

On the origins of Marx's general intellect

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The general intellect of the whole community, male and female, is stunted or perverted in infancy, or more commonly both, by keeping from women the knowledge possessed by men. ... The only and the simple remedy for the evils arising from these almost universal institutions of the domestic slavery of one half the human race, is utterly to eradicate them. Give men and women equal civil and political rights.

William Thompson, *An Inquiry Into the Principles of the Distribution of Wealth*, London, 1824.

It is nearly twenty years since the first impulse was given to the general intellect of this country, by the introduction of a new mechanical system for teaching reading and writing, by cheaper and more efficacious methods than those previously in use. ... The public mind has infinitely advanced: in despite of all the sneers at the phrase of the 'march of intellect', the fact is undeniable, that the general intellect of the country has greatly progressed. And one of the first fruits of extended intelligence has been the conviction, now fast becoming universal, that our system of law, so far from being the best in the world, is an exceedingly bad one; and stands in the most pressing need of revision and reform.

The London Magazine, 1828.

The development of fixed capital indicates to what degree general social knowledge has become a *direct force of production*, and to what degree, hence, the conditions of the process of social life itself have come under the control of the general intellect and been transformed in accordance with it.

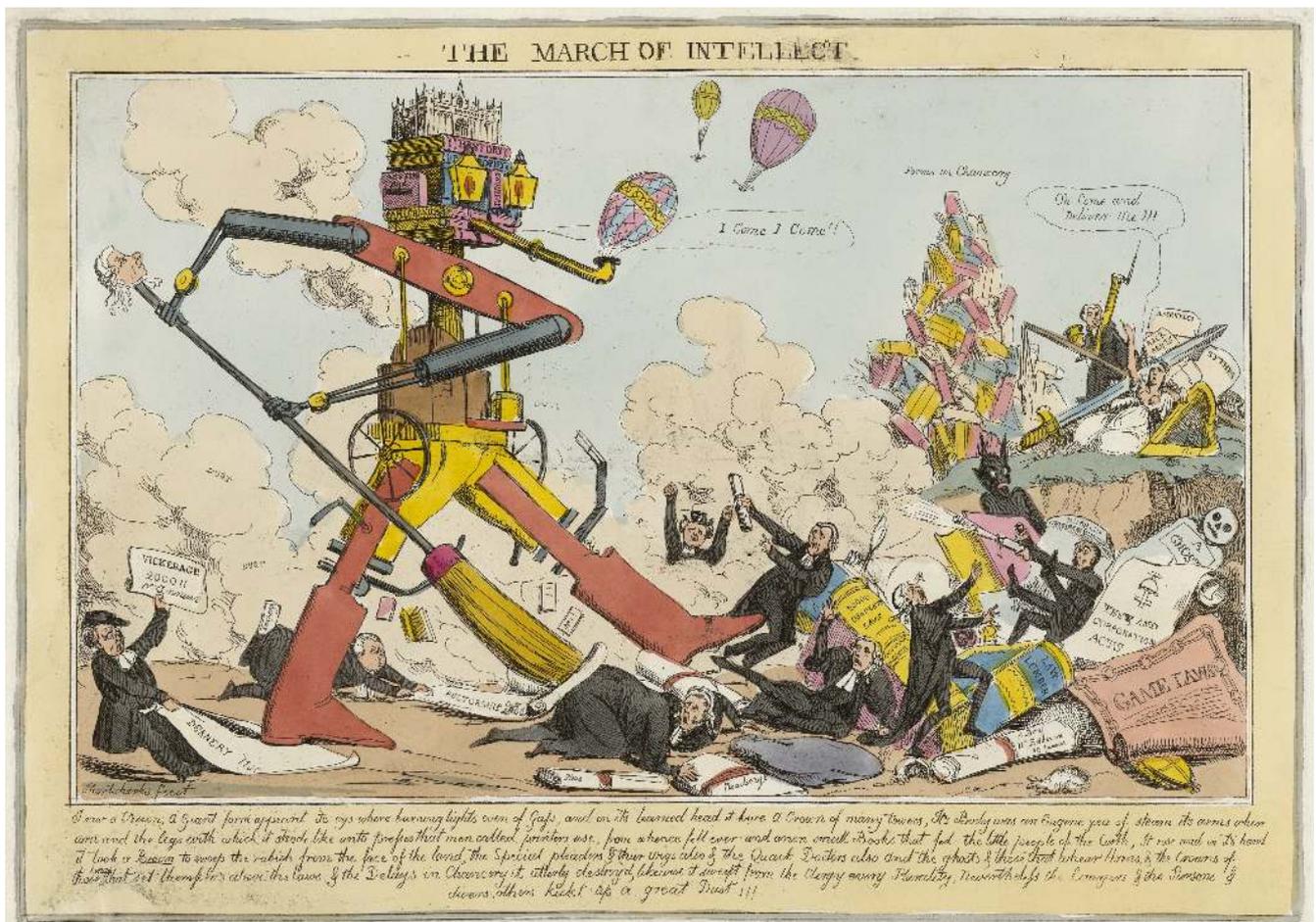
Karl Marx, *Grundrisse*, 1858.

An 1828 caricature by cartoonist William Heath from the series 'March of Intellect' depicts a giant automaton advancing with long strides and holding a broom to sweep away a dusty mass of clerks, clergy and bureaucrats, representing figures of the old order and obsolete laws.¹ The

automaton's belly is a steam engine, its head is made of books of history, philosophy and (importantly) mechanics. Its crown reads 'London University'. In the background the goddess of justice lies in ruins summoning the automaton: 'Oh Come and Deliver Me!!!' Upon closer observation, the caricature appears to ridicule the belief that the technologies of industrial automation (already looking like robots) might become a true agent of political change and social emancipation under the command of public education. Heath's series of satirical engravings was originally commissioned by the Tories to voice their sarcasm regarding a potential democratisation of knowledge and technology across all classes. Nonetheless, by dint of his visionary pen, they became an accidental manifesto for the progressive camp and the invention of the future.²

Initiated as a campaign in England during the Industrial Revolution, the March of Intellect, or 'March of Mind', demanded the amelioration of society's ills through programmes of public education for the lower classes.³ The expression 'March of Intellect' was introduced by the industrialist and utopian socialist Robert Owen in a letter to *The Times* in 1824, remarking that in recent years 'the human mind has made the most rapid and extensive strides in the knowledge of human nature, and in general knowledge.'⁴ The campaign triggered a reactionary and not surprisingly racist backlash: *The Times* started to mock the ambitions of the working class under headlines such as 'The March of Intellect in Africa'.⁵

As a campaign for progress in both literacy and technology, the March of Intellect was part of the so-called 'Machinery Question', that is, the public debate in England on the massive replacement of workers by industrial machines in the first half of the nineteenth century.



William Heath, *The March of Intellect* (1828) © The Trustees of the British Museum

The response to the employment of machines and workers' subsequent unemployment was also the demand for more education about machines, which took the form of initiatives such as the Mechanics' Institute Movement. 1823 saw the establishment of the London Mechanics' Institute (later to become known as Birkbeck College). In 1826, Henry Brougham, future Lord Chancellor, founded the Society for the Diffusion of Useful Knowledge to help those without access to schooling. In the same year the London University (later University College London) was founded. Though often going unacknowledged, a good part of the British academic landscape as it stands today emerged out of the epistemic acceleration of the industrial revolution.

