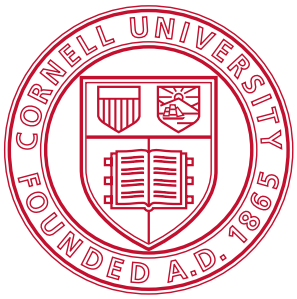
The Rau Model Plow Collection at Cornell University and the Evolution of Plow Design



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Note 1: The policy of The Internet-First University Press is to publicly identify and acknowledge the assistance of its reviewers.

Note 2: A nomenclature of plow parts (from Wikipedia) is contained in the DVD-ROM (and online).

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CONTENTS

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Origin of the Model Plows

Cornell University currently possesses a collection of approximately 126 model plows illustrating the worldwide development of the plow from the origins of tilled agriculture around 3000 B.C.E. up to the 1860s. These 1/8 scale model plows were created during the middle 1860s by a master craftsman at the Royal Agricultural College of Hohenheim, Germany, under the direction of Professor Dr. Ludwig von Rau. The original collection included 187 of these meticulously-detailed models that were first displayed at the Paris Exhibition of 1867. To provide authenticity for each model Professor Rau prepared a directory of the model plows that provides a classification structure, the country of origin, a brief history of the plow and a bibliography of provenance.

An extensive collection of over 500 model plows is now on display in the German Agricultural Museum in Hohenheim, Germany. Deputy Curator Frank Emmerich reports the following (with some of my editing) about the origins of their model plows and machinery, including the origins of the Rau models.

> The Hohenheim manufacture of agricultural tools was founded in 1819, one year after the Royal Agricultural College was opened. It was the first time in the German-speaking world that agricultural tools and equipment were produced on a larger scale beyond workshop standards. Also the scientific world was involved to investigate improvements of existing farming equipment. The Hohenheim facility ceased to exist in 1904, but in the nine decades of its operation it underwent various changes in ownership. The models were primarily used for teaching purposes at the agricultural college, but in the 1860s a large number of these miniatures were also produced for collectors by Professor Rau. The initial idea was to stimulate better farming methods with modern tools; hence students brought models to their local craftsmen to demonstrate improved equipment, which was then copied and sold.
>
> Fortunately, over the decades, the scientific staff at Hohenheim has recognized the value of its collections. Apart from more than 500 different ploughs, we are keeping another 500 models of harrows, carts, scarficators, mills, seed drills, threshers and rollers in our museum. Most likely the world's largest collection of 19th century farming models, the Hohenheim model collection forms the baseline of our museum, which was opened in 1972.
>
> There is one very concise account of the Hohenheim plough collection that will contain most of the Cornell models. The author is Ernst Klein, the title is "Die historischen Pflüge der Hohenheimer Sammlung landwirtschaftlicher Geräte und Maschinen", written in 1967. The book published only in German is still available on the second hand market and it can be purchased from the following antique book dealer:
>
> Mosakowski & Stiasny GbR
> Basaltstrasse 6
> 61197 Florstadt
> Deutschland
> Telefon: 0049-6035 -9031485
> Fax: 0049-6035 -90314 83
> E-Mail: kundenservice@fachbuecher-weltversand.de

The Klein book is also available from the Cornell Library (Call Number S683 K64). Pictures of 454 plow models are included in the Klein book along with a description of each origin of the model depicted. The illustrations are cross-referenced to the Rau directory.

Beyond the extensive collection of model plows at the Agricultural Museum at Hohenheim, it is likely that other plow models of the Rau era are held by private collectors. The German Historical Museum of Berlin also has a collection of model plows.

The Cornell Connection, Storage and Display

Cornell University obtained the Rau model plow collection in 1868 as a result of a European tour by Andrew D. White, the first president of Cornell. President White's objectives for his tour were to obtain materials, information and contacts to support the development of the new university founded by Ezra Cornell. During President White's visit to the Royal Agricultural College at Hohenheim, Germany, he was exposed to the Rau plow models and was immediately interested in acquiring them. The following is an excerpt from A. D. White's letter to Ezra Cornell, dated May 21, 1868.

From Frankfort au Main

> Went to the Royal Agricultural College of Hohenheim. Grounds and palace with a multitude of buildings for the various departments. Significant workshop where agricultural machines made as samples. Workshop where models of machinery made also.
>
> Among others a complete collection of models of ploughs used in all nations and times. One hundred eighty-seven in number. They were on a small scale 1/8 natural size I think but perfectly made that every bolt and screw and every cord (as in the familiar(?) ploughs) were exactly given. From the crudest plough used in bible times and earlier to the English Howard plough and American improved ploughs all important makes and categories[1] are given. Some are exceedingly curious and form wonderful examples of applied ingenuity – but altogether they are very interesting and instructive. They are the result of the studies of Prof. Rau of Hohenheim and the mechanical skills of the master mechanic of the College.
>
> There was also this more complete collection of horseshoes in existence – of - and countries for all[1] (?) and conditions of the animal. If anyone had told me a year or two ago that I could ever be interested in a collection of ploughs and horseshoes I would have laughed heartily at the idea – but – I have rarely seen anything of late more interesting.
>
> Acting on a hint from their master mechanic at Hohenheim I went off the next day from Stuttgart to Karlsruhe hunted up Prof. Rau and found that he had there his complete collection of plough models – even more complete than that at Hohenheim – which he had exhibited at the recent Paris Exhibition. In about an hour it was bought and paid for at 500 francs less than the set he sold to the French Gov't. I insisted that one set in the U.S. was worth a dozen in Europe and an advertisement. Price paid was 2000 francs. If you don't like them I will take them off your hands as an advance. They will be shipped immediately.

These plow models were obviously shipped to Ithaca, NY but where they were immediately housed is unknown. In the *Landmarks of Tompkins County*, New York (1894) by John H. Selkreg. There is reference to the model plows becoming a part of an agricultural museum at Cornell:

> In 1873, Professor Isaac P. Roberts of the Iowa Agricultural College was appointed assistant professor of agriculture. From that time the proper development of the department and scientific direction of the farm date. The farm no longer cultivated simply for the production of crops, but to test certain important

1 Words are obscure in A.D. White's handwriting. A scan of the original handwritten letter is included as part of the supplemental resources.

> principles. Soon after his appointment an appropriation of one thousand dollars was made to fit up the agricultural museum. Certain illustrative material had been ordered by President White, among them the Rau models, a series of one hundred and eighty seven models of plows illustrating the history, development and varied use of the plow in different ages.

Apparently the museum was established on the campus where the plow models were placed on display. The report of Cornell University to the New York State Senate in 1876 refers to the agricultural museum and the various exhibits it contained. See the following: From the Documents of the State of New York, Volume 4 by New York (State) Legislature, Senate (Report for Cornell University for the Academic Year 1875-1876 ending July 1, 1876, pg. 242).

> 1. Agriculture. – The museum contains (1) The Rau models, being one hundred and eighty-seven models of plows made at the Royal Agricultural College of Wurtemburg, under the direction of Professor Rau, and arranged and classified by him for the Paris Exposition of 1867.

In *The Register of Cornell University 1899-1900* (published by the university, December 1899 in Ithaca, New York, by the Press of Andrus and Church, pg. 227) is the statement: "The Agricultural Museum occupies rooms on the second floor of Morrill Hall."

How long the Rau plow models remained in the Agricultural Museum beyond that date is difficult to determine.

Professor Howard Wait Riley, hired to teach farm mechanics in 1907, mentions the Rau model plow collection in his oral history contribution[2] indicated below. Professor Riley apparently was aware of the Rau plow models through a colleague, Professor Stone, who had used the models for exhibitions at fairs and other venues. Perhaps by that time the models had been moved to Roberts Hall (erected in 1906) or the basement of Stone Hall, where Professor Riley occupied a desk starting in 1907.

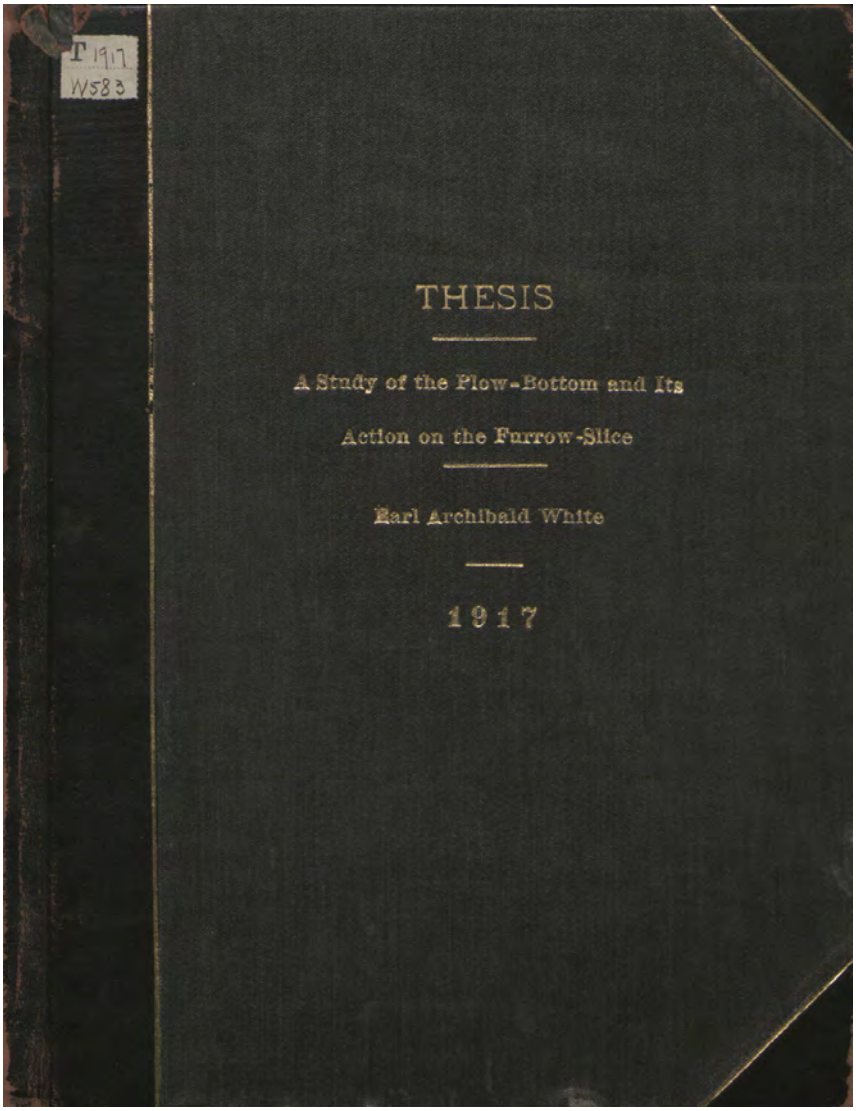
In his audio taped interview by Gould Colman, "In Their Own Voices: A Conversation with Howard W. Riley: Early Agricultural Engineering at Cornell University" on August 15, 20 and 28, 1963, Riley said:

> When President White had gone to Europe to get equipment for the new university, he had found in Germany a very large, historical assortment of models of plows which were known as the Rau plow models. He had contracted to have a duplicate set made, which had come to this country and had been deposited in the College of Agriculture. The models were numbered and there was a complete set of cards to identify them. But I suppose in the confusion and in the pressure to do some extension work, the cards identifying these models were lost and the models were used by Professor (John L.) Stone of the agronomy department in serving as objects of interest in exhibits at fairs, with the result that much important information was lost. Professor (G. N.) Law of the College was interested in these models because of their historical significance, and we tried to set them up properly but didn't succeed very well. At the present time, they are well displayed in the basement of Riley-Robb Hall but the detailed information as to the history of each one is still lacking.
>
> This thinking about what happened at certain times in the history of the department leads me to remember that a professor from one of the western colleges, I think it was Illinois, (E. A.) White, came to us and applied for an opportunity to acquire a PhD degree in agricultural engineering. The project that was in his mind was to study the construction of the plow bottoms in their relation to the turning of the soil. (See opposite page.) To make a long story short, he worked his three years on that project, and the university committee of which I was chairman granted him a PhD degree. This, I believe, was the first PhD ever granted to a man in agricultural engineering. As a matter of fact, I have always felt that the White investigations were completely futile. As it boils down, what he did was to mechanically determine a succession of curves of

2 http://ecommons.library.cornell.edu/handle/1813/7829

the surfaces of a number of plow bottoms. This information he took to the Department of Mathematics in the endowed university, and he then proceeded to establish an equation for these surfaces, for these curves, on the basis of a certain pre-determined pair of axes.

The activity was out of my realm, and was carried on wholly with the Department of Mathematics. As the finale approached, I told them that White should not get his degree under engineering, but should get it under mathematics. To this they objected, because they said that many departments other than mathematics came to them for technical assistance, and if they began to establish a practice that when a man wanted special mathematical help the different departments could not supply, if, when students from other departments went to mathematics for such help, then if mathematics took the student over as their graduate student, they would set up a situation of jealous fear, that other departments would not come to them for help which they currently were being able to supply. So, as I say, White's thesis on plow bottoms was really an example of mathematical gymnastics which had no relation to agriculture, because all he did was to establish mathematical expressions for the curvatures that happened to be the surfaces of plow bottoms. But the results that he obtained had no relation whatsoever to the effect of the mechanical process of turning over the soil. However, it was the first PhD that anybody ever got in agricultural engineering. White has now passed on, and so far as I know, his work did not contribute significantly to studies in tillage.



