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Tracing the Oval—Characterisation and Construction of Original Danish Eighteenth-Century Strainers from Portraits by Jens Juel

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Abstract: Few examples of original strainers for paintings from the eighteenth century or earlier still exist as they have commonly been replaced due to their often-weak construction and inability to expand. Several original strainers, however, are still present in paintings by Danish portrait painter Jens Juel (1745–1802). These preserved strainers provide rare evidence of shape, construction, availability, format, and the production of strainers in the late eighteenth century. By visual analysis of twenty-two paintings, of which seven strainers are preserved, this study characterises the original strainers and their tool marks. Rare markings found on the surface hypothesised to be related to their construction is evaluated in relation to theory of polycentric ovals and layouts on the construction of oval shapes in treatises from the sixteenth to eighteenth centuries. The strainers are very similar and of simple construction with tool marks that correspond with the development in the late eighteenth century. The oval strainers are a construction with given symmetry axes, with two 60° equilateral triangles that the centres of the arcs form when aligned with the major axes. Such a layout would have been published by Christiaan Huygens (1629–1695) and Amédeé François Frézier (1682–1773) by the time of construction by someone in the wood working crafts in Copenhagen, who supplied strainers to Juel's studio.

Keywords: auxiliary support; strainer; painting; paintings production; preservation; technical art history; technical studies; polycentric ovals; tool marks

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1. Introduction

Paintings on canvas require an auxiliary support to generate tension to the surface to be painted, and to reduce the movement of the canvas supporting the ground and paint layers. Auxiliary supports are traditionally made of wood and can vary in construction and form but are usually composed of a frame of at least four members. The auxiliary support is, traditionally and more commonly termed, a strainer or stretcher. Both terms apply to the wooden frame that is behind and supporting the canvas. A strainer has fixed corners, while a stretcher has corner joints which allow for expansion, often by keys, or wedges, in the inside corners. Over time, a stretched and mounted canvas, as exposed to cycles of changes in temperature and humidity, tends to lose tension and become slack. A slack and bulging canvas can obscure the appearance of the painting and is at risk of increased vibrations, which may result in losses of ground and paint layers (Berger and Russell 2000; Andersen et al. 2019). By the addition of keys for expansion of the stretcher joints, tension can be restored in the painting. The use or invention of keyable stretchers is mentioned first by the French writer Antoine-Joseph Pernety (1716–1796) in 1757 (Pernety 1757:xc) in his treaty *Dictionnaire portatif de peinture, sculpture et gravure*. . . .[1]

Traditional strainers in older paintings have commonly been replaced by expandable stretchers as a step in conservation treatments since the nineteenth century, due to their often-weak construction and inability to expand. Few examples of original strainers from the eighteenth century or earlier still exist (Buckley 2008, 2012; Noble and Verslype

2017). In the past, the auxiliary support was considered disposable, but from the 1970s onwards more attention was paid to the preservation of strainers and early stretchers as an artefact, and, it was considered, at least, that they should be well documented. The original strainer or stretcher represents an integral part of a painting, as it conveys the history of its production, manufacture, and preparation for painting, while inscriptions and labels indicate provenance and exhibition history (Buckley 2008, 2012).

For the majority of paintings by Danish portrait painter Jens Juel (1745–1802), stretchers with characteristics that postdate the eighteenth century have replaced the original auxiliary support. However, the original auxiliary support—in all cases, strainers—is still present in some of Juel's paintings.[2] Through visual analysis, this study aims to characterise the original strainers and their tool marks. For the oval strainers, rare markings, seen on the surface of the wood, which is hypothesised to be related to their construction, are evaluated and discussed in relation to ancient theory on the construction of ovals and published treatises at the time of construction. These preserved strainers provide rare evidence of shape, construction, availability, format, and the production of strainers in the late eighteenth century. This study also offers an evaluation of who produced the strainers.

This study includes data from strainers from twenty-two paintings on canvas (nine rectangular and thirteen oval formats) by Danish portrait painter Jens Juel belonging to the collection of the National Gallery of Denmark (SMK) or a private estate collection, Svenstrup. Information on original strainers is supported by a few additional paintings by Juel in the museum inventory that remain with the original strainer and a few images in conservation reports before they were replaced.

Jens Juel—Biographical Outline

Jens Juel (1745–1802) was the most famous portrait painter and the most productive painter of his era in Denmark. His production spans four decades and he left behind more than 600 portraits on canvas. Juel initiated his apprentice years at the age of fifteen in the studio of painter Johann Michael Gehrmann (1707–1770) in Hamburg, Germany. In approximately 1765, Juel returned to Denmark and became a student at the newly established (1754) Royal Danish Academy of Fine Arts in Copenhagen. Portrait painting became Juel's main subject, although he was required to practise classical history painting at the academy in order to participate in the competition for the gold medal and a stipend for a Grand Tour. Juel won the gold medal in 1771; however, the associated stipend went to his colleague, the history painter Nicolai Abildgaard (1743–1809). The following year, Juel embarked on his Grand Tour regardless; private benefactors for four years sponsored him. His travels took him to the most important artistic centres in Europe, such as Hamburg, Dresden, Rome, Paris, Geneva, and Kassel. Juel managed to extend his trip to eight years by painting portraits on commission, especially in Switzerland, where he remained for three years. Following his return to Copenhagen in 1780, he became official court painter (1780), member of the academy (1782), professor (1784) and later director (1795–1797 and 1799–1801) of the academy, while simultaneously maintaining a busy private studio with assistants and students of the academy.

2. Original Strainers in Juel's Paintings

In all cases, the preserved original auxiliary support in Juel's paintings presents as a strainer with fixed corners. They are of simple construction, made of softwood[3] and joined with half-lap joints. Table 1 presents an overview of information on the original strainers.

Unfortunately, none of the nine rectangular paintings included in this study retain their original strainers, but corresponding creases and craquelure in the paint layers indicate that the original strainer bars had a width ranging from 4 to 6 cm (Table 1). Craquelure and creases in the paint layer relating to the inside of the original auxiliary support occur due to interactions between the canvas and strainer bars (Keck 1969; Michalski 1991; Buckley 2012). These cracks function as testimony of the shape and approximate width of the original strainer bars in paintings where they have been replaced.

Table 1. Overview of information regarding original strainers of the twenty-two paintings by Jens Juel included in this study. Where marked in grey, the painting remains mounted on the original strainer.

