

A Companion to Marx's *Capital*

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What Technology Reveals

CHAPTER 15: MACHINERY AND LARGE-SCALE INDUSTRY

In the introduction, I noted that Marx rarely comments on his methodology. It has therefore to be reconstructed by way of careful perusal of occasional side comments, supplemented by a study of his practices. Chapter 15, “Machinery and Large-Scale Industry,” provides an opportunity to grapple with this question at the same time as it advances the general arguments as to the character of a capitalist mode of production. The chapter is long, but the sections are logically ordered. It repays to go over this logical ordering both before and after studying this chapter.

An Important Footnote

I begin, however, with the chapter’s fourth footnote, where Marx, in the cryptic fashion he often deploys in describing methodological considerations, links together a slew of concepts in a configuration that actually provides a general framework for dialectical and historical materialism. The footnote unfolds in three phases. The first focuses on Marx’s relation with Darwin. Marx had read *On the Origin of Species* and was impressed with the historical method of evolutionary reconstruction that Darwin had outlined. Marx clearly envisaged his work as some sort of continuation of Darwin’s, with the emphasis on human as well as (rather than opposed to) natural history. His aim, he stated in the preface to the first edition, is to view “the development of the economic formation of society” from “the standpoint” of “natural history.” From this standpoint, the individual cannot be held “responsible for relations whose creature he remains, socially speaking, however much he may subjectively raise himself above them” (92).

In the footnote, Marx first focuses on “a critical history of technology.” This

would show how little any of the inventions of the eighteenth century are the work of a single individual. As yet such a book does not exist.

Darwin has directed attention to the history of natural technology, i.e. the formation of the organs of plants and animals, which serve as the instruments of production for sustaining their life. Does not the history of the productive organs of man in society, of organs that are the material basis of every particular organization of society, deserve equal attention? And would not such a history be easier to compile, since, as Vico says, human history differs from natural history in that we have made the former, but not the latter? (493)

Vico's argument was that natural history was God's domain and that since God moved in mysterious ways, it was beyond human understanding, but we could certainly understand our own history since we had made it. Marx earlier broached the historical approach to technological change and noted some vital transitions associated with transformations in the mode of production. Having followed Benjamin Franklin in defining man "as a tool-making animal" in chapter 7, he went on to observe that the

relics of bygone instruments of labour possess the same importance for the investigation of extinct economic formations as do fossil bones for the determination of extinct species of animals. It is not what is made but how, and by what instruments of labour, that distinguishes different economic epochs. Instruments of labour not only supply a standard of the degree of development which human labour has attained, but they also indicate the social relations within which men work.

Then, in a footnote: "the writers of history have so far paid very little attention to the development of material production, which is the basis of all social life, and therefore of all real history" (286). In chapter 14 he argued that

the Roman Empire handed down the elementary form of all machinery in the shape of the water wheel. The handicraft period bequeathed to us the great inventions of the compass, gunpowder, type-printing and the automatic clock. But on the whole, machinery played that subordinate part which Adam Smith assigns to it in comparison with division of labour. (468)

This idea that there has been a human evolutionary process in which we can discern radical shifts not only in technologies but in whole modes of social life is clearly very important to Marx.

Marx did not read Darwin uncritically. "It is remarkable," he wrote to Engels, "how Darwin recognizes among beasts and plants his English society with its division of labour, competition, opening up of new markets, 'inventions' and the Malthusian struggle for existence."¹ The problem, as Marx sees it, is Darwin's ahistorical approach to a purely natural evolution without reference to the role of human action in changing the face of the earth. The reference to Malthus is also telling because in his introduction to *On the Origin of Species*, Darwin attributed some of his key ideas to Malthus. And since Marx couldn't abide Malthus, it must have been hard for Marx to swallow the thought that Malthus had so inspired Darwin. Interestingly, the Russian evolutionists who were not exposed to ruthless British industrialism (Darwin was married to a daughter of Josiah Wedgwood, the famous pottery industrialist, and so was familiar at first hand with competition and the division of labor and of function) put much greater emphasis on cooperation and mutual aid, ideas which were translated by the Russian geographer Kropotkin into the fundamentals of social anarchism.

But what Marx appreciated was Darwin's approach to evolution as a process open to historical reconstruction and theoretical investigation. Marx is committed to understanding the human evolutionary process in like fashion. This is where Marx's emphasis on processes rather than things comes in. The chapter on machinery and large-scale industry should be read as an essay on the history of technology in this spirit. It is about how the industrial form of capitalism emerged out of the world of handicraft and manufacturing. Up until this point, nobody had really thought of writing such a history, so this chapter constitutes a pioneering effort that later spawned a whole field of academic study called the history of science and technology. Read in this way, the chapter's argument makes a lot more sense. But like Darwin's theory, there is far more here than just history. There is a theoretical engagement with processes of social transformation, and as such, there is a good deal to debate and discuss.

The second part of the footnote proffers a short, but in my view extremely important, statement that requires elaboration:

Technology reveals the active relation of man to nature, the direct process of the production of his life, and thereby it also lays bare the process of the

1. Marx to Engels, June 18, 1862, in *Selected Correspondence*, ed. S. W. Ryazanskaya, trans. I. Lasker (Moscow: Progress, 1965), 128.

production of the social relations of his life, and of the mental conceptions that flow from those relations. (493)

Marx here links in one sentence six identifiable conceptual elements. There is, first of all, technology. There is the relation to nature. There is the actual process of production and then, in rather shadowy form, the production and reproduction of daily life. There are social relations and mental conceptions. These elements are plainly not static but in motion, linked through "processes of production" that guide human evolution. The only element he doesn't explicitly describe in production terms is the relation to nature. Obviously, the relation to nature has been evolving over time. The idea that nature is also something continuously in the course of being produced in part through human action has also been long-standing; in its Marxist version (outlined in chapter 7), it is best represented in my colleague Neil Smith's book *Uneven Development*,² where capitalist processes of production of nature and of space are explicitly theorized.

