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The Machinery Question

Question:	What is the effect of machinery?
Answer:	To do that labour which must otherwise be done by hand, and to do it more perfectly and expeditiously.
Question:	To whom then ought the machinery to belong?
Answer:	To the men whose work it does – the labourers . . .
Question:	Who are the inventors of machinery?
Answer:	Almost universally the working men.
Question:	But why do not the working men use machinery for themselves?

No Answer!!!

The Pioneer, 1833[1]

The history of the English working classes begins in the second half of the eighteenth century with the invention of the steam engine and of machines for spinning and weaving cotton. It is well known that these incentives gave the impetus to the genesis of industrial revolution.

Friedrich Engels, *The Condition of the Working Class in England*, 1845[2]

1 *The Pioneer* 1, no. 4 (28 September 1833).

2 Friedrich Engels, *Die Lage der arbeitenden Klasse in England,* Leipzig: Wigand, 1845. Translated by W. O. Henderson and W. H. Chaloner as *The Condition of the Working Class in England*, Redwood City, CA: Stanford University Press, 1958, 9.

> *The science which compels the inanimate limbs of the machinery, by their construction, to act purposefully, as an automaton, does not exist in the worker's consciousness, but rather acts upon him through the machine as an alien power, as the power of the machine itself.*
>
> – Karl Marx, *Grundrisse*, 1858[3]

How to question technology

It is commonly believed that the Industrial Revolution took English society by storm and transformed an economy of regular agricultural cycles into one of violent and unstable growth. For a long time, across the political spectrum, it has been accepted that capitalism began as *machine capitalism* and that even the making and destiny of the working class was tied to an industrial machine.[4] Friedrich Engels himself declared this commonplace in the first line of *The Condition of the Working Class in England* (1845, quoted as an epigraph to this chapter). However, his collaboration with Karl Marx would radically challenge this apparently techno-deterministic view into one which recognised workers and the division of labour, rather than technology, as the main drivers of capitalist development.[5]

During the industrial age, machines came to supplant workers, dividing them into skilled and unskilled labourers, further separating mental from manual labour, and imposing new social hierarchies. Workers, however, resisted such division. They rebelled against machines and confronted their 'alien power', they discussed the role of machines, stormed factory floors to destroy them, and demanded, eventually, public education about them. The outcome of this outcry was the often-forgotten 'Machinery Question', the public debate sparked in English

3 Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy,* London: Penguin 1973, 692–3.

4 The industrial age is today seen in a larger context and time scale. To clarify the debt of British industrial capitalism towards its colonies and limits of Marxism itself in regard to this aspect, see Cedric Robinson, *Black Marxism: The Making of the Black Radical Tradition*, Chapel Hill: University of North Carolina Press, 1983.

5 Engels's reading differs from Marx's in *Capital*, where the division of labour and the social relations of production are described as the main driver of technological development. Engels and Marx first met in 1844.

society at this time upon the massive replacement of workers by new technologies.

As a necessary prelude to the study of contemporary AI, this chapter aims to illuminate not just the social conflicts behind the Machinery Question but also the extended field of knowledge production around industrial machines and machine labour. Already during the industrial age, machines presented a problem of *machine intelligence* – also nderstood as lack of collective knowledge about them. Besides its well-celebrated muscular, energetic, and thermodynamic exploits (documented by Anson Rabinbach in his book *The Human Motor*),[6] industrial labour also entailed knowledge about machines, knowledge embodied by machines, and knowledge produced and projected anew by machines. This epistemic dimension of the industrial age, different from but related to its energetic one, is less investigated and appears always secondary in the vast literature of political economy (including Marxism). It is from this point of view – which is to say from the perspective of knowledge production, of the inquiry into the forms of knowledge of the industrial age – that this chapter hopes to cast a different light on and pay respect to a century of hard labour.