Portrait of	Collection Inv. No.	Year	Dimension, cm (h × w)	Shape of Original Strainer	Width of Original Strainer Bars (cm)			
					Top	Bottom	Left	Right
Self-Portrait by Candlelight	SMK KMS3990	c. 1764	57.1 × 49.7	Rectangular	5.7	5.5	4.2	4.2
Peder Rahr, Merchant in Ribe	SMK KMS3499	1770	78 × 62.1	Rectangular	4–4.5	4–4.5	4–4.5	4–4.5
Anna Elisabeth Battier née Storp	SMK KMS3634	1771	79 × 63.8	Rectangular	4–4.5	4–4.5	4–4.5	4–4.5
The Sculptor Jacques-François-Joseph Saly	SMK KMS4801	1772	83 × 67.3	Rectangular	n/a	n/a	n/a	n/a
Self-portrait with Portfolio	SMK KMS3275	1773–1774	56.4 × 44.5	Rectangular	n/a	n/a	n/a	n/a
Postmaster General Frederik Hauch	SMK KMS349	1776	59 × 49	Oval, oval inside shape	6.2	6.2	6.2	6.2
The engraver Johann Friderich Clemens	SMK KMS396	1776	52.4 × 41.8	Rectangular	n/a	n/a	n/a	n/a
Susanne Elisabeth Holm	SMK KMS1766	1778–1779	52.7 × 42.8	Oval, rectangular inner shape	13	13	10–11	10–11
Madame de Prangins	SMK KMS4810	1778–1779	87 × 72.5	Rectangular	5.5–6	5.5–6	5.5–6	5.5–6
Jean-Armand Tronchin	SMK KMS6151	1779	71.7 × 57.2	Rectangular	4	4	4	4
Henrik Hielmstierne	SMK KMS349a	1780	64.2 × 49.9	Rectangular	4	4	4	4
Henrik Gerner	SMK KMS1444	1785	70.5 × 55	Oval, rectangular inner shape	13.2	n/a	10.5–11	10.5–11
Charlotte Sophie Gerner née Rasch	SMK KMS1445	1785	70.5 × 55	Oval, rectangular inner shape	13.2	n/a	10.5–11	10.5–11
Peter Johan Schouw	SMK KMS1113	1799–1800	69.5 × 54	Oval, rectangular inner shape	13	13	12.5	12.5
Ane Christine Schouw née Poulsdatter	SMK KMS1114	1799–1800	69 × 53.5	Oval, rectangular inner shape	13	13	11.5	11.5
Anne Marie Bagge née Eegholm	SMK KMS1115	1799–1800	69.4 × 53.4	Oval, rectangular inner shape	13	13	12	12
Jens Bruun Neergaard of Svenstrup	Svenstrup SV1	1788	69.8 × 54.6	Oval, rectangular inner shape	13.2	13.5	10.8	10.9
Anne Marie Bruun Neergaard née Møller	Svenstrup SV2	1788	69 × 53.5	Oval, rectangular inner shape	13.7	13.3	12.5	12.5
Marie Christine Buchwaldt, née de Svanenskiold	Svenstrup SV3	1780s	69.9 × 54.5	Oval, rectangular inner shape	13.3	13.2	10.6	10.5
Jens Peter Bruun Neergaard to Eckhof	Svenstrup SV4	1790	68.5 × 53.5	Oval, rectangular inner shape	13.1	13.3	12.5	12.4
Joachim greve Moltke to Rønnesbækholm	Svenstrup SV5	1797	69 × 53.4	Oval, rectangular inner shape	13.4	13.4	12.3	12.3
Ellen Moltke née Bruun Neergaard	Svenstrup SV6	1797	69 × 53.5	Oval, rectangular inner shape	13.4	13.3	12.4	12.4

The only rectangular painting by Juel in the inventory at SMK which is found to remain with an original late-eighteenth-century strainer is *The Roman Dwarf Francesco Ravai, called Bajocco*, 1773 (KMS370) (Figure 1a). An image of the verso of *Flowers and Fruit on a Table*, 1791 (KMS3943), in the archives at SMK, displays a similar original strainer before its replacement (Figure 1b). Both strainers resemble original rectangular strainers, which have survived on Juel's contemporary colleague, the history painter Nicolai Abildgaard's (1743–1809) paintings (Filtenborg 2014). Filtenborg reports that the original strainers on Abildgaard's paintings are made of softwood in a slight and simple construction, and the corners are joined with either bridle joints or half-lap joints. There are no signs that keyable stretchers were employed (Filtenborg 2014, 2015).

(**a**) (**b**)

Figure 1. Original late-eighteenth-century rectangular strainers in paintings by Jens Juel: (**a**) the verso of *The Roman Dwarf Francesco Ravai, called Bajocco*, 1773–1776 (1775), National Gallery of Denmark (SMK), KMS370, Oil on canvas, 48.5 × 34 cm; (**b**) the verso of *Flowers and Fruit on a Table*, 1791, National Gallery of Denmark (SMK), KMS3943, oil on canvas, 27.5 × 39.5. Strainer now replaced. Image from SMK archives.

The oval format in Juel's portraits appears after 1770, with a single oval format appearing in 1768 (Poulsen 1991). Following Juel's return to Copenhagen in 1780, the oval format was widely used for standard portraits and this type make up a substantial portion of his production. Of the original oval-shaped strainers from the later period of his career, several have survived. From this study, seven remain with the original strainer. The six paintings from the private estate Svenstrup are all original and even appear to be originally mounted, meaning that the painted canvas has never been temporarily removed from the strainer, for instance during a conservation treatment. Further, one painting which was executed in Paris, *F. Hauch* (KMS349), remains with its original strainer, and this clearly represents a different type of strainer than those produced in Denmark.

The oval strainers used in Juel's paintings produced in Denmark are very similar in construction to one another with only minor variations, and all have a rectangular inner shape. They consist of four members, with the corner joints assembled in a simple half-lap with animal glue.[4] Evenly sawn outer rounded edges suggest that they were cut into an oval shape after assembly into a rectangular figure, while the inside of the strainer remains rectangular. Depending on the side facing the verso, the top and bottom will appear in full width, overlapping the sidebars, while on the other facing side, the sidebars will appear in full height, overlapping the top and bottom (Figure 2). The facing side varies between different paintings.

The members on the oval strainers are wider than the members of the rectangular strainers. The top and bottom bars are generally approximately 13 cm wide at the widest central point, while the sidebars are slightly slimmer of between 10.5 cms and 12.5 cm. The larger width is required for this type of construction, as otherwise it would not give sufficient overlap in the joints when cut into the oval shape.

Similar oval strainers are seen in one instance in the SMK collection on *Dameportræt 1790–1799* (KMS247) (Figure 3a) and in an image from the records of a previous strainer of *S.E. Holm* (KMS1766) (Figure 3b). As with the Svenstrup paintings, both display cracking in the paint layer corresponding to the inside rectangular shape. The examined oval paintings from SMK, whose strainers have been replaced, all display cracking corresponding to a strainer with an inner rectangular shape, supporting the use of a similar type of original strainer, while their current and more modern stretcher has an oval inside shape. The same is observed in additional oval paintings in the inventory at SMK such as the *Portrait of*

Elisabeth de la Calmette (KMS1098) and *Johanne Sophie de Coninck* (KMS1619) as well as at least five oval portraits previously researched (Slotsgaard 2013; Sæter 2016). Two additional portraits from Svenstrup, likely painted by Juel's assistant Herman Kofoed, remain with similar original strainers. This suggests a standardised approach to oval-shaped strainers in this period, which may be further supported in the future by inspection of strainers used in paintings by other artists.