White Ph.D. Thesis, 1917

The Rau collection likely resided in Stone Hall from the early 1900s until they arrived in Riley-Robb Hall at the completion of its construction in 1956. The exact storage location for these models in this period has yet to be

determined. The models were simply stored somewhat casually in filing cabinets in the Riley-Robb shop area. I first became interested in the models in the early 1960s and worked with mechanic Clayton Van Hout to construct a display of the plows in the basement hallway of Riley-Robb. Later a selected subset of the plow models was displayed in a locked glass-fronted display cabinet in the entrance lobby of Riley-Robb; Prof. Riley recollects the display being made available in 1963. (A portion of the Rau collection was also displayed in the Mann Library for several years; the exact period for the display is not known.) In the years following 1963, the Riley-Robb basement hall display of the Rau models was periodically vandalized, and some of the models were stolen. Although the cabinets were secure from casual theft, a determined thief was able to pry open the plexi-glass covers and gain access to the models. To preserve the balance of the collection, the models in the basement hall were moved in the 1990s to locked filing cabinets in Riley-Robb Hall. Approximately 26 models remain on display in the locked-glass display case in the Riley-Robb entrance lobby.

In 2009 I began inventorying and restoring the models that still existed both in the filing cabinets and the entrance lobby display cabinet. One hundred twenty-three (123) models have been identified and photographed. A few other models exist but are not identified, and a random assemblage of wooden and metal parts from some of the missing models has been collected. Tragically many of the models have been broken, trashed or stolen; fortunately the remaining models do represent almost all the categories of plow development classifications.

The Rau Model Plows Directory

In 1881 Professor Rau produced a directory of the model plow collection with a classification scheme for the plow models and identification of the country and region of origin. The directory lists 317 different plow models. The classification scheme has Groups A to I, Classes I to XXV and Sub-classifications of A to U. The classification scheme relates to the major design features of the models. An annotated and referenced directory became available in 1952, based on Professor Rau's original directory. It was obtained from the "Landmaschinen-Institut der Landwirtschaften, Hochschule Hohenheim mit Landesanstalt fur landw. Maschinenwesen," where the director was Prof. Dr.-Ing. W.E. Fischer-Schlemm. The author of the annotated directory is undetermined, but this material appears to have been obtained by the Smithsonian Institution — Section of Agricultural Industries. Apparently a Mr. Edward C. Kendall of the Smithsonian was helpful in the identification of the Rau plow models and provided Cornell with the copy of the directory now in our library collection (Call Number S683 R23).

I have translated the German directory into English with the assistance of notes by Dr. Ari VanTienhoven, I trust that some degree of accuracy of meaning for the classification structure will emerge. All the remaining models at Cornell have been photographed and inserted into an illustrated Rau translation directory. This directory enables the reader to visually connect the design of the plow with the classification designation. By perusing the directory one can scan the evolution of plow design from antiquity to the mid 1800s.

Evolution of Tillage and Plow Design –(partially illustrated with the Rau Plow Models).

Plows may have first been developed and used in Mesopotamia about 3000 B.C.E. There is also evidence that primitive plows were in use in the Egyptian Nile delta about the same time.

Figure 1. An Egyptian plow circa 1700 B.C.E.

Primitive plows had only two parts[3]: a pulling beam and a pointed element for penetrating the soil. In some cases the plow was constructed from a tree with a substantial limb growing from the trunk at a suitable angle and then removing a section of the attached trunk to be shaped into a pointed, penetrating section.

3 See Appendix 1 for a glossary of terms.

Figure 2. Rau plow model 1 from Italy around 500 B.C.E. A two-part version of the hook-shaped plow.

Figure 2 illustrates a two-part improvement of the hook plow that originally was made from limb and trunk in the earlier rendition, seen in Figure 1.

This type of plow remained in use as late as the 1950s in Egypt. Numerous variations of the hook plow were used in India and Greece as well as in Italy.

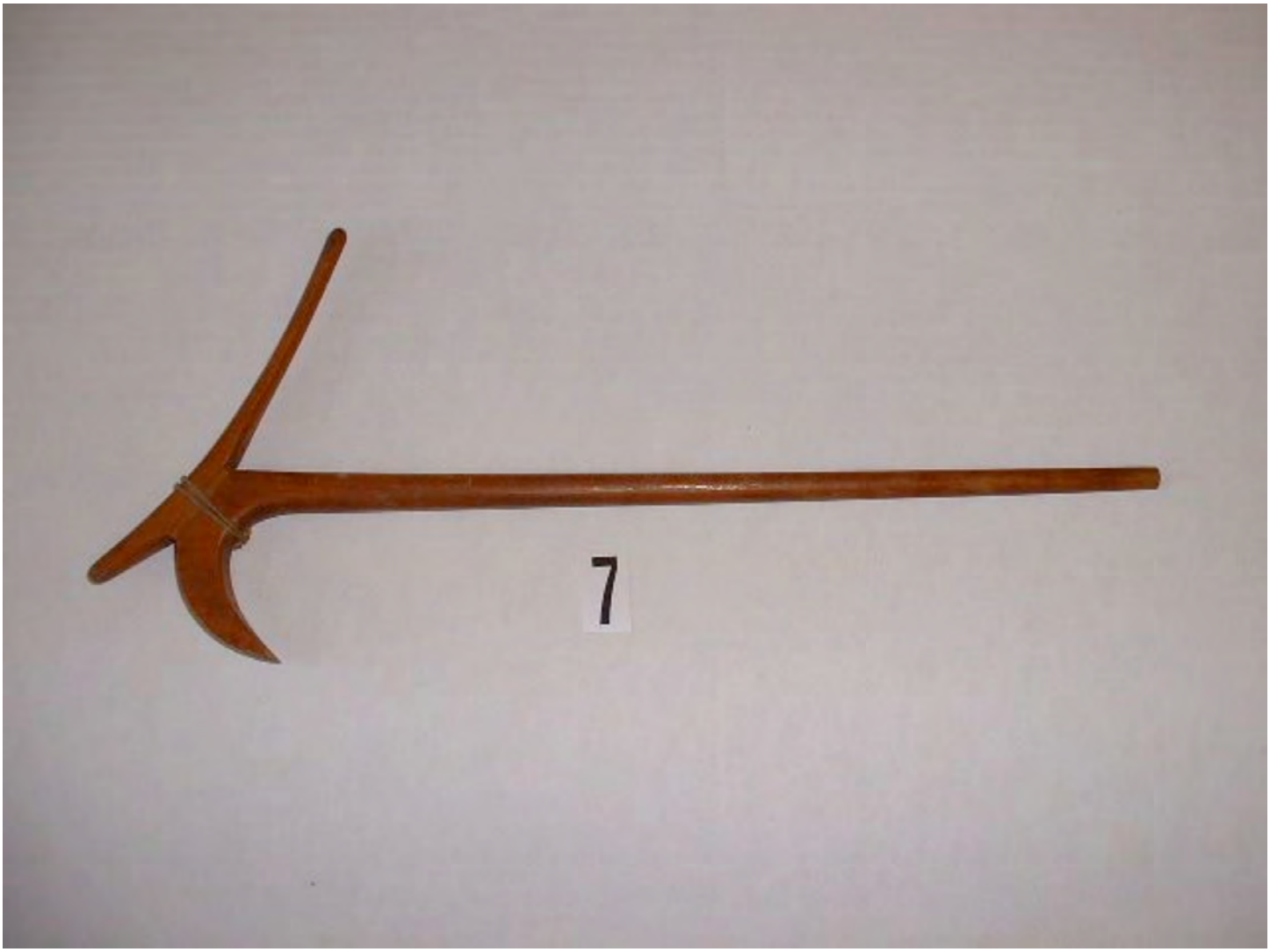


Figure 3. Rau plow model 7 from Greece. Note the attached handle. Also used in India in a similar form.

In some cases a form of a handle was added to assist in stabilizing the plow and maintaining the plow in an upright position. The following Rau plow models are examples of this improvement, which first occurred several hundred years B.C.E.

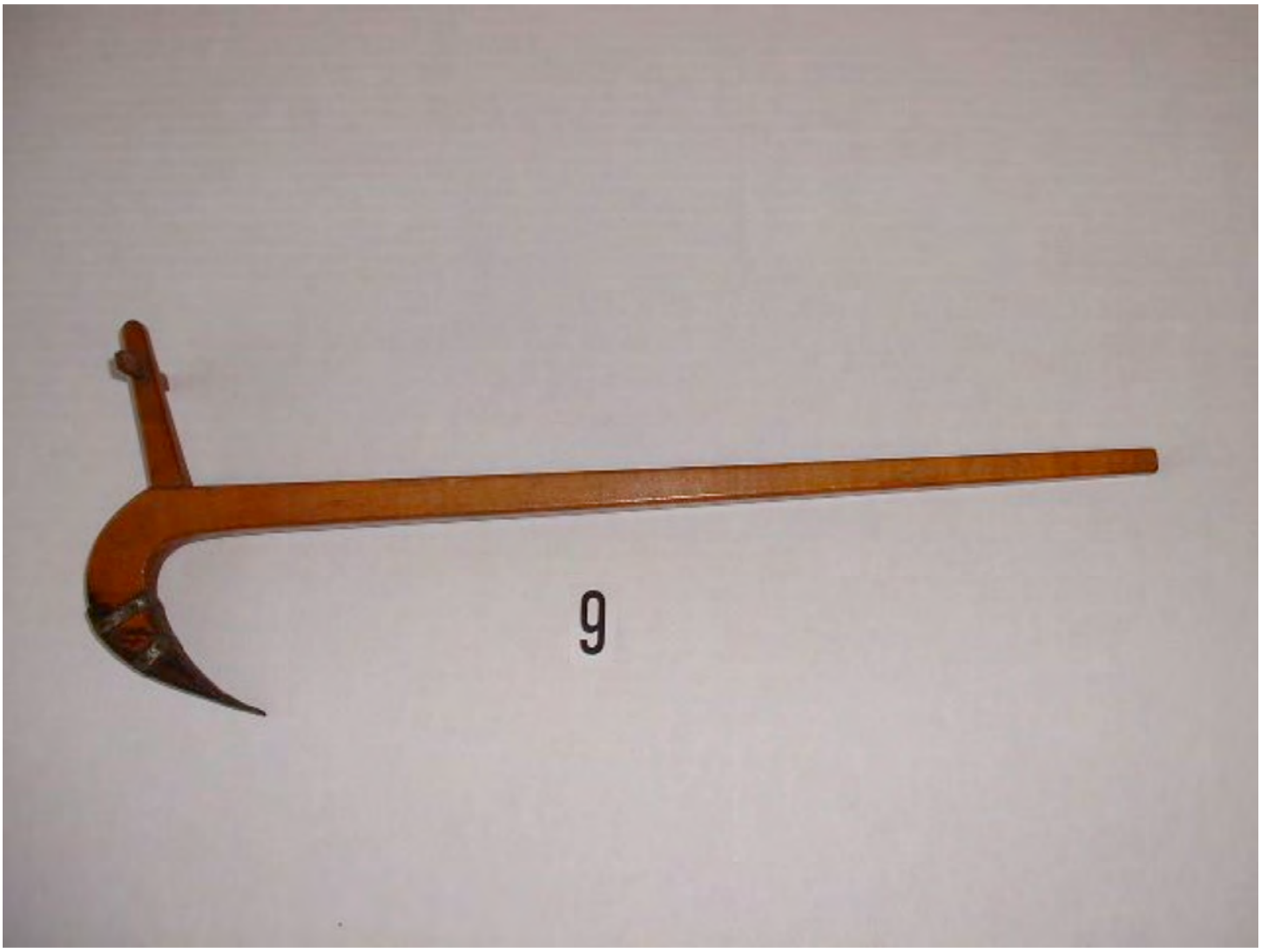


Figure 4. Rau plow model 9 from Italy (Rome) around 800 B.C.E. Note the improvement of a metal point. The main pulling beam and curved hook section are made from a single piece of wood.

Early improvements of the hook plow included the addition of a handle and metal coverings to the wooden points. Many variations of the simple plows were developed for different regions and countries.