In her influential book *The Machinery Question and the Making of Political Economy*, historian Maxine Berg argues that at the time of the industrial age,

> machinery became the most immediate basis for the relationship between capitalist and worker. It was the machine which defined the organisation of work and which held the balance of power in the determination of the distribution of returns from labour.[7]

This is an egregious description of the field of forces, more precisely of the political battlefield, in which social and economic actors had to confront each other. Rather than a campaign of the industrialists, it must be immediately noted that the Machinery Question was first and

6 See Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity*, Berkeley: University of California Press, 1992.

7 Maxine Berg, *The Machinery Question and the Making of Political Economy*, Cambridge: Cambridge University Press, 1980, 101.

foremost a reaction of the working class and an expression of its demand for control and ownership of technological progress. Berg writes:

> Workers criticised the rapid and unplanned introduction of new techniques in situations where the immediate result would be technological unemployment. But they also went beyond this to challenge the uses and property relations of technology. They demanded an equitable distribution of the gains from technical progress. Rather than raising the profits of the few, the machine, they argued, might lighten the labour and increase the leisure of the many. They also demanded greater control over the direction of technological change . . . Technological progress should also be directed to changing the role of women in society, dispensing with the heavy manual labour and the household chores which prevented many women from claiming an equal position with men.[8]

The Machinery Question was canonically established by David Ricardo in the chapter 'On Machinery' that was added to the 1821 edition of his *Principles of Political Economy*. Ricardo's thesis was the following: while it was true that new machinery would cheapen commodity prices, nonetheless the working class would not benefit from this, since wages would be reduced by the competition among workers which is caused by technological unemployment. Berg adds that:

> The [machinery] question was central to everyday relations between master and workman, but it was also of major theoretical and ideological interest. The very technology at the basis of economy and society was a platform of challenge and struggle. The machine was debated at length in all sectors of society. It provoked the village cleric as much as it did the cosmopolitan intellectual; it concerned the politician as much as the workman and employer; the social reformer as much as scientist and inventor. These groups contended over the costs and benefits of the new technology. They hailed the release it provided from limits to growth, but disagreed over the impact it would have on wages, employment, and skill. They speculated on, and then either

8 Ibid., 17.

> welcomed or dreaded, the changes the machine would bring to social relations. The origins and the ownership of machinery even came up for question. There was excitement and fear at this unknown force which swept relentlessly onward, casting the old society in its wake.[9]

The Machinery Question was therefore a complex phenomenon: an issue of popular culture, political propaganda, scientific contestation, and social control through education. The machine became the site of an intellectual struggle and political occupation by radical thinkers, utopian industrialists, and socialist (and sometimes conservative) militants.[10] The ideological struggle around machinery involved popular literature and pamphlets, poems and satires, and also the industrialists' celebration of a machine cult with dancing automata, 'mechanical Turks', and industrial engines set on display in public squares as tourist attractions. Charles Babbage was known for exhibiting a feminised dancing automaton in his salon, 'in the room next to the unfinished portion of the first Difference Engine'.[11] As Berg has stressed, the rise of political economy as a new discipline was part of the intellectual struggle to control the Machinery Question.[12]

The response to the employment of machines and workers' subsequent technological unemployment was also the demand, by both workers and industrialists, for more knowledge about machines, for more education and better training, which took the form of the Mechanics' Institute movement, among other initiatives. The year 1823 saw the establishment of the London Mechanics' Institute, later known as Birkbeck University – which still bears the Latin motto *In nocte consilium* ('Advice comes overnight'), as students were used (or, more accurately, forced) to attend evening and night courses after their daily shift at work. In 1826, Henry Brougham, future lord chancellor, founded the

9 Ibid., 2, 9–10.

10 Ibid., 168. This debate did not always take progressive directions. Thomas Carlyle was a racist thinker, for example, who often employed vitalist and gothic imageries against industrial machinery to attract workers to his cause. See Thomas Carlyle, 'Chartism', in *The Works of Thomas Carlyle*, ed. Henry Duff Traill, vol. 29, *Critical and Miscellaneous Essays IV*, Cambridge: Cambridge University Press, 2010, 118–204.

11 Simon Schaffer, 'Babbage's Dancer and the Impresarios of Mechanism', in *Cultural Babbage: Technology, Time and Invention*, ed. Francis Spufford and Jenny Uglow, London: Faber & Faber, 1996, 53–80.

