CHAPTER 9

The Medieval Horse Harness: Revolution or Evolution? A Case Study in Technological Change

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It is now over twenty-five years since Jean Gimpel's *La revolution industrielle du Moyen age* was published in France and almost as long since it was translated into English and published as *The Medieval Machine*.[2] Although not the first book on medieval technology to appear in English, it certainly was one of the most popular.[3] It brought the technological achievements of the Middle Ages to the

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[1] This chapter was given in somewhat different form as a paper at the Thirty-Fifth International Congress on Medieval Studies in Kalamazoo (Michigan) during a session held in honor of the late Jean Gimpel. It is the result of extended discussions with a large group of scholars, all of whom have contributed to my ideas on the subject. Though I cannot name every one, I would nevertheless like to acknowledge their help. Particular thanks go to Laura Blanchard for obtaining a copy of the narrowly-circulated *Brancards et transport attelé entre Seine et Rhin de l'Antiquité au Moyen age;* to Curt Emanuel for his freely shared knowledge of horses and their anatomy; to Warren Hapke for obtaining and analyzing materials from the University of Illinois Library; to Brian Scott for his logic, and to Kathryn Talarico for discussions as well as help with translations from the French. Nevertheless, responsibility for any remaining errors in fact or interpretation remains mine alone.

[2] First editions are Jean Gimpel, *La revolution industrielle du Moyen age* (Paris, 1975); translated as *The Medieval Machine: The Industrial Revolution of the Middle Ages* (New York, 1976). For further editions, see bibliography in this volume, p. xxxvi.

[3] A complete listing of books on medieval technology in English is impossible. Perhaps the best starting point is the classic *A History of Technology*, 2, *The Mediterranean Civilizations and the Middle Ages, ca. 700 BC to ca. AD 1500,* eds. Charles Singer, E.J. Holmyard, A.R. Hall, and Trevor I. Williams (Oxford, 1956). Other works include Abbott Payson Usher, *A History of Mechanical Inventions* (rev. edn., 1954; repr. New York, 1988); T.K. Deny and Trevor I. Williams, *A Short History of Technology* (Oxford, 1960; repr. New York, 1993); Georges Duby, *The Early Growth of the European Economy: Warriors and Peasants from the Seventh to the Twelfth Century* (Ithaca, 1974); Donald R. Hill, *A History of Engineering in Classical and Medieval Times* (LaSalle, Illinois, 1984). A more recent summary work that is very useful is by Frances Gies and Joseph Gies, *Cathedral, Forge, and Waterwheel: Technology and Invention in the Middle Ages* (New York, 1995). In addition, portions of the economics literature should not be overlooked.

attention of the general public in a way no previous book had done. Looking back, we can see that it was Lynn White who first stressed technology as one of the driving forces behind historical events.[4] But it was Jean Gimpel who reached the wider, public audience. Where White dealt with specific technologies, Gimpel's approach was broader, covering more ground. Today, the integration of technology into history is fairly common; one can, for instance, no longer discuss the notable economic development of western Europe after the millennium without also discussing the technological changes that made it possible. This modern joining of technology and history has caused scholars to reexamine a range of historical issues. A typical example is the very slow introduction of firearms into western warfare, which, thanks to Bert Hall's recent work, is now understood as strongly dependent on available technology and not on political or economic factors.[5]

Medieval historians have considered the role of technology for some time; it is perhaps now appropriate to reexamine conclusions reached by early historians of technology. To look at even a major fraction of those conclusions would be a monumental task. In this paper, I would like to focus on just one aspect of one such conclusion: that is, an issue raised, in particular, by Gimpel in the second chapter of *The Medieval Machine*, entitled "The Agricultural Revolution."[6] There, Gimpel considers several agricultural issues, taking for granted the existence of an "agricultural revolution" in the Middle Ages. Here, "revolution" is taken to mean a sharp break with the past in a short period of time, during which agricultural practice underwent significant change and productivity significantly increased. Of course, one must be careful here. Often what looked like revolution to early investigators was simply the lack of discovery of intermediate steps. Later researchers, having more evidence (archaeological or documentary), may sometimes convert revolution into evolution.