How, then, are we to construe the relationships between these six conceptual elements? Though his language is suggestive, Marx leaves the question open, which is unfortunate since it leaves lots of space for all manner of interpretations. Marx is often depicted, by both friends and foes alike, as a technological determinist, who thinks changes in the productive forces dictate the course of human history, including the evolution of social relations, mental conceptions, the relation to nature and the like. The neoliberal journalist Thomas Friedman, for example, in his book *The World Is Flat*,³ happily admits to the charge of being a technological determinist; when someone pointed out to him (erroneously) that this was Marx's position, he expressed his admiration for Marx and approvingly cited a lengthy passage from the *Communist Manifesto* to prove his point. In a review of Friedman's book, the conservative political philosopher John Gray confirmed Marx's technological determinism and argued that Friedman was indeed merely following in Marx's footsteps.⁴ These observations by those generally unsympathetic to Marx

2. Neil Smith, *Uneven Development: Nature, Capital, and the Production of Space*, 3rd edn. (Athens, GA: University of Georgia Press, 2008 [1984]).

3. Thomas Friedman, *The World Is Flat: A Brief History of the Twenty-first Century* (New York: Farrar, Straus and Giroux, 2005), 201-4.

4. John Gray, "The World Is Round," *The New York Review of Books* 52, No. 13 (August 11, 2005).

are paralleled within the Marxist tradition. The strongest version of the thesis that the productive forces are the leading agent in history comes from G. A. Cohen in his book *Karl Marx's Theory of History: A Defence*.⁵ Cohen, having inspected all Marx's texts from the standpoint of analytic philosophy, defends this interpretation of Marx's theory.

I do not share this interpretation. I find it inconsistent with Marx's dialectical method (dismissed by analytic philosophers such as Cohen as rubbish). Marx generally eschews causal language (I defy you to find much of it in *Capital*). In this footnote, he does not say technology "causes" or "determines," but that technology "reveals" or, in another translation, "discloses" the relation to nature. To be sure, Marx pays a lot of attention to the study of technologies (including organizational forms), but this does not warrant treating them as leading agents in human evolution. What Marx is saying (and plenty of people will disagree with me on this) is that technologies and organizational forms *internalize* a certain relation to nature as well as to mental conceptions and social relations, daily life and labor processes. By virtue of this internalization, the study of technologies and organizational forms is bound to "reveal" or "disclose" a great deal about all the other elements. Conversely, all these other elements internalize something of what technology is about. A detailed study of daily life under capitalism will, for example, "reveal" a great deal about our relation to nature, technologies, social relations, mental conceptions and the labor processes of production. Similarly, the study of our contemporary relation to nature cannot go very far without examining the nature of our social relations, our production systems, our mental conceptions of the world, the technologies deployed and how daily life is conducted. All these elements constitute a totality, and we have to understand how the mutual interactions between them work.

I find this a helpful way to think about the world. For instance, I was on a jury to select ideas for the design of a new city in South Korea. We, the members of the jury, had all the designs in front of us. The jury was made up mainly of engineers and planners, with a few distinguished architects and landscape designers. The latter dominated the initial discussion on the criteria we should deploy in reaching our decisions, and it mainly

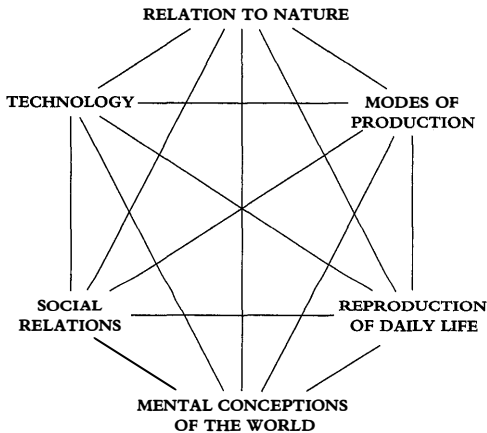
5. G. A. Cohen, *Karl Marx's Theory of History: A Defence*, expanded edn. (Princeton, NJ: Princeton University Press, 2000 [1978]).

devolved into a discussion of the relative symbolic strengths and practical implications of circles and cubes in built forms. In other words, decisions were to be made largely on the basis of geometric and symbolic criteria. At some point, I intervened to ask: if you are building a new city, what are the things you would want to know? I would want to know, what kind of relation to nature is going to be created here (the ecological footprint, etc.)? What kinds of technologies are going to be embodied in this city, and why? What kinds of social relations are envisaged? What systems of production and reproduction are going to be incorporated? What is daily life going to be like, and is that the kind of daily life we would want? And what mental conceptions, symbolic and all the rest of it, are going to be engaged here? Is this going to be built as a nationalist monument or as a cosmopolitan place?

