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The Economic History of Byzantium: From the Seventh through the Fifteenth Century

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The Means of Agricultural Production: Muscle and Tools

Anthony Bryer

The principal means of Byzantine production was the muscle of its peasants. The Byzantine state, its administration, defense, even patronage of its arts, eventually depended upon how efficiently it exploited this simple resource. So did the peasant: in the absence of a work ethic, he had an approach to manual labor, which was to avoid it beyond the immediate needs of domestic autarky, unless coerced by taxation, tithe, or impost, or (more rarely) lured by a market for surplus that lay within a day's walk of a burdened beast or woman. In turn, the peasant knew how to exploit his muscle by implements, which offer almost infinite leverage. A simple crowbar gives a mechanical advantage of factor 4, but given the right gearing a child can, in theory and with his little finger, perch an 800-ton Egyptian obelisk on four brazen blocks in the Hippodrome of Constantinople. In fact, it took the men of Emperor Theodosios I a month to erect it in 390. The question is where and why the line of technological stimulus stops? For example, the peasant did not just know that a crowbar gave him an advantage of four, but that any tool was more efficient if iron-shod—and even wooden implements need iron to shape them. While the study of Byzantine art is now highly refined, the history of the Byzantine village blacksmith has yet to be written, even though he made the nails upon which eventually hung the fate of the empire. Yet how many today can readily distinguish between such banausic commonplaces as Byzantine horseshoes (which were flat) and oxshoes (which were cloven)? Research naturally advances at different speeds in different fields. But the constants I have stated are common not just to Byzantine, but to medieval Mediterranean, indeed, to all preindustrial societies.1

¹ A basic bibliography starts with a journal devoted to the subject: *Tools and Tillage* 1– (1968–) (National Museum of Denmark, Copenhagen). Discussions of such questions include the following (in order of publication): L. White, Jr., *Medieval Technology and Social Change* (Oxford, 1962), and subsequent discussion by R. H. Hilton and P. H. Sawyer, "Technical Determinism: The Stirrup and the Plough," *Past and Present* 24 (1963): 90–100; K. D. White, *Agricultural Implements of the Roman World* (Cambridge, 1967), idem, *Roman Farming* (London, 1970), and idem, *Farming Equipment of the Roman World* (Cambridge, 1975); G. Duby, *Rural Economy and Country Life in the Medieval West* (London, 1968), 16–22; M. Blagojević, *Zem'loradn'a u Sredn'oveklovnoj Srbiji* (Agriculture in medieval Serbia) (Belgrade, 1973); J. W. Nesbitt, "Mechanisms of Agricultural Production on Estates of the Byzantine Praktika"

Even these simple constants need questioning. Take iron again. Iron had been forged in Anatolia since Hittite times; there is plenty of written and archaeological evidence for "Saxon" ironworking in the southern Balkans in the late Middle Ages.² But it has been argued that at times Byzantium almost dropped out of the Iron Age. Does it matter? After all, the polished granite obelisk in the Hippodrome had originally been cut for the Egyptian pharaoh Thutmoses III (1549–1503 B.C.) without using iron at all. This should give us pause for thought.

Byzantine pastoralism and transhumance are prime examples of the intricacy of our problem: how to estimate their economic importance on the evidence we have? Pastoralism requires investment, forethought, and social organization on a scale far beyond that of a peasant's holding. The English medieval manorial three-field system of textbook legend is complicated enough, but the unrecorded details of the long-term seasonal rhythm of transhumance are far more intricate, depending upon deals between permanent winter villages primarily pursuing agriculture, concerning their respective summer stations and grazing, maybe 50 km distant and 1,000 m above, for negotiated droving routes and rights that rarely make much sense on the map, and none at all above the tree line, where the apparently endless freedom of the pastures is deceptive. Until quite recently in Chaldia, for example, if your flock trespassed quietly past an unregarded boundary cairn in the Pontic Gates one summer, there would be murder in Trebizond next winter—niceties compounded in the Middle Ages by the intrusive claims of more purely pastoral Turkomans when spring battles were carried up into the mountains and coastal grazing defended in autumn.³

⁽Ph.D. diss., University of Wisconsin, Madison, 1973), and cf. T. Teoteoi, "Le travail manuel dans les typika Byzantins des XIe–XIIIe siècles," RESEE 17 (1979): 455–62; A. E. Laiou-Thomadakis, Peasant Society in the Late Byzantine Empire (Princeton, N.J., 1977); P. Lemerle, The Agrarian History of Byzantium from the Origins to the Twelfth Century: The Sources and the Problems (Galway, 1979); A. A. M. Bryer, "The Estates of the Empire of Trebizond: Evidence for Their Resources, Products, Agriculture, Ownership and Location," Αρχεῖον Πόντου 35 (1979): 370–477, reprinted in idem, The Empire of Trebizond and the Pontos (London, 1980), art. 7, and idem, "Byzantine Agricultural Implements: The Evidence of Medieval Illustrations of Hesiod's Works and Days," BSA 81 (1986): 45–80; S. E. Rees, Ancient Agricultural Implements (Aylesbury, 1981); A. M. Watson, Agricultural Innovation in the Early Islamic World: The Diffusion of Crops and Farming Techniques, 700–1100 (Cambridge, 1989), 120–62; M. Kaplan, Les hommes et la terre à Byzance du VIe au XIe siècle: Propriété et exploitation du sol (Paris, 1992), 46–54, and subsequent discussion by A. Kazhdan and M. Kaplan, "One More Agrarian History of Byzantium," BSl 55 (1994): 66–95; K. Greene, "Technology and Innovation in Context: The Roman Background to Medieval and Later Medieval Developments," JRA 7 (1994): 22–33.

² See S. Andreev and E. Grozdanova, *Iz Istoriiata na Rudarstvoto i Metalurgiiata na Bŭlgarskite Zemi prez XV–XIX vek* (Historical survey of ore mining and metal working in the Bulgarian lands in the 15th–19th century) (Sofia, 1993).

