

# **Labor, Machines and Energy in Capital's Ecology: The Case of Artificial Intelligence**

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## *Introduction: living and dead labor*

“The articulation between living labor and dead labor is the condition upon which the capitalist system of production is maintained.”  
Ricardo Antunes (2018: 97)

Capital is famously resilient in the face of crisis. When profits fall, it excels at finding new ways of cutting labor costs, securing subsidies and bailouts from the state, threatening workers, dreaming up new financial instruments, assimilating fresh frontiers where cheap resources can be extracted, managing the resulting resistance, and creating new commodities whose sale promises to mitigate problems the old ones caused. Not only has capital survived numerous crises, such as those of 1550-1700, the late 1700s, the 1930s and the 1970s. Today, top capitalists have managed to annex a bigger share of world economic wealth than ever before (Oxfam International 2026).

But capital's crises are resilient too. They come back again and again because they are built into the process of capital accumulation itself. As Karl Marx wrote in 1881, capital accumulation is a series of “antagonisms, crises, conflicts and disaster” that has “unveiled its purely transitory character to all except those who have an interest in remaining blind” (Shanin 1983: 102). To put it another way, the machinery of profit is always undermining its own foundations. That necessitates recurring scrambles to find new ones – which it likewise progressively degrades (Moore 2022).

This contradiction goes by many names. Marx (1990 [1867]) referred to a running opposition between “living” and “dead” labor – between the activities of humans, full of “vital force”, “will”, “bodily subjectivity”, “form-giving fire”, “self-negating capacity” and the swift, repetitive routines of machines in which past labor was “congealed” or “crystallized.” Marx saw the two as yoked together in industrial capital yet irredeemably at odds. Machines helped control, reorganize, recruit and regiment workers' actions and speed up the production and circulation of the commodities that they were made to need for survival. Yet profits couldn't be made without finding more and more dependent, living human workers to work the new machines and correct their problems. Far from machines decreasing human toil, they expanded its range, “spreading the wage labor relation throughout the world” (Huber 2009) – not to mention the master-slave relation (Fiori 2020). As will be argued below, this dynamic is being repeated with artificial intelligence (AI). What has traditionally been called “automation,” write Hamid Ekbia and Bonnie Nardi (2017), is an unstable amalgam better deserving the name “*heteromation*,” involving machines and humans in ever-changing interactions (see also Gray and Suri 2019; Collins and Kusch 1998).

The amalgam is unstable partly because industrial machines owned by capital have an inherent tendency to interfere with the “life of labor-power, in the same way as a greedy farmer snatches more produce from the soil by robbing it of its fertility” (Marx 1990 [1867]: 376). Humans have customarily returned the favour by wrecking machines or messing with their operations in less visible ways (Merchant 2024; McKittrick 2016). Hence when capital tries to recover from crisis by combining new machines with new initiatives to plunder and degrade the nature that is required to run them (including human nature), the solution is always temporary (Moore 2011; see also

Mitchell 2000: 303). That has made it repeatedly necessary for capital to look for fizzy new frontiers of life when old ones go flat (Colatrella 2002: 39-40; Malm 2012; Perelman 2000) – or at least to try to revive or tolerate the encystment of some “terrain[s] of non-market relations” within range of its power (Lapavistas, 2003: 42-5). For example, soil-degrading Caribbean plantation regimes would be unlikely to have functioned without slave gardens acting as internal refugia for a billion-year heritage of soil fertility (Carney 2000). Capital “draws its lifeblood from uncommodified life-activity” in its environs (Moore 2015: 19). Its machinery is like a vampire in that it “lives only by sucking living labor, and lives the more, the more labor it sucks” (Marx 1990 [1867]).

It isn’t exactly a recipe for sustainability. Where do vampires go once they have bitten everybody on the planet? Profit is always on the point of falling as the number of unbitten blood donors dwindles. Eras of high productivity regularly slump into periods of what Moore calls “falling ecological surplus.” There can be no such thing as a globally “circular”, “steady-state”, “no-growth” “self-sustaining” or “green” capitalist economy. Efficiency is no road to dematerialization (Polimeni, Mayumi, Giampetro et al. 2008). “Internalization” must always be accompanied by fresh “externalization.” Such expanding, seasick oscillations can’t go on forever. Contemporary capitalist icons such as Jeff Bezos and Elon Musk are in full agreement with many of their Marxist critics that the logic of capital will ultimately require the abandonment of the earth itself as a matrix for accumulation (Asher Hamilton 2019, Tangermann 2025, Bezos 2019).

In fleshing out this theme, this chapter aims to update Marx’s notions of living and dead labor to illuminate the triple theme of this book (capitalism, nature and sustainability). It will use the example of AI to help explicate the enduring contradiction between the two at the same time it uses them to help explain the contradictions of AI.