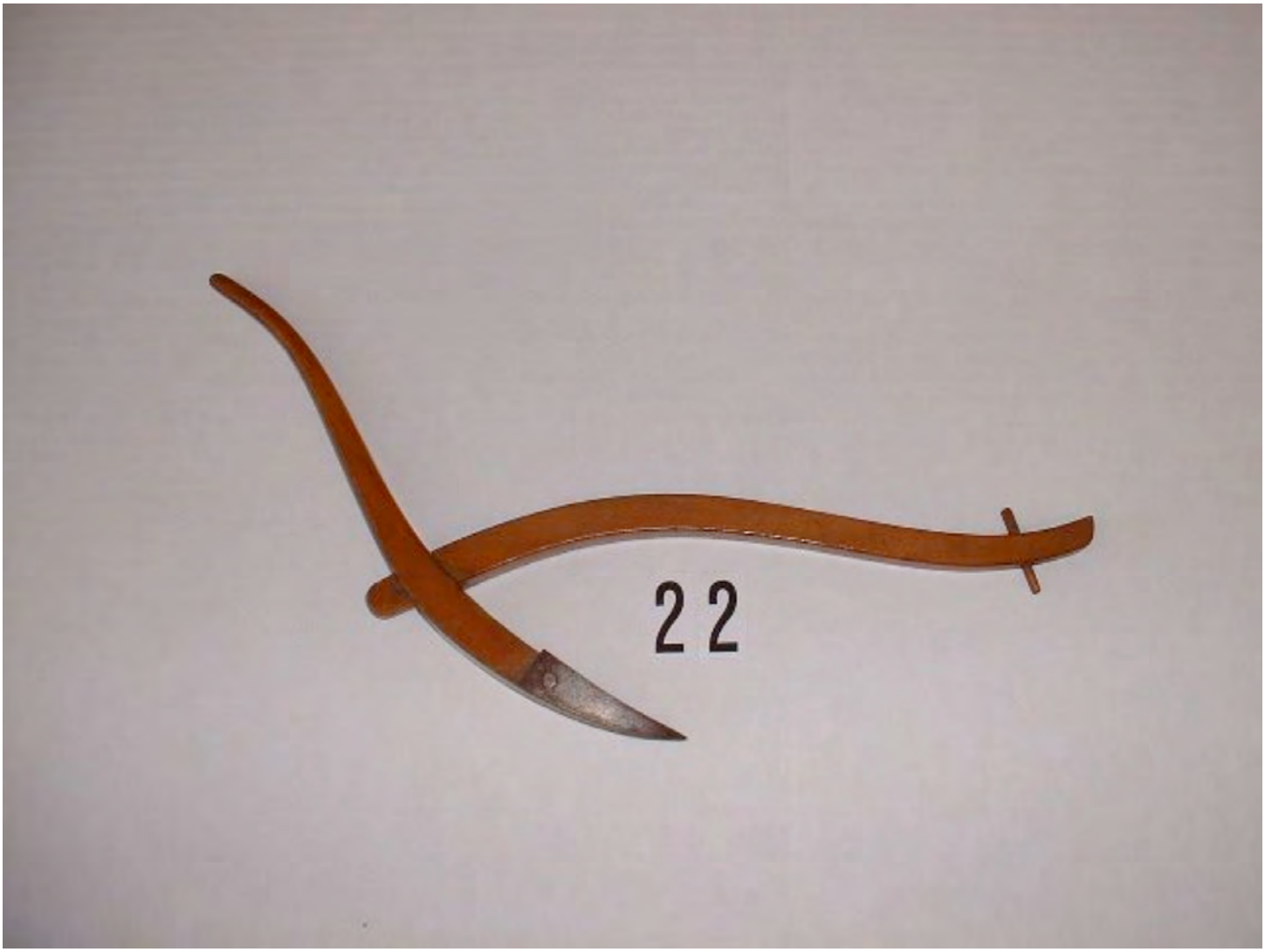


Figure 5. Moroccan plow related to ancient Egyptian plows. Rau plow model 22.

For example, in Figure 5 a two-piece plow with a metal point has a curved pulling beam and curved handle and plow shank. This plow originated in Morocco.

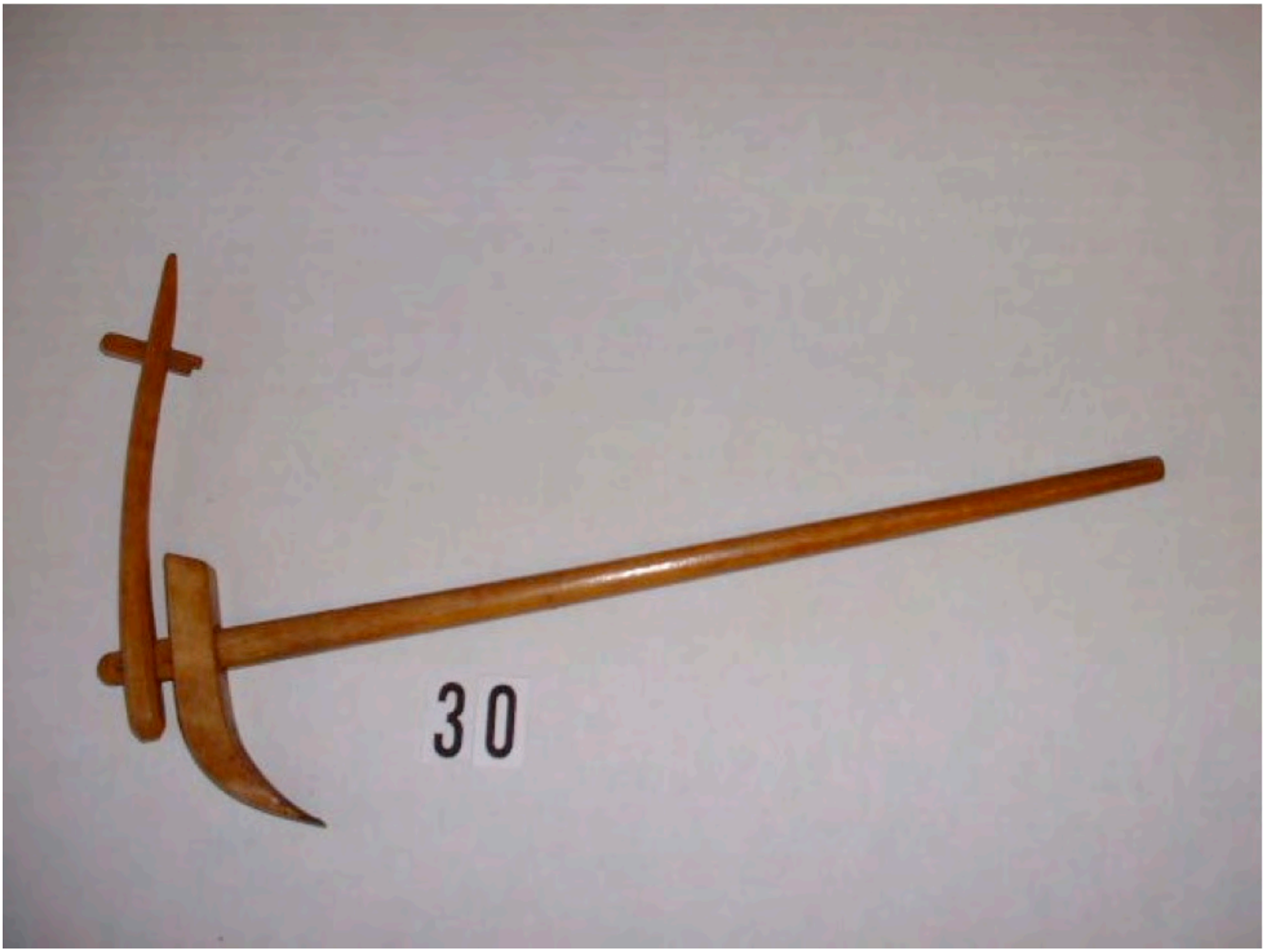


Figure 6. Indian plow in use as late as 1820 Rau plow model 30.

A slightly more sophisticated version of the primitive plows is the Indian plow illustrated in Figure 6. Note the straight pulling beam providing support for the separately attached plow beam point and the upright handle. This plow was in use up to 1820 in India.

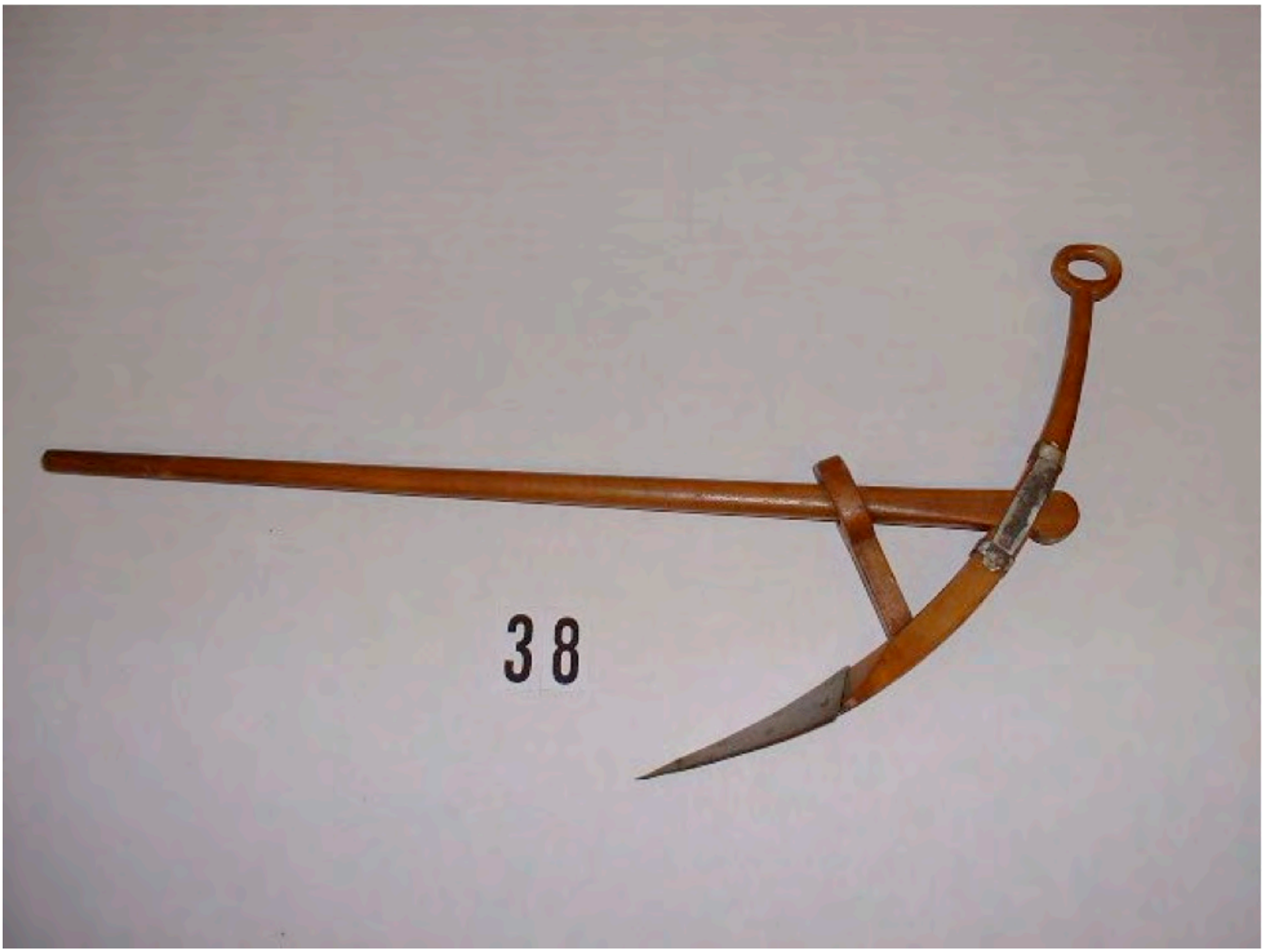


Figure 7. Ancient Egyptian plow. Rau plow model 38

The strength of a triangular configuration of the plow elements was reflected in ancient plows as shown in Figure 7. The ancient Egyptian plow consists of a straight pulling beam, a curved metal-tipped plow point and a handle piece strengthened with a straight connecting brace. This plow was still in use in Egypt in the 19th century.

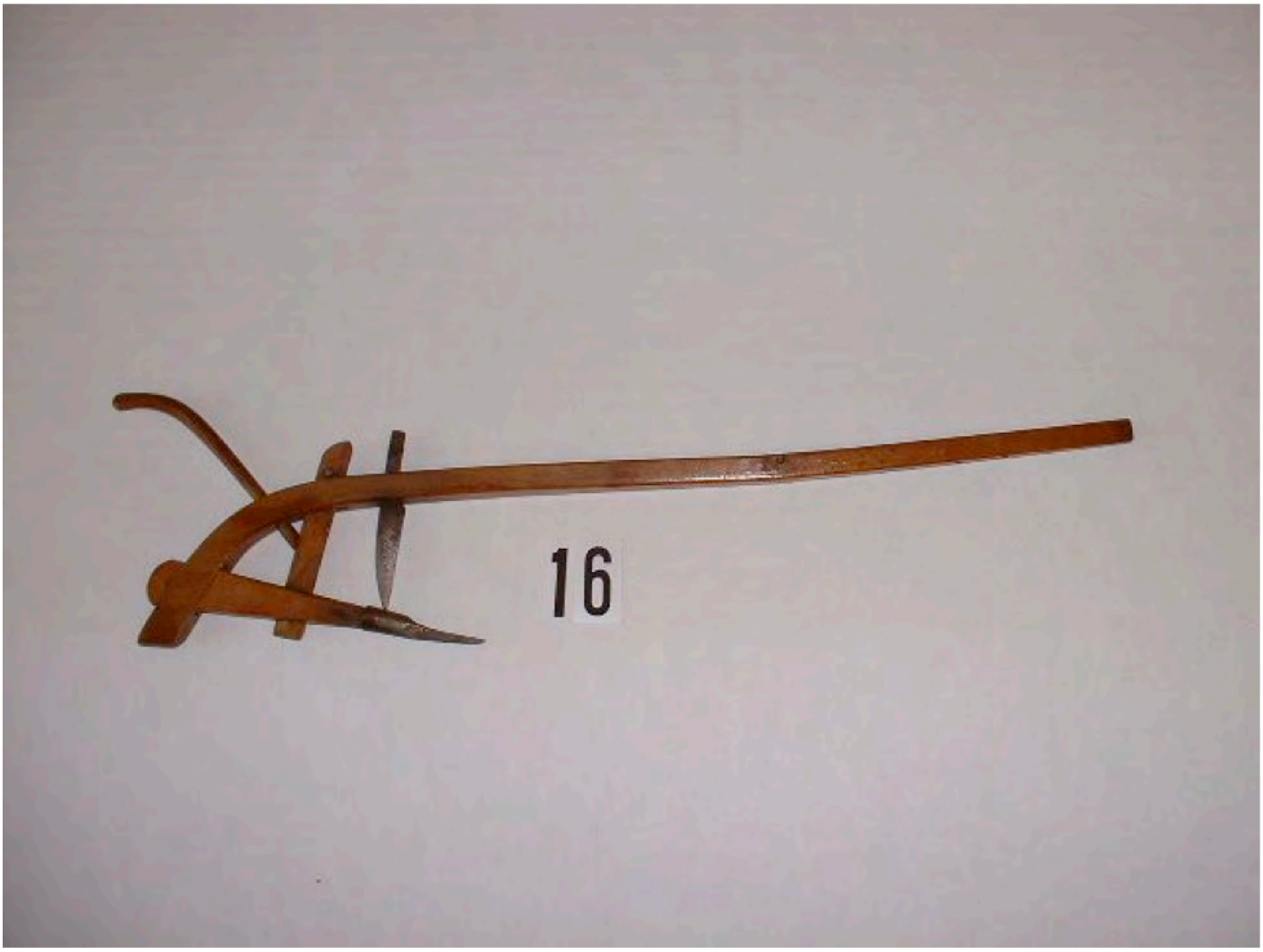


Figure 8. Rau plow model 16 from Switzerland.