The other jurors seemed to find this formulation both innovative and interesting. We discussed it for a while until it got a bit too complicated relative to the time at our disposal. One of the architects then suggested that out of the six criteria, only mental conceptions really mattered, which came down to the symbolism of forms, which brought us neatly back to the question of the relative strengths of circles and cubes! But afterward I was asked where they could find out more about such an interesting way of thinking. I made the mistake of saying it's in footnote 4 of chapter 15 of Marx's *Capital*. I should have known better, because there are two typical reactions to saying this kind of thing. One is nervous and even fearful, for to concede that Marx might have said something so powerfully obvious and interesting is tantamount to admitting Marxist sympathies, and that would be horrible for one's professional and even personal prospects. The other is to regard me as an idiot, so lacking in ideas that I can only parrot Marx and, even worse in this instance, fall so low as to cite a mere footnote! So the conversation stopped. But this is, I think, an interesting way to evaluate urban design and to critique the qualities of urban life.

This framework helps ground the theory of historical materialism in a fundamental way, and there is strong evidence, as I hope to show, that it grounds much of Marx's tangible approach to understanding the evolution of capitalism. Let me expand on this for a moment. Imagine a framework of thought in which these six elements hang together in a single space but in intense interrelation (see figure opposite). Each of the elements is internally dynamic such that we consider each constituting a "moment" in the process of human evolution. We can study this evolution

from the perspective of one of the moments or examine interactions among them, such as transformations in technologies and organizational forms in relationship to social relations and mental conceptions. How are our mental conceptions altered by the technologies available to us? Do we not see the world differently once we have microscopes, telescopes and satellites, X-rays and CAT scans? We understand and think about the world in a very, very different way now, because of the technologies we have. But by the same token, somebody somewhere must have had the mental conception that making a telescope was an interesting thing to do (recall Marx's take on the labor process and the worst of architects). And when that person had that idea, he had to be able to find lens grinders and glassmakers and all the elements necessary in order to make the idea a reality through the production of the telescope. Technologies and organizational forms do not descend from the sky. They get produced out of mental conceptions. They also arise out of our social relations and concretely arise in response to the practical needs of daily life or of labor processes.



I like the way Marx sets this up, provided it is viewed dialectically, not causally. This way of thinking permeates *Capital*, and the book should be read with this framework in mind. It also provides a standard of critique, because we can analyze Marx's own performance by how well he links these different elements together. How exactly does Marx bring together mental conceptions, social relations and technologies, and does he do it

adequately? Are there aspects, such as the politics of daily life, that are left in the shadows? In other words, the dialectic between this formulation and Marx's practices needs to be scrutinized.

So let me summarize. The six elements constitute distinctive moments in the overall process of human evolution understood as a totality. No one moment prevails over the others, even as there exists within each moment the possibility for autonomous development (nature independently mutates and evolves, as do ideas, social relations, forms of daily life, etc.). All these elements coevolve and are subject to perpetual renewal and transformation as dynamic moments within the totality. But it is not a Hegelian totality in which each moment tightly internalizes all the others. It is more like an ecological totality, what Lefebvre refers to as an "ensemble" or Deleuze as an "assemblage," of moments coevolving in an open, dialectical manner. Uneven development between and among the elements produces contingency in human evolution (in much the same way that unpredictable mutations produce contingency in Darwinian theory).

The danger for social theory is to see one of the elements as determinant of all the others. Technological determinism is as wrongheaded as environmental determinism (nature dictates), class-struggle determinism, idealism (mental conceptions are in the vanguard), labor-process determinism or determinism arising out of (cultural) shifts in everyday life (this is the political position taken by Paul Hawken in his influential text *Blessed Unrest*⁶). Major transformations, such as the movement from feudalism (or some other precapitalist configuration) to capitalism, occur through a dialectic of transformations across all the moments. This coevolution developed unevenly in space and time to produce all manner of local contingencies, albeit contingencies limited by the interplay within the assemblage of elements implicated in the evolutionary process and the growing spatial (and sometimes competitive) integration of economic-development processes in the world market. Perhaps one of the biggest failures of the conscious attempt to build socialism and communism on the basis of capitalism was the failure to recognize the need to engage politically across all these moments in a way that was sensitive to geographical specificities. The temptation for revolutionary

6. Paul Hawken, *Blessed Unrest: How the Largest Movement in the World Came into Being and Why No One Saw It Coming* (New York: Viking, 2007).

communism was to reduce the dialectic to a simple causal model in which one or another moment was placed in the vanguard of change, and that was supposed to be that. This approach inevitably failed.

On the surface, the third phase of the footnote appears to contradict my interpretation of the second:

Even a history of religion that is written in abstraction from this material basis is uncritical. It is, in reality, much easier to discover by analysis the earthly kernel of the misty creations of religion than to do the opposite, i.e. to develop from the actual, given relations of life the forms in which these have been apotheosized. The latter method is the only materialist, and therefore the only scientific one. (493–4)

Marx considered himself a scientist, and he is here asserting that this means a commitment to materialism. But his materialism is different from that of the natural scientists. It is historical. “The weaknesses of the abstract materialism of natural science, a materialism which excludes the historical process, are immediately evident from the abstract and ideological conceptions expressed by its spokesmen whenever they venture beyond the bounds of their own speciality” (494). Darwin’s findings on evolution were flawed because he ignored the impact of the historical context on his theorizing (the power of the metaphors that he drew from British capitalism) and failed to carry over his argument onto and integrate his findings with human evolution. Marx was writing before Social Darwinism became popular, of course, but he prefigures a critical response to the way in which the Social Darwinists legitimized capitalism as “natural” by appealing to Darwin’s theory of evolution. Since Darwin’s theory drew its guiding metaphors from capitalism and was inspired by the social theory of Malthus, it was hardly surprising to see capitalism confirmed as wholly consistent with supposedly natural processes of competition, struggle for survival and, of course, survival of the fittest (without paying attention to Kropotkin’s mutual aid).

