The Medieval Roots of Colonial Iron Manufacturing Technology

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Introduction

Europe, between the eleventh and sixteenth centuries, saw an unprecedented surge in iron manufacture technology that would quickly spread throughout the western world, including the American colonies. Although often deemed a stagnant and uninventive period, the Middle Ages, on the contrary, gave birth to a wealth of technological innovation that would long remain particularly suited to the needs of colonial American iron workers. Economic, technical and, most importantly, natural resources in the colonies made the medieval method of iron manufacture distinctively attractive and efficient, as opposed to the strikingly different method used concurrently in early modern Europe. Owed to the Middle Ages are two vital technological innovations that abounded in the American colonies, the blast furnace and the application of waterpower to almost every stage of the iron manufacture process. The blast furnace used waterpower to increase draft and, therefore, temperature, allowing iron to be smelted much faster, cheaper and with the option of creating cast or wrought iron. In addition to powering the bellows of the blast furnace, waterpower was also applied to numerous other applications, including the washing and grinding of iron ore, the drainage of mines, the wire-drawing mill, the slitting mill, and the tilt-hammer. The discussion of the development of this technology in the Middle Ages and its similar adaptation in the colonies is the goal of this essay.

Iron Manufacture in Medieval Europe

Iron manufacture in the Middle Ages was comprised of essentially three practices: mining, smelting and smithing. As will be argued in more detail below, these practices were basically identical to those used in colonial America. In effect, mining is the extraction of an ore or minerals, for example iron ore, from the earth, generally by means of tunneling or excavation. Although much of the earliest iron ore used in Europe was found in exposed areas of earth that did not require much digging, these surface deposits were exhausted by the twelfth century and means of acquiring the increasingly popular iron ore that was more deeply buried needed to be devised. Much of what we know today about medieval mining methods comes from the great textbook on mining, *De re metallica* (*On metallic matters*), written in 1556 by Georgius Agricola, otherwise known as Georg Bauer. From this text, we know that the technology developed for mining in the Middle Ages included tools for digging and splitting rock, hauling implements, drainage pumps and ventilating machines. Necessary for the initial stages of the mining process, a miner's tools were generally constructed of iron with wooden handles and included a shovel, pike, hoe, pick, hammer and wedge. The ore reaped by these tools then needed to be hauled to the surface through a variety of means. Buckets, wooden and ox-hide bound by iron were the basic ore-moving devices. Other hauling implements, such as windlasses, employed cranks powered both by man and by animals. A labor-saving innovation particular to the Middle Ages was the wheelbarrow, which gave one man the transporting power of two. This search for labor-saving devices was characteristic of medieval man, as well as the American colonist, and will be addressed in further depth below. Another example of this style of thinking was the invention of the wagon mounted on wooden rails and drawn by animal power, an early forerunner of the locomotive.

Complications in the mines, such as flooding and ventilation difficulties, inspired medieval miners to create often inventive means of overcoming them. Agricola wrote that mines were most often not abandoned because they were barren of ore, but because they were flooded.[1] In response to flooding, drainage pumps were devised for the removal of water from the mine. The simplest type of pump was a series of dippers attached to a chain. These were powered by animals on treadmill, by hand and even by waterwheel. Waterwheels also powered the more sophisticated suction-pumps, which drew by means of pistons. A third type, rag-and-chain pumps, were powered manually and used balls stuffed with horsehair, spaced along the chain, that acted as one-way pistons. Delving deeper beneath the surface of the earth led to a second complication for the miners: less oxygen for those working in the elongated tunnels. Rather than limit the depth that the mines could extend, ventilating machines were developed as a solution. The simplest form of ventilation, sufficing only for the shallower mines, was merely the flapping of cloths to circulate air. Later, revolving fans and single- or double-acting bellows maintained air flow, while allowing miners to dig to new depths.

Workers in the mines also followed a particularly medieval form of labor organization. The first “customs of miners” was recorded in Trento in 1185, closely resembling the medieval manorial pattern of agriculture. A seam of ore was allotted to each family of miners, who followed the guidance of their lord, the landowner. The lord decided the working methods, hours and profit distribution.[2] This organizational scheme is strikingly similar to that of the better-known medieval agricultural manor.