12 Berg, *The Machinery Question*, 17.

Society for the Diffusion of Useful Knowledge to help those who had no access to schooling, the same year that the London University (later University College London) was founded. The Owenite Hawkes Smith went so far as to forge mechanical metaphors for education: 'There is an *intellectual* machinery, a *mental steam power* at work, and still rising in its action which renders education proportionately as cheap and as attainable to the man of small means as his clothing and his domestic appointments.'[13] It has indeed been forgotten how a good part of the British academic landscape finds its roots in the epistemic acceleration of the Industrial Revolution.[14]

Which *forms of knowledge* were debated under the auspices of the Machinery Question? Knowledge understood as skill and mechanical invention, applied rather than abstract science, was the mission of workers, engineers, educators, and industrialists. The Mechanics' Institutes were the incarnation of such a trend, searching, in Berg's words, for the 'optimal combination of science and skill . . . a higher form of skilled labour, one freed from the degradation of the division of labour and imbued with creative and innovative instincts'.[15] Everyone maintained that economic growth was bound to the invention of new machines and considered the *intellect as the machine within the machine*; however, the role of the intellect in this process was not then completely clear (and it is not yet today).

In this debate, Marx was probably one of the most original and acute voices. He came to question the technological determinism according to which the machine would be the prime mover of industrial capitalism. Reversing the common perception of the relation between technology and economy, he argued that technological development (the *means of production*) is triggered by the division of labour (the *relations of production*) and not the other way around.[16] According to Marx, capitalist accumulation is pushed by the exploitation of surplus value, by an

13 Hawkes Smith, 'On the Tendency and Prospects of Mechanics' Institutions', *The Analyst*, 1835.

14 For an account of the Mechanics' Institute movements as form of social control and ideological battleground, see Steven Shapin and Barry Barnes, 'Science, Nature and Control: Interpreting Mechanics' Institutes', *Social Studies of Science* 7, no. 1 (1977): 31–74.

15 Berg, *The Machinery Question*, 149.

16 Ibid., 158.

ever-growing division of labour, rather than by technological acceleration. In his view, it was the emerging intelligence of the division of labour, the spontaneous and distributed cognition of masters and workers, which invents machines, not science per se. Science came into play only afterwards, to improve machines that emerged from a social configuration. For Marx, to be precise, the actual *alien power* that moves capitalism is not machinery but living labour.

These sketches of the Machinery Question aim to reveal the full spectrum of social forces which lay behind the intellectual universe of the industrial age, rather than accept technological determinism as its main theory. Indeed, during that age a complex dialectics between social, technical, scientific, and cultural forms took place which cannot be reduced to any of them. The extended list of *knowledge models* and modalities of *knowledge production* that crossed the industrial age should at least include: the type of knowledge that is represented by the act of *invention* of a machine; the *division of labour* that inspires its *design*; the *know-how* of engineering and the *symbolic language* that is necessary to describe mechanism; *hard sciences* such as mechanics and thermodynamics; *non-technical disciplines* such as political economy; the *metrology* of manual and mental labour and the instruments to measure them; *collective knowledge* as embodied in both machinery and social relations (the so-called 'general intellect'); *educational movements* such as the Mechanics' Institutes; *political campaigns* such as the March of Intellect; and, finally, *popular mythologies* around automata such as the Mechanical Turk. The Machinery Question contained all these contested forms of knowledge. This was not entirely a public history – one of visible movements and effects – but more often an anonymous history: one of invisibilisation (of women's labour, especially) and of political amnesia surrounding early notions of political economy such as mental labour.

Against the spell of invisibilisation of the workforce, especially to better understand the demonisation of mental labour in the following century and the reason why mental labour disappeared from the debates on technology, this chapter expands, from opposite angles, upon the previous chapter's reflection on Babbage's labour theory of the machine. On the one hand, it illustrates the influence of knowledge in the definition of labour, framing a *knowledge theory of labour* (dear in the same way to nineteenth-century Ricardian socialists and twentieth-century

knowledge economists). On the other hand, it illustrates the key influence of new machines and instruments on the development of new knowledge, expanding upon a *machine theory of science* that is key to the materialist epistemology of this book.