Marx’s general point is that natural scientists, because they failed to understand their historical moment and were barred by their methodological commitments from integrating human history into their models of the world, frequently ended up with at best partial and at worst serious misinterpretations of that world. At worst, they concealed their historical and political assumptions under a supposedly neutral

and objective science. This critical perspective, which Marx pioneered, is now standard practice within the field of science studies, where it has repeatedly been shown that the importation into science of social metaphors about gender, sexuality or social hierarchies leads to all kinds of misreadings of what the natural world is actually about, even as it is understood that without metaphors scientific inquiry would go nowhere.

But there is a much deeper issue here that needs to be addressed. In the first lecture, I talked about Marx's way of moving by descent: you start with the surface appearance, then dive deep down beneath the fetishisms to uncover a theoretical conceptual apparatus that can capture the underlying motion of social processes. That theoretical apparatus is then brought step by step back to the surface to interpret the dynamics of daily life in new ways. This is, Marx confirms in the footnote, "the only materialist and therefore the only scientific (method)." We have already seen a specific example of this method at work in the chapter on the working day. Value as socially necessary labor-time internalizes a specific capitalist temporality, and a vast field of social struggles on the surface of society ensues, concerning the appropriation of the time of others. The fact that "moments are the elements of profit" leads capitalists to be obsessed with time discipline and time control (and will shortly also explain why they are obsessed with speed-up).

But how are we to think about the relation between, say, the deep-value theory and the unpredictable ferment of surface struggles over the length of the working day? Back on page 175, Marx approvingly cites (in yet another footnote!) a famous passage from an earlier work, *A Contribution to the Critique of Political Economy*:

My view is that each particular mode of production, and the relations of production corresponding to it at each given moment, in short 'the economic structure of society', is 'the real foundation, on which arises a legal and political superstructure and to which correspond definite forms of social consciousness' [mental conceptions, if you like], and that 'the mode of production of material life conditions the general process of social, political, and intellectual life.

He leaves out the following sentence from the *Critique*, which explains that it is in the superstructure that we become conscious of political issues and fight them out.

This is what is usually referred to as the base-superstructure model. The supposition is that there is an economic base on which there arise frameworks of thought as well as a political and legal superstructure that collectively define how we become conscious of problems and fight them out. This formulation is sometimes read deterministically: the economic base *determines* the political and legal infrastructure, determines the forms of struggle that are found there and, to the degree that there are transformations occurring in the economic base, actually determines the outcomes of political struggles. But I can't see how the argument can be viewed as deterministic or even causal. This is not how the chapter on the working day unfolds at all. There are class alliances, conjunctural possibilities, discursive shifts in sentiments, and the outcome is never certain. But there is always such a deep concern over the appropriation of the time of others that the issue never goes away. It is a perpetual point of contestation "between equal rights" within capitalism that can never arrive at some ultimate solution. Struggles over time are fundamental to the capitalist mode of production. This is what the deep theory tells us, and no matter what happens in the superstructure, that imperative cannot be overcome without overthrowing capitalism.

In any case, productive forces and social relations cannot exist without expression and representation in the political and legal superstructure. We have seen this with money, which is a representation of value surrounded by all manner of institutional and legal arrangements, and certainly an object of struggle and political manipulation (as is also the case with legal frameworks of private property rights). But Marx has also shown that without money (or a legal framework of private property rights), value could not exist as a foundational economic relation. Things get worked out in the monetary sphere in very particular ways depending on the dynamics of class struggle, and this has implications for how the value theory works. Is money in the political superstructure or down in the economic base? The answer, surely, has to be both.

Similarly, one would not say, from the chapter on the working day, that the outcome of the working-day struggle was determined by movements in the economic base. Furthermore, the political restriction on the length of the working day in part led capitalists to look for another way to gain surplus-value, i.e., relative surplus-value. Marx clearly does not intend this base-superstructure model to operate mechanically or causally, but he does use it dialectically.

Yet it is also true that the “working out” that goes on in the realm of struggle over the length of the working day is a working out of the fundamental fact that moments are the elements of profit, which derives from the definition of value as socially necessary labor-time. There was not a concerted struggle over the length of the working day in precapitalist societies or even in ancient Rome. Only within the rules of a capitalist mode of production does this sort of struggle make sense. Formal issues such as the length of the working day (week, year, lifetime) get thrown up precisely because of the deep structure of what capitalism has become. How these struggles get resolved depends on you and me and everybody else. And indeed, the struggle could potentially be resolved in such a way as to entail the abolition of the capitalist mode of production. A society would be constructed in which moments are *not* the elements of profit. Can you imagine what that would look like? Sounds rather nice, no?

My main point here is that the ways in which these things get worked out—through political and legal means, the balance of class forces, hegemonic mental conceptions and the like—are not ineffectual in relation to the deep concept of the circulation of value as capital. The real scientific method is to identify those deep elements which explain to you why certain things go on in our society the way they do. We saw that in the struggle over the length of the working day. We also see it in the struggle over relative surplus-value, which explains why capitalism has to be so technologically dynamic. We seem not to have choices over whether or not to grow or to invent because that's what the deep structure of capitalism mandates. The only interesting question is, therefore, how is growth going to occur, and with what kinds of technological change? This forces us to consider the implications for mental conceptions, the relation to nature and all the other moments. If we don't like these implications then we have no recourse except to engage in struggle with respect not only to one or another of the moments but to all of them simultaneously, until we ultimately come to terms with having to transform the very rule of value itself.