³ M. Gyóni, "La transhumance des Vlaques balkaniques au Moyen Age," *BSl* 12 (1951): 29–42; A. A. M. Bryer, "Greeks and Turkmens: The Pontic Exception," *DOP* 29 (1975): 113–49, reprinted in idem, *Empire of Trebizond and the Pontos*, art. 6; J. E. Woods, *The Aqquyunlu: Clan, Confederation, Empire* (Minneapolis–Chicago, 1976), esp. fig. 2; C. J. Wickham, "Pastoralism and Underdevelopment in the Early Middle Ages," *Settimane* 31 (1981): 430; R. P. Lindner, *Nomads and Ottomans in Medieval Anatolia* (Bloomington, Ind., 1985); M. F. Hendy, *Studies in the Byzantine Monetary Economy c.* 300–1450 (Cambridge, 1985), 54–56; A. Harvey, *Economic Expansion in the Byzantine Empire*, 900–1200 (Cambridge, 1989), 149–53.

But today there is almost nothing to show for Byzantine pastoralism and transhumance. Apart from sheep shears, which are substantial scissors, the only implement it requires is a crook. The Byzantine bishop may have been called a *poimen*, or shepherd, but unlike that of his western counterpart, his crozier was not actually a crook to provide us with a surviving example. Otherwise the brown marks left by the black tents of nomads in the Isaurian uplands turn green again overnight, but the shallow trenches for their loom weights may still be traced.4 So can mandrai, the drystone sheepfolds that litter the Pontic Alps. Here, for example, there is a tenth-century lead seal of Dositheos, spatharokandidatos, perhaps imperial notarios of the herds (agelon) and anagrapheus of Chaldia,⁵ but flocks are notoriously difficult to track down and put on a tax record. In Roman Pisidia and Pamphylia there are epigraphic hints of people in the cities of the coast holding a dual citizenship with associated summer stations, confirmed by pollen analysis of the relative exploitation of the mountain forests and pastures, but all such evidence that this transhumant rhythm and economy are very old is also very tentative. Osteology and teeth can provide evidence for kill-off patterns, and hence an indication of the size of ancient flocks, but I do not know of any specifically Byzantine sample that has been analyzed. 6 Of course, before selective breeding, and by western analogy, Byzantine stock was by modern standards on a Lilliputian scale. Today you could probably lift a Byzantine calf in one hand: precise evidence of how small it was should in theory be revealed in libraries by the size of manuscript folio skins of uterine calf (vellum) or lamb (parchment), however cut and trimmed to octavo size: an analysis that I do not think has been attempted for Byzantium.

Diet may offer a clue to the extent of pastoralism. Of course, there is literary evidence for white cheese, especially Vlach, which was disparaged fasting food, but none of the spheroid wooden churns in which it is made, still swung to song by children and grandmothers. As for Galen's oxygala, the first traveler from colder western climes does not seem to have noticed it in Anatolia until 1555, when he heard it called with a name that sounded something like yoğurt.⁷ But the mark of a transhumant (as opposed to pure pastoralist) is his porridge, for it requires access to cereal agriculture and can be taken up to the summer pastures as the oldest packet soup in the world: the Anatolian

⁴ T. Faegre, Tents: Architecture of the Nomads (London, 1979).

⁵ Barber Institute of Fine Arts, University of Birmingham, seal 0181, for which I am grateful to Archie Dunn for discussion. Cf. N. Oikonomides, *Les listes de préséance byzantines des IXe et Xe siècles* (Paris, 1972), 338; A. A. M. Bryer, "David Komnenos and Saint Eleutherios," Άρχεῖον Πόντου 42 (1989): 162 (on Paphlagonian droved swine and cured pork, pp. 173–74, 182).

⁶ Cf. S. Payne, "Kill-off Patterns in Sheep and Goats: The Mandibles from Asvan Kale, *AnatSt* 23 (1973): 281–303; C. N. Constantinides, *Higher Education in Byzantium in the Thirteenth and Early Fourteenth Centuries*, 1204–ca. 1310 (Nicosia, 1982), 135: "During Lent when fasting was practised sheepskins were not available. The best period for collecting parchment seems to have been in spring after Easter Sunday."; J. J. Coulton, "North Lycia before the Romans," *Akten des II. Internationalen Lykien-Symposions*, ed. J. Borchhardt and G. Dobesch (Vienna, 1993), 1:82–83, and idem, "Balboura and District Research Project, 1993," *AnatSt* 44 (1994): 10.

⁷ A. G. Busbecq, *Omnia quae extant* (Louvain, 1633), 90, letter 1 of 1555 from near Amasya: "Galeno non ignoti, quod ipse Oxygalam, iste *Iugurtham* dicunt." Jugurtha is evidently not the king of Numidia but *yoğurt*, unknown to shepherds in colder climes.

Greek and Turkish name is *trachana* or *tarhana*, but it was made under various other names (an old English one is "hasty pudding") from Spain to Syria by all shepherds.⁸ Toponymy can help too, but while the survival of its name may be the first and last evidence of the existence of a place, pastoralists graze across space. Yet it is worth working through old Balkan and Anatolian maps to detect which fixed villages gave names to their summer pastures. More precisely, Byzantines had technical terms for the system of summer and winter pastures (*parcharia/cheimadia*) before their Turkish equivalents in Anatolia (*yayla/kişla*).

For this huge and hidden economy, the art historian may still have the most vivid evidence because of the happy accident that shepherds attended the Birth of Christ. The shepherds who watched their flocks by night are depicted in mosaic, such as in the Holy Apostles, Thessalonike of about 1312–15; they are strange, shy figures in their sheepskins and woolen leggings, oddballs rarely encountered in town. They are also invariably male, as is the milkman depicted in the Great Palace mosaics. Was the Arcadian tradition of the shepherdess in pastoral poetry perhaps replaced by a taboo, against women milking sheep, which survives among the Sarakatsans? It depends on the culture: Turkoman women were notoriously free of the veil to get down to work in the pastures. Was the real scandal of twelfth-century Mount Athos not that Vlachs introduced their womenfolk along with their flocks onto the Holy Mountain, but that their ewes were milked by transvestite shepherdesses? All this is speculation because, like that of the Byzantine blacksmith, the history of the Byzantine shepherd has yet to be written; but it does reveal problems of evidence.