Smelting was the second of the three basic steps of iron manufacture. Basically, smelting is the process of melting down ore in order to separate its metallic components from impurities. Charcoal, technically charred wood, was the predominant heating source of the Middle Ages, the abundance of wooded acreage across Europe making it the easiest and most transportable, if not most efficient, resource for smelting and blacksmithing. Lime flux, usually either limestone or oyster shells, was often added so that it would combine with impurities to create a brittle slag, the residue formed through the oxidation of the iron due to smelting.[3] Smelting took place in various types of furnaces; there were a number of furnace styles that appeared during the Middle Ages. The most primitive of these was the bloomery hearth. Here the ore was covered with charcoal and held together by a circle of stones. A bellows, invented in the early Middle Ages, supplied a draft of air towards the middle of the hearth. The Corsican and Catalan forges improved upon the bloomery hearth’s design by utilizing more permanent masonry walls on two or more sides. The subsequent Stückoven, however, remained the most advanced furnace until the fourteenth century, and in many areas,

[1] Bromehead 19
[2] Gies 128-129
[3] Tunis 148

the sixteenth, increasing output to as much as three times the earlier furnaces. Its masonry construction reached heights of ten to fourteen feet and often employed a water-driven bellows. The use of waterpower, though, reached its pinnacle in the blast furnace, referred to by some as the "greatest technical achievement of the period."[4] Although the Chinese developed a waterpowered blast furnace whose technology spread as far west as Persia, it is believed that the technology was probably developed independently in Europe, the earliest known example being at Lapphytten, Sweden in 1350.[5] The blast furnace's waterpowered technology increased combustion and allowed the iron to be held in contact with the charcoal, producing a higher carbon content with a low melting point. The effect of this magnified dependence on waterpower, particularly in iron manufacture, can be seen in the great increase of laws and lawsuits after 1300 in regard to navigation rights versus power rights.[6] Dams and millraces were constructed on ever larger rivers, rather than limiting their power consumption to only tributaries and small rivers.

The greatest benefit produced by the blast furnace was that the iron could be handled to produce pig or wrought iron both easily and at will. The term "pig iron" comes from the image of the molten iron that separated from the slag, ran into a canal of sand, called a "runner," and on into shallow, radiating depressions. The depressions reminded medieval iron workers of a sow with suckling pigs. Although this choice between pig and wrought iron was possible in some previous furnaces, the quality of the blast furnace's iron greatly exceeded anything seen before, with a much greater efficiency and higher percentage of iron from the ore. The waterwheel powered enormous pairs of bellows that alternatingly blew through an opening in the furnace called a "tuyere." This greatly increased the draft into the furnace and thereby the temperature; higher temperatures meant that the ore was heated to a point where the carbon uptake was intensified, turning out an alloy of about 4% carbon and 96% iron. Not only the greater efficiency of the blast furnace, but also its ability to run continuously, allowed for a marked increase in output; the waterpowered blast furnace could run for weeks or even months at a time.

Blacksmithing during the Middle Ages experienced not only an increase in demand, but also an increase in technological innovation. By the sixteenth century, blacksmiths worked not only in the castle's armory, but had also moved into towns and villages, supplying the increasingly popular iron housewares and farming implements. One result of this was that a peasant in the later Middle Ages was now much more likely to have a full set of farming tools than his ancestors a century or two before.[7] Some of the most common iron pieces commissioned of a blacksmith included cooking utensils, carpenter's nails, spurs, fire tongs, hinges, tips for spades, parts for axles, the multifunctional cauldron, as well as blades for sickles, scythes, axes, adzes and mattocks. Repairs of every nature and sharpening of tools also made up a huge portion of the blacksmith's business.

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[4] Forbes, *Man the Maker* 117
[5] Gies 200-202
[6] Reynolds 64
[7] Gies 268

Our knowledge of medieval blacksmithing techniques is largely derived from the work of the Benedictine monk, Theophilus Presbyter, believed to be Roger of Helmarshausen. His three-part text, *De diversis artibus* (*On diverse arts*), written around 1122, gives a detailed description of "The Art of the Painter," "The Art of the Worker in Glass," and, obviously his personal favorite, claiming two-thirds of the entire book, "The Art of the Metalworker." He describes the appearance of the workshop, how to work at the forge, and how to make an array of metalworking tools, including bellows, anvil, hammer, tongs, wire drawplate, punch, chisel and pliers. An excerpt from his text describes the use of iron:

> Iron is engendered in the earth in the form of stones. When it has been dug out, it is broken up in the same way as copper above and smelted down into lumps. Then it is melted on an iron-worker's forge and hammered, so that it becomes suitable for any kind of work.[8]

The smithing process generally followed the same pattern as laid out by Presbyter, with a few variations, depending on the desired product. The piece was first heated in the charcoal-fueled forge, made hotter by the draft from a bellows, then hammered out on an iron anvil usually mounted on a short tree stump. An assistant, often an apprentice, regularly helped with the first stages of hammering by wielding the sledgehammer while the smith positioned the hot iron piece. Later, it was refined with smaller hammers, punch, lathe, grindstone, files and chisels. Chisels varied, depending on whether they would be used on hot or cold metal; the "cold" chisels needed to have a much harder edge. Fabricating tools that would later be used to cut hard materials, like stone or metal, also required tempering, a process of repeated heating and quenching, to provide hardness and ductility. Because of its time-consumption, tempering was reserved for only the tools that absolutely required it, like those mentioned or for weaponry. In addition to the work done on cast iron, the pig iron supplied by the new blast furnaces could also be converted into wrought iron through the practice of reheating and hammering at the forge. This practice gained popularity throughout the fifteenth and sixteenth centuries.