The circulation of capital is, however, the driver of the dynamics under capitalism. But what is socially necessary for this process to be sustained? Consider, for example, the necessary mental conceptions. If you go down to Wall Street with a big banner saying, “Growth Is Bad, Stop It Now,” would that be considered an anticapitalist sentiment? You bet it would. You would be dismissed, however, not necessarily for being

anticapitalist but for being antigrowth, because growth is considered both inevitable and good. Zero growth signals serious problems. Japan hasn't grown much at all in recent times, poor folk. But the growth in China has been spectacular, so the Chinese are the grand success story. How can we emulate them? We all happily sit around and say growth is good, technological change is good and so capitalism, which requires both, must also be good. This is the sort of common belief system that Gramsci often referred to as "hegemony." The same sorts of issues arise concerning institutional arrangements. Capitalism requires adequate legal arrangements to function effectively. The more the Chinese moved down a capitalistic path, the less plausible it was for them to maintain a legal system that didn't acknowledge some sorts of private property rights. But there is a great deal of latitude and contingency in the institutional arrangements that might work.

Sections 1–3: Machine Development, Value Transfers and Effects on Workers

So, finally, let us take up the materials assembled in this long chapter. I suggest you pay careful attention to the sequence of the section headings. These define a logical line of argument that structures Marx's inquiry into the rise of the factory system and the use of machinery. He begins, however, with John Stuart Mill's surprise at the fact that mechanical inventions, supposedly designed to lighten the load of labor, had done nothing of the kind. In fact, they had generally made matters worse. Marx himself is in no way surprised, since machines are used to produce surplus-value, not to lighten the load of labor. But this means, notice, that "the machine is a means for producing surplus-value" (492). This sounds odd, since Marx has argued that machines are dead labor (constant capital) and cannot produce value. Yet they can, however, be a source of surplus-value. The reduction in the value of labor-power through rising productivity in the wage-goods sector yields relative surplus-value to the capitalist class, while the capitalist with the best machinery will acquire the temporary form of relative surplus-value that accrues to the producer with higher productivity. No wonder capitalists hold to the fetish belief that machines produce value!

Marx then considers the difference between tools and machines. To "call a tool a simple machine and a machine a complex tool" and "see no essential difference between them" misses something essential, most

notably “the historical element” (that element that he, incidentally, makes so much noise about in the footnote) (492–3). Marx was one of the first people ever to use the phrase “industrial revolution” and to make it central to his historical reconstruction. So what constitutes the heart of this industrial revolution? Was it simply a change of technology, the fact that tools become machines? Is the difference between machines and tools that machines have an external source of power? Does it entail a radical shift in social relations to parallel the transformations in productive forces? The answer is all of the above.

The machine, which is the starting-point of the industrial revolution, replaces the worker, who handles a single tool, by a mechanism operating with a number of similar tools and set in motion by a single motive power, whatever the form of that power. Here we have the machine, but in its first role as a simple element in production by machinery. (497)

This is predicated, however, on a transformation in the positionality (social relation) of the worker. This is just as important as the machine itself. While workers can continue to provide the motive power, at some point or other the need arose to supplement that power from an external source. Water power had long been pressed into service, but its application was limited and restricted by location.

Not till the invention of Watt's second and so-called double-acting steam-engine was a prime mover found which drew its own motive power from the consumption of coal and water, was entirely under man's control, was mobile and a means of locomotion, was urban and not—like the water-wheel—rural, permitted production to be concentrated in towns instead of—like the water-wheels—being scattered over the countryside and, finally, was of universal technical application, and little affected in its choice of residence by local circumstances. (499)

The steam engine liberated capital from dependence on localized sources of power, because coal was a commodity that could, in principle, be shipped anywhere. But be careful not to read too much into this invention, because “the steam-engine itself . . . did not give rise to any industrial revolution. It was, on the contrary, the invention of machines that made a revolution in the form of steam-engines necessary” (496–7).

And while Marx doesn't mention it, coal also eliminated the acute

rivalry, which had limited industrial development before this time, between the use of land for food production and the use of land's biomass as an energy source. All the time wood and charcoal were primary fuel sources, the competition for land between food and biofuels raised the cost of both. With coal it became possible to mine the stored energy of the Carboniferous period; then, with oil, that of the Cretaceous period. This liberated the land for food and other forms of raw-material production and liberated industry to proliferate using cheap fuels, with all kinds of implications both for urbanization and, of course, for the way we live our lives right now. Interestingly, a response to fuel scarcities in recent times has been to go back to the land for fuel (ethanol, in particular), and this has had the predictable consequence of rapidly increasing food and other raw-material prices (with all manner of social consequences, such as food riots and increasing hunger; even my bagel has gone up in price by thirty cents). We are currently re-creating the barriers to capital accumulation that the shift to fossil fuels in the late eighteenth century so successfully circumvented by revolutionizing the relation to nature.

But the hallmark of the industrial revolution was more than just a shift in energy production. The "co-operation by division of labour which is peculiar to manufacture" now appears "as a combination of machines with specific functions." There is a significant evolution in social relations.

In manufacture, it is the workers who, either singly or in groups, must carry on each particular process with their manual implements. The worker has been appropriated by the process; but the process had previously to be adapted to the worker. This subjective principle of the division of labour no longer exists in production by machinery. Here the total process is examined objectively, viewed in and for itself, and analysed into its constitutive phases. The problem of how to execute each particular process, and to bind the different partial processes together into a whole, is solved by the aid of machines, chemistry, etc.