The evidence of art is invariably the most attractive. For example, anyone interested in Byzantine diet, kitchen utensils, cutlery, indeed napkin etiquette, looks closely at paintings of what is laid out on the table at the Marriage at Cana. Similarly, anyone interested in Byzantine agricultural implements looks at manuscript illustrations of the parable of the Laborers in the Vineyard: Matt. 20:1–16. The example illustrated in figure 1 comes from the Four Gospels commissioned by Tzar Ivan Alexander of Bulgaria in 1355 (British Library Add. ms. 39627, fol. 59). Ostensibly referring to Palestinian viticulture of the first century A.D., it provides in fact one of the clearest surviving illustrations of a principal Byzantine digging implement, the two-pronged *lisgari* "spadefork" wielded by the first and fourth figures. May it therefore be taken to be firsthand evidence for fourteenth-century Bulgarian agriculture? Yes, and no, because the artist is palpably copying the same scene, or an archetype, in the eleventh-century Paris. gr. 74, fol. 39v: an illustration of Byzantine agriculture so often reproduced that it

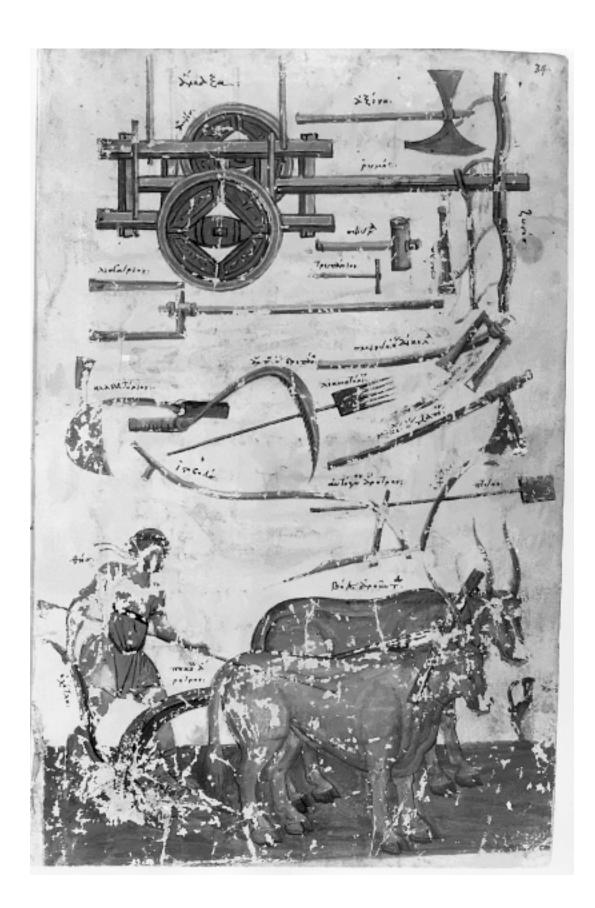
⁸ A. Bryer and S. Hill, "Byzantine Porridge: *Tracta, Trachanas, Tarhana*," in *Food in Antiquity*, ed. J. Wilkins, D. Harvey, and M. Dobson (Exeter, 1995), 44–54.

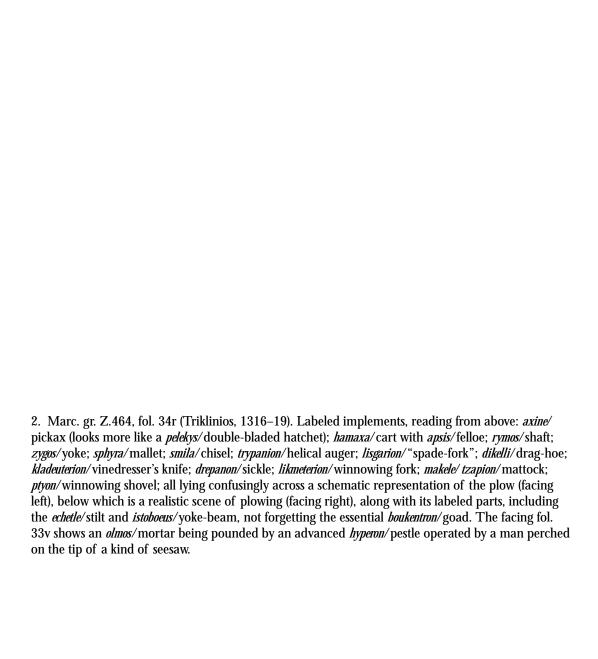
⁹ J. K. Campbell, *Honour, Family, and Patronage* (Oxford, 1964), 274: "women never milk sheep or use a shepherd's crook; men almost never milk goats." For the Athonite scandal, see E. Amand de Mendieta, *Mount Athos* (Amsterdam, 1972), 79–81, and A.-M. Talbot, "Women and Mount Athos," in *Mount Athos and Byzantine Monasticism*, ed. A. Bryer and M. Cunningham (London, 1996), 69–70.

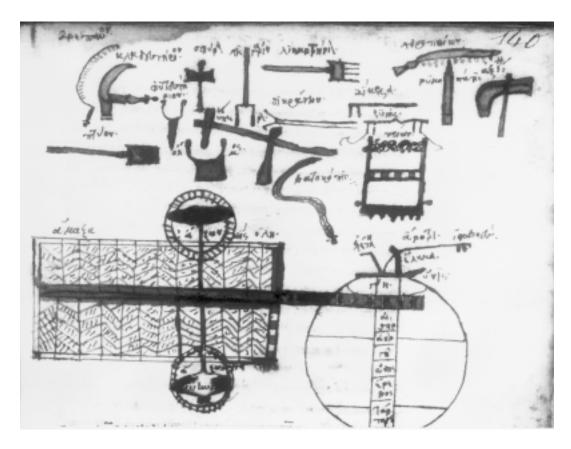
¹⁰ E. Dimitrova, *The Gospels of Tsar Ivan Alexander* (London, 1994), 54, fig. 56.