In the continuing evolution of the plow the horizontal plow sole was added. This stabilizing configuration is shown in Figures 8 and 9. Note that the horizontal-pointed plow sole is stabilized with the triangular shape consisting of the handle, plow sole and nearly vertical brace. A vertical cutting blade (coulter) was added to the Swiss plow of Figure 8. Note that the handle rises from the pulling beam. Later plow designs have the handle rising from the horizontal plow sole.

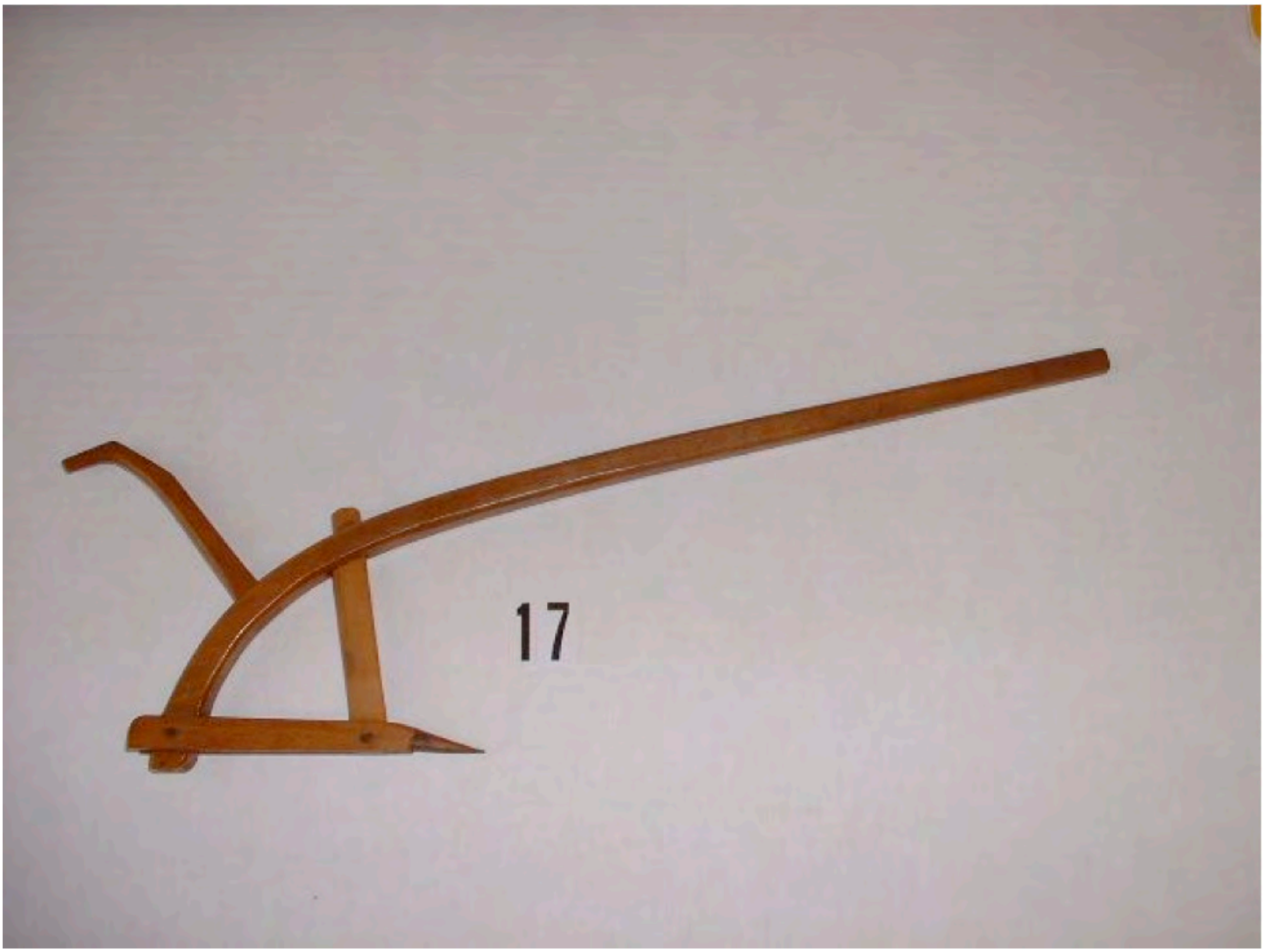


Figure 9. Rau plow model 17 from Abyssinia (formerly Ethiopia). Still in use in 1900.

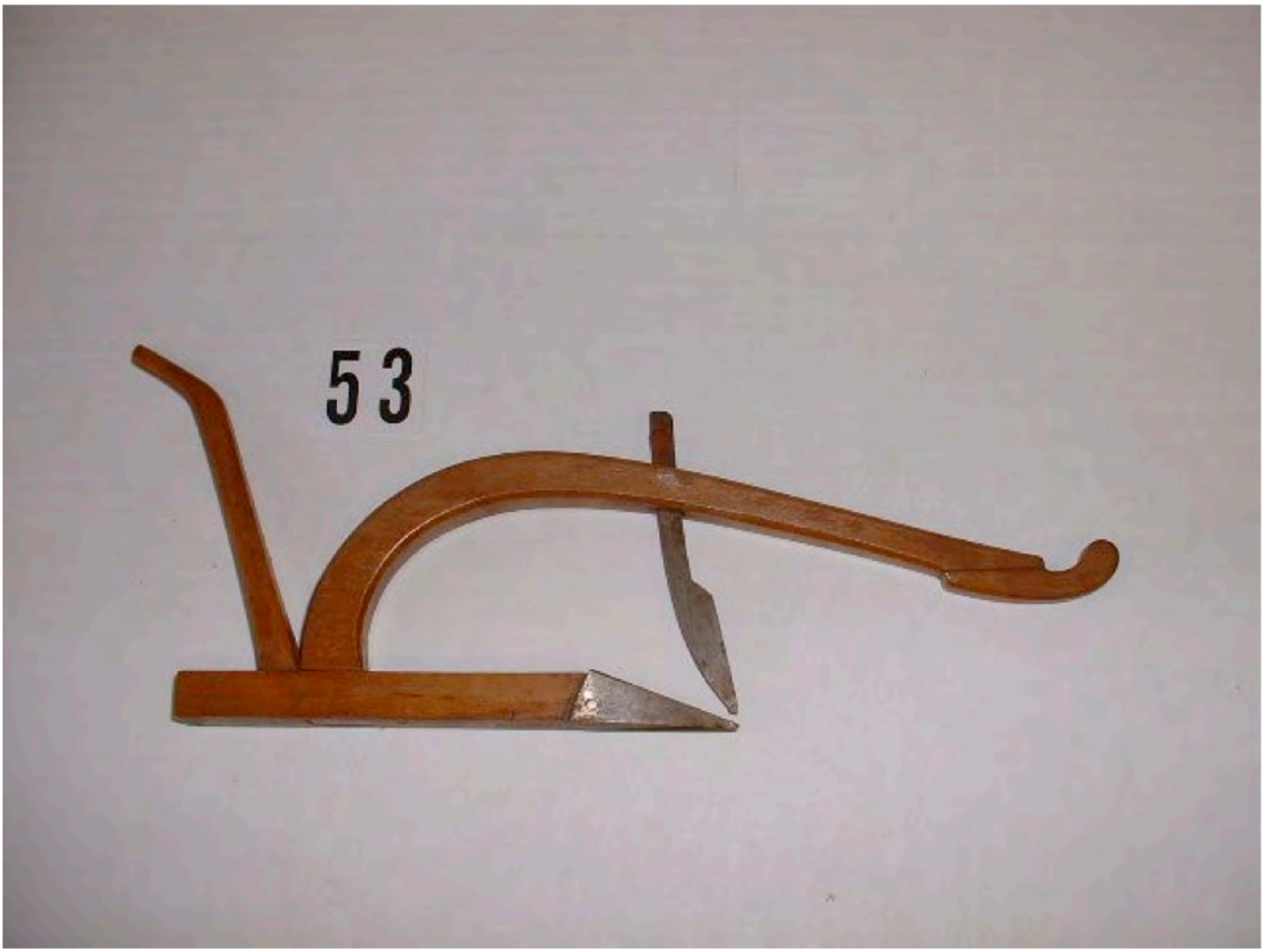


Figure 10. Russian plow from the Caucasus region.

An example of a design with the pulling beam and handle rising from the plow sole is shown in Figure 10. Rau model 53 illustrates a plow from the Russian Caucasus region, claimed to be "a plow easily pulled by animals." Several variations of this basic design were used in Tibet, Italy, India and other nations. Many of these designs were in use from 500 B.C.E. through the 19th century.

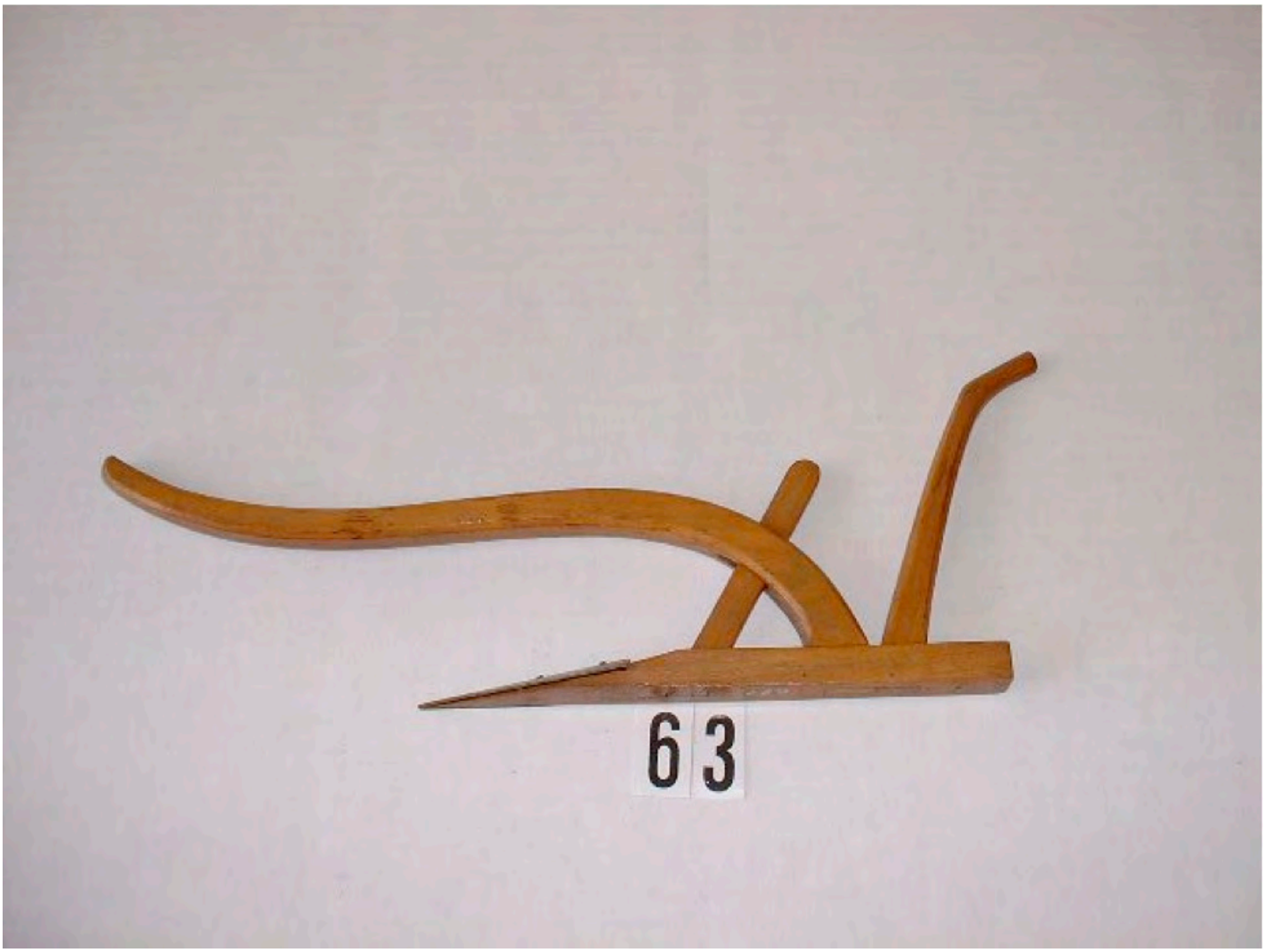


Figure 11. Greek plow. "Demeter's plow." Demeter, the Greek goddess of agriculture, marriage and fertility.