In 1828 *The London Magazine* endorsed the March of Intellect for the benefit of the 'general intellect of the country', a country which, thanks to mass education, would understand the need to reform a decaying legislative system.⁶ When in 1858 Marx used the expression

(in English) 'general intellect', in the famous 'Fragment on Machines' of the *Grundrisse*, he was echoing the political climate of the March of Intellect and the power of 'general social knowledge' to, in his reading, weaken and subvert the chains of capitalism rather than those of old institutions.⁷

But it was specifically in a book of the utopian socialist, William Thompson, that Marx encountered the idea of the general intellect and, more importantly, the argument that knowledge may become a power inimical to workers, once it has been alienated by machines. Thompson's book carried the optimistic title *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* and was published in 1824, the same year in which Owen launched the March of Intellect.⁸ The book contains probably the first systematic account of mental labour – followed by Thomas Hodgskin's own account in *Popular Political Eco-*

nomy (1827) and Charles Babbage's project to mechanise mental labour in *On the Economy of Machinery and Manufactures* (1832).⁹ Afterwards, because of the decline of the Mechanics' Institutes and tactical decisions within the workers' movement, the notion of mental labour encountered a hostile destiny in the Machinery Question.¹⁰

So when in the twentieth century authors began to analyse the so-called knowledge society and thought they were discussing for the first time forms of symbolic, informational and digital labour, they were actually operating in an area of political amnesia. Marx was partly responsible for bringing about this amnesia.¹¹ He engaged with Thompson's and Hodgskin's political economy, but considered their emphasis on mental labour as the celebration of individual creativity – as the cult of the gifted artisan, the ingenious toolmaker and the brave engineer – *against* labour in common: in *Capital*, Marx intentionally replaced the mental labourer with the 'collective worker' or *Gesamtarbeiter*. Marx's refusal to employ the concept of mental labour was due to the difficulty of mobilising collective knowledge into campaigns on the side of workers. The substance of knowledge and education is such that they can only be summoned for universalist battles (for the 'general intellect of the country') rather than partisan ones on the side the proletariat. Besides, since *The German Ideology*, Hegel's notion of absolute spirit appeared to be the antagonist of Marx's method of historical materialism: Marx transposed his famous anti-Hegelian passage 'life is not determined by consciousness, but consciousness by life' to industrial England, in order to claim that labour is not determined by knowledge, but knowledge by labour.¹²

Traditionally, for Marxism, the distinction between manual and mental labour evaporates in the face of capital insofar as any kind of labour is *abstract labour*, that is, labour measured and monetised for the benefit of producing surplus value. What follows shares this traditional starting point, but goes on to depart from orthodox Marxist positions. I wish to consider that any machinic interface of labour is a social relation, as much as capital, and that the machine, as much as money, mediates the relation between labour and capital – what could be termed a *labour theory of value mediated by machines*. Thinking with, as well as beyond, Marx, I want to stress that any technology influences the metrics of abstract labour. For this purpose, this essay traces the origins of Marx's gen-

eral intellect in order to reconsider unresolved issues of early political economy, such as the econometrics of knowledge, that are increasingly relevant today.¹³ In the current debates on the alienation of collective knowledge into corporate AI we are, in fact, still hearing the clunky echoes of the nineteenth-century Machinery Question.

The discovery of Marx's 'Fragment on Machines'

Sophisticated, materialistic notions of mental labour and knowledge economy were already offered at the dawn of the Victorian age and they were already given very radical interpretations. Marx addressed the economic roles of skill, knowledge and science in his *Grundrisse*, specifically in the section that has become known as the 'Fragment on Machines'. There Marx explored an unorthodox hypothesis which was not to be reiterated in *Capital*: that because of the accumulation of the general intellect (particularly as scientific and technical knowledge embodied in machinery), labour will become secondary to capitalist accumulation, causing a crisis of the labour theory of value and blowing the foundations of capitalism skywards.¹⁴ After 1989 Marx's 'Fragment on Machines' was rediscovered by Italian *post-operaismo* as a prescient critique of the transition to post-Fordism and the paradigms of a knowledge society and an information economy.¹⁵ Since then this esoteric fragment has been mobilised by many authors, including those outside Marxism, as a prophecy of different economic crises, especially since the Internet bubble and 2000 Nasdaq stock market crash. The way Marx's 'Fragment on Machines' has reached even the debate on artificial intelligence and post-capitalism is a philological adventure that is worth recapitulating.¹⁶

The *Grundrisse* is 'a series of seven notebooks rough-drafted by Marx, chiefly with the purpose of self-clarification, during the winter of 1857–8'.¹⁷ The notebooks frequently reveal the method of inquiry and subtext of *Capital*, published a decade later. Yet the *Grundrisse* remained unpublished until the twentieth century, which means that its reception entered Marxist debates almost a century after the publication of *Capital*. The *Grundrisse* was published for the first time in Moscow in 1939 and then in Berlin in 1953. A partial Italian translation started to circulate in 1956. The complete English

translation was to become available only in 1973, twenty years after the German edition.¹⁸ The denomination ‘Fragment on Machines’, to define specifically notebooks 6 and 7 of the *Grundrisse*, became canonical due to the editorial choice of Raniero Panzieri, who published their translation under the title ‘Frammento sulle macchine’ in the 1964 issue of *Quaderni Rossi*, the journal of Italian *operaismo*.¹⁹ In the same year Herbert Marcuse drew upon notebooks 6 and 7 in his *One Dimensional Man*, while discussing the emancipatory potential of automation.²⁰ In 1972, in a footnote in *Anti-Oedipus*, Gilles Deleuze and Felix Guattari also refer to them as the ‘chapter on automation’.²¹ In 1972 they were partially published in English as ‘Notes on Machines’ in the journal *Economy and Society*.²² In 1978 Antonio Negri gave an extended commentary on the ‘chapter on machines’ in his *Marx Beyond Marx* seminar in Paris (on the invitation of Louis Althusser), reading it against the background of the social antagonism of the 1970s. But it was only after the Fall of the Berlin Wall that Italian *operaismo* rediscovered and promoted the ‘Fragment on Machines.’ In 1990 the Italian philosopher Paolo Virno drew attention to the notion of general intellect in the journal *Luogo comune*. Paying ironic tribute to the Spaghetti Western, he was already warning about the cycles of the concept’s revival:

Often in westerns the hero, when faced by the most concrete of dilemmas, cites a passage from the Old Testament. ... This is how Karl Marx’s ‘Fragment on machines’ has been read and cited from the early 1960s onwards. We have referred back many times to these pages ... in order to make some sense out of the unprecedented quality of workers’ strikes, of the introduction of robots into the assembly lines and computers into the offices, and of certain kinds of youth behaviour. The history of the ‘Fragment’s’ successive interpretations is a history of crises and of new beginnings.²³

Virno explained that the ‘Fragment on Machines’ was quoted in the 1960s to question the supposed neutrality of science in industrial production, in the 1970s as a critique of the ideology of labour in state socialism and, finally, in the 1980s as a recognition of the tendencies of post-Fordism, yet without any emancipatory or conflictual reversal, as Marx would have wished. Whilst Marxist scholars aimed for greater philological rigour in their reading of the general intellect, militants updated its interpretation in the context of current social transform-

ations and struggles.²⁴ *Post-operaismo* famously forged new antagonistic concepts out of Marx’s general intellect, such as ‘immaterial labour’, ‘mass intellectuality’ and ‘cognitive capitalism’, stressing the autonomy of ‘living knowledge’ against capital. A lesson worth recalling from the Machinery Question, however, is that the issue of collective knowledge should never be separated from its embodiment in machines, instruments of measurement and *Kulturtechniken*. The employment of artificial intelligence in the twentieth century has abruptly reminded everyone that knowledge can be analysed, measured and automated as successfully as manual labour.