Gimpel supposes that a major causative factor in this agricultural revolution was the impact of a new horse-harnessing method on productivity. What I wish to discuss here is not the agricultural revolution, per se, which may or may not have

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Valuable sources include Carlo M. Cipolla, *Before the Industrial Revolution: European Society and Economy, 1000–1700*, 3d edn. (New York, 1994); and Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (Oxford, 1990). Lastly, a neglected area is medieval Islamic technology, an introduction to which is provided by Ahmad Y. al-Hassan and Donald R. Hill, *Islamic Technology* (Cambridge, Eng., 1986).

[4] Lynn White, Jr., *Medieval Technology and Social Change* (Oxford, 1962). See also the works listed in note 3.

[5] Bert Hall, *Weapons & Warfare in Renaissance Europe* (Baltimore and London, 1997).

[6] Gimpel uses the term "revolution" in the title of the second chapter, but does not use it in his text.

taken place in a rapid way, but the horse harness itself and other new technology affecting how the horse was used. In so doing, I shall argue that while the impact of the new harness was strong, the introduction of the horse into medieval agriculture was, nevertheless, gradual and dependent on a number of factors, technological and otherwise.

It is well established that the ox was ubiquitous in early medieval agriculture, the horse relatively rare, and that over time, the ox remained very common while the presence of the farm horse increased. On this basis alone, the notion of a sudden improvement in agricultural productivity due to the new horse harness is not supportable. Indeed, the main effect of the new harness seems only to have rendered the horse, in principle, usable for agricultural purposes. The actual incorporation of the horse as a common feature on farms was slow until the other factors came into play.

To understand why the horse played little role in agriculture during most of the Middle Ages, it is necessary to begin with the Roman period. The popular view today, one with which most scholars agree, is that the Romans, their predecessors, and contemporaries, did not make full use of the horse as a utilitarian animal for hauling, plowing, harrowing, and other sundry agricultural purposes. The primary reason for this, it is argued, was that the Romans did not know how to properly harness a horse![7] This is a rather extraordinary claim, given that they were famous for their technology. Therefore, it is further argued that it took the medieval development of a proper harness for the horse to lead to widespread use of the now more efficient horse, rather than the less efficient ox.

Curiously, this view is due almost entirely to the work of a single person, Richard Lefebvre des Noettes. A cavalry officer in the French Army, Lefebvre des Noettes assiduously collected historical information about horse saddling and harnessing. In 1924, he published a slim volume on his findings. What made him famous and the Roman horse harness a major issue, however, is the second edition, revised in two volumes and published in 1931, under the title *L'attelage et le cheval de selle a travers les âges*.[8] In that book, Lefebvre des Noettes appears to have been the first to point out that pre-medieval societies did not use the "modern" horse collar. He documented this observation in the second volume of his work, devoted entirely to photographs he had taken or collected of both modern harnessing methods and pre-modern images of harnesses.

Lefebvre des Noettes noted that earlier societies used a harness almost identical to the harness used for oxen: a neck strap or yoke. This type of strap

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[7] Essentially all books cited in n. 3 above echo this but, as will be seen, the echoes all emanate from a single source.

[8] Richard Lefebvre des Noettes, *L'attelage et le cheval de selle a travers les ages*, 2 vols. (Paris, 1931).

encircled the ox's neck; where the strap goes over the back of the ox was a point of attachment, to which one could affix the load to be hauled. Because of anatomical differences this harnessing arrangement works well for oxen, but not at all well for horses. This inefficiency was clear to Lefebvre des Noettes: it would work for light loads, but as the load got larger trouble would ensue; and under heavy load, the harder the horse pulled, the more pressure the neck strap exerted on the carotid artery, hampering the horse's breathing and making the exertion for a heavy effort difficult, if not impossible.

The second edition of Lefebvre des Noëttes' study included an introduction by Jerome Carcopino, a noted archaeologist and historian of Rome. In the introduction, Carcopino stressed this inefficiency of the Roman horse harness, using the word "strangulation" several times to describe its effect on a horse.[9] This rather dramatic terminology seems to have had a major impact on historians and from then on many authors, including Jean Gimpel, repeated it.[10] (In fairness, it must be said that Lefebvre des Noettes used the term once himself but not in quite so dramatic a way.) While it is doubtful that any Roman actually strangled horses in this manner, the term's imagery persists today in the minds (and writings) of many medievalists.