What may be considered an improvement on the Russian plow of Figure 10 is a design that adds a brace between the pulling beam and plow sole. Figure 11 depicts a Grecian plow that incorporates this design improvement. The brace between the plow sole and the pulling beam provides stability and strength to the entire structure. This design was used in Turkey, Arabia, Spain, Tunisia, France Egypt and Italy.

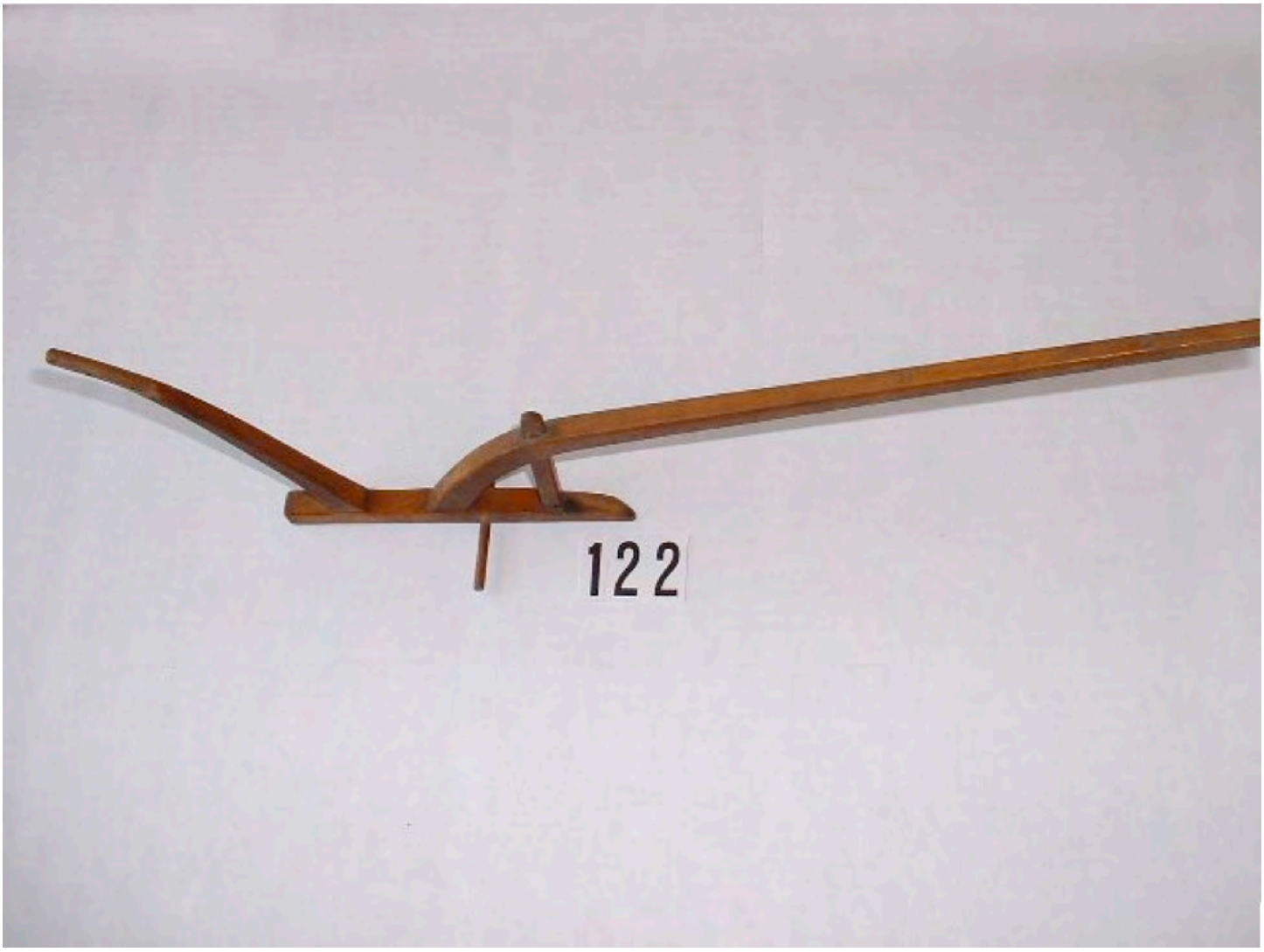


Figure 12. Algerian plow with round peg-like pieces to move the soil after cutting. The peg protrudes laterally from the plow sole.

There were early attempts to provide mechanisms to move the soil to one side and begin the process of turning the soil over. Some designs behaved much like our current minimum-tillage tools where a pointed tine or share simply cuts a furrow in the soil surface. Figure 12 illustrates this mechanism in an Algerian plow with round peg like pieces projecting outward from the plow sole to push the soil away from the soil furrow.

Note: Figures 12 through 29 date from the 19th century on.

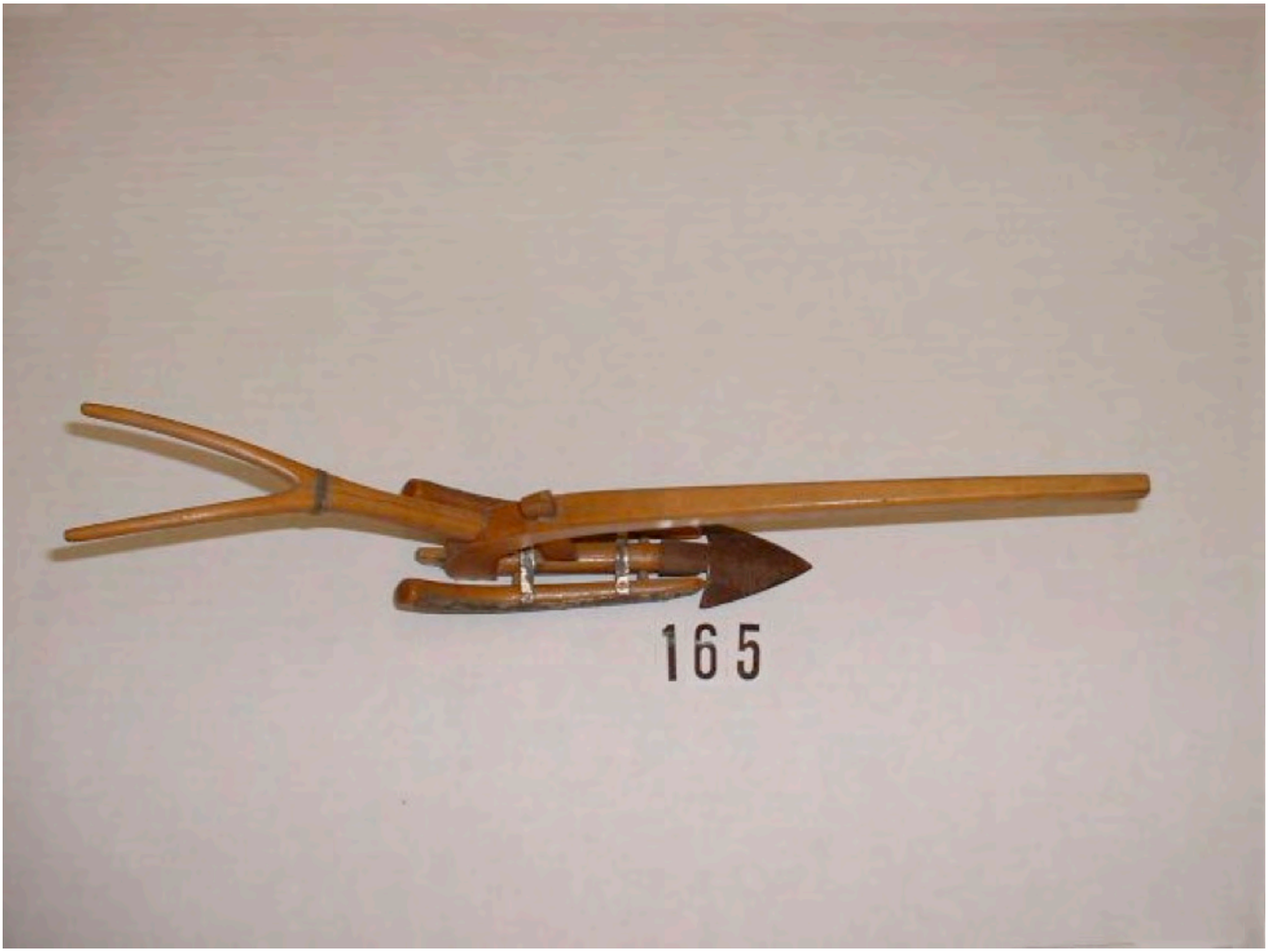


Figure 13. Italian plow with rounded projections to either side of the plow sole.

There were multiple designs for improved lateral displacement of the soil as the plow sole moved through the soil. The earliest designs had projections to both sides of the plow sole, thus essentially widening the furrow and more completely breaking up the soil surface. Figure 13 illustrates an Italian plow design that improved on the spigot -like ears (see Figure 12) by slanting the projections from the plow sole to the rear.

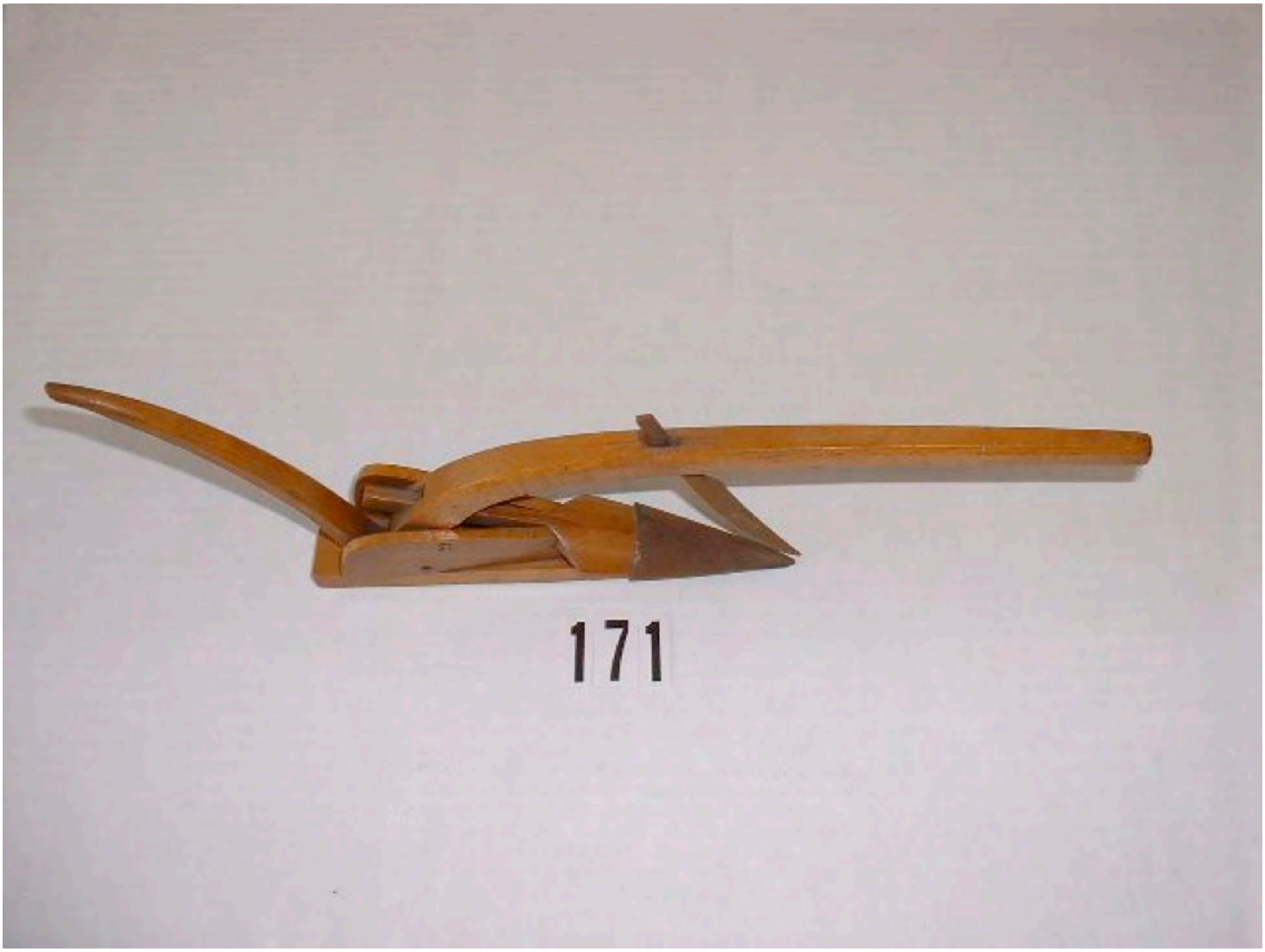


Figure 14. An Italian plow with two primitive wooden moldboards projecting to the rear and attached to the plow sole.