Scholars have wondered where the expression ‘general intellect’ came from, as it appears only once, in English, in the *Grundrisse*. Virno thought he detected the echo of Aristotle’s *nous poietikos* and Rousseau’s *volonté générale*.²⁵ As the ‘Fragment on Machines’ follows strains of argumentation that are similar to chapters 14 and 15 of *Capital* on the division of labour and machinery, it is not surprising that the missing sources can be found in the footnotes to these chapters of *Capital*. These common strains of argumentation are, fundamentally, Babbage’s theory of machinery, and it is by following Marx’s reading of Babbage in chapter 14 of *Capital* that the notion of general intellect can be reliably traced back to William Thompson’s notion of ‘knowledge labour’.

Marx’s interpretation of Babbage

‘The workshops of [England] contain within them a rich mine of knowledge, too generally neglected by the wealthier classes’, Babbage advised his fellow industrialists in 1832.²⁶ Following the invitation to the industrial workshops as ‘mundane places of intelligence’, the historian of science, Simon Schaffer, finds that ‘Babbage’s most penetrating London reader’ was Marx.²⁷ Marx had already quoted Babbage in *The Poverty of Philosophy* during his exile in Brussels in 1847 and, since then, adopted two analytical principles that were to become pivotal in *Capital* in drawing a robust theory of the machine and in grounding the theory of relative surplus value.

The first is what could be defined as ‘the labour theory of the machine’, which states that a new machine comes to imitate and replace a previous division of labour. This is an idea already formulated by Adam Smith, but better articulated by Babbage due to his greater tech-

nical experience.

The second analytical principle is usually called the ‘Babbage principle’ and is here renamed ‘the principle of surplus labour modulation’. It states that the organisation of a production process in small tasks (division of labour) allows exactly the necessary quantity of labour to be purchased for each task (division of value). In this respect the division of labour provides not only the design of machinery but also an economic configuration to calibrate and calculate surplus labour extraction. In complex forms of management such as Taylorism, the principle of surplus labour modulation opens onto a clockwork view of labour, which can be further subdivided and recomposed into algorithmic assemblages. The synthesis of both analytical principles ideally describes the machine as an apparatus that actively projects back a new articulation and metrics of labour. In the pages of *Capital* the industrial machine appears to be not just a regulator to discipline labour but also a calculator to measure relative surplus value, echoing the numerical exactitude of Babbage’s calculating engines.

I aim to read the *Grundrisse* and *Capital* through the lens of Babbage’s two analytical principles. It will be shown how Babbage’s labour theory of the machine is used by Marx to raise the figure of the collective worker as a sort of reincarnation of the general intellect, and furthermore, how Babbage’s principle of modulation of surplus labour is used to sketch the idea of relative surplus value. Taken together, Babbage’s two principles show that the general intellect of the *Grundrisse* evolves in *Capital* into a machinic collective worker, almost with the features of a proto-cybernetic organism, and the industrial machine becomes a calculator of the relative surplus value that this cyborg produces.

In discussing the relation between labour and machinery, knowledge and capital, Marx found himself embedded in a hybrid dialectics between German idealism and British political economy. The similar argumentation in the *Grundrisse* and *Capital* in the sections on machinery and division of labour follows four movements to which I will turn now: (1) the invention of machinery through the division of labour, (2) the alienation of knowledge by machinery, (3) the devaluation of capital by knowledge accumulation and (4) the rise of the collective worker.

The invention of machinery through the division of labour

Who is the inventor of the machine? The worker, the engineer or the factory’s master? Science, cunning or labour? As a fellow of the Royal Society, Babbage publicly praised the gifts of science, but theoretically maintained that machinery emerges as a replacement of the division of labour. Babbage’s theory could be defined as a *labour theory of the machine*, since for him the design of a new machine always imitates the design of a previous division of labour. In *The Poverty of Philosophy* (1847), Marx already mobilised Babbage against Proudhon, who thought that machinery is the *antithesis* of the division of labour. Marx argued the opposite, that machinery emerges as the *synthesis of the division of labour*: ‘[W]hen, by the division of labour, each particular operation has been simplified to the use of a single instrument, the linking up of all these instruments, set in motion by a single engine, constitutes – a machine.’²⁸ Later, in the *Grundrisse*, Marx kept on drawing on Babbage to remark that technology is not created by the ‘analysis’ of nature by science, but by the ‘analysis’ of labour:

It is, firstly, the analysis [*Analyse*] and application of mechanical and chemical laws, arising directly out of science, which enables the machine to perform the same labour as that previously performed by the worker. However, the development of machinery along this path occurs only when large industry has already reached a higher stage, and all the sciences have been pressed into the service of capital Invention then becomes a business, and the application of science to direct production itself becomes a prospect which determines and solicits it. But this is not the road along which machinery, by and large, arose, and even less the road on which it progresses in detail. This road is, rather, dissection [*Analyse*] – through the division of labour, which gradually transforms the workers’ operations into more and more mechanical ones, so that at a certain point a mechanism can step into their places.²⁹

Marx adopted Babbage’s theory also methodologically: in *Capital*, the chapter on machinery follows after the chapter on the division of labour. There a structural homology between the design of machinery and the division of labour is highlighted: ‘The machine is a mechanism that, after being set in motion, performs with its

tools the same operations as the worker formerly did with similar tools.³⁰ In a footnote Marx refers to Babbage's synthetic definition of machine ('The union of all these simple instruments, set in motion by a motor, constitutes a machine') and offers his own paraphrase:

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.³¹

It is at this point of *Capital* that Marx advances a further analytical principle that will have enormous influence on the methodology of the history of science and technology in the twentieth century.³² After challenging the belief that science, rather than labour, is the origin of the machine, Marx reverses the perception of the steam engine as prime catalyst of the Industrial Revolution. Marx contends that it is the growth of the division of labour, its tools and 'tooling machines', that 'requires a mightier moving power than that of man', a source of energy that will be found in steam.³³ It was not the invention of the steam engine (*means of production*) that triggered the industrial revolution (as it is popular to theorise in ecological discourse), but rather the developments of capital and labour (*relations of production*) demanding a more powerful source of energy.³⁴

The steam-engine itself, such as it was at its invention during the manufacturing period at the close of the seventeenth century, and such as it continued to be down to 1780, did not give rise to any industrial revolution. It was, on the contrary, the invention of [tooling] machines [*Werkzeugmaschinen*] that made a revolution in the form of steam-engines necessary.³⁵