The most significant technological innovations in blacksmithing during the Middle Ages, however, came from the application of natural forces to metalworking machines. The waterwheel supplied the power for numerous new devices, including the tilt- or trip-hammer, which hammered an iron head attached to a wooden shaft onto a sprung beam, whose recoil added to the power of the stroke. Water also supplied a solution to the increasing demand for nails: the slitting mill. An ancestor of the rolling mill, its two rotary disks cut iron into slender rods that could quickly be transformed into nails by the smith. Wire-drawing also became significantly easier with a series of inventions surrounding the drawplate and culminating in the addition of waterpower. In the early Middle Ages, wire for chain mail and other applications had been painstakingly hammered out by hand. Beginning in the tenth century, smiths started using a drawplate, through which a series of gradated conical holes were cut, allowing the wire

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[8] Hawthorne & Smith 183

to be easily pulled into shape. The addition of waterpower in the fourteenth century brought about the full implementation and efficiency of this technology.

The Blacksmith in Medieval Europe

The importance of the blacksmith in the Middle Ages cannot be overstated. Not only were his individual products invaluable, but also those commodities that complemented the work of other craftsmen. Countless other craftsmen depended upon the blacksmith for the construction of their goods or performance of their craft, however, the blacksmith depended on no other to maintain his business. Carpenters required nails, saws and hammers; masons, mallets, picks, wedges and chisels; carters and wagoners, iron axles and parts; millers, iron components of mill machinery; shipbuilders, nails and fittings. The eleventh-century writer AElfric illustrated this dependence with a debate among teacher, student and workers:

TEACHER:	Ah, monk, you who first addressed me: I've found out that you do indeed have good friends, and very necessary ones. But let me ask you, what are all the rest of them?
STUDENT:	My fellow monks include all sorts of artisans—blacksmiths, goldsmiths, silversmiths, carpenters, and those who work in many other kinds of crafts.
TEACHER:	But do you have any wise and learned counselors?
STUDENT:	I certainly do. How else could our fellowship be guided and instructed?
TEACHER:	And what do you have to say, oh wise one? Which of all these crafts do you think is the best?
COUNSELOR:	What I say is that God's service is the highest of all these crafts, for as we can read in the Gospel: "First of all, seek out God's kingdom, and His righteousness, and then all other things shall be given to you."[9]
TEACHER:	But among all the wordly crafts, which is the best?
COUNSELOR:	Tilling the earth, because the farmer feeds us all.
THE SMITH SAYS:	But where then does the farmer get his plowshare, or his colter-knife, if not from my craft? Where does the fisherman get his fishhooks, or the shoemaker his awl,

[9] Matthew 6:33

	or the tailor his needle? Doesn't all of it come from my work?
THE COUNSELOR ANSWERS:	Indeed, what you say is true. But we'd all prefer to live with the farmer, smith, than with you. Because he provides us with food and drink. What comes to us from your smithy, except sparks of iron and the noise of beating hammers and puffing bellows?
THE CARPENTER SAYS:	And which of you doesn't make use of my craft—the houses and barrels and boats that I make for all of you?
THE SMITH ANSWERS:	Oh, carpenter, why do you say these things, when you know you couldn't make so much as a single hold without my craft?
THE COUNSELOR SAYS:	Ah, my friends, good workmen all! Let us quickly turn away from these arguments, and have peace and harmony among us, and each of us make use of the other's skills—and make sure we are all at peace with the farmer. And let me give this advice to every workman: let each be diligent in the practice of his own craft, because he who abandons his craft will be abandoned by that craft. No matter who or what you are, whether a priest, or a monk, or a peasant, or a soldier, concern yourself with the task before you and perform it, and be what you are, for it is infinitely harmful, and disgraceful, for a man not to know who and what he is and what he needs to be.[10]

The feelings of superiority displayed by the smith in the above dialogue were well-founded: the importance and the ubiquity of blacksmithing, as well as the related occupations of mining and smelting, warranted its control by the guild system. Around the twelfth century, guilds began to incorporate not only merchants, but also significant craftsmen as well. Its primary concerns were to aid fellow members of the guild and their families, and to control production, including quality, working hours, prices, and wages. The guild also set up a hierarchy of apprentices, journeymen and masters, and an educational system to teach the craft. Two period texts illustrate this practice. The first is the record of a standard indenture between apprentice and here, a master fisherman, from which we glean an understanding of the general expectations outlined in a apprenticeship contract:

[10] Olsen & Raffel 210-212

> This indenture made by John Pentreath of Penzance in the country of Cornwall witnesses that John Goffe has put himself to John Pentreath to learn the craft of fishing, and to stay with him as his apprentice until the end of eight years fully complete. Throughout this time, John Goffe shall well and truly serve John Pentreath and Agnes his wife, shall keep their secrets, shall willingly do their lawful and honorable commands, shall do his masters no injury, nor see injury done to them by others, but prevent the same as far as he can, shall not waste his master's goods, nor lend them to any man without his special command.
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> And John Pentreath and Agnes his wife shall teach John Goffe the craft of fishing in the best way they know, chastising him duly, and finding him food, clothing and shoes as befits an apprentice. And at the end of the term aforesaid, John Goffe shall have of John Pentreath twenty shillings.[11]

