could be purchased for between \$7 and \$40 (possibly wholesale price) a wooden coffin typically ranged in price from \$2 to \$6 (Tharp 2003). All available evidence, however, suggests that John Stewart and his wife Elizabeth were a middle class family without the wealth typically attributed to individuals buried in Fisk Cases (Owsley et al. 2006). Therefore, the question arises as to why a middle class woman was buried in a rather expensive Fisk Case.

As Little et al. (1992) point out, the relationship between mortuary behavior and social status can only be understood within its historical and social context. It must be

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remembered that social status may be based on not only economic worth, but political power, social standing, or a combination of factors. Elizabeth Stewart's obituary indicates she was an exemplary member of Lexington and the local Christian church (*Lexington Weekly Express* 1854:3). Her young age, poor health, and relatively short residence in Lexington, however, probably prevented Elizabeth from having substantial political or social power in Lexington.

One unlikely scenario is that John Stewart acted as an undertaker and was able to purchase the Fisk Case at wholesale price. Undertaking was a relatively new field in the mid-19th century and commonly performed by the local carpenter. There is no evidence, however, that John Stewart was a part-time undertaker or ever built coffins.

Another possibility is that the prohibitive cost of metallic coffins has been overstated by historical archaeologists. While the cost of the Fisk Case was higher than a traditional wooden coffin, Fisk Patent Metallic Burial Cases gained national brand-name recognition in the 1850s signifying that it was accessible to not only the upper class but to the growing middle class as well (Tharp 2003). The brand-name recognition of the Fisk Case is apparent by its widespread distribution and availability in nearly every town in the United States accessible by railroad or steamboat. The increased mobility of the American society, rapid urbanization, the connection of cities and towns by the railroad, new manufacturing techniques, and changing American burial practices combined to make coffin manufacturing a highly profitable commodity in the mid-19th century (Tharp 2003). Therefore, it is likely that the Fisk Case was not outside of the price range of middle class people living in western Missouri.

Another possible scenario is that Elizabeth Stewart was placed in a Fisk Case after her death to help preserve her body and to prevent the spread of disease. Preservation of the body and protection of citizens from disease were well known practical aspects of the Fisk Case. The Stewarts had migrated from Kentucky in the late 1840s and most of their family was still in Kentucky in 1854. It is possible that Elizabeth was buried in a Fisk Case to help preserve the body while her family traveled from Kentucky to Missouri to attend the funeral. In addition, the sealed nature of the coffin would have allegedly protected family and friends from disease.

Burial receptacles can provide significant information about the socioeconomic status of the deceased individual, but a number of factors were probably involved in the decision to place Elizabeth Stewart in a Fisk Case. Most likely the availability, beauty, and practicality of the Fisk Case played a role in the choice of burial receptacle for Elizabeth Stewart. Therefore, it is not unrealistic to assume that a middle class woman on the frontier edge would be buried in a Fisk Case.

Conclusions

The discovery of the cast-iron coffin from the Machpelah Cemetery in Lexington, Missouri provides a unique opportunity to learn about mid-19th century frontier life in Missouri. The Fisk Case provides a narrowly dated capsule that allows a snapshot of the lifestyle, health, mortuary practices, and even commercialization in mid-19th century America. Several investigations of cast-iron coffins discovered in the eastern United States have been conducted (Allen IV 2002; Dowd 1980; Owsley et al. 2006; Rogers et al. 1997), but none this far west on the frontier edge have been examined. A multifaceted and multidisciplinary study was undertaken to derive as much historical and empirical information as feasible and to facilitate identification of the deceased individual. Attempts to identify the individual were not only important for the descendants, but the Lexington community at large. The woman in the Fisk Case represents the family, community and society. While a positive identification is not possible at this time, multiple lines of evidence indicate the woman from the Machpelah Cemetery in Lexington was Elizabeth Stewart. Elizabeth and her husband John migrated to Lexington in the late 1840s from Kentucky. Unfortunately, Elizabeth died at the young age of 26 years. The discovery of her skeletal remains and the Fisk Case allows for the documentation and interpretation of mortuary practices on the western frontier in the mid-19th century. Based on available evidence, Elizabeth Stewart was physically typical of middle-class females in the mid-19th century but died at a young age of pulmonary tuberculosis. She was most likely buried in a black dress, chemise, and corset with leather shoes and veil but with no jewelry or other personal belongings.

Postscript

After the manuscript was submitted the Ancient DNA laboratory was moved to a new location within the same facility. The sternal body included in the current study was re-examined as part of a validation test of the new facilities with newly prepared reagents. Consistent with the previous findings, the bone was found positive for tuberculosis.

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