The knowledge theory of labour

The study of the relation between knowledge and labour has been complicated by the hegemony that science has maintained, in the modern era, in defining and enforcing social hierarchies. The epistemic imperialism of science institutions has obfuscated the role that labour, craftsmanship, experiments, and spontaneous forms of knowledge have played in technological change: it is still largely believed that only the application of science to industry can invent new technologies and prompt economic growth, while this is in fact rarely the case. Indeed, early nineteenth-century political economy already recognised the productive role of mental labour and the knowledge component of any form of manual labour in technological invention. Ricardian socialists such as William Thompson and Thomas Hodgskin, for instance, provided an analysis of mental labour that largely predates the theorists of the knowledge society of the twentieth century. Their position is illustrated, in this book, as a knowledge theory of labour, according to which the main component of labour is not muscular, physical, and energetic, but primarily psychological, intellectual, and informational.

William Thompson was 'an Irish landowner who embraced Owenism, and criticised political economy from a utopian socialist position, but on the basis of Ricardo's doctrines'.[17] In 1824, Thompson published a since-forgotten book with the optimistic title *An Inquiry into the Principles of the Distribution of Wealth Most Conducive to Human Happiness Applied to the Newly Proposed System of Voluntary Equality of Wealth.* There Thompson provided one of the first systematic definitions of knowledge labour of the modern age:

17 A footnote from Marx's *Grundrisse* introduces Thompson this way. Marx, *Grundrisse*, 537.

> In speaking of labour, we have always included in that term the quantity of knowledge requisite for its direction. Without this knowledge, it would be no more than brute force directed to no useful purpose. In whatever proportion knowledge is possessed, whether in whole or in part, by the productive labourer, or by him who directs his labour, it is necessary in order to make his labour productive that some person should possess it.[18]

Presciently, Thompson argued that the economy of knowledge follows rules of diffusion that are different than the economy of scarcity of material goods and instead are driven by continuous expansion and free multiplication:

> Wealth, the produce of labor, is necessarily limited in its supply . . . Not so with the pleasure derived from the acquisition, the possession, and diffusion of knowledge. The supply of knowledge is unlimited . . . The more it is diffused, the more it multiplies itself.

Thompson, however, perceived the ambivalence of instrumental knowledge, in a sort of 'dialectics of enlightenment' *ante litteram*. In a typical polemic of Owenism, Thompson described machinery as humiliating the 'general intellectual powers' of the workers that were reduced, in this way, to 'drilled automata'. The factory was an apparatus to keep the workers 'ignorant of the secret springs which regulated the machine and to repress the general powers of their minds' so 'that the fruits of their own labors were by a hundred contrivances taken away from them'.[19] Marx's quote from Thompson in *Capital* is a perfect distillation of this thought:

> The man of knowledge and the productive labourer comes to be widely divided from each other, and knowledge, instead of remaining the handmaid of labour in the hand of the labourer to increase his productive powers . . . has almost everywhere arrayed itself against

18 William Thompson, *An Inquiry into the Principles of the Distribution of Wealth Most Conducive to Humane Happiness Applied to the Newly Proposed System of Voluntary Equality of Wealth*, London: Longman, Hurst, Rees, Orme, Brown and Green; Wheatley and Adlard, 1824, 272.

19 Thompson, *Principles of the Distribution of Wealth*, 272–5, 290, 292.

> labour. 'Knowledge' becomes 'an instrument, capable of being detached from labour and opposed to it'.[20]

Thompson's was not only the first modern account of knowledge labour and of the cognitive component of all labour, but also one that recognised the alienation of knowledge from workers and its transformation into a repressive power inimical to the workers themselves.