The anatomical differences between the horse and the ox are worth a moment's discussion. The important features in question are the neck, the shoulders and the chest. While they superficially look similar in both horse and ox, they are not. The horse's neck is set further forward and is exposed, so that if one presses a horse on the front of its body, one is pressing on its neck. Not only is the horse's trachea prominent and forward, but the carotid artery, among others, lies rather close to its surface. Thus, pressure on its neck can cause difficulty breathing and in the circulation of blood to the brain. The ox is quite different in that its neck is more protected. Pressing on the chest does not compress the ox's neck, or any of the structures in it. As a result, a high collar (or harness) on an ox allows the animal to use its chest and shoulders to pull the load. A horse is anatomically more limited in this context. The load must be displaced from the neck onto the shoulders and chest. At the same time, the load must not be attached to the horse's back, but as low down as is practical, to keep the harness from being pulled up onto the neck.

The Romans seem to have been cognizant that their horse harness was not well designed. In the Late Empire (and possibly before), limits were placed on the load a horse was allowed to haul on the *Cursus Publicus* (the state-owned and

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9 Lefebvre des Noettes, *L'attelage*, p. iii.

10 Indeed, Gimpel uses the notion of "strangulation" to explain the common wild-eyed, extended tongue look seen in antique sculpture and illustration *(Medieval Machine,* pp. 32-33).

controlled, public roads.) The Theodosian Code limited such hauling to about 1100 pounds for a heavy wagon,[11] whereas horses today are able to haul much heavier loads.[12] There are two possible reasons for imposing this limitation. One is that heavier loads increase the wear on the roads. But since ox-hauled loads were not so restricted in weight, it is doubtful the limitation was put into place for that reason. The other reason is that heavy loads, coupled with the Roman harness, would have broken horses down early in life. They would then have to be replaced early and often. Since the cost of replacement horses for the *Cursus Publicus* was already a major imperial expenditure, even with the imposed load limitations, this would have been an extravagant expense.[13] This knowledge doubtless came from experience. Thus, it seems certain that the Romans were aware of the distress caused in horses by pulling heavy loads.

This unsatisfactory situation had no immediate solution. The Chinese as well as the Romans of the Late Empire attempted remedies. One region in northern Europe, between the Seine and Rhine, has been intensively studied by archaeologists and yields much evidence of experimentation. Both Georges Raepsaet[14] and John Langdon[15] offer descriptions of some of the different types of harnesses found there. This proliferation of designs and modifications of existing designs itself points out the degree to which the contemporary harnessing methods were considered unsatisfactory. Langdon notes explicitly that there seemed to be a "good deal of uneasiness" in this multitude of new harness types. He has written of similar problems and multiple innovations with regard to the windmill.[16] Langdon observed:

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[11] *Codex Theodosianus*, bk. 8, sec. 5, De cursu publico angariis et parangariis, pts. 8, 30, 47–48, cited here after Ann Hyland, *Equus* (New Haven, 1990), pp. 256-57.

[12] Hyland, *Equus*, p. 256, notes in discussing the limits in the Theodosian Code that "[i]n the heyday of coaching in England and Europe, ... a four- or six-horse hitch pulled a three ton coach plus freight and many passengers. Allowing another ton for driver, passengers, and freight, this amounts to about twice the load limit imposed by the code."

[13] Hyland, *Equus*, pp. 255-62, discusses this point.

[14] Georges Raepsaet, "The Development of Farming Implements between the Seine and the Rhine from the Second to the Twelfth Centuries," in *Medieval Farming and Technology. The Impact of Agricultural Change in Northwest Europe*, eds. Grenville Astill and John Langdon, Technology and Change in History, 1 (Leiden, 1997), pp. 41-68.

[15] John Langdon, "Double-Shafted Vehicles and Other Elements in the 'Revolution' of Land Transport in Medieval Europe," in *Brancards et transport attelé entre Seine et Rhin de rAntiquite au Moyen age*, eds. Georges Raepsaet and Catherine Rommelaere (Treignes, 1995), pp. 113–26, esp. 117.

[16] Langdon, "Double-Shafted Vehicles" (as in n. 15 above), p. 117.