(**a**) (**b**)

Figure 2. (**a**) The original strainer on the verso of *J.B. Neergaard* (SV1). The reverse facing side shows the full length of the upper and lower bar and is opposite to (**b**). Similar positioning is seen on the strainer of *M.C. Buchwaldt* (SV3). (**b**) The original strainer on the verso of *A.M.B. Neergaard* (SV2). The reverse facing side shows the full height of the sidebars and is opposite to (**a**). Similar positioning is seen on the strainers of *J.P.B. Neergaard* (SV4), *J. Moltke* (SV5) and *E. Moltke* (SV6). The strainer also displays incised lines across the centre of each member which represent the major and minor axes.

(**a**) (**b**)

Figure 3. Original oval strainers from the collection of SMK, which is similar to the strainers from Svenstrup Estate: (**a**) the verso of *Dameportræt 1790–1799* (KMS247); (**b**) image of the verso of *S.E. Holm* (KMS1766), before replacement with a modern stretcher. The strainer bears an inscription: "Julie Holm, Professor Jens Juels/ første forlovede, død I sit 22de/Aar/Malet af Jens Juel" (Julie Holm, Professor Juel's first betrothed, died in her 22nd year, painted by Jens Juel).

In contrast to the Danish strainers, the strainer on *F. Hauch* (KMS349) displays an inside oval shape and the bars have different dimensions, being only 6.2 cm wide. Like in the Danish strainers, the members are joined in half-lap joints (Figure 4). The painting was executed in Paris and thus the strainer could be of French origin. The overall dimension of the strainer (59 by 49 cm) fits closely with the dimensions of one of the standard-size strainers reported by the French writer Antoine-Joseph Pernety (1716–1796) (1757): Toile, no. 12: 1 pied, 10 pouces, 6 lignes by 1 pieds, 6 pounces, 6 lignes, which is equal to approximately 60 by 50 cm. The strainer on *F. Hauch* (KMS349) is seemingly similar to other preserved French strainers from the same era (personal correspondence with Pascal Labreuche, May 2020).

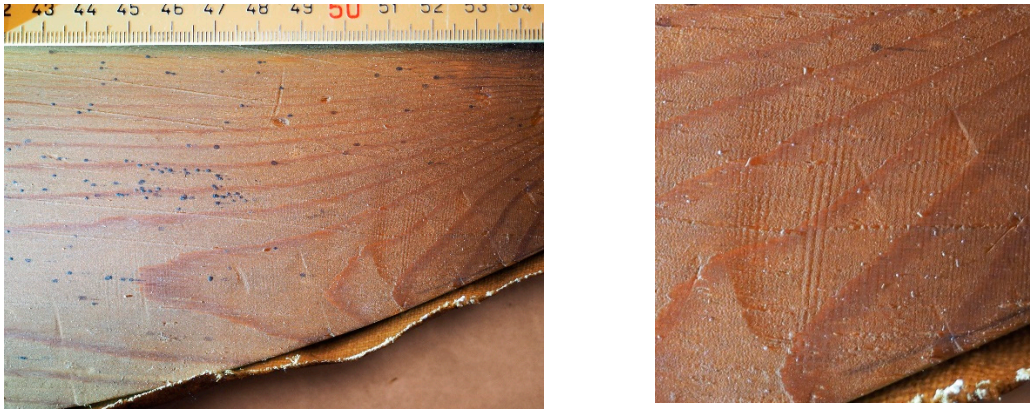
(**a**) (**b**) (**c**)

Figure 4. The verso of *F. Hauch* (KMS349): (**a**) displaying the likely original French strainer with inscription "*F.v. Hauch Malet i Aaret 1776 i Paris af Professor Juel*" (F.v. Hauch painted in 1776 in Paris by Professor Juel). Juel did not become Professor until the mid-1780s, thus the inscription is added to the strainer postproduction; (**b**) a detail, displaying the half-lap joint; (**c**) detail of the central lower member displaying rippling from a hand plane and a pencil-line indication of the major axis.

3. Tool Marks on the Strainers

The surface of the original strainer bars of the Svenstrup paintings bear marks corresponding to tools used in the eighteenth century. After sawing, diverse types of planes would have been used to remove sawing marks and other irregularities (Williams 2008). A multitude of planes existed in the eighteenth century for different purposes (Diderot and d'Alembert 1751–1772 (1769, vol. 7, Joinery work in building, pl. 13)). Longitudinal lines and indentations from the edge of the plane iron are seen on the surface parallel to the wood grain in the length of the boards (Figure 5). In a couple of instances, comb-like marks are seen as deeper indentations in the wood (Figure 6). This suggests the use of a toothing plane. A toothing plane more aggressively cut down the surface and is often used for the initial surfacing before the finer plane. The toothing plane was also good for scratching up surfaces to be glued together (Williams 2008). A regular rippling, seen as shadowy indentations and undulations with 0.5–1-millimetre intervals, corresponds to chatter marks from a hand plane without a cap iron (Figure 5) (Hoadley 2000; Alberdi 2013). The invention of the cap iron in the second half of the nineteenth century prevented this occurrence and the invention significantly improved wood-surface-smoothing abilities (Welsh 1966; Hoadley 2000; Alberdi 2013). In wooden surfaces planed before the mid-nineteenth century,

this type of rippling can thus often be seen. Also visible on the surface of the wood, are curvilinear indentations adjacent to each tack, indicating the use of a type of stretching pliers (Figures 5 and 6). Furthermore, four of the Svenstrup paintings have visible lines incised by a sharp tool into the surface across the centre of each member, representing the major and minor axes of the oval shape, as well as visible pencil lines along the edges and particular holes, which all appear to be related to the construction of the oval shape (Figure 2b). These appearances are discussed in the following section. The surface of the French strainer on the portrait of *F. Hauch* (KMS349) displays similar tool marks consistent with an eighteenth-century hand plane with a single iron, as well as a pencil line indicating the major axis (Figure 4).



(**a**) (**b**)

Figure 5. The wooden surface of the original strainer of *E. Moltke* (SV6): (**a**) showing longer linear lines from the plane iron, rippling from the hand plane and canvas-plier indentations; (**b**) enhanced detail of rippling from the hand plane.

Figure 6. The wooden surface of the original strainer of *M.C. Buchwaldt* (SV3) showing deep indentations running parallel to the wood grain likely from a toothing plane. Indentations from the use of stretching pliers are visible along the edge adjacent to each tack.