1. British Library, Add. ms. 39627, fol. 59r (1355), "The Laborers in the Vineyard"







3. Paris gr. 2786, fol. 140r (late 14th century). At the top left, reading labels of implements from left to right: drepanon/serrated sickle; ptyon/winnowing shovel; a fine example of a kladeuterion/ vinedresser's pruning knife; phyteuterion/vine fork or prop; sphyra/double-headed mallet; below an olmos/mortar in section, operated by a rocking hyperon/pestle to the right; above which lisgarin/ "spade-fork"; a rather etiolated *dikranion*/pitchfork; with *likmeterion*/winnowing fork above and a snaky batokopin/bramble-slasher below. Moving to the right, a dikella/drag-hoe above a zygos/double yoke with harnessing are notably out of comparative scale. Below them is an apparently unique but well-observed Byzantine illustration of a prion/frame-saw, demonstrating how the double-handled toothed blade at the bottom is held in tension by a torque of swirling gut or leather thongs at the top, with an elegant crossbar in the middle of the wooden frame. Above it is a cheiroprion/handsaw with serrated blade, perched above a mysterious vertical spindle or dibble labeled *rymostates*, of which this picture is our only evidence: it may have been the essential peg that locks the plow-beam to either the yoke or the sole. At the top right is an axine/pickax, which looks more like a hatchet. Below this agricultural catalogue are the hamaxa/cart and plow. The cart (with axona/axle and apsis/felloe) follows Hesiod's lines bravely, but the artist has a more adventurous idea of perspective than Triklinios: his depiction makes sense if you disentangle the way he views it at all angles at once. The high basket rick is there, but the disk wheels are shown both laterally and in plane. The circle to the right is not a wheel, but explains the Hesiodic cosmography, above which is balanced an elemental ard with all its named parts: echetle/stilt, elyma/sole, hynis/share, and istoboeus/yoke-beam.

is unnecessary to do so here.¹¹ But it raises other problems, some unexpected. One commentator pronounces this famous scene not to be of a vineyard at all, but of a sunflower field, ignoring the fact that sunflowers were not introduced from America to the Balkans until the sixteenth century. The bushy-topped trees are in fact a Byzantine artistic convention and may represent olives up which Byzantines trained vines, among other crops that needed supports. Another problem is the lisgari, which has evidently puzzled both British and Albanian interpreters, who have tacitly and independently redrawn it for publication as the more familiar modern single-bladed garden spade—an implement hardly known to Byzantines.¹² The *lisgari* is a "spade-fork," used to prepare the ground for sowing, especially in soil where a plow cannot be used. But our problem is different. The scene is clearly labeled as, and intended to be of, what Byzantines would recognize as a vineyard, so is good evidence. But the tools most appropriate to a vineyard are not actually the *lisgari* and *drepanon* sickle, shown in it, but the dikelli hoe and kladeuterion vinedresser's knife, nor is there any sign of a phyteuterion, or forked vine support. The kladeuteri was developed from the billhook, to which it seems to be receding in modern Turkish examples from former Greek areas of vine growing. But it was the most neatly designed tool that the Byzantines inherited fully armed from antiquity, recorded in figures 2 and 3 and elsewhere, but not so far in archaeological evidence.¹³ A sort of Byzantine Swiss army knife, the kladeuteri serves up to six distinct functions and met no rival until the invention of the sécateur by Bertrand de Molleville (1744-1818)—some vinedressers still prefer it. But it does not seem to feature in figure 1. Perhaps the author was just a better artist than a laborer in the vineyard. Perhaps we should be more wary about Gospel illumination, or perhaps we should learn more about medieval vinedressing.

The obvious evidence is archaeology, but of that there is pitifully little and mostly from the western shores of the Black Sea, now in Romania and Bulgaria—Crimean Cherson also yields material, along with *garum*-pans for making that powerful and universal relish from the entrails of fish. Hut I do not know, for example, of a single identified *lisgari* tine. How, therefore, do we know what it is? The answer is partly in the survival of a name, under various morphologies that diverge with the tool's actual shape and use. The Homeric *listron* with which Telemachos scraped the floor of the massacred suitors in *Odyssey*, 22.455, is clearly not the same tool shown in figure 1, however redrawn, any more than it is the modern Greek *lisgari* rake or harrow. In this

¹¹ H. Omont, Evangiles avec peintures byzantines du XIe siècle, vol. 1 (Paris, 1908), pl. 33; still the best reproduction, redrawn yet again for the jacket of Harvey, Economic Expansion, where it is unaccountably ascribed to the Labours of the Month from the St. Eugenios monastery, Trebizond.

¹² Examples in Bryer, "Agricultural Implements," 50; for such methodological problems, see M. O. H. Carver, "Contemporary Artefacts Illustrated in Late Saxon Manuscripts," *Archaeologia* 108 (1986): 117–45.

¹³ White, Agricultural Implements, 93-96 (falx vinitoria).