> It has been my experience that when several different solutions appear for a particular aspect of a technological innovation, it tends to indicate a problem area in the innovation. A comparable example was the late medieval search for a suitable way of securing windmills to the ground. This went through several variations, including burying the base of the windmill in a mound of earth, building a wall around it, bolting the wooden substructure of the mill onto piers of stone or brick, etc. Despite this, windmills kept being blown down on a regular basis.[17]

In time, a satisfactory windmill was developed. The analogy to the technology of the horse harness is obvious. The Roman horse harness was not satisfactory. Experimentation was rife up until satisfactory harnesses were developed; and once such harnesses appeared, further major innovation ceased. None of the experiments survived. In that sense, the new harnessing methods were revolutionary.

But it took several hundred years before the first real success at improving the antique harness appeared. This was the breast strap, which probably was introduced into Europe about the sixth century.[18] As the name implies, the breast strap uses a band across the horse's chest, with a second one over the back and belly. The two straps were connected so as to keep this harness from riding up from the horse's chest to its neck. Also, the load was not attached where the straps went over the horse's back, as in the ox harness, but low down on the breast strap itself. Pulling the load in such a harness kept pressure off the neck and on the chest. Thus the horse could exert more effort without causing discomfort and possible physical injury to itself. While this solution is not perfect, it does survive today. Its advantages are that it is relatively cheap and easy to repair. It is also easy to put on and remove such a harness from a horse. Illustrations of the hauling of field cannon during wars of the last few centuries show this type of harness. The need for extra horses to haul the load is offset by the ease and speed with which the horses could be unhitched and removed from the field.

The second notable success was the padded horse collar introduced perhaps in the eighth or ninth century.[19] It is a round, padded tube containing a rigid frame

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[17] Langdon, "Double-Shafted Vehicles," p. 123, n. 26, cites Terence Paul Smith, "The English Medieval Windmill," *History Today* 28.4 (April 1978), 256-63, esp. 258-61; and John Langdon, "The Birth and Demise of a Medieval Windmill," *History of Technology* 14 (1992), 54-76, esp. 59, as sources.

[18] John Langdon, *Horses, Oxen and Technological Innovation: The Use of Draught Animals in English Farming from 1066 to 1500* (Cambridge, Eng., 1986), p. 19.

[19] White, *Medieval Technology* (as in n. 4 above), p. 61. Raepsaet ("Development of Farming Implements" [as in n. 14 above], p. 57, n. 68) notes that an archaeological find in La Grande Paroisse (Seine-et-Marne) has been dated to the tenth century and so might be the oldest archaeological evidence available to date for the new horse harness. Gimpel

often closed at the top. This fits over the horse's head and does not touch the neck. The load, as in the breast strap, is attached low down on the collar. The horse pulls against the collar using the shoulders and chest; the collar is padded to keep it from chafing the animal. Major innovation ceased with the development of this collar since today's horse collar, a thousand years later, is basically the same as the medieval collar. The collar is shaped like the letter O: the upright parts lie on the horses' shoulders, while the bottom of the O rests against the chest. As in the Middle Ages, the load is attached near the bottom of the O (somewhat similar to -O-) and it is similarly padded. This collar was not a design that suddenly popped out of the blue; it was the result of hundreds of years of development. Georges Raepsaet, in discussing the development of the medieval horse collar, has described it this way: "The 'modern' horse collar combines in one traction apparatus two antique harnesses, the 'shortened' breast harness attached to the chest, and the small rigid yoke which rests on the shoulders."[20] The shortened breast harness is the bottom part of the O; the rigid yoke consists of a metal frame inside the collar, supporting it from the shoulders of the horse, and corresponds to the top part of the O.

Although much of the archaeological evidence comes from this one region, one cannot conclude that the padded horse collar (or the earlier breast strap) was developed in the region between the Seine and the Rhine. By happenstance, this region has been well explored archaeologically. In fact, it is not known where these new harnesses were first developed. Lynn White, who briefly traces diffusion of the horse collar and breast strap, notes Needham's statement that both originated in China.[21] A final determination awaits further study. While diffusion from China cannot be ruled out, the great amount of evidence for local experimentation - literally unearthed through archaeology - makes it plausible that the harness used in Europe was also developed there. In any case, by the ninth century at the latest, the "modern" horse harness had reached or had been developed in Europe. There is no doubt that this harness was useful in the extreme since it enabled the horse to be utilized to its full potential. Does that mean that the introduction of this harness, therefore, caused an agricultural revolution? We cannot leap to that conclusion. Among other things, horses were not plentiful and not at all common on farms as work animals in the ninth century.