4. Tracing the Origin of the Oval in Juel's Danish Strainers

The question of how the oval shape of the strainers for Juel's paintings were created might have evaded the attention of this study was it not for a number of significant indicators, or markings, visible on some of the strainers, which hypothesised insight into the craft, practice and thought behind their production. Incised lines, holes and pencil lines on the surface of the wood indicate correlation to the creation of the oval form, which allow for a reconstruction of the layout of the oval and tracing the original layout published in treatises.

4.1. Theory of Polycentric Ovals

The oval strainers in Juel's paintings can be characterised as a polycentric oval. The theory of drawing geometric shapes goes back to Euclid (c. 325-265 BC), and throughout history, methods for drawing and constructing an oval shape have undergone several studies, with treatises published on the subject starting in the sixteenth century (Figure 7) (Dürer 1525; Serlio 1584; Van Schooten 1646; Bosse 1655 and more; López Mozo 2011; Mazzotti 2019). A very simple way of creating an ellipse, which has been employed for centuries, is the nail and string method, also known as "The Gardener's Method" (Van Schooten 1646; Huerta 2007; López Mozo 2011). Apply two nails into a board, place a loop of string around the nails, pull the string tight with a pencil, and trace the pencil tip's path as you pull the pencil around the taut string (Figure 8). The length of the string adjusts the wanted size of the ellipse.

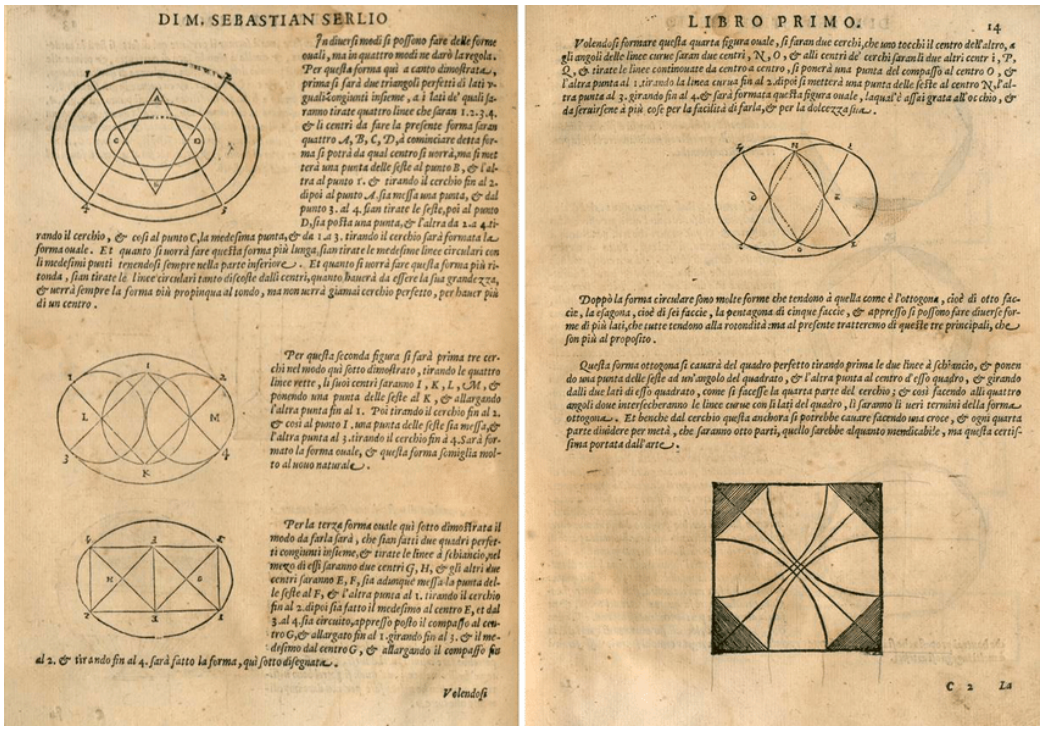


Figure 7. Throughout history, methods for drawing and constructing an oval shape have undergone several studies, with treatises published on the subject starting in the sixteenth century. An example of four methods of constructing ovals is seen in *Il Primo libro d'Architettura di Sebastiano Serlio [. . .]*, first published 1545 (Serlio 1584).

The term oval can apply to both oval and elliptical shapes, but, like the ellipse, the oval is not made up of an equation, but can be modified by the creator in regard to choices in properties and form (Huerta 2007; Mazzotti 2019). In an ellipse, the curvature continuously changes, while in an oval, also known as a polycentric oval, the curvature is given by at least two consecutive sets of arcs. This allows for many different ruler and compass constructions in arrangement to fit any given dimension if enough parameters are known (López Mozo 2011; Mazzotti 2019). Polycentric ovals are and have been used by architects, painters, craftsmen, engineers, and many other artists and specialists throughout the centuries.

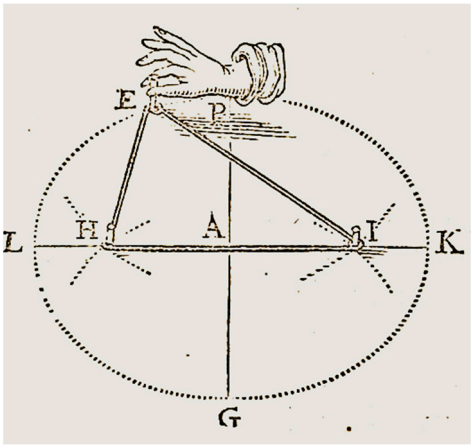


Figure 8. Illustration from Frans van Schooten, *De Organica Conicarum Sectionum [. . .]*, (Van Schooten 1646, p. 31) displaying the creation of an ellipse using a nail and string, also known as The Gardeners Method.

A polycentric oval is double symmetrical, constructed through two pairs of circular arcs, one major and one minor, sharing a common tangent at the connecting point. The simplest oval has four centres and the double symmetry implies that it is enough to arrange a quarter-oval with O as the symmetric centre, and then reflect it on the two axes. Lines between the centres of the arcs will usually form an angle of 30°, 45° or 60° to the major axis line. In this respect, the basic characteristics of an oval are defined in relation to Figure 9, signifying a simple oval construction (López Mozo 2011; Mazzotti 2019):

- O as the intersection of the two symmetric axes.
- A and B as the intersection points between the quarter-oval and the horizontal and vertical axes. Let OA > OB.
- K and J as the centres, respectively, of the small and big circles, with radii r1 and r2, whose arcs form the quarter-oval.
- H as the connecting point of the two arcs, with shared tangents parallel to the other axis.