¹⁴ For example, P. Diaconu and S. Baraschi, *Păcuiul lui Soare* (Bucharest, 1977); much more is to be expected, most recently from the 7th–century Yassı Ada shipwreck.

case the *lisgari* survived along with its Pontic Greek medieval and modern name as [e]*liktrin*, as well as in modern Pontic Turkish practice. Such survivals present problems, too. For example, the British Institute of Archaeology at Ankara's Aşvan Project, which from 1968 recorded all facets of an ancient site on the Euphrates near Elaziğ, duly included an account of traditional agricultural implements still used there, before the place was flooded for the Keban Dam after 1972. But this otherwise admirable record does not mention the vital fact that it is valid only for the Bulgarian and Romanian Turks who replaced the original Armenian villagers of the place after 1922. Similarly, exemplars in "village museums" in Bucharest (Romania), Kazanlåk (Bulgaria), Skyros (Greece), or Yeroskipos (Cyprus) must be treated with great caution. A recent album of more than three thousand agricultural implements from most Balkan countries illustrates nothing looking like our medieval *lisgari*. ¹⁶

On such shaky ground one must tread delicately. The safest ground is the evidence of inventories and wills. To take the *lisgari* again, the widow Kalana Spelianitopoulos, crofter of Vazelon monastery, willed her eliktrin (along with a plowshare and two sickles) at some time in the thirteenth century in a valley where that tool is still employed today.¹⁷ For an idea of what Byzantine implements actually looked like, there is an unexpected pictorial source, besides wall paintings and Gospel illuminations: Byzantine illustrations of Hesiod's great poem of the eighth century B.C., Works and Days, in more than fourteen manuscripts from the tenth century A.D. 18 The facts that this ancient work of "wisdom literature" is largely irrelevant to Byzantine farming, that no illustrator appears to copy another, and that most introduce and label implements not even mentioned by Hesiod give these contemporary authority. The finest example comes from Cardinal Bessarion's library. It is the autograph of Demetrios Triklinios, finished on 20 August 1316, to which he or another added an illustration before 1319 in Marc. gr. Z.464 (= 762), fol. 34r, shown in figure 2; figure 3, from the end of the fourteenth century, is a comparative display of ironmongery in Paris. gr. 2786, fol. 140r. Our tool, labeled lisgarion, lies horizontally beneath the cart in figure 2 and stands upright at the top middle of figure 3. Both examples are shown full faced. Without modern survivals we would not learn from this that the wooden shaft of the tool is in fact crook-backed, or, without digging with it, that the peasant puts his foot not, as with a spade, on the iron shoulders of the tines, but on the wooden heel of the shaft (they fall apart otherwise). Nor, without using it, would one realize that it weighs a

¹⁵ D. Williams, "Modern Agricultural Technology in Aşvan, *AnatSt* 23 (1973): 277–80.

¹⁶ G. Ostuni, *Les outils dans les Balkans du Moyen Âge à nos jours*, ed. A. Guillou, 2 vols. (n.p., 1986). I am as dubious of the use of this compilation, as of the reconstruction of a heavy plough from three iron scraps exhibited in Odessa (Ukraine), but the sole ard exhibited in Tirana (Albania) seems to have been reassembled more efficiently. The imperial Russian collection of medieval agricultural implements was allotted to the grand duchy of Finland, but still languishes in store in the Helsinki museum. Cf. R. E. F. Smith, "Some Tillage Implement Parts in the Zausailov Collection, National Museum of Finland," *Tools and Tillage* 4 (1983): 205–15.

¹⁷ F. Uspenskii and V. V. Beneshevich, Vazelonskie Akty: Actes de Bazélon (Leningrad, 1929), no. 118.

¹⁸ Bryer, "Agricultural Implements," 52–56; cf. Z. Mihail, "Southeastern European Ethnolinguistic 'Convergencies' (in the Field of Agricultural Implements)," *RESEE* 24 (1986): 179–89.

backbreaking 4.5 kg, three or four times heavier than a modern western tempered spade or fork (a Balkan vineyard hoe can weigh in at 3.5 kg). Nor without buying a modern Anatolian *lisgari* would one know the relative value of iron and wood: for the Π-shaped tine of this spade-fork, the village blacksmith now charges five times as much as the village carpenter does for fashioning the wooden shaft and handle—a ratio that is at least an indication of relative medieval costs.

I have taken the example of the *lisgari* to test our sources, not only because it seems to be a peculiarly Byzantine tool, which perhaps never caught on either because it is peculiarly heavy on the peasant's muscles or peculiarly inefficient in most soils, but because it must be remembered that the basic business of turning the soil was largely done by such hand tools, rather than through the miracle of the plow, with which most studies of agricultural implements have by tradition started since Hesiod. But to begin with the heavy plow, or the elaborate water mill, may be misleading. Technological advances overrun practice. For example, the Romans elaborated gigantic ox-drawn winnowing machines, which can have had little significance if most peasants continued to winnow by hand. But we had still better begin with the plow.

The Byzantine plow was, technically, not a plow at all, but a sole ard. The only elaboration since Hesiod was the iron tip of its hynis share, mentioned in some wills, but its wooden point is still often simply hardened in fire. It is incapable of turning the soil, so that the scratch it makes across the soil (furrow is the wrong word) is rarely more than 12 cm deep, requiring cross-plowing, sometimes four times over, harrowing (with bundles of twigs attached to a frame), and simply endless clearance of stones, the traditional first fruit of an Anatolian field, to cairns or field boundaries. Its yoke, like the Latin iugum, Greek zeugarion, English ox-gang, or Turkish çiftlik, is a nominal measure of land, which would have been greatly extended if the Byzantine ard had been furnished with the refinements that spread throughout the western medieval world: a coulter for cutting the turf, a moldboard for turning it, and above all wheels that fixed the share at an angle, turning the machine into a true plow that is forced to dig deep. This is hard work, but it is largely transferred from the muscle of the peasant to the beasts on the yoke. I say "beasts," but this raises another variable known to anyone balancing the costs of buying a motor car: oxen are heavier and weaker, but cost less to fuel and maintain than more expensive and efficient horsepower. Humans can drag a plow too.

As anyone who has plowed with the Byzantine sole ard knows, the problem is how to stop the share erupting and just slithering across the surface of the soil, by keeping the pressure of one's foot—almost hopping—on the heel of the sole (*elyma*), along with holding down the stilt (*echetle*) by hand. It is not easy, and such gymnastics do not end there, because the other problem is how to stop the oxen wandering all over the place, which is achieved by an essential accessory known to Hesiod as the *orpex* and to Byzantines as the *boukentron*. This symbol of the plowman is a goad, a stick held in the left hand (while the right steadies the stilt), to encourage the beasts by poking them from behind in their most tender parts: Triklinios illustrates this animated scene well in figure 2. The question remains: why is the western heavy plow apparently unknown

in Byzantium? An obvious answer is that it is best suited to the heavy loams of Flanders or the south Russian Donbass and would play havoc with some thin topsoils of Anatolia, which rains would wash away (manuring is another question). Western Crusaders or conquerors do not seem to have brought it substantially to the Levant or Crete. Another answer may be that most Byzantines cleared and tilled the soil with quite developed specialized hand tools, most of which are illustrated in figures 2 and 3.