The result is the evolution of "an articulated system composed of various kinds of single machine, and of groups of single machines," and this "becomes all the more perfect the more the process as a whole becomes a continuous one" (501-2).

There are a number of points to make about this statement. First is the importance of continuity in the production process, which is

crucial because the continuity of the circulation of capital requires it, and machinery helps achieve this. Second, note that social relations are being transformed alongside the technical relations. Third, the analysis of the production process into its constitutive phases entails a mental transformation which brings a science (such as chemistry) to bear on technology. In other words, there is an evolution in mental conceptions. At least three of the elements examined in the footnote come into play here, while the relation to nature and to locational requirements also shifts as coal resources replace waterfalls and biomass as primary sources of energy. We see in paragraphs of this sort how Marx's formulation in the footnote is working. The different elements flow easily together to constitute a compelling narrative of coevolution rather than causation. The outcome is an "organized system of machines to which motion is communicated by the transmitting mechanism from an automatic centre," and this, he says, "is the most developed form of production by machinery. Here we have, in place of the isolated machine, a mechanical monster"—Marx loves images of this sort, as we have already seen—"whose body fills whole factories, and whose demonic power, at first hidden by the slow and measured motions of its gigantic members, finally bursts forth in the fast and feverish whirl of its countless working organs." But, Marx reminds us, "the inventions of Vaucanson, Arkwright, Watt and others could be put into practice only because each inventor found a considerable number of skilled mechanical workers available, placed at their disposal by the period of manufacture." That is, the new technologies could not have come on line if the necessary social relations and labor skills had not already been in place. In some cases, these workers "were independent handicraftsmen of various trades," while others were already "grouped together" (503).

But the evolutionary process had its own momentum. "As inventions increased in number, and the demand for the newly discovered machines grew larger, the machine-making industry increasingly split up into numerous independent branches, and the division of labour within these manufactures developed accordingly." Social relations were in full flood of transformation. "Here, therefore in manufacture, we see the immediate technical foundation of large-scale industry. Manufacture produced the machinery with which large-scale industry abolished the handicraft and manufacturing systems in the spheres of production it first seized hold of." After the system had "undergone further development in its old form," it finally created "for itself a new basis appropriate to its own mode of

production" (503–4). Capitalism, in short, discovered a technological basis more consistent with its rules of circulation.

This is, in my view, an evolutionary, not a determinist, argument. The contradictions of capitalism as they arose in the manufacturing and handicraft period could not be resolved given the nature of the technologies which existed. Therefore, there was considerable pressure to come up with a new technological mix. Marx is telling the story of how capitalism came to "create for itself a new basis appropriate to its own mode of production." But this whole process was

dependent on the growth of a class of workers who, owing to the semi-artistic nature of their employment, could increase their numbers only gradually, and not by leaps and bounds. But, besides this, at a certain stage of its development large-scale industry also came into conflict with the technical basis provided for it by handicrafts and manufacture. (504)

The expansionary force of capital encountered limits. The capitalist system had arrived at the point where it needed skilled workers to make the machines that would facilitate its development at the same time as its own technological basis acted as a drag on the capacity of built machines.

But the evolutionary process was hard to stop. "The transformation of the mode of production in one sphere of industry necessitates a similar transformation in other spheres." Note here, by the way, Marx's use of the term "mode of production." He sometimes uses this term, as he does in the opening paragraph of *Capital*, to contrast, say, the capitalist and feudal modes of production. But here it means something much more specific: the mode of production in a particular industry. These two meanings interrelate: the mode of production in a particular industry creates new machine forms which actually are consistent with the capitalist mode of production understood in the broader sense. Here, however, we are talking about specific transformations in modes of production in particular spheres of industry and the dynamic interactions between them.

This happens at first in branches of industry which are connected together by being separate phases of a process, and yet isolated by the social division of labour . . . Thus machine spinning made machine weaving necessary, and both together made a mechanical and chemical revolution compulsory in bleaching, printing and dyeing.

Spill-over effects between different segments of a production process create mutually reinforcing changes. Furthermore, “the revolution in the modes of production of industry and agriculture made necessary a revolution in the general conditions of the social process of production, i.e. in the means of communication and transport” (505–6). This introduces one of the other themes that I find extremely interesting in Marx: that is the importance of what he calls in the *Grundrisse* the “annihilation of space by time.”⁷ The evolutionary dynamic of capitalism is not neutral in terms of its geographical form. We’ve already seen hints of this in his discussion of urbanization, the concentration that could arise through the steam engine, and the locational freedoms conferred by steam power. Connectivity in the world market also changed.

Hence, quite apart from the immense transformation which took place in shipbuilding, the means of communication and transport gradually adapted themselves to the mode of production of large-scale industry by means of a system of river steamers, railways, ocean steamers and telegraphs. But the huge masses of iron that had now to be forged, welded, cut, bored and shaped required for their part machines of Cyclopean dimensions, which the machine-building trades of the period of manufacture were incapable of constructing.

And here comes the final link in the argument:

Large-scale industry therefore had to take over the machine itself, its own characteristic instrument of production, and to produce machines by means of machines. It was not till it did this that it could create for itself an adequate technical foundation, and stand on its own feet. (506)

The capacity to produce machines with the aid of machines is, in short, *the* technical foundation of a fully fledged, dynamic capitalist mode of production. In other words, the growth of engineering and the machine-tool industry is the ultimate phase of a revolution that created the “adequate technical foundation” for the capitalist mode of production in general. “As machinery, the instrument of labour assumes a material mode of existence which necessitates the replacement of human force by natural forces, and the replacement of the rule of thumb by the conscious

7. Marx, *Grundrisse*, 524.

application of natural science.” This entails a revolution not only in mental conceptions but also of their application.