The layout and construction of a basic oval requires that at least three independent parameters are given, such as dimension, a radius of either circles or distances between points, while the remaining will derive automatically. Considering only the quarter oval, the following ten parameters apply for the general construction of ovals, which can also be defined in relation to Figure 9 (Mazzotti 2019):

- a = OA, the length of half the major axis,
- b = OB, the length of half the minor axis,
- k = OK, the distance from O of the centre of the smaller circle,
- j = OJ, the distance from O of the centre of the bigger circle,
- h = the distance of the connecting point H from OB,
- m = the distance of the connecting point H from OA,
- $r1$ = the length of the radius AK,
- $r2$ = the length of the radius BJ,
- β = AKH, the angle formed by the line of the centres and the major axis, and
- p = OB/OA, the ratio of the two axes.

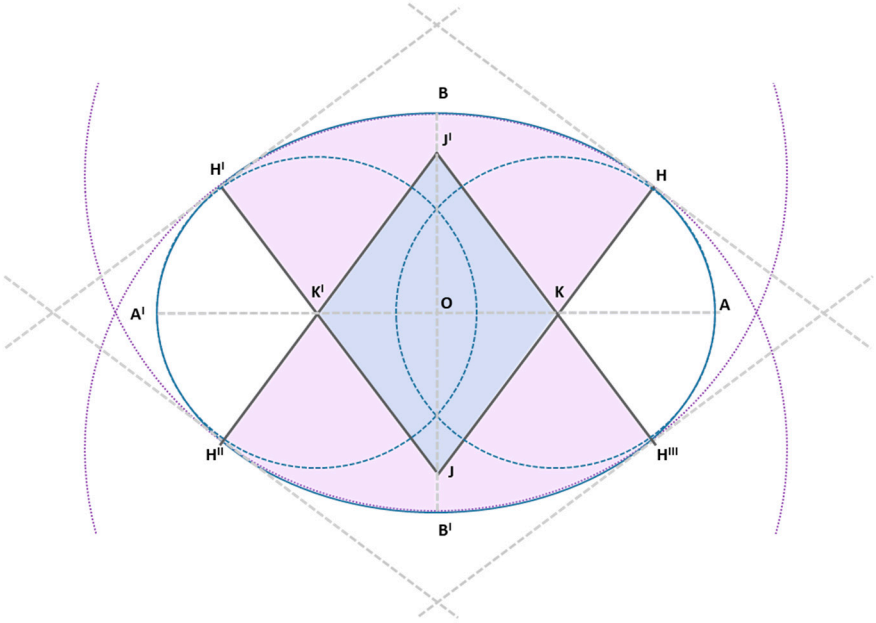


Figure 9. A polycentric oval with four centres, aligning the major and minor axes and with tangents at their connecting points, as defined by basic characteristics. The raised number behind the letters indicate the double symmetry.

4.2. The Oval of Juel's Strainers

With the definitions of polycentric ovals in mind, attention moves to the oval construction of the strainers of Juel's paintings and the present indicators, or markings, which seemingly remain from their construction. Four of the Svenstrup strainers, portraits of *A.M.B. Neergaard* (SV2), *J.P.B. Neergaard* (SV4), *J. Moltke* (SV5) and *E. Moltke* (SV6), all have lines incised by a sharp tool into the surface across the centre of each member. These lines represent the major and minor axes (Figures 2b and 10). On all four strainers, the minor axis lines have symmetrically located holes from a nail in the member on each side (Figure 10). These nail holes seem to be placed in the same location an all four strainers and are related to the curvature of the two major arcs, or circles. Lastly, pencil marks are present both towards the top and bottom, on the left bar of the strainer of *E. Moltke* (SV6), corresponding to a circular arched shape—in this case, the two minor circles of the oval (Figure 11). There are seemingly no visible markings on the surface of the remaining preserved strainers but they could be present on the opposite side facing the verso of the canvas.

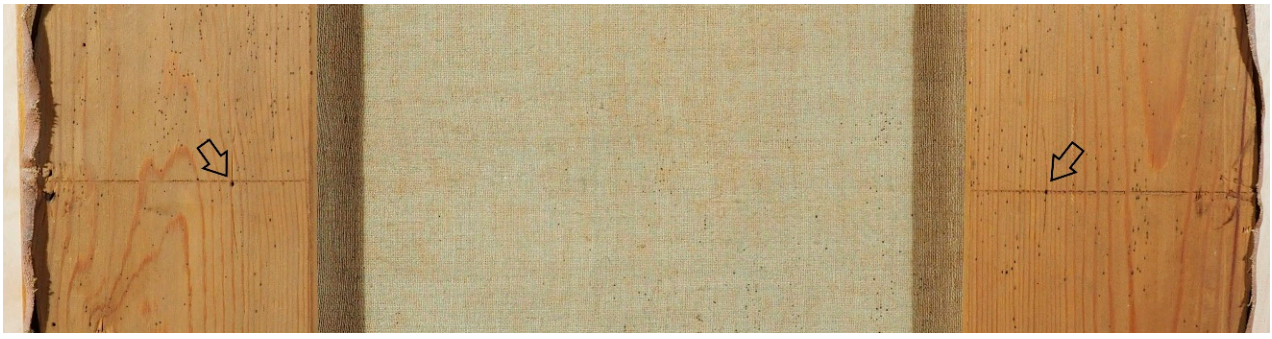


Figure 10. Symmetrically located holes (indicated by arrows) on the minor axis in each side of the strainer on of *E. Moltke* (SV6). Similar holes and positioning on the minor axis are also visible on the strainers of *A.M.B. Neergaard* (SV2), *J.P.B. Neergaard* (SV4), and *J. Moltke* (SV5).

(**a**) (**b**)

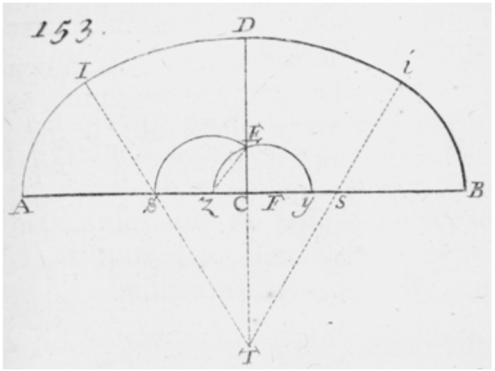
Figure 11. Pencil marks present both towards the top (**a**) and bottom (**b**), on the left bar of the strainer of *E. Moltke* (SV6), corresponding to a circular arched shape—in this case, the two minor circles of the oval.