The argument is structured as follows. The next section unpacks three key features of living labor (animate movement, rhythms and rules), using materials from contemporary research in biology, archaeology, robotics, music, philosophy, history, anthropology, psychology, linguistics and other fields. The following section turns to dead labor. It enlists Marxian explorations of thermodynamics and history in order to understand the actions of digital and other industrial machines in terms of the incessant reorganizations of the world energy landscapes that they rely on. The next section applies the analysis to spell out why the example of AI helps illuminate broader questions about capitalism, nature and sustainability, and vice versa. The concluding section draws the lesson that the category of “life” needs to be given more careful political attention in efforts to understand the history of environmental crisis.

## *What Underpins Living Labor?*

### Movement

“There is in fact no position that the body is *in* in walking any more than there is a position that the wind is *in* in blowing, or that a wave is *in* in rolling forward.”  
Maxine Sheets-Johnstone (2009: 274).

What does the living labor of humans provide to capital that the dead labor of machines can’t? Karl Marx was partial to phrases like “vital force,” “will” and “form-giving fire.” Today there may be better ways of making the distinction – or at least ones less redolent of vitalism. Perhaps the most

fundamental come out of the energetics of life, a field pioneered by figures such as Erwin Schroedinger (1944) and Ilya Prigogine (1997).

The first ecological lesson of this growing body of theory is that workers are *dissipative structures* (Smithers 2000) while machines are not. What that means is that living laborers, unlike machines, can exist only by staying a long way from thermodynamic equilibrium with their surroundings. They can fulfill their role in accumulation only by “maintaining their low entropy by increasing the entropy of the surroundings” (Lane 2015). That can happen only via constant energy fluxes and a whole hive of long-evolved internal entropy rate-modifying respiratory chains including protons flowing back and forth across baroque membrane structures and electrons hopping from one redox centre to another using quantum means. Movement that brings food across the boundary of the organism is of course central, whether it is the whole-body movement of the organism relative to its environment or movement of the environment around the whole body of the organism.

Industrial machines such as computer processors, on the other hand, need neither movement nor complicated biochemical mechanisms in order to exist. Even then they are in motion or accumulating corrosion on their surfaces, their identity is compatible with achieving thermodynamic equilibrium with their surroundings. The internal and external entropy differentials that they require if they are to function for capital can be created only when humans hook them up to energy sources, turn them on, and carefully maintain them. That presupposes an ongoing process of restructuring and devaluing surrounding living landscapes into moving, entropic frontiers organized around the political subordination of previously incommensurable energies of the commons into the abstract or omnibus imperial energy developed during the 19<sup>th</sup> century (Lohmann 2025). This is a theme explored further in “What Structures Dead Labor?” below.

To be classified as “living,” then, labor has to have become able, through hundreds of millions of years of biological evolution, to self-organize at every moment a thermodynamic boundary between an “inside” and an “outside” with which it is nevertheless in constant interaction. It has to keep structuring and restructuring itself to survive and maintain its own homeostasis. Crudely parallel boundaries can be created for machines – in particular energy conversion devices like steam or internal combustion engines – but only when people external to them do the organizing from without. This is to update into contemporary thermodynamic terms a distinction dating back several centuries (Riskin 2016).

One consequence is that the movements of workers, unlike those of machines, are everywhere distinguished by *proprioception*, or a built-in sense of one’s own body’s position, movements and orientation in relation to its surroundings. Animate self-movements of this kind, obvious in vertebrates and arthropods but also present even in single-celled motile organisms such as stentors, have been argued to be fundamental to the evolution of hominin cognition, language, mind, and value (Sheets-Johnstone 2005, 2009; Rosch 1991: xxxviii).

The ability to make this class of purposive movements has been selected for by evolutionary conditions of unpredictability. One basic type of unpredictability has been spelled out in formal terms by the theoretical physicist Michael Berry (1978). His thesis can be stated using the humdrum Newtonian illustration of colliding billiard balls. Knowing approximately what will happen when one ball strikes another on the pool table takes little effort. But anticipating what will happen after the eighth hit already requires taking account of the “gravitational pull of someone standing next to the table,” while calculating the results of the 56<sup>th</sup> impact would mean figuring out the position of an “electron at the edge of the universe, separated from us by 10 billion light-years” (Taleb 2007: 178). No hard and fast cutoff point exists after which such predictions become impossible. That depends on how big your data set is, how good your predictive algorithms, and how much energy is

available to run your computer processors. The point is that no competitive billiards player or other worker has evolved to be able to make this kind of prediction. Indeed, if such abilities were necessary for life, living labor and capital accumulation alike would be impossible.