In manufacture the organization of the social labour process is purely subjective: it is a combination of specialized workers. Large-scale industry, on the other hand, possesses in the machine system an entirely objective organization of production, which confronts the worker as a pre-existing material condition of production. (508)

The nature of cooperation is fundamentally changed, for example.

I have gone over this section at length, in order to show how the synergistic spread of revolutions in technology both rests on and provokes transformations in social relations, mental conceptions and modes of production (in the concrete and particular sense), as well as in spatial and natural relations. The rise of this new technological system which is suited to a capitalist mode of production (in the grand sense) is an evolutionary story in which all the elements in the footnote coevolve.

In the chapter’s second section, Marx asks the following question: how is value transferred from the machine to the product? The other two modes of acquiring relative surplus-value—through cooperation and division of labor—cost capital nothing, apart from some incidental expenses. But a machine is a commodity that has to be bought in the market. This is very different from, say, merely reconfiguring the division of labor in a workplace. Machines have a value, and that value has to be paid for. Somehow the value congealed in the machine must be transferred into “the product it serves to beget,” even though no physical transfer of matter is involved (509). Initially, Marx appeals to the idea of straight-line depreciation. If the machine lasts ten years, one-tenth of the value of the machine ends up in the product each year over that time. But then he goes on to derive an important limit to the deployment of machinery:

The use of machinery for the exclusive purpose of cheapening the product is limited by the requirement that less labour must be expended in producing the machinery than is displaced by the employment of that machinery. For the capitalist, however, there is a further limit on its use. Instead of paying for the labour, he pays only the value of the labour-power employed; the limit to his using a machine is therefore fixed by the difference between the value of the machine and the value of the labour-power replaced by it. (515)

This assumes (as most economists tend to) that capitalists are rational in their decisions. If the machine is expensive and you save very little labor by it, then why buy it? The cheaper the machine and the more expensive the labor, the greater the incentive to employ machinery. The calculation that the capitalist has to make, therefore, is between the value expended to buy the machine and the value saved on labor (variable capital) employed. This limit on the deployment of machinery is typically enforced by the coercive laws of competition. Capitalists who buy costly machines but save little labor by them are going to be driven out of business.

How much variable capital gets saved depends, however, on the value of labor-power. "Hence the invention nowadays in England of machines that are employed only in North America" (516). In North America, the relative scarcity of labor meant high labor costs, so employing machines made sense, but in Britain the existence of surplus labor meant cheap labor and less incentive to use machines. This calculation on the limiting conditions to the employment of machinery is significant, both theoretically and practically. There are contemporary examples in China where, with the abundance of cheap labor, something which is made with a sophisticated and expensive machine in the United States has been broken down into smaller labor processes that can be done by hand. Instead of employing one very expensive machine with twenty laborers in the United States, you employ two thousand laborers in China using hand tools. This example counters the idea that capitalism inevitably marches onward toward ever-greater mechanization and technological sophistication. Given the importance of the limiting conditions and the value relations, then all manner of oscillations can occur in the deployment of machine technologies.

In the third section, Marx considers three consequences of machine deployment for the worker. Machinery facilitated the "Appropriation of Supplementary Labour-Power by Capital. The Employment of Women and Children." Machine technologies effectively destroyed the skill basis that existed in the handicraft period. It then became much easier to employ unskilled women and children. A number of consequences followed. It became possible to substitute the family wage for the individual wage. The latter could be reduced, but the family wage could remain constant as women and children entered the workforce. This has been an interesting and persistent theme in capitalist history. In the United States since the 1970s, individual wages have either declined or remained fairly constant

in real terms, but family wages have tended to rise as more women have gone to work. What the capitalists class gets is two laborers for close to the price of one. The Brazilian economic miracle of the 1960s was likewise dominated by a catastrophic diminution of individual wages under the military dictatorship, but family wages managed to stabilize because not only women but kids went to work (child labor in the iron mines surged). This led to the famous comment by the Brazilian president Emílio Garrastazu Médici that “the economy” (he should have said the capitalist class) “is doing very well but the people are doing very badly.” There are many historical circumstances where capitalists have pursued this solution to gaining surplus-value.

This also raises the question of the relationship between the individual and the family wage. The latter is necessary for the reproduction of the working class. But who bears the cost of this reproduction? Marx is not very sensitive, as many have pointed out, to questions of gender, but he does in a footnote acknowledge the importance of the relation between household work and the buying and selling of labor-power in the market. If women enter the labor force, then

domestic work, such as sewing and mending, must be replaced by the purchase of ready-made articles. Hence the diminished expenditure of labour in the house is accompanied by an increased expenditure of money outside. The cost of production of the working-class family therefore increases, and balances its greater income. In addition to this, economy and judgement in the consumption and preparation of the means of subsistence become impossible. (518)

Consideration of the family wage raises other issues. It was very common in Marx’s time for the male, particularly in the countries Marx was familiar with, to be deliverer of the whole family labor. The result was the creation of a “gang system” for labor supply. One male figure would be held responsible for delivering the labor-power of several kids, maybe the labor-power of a wife and a sister, as well as the labor-power of nephews and kin. In France, the labor market was frequently constituted as a gang system whereby a patriarchal figure would command the labor of everybody around him and deliver that labor to his employers, leaving the question of the remuneration of that labor and distribution of the benefits to the patriarchal figure. Systems of this sort are not at all uncommon in