For clearing trees, coppicing, slashing, and generally taming forest and scrub in the first place, there were a number of well-attested iron-shod tools, beginning with the all-purpose *axine* pickax in various forms. The *batokopin* was a rather specialized and still handy bramble-slasher. But the most fearsome and destructive implement was the *pelekys*, the double-edged hatchet of Varangian fame, which even appears on seals. It was a *pelekys* that St. Neilos (d. 1004) slung over his shoulder to lay waste the vineyards of Calabria (quite why no one knows, but it showed he meant business). In his will of 1059, Eustathios Boilas describes how he tamed his wilderness by slashing and burning: "the land was inaccessible to most people and unknown. I reduced it with *pelekys* and fire, as the psalm saith." The psalm in question is 74:5–6: "They brought it crashing down, like woodmen plying their axes in the forest; they ripped the carvings clean out; they smashed them with hatchet and pick" (New English Bible).

After the *pelekys* had done its striking work and tree stumps had been burned out, there was a range of digging tools to hand even before thinking of a plow on such terrain. Besides the *lisgari*, for example, in Macedonia in 1326/27 the *skouterios* Theodore Sarantinos willed two *sideroptya* (apparently our only evidence for *iron*-shod spades), 14 *tzapia* (mattocks of various kinds, with an angled blade), and 36 *dikellia* (two-pronged drag-hoes, of which one is best illustrated in the Great Palace mosaics).²¹

Following the agricultural cycle, reaping comes after digging, plowing, and sowing. When and where crops are ripe for harvest depends upon climate and geography: variables that make it impossible to reduce Byzantium to a common pattern. But for harvesting everywhere the essential implement is the *drepanon* sickle, a 30 cm crescent of tempered, sharpened, and sometimes toothed iron on a wooden handle. It is a simple, unchanging, and beautifully balanced tool, so universal that it is the symbol of the peasant, perhaps adopted by Emperor Andronikos I Komnenos (1183–85) in his curious depiction as a man of the people, on the door of the church of the Forty Martyrs in Constantinople.²² But there seems to have been no taboo against women reaping; indeed, by observation in former Byzantine lands, it seems to be where they enter the agricultural cycle. Where grain is cut at no more than 50 cm high it is a backbreaking job, done at flashing speed. Clutching a sheaf in the left hand, you bring the sickle

¹⁹ A. Guillou, "Production and Profits in the Province of Italy (Tenth to Eleventh Centuries): An Expanding Society," *DOP* 28 (1974): 92–96; cf. A. Dunn, "The Exploitation of Woodland and Scrubland in the Byzantine World," *BMGS* 16 (1992): 235–98.

²⁰ P. Lemerle, Cinq études sur le XIe siècle byzantin (Paris, 1922), 22.

²¹ G. I. Theocharides, Mia diatheke kai mia dike Byzantine (Thessalonike, 1962), 23.

²² Cf. F. Grabler, "Niketas Choniates als Redner," JÖBG 11-12 (1962-63): 68.

across and behind with the right. The problem is obvious: in cutting the crop you are in danger of slicing off your left-hand fingers too. The solution is obvious: wooden finger-guards (modern Greek *palamaries*) or thimbles, sometimes articulated into whole palms, sometimes with a clever hook to clutch the sheaf. I know of no archaeological, illustrative, literary, etymological, or other evidence for such finger-guards in Byzantium, but they remain so widespread and essential that we can safely assume that Byzantines wore them for their own safety too.

The *drepanon* sickle brings, like the plow, its own problem of where and why technological progress stops. In the medieval West, the scythe became common, for hay-making especially, with a blade maybe 1 m long, wielded with both hands. There is no medieval Greek word for it, or any recognizable Byzantine, but some Serbian, evidence. The scythe is about six times more efficient than a sickle, though in this case you have to watch out not to slice off your toes. Was it that Byzantine blacksmiths were simply not up to forging such a tool? Was it that a stony terrain makes it, as in parts of Scandinavia, unsuitable—for a scythe is easily broken? Or was it that the Byzantine peasant followed the well-attested and surviving practice of reaping twice, taking first the precious sheaves of grain and then cutting the straw, if he did not simply turn out his swine to grub about on the field?

After reaping comes threshing and winnowing, the business of separating the grain from the chaff, where at least the Byzantine peasant had a climatic advantage over his western or northern counterpart. Left beneath the elements, cut grain deteriorates rapidly in rain. In medieval England, for example, it was therefore largely flailed indoors and by hand—another tiring job that depends upon the muscles of the right arm. But in the Mediterranean, the circular open-air threshing floor (aloni) is said to be as old as the village harvest ring dance upon it; in hagiography St. Theodore of Sykeon exorcised demons howling beneath one, and in balladry it is the stage upon which Digenis fought Death.23 The diameter of threshing floors, at about 10 m, is so natural and consistent that I have not thought to measure examples. But it may well be found that, like the English long-clock, whose pendulum has swung since 1666 at the precise drop of 39.1 inches, the aloni follows such a golden mean. In fact, threshing offers an authentically dramatic and bucolic break in the agricultural cycle, because the work is largely harnessed by beasts. Threshing floors are instantly recognizable and difficult to erase from the landscape long after they are abandoned (as in the Pontos) because new crops, such as maize, no longer require them. Yet archaeological evidence of associated flints, obsidian chips, or broken oxshoes, discarded because they have worn one way, is rarely recognized.