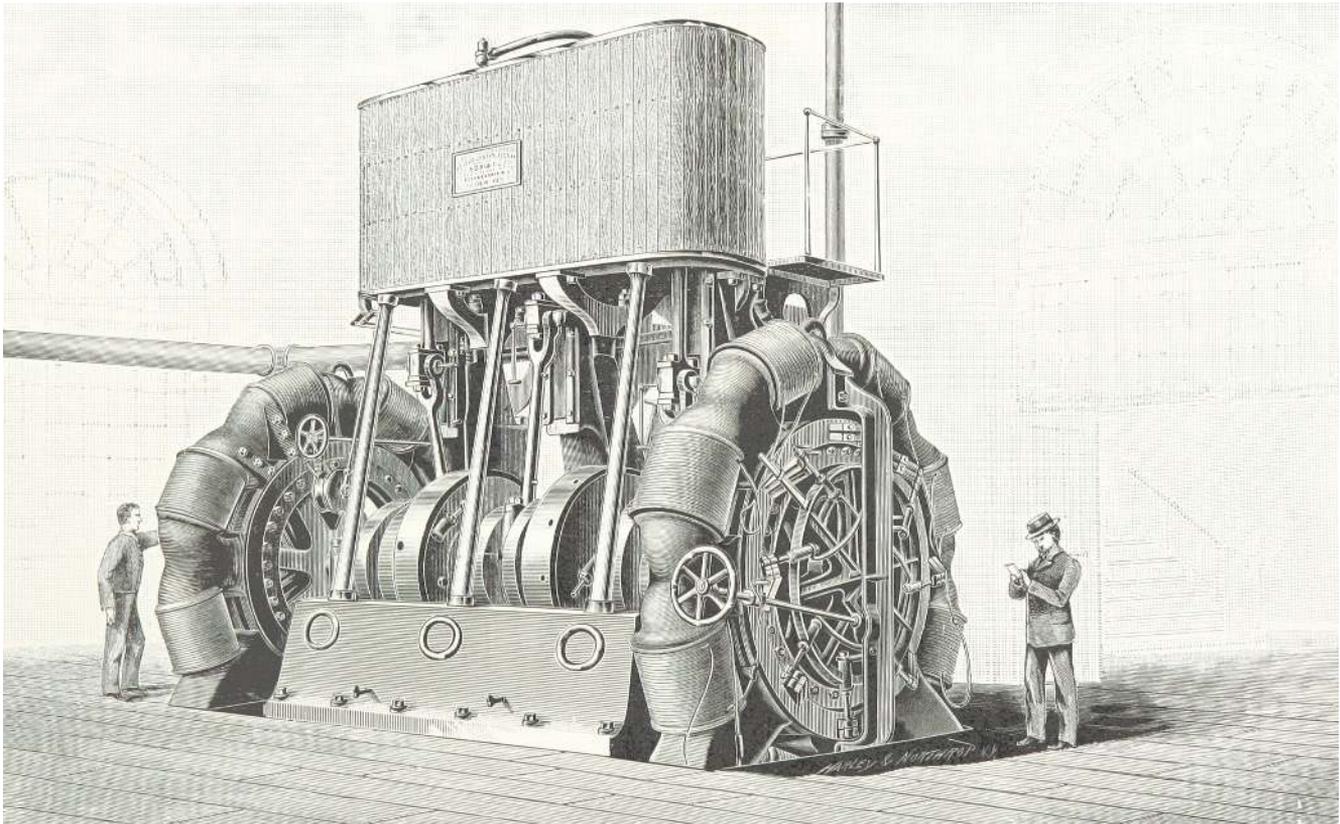
The 'mechanical monster' of the industrial factory was summoned first by labour and then accelerated by steam power, not the other way around.³⁶ Marx was clear: the genesis of technology is an *emergent process* driven by the division of labour. It is from the materiality of collective labour, from conscious and unconscious forms of cooperation, that extended apparatuses of machines emerge. Intelligence, here, resides in the ramifications of human cooperation rather than in individual mental labour. Machine intelligence mirrors, embodies and amplifies the analytical intelligence of collective labour.³⁷

The alienation of knowledge by machinery

'What distinguishes the worst architect from the best of bees is that the architect builds the cell in his mind before he constructs it in wax.'³⁸ This is Marx's recognition, in *Capital*, of labour as a mental and individual activity: the collective division of labour, or labour in common, however, remains the *political inventor* of the machine.³⁹ A process of alienation of skill and knowledge starts as soon as machinery appears in front and in place of labour. Tools pass from the hands of the worker to the hands of the machine, and the same process happens to workers' knowledge. 'Along with the tool, the skill of the worker in handling it passes over to the machine.'⁴⁰ The machine is but a crystallisation of collective knowledge. Marx condemns this alienation of the human mind, seconding Owen: 'Since the general introduction of soulless mechanism in British manufactures, people have with rare exceptions been treated as a secondary and subordinate machine, and far more attention has been given to the perfection of the raw materials of wood and metals than to those of body and spirit.'⁴¹ The introduction of machinery marks a dramatic dialectical turn in the history of labour, whereby the worker ceases being the *subject* of the machine and becomes the *object* of capital: 'The hand tool makes the worker independent – posits him as proprietor. Machinery – as fixed capital – posits him as dependent, posits him as appropriated.'⁴² This shift in power between human and machine in the Victorian age is also the inception of a new imagery, in which machines acquire features of the living and workers that of automata.⁴³ Let's compare two similar passages from the *Grundrisse* and *Capital*, respectively, in which Marx describes the alienation of science from workers.

[It] is the machine which possesses skill and strength in place of the worker, is itself the virtuoso, with a soul of its own in the mechanical laws acting through it The worker's activity, reduced to a mere abstraction of activity, is determined and regulated on all sides by the movement of the machinery, and not the opposite. 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.⁴⁴

This reflection on the alienation of knowledge from



workers continues in *Capital*, where Marx makes the process of knowledge extraction culminate in the full separation of science as productive agent from labour.

The knowledge, judgement and will which, even though to a small extent, are exercised by the independent peasant or handicraftsman, in the same way as the savage makes the whole art of war consist in the exercise of his personal cunning, are faculties now required only for the workshop as a whole. The possibility of an intelligent direction of production expands in one direction, because it vanishes in many others. What is lost by the specialised workers is concentrated in the capital which confronts them. It is a result of the division of labour in manufacture that the worker is brought face to face with the intellectual potentialities [*geistige Potenzen*] of the material process of production as the property of another and as a power which rules over him. This process of separation starts in simple co-operation, where the capitalist represents to the individual workers the unity and the will of the whole body of social labour. It is developed in manufacture, which mutilates the worker, turning him into a fragment of himself. It is completed in large-scale industry, which makes science a potentiality for production which is distinct from labour and presses it into the service of capital.⁴⁵

Marx comments upon the latter passage from *Capital*

with a footnote to William Thompson's book *An Inquiry Into the Principles of the Distribution of Wealth*. Thompson claims, as quoted by Marx:

'The man of knowledge and the productive labourer come 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 labour.' 'Knowledge' becomes 'an instrument, capable of being detached from labour and opposed to it.'⁴⁶

Thompson provided a definition of knowledge labour that predates the twentieth-century theorists of the knowledge society and cognitive labour: '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.'⁴⁷ Presciently, he recognized that the economy of knowledge follows different rules of diffusion than the economy of capital: '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.'⁴⁸ In a polemic typical of

Owenism, Thompson described machinery humiliating the ‘*general intellectual powers*’ of the workers reduced to ‘drilled automata’. The factory is 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’.⁴⁹ In different passages Thompson used the expressions ‘general intellect’, ‘general intellectual power’, ‘general knowledge’ and ‘general power of the minds’ (often in italics) in direct resonance with identical or equivalent terms used by Marx in the *Grundrisse*, such as ‘general social labour’, ‘general scientific labour’, ‘general productive forces of the human brain’, ‘general social knowledge’ and ‘social intellect’.⁵⁰ Importantly, as remembered in the opening quote, Thompson drew a direct link between the construction of a primarily white male general intellect and issues of gender and race discrimination. In Thompson’s utopian view, people are racist and chauvinist due to the lack of proper knowledge and education:

Why also, it may be asked in reply, has the slavery of the blacks, and of women, been established? Because the whites in the one case, because the men in the other, made the laws: because knowledge had not been obtained on these subjects, the whites and the men erroneously conceiving it to be their interest to oppress blacks and women.⁵¹

Marx, too, recognised the psychopathologies of industrial labour and the tactics to keep the workforce as illiterate as possible. Adam Smith’s mentor, Adam Ferguson, wrote: ‘Ignorance is the mother of industry as well as of superstition. Reflection and fancy are subject to err; but a habit of moving the hand or the foot is independent of either. Manufactures, accordingly, prosper most where the mind is least consulted, and where the workshop may ... be considered as an engine, the parts of which are men.’⁵² This all reminds us that the public mythology of artificial intelligence has always operated on the side of capital with a hidden agenda to foster human stupidity, including racism and sexism.