A further dimension of unpredictability is added when the habitats in question include other living beings. Lionesses working together on the hunt or birds moving around on a swaying twig to accommodate each other have to be able to sense one another's intentions as well as those of their prey. So too do truck drivers need to be able to read the eyes of other drivers about to cut them off; symphony musicians to anticipate the movements of soloists and conductors; and religious or political leaders to know what "response" their hearers will give to the "call" that they offer (Wynter n.d.: 845). To use Sheets-Johnstone's terminology, one reason why the ability to move around in real-life environments that is shared by laborers and other social animals resists programming is that it has evolved to be *intercorporeal* (2009: 329-30). Hence the weaknesses of the view espoused by both leftist thinkers such as Mauricio Lazzarato (2014: 89) and far-right AI ideologues such as Elon Musk that lowly labor skills of attention, perception and reaction involved in activities like driving can theoretically become enclosed in machinic apparatuses driven by predictive algorithms, fast processors and abstract energy (see "What Structures Dead Labor?" below). Basic work skills like driving, changing diapers, or folding sheets with a partner are available for capital to exploit only because of the biosocial evolution of improvisation abilities over tens or hundreds of millions of years in a world that combines unpredictability with predictability. This is why capital's continual grabs of living labor power constitute an ecological appropriation parallel in magnitude to its grabs of the petroleum, timber, soil or iron ore that are also part of the common heritage bestowed on today's human beings by earth's deepest past.

## Rhythm

"Marx insists on the transformation of brute nature through human work, through technology and inventions, through labor and consciousness. Yet he doesn't discover rhythms."  
Henri Lefebvre (2013 [1992])

If animate organisms have to be ready for the unforeseen, they also have to organize themselves around certain kinds of sameness, constancy and cyclicity: the repeating patterns of the seasons, the day, the tides, the built environment, their own well-established metabolic pathways; the symmetries of physics and their associated conservation laws; even the behavior of new machines.

The very bodies of living beings are structured in regular ways. Babies are bilateral. When learning to walk, they have to work out how to keep alternating one foot with the other in "a controlled way of falling" (Viveires de Castro 2004: 3). While toddlers' efforts at locomotion might be in halting 2/4 time, the 5/4 or 7/4 rhythms followed by extraterrestrial starfish or alien heptapods (Chiang 2002) would likely be no less repetitive.

One challenge in updating Marx's concept of living labor lies in pinning down precisely what *kind* of repetitive whole-body movement humans need to survive, flourish and be employable by capital in a world that is nonetheless irregular. Here modern students of labor tend to be at a disadvantage because they are so often entranced or confused by the historically late-arriving example of the regular motions of idealized machines in controlled, predictable environments (Daston 2022).

Even some of the most strikingly independent thinkers of the machine age, like the early Soviet psychologist Nikolai Bernstein (1967), the French sociologist Henri Lefebvre (2013 [1992]), or the

British anthropologist Tim Ingold (2006), have generally had to make an *effort* to (re)learn and express the fact that human repetitions are wholly different from, and historically and evolutionarily prior to, the much narrower class of machine repetitions. Many modern music students have to make an equivalent effort to overcome the entrenched pedagogical doctrine that defining a regular beat must be the prerogative of the metronome (an invention of the early industrial era) rather than of the skilled, biological body in self-movement among others (Ito 2015, Havas 2003, Danielsen 2019). Most contemporary political and IT pundits on both left and right find it almost impossible to shake themselves free of the modern false dichotomy between machinic (blue-collar, “bodily,” “material,” “routine”) technique and “imaginative” (white-collar, symbolic, cognitive, mental, “immaterial”) improvisation (Iyer 2016).

This false dualism was already present in its embryonic Cartesian form in early colonial propaganda that “elevated managers (‘thinking substances’) from the riff-raff of ‘extended substances’” (Moore 2022: 7; see also Braverman 1974: 79) such as slaves and other workers. But it was during the Industrial Revolution’s efforts to rejigger the division of labor that the campaign to associate the biological body with the “automatism demanded by capitalist work discipline” (Federici 2004: 140) really went live (Ingold 2007: 127). The 19th-century AI pioneer Charles Babbage (Schaffer 1994), together with predecessors such as Andrew Ure and successors such as Etienne-Jules Marey and Frederick Winslow Taylor (Rabinbach 1990) and, later on, Alan Turing, were among the intellectuals who helped cement this association into the common sense of the educated public. As mentioned in the last section, even many thinkers on the contemporary left continue to assimilate the movements of, say, auto assembly workers, Amazon warehouse associates, surgeons, metal punchers, software engineers or copy machine repairers to the motions of the machines that they work with, or to suggest that the one can some day replace the other. The same fallacy keeps popping up in contemporary AI hype, which attempts to float the idea that merely by “scaling up” (Hao 2025) the number of repetitive electromechanical motions that computer processors make using increased inputs of abstract energy, those motions will one day transform themselves into the equivalents of the repetitive self-movements of a living dissipative structure striving to “preserve the integrity of its boundaries while having constant interchange with the environment” (Rosch 2017 [1991]).