A variation on this approach to plow design is another Italian plow, Figure 14 where two boards vertical to the plow surface slant to the rear from the plow point to widen the furrow made by the point.

Numerous variations on the basic idea of double-sided projections from the plow sole were used in various designs originating in England, Japan, Germany, China, Switzerland, and France as well as other nations.

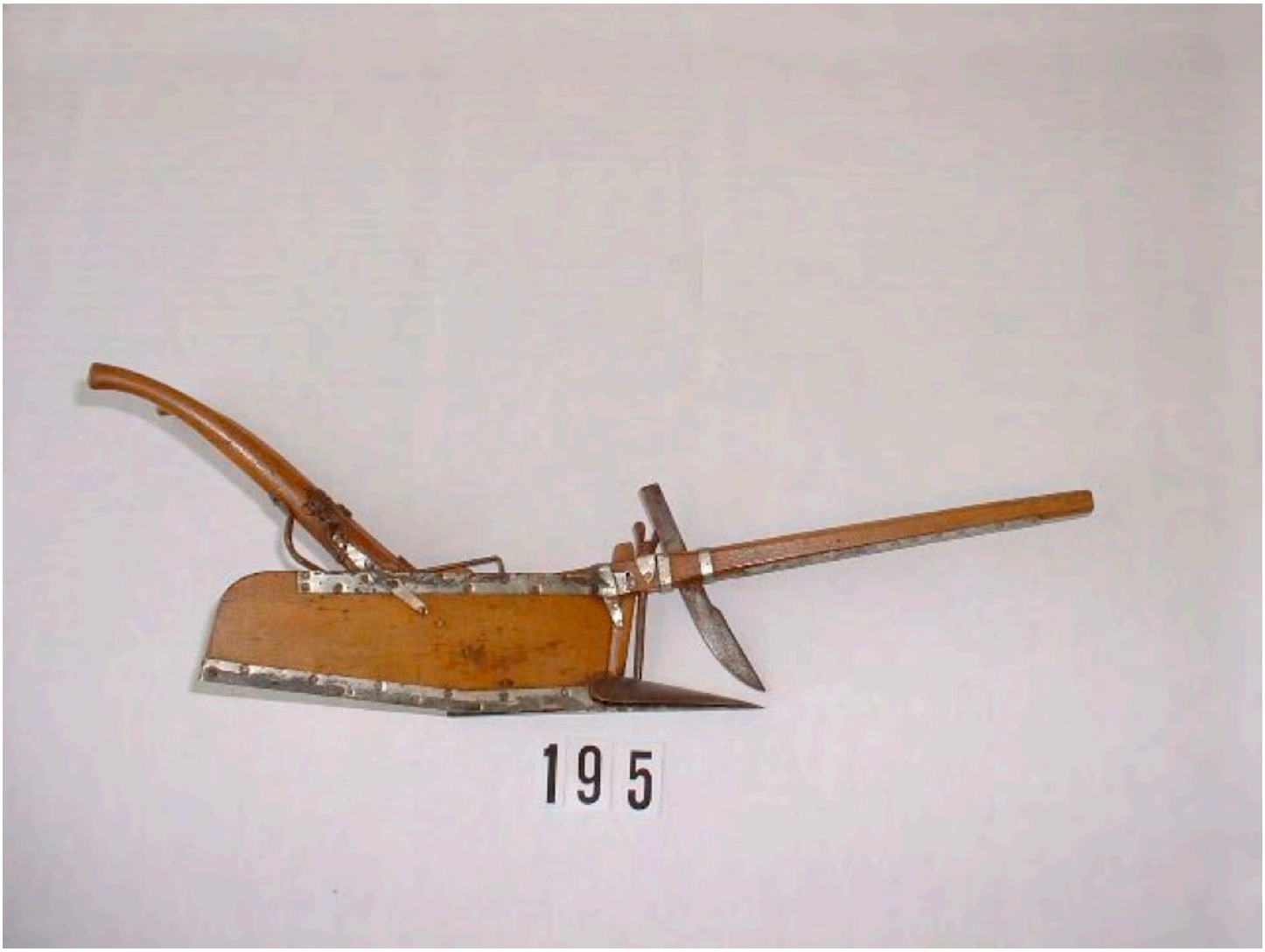


Figure 15. German "country plow" in elevation view

Eventually a moldboard moving the soil to either the right or left side became a preferred design for certain soil and turf conditions. These designs were common in the temperate climates of the European nations of Germany, Russia, Poland, England and the former Yugoslavia, for example. Figures 15 and 16 illustrate this design as the "country plow" in use in Germany in 1832. Plows of this design, however, did not invert the soil.

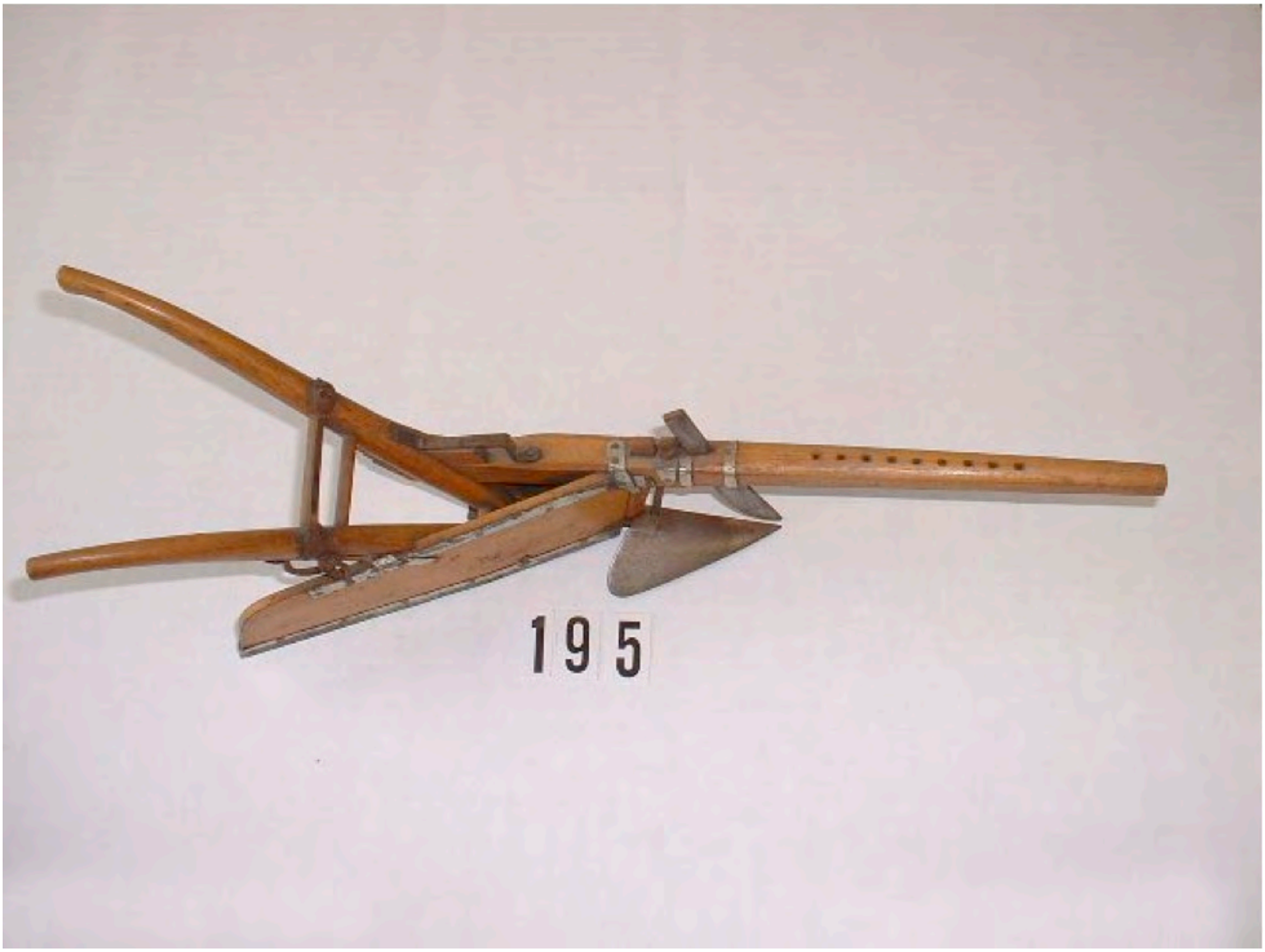


Figure 16. German "country plow" in plan view: A precursor design to the modern moldboard plow.

The next level of sophistication in the design of the plow was the development of a twisting or spiraling moldboard – either of wood or metal – that would become widely used in the 19th century.

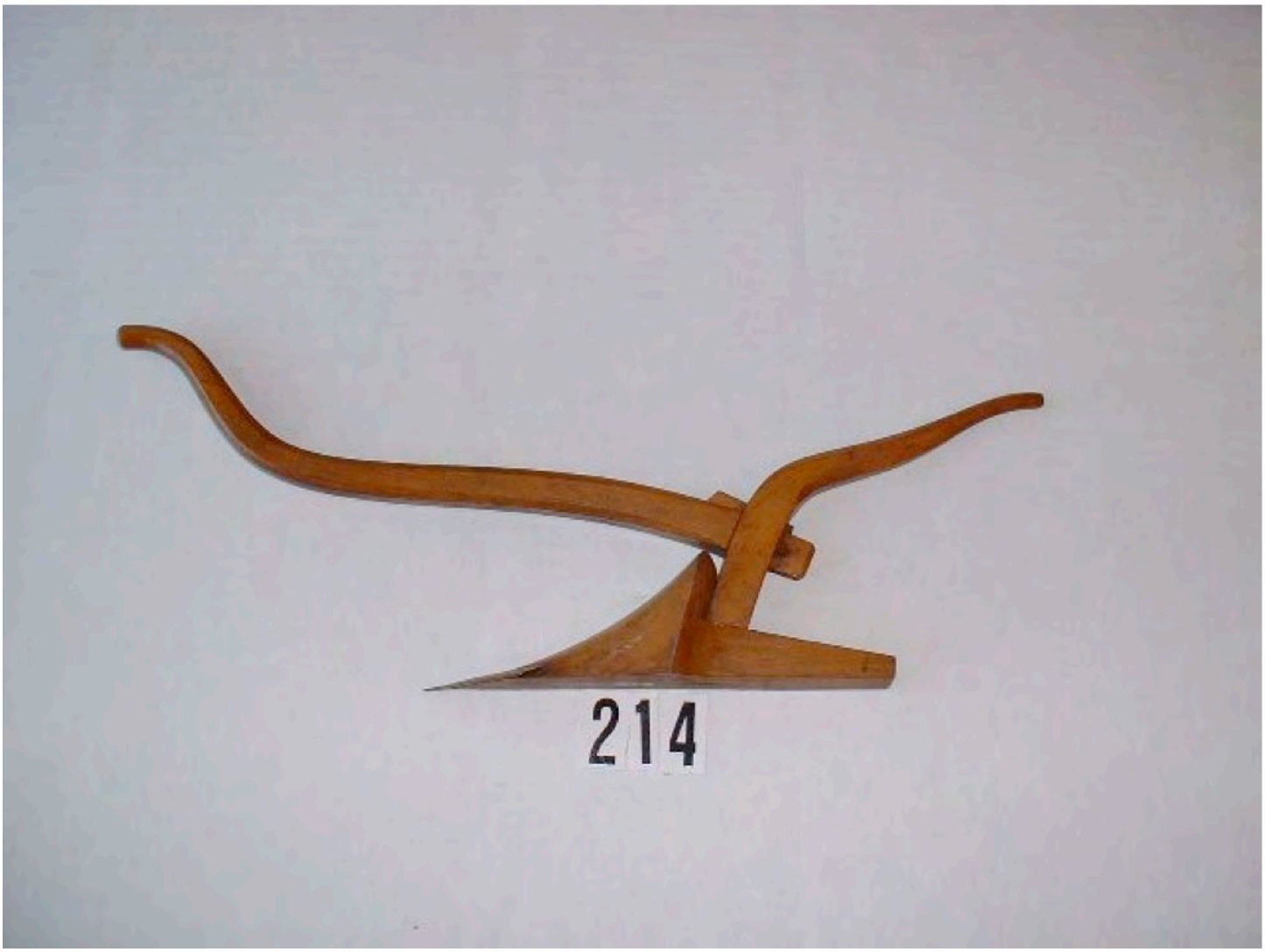


Figure 17. Elevation view of a moldboard plow model from India.

Figures 17 and 18 depict an Indian plow from Malacca with a wooden moldboard, sole and iron point. The moldboard twists to the left to invert the soil slice.

Figure 18. Plan view of the moldboard plow model from India seen in Figure 17.