Similar positions were advanced also by Thomas Hodgskin, a Ricardian socialist of libertarian tendency who believed in the progress of collective knowledge and the autonomy of society from both capital and state intervention. Hodgskin was one of the founders of the London Mechanics' Institute, where in 1826 he presented the lecture 'On the Influence of Knowledge', later published as part of his book *Popular Political Economy* (1827). Socialists such as Thompson and Hodgskin argued that knowledge is key to economic prosperity. Hodgskin complained that Adam Smith, the father of political economy, did not give a proper treatment to the subject, commenting:

> Those books, therefore, called Elements, Principles, or Systems of Political Economy, which do not embrace and fully develop . . . the whole influence of knowledge on productive power, and do not explain the natural laws which regulate the progress of society in knowledge, are and must, as treatises on Political Economy, be essentially incomplete.[21]

In a clear anti-Malthusian argument, Hodgskin anchored the virtuous growth of knowledge to the needs of a growing population, in this way also reclaiming the territory of knowledge production from the monopoly of state academies and science institutions. He positively declared: 'Necessity is the mother of invention; and the continual existence of necessity can only be explained by the continual increase of people.'[22]

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20 Karl Marx, *Capital: A Critique of Political Economy*, trans. Ben Fowkes, vol. 1, London; New York: Penguin Books; New Left Review, 1976, 482–483; Thompson, *Principles of the Distribution of Wealth*, 274.

21 Thomas Hodgskin, *Popular Political Economy: Four Lectures Delivered at the London Mechanics' Institution*, London: Tait, 1827, 97.

22 Ibid., 86. See Malthus's elitist account of knowledge in 'An Essay on the Principle of Population', 1798.

According to Hodgskin, it is the growth of population that demands better skill in producing and distributing wealth, thereby generating advanced knowledge: 'As the world grows older, and as men increase and multiply, there is a constant, natural, and necessary tendency to an increase in their knowledge, and consequently in their productive power.' Like Thompson, Hodgskin maintained that the rules of the knowledge economy are not those of capitalism: 'The laws which regulate the accumulation and employment of capital are quite dissimilar to and unconnected with the laws regulating the progress of knowledge.' In Hodgskin's view of society, there should be no intellectual hierarchies, no division of head and hand, no labour aristocracy to promote, because 'both mental and bodily labour are practised by almost every individual.'[23]

The demonisation of mental labour

As Berg noted, for participants in the Machinery Question and those within the Mechanics' Institute movement, the apparently benevolent celebration of craftsmanship was actually instrumental to dividing the working class and inciting a fabricated 'labour aristocracy' to mimic bourgeois customs:

> The rhetoric on the connection between technological progress and economic improvement in the Mechanics Institute Movement . . . meant to contribute to the formalisation of hierarchies in the labour movement. The skilled artisan was to be separated from unskilled common labour, and both were to be detached from the middle class. This design for creating a 'labour aristocracy' was complemented by efforts to contribute to the discipline of the labour force.[24]

Cultivating the figure of the ingenious artisan among other gifted personalities (such as scientists and philosophers), the industrialist class aimed to divide the proletariat according to a hierarchy of deskilled and skilled workers, and to impose a gradual disciplining of labour. The workers' movement, on the other hand, fought to maintain a united

23 Ibid., 95, 78, 47.
24 Berg, *The Machinery Question*, 179.

front in which both unskilled workers and skilled artisans could perceive each other on the same side of the political confrontation. But in order to maintain such a position, for tactical reasons, it had to both conceal and absorb the difference of *mental labour* within the manual, and of individual labour within the collective. In terms of political strategy, in order to unify a divided front, it was therefore necessary to declare that all labour is manual (without implying that all labour is also mental). All collective knowledge, including skill, know-how, and even science, thus had to become an expression of *labour in common*.

Ultimately, this reaction against the social hierarchies of knowledge in the workers' movement led to the refusal of status for mental labour among its ranks and, in this way, the unconscious adoption of a bourgeois social segmentation. As such, it was in order to maintain the political unity of workers that mental labour was ostracised from the Machinery Question. The focus on manual labour has since then imposed an interpretation of labour as energetic performance only (as Rabinbach has noted, even Marx's *Arbeitskraft* was originally a notion from thermodynamics).[25] Both the middle class's discrimination of mental and manual labour and the working class's neutralisation of mental labour within manual labour were dictated by reasons of political tactics within the field of social forces of the industrial age. What is remarkable is that the twentieth-century amnesia surrounding the nineteenth-century theory of mental labour finds its explanation in the strength of the workers' movement in its confrontation with the capitalist class.