The two holes on the minor axis first suggested the use of a technique such as the nail and string in The Gardener's Method. However, this technique applies to an ellipse, not an oval, and would require the nails to be located on the major axis and not the minor axis, the way they are. Thus, the use of this method could be dismissed. As mentioned, the layout of a symmetrical oval requires at least four tangent circular arcs and their corresponding centres aligned with the orthogonal lines of the major and minor axes. The incised lines in the centre of the strainer bars designate the orthogonal lines of the major and minor axes with their intersecting point (O) located centrally in the void space of the inside square of the strainer. The holes located on the minor axis correspond to the centre of the major arcs (J) making up the curvature on the opposite side. The arched pencil lines seen on *E. Moltke* (SV6) correspond to the curvature of the two minor arcs and are located close to the point of the tangent where the two arcs connect (H). The centre of the two minor arcs (K), like the centre of the axes (O), is located inside the void space of the inside of the strainer. These centres can be found by making a line from H to the opposite J. The intersection of this line with the major axis is the location of the centre of the minor arcs (K). It can also be found that an alignment of the centres of the arcs actually forms two 60° equilateral triangles to the major axis.

When the parameters are already known, it is easy to layout the oval, but the question is how the creator decided on the three parameters to follow to create the oval. The dimension of the oval is already given as this is defined by the size of the strainer—in this case, 69 × 53.5 cm—which relates to the desired format for the painting. From the construction of the strainers, they seem created from a rectangle and hence sawn or assembled into the oval form. When an oval is inscribed in a rectangle, the lengths of a and b are already given—in this case, the dimension of the strainer. An infinite number of ovals, however, can be inscribed in a rectangle, so the proportions between the height and width of the oval are not enough for a specific application of an oval layout; a third parameter is required. The curvature relies on the location of the centres for the arcs. The layout of the oval thus depends on how and where the creator decided on the location of the centres to generate the curvature of the oval.

In the book *All Sides to An Oval*, the mathematician Angelo Alessandro Mazzotti, shares a comprehensive collection of geometrical constructions and mathematical equations of polycentric ovals, their properties and the main parameters for managing them, with references to historical treatises and, in addition, poses some new geometrical constructions (Mazzotti 2019). Several methods described in the book, with reference to historical treatises, were compared to the strainers of Juel's paintings.

Starting from the rectangle inscribing the oval with a construction fitting the indicators, only one layout seemingly has the centres on the shorter axis corresponding to the location of the nail holes present on Juel's strainers. A solution that fit the above parameters and indicators is found in a generalised construction attributed and derived from the seventeenth-century treatises of the Dutch mathematician Christiaan Huygens (1629–1695) (Mazzotti 2019). This is a construction with given symmetry axes, which allows for the definition of the angles that the centres of the arcs form when aligned with the major axes as the third parameter (Dotto 2002). At the time the strainers were made, such a construction, for any choice of angle, but illustrated exactly for a 60° angle had been published by Huygens, and later, in 1737, by the French mathematician Amédeé François Frézier (1682–1773) (Figure 12) (Frezier 1737–1739; López Mozo 2011).



(**a**)

PROBLEME XXI.

Deux arcs étant donnés, imiter une ellipſe par un aſſemblage de quatre arcs de cercles.

Ou ce qui eſt le même, imiter une demi-ellipſe par trois arcs de 60 degrés chacun.

Soit le grand axe AB (*Fig.* 153) & la moitié du petit axe CD: on portera premierement la longueur CD de cette moitié ſur le grand axe en By, pour avoir la différence des deux demi-axes Cy, qu'on diviſera en deux également en F, puis on portera CF en Cz, ſur zy, comme diametre; on fera le demi cercle z Ey, qui coupera CD en E, on portera la longueur zE en z S, & la diſtance CS d'un côté à l'autre, CS en Cs: les points s & S ſeront les centres des petits arcs des extrêmités de l'ovale, & les lignes AS & sB leurs rayons; enfin des points s & S, comme centres, & de l'intervalle sS, on fera le triangle équilatéral STs, dont le ſommet T ſera le troiſieme centre que l'on cherche; & les côtés de ce triangle prolongés, détermineront la jonction des grands & petits arcs en *i* & I, ſur leſquels on prendra T s + sB pour rayon du grand arc; ainſi les trois arcs ſeront de ſoixante degrés chacun, & auront des rayons communs; *ce qu'il falloit faire.*

PL. 14. Fig. 153.

(**b**)

Figure 12. The French mathematician Amédeé François Frézier's (1682–1773) layout of a polycentric oval inscribed in a rectangle with the third parameter defined as specific 60° angles that the centres of the arcs form when aligned with the major axes. Frézier's approach is finding the centre of the minor arc first and creating the 60° angle from there (Frezier 1737–1739, Fig.153, Pl.14).

Huygens and Frezier have different approaches for finding the position of the centres in relation to the 60° triangles. Frézier's approach is finding the centre of the minor arc first and creating the 60° angle from there, as described and illustrated in Figure 12, while in Huygens' method, a 60° angle is used first to establish the connecting tangent point of the two arcs. The Huygens construction as explained by Mazzotti (2019) is applied to Juel's strainers. The approach for the construction, illustrated in Figure 13 overlaying the image of the strainer of *A.M.B. Neergaard* (SV2), is as follows:

- Draw a line in an angle of 60° onto OA with the centre in O;
- Draw a circle with centre O and the radius OA and name D and C the intersections with OB and the second side of the α angle;
- Draw the segment AC followed by segment DC and its parallel from B, and call H the intersection of this line with the segment AC;
- The parallel to OC through H is the line where K and J can be found as intersections with the two axes;
- The centre points are reflected on the two axes;

- K and K_1 marks the centre of the small circles, while J and J_1 mark the centres of the big circles, that is the centre opposite to B with reference to O, whose arcs form the curves of the oval.

As can be seen from the illustration (Figure 13), an oval inscribed in such a rectangle forms two equilateral triangles, as the straight lines connecting two centres on the different axes form an angle of 60° (pi/3 radians). The arcs share a common tangent because K, H and J are co-linear.