The second is the report of an Italian who visited England around 1500:

> The want of affection in the English is strongly manifested towards their children; for after having kept them at home till they arrive at the age of seven or nine years at the most, they put them out, both males and females, to hard service in the houses of other people, binding them generally for another seven or nine years. And these are called apprentices, and during that time they perform all the most menial offices; and few are born who are exempted from this fate, for every one, however rich he may be, sends away his children into the houses of others, whilst he, in return, receives those of strangers into his own.[12]

Although recognized by both the guild and the community for the necessity of his craft, the medieval smith was rarely welcome as a neighbor. We find a considerable number of period texts complaining about the blacksmith. In London in 1397, smiths were asked by city officials to relocate because of "the great nuisance, noise, and alarm experienced in divers ways by neighbors around their dwellings."[13] Spurriers, blacksmiths specializing in spur-making, were apparently even less desirable neighbors, reputed to "wander about all day without working," get drunk, and be apt to "blowing up their fires so vigorously" that they blazed "to the great peril of themselves and the whole neighborhood."[14] The neighbors of a London armorer named Stephen atte Fryth even submitted a formal complaint against him in 1377, stating that "the blows of the sledge-hammer when the great pieces of iron…are being wrought into…armor, shake the stone and earthen party walls of the plaintiffs' house so that they are in danger of collapsing, and disturb the rest of the plaintiffs and their servants, day and night, and spoil the wine and ale in their cellar, and the stench of the smoke from the sea-coal used in the forge

[11] Speed 83: An indenture made in 1459 from the Records of the County of Cornwall.
[12] Speed 169: From Camden Society, *Italian Relation of England*
[13] Geddes 174-175
[14] Ibid 174-175

penetrates their hall and chambers".[15] Another period text in the alliterative style of *Piers Plowman* colorfully illustrates the great racket that so irritated the smith's neighbors:

> "A Complaint Against the Blacksmith"
> Swart smutted smiths, smattered with smoke,
> Drive me to death with din of their dints;
> Such noise on nights ne heard men never.
> What with knaven cry and clattering of knocks!
> The crooked caitiffs cryen after coal! coal!
> And bloweth their bellows till their brain bursteth.
> Huf! puf! says the one; haf! paf! says the other;
> They spitten and they sprawlen and they spellen many spells.
> They gnawen and gnashen and they groan all together,
> And holden them hot with their hard hammers.
> Of a bull-hide be their barm-fells;
> Their shanks be shackled for the fiery flinders;
> Heavy hammers they have that are hard to be handled,
> Stark strokes they striken on a steely stock,
> Lus! bus! las! das! snore they by the row,
> Such doleful a dream that the devil it to-drive!
> The master loungeth a little and catcheth a less,
> Twineth them twain and toucheth a treble,
> Tik! tak! hic! hac!, tiket! taket! tyk! tyk!
> Lus! bus! las! das!... Christ give them sorrow!
> May no man for brenn waters on night have his rest?[16]

In his *Sermons*, Berthold von Regensburg, a German friar of the mid-thirteenth century, also chastises the smith, among others, and clarifies for us the kind of indiscretion that was common during the period:

> The second folk are all such as work with iron tools, goldsmiths, penny-smiths, and other smiths, and carpenters or blacksmiths,… and stonemasons and turners, and all who work with iron…. When they work by the day, they should not stand idle so that they multiply the days at their work. If you labor by the piece, then you should not hurry so that you may be rid of the work as quickly as possible…. You should work it truly, as if it were your own. You, smith, you will shoe a steed with a shoe that is worthless; and the beast may perhaps go scarce a mile before it is broken, and the horse may go lame, or the rider may be taken prisoner or lose his life. You are a devil and an apostate….[17]

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[15] Ibid 174-175.
[16] Speed 80-81. From *British Museum*, *Arundel MS* 292.

[17] Speed 98. From *Sermons*.

Although he was somewhat disliked by the community, no criticism could diminish the value of the blacksmith's trade, necessary to almost all other trades and ubiquitous in the daily life of all classes.