Marx had a specific role in organising the political amnesia of mental labour (see chapter 4). Although familiar with Thompson and Hodgskin, both of whom he quoted, in *Capital* Marx removed all references to mental labour, knowledge labour, and the 'general intellect' to replace them with the inventive capacity of the division of labour and the new figure of the collective worker, or *Gesamtarbeiter.* Following Babbage, Marx adopted the idea that the extended division of labour, rather than science, was the inventor of the machine. In this way, Marx reversed Thompson and Hodgskin's *knowledge theory of labour* into the more materialistic *labour theory of knowledge*, in which forms of labour that are spontaneous, unconscious, tacit, and collective are also eventually recognised as producing knowledge. Industrial machinery, nonetheless,

25 See Rabinbach, *The Human Motor.*

ended up polarising the distance between skilled and deskilled labour. As Marx sharply summarised: 'By the introduction of machinery the division of labour inside society has grown up, the task of the worker inside the workshop has been simplified, capital has been concentrated, human beings have been further dismembered.'[26] It is on this basis which Berg concludes that 'machinery did not displace labour. Rather, it differentiated this labour by dismembering the old craft.'[27]

The distinction of head and hand, of mental and manual labour, is not only typical of modern industrial societies; it has been part of Western culture at least since the Aristotelian opposition of *episteme* ('knowledge') and *techne* ('art' or 'craft') in ancient Greece, which later became functional for defining social hierarchies across the West. Historians of mathematics such as Peter Damerow actually predate the social separation of mental and manual labour to the dawn of civilisations due to the need to count populations, plan agriculture, and administer resources. The control of abstract symbols would later develop into the domain of letters and spirit and a long-lasting class segmentation of society, as historians of science Lissa Roberts and Simon Schaffer record:

> Self-appointed mental workers, such as philosophers, scientists, policy-makers and bureaucrats, then as now, claimed and constructed the dominion of their 'understanding' over hand-workers and their crafts. They relied on the mutual reinforcement of coercive rhetoric and brutal deed. The easy acceptance of their categories has left us with a historical map shaped by oppositional and hierarchically ordered pairs: scholar / artisan, science / technology, pure / applied and theory / practice.[28]

It could therefore be argued that the first *division of labour* in the modern sense is the separation of head from hand that gradually emerged out of the workshops of the Renaissance to be fully severed

26 Karl Marx, *The Poverty of Philosophy. Answer to the 'Philosophy of Poverty' by M. Proudhon,* Moscow: Progress Publishers, 1955.

27 Berg, *The Machinery Question*, 34.

28 Lissa Roberts, Simon Schaffer, and Peter Dear (eds), *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation*, History of Science and Scholarship in the Netherlands, vol. 9, Amsterdam: Koninkliijke Nederlandse Akademie van Wetenschappen, 2007, xiii.

precisely in the industrial factories as the division of mental and manual labour. For instance, Edgar Zilsel, a historian of science, documented how even the 'heroes' of the so-called Scientific Revolution, such as Galileo Galilei, learned more in clandestine workshops, hidden libraries, and nomadic classrooms than at universities.[29] Roberts and Schaffer, for their part, have proposed the elegant image of the 'mindful hand' as a way to recognize and recompose the ingenuity of manual labour, mechanical experiments, and scientific workshops throughout modernity, without romanticising craftsmanship as conservative discourse so often does.[30] Rather than cultivating the provincial 'heroism' of craftsmen in a reactionary way, the image of the 'mindful hand' stresses the convivial dimension of experimental life and its inventions.