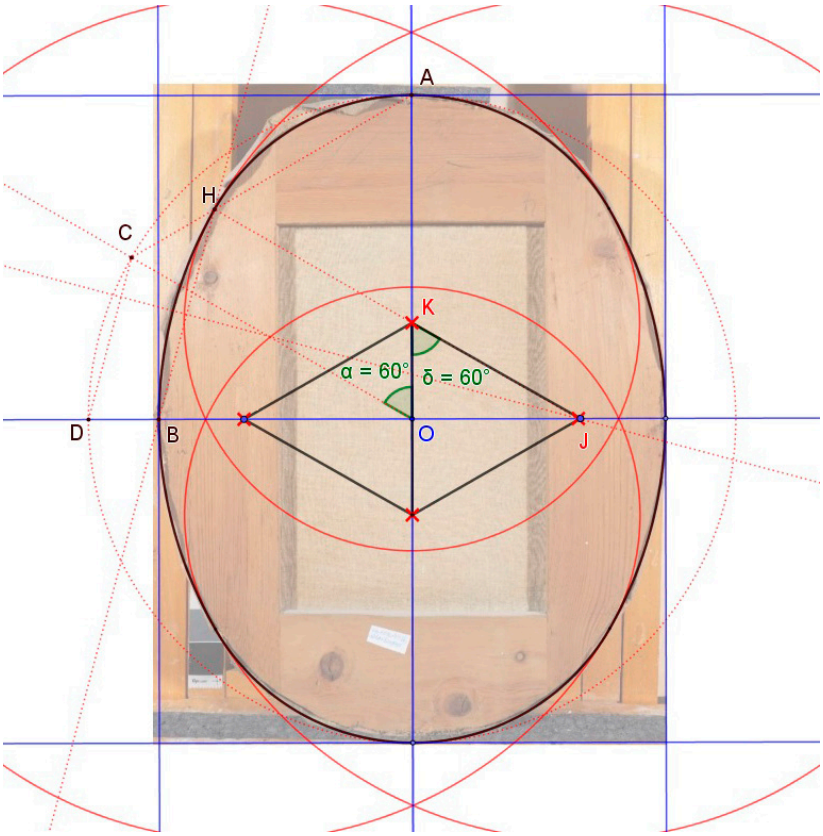


Figure 13. The Huygens construction applied to the strainer of *A.M.B. Neergaard* (SV2) (illustration courtesy of Angelo Alessandro Mazzotti). The construction presents an oval inscribed in a rectangle with two equilateral triangles, as the straight lines connecting two centres on the different axes form an angle of 60° (pi/3 radians). The arcs share a common tangent because K, H and J are co-linear.

The reconstruction fits very well with the oval form and the specific curvature of the four strainers and with the indications on the surface. Both Huygen's and Frezíer's approach can be applied to Juel's strainers and seemingly provide the same result. As both methods were published by the time the strainers were made, the creator of the strainers could have employed the methods as described by either of the two authors. However, a comparison of written sources and the constructed heritage shows that the two sides of reality, theory and practice, do not always concur. The treatises confirm the state of knowledge at a certain moment in time, but the knowledge needed to draw the desired shape has in the past likely spread either by word of mouth or found out by methods of trial and error (Huerta 2007; López Mozo 2011; Mazzotti 2019).

Knowing the construction and the parameters for creating ovals, in any case, the creator is free to choose three parameters, the rest coming automatically. For this oval, the creator would have had to choose either width, length, and angle of the lines of two centres on the axes or, width, position of the centres on either axis and angle of the lines of the two centres to construct this type of oval, although the location of the holes on the minor axis is approximately one-third of the half of the minor axis. This point could have been found by

common construction methods using a compass and ruler for dividing a span into equal parts (López Mozo 2011). A line from this point in a 30° angle would have given the same results, as the intersection on the major axes establishing the centres of the minor arc and the tangent point is linear.

The clear formation of the holes that make up the centres on the minor axis (J) is likely a result of the method by which the arch was drawn. A taut string, attached to a nail in the given position, with a length of JB could have been used in a matter similar to that of the nail and string method (Figure 8) or from the pointed tip from the use of a large compass. The two other centres on the major axis fall inside the void centre of the strainer and is not visible.

At the current time, it is not possible to compare and determine whether all of Juel's oval paintings have the exact same curvature corresponding to the curvature of the original strainers studied here. Depending on the curvature of the ovals, the layout may have been constructed in a different way, which cannot be currently accounted for. If the format was freer, the creator may not have had complete control over the dimension and would have been free to choose where to place the centres and adjust the dimension if needed or start over by trial and error. In other cases, with no indicators present on the strainer, the oval layout may have been drawn out in smaller scale in the desired shape, with a notion to the location of the centres, or traced from another element. The presumable French strainer supporting *F. Hauch* (KMS349) displays only a pencil line indicating the major axis, but no other indications appear towards the construction of the strainer. However, the ratio between the length and the width is slightly smaller (1.2) than those of the Svenstrup strainers (1.3). However, even just the presence of the indicated axes line suggests that a similar approach could have been used on this strainer as well, and thus suggests connected approaches across borders in Europe.

5. Who Made Juel's Strainers?

The strainers for Juel's portraits were likely not manufactured in his studio but purchased from a supplier specialising in woodworking craft. This could have been a carpenter (*tømrer*), but most likely a joiner and cabinetmaker (*snedker*). Carpenters usually performed coarser building work while joinery involved finer tasks such as installing of panelling, moulding, mantelpieces, windows, staircases, and similar interior trim in houses, as well as furniture of the plainer sort. Cabinetmaking demanded skills of a higher order to create furniture with such refinement as curved surfaces, joints, carved ornamentation, veneering or inlaid surfaces (Heuvel 1969; Clemmensen et al. 1954; Edwards 2000; Duus and Duus 2002; Alberdi 2013).

From the Middle Ages up until the mid-nineteenth century, these crafts were connected to the guilds and guilds' trade organisations, which were strongly influenced by German guild cultures called *Zünften* as a result of mutual migration of workers and the wandering journeymen. The guild had strict rules regarding competition and who was allowed to import, distribute and undertake different tasks and products (Clemmensen et al. 1954; Dybdahl and Dübeck 1983; Karmark 1989; Juul 2013; Bøndergaard 2014; Parby 2015). Zünften was the secret life and work of the guilds which included knowledge of the craft and its history, as well as rules about ceremonies and rituals, working relationships, legal matters and behaviour (Clemmensen et al. 1954; Dybdahl and Dübeck 1983; Karmark 1989; Juul 2013; Parby 2015). As with other trades, the training primarily consisted of oral transfers and practical instructions in the workshop based on tradition and with traditional tools, which remained the same for centuries until the mid-nineteenth century (Dybdahl and Dübeck 1983; Juul 2013). With the publication of Diderot and D'alemberts encyclopedia in the mid-eighteenth century, it was the ambition to make a systematic description of all crafts, their tools and procedure. The intention was to undermine the guild secrets and stimulate technological development (Juul 2013).

Sporadic accounts and receipts from the seventeenth and eighteenth centuries provide evidence that joiners and cabinetmakers usually supplied strainers (Friis 1872–1878; Eller

1971; Elling 1945, 1958) (Figure 14). Philipp Otto Runge mentions in a letter from 1803 that he could order a strainer (*blendrahmen*) from his joiner from one day to the next (Möckel and Castro 2013). Eckersberg mentions frequently in his diary that he acquired strainers from carpenters (Villadsen 2009: for instance 2 October 1816, 28 April 1817). No specific information on any purchases of strainers by Juel have so far been found, but there appear to have been plenty of woodworking craftsmen in Copenhagen that could have supplied strainers for Juel's studio. In *Stats-og Handelsspejlet* from 1780, one of the earliest directories of trades and addresses, are listed 146 masters of joinery and 22 masters of carpentry in Copenhagen, as well as 15 turners (*drejere*), 15 chair makers (*stolemagere*), 18 coachbuilders (*hjulmænd/Karetmænd*) and other masters of less common woodworking crafts, such as organ builders (Holck 1780). Cabinetmakers are not listed separately from joiners. Depending on demand, the different specialised tasks were often taken on by the same craftsmen, while in other cases such as coachbuilding, the work was performed in collaboration between multiple crafts (Dybdahl and Dübeck 1983). In addition to masters were journeymen and apprentices, who are not listed in the directory, but there were generally one to two times as many of these as the masters (Parby 2015).