Iron Manufacture in Colonial America

The technology of colonial iron manufacture differed very little from that of medieval Europe. Mining, smelting and smithing techniques remained virtually unchanged, due to the strikingly similar conditions that existed in our two paralleled times and locations. As an example, one period text describes the appearance of a colonial furnace, in particular Colebrook Furnace, located in Lebanon County, Pennsylvania. This poem by George H. Boker reminds us of the sow and pigs of the furnace of medieval Europe, illustrating the appearance of the molten iron on the casting floor:

> "The Legend of the Hounds"
> Colebrook Furnace in Cornwall stands,
> Crouched at the foot of the iron lands,
> The wondrous hill of iron ore
> That pours its wealth through the furnace door,
> Tortured with fire till a molten flood,
> Leaps from the taps to the sow below
> And her littered pigs that round her glow;
> So that the gazer, looking down
> The moulding floor from the platform's crown,
> Might think, if fancy helped the spell,
> He saw a grate in the roof of Hell.[18]

Although techniques differed very little, laws surrounding iron manufactiure in the colonies differed sharply from their late medieval counterparts. The predominant theory in England at the time was mercantilism; one manifestation of the policies arising from mercantilism was the belief that the mother country was more important than its colonies. The mother country strove to sell abroad, but not buy there. In this way, they could accumulate capital [i.e. gold] through more exports than imports. The colonies were expected to supply their mother country with raw materials, particularly timber and pig iron. In 1737, the *London Daily Post*, distressed over the fact that England was annually consuming more bar iron than the 18,000 tons she produced, predicted that the future lay in production in the colonies: "In our American colonies are now erected several Forges and Bloomeries for making Bar-Iron."[19] By 1751, Maryland and Virginia alone furnished England with 2,950 tons of iron, one-sixth of the mother country's own production.[20] [21] Finished goods such as pots, pans, hinges and tools were not to be made in the colonies, however, but bought and shipped from England. Beginning in 1660 and lasting until the Revolutionary War, a list of "enumerated articles" was published by the British government under the

[18] Kauffman 24-25
[19] Bridenbaugh 16
[20] Ibid 16
[21] Eggert, *Iron Industry in Pennsylvania* 23

heading of the Navigation Acts. These articles, including cast pig iron, wrought bar iron, among others, were to be produced in the colonies, but shipped only to British ports.[22] Later, the Iron Act of 1750 reiterated those sentiments and prohibited all export of iron from the colonies to other countries. It did, however, remit all duties on exports to England, increasing the tonnage of iron exported from 3,000 in 1750 to 8,000 in 1770.[23] Understandably, complying with these laws would have eventually led to the undermining of all colonial iron manufacture efforts, which became a contributing factor to the ensuing revolution. Harold Livesay, summed it up in his statement, “The English passed laws to protect their market; the colonists developed iron works to ensure their iron supply.”[24]

As similar as colonial iron manufacture was to that of medieval Europe, yet it differed greatly from the type of iron manufacture in eighteenth century early modern Europe. Existing conditions of natural resources greatly affected the development of technical innovation in the field of iron manufacture. Differences between these conditions in the colonies and Europe was the primary cause of their striking dissimilarity.

As has been stated, the colonies utilized the iron manufacture technology of the Middle Ages. One reason for this, obviously, is that the Middle Ages directly preceded the Early Modern period, in which the New World was colonized. But, in addition to this, the Middle Ages were also a period of particularly intense technological advancement. The centuries up until the age of Leonardo da Vinci witnessed a continuously rising level of technological improvement, but afterward, according to Frances and Joseph Gies, the succeeding age experienced a “relaxation of the pace of technical change.”[25] These groundbreaking medieval innovations included a switch from slave labor to free labor, from human power to animal, water and wind power, from a few handwritten manuscripts to widely-distributed printed material, as well as a surge of metal tools, and the invention of canal locks, gunpowder weapons and clocks.[26]

The Middle Ages also possessed a previously unheard-of spirit of progress, allowing innovators to make use of their “God-given” right to succeed financially, their intellectual curiosity to tinker and finally their technical ability to create. A sense of progress was impossible, however, without a concept of history and improvement throughout the ages. Unlike the societies of classical antiquity, the Egyptians, Greeks and Romans, medieval man no longer looked back to a “golden age,” but employed a noncyclical view of history, enabling them to conceptualize technology in a broader scope. Christianity also brought about the disappearance of animism and the advent of the use of natural resources. Animism was a belief that had long hindered the Romans from developing technology that utilized nature to the benefit of man.[27]

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[22] Tunis 12
[23] Eggert, *Iron Industry in Pennsylvania* 24
[24] Ibid 24
[25] Gies 290
[26] Gies 286-287
[27] Forbes, “Power” 606

The continual search for a superior way of doing things also led to the recognition of the usefulness of machines. Francesco di Girgio Martini of the fifteenth century explained: "Without mechanical ingenuity the strength of man is of small avail."[28] This realization led to a number of inventions, most importantly the waterwheel, which affected almost all handcrafts in some form, from the production of lumber to leather, flour to textiles, paper to iron. In particular, the manufacture of iron by waterpower led to the invention of the hugely significant blast furnace.