(Medieval Machine, p. 33) says that the new harness "seems to have been used for the first time somewhere in the steppes separating China from the Siberian forests, and was originally designed for camels." Somewhat maddeningly, Gimpel provides no reference.

[20] Raepsaet, "Development of Farming Implements," pp. 56–57.

[21] White, *Medieval Technology,* pp. 60–61. White cites Joseph Needham, *Science and Civilization,* 4, pt. 2 (Cambridge, Eng., 1965), pp. 304-28.

Western Europe is not natural horse country. It did not have the open savannahs preferred by horses. Nevertheless, horses were as we know valuable in warfare, both as mounts for warriors and, in Antiquity, as locomotive power for chariots. The ox, however, predominated as the source of animal power in agriculture and hauling. Why was this? For the Romans, horses were expensive to breed, expensive to feed, and expensive to maintain. As a result they were few in number compared to oxen and used only where speed or military necessity demanded. The post-Roman development of the horse-collar did not immediately change that. Even had the desire existed to quickly replace oxen by horses on farms, lack of availability and the maintenance cost prohibited it.

While the Romans maintained extensive breeding programs, these programs vanished after the "fall" of the western Roman Empire. It was not until similar (though smaller-scale) breeding programs were developed during the medieval period that horses became more widely available. These programs, often haphazard, had begun by the Carolingian period and continued thereafter.[22] These programs were for the benefit of nobles and warriors: after the men controlling the breeding programs selected the horses they wanted, the remainder was sold for other uses, including agriculture. This tended to improve the breed of horses available for non-military use, as well as to lower the price of ordinary horses.

The increased availability of horses was in itself not enough to fuel a sudden change in usage on farms. Oxen were the traditional animals, undoubtedly because they were cheap, easy to feed and, at the end of their working life, had a residual value as a source of food and leather. Compared with oxen, horses were expensive, required a special diet, and had no particular residual value. They did however, have multiple advantages over oxen. One in particular is that horses are notably faster than oxen both at walking and while pulling a load.[23] Thus, work such as plowing that might take an ox-team three days could be done by horses in two. Horses could also be ridden, and used as pack animals or for cartage. They could be used in harrowing, where they again are faster than oxen. Time saved in plowing and harrowing was particularly important as it meant that more land could be plowed with fewer animals. But the diet of a horse caused difficulty: as Davis notes, one cannot feed a working horse on grass alone. Additional food had to be provided or the horse was forced to spend almost all of its daylight time feeding.[24] Otherwise useful land had to be devoted to growing this extra food, usually oats. Oats were not considered decent food for humans and so were not otherwise useful. In short, while more versatile than oxen, horses were more

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[22] R.H.C. Davis, *The Medieval Warhorse* (New York, 1989), chaps. 2–4; and Hyland, *Equus* (as in n. 11 above), chap. 5.

[23] Usher, *History of Mechanical Inventions* (as in n. 3 above), pp. 156-57.

[24] Davis, *Medieval Warhorse* (as in n. 22 above), p. 92.

expensive and difficult to maintain. Walter of Henley, in his famous thirteenth-century work on husbandry, claims that they were four times or more expensive than oxen.[25]

It is likely that this extra expense and the need for special fodder kept the horse out of reach for all but the richest peasants. Useful as the horse was, it represented a major investment in both money and land for food. But this may not be the only reason horses were not quickly adopted; there was quite likely another problem as well. We think of horses (and oxen) as large heavy animals; there is evidence, however, that farm animals in Antiquity were significantly smaller than they are now. This size differential seems to have persisted into the medieval period. For example, Georges Comet notes archaeological work has shown that in Charavines around the year 1000, a cow or ox weighed from 200 to 250 kilograms (440 to 550 pounds), whereas in the same region today an ox might weigh as much as 650 kilograms (1430 pounds).[26] These are surprising numbers.[27]

If horses followed the same pattern they certainly would not have been able to haul anything like the heavy loads pulled by a modem horse. Evidence for the size and weight of agricultural horses (as opposed to those used in war) is hard to find, although they were certainly smaller than horses today. Hyland discusses the size of some breeds in Roman times, which seem to vary from small (11 to 12 hands) to largish (15 to 16 hands).[28] This spread may have persisted well into the Middle Ages. R.H.C. Davis notes that in the period from 1250 to 1350 a carthorse or a peasant workhorse could be had for about two shillings six pence, while a cheap riding horse might cost as much as several pounds.[29] If price correlates with size and strength, we must conclude that the horses available for agricultural use were relatively small or weak, or both. Still it is possible that the horse was at that time proportionately larger in comparison to the ox than it is now. This would go a long way to explaining the growing interest in using horses in agriculture. But it must be emphasized that this is an area in which more work remains to be done and little can be said with certainty now about the size of medieval horses used in agriculture.