Figure 14. Thomas Larsen Borup, *Cabinetmaker at his workbench*, 1767. Woodcut.

The increase in economy during the latter half of the eighteenth century gave rise to many crafts. The woodworking sector was one of the most advanced in Copenhagen as many joiners and cabinetmakers fitted out interiors and supplied furniture to the wealthy aristocracy and the upwardly mobile bourgeoisie in the construction and decoration of castles, estates, mansions, houses, churches, etc. (Elling 1958; Langen 2008; Parby 2015). It was a trend, as seen in the rest of Europe towards the end of the eighteenth century, which reached a climax in Paris, where an explosion of luxury, taste and fashion had taken place by 1780, with furniture becoming the most important object of luxury and expense (Stürmer 1979; Farr 1997). By the middle of the eighteenth century, stores where one could buy ready-made furniture rather than by commission started to appear in Copenhagen. Joiners were the first to practice this type of commerce in Copenhagen, although other professions soon followed (Dybdahl and Dübeck 1983). Several joiners and cabinetmakers went into collaboration and founded furniture stores. The very first at *Børsen* did not have great success, but by the turn of the century, approximately a dozen such stores existed (Dybdahl and Dübeck 1983). The furniture displayed a high level

of craftsmanship and an approach with fine drawings and the use of geometry to create intricate shapes of furniture (Chippendale 1754); this level of precision would not have been required for the construction of strainers. There seem to have been plenty of woodworking craftsmen with skills to have supplied strainers for Juel's studio, as the strainers were basic structures with simple half-lap joints. Making strainers was likely considered slightly coarser woodworking. No matter the status and specialisation involved in making cabinets and luxurious furniture, records show that joiners at times produced both finer and coarser woodwork (Elling 1958). This information provides insight into the developments and demands of different trades in Copenhagen in the latter half of the eighteenth century and the suggested construction of the oval form in Juel's strainers provides an insight into the secret knowledge of the guilds.

6. Conclusions

Few original strainers from the eighteenth century or earlier still exist. Seven oval preserved strainers in paintings by Jens Juel as well as evidence of their shape and format from creases and craquelure in the paint surface provide evidence of the construction, format, and production of strainers in the late-eighteenth century. In all cases, the preserved strainers are of simple construction, made of softwood and assembled from four members with fixed corners joined with half-lap joints.

The rectangular strainer bars had a width ranging from 4 to 6 cm, while the oval strainers produced in Denmark had top and bottom bars that are generally approximately 13 cm wide at the widest central point, while the sidebars are between 10.5 cm and 12.5 cm wide. The oval strainers are very similar, and all have a rectangular inner shape. A presumed original French strainer in contrast, has members only 6.2 cm wide and with an oval inside shape. All the preserved strainers have tool marks on the surface of the wood that corresponds with late-eighteenth-century developments.

The oval strainers in Juel's paintings can be characterised as a polycentric oval, which is a double symmetrical shape, constructed through two pairs of circular arcs, one major and one minor, sharing a common tangent at the connecting point. Incised lines representing the major and minor axes, symmetrically located holes on the minor axis that represent the centres of the major arcs and pencil lines from the minor arcs present on the surface of the wood, provide evidence of the construction of the oval shape.

The oval strainers are a construction with given dimensions and with two 60° equilateral triangles that the centres of the arcs form when aligned with the major axes. The two dimensions and choice of 60° triangles are three possible parameters that the creator had to choose to find the centres of the arcs to generate the curvature of the oval. Such a layout would have been published by Christiaan Huygens (1629–1695) and Amédeé François Frézier (1682–1773) by the time of construction by someone in the wood working crafts in Copenhagen, who supplied strainers to Juel's studio. They may have been aware of the published layouts or found the centres by either skilled knowledge or trial and error. This suggested know-how provides insight into the craft, practice and thought behind the production of the strainer which could be part of the secret knowledge of the guilds. A presumable French preserved strainer displays only a pencil line indicating the major axis, with seemingly no other indications towards the construction of the strainer. However, even just the presence of the indicated axes line suggests that a similar approach could have been used on this strainer as well, and thus suggests connected approaches across boarders in Europe. The information obtained in this study may act as a comparison for markings on and construction of other preserved strainers in future studies.

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Conflicts of Interest: The author declares no conflict of interest.

Notes

1 "*On a inventé depuis peu une maniere de faire des chassis qu'on appelle chassis à clefs; ils sont preferable en tout aux anciens chassis parce qu'au moyen des clefs, on tend la toile plus fortement, & toutes les fois que la sécheresse la relâche. Ces clefs se mettent dans tous les coins d'assemblage & aux bouts de chaque traverse.*"

2 Differentiation between the terms strainer and stretcher is made in the English language, while in Danish, the term *blindramme* or *blændramme* applies for both and does not allow differentiation. At times, the term *kileramme* (*kile* = key/wedge) is used to signify a stretcher type.

3 Wood species identification was performed on the preserved strainer of *Marie Christine Buchwaldt, née de Svanenskiold* (SV3) as well as a related portrait by Juel's assistant Herman Kofoed portraying *Peter Johansen Neergaard*, also in the Svenstrup collection. Both suggest pine (Pinus Sylvestris) (Claudia Baittinger, curator at the Department of Environmental Archaeology and Materials Science at the National Museum of Denmark, September 2018). Pine and spruce (Picea) are typical softwoods used for strainers and stretchers (Buckley 2012).

4 The adhesive displayed significant UV fluorescence and was confirmed by Attenuated Total Reflection–Fourier Transform Infrared Spectroscopy (ATR-FTIR) with spectra showing specific bands associated with animal glue such as the Amide II (1537 cm^{-1}) and Amide 1 (1633/1642 cm^{-1} C-O stretch). Spectra were collected on a PerkinElmer Spotlight 400 Imaging System and Frontier spectrometer in the range of 4000–4750 cm^{-1} at 4 cm^{-1} resolution with a liquid-N2-cooled MCT detector. The spectra were analysed using the Perkin Elmer Spectrum IR (version 10.6.1) software package. Canvas samples were placed on a glass slide and data were acquired using a drop-down micro ATR accessory with 100 µm Ge ATR crystal.

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