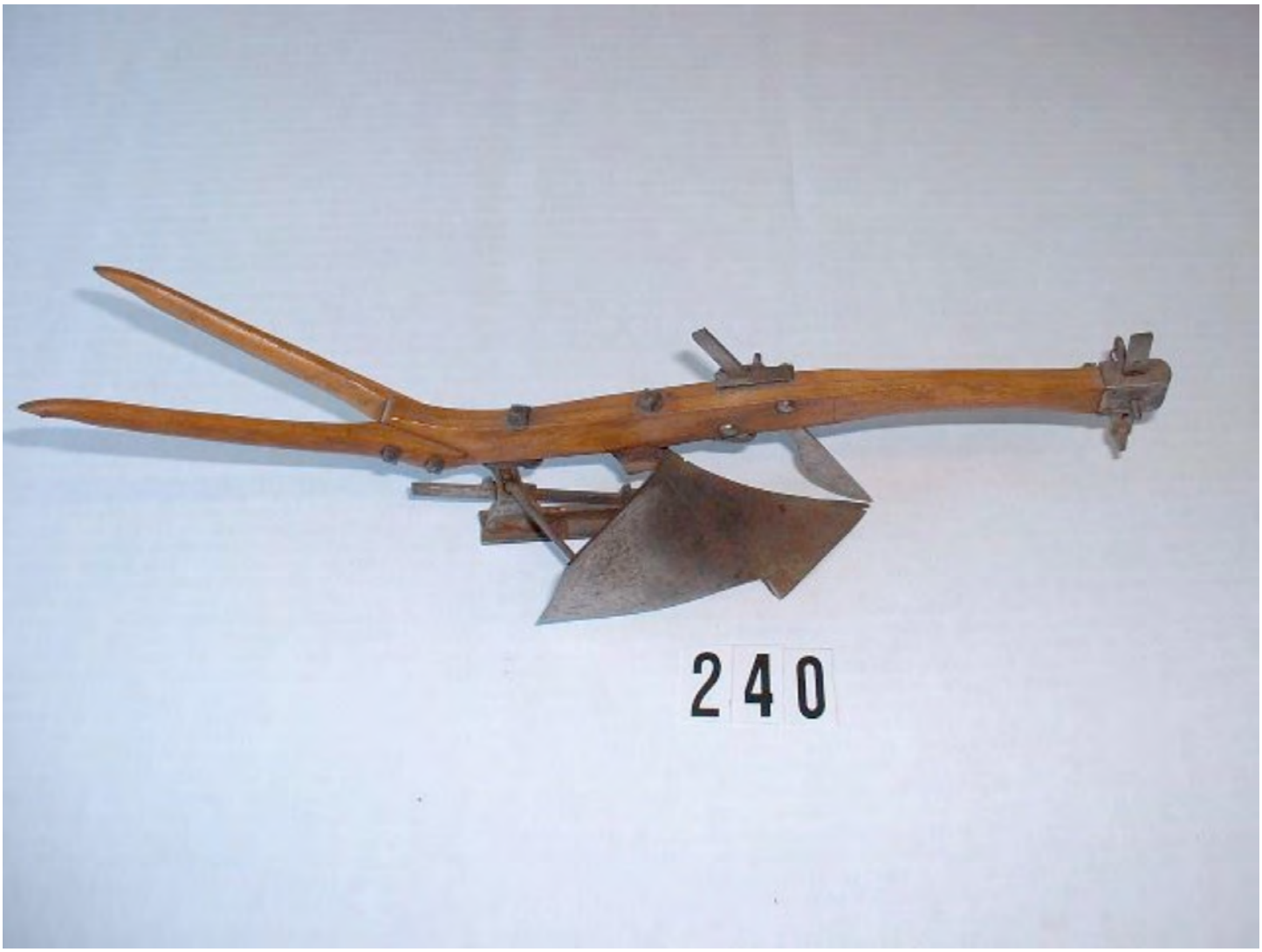


Figure 19. Rau plow model representing the French "Armelin's" plow with metal moldboard.

In addition to those in India, metal moldboard plow designs also appeared in European countries in the 19th -century in several variations. The basic configuration is very similar to present day (21st century) plows. Figure 19 illustrates a French 19th century plow with a share, coulter and inverting moldboard. Share, moldboard and coulter are all made of iron, and the moldboard is shaped to partially invert the soil slice.

The iron moldboard plow was not in widespread use in Europe until the 19th century. There is evidence that the Chinese introduced the iron moldboard plow as early as the first century B.C.E. and they also had been using iron plow shares as early as the third century B.C.E. Apparently moldboards were unknown in Europe until the 10th century; (computersmiths.com – History of Chinese Invention – Iron Plow). According to blogs.com/agricultural technology, "when Chinese agricultural implements were shown in Holland in the 17th century, they were far in advance of European technology."

Improvements on the moldboard plow have continued over several hundred years, but the basic configuration has remained the same. The refinements mostly have been in improved materials, manufacturing and geometry. Interchangeability of parts was a major step forward to provide mass manufacture of plows rather than the construction of a one-of-a-kind by a local smithy. Pioneering plow makers who were making primitive plows from tree trunks and limbs were not able to create repeatable plow designs because of the variability in the raw material. Until steel or cast-iron moldboards and shares were developed that could be forged to a particular shape there was little opportunity for interchangeability.

Figure 20. "Latvian Hook" plow model from the Socha area of Russia, which lies to the east of Latvia.

A number of the Rau plow models illustrate unique designs for special tillage conditions. Among these designs is the "hook-" or tined-type of plow. Figures 20 and 21 illustrate the "Latvian Hook." Note the narrow shares and hook configuration. This plow was still in use in 1930.

Figure 21. "Latvian Hook" plow model. Note the two hooks for entering the soil.

Figure 22. Italian wheel plow of south Tyrol.

Other Rau plow models illustrate wheeled plows, moveable moldboard plows and bi-directional plows. An example is shown in Figure 22 for a plow from the south of Tyrol in Italy. A leading wheel provides directional stability. The wooden moldboard to the rear of the iron share provides movement of the soil to the side, and soil breakup.

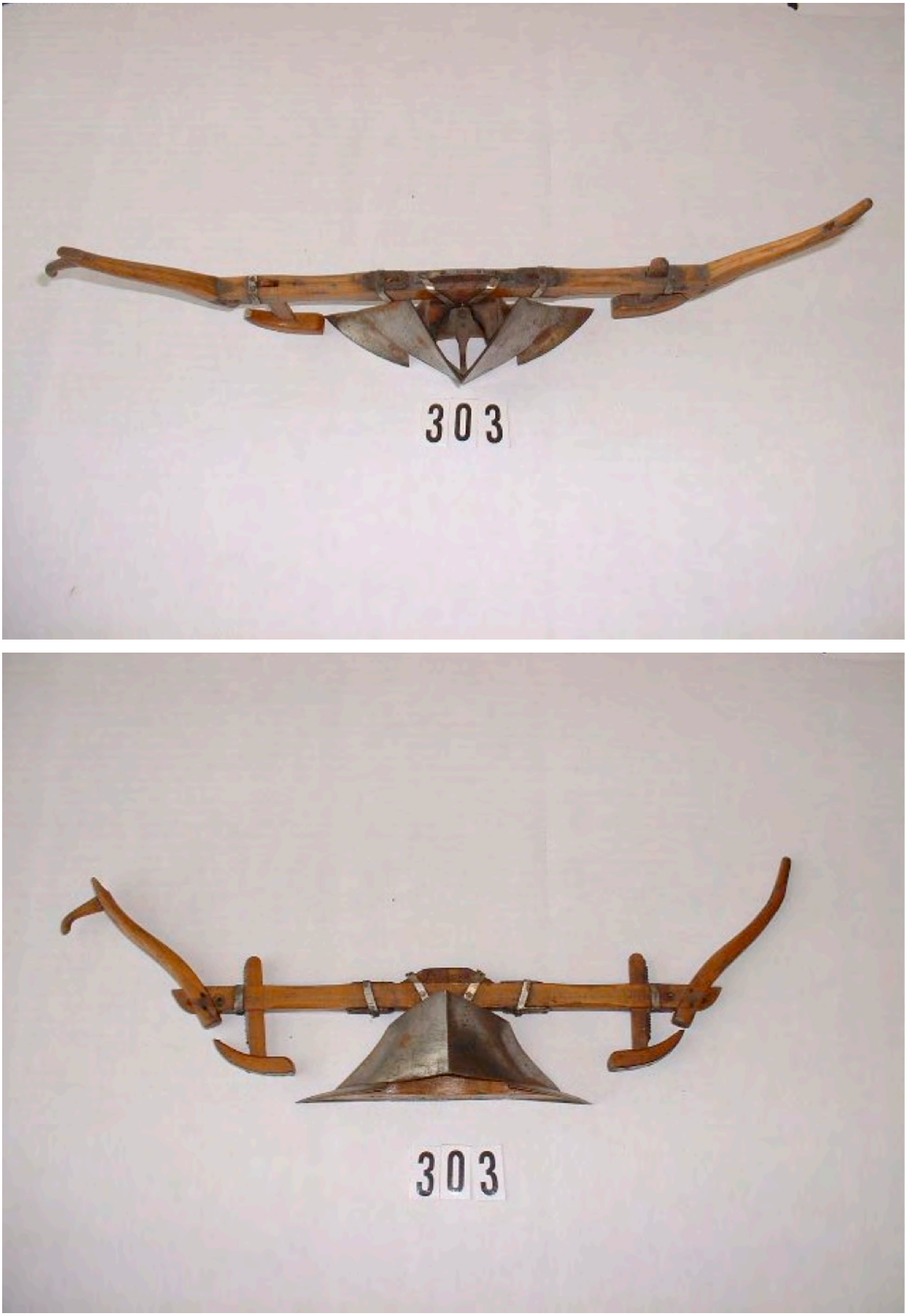


Figure 23. German bi-directional plow of Wurtemberg. The top is a plan view and the bottom is an elevation view.,

Rather than plowing with idle movement across the headlands when turning around, bi-directional plows were developed to allow throwing the furrow in the same direction while travelling back and forth across the field. Figure 23 illustrates a bi-directional plow originating in Wurtemburg, Germany. Apparently this plow was once displayed at a festival to inform farmers about this development. There are two central plow bodies – one right-hand and one left-hand moldboard – and symmetrical pulling beams.

The Mature Phase of Plow Design Development.

Ancient, medieval and 17th and 18th century plow designs were mostly intuitive adaptations to regional conditions, resulting in a multitude of special designs. Most of these plows were hard to pull and relatively inefficient in achieving the best soil-cropping condition. Thomas Jefferson in the late 18th century is probably the first person to attempt a rational design of the moldboard plow[3]. He sought a moldboard design "of least resistance." His approach was to attempt to describe the path of a unit of soil passing over the moldboard as it was lifted and rotated to one side. German scholars also in the early 19th century and on into the 20th century developed rational designs of the moldboard through mathematical analysis. These ideas were later refined and improved with modern computing capacity. Some designers were able to describe mathematically a soil movement to achieve uniform acceleration over the moldboard surface.

3 http://www.monticello.org/site/plantation-and-slavery/moldboard-plow

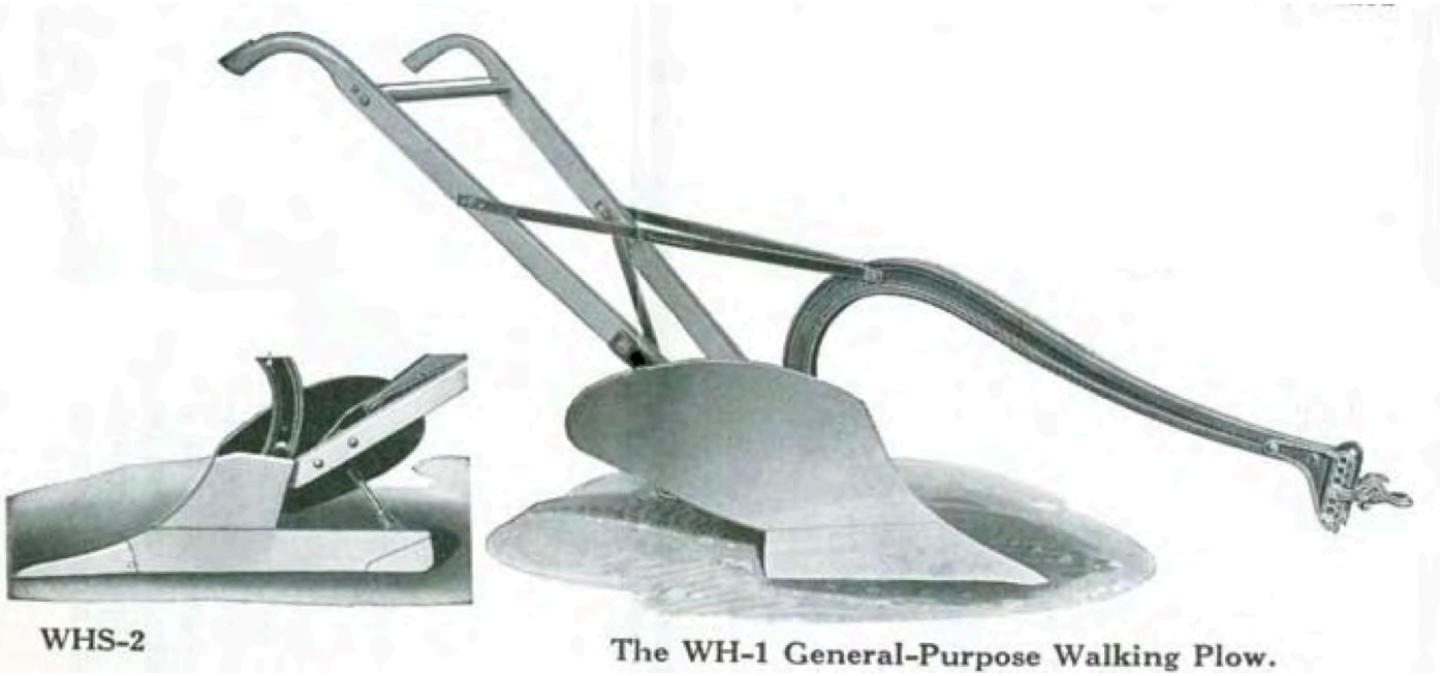


Figure 24. A McCormick-Deering Walking Plow[4] from a 1930s catalog.