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[25] Walter of Henley, *Husbandry*, as cited in Langdon, *Horses* (as in n. 18 above), pp. 158 ff. Langdon includes a detailed discussion of this point.

[26] Georges Comet, "Technology and Agricultural Expansion in the Middle Ages: The Example of France North of the Loire," in *Medieval Farming* (as in n. 13 above), p. 20 and n. 58.

[27] One is reminded of the image of knights in the Muslim siege of Antioch during the First Crusade - riding out of the city to do battle - but riding on pack animals and oxen. Such oxen could not have been too large. See John France, *Victory in the East: A Military History of the First Crusade* (Cambridge, Eng., 1994), p. 245.

[28] Hyland, *Equus* (as in n. 11 above), pp. 23, 25.

[29] Davis, *Medieval Warhorse*, p. 67.

It is clear that the horse collar alone was not in itself the only factor in the adoption of the horse for agricultural use. Other developments were also important. Among these are horseshoes, harnessing in file instead of abreast, and whippletrees.[30] The horseshoe, a development of the early Middle Ages, was necessary in the wet soils of the north where, otherwise, the hoof of the horse would deteriorate from the dampness of the soil.

In multiple-horse teams, the Romans almost always harnessed abreast. This means that in a multi-horse team only one or two animals were pulling straight ahead, while the others were pulling at an angle, hence generating less work. This may not be obvious at first glance. The horses on the outside of the team are certainly moving straight ahead, but the ropes attaching them to the load are at an angle. This can be understood by mentally picturing three horses harnessed abreast pulling a wagon by ropes; only the rope to the center horse extends straight ahead. The ropes to the other horses are not in parallel alignment; rather they extend at an angle, from the wagon to the horse. Thus, some of the effort exerted by the outside horses tends to pull the wagon sideways. If the angle made by one of these outside ropes is as much as 30°, only about 86% of the effort of the horse will move the wagon straight ahead. Thus, a portion of their total effort would be wasted. Further, imagine a wagon pulled by two horses, side by side, with one horse notably stronger than the other. If these are simply attached to the wagon the stronger horse tends to move his side of the cart faster than the weaker one. The difference in speed tends to cause the cart to turn in the direction of the weaker horse. The stronger horse must, therefore, be made to pull at an angle away from the weaker horse in order to keep the cart going in a straight line. Again, pulling at an angle wastes effort.

The whippletree, an eleventh-century innovation curiously unknown in urban societies today, is a clever device that solves several harnessing problems. It not only solves the angle problems discussed above, but also lowers the point of attachment of the load to the horse, and allows teams of horses of variable strength to be harnessed abreast without straining the weaker member(s) of the team. The whippletree is basically a wooden bar. Instead of harnessing the horses directly to a cart, imagine now that there is a bar of wood of suitable strength and length attached to the center front of the cart. Harness attachment points are placed on the front of the log. These points need not be symmetric. The stronger horse can be attached to the log nearer the center of the cart. The weaker is attached further from the center. Thus the weaker horse has more leverage than the stronger. Indeed more than two horses can be attached to a load this way. When in motion, if the horses are properly attached, the whippletree remains straight across the front of the cart, and the horses all pull straight ahead. There is

[30] List taken in part from Langdon, *Horses* (as in n. 18 above), pp. 10 ff.

a cost to pay by adding the extra weight of the tie-log, but a major gain in that all horses can now pull straight ahead.

This technique can be extended to horses in file. Each rank has its own whippletree. The whippletrees are attached together by a rope or chain running from the center of each to the center of the next behind. The hindmost whippletree is attached to the load to be hauled. Such an arrangement is not limited to horses. It can be used for mixed teams of horses and oxen or, of course, just for teams of oxen alone. Mixed teams are an advantage, since one can now perhaps justify having one horse - insufficient for plowing alone, but advantageous for harrowing, riding, and carting.