Basic threshing may be done simply by urging beasts to lacerate the grain (occasionally lentils), beneath their hoofs. But it is done more efficiently by tribulating it under a beast-drawn threshing sledge: the Roman *tribulum*, Greek *dokani/tykani* and Turkish

²³ Vie de Théodore de Sykéon, ed. A.-J. Festugière (Brussels, 1970), 89–90; Digenes Akrites, ed. R. Beaton and D. Ricks (London, 1993), 139, 145, 147, 148, 163; L. Cheetham, "Threshing and Winnowing—An Ethnographic Study," Antiquity 56 (1982): 127–30.

duğan, which gyrates round the floor. It is usually a double-boarded affair, embedded with up to seven hundred flints and the like, upon which it is often children's work to surf. It was under the teeth of such threshing sledges that Emperor Nikephoros I supposedly tossed Bulgar babies for tribulation at Pliska on 20 July 811—Khan Krum got his revenge within a week when he toasted his boyars from that emperor's skull. The threshing sledge figures in wills, but I think only twice in Byzantine manuscript illumination, and in Anatolia does not seem to have caught the eye of a westerner before 1712.²⁴

After threshing comes winnowing, the separation on the threshing floor of the grain from the chaff. This is vigorous work: tricky too because one must stand at right angles to a steady wind, to toss it time and again so that the heavier ears fall in one pile and the lighter straw onto another. The winnower must adjust his tossing to quite small changes of the wind's strength and direction, before he has a discrete heap of grain ready for a final sieving. His tools are the *ptyon* winnowing shovel, which has a flat-fashioned blade, and two forks for heaving sheaves, which are commonly trimmed natural branches: the *dikrani* pitchfork and the *likmeteri* winnowing fork—the latter sprouts more spokes. Entirely wooden, these elegant implements are too modest to appear in wills and are unlikely to do so in archaeology, but are well illustrated; their survival is universal.

The next stage is milling. The water mill has aroused quite as much discussion as the plow. In poetry it released the energies of water nymphs to relieve the drudgery of women villagers. ²⁵ I suspect that milling, like tilling, was done largely by hand too. I cannot prove it (no one can), but while the plow is not many times more efficient than the hoe, the mill is certainly a much mightier machine than the hand mill. Yet the hand mill or quern has its advantages to the peasant household. You can grind what and when you want according to domestic convenience, so saving negotiations with a miller. In any decent Anatolian general store you can still get a handy striated stone-cut quern, about 35 cm in diameter, with a wooden handle, to balance on the lap—along with other useful things, such as black whetstones or wooden packsaddles. Although the hand quern hardly shows up in Byzantine evidence, modern examples are indistinguishable from regular Roman ones. Larger mortars and pestles (Hesiod specifies three feet each), remain used for crushing pulses—Byzantines seem to have eaten their peas and beans smashed in the pod. ²⁶

But, like the plow, there are mills and mills. Byzantines could presumably, like twelfth-century westerners, have graduated from the sole and to the heavy plow. Similarly they could, like twelfth-century westerners, have adopted the more efficient overshot water mill, of which they inherited the technology and some examples. But they stuck to the "Greek" mill of Strabo's time. What is this mill?

²⁴ Voyage du Sieur Lucas, fait par ordre du roy dans la Grèce, l'Asie Mineure, la Macédoine et l'Afrique (Paris, 1712), 1:131; Bryer, "Agricultural Implements," 79–80, with comparative table.

²⁵ The Greek Anthology, ed. W. R. Paton III (London-Cambridge, Mass., 1917), 176–79: 9.326–31; Strabo, Geography, 12.3.30.

²⁶ Hesiod, Works and Days, 11.423-36.

The common Byzantine water mill is technically a horizontal direct-drive scoopvaned turbine. In simple terms, what happens is that a flow of water is drawn off a natural stream, diverted as much as 500 m upstream into a parallel millrace until it has built up a head, to be sent down a steep vertical flume, a chute maybe as high as 10 m, to strike the twenty-odd horizontal scoop-vanes of a wooden mill wheel obliquely, so debouching the tailrace back into the main stream down below it at an angle—such as appears to be depicted in a Great Palace mosaic. In turn the mill wheel in a lower chamber drives the upper millstone, or runner, through the floor of a chamber above by a direct vertical shaft locked into its lower face by a cross-fitting, or rynd. The runner lies on top of a static nether- or bed-stone on the floor on the upper chamber. Both millstones are about 85 cm in diameter, the mill wheels rather larger. My observations of this type show that the upper millstone runs at between 60 and 120 rpm, depending upon water flow: paddle-vaned mill wheels simply placed in a streambed below may drag the millstone round as sluggishly as once a minute. On the rough surface of the runner hangs a spatula, called by English molinologists a "damsel" or "dandelion," which agitates strings attached to the mouth of a cradled hopper—an inverted pyramid—which encourages a thin flow of grain to spill into the central hole of the upper millstone, which finally emerges ground between both stones in a pile of flour on the floor of the upper chamber.²⁷

This machine may sound complex, but is, apart from the paddle-vaned mill wheel, the simplest and least efficient of all mills, which may explain why it is so widespread, from Byzantium to the American Appalachians—in southern Spain they actually claim it as a Byzantine heritage. It uses only 15-20% of the water pressure available. The rival to the "Greek" mill is the "Vitruvian" or "Roman" one, where the mill wheel is vertical, whether undershot, or, most efficient of all, overshot (i.e., the water flow starts in buckets at the top of the wheel, using its pressure to near 100% advantage). But while these can drive larger millstones, they require gearing to translate vertical into horizontal pressure, an expensive investment which in the West put milling into the hands of those who could compel peasants to use their mills (where the common charge is a proportion of the flour milled). Instead, Byzantine mills seem to have been in quite modest hands, and development was lateral—to two- or three-"eyed" mills, sometimes mentioned in charters, where stones ran together on a bench above the same flume. Windmills are more complex and unpredictable still; there is evidence for them on the Ionian coast and in the windy Aegean from the thirteenth century which may be associated with western innovation, along with the great sugarcane mills of Cyprus and Candia, whence came candy by another Arabic etymology. The colossal vertical undershot noria, antique irrigation wheels that still turn today in Cordoba,

²⁷ Bryer, "Estates," 404–11; H. H. Guhan Danişman, "A Survey of Turbine-type Water-mills in the Bolu Region of the Central Anatolian Plateau," *Journal of the Faculty of Architecture* (Middle East Technical University) 3 (1977): 17–37; R. A. Holt, *The Mills of Medieval England* (Oxford, 1988); Harvey, *Economic Expansion*, 128–34. For a 9th–10th-century "Roman" water mill in Thebes, see C. Koilakou, "Ένας βυζαντινός ὑδρόμυλος στη θήβα," *Technologia* 9 (1999): 57–59.