The devaluation of capital by knowledge accumulation

What is the economic value of knowledge and science? Which role do they play in capitalist accumulation? Marx

explored these questions in an age that was flourishing with mechanical ingenuity, technical intelligence and large infrastructures, such as railway and telegraph networks. In the passage on the general intellect Marx considered knowledge in three ways: first, as a ‘direct force of production’ [*unmittelbaren Produktivkraft*]; second, under the form of ‘social forces of production’ [*gesellschaftlichen Produktivkräfte*]; and, third, as social practice [*gesellschaftlichen Praxis*], which is obviously not abstract knowledge *per se*.

Nature builds no machines, no locomotives, railways, *electric telegraphs*, *self-acting mules* etc. These are products of human industry; natural material transformed into organs of the human will over nature, or of human participation in nature. They are *organs of the human brain, created by the human hand*; the power of knowledge, objectified. /The development of fixed capital indicates to what degree general social *knowledge* has become a *direct force of production*, and to what degree, hence, the conditions of the process of social life itself have come under the control of the *general intellect* and been transformed in accordance with it[s measure]. / To what degree the powers of social production have been produced, not only in the form of knowledge, but also as immediate organs of social practice, of the real life process.⁵³

The general intellect becomes a transformative agent of society in a way that clearly echoes Thompson’s optimism about the ‘distribution of knowledge’ as conducive to ‘voluntary equality in the distribution of wealth’. The ‘Fragment on Machines’ contains an unresolved tension between *knowledge objectified in machinery* (as ‘development of fixed capital’) and *knowledge expressed by social production* (as ‘development of the social individual’). Marx considers the primacy of knowledge in the production process and, then, the primacy of praxis over knowledge itself. The same thesis emerges in *Capital*, where Marx registers the stress of industrial labour on the workers’ nervous system. Marx compares the economic value of individual skill against that of science. The competition between the two is deemed unfair, since after a long process of ‘separation of the intellectual faculties’, the special skills of the worker vanish before the magnitude of the science, natural energy and social labour that animates machinery:

The separation of the intellectual faculties of the production process from manual labour, and the transformation

of those faculties into powers exercised by capital over labour, is ... finally completed by large-scale industry erected on the foundation of machinery. The special skill of each individual machine-operator, who has now been deprived of all significance, vanishes as an infinitesimal quantity in the face of the science, the gigantic natural forces, and the mass of social labour embodied in the system of machinery, which, together with those three forces, constitutes the power of the 'master'.⁵⁴

In the 'Fragment on Machines', we have not only the recognition of knowledge as an alien power embodied in machinery (as found in Thompson) but also the attempt to assess the magnitude of its valorisation (which is missing in Thompson). Here Marx uses a criterion to assess knowledge from the work of Thomas Hodgskin, a Ricardian socialist of libertarian tendency and a rationalist optimist 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 to be published as part of his book *Popular Political Economy* (1827). Marx often quoted this book and also praised his *Labour Defended Against the Claims of Capital* (1825). Hodgskin pits a positive emphasis on fixed capital as a concrete accumulation of past labour, knowledge and science, against the 'fiction' of circulating capital. In the *Grundrisse*, there is an echo of Hodgskin's ideas in Marx's claim that machinery is the 'most adequate form of fixed capital':

The accumulation of knowledge and of skill, of the general productive forces of the social brain, is thus absorbed into capital, as opposed to labour, and hence appears as an attribute of capital, and more specifically of fixed capital, in so far as it enters into the production process as a means of production proper. Machinery appears, then, as the most adequate form of fixed capital, and fixed capital ... appears as the most adequate form of capital as such.⁵⁵

Modernising the Baconian motto 'knowledge is power', authors of the industrial age such as Babbage, Thompson and Hodgskin argue that knowledge is without doubt a productive and economic force. Knowledge is so crucial to Hodgskin that he even complained that Adam Smith did not dedicate a proper treatment to the subject: '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.'⁵⁶

For Hodgskin, as much as for Thompson, labour is primarily mental labour, that is, knowledge. 'Mental labour' is 'the labour of observing and ascertaining by what means the material world will give us the most wealth'. 'Unless there be mental labour, there can be no manual dexterity; and no capability of inventing machines. It therefore is essential to production.'⁵⁷ Hodgskin relates the growth of knowledge to the material substrate of population growth: 'Necessity is the mother of invention; and the continual existence of necessity can only be explained by the continual increase of people.'⁵⁸ Population growth demands increased 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.'⁵⁹ But Hodgskin remarks that the economy of knowledge follows different laws than the economy of capital: 'the laws which regulate the accumulation and employment of capital are quite dissimilar to and unconnected with the laws regulating the progress of knowledge.'⁶⁰

Importantly, in Hodgskin's view of society, there are neither intellectual hierarchies, nor division of hand and mind, nor a labour aristocracy in need of promotion: 'both mental and bodily labour are practised by almost every individual.'⁶¹ In fact, Marx quotes Hodgskin in *Capital* to stress that skill is a common resource that is shared among workers and passes from one generation to the next.⁶² Knowledge is a power that is collectively produced and shared, and this power constitutes (together with machinery and infrastructures) the core of fixed capital that must be re-appropriated by workers (against the 'fiction' of circulating capital).⁶³

The most visionary passages of the *Grundrisse* refer to the crisis of capitalism due to the crisis of the centrality of labour, and therefore of the labour theory of value, which is to say, due to the fact that 'direct labour and its quantity disappear as the determinant principle of production ... compared to general scientific labour, technological application of natural sciences ... and to the

general productive force arising from social combination [*Gliederung*].⁶⁴ Further, says Marx:

Capital itself is the moving contradiction, [in] that it presses to reduce labour time to a minimum, while it posits labour time, on the other side, as sole measure and source of wealth. ... On the one side, then, it calls to life all the powers of science and of nature, as of social combination and of social intercourse, in order to make the creation of wealth independent (relatively) of the labour time employed on it. On the other side, it wants to use labour time as the measuring rod for the giant social forces thereby created, and to confine them within the limits required to maintain the already created value as value. Forces of production and social relations – two different sides of the development of the social individual – appear to capital as mere means, and are merely means for it to produce on its limited foundation. In fact, however, they are the material conditions to blow this foundation sky-high.⁶⁵

What looks like a contradiction in Marx's system (the obliteration of the political centrality of labour) is actually the consequence of such centrality. Everywhere in the world workers have been working enough! They have been producing so much and for so long that their past accumulated labour (under the forms of machinery, infrastructures and collective knowledge) affects the rate of profit and slows down the economy. This is the thesis of the productivity of labour pitted against the unproductivity of capital that is found specifically in Hodgskin's *Labour Defended Against Capital*. Marx tries to prove that the accumulation of fixed capital (as machinery, infrastructures, collective knowledge and science) could have profound side-effects on the side of circulating capital (beside the chance of an overproduction crisis). In the *Grundrisse* Marx explores the hypothesis that a growth of collective and technical knowledge could undermine capital's dominance, as Thompson and Hodgskin envisioned. The utopian enthusiasms of the *Grundrisse* are reabsorbed in *Capital* by a realistic calculation of relative surplus value, which is adopted as the metrics of machinery and implicit metrics of knowledge value as well.