What has been seen over time is not just the development of the medieval horse collar, but also the development of a series of devices - each aiding the other - that makes the horse useful for agricultural work. John Langdon has written:

> Consequently, I think it is time to broaden the view that we have of early transport away from a narrow consideration of harnessing and to consider transport systems as a whole, and in particular to realize that each system consisted of a package or bundle of technological developments that were occurring throughout time. Periodically a new technological element would be introduced that would improve some aspect of transport - the horse collar or the development of horse-shoes, for example - but that rarely would one specific improvement be so overwhelmingly important as to revolutionize early transport.[31]

Exactly the same can be said for the agricultural use of horses. The evidence we have is that the introduction of the horse into agricultural life was gradual, not "revolutionary." Even after the padded horse collar became common, horses did not rapidly supplant oxen as beasts of burden. In a major study of this problem, Langdon noted the slow and steady but still incomplete replacement of ox-power with horsepower in England during the period from 1200 to 1500.[32] Similar patterns of slow adoption can be discerned on the continent. Indeed, oxen remained important in agriculture down to very recent times.

And the way in which the horse was used only slowly varied. The first illustration we have of the horse in use as an agricultural animal dates to the late eleventh century: on the lower border of the Bayeux Tapestry a horse can be seen pulling a harrow across a field. A harrow is a light, toothed frame dragged over an already plowed field in order to crumble the clods of earth. A single ox can readily pull a harrow, but a single horse can do it much faster. And of course, it is

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[31] Langdon, *Horses* (as in n. 18 above), p. 114.

[32] Langdon, *Horses*, chap. 4, sect. a, pp. 176–212, esp. Table 25 (p. 191).

much more likely that a single horse might be available than an entire team. Images showing horses pulling plows appear later. Even the calendar pages of the *Très Riches Heures* of the Duke of Berry (early fifteenth century) shows oxen pulling a plow in March, and a horse pulling a harrow in October. But by the fourteenth century, there is much evidence that horses are often being used in the full range of medieval agricultural activities.

In summary, it is possible to construct a plausible, but not proven, scenario for the introduction of the horse into medieval agriculture. In the Roman period, oxen were relatively small but cheap to purchase, maintain and feed and so were used almost exclusively in agriculture. Horses were relatively rare, expensive and difficult to feed. However, the advantage of their versatility, greater strength and speed was important. As more horses rejected from breeding programs became available for agricultural use, and as local breeding on farms increased, the horse became more promising as a farm animal. There was then a series of attempts to adapt the horse to such use. These experiments led to improvements in both harnessing and ancillary equipment. By about the ninth or tenth century, the parts needed for a truly efficient harnessing system were in place. The horseshoe had long existed, and the horse collar had been developed. By the eleventh century, the whippletree had been developed and new ways of hitching teams to a load were found. The remaining difficulty was the expense of the horse. This would continue to limit the number of horses that individual peasants could afford.

Thus, we would expect that, at first, single horses found their way onto the farms of richer peasants. There the horse would augment the plow oxen, be used for harrowing and cartage, be ridden when needed, and in general constitute a useful investment. In time, other horses would be added, eventually supplanting the ox-plow team on many peasant holdings. The downside would have been the increased expense of providing fodder. We would also expect that the manor would be among the last places where the horse would be utilized in agriculture. The constraints there were different, horses for riding would already be available, and oxen were relatively plentiful. Thus the need for more efficient farm animals would not be as strong.[33]

In this view, the horse would only slowly penetrate into agricultural usage. The ox would be displaced first in small ways like harrowing and carting, and only later, as the relative expense of a farm horse dropped, in plowing and heavy hauling. And even then, in some areas, the ox would persist to the present day. Thus, I conclude that the horse collar, rather than being a revolutionary invention was in fact an evolutionary change that was part of the development of the horse as an agricultural animal. Other necessary elements included the horseshoe and

[33] Langdon has found just this pattern in medieval England. I have, of course, made my scenario fit his data.

the whippletree, and an agricultural structure that could allow for the specialized feeding that horses needed. The change did take place and it was a major change, but it was evolution, not revolution.