Asia and are frequently found in the organization of immigrant groups in Europe and North America. Some of the worst aspects of this, then as now, as Marx points out in a footnote, arose (and arise) through trafficking in children and the equivalent of slave dealing. Relying very much on the reports of the factory inspectors (suffused with Victorian morality that Marx does not criticize) and Engels's account in *The Condition of the Working Class in England*, Marx focuses on the "moral degradation which arises out of the exploitation by capitalism of the labour of women and children," and the weak attempts by the bourgeoisie to counter this moral degradation through education (522). As in the case of the Factory Acts, a contradiction emerges between what individual capitalists are compelled to do by the coercive laws of competition and what the state tries to do in the way of educating children. Marx does therefore raise, albeit in a not very adequate way, issues concerning the reproduction of life (again an important but somewhat neglected element in footnote 4).

The second subsection deals with "The Prolongation of the Working Day". Machinery in fact creates new conditions not only permitting capital to lengthen the working day but also creating "new incentives" to do so.

Because it is capital, the automatic mechanism is endowed, in the person of the capitalist, with consciousness and a will. As capital, therefore, it is animated by the drive to reduce to a minimum the resistance offered by man, that obstinate yet elastic natural barrier.

The machine is in part designed to overcome worker resistance, which is in any case "lessened by the apparently undemanding nature of work at a machine, and the more pliant and docile character of the women and children employed by preference" (526–7). This is, of course, a typical Victorian prejudice. In fact the women were by no means docile, any more than the children were.

But the heart of the problem here is the temporality and continuity of production. The machine wears out faster the more it is used, and there are strong incentives to use up the machine as fast as possible. To begin with, "the physical deterioration of the machine is of two kinds. The one arises from use," and the other from non-use, i.e., it just rusts away. "But in addition to the material wear and tear, a machine also undergoes what we might call a moral depreciation." I always find this term strange. What

Marx really means is economic obsolescence. If I bought a machine for two million dollars last year, and this year all my competitors can buy it for one million (or, what amounts to the same thing, buy a machine for two million dollars which is twice as efficient as mine), then the value of commodities produced will fall, and I will lose half the value of my machine. "However young and full of life the machine may be, its value is no longer determined by the necessary labour-time actually objectified in it, but by the labour-time necessary to reproduce either it or the better machine." The threat is that the machine will be "devalued to a greater or lesser extent" (528). To protect against this threat, capitalists are impelled to use their machinery up as fast as possible (keeping it employed twenty-four hours a day if possible). This means lengthening the working day (or, as we will see, resorting to shift work and relay systems). Machines supposed to get around lengthening the working day actually stimulate a need to further lengthen it.

Capitalists fall in love with machines because they are a source of surplus and relative surplus-value. The fetish of a "technological fix" becomes ingrained in their belief system. Yet machines are also the source of "an immanent contradiction" because "of the two factors of the surplus-value created by a given amount of capital, one, the rate of surplus-value, cannot be increased except by diminishing the other, the number of workers" (531). And since the mass of surplus-value, so crucial to the capitalist, depends on the rate of surplus-value and the number of workers, labor-saving innovations may leave the capitalist no better off. Throwing workers out of work through technological innovations from this standpoint does not seem a good idea, because the real value producers are lost from production. This contradiction will be made much of in the third volume of *Capital*, where the dynamics of technological innovation are seen as destabilizing and a source of serious crisis tendencies.

But the incentive for capitalists to keep on innovating is all-powerful. The competitive search for the ephemeral form of relative surplus-value becomes overwhelming in spite of the contradictions. Individual capitalists, responding to the coercive laws of competition, behave in a way that is not necessarily in the interests of the capitalist class. But the social consequences for labor can also be catastrophic.

Partly by placing at the capitalists' disposal new strata of the working class previously inaccessible to him, partly by setting free the workers

it supplants, machinery produces a surplus working population, which is compelled to submit to the dictates of capital. Hence that remarkable phenomenon in the history of modern industry, that machinery sweeps away every moral and natural restriction on the length of the working day. Hence too the economic paradox that the most powerful instrument for reducing labour-time suffers a dialectical inversion and becomes the most unfailing means for turning the whole lifetime of the worker and his family into labour-time at capital's disposal for its own valorization. (531–2)

Now we see why John Stuart Mill was so right.

The third subsection explicitly takes up the question of intensification. Earlier usually mentioned in passing (as, for example, in the definition of socially necessary labor-time), intensity is here confronted head-on. Capitalists can use machine technology to change and regulate the intensity and pace of the labor process. Reducing what is called the porosity of the working day (moments when work is not being done) is a key objective. How many seconds in a working day can a worker goof off? If they are in charge of their own tools, then they can lay them down and pick them up again. Laborers can work at their own pace. With machine technology, the speed and the continuity are determined internally to the machine system, and workers have to conform to the movement of, say, the assembly line (as in Chaplin's *Modern Times*). There is an inversion in social relations, such that workers now become appendages of the machine. One of the great advances that occurred after 1850, once the industrial bourgeoisie got over the fact that they were going to have to deal with the Factory Acts and the regulation of the length of the working day, was that capitalists discovered that a shorter working day was compatible with increasing intensity. This repositioning of the laborer as an appendage to the labor process is of utmost importance in what follows.