The rise of the collective worker

In *Capital* Marx replies to the Machinery Question by casting an extended social actor, the collective worker (*Gesamtarbeiter*), at the centre of the industrial theatre,

whereas for the bourgeoisie it was an engineer with a steam engine. The figure of the collective worker replaces the personality cult of the inventor (individual mental labour) but also the idea of the general intellect (collective mental labour). Drawing on Babbage's labour theory of the machine, which explains the machine as the embodiment of the division of labour, Marx asserts the collective worker as the true *political inventor* of technology. The ambiguous hypothesis of the *knowledge theory of value* of the *Grundrisse*, is finally grounded on an empirical basis: intelligence is logically materialised in the ramifications of the division of labour. The collective worker is a personification of the general intellect and, precisely, of its mechanisation.

Marx follows closely Babbage's labour theory of the machine in both the *Grundrisse* and *Capital*, but only in the latter does he make use of Babbage's principle of surplus labour modulation, which helps Marx to sketch the concept of relative surplus value and to measure the productivity of labour and machinery. Babbage's principle as quoted by Marx is as follows:

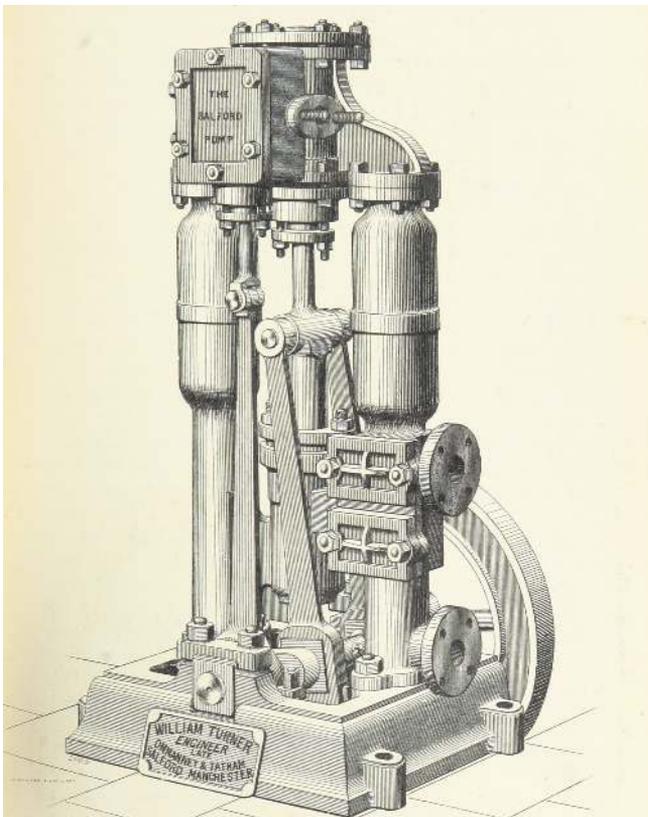
The master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious of the operations into which the art is divided.⁶⁶

Marx reverses the mystification of 'the master manufacturer' by restoring at the centre of the Babbage principle the collective worker who, needless to say, becomes now the main actor of the division of labour. The collective worker acquires features of a super-organism:

The collective worker, formed out of the combination of a number of individual specialized workers, is the item of machinery specifically characteristic of the manufacturing period. ... In one operation he must exert more strength, in another more skill, in another more attention; and the same individual does not possess all these qualities in an equal degree. ... After the various operations have been separated, made independent and isolated, the workers are divided, classified and grouped according to their predominant qualities. ... The collective worker now possesses all the qualities necessary for production in an equal degree of excellence, and expends

them in the most economical way by exclusively employing all his organs, individualised in particular workers or groups of workers, in performing their special functions.⁶⁷

In Marx's language the collective worker becomes an 'item of machinery', a 'social mechanism', a 'collective working organism'.⁶⁸ Vivid machinic metaphors accompany the reincarnation of the general intellect as collective worker. The prehistory of the cyborg can be read between the lines of *Capital*: 'The social mechanism of production, which is made up of numerous individual specialized workers, belongs to the capitalist. ... Not only is the specialised work distributed among the different individuals, but the individual himself is divided up, and transformed into the automatic motor of a detail operation.'⁶⁹



The 'Fragment on Machines' did not just emphasise the growing economic role of knowledge and science but also the role of social cooperation, that is, the growing role of the *general machinery* of social relations beyond the factory system. In a movement that resembles that of the construction of the *Gesamtarbeiter* within the factory, in the *Grundrisse* Marx sets 'the social individual ... as the great foundation-stone of production and of wealth' in the society to come:

[The worker] steps to the side of the production process instead of being its chief actor. In this transformation, it is neither the direct human labour he himself performs, nor the time during which he works, but rather the appropriation of his own general productive power, his understanding of nature and his mastery over it by virtue of his presence as a social body – it is, in a word, the development of the social individual which appears as the great foundation-stone of production and of wealth.⁷⁰

It seems that, with the transmutation of the general intellect into the collective worker, the prediction of capitalism's implosion due to the overproduction of knowledge as fixed capital is abandoned by Marx. Capitalism will no longer collapse due to the accumulation of knowledge, because knowledge itself helps new apparatuses to improve the extraction of surplus value. Michael Heinrich has noted that in *Capital* 'when dealing with the production of relative surplus value, we can find an implicit critique of the "Fragment on machines"'.⁷¹ In *Capital* Marx appears to employ Babbage's principle of the modulation of surplus labour to design a theory of relative surplus value that recognises capitalism's capacity to maintain exploitation in equilibrium. According to Marx, surplus value can be augmented not just by reducing wages and material costs but also by increasing the productivity of labour in general, that is, by redesigning the division of labour and machines. If, according to Babbage's principle, the division of labour is an apparatus to modulate regimes of skill and therefore different regimes of salary according to skill, the division of labour becomes a modulation of relative surplus value. Being itself an embodiment of the division of labour, the machine then becomes the apparatus to discipline labour and regulate the extraction of relative surplus value.⁷² As in Babbage's vision, the machine becomes a calculating engine – in this case, an instrument for the measurement of surplus value.

The machine is a social relation, not a thing

In the twentieth century Harry Braverman was probably the first Marxist to rediscover Babbage's pioneering experiments in computation and influence on Marx's theory of the division of labour.⁷³ Marx read Thompson, Hodgskin and Babbage, but never employed the notion of mental labour, probably in order to avoid supporting a labour aristocracy of skilled artisans as a political subject

separate from the working class. For Marx, labour is always collective: there is no individual labour that is more prestigious than others and, therefore, mental labour is always general; the mind is by definition social. Rather than a *knowledge theory of labour* that grants primacy to conscious activity, like the one in Thompson and Hodgskin, Marx maintains a *labour theory of knowledge* that recognises the cognitive import of forms of labour that are social, distributed, spontaneous and unconscious. Intelligence emerges from the abstract assemblage of workers' simple gestures and micro-decisions, even and especially the unconscious ones.⁷⁴ In the general intellect studies and the history of technology, these are the in-between worlds of collective intelligence and unconscious cooperation but also of 'mechanised knowledge' and 'mindful mechanics'.⁷⁵ It ends up being Babbage who provides Marx with an operative paradigm to overcome Hegel's *Geist* and imbricate knowledge, science and the general intellect into production.