The combined result of this incredibly successful series of centuries obviously had its appeal for the colonists attempting to settle the wild territory of the New World; where they found natural resources similar to those of medieval Europe and therefore compatible with the technological advances made in the Middle Ages. This was almost entirely due to the fact that conditions in the colonies were naturally identical. Need begets change, and where there is no necessity for change, new technology is rarely invented. The peasants and craftsmen who colonized the New World brought with them the only heritage of technological innovation they had, a heritage of medieval innovation.[29]

The primary reason for the differences between early modern European and colonial iron manufacture technology was the variation in natural resource availability. Medieval Europe utilized timber, particularly for the production of charcoal, to a dizzying extent. By the High Middle Ages, forest resources had all but disappeared. In the winter of 1623-1624, before embarking for the colonies, John Winthrop noted "the Common scarcitie of woods and Tymber in most places of this Realme."[30] In order to heat their homes in a predominantly wood-fueled, but increasingly expensive, society, the poor were chopping down young trees, hedges, gates and bridges.[31] Although there were early attempts at conservation, they became virtually ineffective, due to the intense need for fuel. Additionally, as a nation's power at sea was increasingly necessary, the desire for ships made the demand for wood reach its peak. The reign of Charles I saw only a few tracts of woodland in England that still covered more than twenty square miles. All others had been completely chopped down, save for some hedgerows necessary to break wind gusts.[32] Carlo Cipolla has stated that "throughout the Middle Ages and Renaissance, the Europeans behaved toward the trees in an eminently parasitic and extremely wasteful way."[33] However, one must also keep in mind their dependence on wood for the forge, blast furnace, cooking, baking and heating, in addition to other crafts, including pottery, tile and brick making, glassmaking and distilling, a dependence whose scope can be equated to ours today on petroleum products. Additional pressure on woodlands came from the growing population, which necessitated deforestation to clear land for crop production.[34]

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[28] Cipolla, *European Culture and Overseas Expansion* 16
[29] White 108-109
[30] Carroll 14-15
[31] Ibid 15
[32] Ibid 14
[33] Cipolla, *Before the Industrial Revolution* 112
[34] Gies 290-291

This image of medieval dependence on wood was mirrored in that of the colonists.[35] Here the colonists diverged sharply from their European contemporaries. They were using the seemingly endless supply of wood for every purpose to which they could apply it, including houses, canals, road surfaces (the plank roads), railroad ties, bridges, compasses and even mathematical instruments.[36] On a positive note, this excessive use also led to American leadership in wood-working tools, such as the muley saw and the American axe. While their European counterparts were struggling with iron production due to deforestation issues, the colonists were using their abundance of forest to produce more, and superior, iron than their mother countries. Until Europe eventually developed the puddling technique, a method of purifying pig iron in an oxidizing atmosphere, charcoal-produced iron was significantly superior to that produced using coal. In the great tradition of American entrepreneurship, the availability of natural resources, namely water privileges for power, limestone for flux and several square miles of timber for charcoal, allowed practically any man with merely modest means to start his own industrial enterprise.[37] Like their medieval forebears, the colonists' reliance on wood would eventually lead to the same outcome as that in Europe: vast deforestation. The destruction of virgin forests was by far the work of charcoal colliers over any other industry, including lumbermen and farmers.[38] Although at the time of the colonists' arrival, hundreds of millions of acres of virgin forests sprawled across the United States, today only five percent of those remain, much of the deforestation of the east coast done during the first two centuries after colonization.[39]

Despite the fact that charcoal-produced iron was for a time superior to that produced by coal, there were also numerous other reasons for the colonists' decision to continue using it. These revolve around the difficulty surrounding the utilization of coal in almost every aspect of iron production, a problem solved by the Europeans. For the colonists, these difficulties in the use of coal were evident in mining, transportation and use, impediments that also led to a greater expense, even though the sale of coal fetched only a small price. Only after a lengthy series of innovations and adaptations did the use of coal become financially rewarding. After the initial exhaustion of surface seams of coal in Europe, miners were forced to delve to considerable depths. Flooded coal-pits were a constant problem and a costly one. Early sources of draining power, wind, water and animals, proved to be inadequate, and the costs to maintain the numerous teams of horses needed to drive the drainage machines were high. Diverting streams and rivers from their courses or damming up water so that it could drive the engines was also expensive.[40] This difficulty would eventually be solved by the advent of technology to generate power by a jet of steam.

Once the hard-earned coal was finally ready to transport, even more difficulties arose. Coal needed to be increasingly mined at further distances from harbors and navigable

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[35] For an excellent description of the extent of the colonists' and later Americans' dependence on wood, see the singular text, *America's Wooden Age*, edited by Brooke Hindle.
[36] Hindle, "The Exhilaration of Early American Technology" 64-65
[37] Gordon 242-243
[38] Tunis 148
[39] Ross, quote from Senator Torricelli
[40] Nef 83

rivers.[41] Unlike charcoal, it was extremely bulky and an unpleasant material to handle. The construction of vast systems of canals in the eighteenth century solved this problem.[42]