Industrial modernity has established itself on the capture of this collective knowledge by state and economic apparatuses, by institutions of knowledge and technologies of knowledge, which eventually turned mental labour into a *Geist*, to use the ambivalent German term – a ghost, more than an intellectual spirit, that political theory still struggles to grasp. Extorted from workers and social cooperation, mental labour assumed the nature of a half-visible demon: a political issue to be exorcised, for opposite reasons, by the workers' movement as much as by corporate interests.[31]

The machine theory of science

Tool-makers and machine operators knew that they were contributing to the invention of new technologies. What they were rarely aware of is that they were also contributing to new scientific discoveries. New machines prompt scientific notions and paradigm shifts more often than science happens to invent new technologies from above. As in an

29 Edgar Zilsel, *The Social Origins of Modern Science*, History of Philosophy of Science, Dordrecht: Springer, 2002, 5.

30 For a progressive reading of craftmanship, see Richard Sennet, *The Craftsman*, New Haven, CT: Yale University Press, 2008. For a conservative reading of craftsmanship, see Peter Sloterdijk, *You Must Change Your Life*, London: John Wiley & Sons, 2014, 292: 'Whoever has no interest in craftsmen should therefore be equally silent about heroes.'

31 Roberts and Schaffer address this ambivalence in the idea of the modern 'denial of cunning'.

example mentioned earlier, it was the steam engine which gave birth to thermodynamics, rather than the other way around. The science of heat and energy transformation developed to ameliorate the steam engine: it was a projection of the lucrative ambitions of autonomous motion, not just the child of curiosity towards the universe. In the study of the forms of knowledge that undergo mechanisation, it is important to also highlight the knowledge of the world that is expressed anew by machines. The idea that tools, instruments, and machines project and constitute the ontology of scientific theories about the world can be defined as a *machine theory of science*. As Peter Damerow and Wolfgang Lefèvre have stressed, among others, the tools of work are also tools for exploring the world and speculating upon it: 'The development of science depends on the development of its material tools . . . When using a material tool, more can always be learned than the knowledge invested in its invention.'[32] Yet Damerow and Lefèvre also stress that science is never fully independent from the materiality of its instruments:

> Science is not free in forming its abstractions; in this activity it is restricted by material preconditions, more precisely, by the specific tools at its disposal that provide cognition with abstractions which are capable of realization . . . The material tools of scientific labor define a scope of objective possibilities that represent the framework for developing scientific abstractions.[33]

Tools and machines, however, are never fully transparent in their implications. Machines are born as experiments, and they are often operated without full knowledge of their workings. Science is developed to cover these blind spots in our knowledge of machines, not just of the universe. On the other hand, the perception of nature is often machine based, not simply because of the mediation of instruments on perception but because machines have influenced, indirectly, the ontology of entire scientific paradigms. For example, into the twenty-first century,

32 Peter Damerow and Wolfgang Lefèvre, 'Tools of Science', in Peter Damerow, *Abstraction and Representation: Essays on the Cultural Evolution of Thinking*, Berlin: Springer, 2013, 401.

33 Ibid., 400.

the standard theory of time remains based on the irreversible arrow of entropy that was encountered and conceptualised, for the first time, in the chambers of the steam engine before being canonised in the second principle of thermodynamics.[34] It is not an exaggeration to say that the universe is still perceived nowawdays as from the belly of an industrial engine.

In 1931, with his lecture 'The Social and Economic Roots of Newton's *Principia*', Boris Hessen consolidated the history of science and technology upon the method of historical materialism, arguing that Newton's endeavours were indebted to the tools and machines of the time which happened to be, unsurprisingly, also the main *means of production* of the time: water canal transport techniques, water pumps and pulleys used in the mining industry, new firearms and their ballistic control, and so forth.[35] More recently, Peter Galison has accounted for the difference between Newtonian and Einsteinian physics through analysing the technical perception of time in their respective ages and the definition of synchronisation: a centralised universal clockwork maintained a uniform time in Newton's case, whereas it was 'an electromechanical world' connected by new networks of communication such as the telephone in Einstein's case.[36] Going back to the industrial age, the historical epistemology of science and technology suggests that we reconsider the project of machine intelligence as a prism reflecting multiple forms of knowledge. Stretching its definition across a larger time scale, the expression 'machine intelligence' ultimately acquires at least four meanings: (1) the human knowledge of the machine; (2) the knowledge embodied by the machine's design; (3) the human tasks automated by

34 Arthur Stanley Eddington, *The Nature of the Physical World*, Cambridge: Cambridge University Press, 1928; Harold Francis Blum, *Time's Arrow and Evolution*, Princeton, NJ: Princeton University Press, 1955.