As already stressed, the distinction between manual and mental labour disappears in Marxism because, from the abstract point of view of capital, all waged labour, without distinction, produces surplus value; all labour is abstract labour. However, the abstract eye of capital that regulates the labour theory of value employs a specific instrument to measure labour: the clock. In this way, what looks like a universal law has to deal with the metrics of a very mundane technology: clocks are not universal.⁷⁶ Machines can impose a metrics of labour other than time, as has recently happened with social data analytics. As much as new instruments define new domains of science, likewise they define new domains of labour after being invented by labour itself.⁷⁷ Any new machine is a new configuration of space, time and social relations, and it projects new metrics of such diagrams.⁷⁸ In the Victorian age, a metrology of mental labour existed only in an embryonic state. A rudimentary econometrics of knowledge begins to emerge only in the twentieth century with the first theory of information. The thesis of this text is that Marx's labour theory of value did not resolve the metrics for the domains of knowledge and intelligence, which had to be explored in the articulation of the machine design and in the Babbage principle.

Following Braverman and Schaffer, one could add that Babbage provided not just a labour theory of the machine but a *labour theory of machine intelligence*.⁷⁹

Babbage's calculating engines ('intelligent machines' of the age) were an implementation of the analytical eye of the factory's master. Cousins of Bentham's panopticon, they were instruments, simultaneously, of surveillance and measurement of labour. It is this idea that we should consider and apply to the age of artificial intelligence and its political critique, although reversing its polarisation, in order to declare computing infrastructures a concretion of labour in common.⁸⁰

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Notes

1. The author would like to thank Henning Schmidgen, Jon Beller, Max Stadler, Manuel Disegni, Wietske Maas, Ariana Dongus, Sami Khatib, Jason King and Ben Seymour for their comments and feedback on this essay.
2. 'Even though Heath was satirising the movement, his posters include some wonderful future ideas for transport, including a steam horse and a steam coach, a vacuum tube, a bridge to Cape Town, and various forms of flight, including a flying postman.' Mike Ashley, 'Inventing the Future', British Library blog, 15 May 2014, www.bl.uk/romantics-and-victorians/articles/inventing-the-future.
3. See Don Herzog, *Poisoning the Minds of the Lower Order* (Princeton: Princeton University Press, 2000).
4. Ashley, 'Inventing the Future'.
5. See Michael Hancher, 'Penny Magazine: March of Intellect in the Butchering Line', in *Nineteenth-century Media and the Construction of Identities*, eds. Laurel Brake, Bill Bell and David Finkelstein (London: Palgrave, 2016), 93.
6. Author unknown, *The London Magazine*, April and June 1828 issues. See opening quote.
7. Karl Marx, *Grundrisse der Kritik der politischen Ökonomie* (Moscow: Verlag für fremdsprachige Literatur, 1939); *Grundrisse: Foundations of the Critique of Political Economy*, trans. Martin Nicolaus (London: Penguin, 1993).
8. 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, 1824).
9. Thomas Hodgskin, *Popular Political Economy: Four lectures delivered at the London Mechanics Institution* (London: Tait, 1827). Charles Babbage, *On the Economy of Machinery and Manufactures* (London: Charles Knight, 1832).
10. Edward Royle, 'Mechanics' Institutes and the Working Classes, 1840-1860', *The Historical Journal* 14:2 (June 1971).
11. In *Capital* Marx refers to Wilhelm Schulz's distinction between tool and machine, yet without commenting on Schulz's account of 'mental production' (*geistige Produktion*) from *Die Be-*

wegung der Produktion (Zurich, 1843). He adds: 'in many respects a book to be recommended'. Karl Marx, *Das Kapital. Kritik der politischen Ökonomie*, vol. 1 (Hamburg: Meissner, 1867); *Capital: A Critique of Political Economy*, vol. 1, trans. Ben Fowkes (London: Penguin, 1981), 493. See Walter Grab, *Dr. Wilhelm Schulz aus Darmstadt. Weggefährte von Georg Büchner und Inspirator von Karl Marx* (Frankfurt am Main: Gutenberg, 1987). Thanks to Henning Schmidgen for this reference.

12. Karl Marx and Friedrich Engels, *Die deutsche Ideologie* (1846) (first edition: Moscow: Marx-Engels Institute, 1932); *The German Ideology*, ed. C.J. Arthur (New York: International Publishers, 1970). But argument against Malthusian logic (on the process, a

13. In the nineteenth century, physiologists and political economists tried to figure out a 'metrology' of 'cerebral labour': according to Schaffer, the attempts to quantify intelligence with the aid of instruments contributed to the project of artificial intelligence in the following century. See Simon Schaffer, 'OK Computer', in Michael Hagner, ed., *Ecce Cortex: Beiträge zur Geschichte des modernen Gehirns* (Göttingen, Wallstein Verlag, 1999), 254–85.

14. This visionary hypothesis did not emerge again in *Capital*, again as a result of historical circumstances. Notebooks 6 and 7 were written in the winter 1857–1858, amid a financial crisis, whereas *Capital* was published after the crisis was over.

15. The primary sources of the complex debate on Marx's general intellect can be succinctly reconstructed as follows: Paolo Virno, 'Citazioni di fronte al pericolo', *Luogo comune* 1 (November 1990); translated as 'Notes on the general intellect', trans. Cesare Casarino, in *Marxism beyond Marxism*, eds. Saree Makdisi et al. (New York: Routledge, 1996), 265–272. Christian Marazzi, *Il posto dei calzini. La svolta linguistica dell'economia e i suoi effetti sulla politica* (Torino: Bollati Boringhieri, 1994); translated as *Capital and Affects: The Politics of the Language Economy*, trans. Giuseppina Mecchia (New York: Semiotexte, 2011). Maurizio Lazzarato and Antonio Negri, 'Travail immatériel et subjectivité', *Futur antérieur* 6 (1991), 86–99. Paolo Virno, *Grammatica della Multitudine* (Rome: Derive Approdi, 2002); translated as *A Grammar of the Multitude*, trans. Isabella Bertolotti et al. (New York: Semiotexte, 2004). Carlo Vercellone, 'From formal subsumption to general intellect: Elements for a Marxist reading of the thesis of cognitive capitalism', *Historical Materialism* 15:1 (2007), 13–36. Probably the first reception of this debate in English is Nick Dyer-Witheford, *Cyber-Marx: Cycles and Circuits of Struggle in High-Technology Capitalism* (University of Illinois Press, 1999). See also, of course, Michal Hardt and Antonio Negri, *Empire* (Cambridge, MA: Harvard Univ. Press, 2000). For a critique of *operaismo's* interpretation, see Michael Heinrich, 'The Fragment on Machines: A Marxian Misconception in the *Grundrisse* and its Overcoming in *Capital*', and Tony Smith, 'The General Intellect in the *Grundrisse* and Beyond', in *In Marx's Laboratory: Critical Interpretations of the Grundrisse*, eds. Riccardo Bellofiore et al. (Leiden: Brill, 2013), 195–212 and 213–231.

16. See Paul Mason, 'The end of capitalism has begun', *The Guardian*, 17 July 2015, and Paul Mason, *Postcapitalism: A Guide to Our Future* (London: Macmillan, 2016). See also MacKenzie Wark,

General Intellects (London: Verso, 2017).

17. Martin Nicolaus, 'Foreword', in Marx, *Grundrisse*, 7.

18. Marcello Musto, 'Dissemination and reception of the *Grundrisse* in the world', in *Karl Marx's Grundrisse*, ed. Marcello Musto (London: Routledge, 2008), 207–216.