Homs on the Orontes, and in the lower reaches of the Iris (Yeşilirmak), survived the Middle Ages, but I know of no Byzantine reference to the Anatolian ones.

After milling comes baking. Byzantine monastic domed ovens may confirm the surviving evidence of Anatolian village counterparts. Pastoralists had no fixed ovens at all, so ate porridge. But they may have been better off than monks and peasants, whose bread is baked to last: in at least one Anatolian village the headman stokes the oven nightly for one of thirty families' monthly supply. The trouble is that, despite the distinctions from black, through *hemilefko*, to *artos katharos* or white bread, any idea of what Byzantine bread, emmer, spelt, bulgur, wheat, barley, or rye tasted like is irretrievably lost—along with the quality of their wine.²⁸

Besides the elemental plow, it was the wonderful *hamaxa*, a single-axle beast-drawn cart and its parts, that most excited Hesiod and has puzzled both Byzantine illustrators and modern commentators. It is real enough, but Greek of any kind is unable to explain what is going on. The illustrator in figure 3 bravely interprets ancient instruction, showing a hay wagon from below, with an apology for an *apsis* or felloe. Triklinios' version in figure 2 introduces an innovation, once attested elsewhere, which you can see by looking closely at the cart wheel. Here quarter-felloes frame four truncated quadrants that leave a square opening in the center of the wheel into which an oval block, through which the axle runs, is wedged, so that any turn of the wheel locks it tighter. Was this neat, but sturdy, design the Byzantine contribution to the technology of the wheel? If so, it never caught on: modern Anatolian versions sport simple pre-Hesiodic discs, which screech across the plain.

This is the problem. Carts are good for plains, indeed they occasionally appear in Balkan wills, but do not get very far elsewhere. The standard paved and curbed Roman road is about 6 m wide, a carriageway fit for such carts. There is no standard Byzantine road, but at some time in late antiquity, pack-animal tracks (sometimes along ridges) superseded old roads (which often followed valleys). This fundamentally important general proposition is not based upon any quantifiable published evidence, for which research cries out loud, or even speculation as to whether the camel replaced the wheel in the Levant, but on simple observation from Hadrian's Wall to Armenia.²⁹ At about 1.5 m wide, the new paths were commonly ridged, even stepped to give beasts and humans a footing, and would have given carts a bumpy ride. Perhaps the most accessible surviving network of such medieval tracks is on Mount Athos, where, as in the

²⁸ M. Solomidou-Ieronymidou, "The Medieval Sugar-mill at Episkopi-'Serayia', Cyprus," in "*The Sweet Land of Cyprus*," ed. A. A. M. Bryer and G. S. Georghallides (Nicosia, 1993), 430; J. C. Baroja, "Sobre le historia de la noria de tiro," *Rivista de dialectologia y tradiciones populares* 11 (1955): 15–79; N. Jasny, *The Wheats of Classical Antiquity* (Baltimore, Md., 1944); Harvey, *Economic Expansion*, 167; C. Dyer, *Standards of Living in the Later Middle Ages* (Cambridge, 1989), 151–60. Vat. Ottob. gr. 210, fol. 42v in Bryer, "Agricultural Implements," fig. 15, clearly and exceptionally illustrates the distinctions between wheat and barley.

²⁹ A specific case is reported from Antalya by D. H. French, "Roman Roads and Milestones of Asia Minor," *AnatSt* 42 (1992): 5. I am grateful to J. J. Coulton and J. Crow for discussion of unpublished research.

Pontos and other parts of Anatolia, they have only recently been abandoned for modern roads and wheeled traffic.

Byzantine systems of weights and measures may reflect and confirm the first and undatable shift from the cart road to the mule track. On land, medieval people reckoned basically by yield (nominal bushels or rations like the Spanish fanega, or Byzantine modios³⁰ and choinix), an elastic estimate of value more useful than the surface measurement that it soon became. There are statistical scraps for taxable yields, which are no more use than trying to recover the taste of Byzantine bread. On sea, Byzantine weights were sensibly geared to capacities (such as pithoi or tuns) that cannot be lifted by hand or on land. In town, the hamal porter races colossal weights, bent double under his saddle. But in the village, dry and liquid measures were calibrated not by what can be carried by a hamaxa cart on the road, but by the size and weight of a brace of baskets, buckets, or pitchers that can most conveniently be balanced on the shoulders of a yoked woman (or flanks of a mule) to take the long path to market.³¹ There is no real research on these simple correlations between carriage and weight, but I suspect that it would confirm my general conclusion: that most Byzantines may have tilled the soil not with a plow but by hand, ground their grain not by a mill but by hand too, and carried their produce not on a cart but on their own and their pack animals' backs. The principal means of Byzantine production ends, as we began, with the muscle of its peasants.

³⁰ Editor's note. According to common scholarly opinion, the modios measured not yield but seed, i.e., 1 modios (measure of surface) of land was the land that required 1 modios (measure of volume) of seed. See, for example, E. Schilbach, *Byzantinische Metrologie* (Munich, 1970), 56ff. The term is used in this sense (seed) in the chapters on agriculture, below.

³¹ The basic work is Schilbach's *Byzantinische Metrologie*. For an example of its application for this purpose, see A. A. M. Bryer, "The *Sabur* or *Çabur*," in *Continuity and Change in Late Byzantine and Early Ottoman Society*, ed. A. A. M. Bryer and H. Lowry (Birmingham–Washington, D.C., 1986).