By far the greatest technological problems posed by the substitution of coal for charcoal stemmed from its use at the furnace. During the period of the colonization of the New World, production of wrought iron by the indirect process, pig-iron that would be hammered out into wrought iron at the forge, was coming into increasing popularity, particularly in northern Europe, the Low Countries, Sweden and Britain.[43] Substitution of coal for charcoal in this process required many stages where the ore and iron came into contact, and each of those presented its own particular challenges. Simply replacing charcoal with raw coal damaged the iron, making it brittle and useless. The earliest stages of a solution to this dilemma actually came about in 1603 through the beer industry, by an innovative promoter, Sir Hugh Platt. The same properties of raw coal that damaged the iron also transmitted a foul taste to beer when it was used to dry malt. The idea to coke the coal, similar to charring wood for charcoal, in order to remove some of its impurities, ultimately solved the problem. The first efforts to coke coal, however, were unsuccessful and the first successful coking did not occur until the middle of the seventeenth century. For some unknown reason, this technology lagged in the iron industry for an additional fifty years.[44] From the time in which the first serious demands for the substitution of coal for charcoal came about, almost 200 years elapsed before coal could be used effectively in the iron production process. The combination of the difficulty of using coal plus the obvious ease of access to the virgin timber caused the colonists to fall back on the example of the medieval predecessors, not only in regard to the use of resources, but also in regard to technique and instruction.

The Blacksmith in Colonial America

In contrast to the Middle Ages, the smith of colonial America was greatly revered as a model of honesty and uprightness. Although the colonial blacksmith performed the same duties as the medieval one, perhaps this altered opinion was due to the geographical location of the smith's workshop. In medieval Europe, the smith was in extremely close proximity to other buildings and homes. Space was a limited commodity, making for the tensions between neighbors discussed previously. In contrast, the availability of land in the colonies was limited only by the ability to clear it, which allowed farms and workshops to spread out in all directions as needed.

Another influence adding to the blacksmith's improved popular opinion stems from American society's changing view of the laborer. The fledgling nation was founded on a strict, particularly Protestant, work ethic. Under this ethic, a laborer could not only establish his wealth, but also his social status and respectability through hard work and frugality. Benjamin Franklin was one avid supporter of this rags-to-riches ideal, and advertised in Europe for artisans to emigrate to America to "practice profitable mechanic

[41] Ibid 84
[42] Ibid 85
[43] Ibid 79
[44] Ibid 80

Arts, without incurring Disgrace on that Account, but on the contrary, acquiring Respect by such Abilities."[45] Blacksmiths were just some of these artisans, whose lifestyle was glorified by the new American standard.

Among other valued traits, the honesty associated with the blacksmith is illustrated quite clearly by the story of Patrick Lyon, colonial blacksmith, lockmaker and builder of fire engines. Lyon was commissioned to build locks for the safe at the bank of Pennsylvania. One Sunday in 1798, the safe was robbed by means of duplicate keys, actually the colonies' very first bank robbery, and Lyon was accused. Even though he was undeniably in Delaware at the time of the robbery, he was placed in the Walnut Street Prison for the crime. Later, the real thief was caught with most of the money, but Lyon was still suspected as an accomplice. This suspicion ruined his smithing business until he was eventually cleared, making him a hero in the public's eye. Nine years later, the bank paid him nine thousand dollars in damages. As a testament to the pride he had in his craft and its symbol of uprightness, in 1829, Lyon commissioned artist, John Neagle, to paint him, not in his best Sunday attire, as was customary for portraits, but rather in his leather apron at the forge.[46]

Period texts vividly illustrate for us today the popular opinion held of the blacksmith in the colonies. As one example of other craftsmen's dependence on the smith, and one strikingly similar to those previously mentioned in regard to the Middle Ages, James Moxon, in 1683, began his treatise on various handcrafts, *Mechanick Exercises or the Doctrine of Handy Works*, with this sentence on smithing:

> Some perhaps would have thought it more proper, to have introduced these Exercises with a more Curious, and less Vulgar Art, than that of Smithing; but I am not of their Opinion; for Smithing is in all parts, as curious a Handy-Craft, as any is: Besides it is a great Introduction to most other Handy-Works, as Joynery, Turning, etc. they (with the smith) working upon the Straight, Square or Circle, though with different Tools, upon different Matter; and they all having dependence upon the Smith's Trade, and not the Smith upon them.[47]

The community's high regard for the blacksmith can obviously be seen in this excerpt, just as its demand can be seen in sheer numbers. The necessity of the smith's product made him one of the first and foremost craftsmen in the colonies. In May 1607, James Read, a blacksmith, arrived in Virginia with the Jamestown colonists. One year later, Richard Cole, another blacksmith, was sent to aid in abetting the increasing demand for ironware. In 1611, a shipload of mechanics from the Virginia Company of London also included four blacksmiths, making the total six in only four years. Throughout the eighteenth and nineteenth centuries, the blacksmith far outnumbered any other craftsmen in metals. A business directory of Boston in 1789 listed the types of existing

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45 Craven, Colonial American Portraiture, 334-35.