19. Karl Marx, 'Frammento sulle macchine', trans. Renato Solmi, *Quaderni Rossi* 4 (1964).

20. Herbert Marcuse, *One Dimensional Man* (Boston: Beacon Press, 1964), 39.

21. Gilles Deleuze and Félix Guattari, *Anti-Oedipus: Capitalism and Schizophrenia*, vol. 1, trans. Robert Hurley et al. (Minneapolis: University of Minnesota Press, 1983), 232, n. 76. See also Matteo Pasquinelli, 'Italian Operaismo and the Information Machine', *Theory, Culture & Society* 32:3 (2015).

22. Karl Marx, 'Notes on Machines', *Economy and Society* 1:3 (1972), 244–254.

23. Virno, 'Notes', 265.

24. Wolfgang Fritz Haug has warned that the nebulous origins of the general intellect contributed to a sloganistic use 'at the cost of theoretical arbitrariness'. The general intellect belongs, Haug asserts, to a galaxy of similar Marxian terms to be taken into consideration, such as 'general social labour', 'general scientific labour', 'accumulation of knowledge and of skill, the general productive forces of the human brain', 'general progress', 'development of the general powers of the human head', 'general social knowledge', 'social intellect'. See Wolfgang Fritz Haug, 'Historical-Critical Dictionary of Marxism: General Intellect', *Historical Materialism* 18:2 (2010), 209–216.

25. Virno, 'Notes'.

26. Babbage, *On the Economy of Machinery*, vi.

27. Simon Schaffer, 'Babbage's Intelligence: Calculating Engines and the Factory System', *Critical Inquiry* 21:1 (1994), 203–227.

28. Babbage, *On the Economy of Machinery*, as quoted in Karl Marx, *The Poverty of Philosophy*, trans. Harry Quelch, in *Marx-Engels Collected Works*, vol. 6 (New York: International Publishers, 1976). Marx translated Babbage from French.

29. Marx, *Grundrisse*, 704.

30. Marx, *Capital*, 495.

31. *Ibid.*, 497.

32. See Gideon Freudenthal and Peter McLaughlin, eds. *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann* (Springer Science & Business Media, 2009).

33. 'An increase in the size of the machine and the number of its working tools calls for a more massive mechanism to drive it; and this mechanism, in order to overcome its own inertia, requires a mightier moving power than that of man' (Marx, *Capital*, 497).

34. Marx is mistakenly considered a *techno-determinist* for the prominence he grants to machinery in capitalism, but if he is determinist at all, he is a determinist of the *relations of production* and not of the *means of production*, as the division of labour, and not technology, is the driving force of capital. 'The inclusion of labor power as a force of production thus admits conscious human agency as a determinant of history: it is people, as much as or more than the machine, that make history.' Donald MacK-

- enzie, 'Marx and Machine', *Knowing Machines* (Cambridge, MA: MIT Press, 1998), 26.
35. Marx, *Capital*, 496.
36. *Ibid.*, 507.
37. For the idea of analytical intelligence see Lorraine Daston, 'Calculation and the Division of Labour, 1750–1950', *Bulletin of the German Historical Institute*, 62 (after being invented by labour itself intelligence that links them well, I think) (Spring), 9–30.
38. Marx, *Capital*, 284.
39. Hodgskin gave great importance to observation (i.e. mental design) in the invention of machinery.
40. Marx, *Capital*, 545.
41. Robert Owen, 'Essays on the Formation of the Human Character' (London, 1840). As quoted in Marx, *Grundrisse*, 711.
42. Marx, *Grundrisse*, 702. Marx quotes Hodgskin also at 709: 'As soon as the division of labour is developed, almost every piece of work done by a single individual is a part of a whole, having no value or utility of itself. There is nothing on which the labourer can seize: this is my produce, this I will keep to myself' (*Labour Defended*, 25, 1, 2, XI).
43. Simon Schaffer, 'Babbage's Dancer and the Impresarios of Mechanism', in *Cultural Babbage*, eds. Francis Spufford and Jenny Uglow (London: Faber & Faber, 1997), 53–80.
44. Marx, *Grundrisse*, 692–93.
45. Marx, *Capital*, 482.
46. *Ibid.*, 483. Thompson, *Principles of the Distribution of Wealth*, 274.
47. Thompson, *Principles of the Distribution of Wealth*, 272.
48. *Ibid.*, 274–290.
49. *Ibid.*, 292.
50. *Ibid.*, 272–362.
51. *Ibid.*, 303.
52. Ferguson as quoted by Marx in *Capital*, 483. Marx cites Ferguson also for recognising as early as 1767 that 'thinking itself, in this age of separations, may become a peculiar craft'. Marx, *Capital*, 484.
53. Marx, *Grundrisse*, 706. The terms marked by asterisks appear in English in the original manuscript.
54. Marx, *Capital*, 549.
55. Marx, *Grundrisse*, 694.
56. Hodgskin, *Popular Political Economy*, 97.
57. *Ibid.*, 45, 47.
58. *Ibid.*, 86. This is clearly an anti-Malthusian argument. See Malthus' elitist account of knowledge in 'An Essay on the Principle of Population' (1798).
59. Hodgskin, *Popular Political Economy*, 95.
60. *Ibid.*, 78.
61. *Ibid.*, 47.
62. 'Easy labour is transmitted skill.' *Ibid.*, 48.
63. 'Hodgskin called circulating capital a "fiction". Fixed capital was the stored-up skill of past labour'. Maxine Berg, *The Machinery Question and the Making of Political Economy* (Cambridge: Cambridge University Press, 1980), 274.
64. Marx, *Grundrisse*, 700.
65. *Ibid.*, 706.
66. Marx, *Capital*, 469. The Penguin edition wrongly says 'Ch. 19, pp. 175' of Babbage's book: it is chapter 18, page 137.
67. Marx, *Capital*, 468–69.
68. See Henning Schmidgen, '1818: Der Frankenstein-Komplex', afterword to Bruno Latour, *Aramis: oder Die Liebe zur Technik*, trans. Gustav Roßler (Heidelberg: Mohr Siebeck, 2018), 303–319.
69. Marx, *Capital*, 481.
70. Marx, *Grundrisse*, 705.
71. Michael Heinrich, 'The Fragment on Machines', 197.
72. 'One great advantage which we may derive from machinery is from the check which it affords against the inattention, the idleness, or the dishonesty of human agents.' Babbage, *On the Economy of Machinery*, 54.
73. Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (New York: Monthly Review Press, 1974).
74. For the notion of micro-decision, see Romano Alquati, 'Composizione organica del capitale e forza-lavoro alla Olivetti', Part 2, *Quaderni Rossi* 3 (1963); partially translated in Matteo Pasquinelli, 'Italian Operaismo and the Information Machine', *Theory, Culture & Society* 32:3 (2015), 55.
75. What in the following century will become the core of operationalism: management, logistics and computer science. See Sandro Mezzadra and Brett Neilson, *The Politics of Operations: Excavating Contemporary Capitalism* (Durham: Duke University Press, 2019).
76. See Antonio Negri, *Time for Revolution* (London: Continuum, 2003), 27.
77. See Peter Damerow and Wolfgang Lefèvre, 'Tools of Science', in *Abstraction and Representation: Essays on the Cultural Evolution of Thinking*, ed. Peter Damerow (Dordrecht: Kluwer, 1996), 395–404.
78. The idea that each machine establishes its own labour unit of measure constitutes a *machine theory of labour* which cannot be expanded here.
79. See Schaffer, 'Babbage's Intelligence'.
80. See Antonio Negri, 'The Re-Appropriation of Fixed Capital: A Metaphor?', in *Digital Objects, Digital Subjects*, eds. David Chandler and Christian Fuchs (London: University of Westminster Press, 2019), 205–214; and Fredric Jameson, *An American Utopia: Dual Power and the Universal Army* (London: Verso, 2016).