Figures 24 and 25 illustrate design of the general-purpose plow that is very similar to the design of current tractor-drawn plows. There are variations in the share, sole, moldboard, landside and coulter, but these elements exist in all modern designs. Materials have changed and the geometry of the elements has been varied, but modern plows are essentially identical.

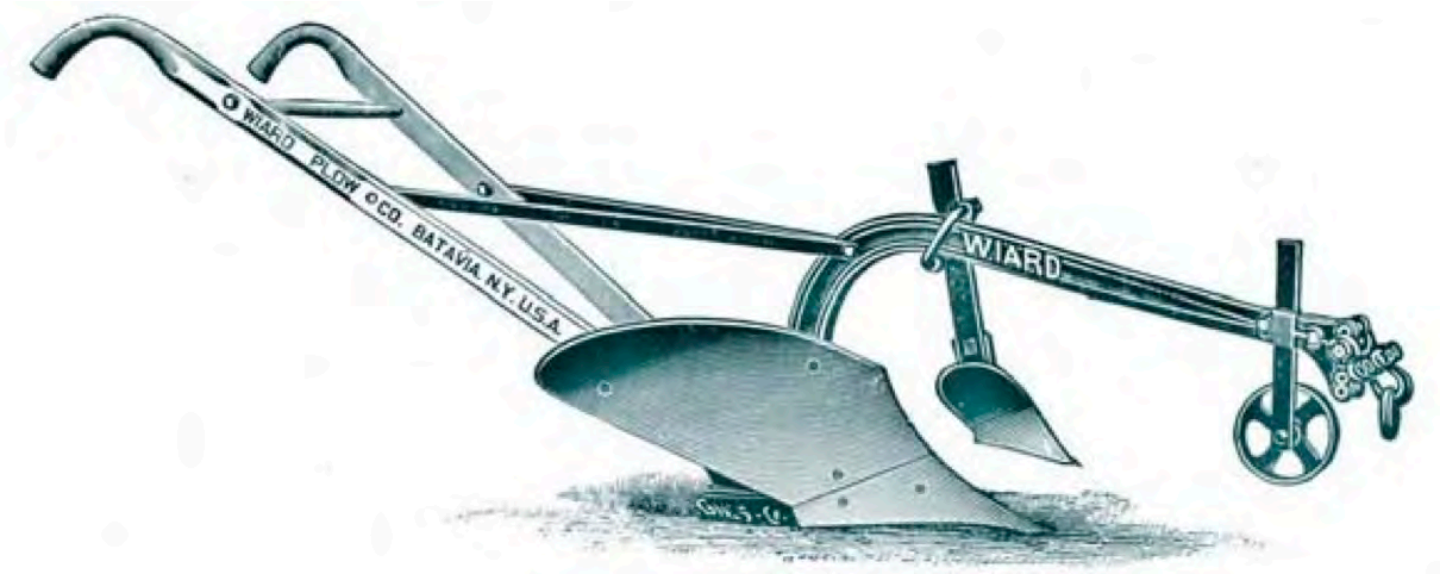


Figure 25. Wiard Plow from Wiard Plow Company, Batavia, New York. Circa 1912.

Figures 24 and 25 come from *The Walking Plow* by Bob Powell. (See footnote below.)

4 http://www.alhfam.org/pdfs/FARM_PIG_Info_sheet-1.pdf

Plow Development in the United States.

The following is adapted from *History of the Plow – Inventing the Plow and Moldboard* by Mary Bellis, About.com Guide:

Early plows in the United States were mostly a crooked stick with an iron point attached. Figures 2 and 4 show the Rau plow models that would be similar to the early American plows. These plows were sometimes shaped with carved moldboards, and the shapes varied from plow to plow. Later plows were formed similar to the "Old Colony Plow" which had an iron-pointed wooden share. An example of this plow is held in the Agricultural Museum at the University of Nebraska in Lincoln, Nebraska. The statue of the Minuteman at Concord, Massachusetts, includes a rendition of this plow. See Figure 26.

Figure 26. Minuteman statue in Concord, MA. "Old Colony Plow" is a part of the statue.

Jefferson's ideas about moldboard shape were made practical in a cast-iron plow patented by Charles Newbold of Burlington County, New Jersey, in June of 1797. David Peacock in 1807 received a plow patent, but Newbold challenged his design as a patent infringement.

Jethro Wood, a blacksmith from Scipio, New York, near the present day Moravia, New York, received patents in 1814 and 1819 for a multi-part cast-iron plow. The standardized parts permitted replacing only selected parts without purchasing an entire plow.

James Oliver of South Bend, Indiana, developed the "chilled" iron plow that was patented in 1868. A hard-wear resistant surface on a more ductile iron backing was created by a unique cooling process. These plows were more resistant to breakage. Oliver later founded the Oliver Chilled Plow Works.

Perhaps the most revolutionary plow design of U.S. origin was the John Deere plow developed in 1837. Deere's self-polishing steel surfaced plow was uniquely adapted to prairie soil conditions. The steel plow moved more easily through the prairie soils because the soil did not stick to the surface as it did with cast iron plows. This design provided the impetus for the success of his company and — as Deere and Company— ascendance to a world-wide power in the agricultural equipment industry today.

Figure 27. Typical two-bottom plow pulled by early gasoline engine tractors such as the John Deere B or Farmall H models. (A retired 1930s era plow as a decoration at the Rock Hill, South Carolina home of Rick Howell).

Thus with the advent of steam tractors and—eventually—internal combustion engine-driven tractors, multiple-bottom plows became common. See Figure 28 for an example of a modern multi-bottom plow.

Figure 28. Modern multi-bottom plow.

Plow Hitching

Mechanisms for hitching the plows to the pulling source also evolved over the centuries. Early plows were likely pulled by humans with a simple pulling beam or some kind of rope. In some of the literature you will find the comment that a particular plow was "easily pulled by women." Figure 29 illustrates such a plow. Two women would grasp the handles on the pulling beam to move the plow through the soil. The share point and moldboard are shaped to ease the plow through the soil with less resistance.

Oxen, mules, water buffalo and horses have frequently been used for plow-pulling power. Because oxen have broad shoulders, a yoke and pulling beam are efficient means of transferring animal power to the plow. There is biblical reference in Isaiah to the use of oxen for plowing. Horses and mules became efficient means of pulling plows with the invention of the horse-collar and harnesses.

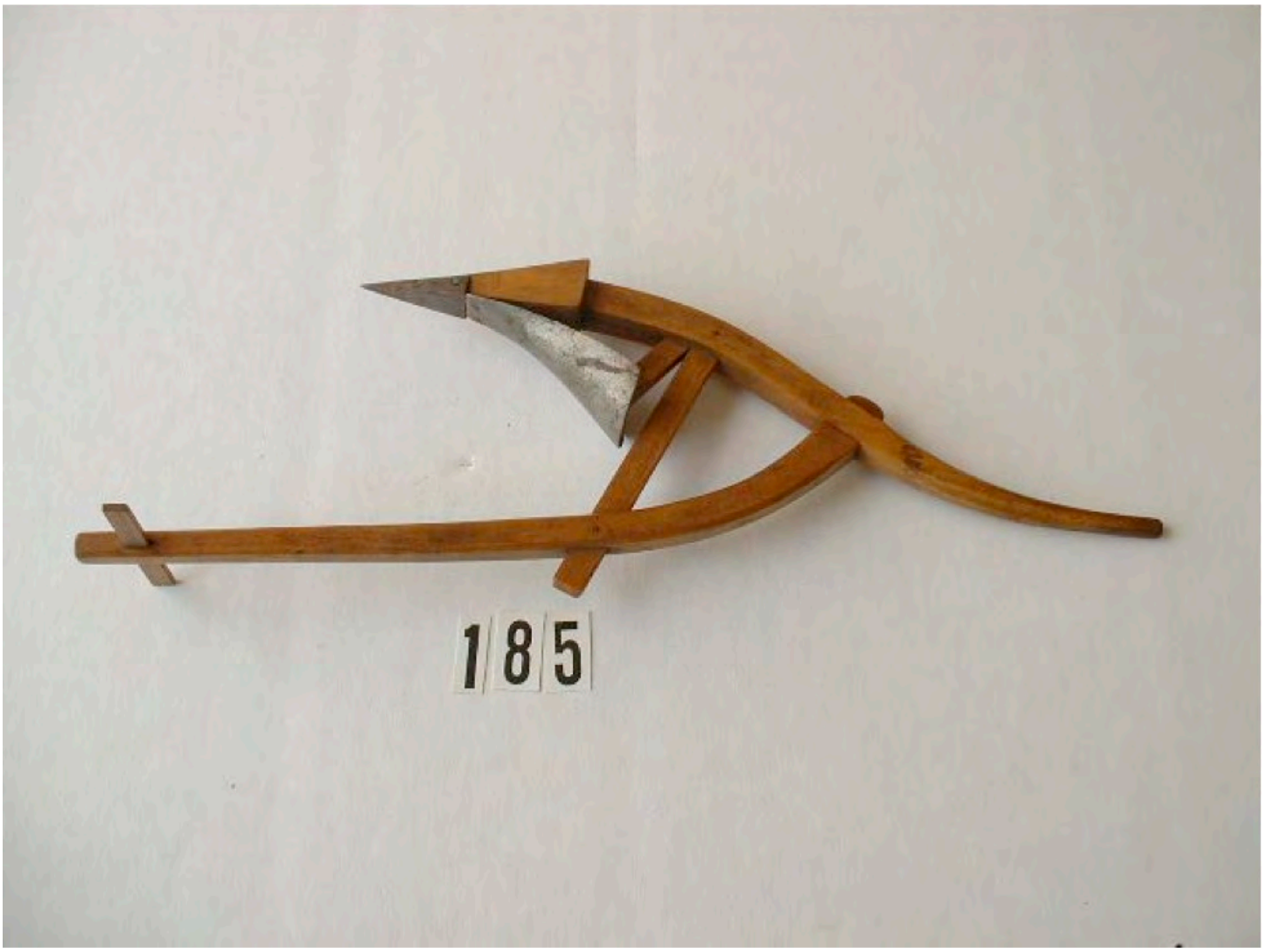


Figure 29. Chinese plow from Tschangli, still in use in 1850.

With the advent of tractors, plow-pulling beams were first attached to the drawbar by a simple pin connection (See Figure 27). Multi-bottom plows would have wheels for stabilizing the plow from side to side and to permit raising the plow bottoms when turning at the end of the furrow. (See Figure 27.) In the 1940s a three-point hitch was developed that enabled mounting the plow without side wheels to the tractor. If necessary, a simple tail wheel was used at the rear for transport support for the large multi-bottom plows. However, with the increasing size of plows and tractors, hitching returned to the single drawbar point with a hydraulically-operated mechanism for raising and lowering the plow via support wheels (Figure 28).

In recent years moldboard plowing has diminished in popularity with the advent of minimum tillage whereby crop debris is allowed to remain on the surface; the land is then prepared for cropping by pulling tines through the soil to provide a seed bed. Chemicals may be used to control vegetation prior to establishing the crop. This approach, which conserves moisture and reduces erosion, has been proven to be an effective agricultural practice.

Historically plowmen were proud of their skill in forming a straight furrow and completely covering the surface debris. Plowing contests were often held to display the talents of the best plowmen. Success in the contests depended on good equipment that was properly adjusted and a skilled plowman who had honed his skills with many hours of practice. There is the expression that "once you put your hand to the plow, you should not look back." This

practical advice forces one to look ahead and plow a straight line to the destination at the end of the field. Looking back inevitably causes one to stray from the straight line. Today the plowman would use a Global Positioning System.

Conclusion

The Rau plow models provide a means of reviewing the improvements in plow design over the centries. Enhanced by advanced engineering techniques, the plow of the 21st century is the culmination of a long history of development. So long as a crop culture continues to be viable, it is reasonable to assume the plow will play a vital role in the world of food production. However, the widespread adoption of minimum tillage agriculture has vastly diminished the importance of plows and plowing.

Appendix 1: Glossary of Plow Terms

Furrow side view.

Landside view.

A- Moldboard.

B- Plow share or sometimes called the plow point.

C- Pullling beam.

D- Landside. Rides against the vertical furrow wall. Bottom of the plow is called the sole.

Not pictured. Coulter. A knife or disc extending downward from the pulling beam to divide the soil in front of the plow share and moldboard.