35 Now included in Gideon Freudenthal and Peter McLaughlin (eds), *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*, Berlin: Springer, 2009.

36 The historical epistemology of science can take different names: Andrew Pickering has called it a 'cyborg history', Galison a 'technological reading' of science's theoretical developments, Henning Schmidgen a 'machine history' (*Maschinen-Geschichte*) of science. Andrew Pickering, 'Cyborg History and the World War II Regime', *Perspectives on Science* 3, no. 1 (1995): 1–48; Peter Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time,* New York: Norton, 2003, 290; Henning Schmidgen, *Hirn und Zeit: Die Geschichte eines Experiments, 1800–1950*, Berlin: Matthes & Seitz 2014, 44.

the machine; and (4) the new knowledge of the universe made possible by its use.

The Machinery Question in the age of AI

The industrial machine is a powerful artefact because it imbricates in one thing the relations between energy and matter, knowledge and science, but more importantly between capital and labour. In this sense, the industrial machine appears to be the incarnation of the many contradictions of capitalism and a concrete locus of a social and ideological struggle. A similar fascination with the political centrality of technology has extended until the present day, reiterating ambivalent impressions of the industrial age. Both academic techno-determinism and corporate techno-solutionism, for instance, consider it today as the core of the political question. However, it would be a gross mistake to consider technology the *unique locus* of political conflict. As this book is trying to explicate, social relations and in particular labour cooperation are the 'engines' of technical and political development. But, in their own terms, such social relations and the category of labour itself have to be scrutinised. What is labour cooperation made of, by the way? How was the notion of labour constructed, employed, narrated, and analysed by the political economy of the nineteenth and twentieth century? This is not a trivial question, because the idea of labour that is still used today is an inheritance from the nineteenth century and a product of the bold political confrontations of that time: of labour as a manual activity often devoid of any mental component.

Industrial capitalism was not only an energetic intensification of labour and production; it was also a transformation of the division of labour and social relations, to the point of becoming the matrix of a new kind of knowledge production – not only mathematics, mechanics, and physics, but knowledge of the most diverse kinds. In the early nineteenth century, Ricardian socialists such as Thompson and Hodgskin were already discussing the social potentialities and psychic implications of 'mental labour' claiming that knowledge is the first source of labour. Other political economists, such as Marx, agreed but argued that both mental and manual labour, without distinction, were the source of collective knowledge. It was close to the workshops of the industrial age

that modern computation, eventually, was born as the project to mechanise the division of mental labour, as Babbage experimented with his calculating engines.

This chapter has explored the hypothesis that during the industrial age, knowledge and intelligence comprised the true hidden transaction between labour and capital. As we have seen, all labour, without distinction, was and still is cognitive and knowledge-producing. The most important component of labour is not energy and motion (which are easy to automate and replace) but knowledge and intelligence (which are far from being completely automated in the age of AI). The industrial age was also the moment of the *originary accumulation of technical intelligence* as the dispossession of knowledge from labour. AI is today the continuation of the same process: it is a systematic mechanisation and capitalisation of collective knowledge into new apparatuses, into the datasets, algorithms, and statistical models of machine learning, among other techniques. Ultimately, it is not difficult to imagine AI as a late avatar of the collective worker, the *Gesamtarbeiter* that was for Marx the main actor of industrial production. As we shall see, the nineteenth-century Machinery Question is also of signal importance for figuring out how to question this generalised process of automation in the age of AI. Aptly, in 2016 the *Economist* issued a special report on AI forewarning 'The Return of the Machinery Question'.[37]

37 'The Return of the Machinery Question', special report, *Economist*, June 2016, economist.com.