[46] For more details on Pat Lyon and John Neagle, please see my article entitled "*Pat Lyon at the Forge*: America's Glorified Laborer," included in this web site.

[47] Lasansky 5

metal trades and the number of men employed in each: coppersmiths 2, silversmiths 2, braziers (workers in brass) 3, pewterers 4, founders 5, farriers (shoers of horses) 7, tinsmiths (workers in tinplate) 7; blacksmiths totaled no less than 25. By 1800, the *New Trade Directory of Philadelphia* reported approximately the same ratio, but with an additional 22 whitesmiths (workers who filed, polished and assembled a blacksmith's products[48]).[49] In addition to these numbers, the town records of Derby, Connecticut detail the attempts to persuade a blacksmith to settle there, indicating the dire need for this craft around 1711.

> Voted that the town grant John Smith of Milford, blacksmith, four acres of land for a home lot, to build upon. Anywhere within one mile of the meeting house where he shall choose, in land not laid out, upon condition that he build a mansion house and smith's shop, and set up the trade of a blacksmith, and follow it for the benefit of the inhabitants for the space of seven years.[50]

The great demand for blacksmiths was not, however, without discretion as to the quality of the smith's work and his expertise in the craft. As occurred in medieval Europe, the colonies also employed an apprentice system for the training of young blacksmiths, although only this particular portion of the European guild system would survive in the New World. Shortage of labor quickly destroyed any attempt at establishing an entire comprehensive guild system, outside of a few rare cases in religious communities, such as the Moravian Brethren at Bethlehem, Pennsylvania, and at Wachovia, North Carolina.[51] The colonial apprentice system essentially remained very similar to that of medieval Europe, although it was much easier to be apprenticed in the colonies, due to shortage of labor; in Europe, the labor market was saturated.[52] Joseph Moxon illustrates the importance of apprenticing, stating that "HandCraft signifies Cunning, or Sleight, or Craft of Hand, which cannot be taught by words, but is only gained by Practice and Words and Exercise."[53] There were two types of apprenticeship, one compulsory, for orphans and bastard children, and the other voluntary, with parental consent.[54] Boys were also often apprenticed to their fathers, keeping the trade and the business in the family. In addition to being taught the smith's craft, they were also taught basic reading, writing and arithmetic. This advertisement in the *Pennsylvania Packet and Daily Advertiser*, August 1, 1789, depicts the expectations of apprenticeship outside the home:

> DELAWARE WORKS
> Wanted at said works: Apprentices from ten to fourteen years of age, to learn the Nailing and Smith's business. The boys will be placed under the direction of sober, industrious workmen, and will be suitably cloathed and

[48] For a discussion on the vagueness surrounding the duties of the whitesmith, see Kauffman 81.
[49] Kauffman 51
[50] Ibid 51
[51] Tunis 16
[52] Tunis 14-16
[53] Lasansky 8
[54] Lasansky 10

> fed during their apprenticeship; and instructed in reading, writing, and arithmetic; and when of age will each receive one new suit of cloaths, and fifteen dollars in money, for the purpose of furnishing themselves with a set of tools.[55]

The similarities between this advertisement and the corresponding medieval one, discussed in The Blacksmith in the Middle Ages section, are obvious.

Without the guilds, quality control and prices needed to be assessed by the individual community. The colonists found the method of printing the names and facts of faulty craftsmanship in the newspaper eliminated some of their lesser competition, but simply the number of control ordinances existing at the time provides evidence of the frequency of defective products.[56] Generally speaking, however, quality control seems to have been maintained by the customer's purchasing power. Addtionally, prices were for the most part determined by the seller and customer at the time of purchase. Although attempts were made by the Quakers to disseminate their concept of pricing merchandise at only its cost plus an honest profit, this initiative unfortunately never seems to have caught on.[57]

We find then both similarities and differences in medieval and colonial blacksmithing, the differences lying not in the craft itself, which was actually quite similar, but in its interaction with society on the whole. Popular opinion of the smith had improved and control of the trade had moved from the guild to the relationship with the customer. The importance and nature of the smith's trade, however, remained remarkably consistent.

Conclusion

The story of the transfer of iron manufacture technology from medieval Europe to the American colonies is a prime example of the fact that, without an outside factor necessitating technological change, none will be initiated. The ingenuity of medieval man had perfected an iron manufacture system that translated aptly to colonial resources and skill. This wealth of technological knowledge was not without its negative repercussions, however, namely its effects on the environment and its lack of long-term sustainability. Medieval man had scarcely begun to counter the environmental problems of deforestation and air and water pollution and, as is the way with history, these faults were also passed on to the heirs, a problem still needed to be dealt with today. Their lack of foresight in the use of natural resources would eventually lead the colonists' descendants to fall into the same dilemma as the early modern Europeans, thereby forcing them into the inevitable race to catch up technologically.

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[55] Kauffman 54
[56] Tunis 16-17
[57] Tunis 17

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