It’s all the more important, then, to try to articulate various points of difference between repetitive human and repetitive machine movements. One is that repeated human motions are what the roboticist Tim Smithers (1998) calls *in time*, whereas repeated machine motions are *over time*. With living things, the time taken for a process matters to its structure and outcome. Humans can’t walk, speak, sing, weave, calculate, translate (Liu 2019), diagnose or work 100 times faster or slower than they do, any more than the soil that Marx referred to in *Capital* can accelerate 100 times the repetition-filled biochemical and ecological interactions that make it fertile enough to sustain human life. Machine movements, on the other hand, can in theory be speeded up or slowed down indefinitely while remaining the same movement and issuing in the same commodity. For instance, the “temporality of a computational process” is “theoretically immaterial” to the result of that process (Iyer 2004: 161). It’s irrelevant to an algorithm how quickly an assembly of computer chips can run through its steps.

To take another example, the regularity of the motions of a carpenter wielding a hand saw differ in kind from the regularity of the motions of a mechanical rotary saw (Ingold 2006). While each of the virtuoso carpenter’s strokes is the same, it is also *not* the same (Bernstein 1967). It involves “repetition without repetition” (Ito 2015). To make sure of doing the “same” thing with every stroke, the carpenter will also have to do something different – for instance, to vary the point she starts her upstroke from depending on workshop circumstances, to adjust her balance in accord with her body’s physiological endurances, to correct for the slight inaccuracy of her last stroke, even to

perceive the board that she is sawing differently (Gibson 1979). Force, amplitude, speed and torque will have to vary from stroke to stroke, as will the carpenter's posture (Ingold, 2006: 74), which depends on uninterrupted proprioception. All such activities are full of "differences induced or produced by repetition" (Lefebvre 2013 [1992]).

By the same token, babies don't learn the repeated, symmetrical motions of walking on the vast, polished floors of gymnasiums or airports, however much they may later delight in the novel freedom of movement afforded by such quasi-Cartesian surfaces. Like the adults they become, and like their evolutionary forebears, they face irregular terrains and unforeseeable interruptions from the jump (Smithers 2000; Sheets-Johnstone 2009). Unpredictability is their natural habitat. Flexibility and improvisation is their response. Intelligence and skill is the result. Children can learn to walk like machines only *after* they learn to walk like humans. Robot impersonation is a painstakingly-acquired speciality of little interest to capital other than as entertainment. It is useful neither for life nor assembly lines nor capital accumulation. Similarly, metronomes or click tracks become useful devices for music students only long *after* they have first displayed, as prelinguistic babies, the foundational ability to keep the social beat with their little feet, legs and arms. In short, the regularity of the movements peculiar to living labor cannot evolve within the isolation of machine environments but only in an unpredictable wider socionatural world and its multidimensional, long-evolved "taskscape" (Ingold 2000), where what archaeologists have referred to as pre- and post-linguistic "rehearsal loops" have become active (Tomlinson 2015).

In these taskscapes, self-movements tend to get "chunked" into precursors of what the Soviet psychologist A. R. Luria (1973) referred to as "kinetic melodies" (see also Sheets-Johnstone 2009: 253-277). An elementary schoolchild from Massachusetts put it well during a profound discussion about ways of notating musical meter with the educator Jeanne Bamberger (1991: 61): "You can't put the [musical] piece on the beat, you have to find the beat *in* the piece." Lefebvre's "differences within repetition" can be found only in beings primed to respond to vast ranges of contexts with variations on sequences of individually diverse elements.

Henri Lefebvre (2013 [1992]) and Tim Ingold (2006) encapsulate the point by noting that while machines move repetitively, it is only living beings that have *rhythm*. One corollary of this view, developed in the next section, is that only living entities have skills. It is partly because the differences between animate and machine repeated movements have become so obscured in modern European culture (Daston 2022) that it has become difficult even to formulate the truths that power looms cannot weave, metronomes cannot keep a beat, and, as Wittgenstein once remarked, apparently to the great consternation of Alan Turing, computers cannot calculate or learn (Shanker 1998; see also Collins 1990 and Collins and Kusch 1998).

## Rule

*Rhythms* offer stepping stones toward *rules*, another concept central to understanding living labor and its contradictory relations with dead labor.

How are rhythms and rules connected? Archaeologists have described sequences of practices that hominins all the way from the west coast of Africa to present-day Korea would have used to make highly symmetrical Acheulean stone bifaces between 1.75 million and 150,000 years ago (Tomlinson 2015). Such sequences would have included the kind of rhythmic, situated "same-but-not-the-same" strokes described in the previous section – the kind of strokes needed to chip flake after flake off some likely lump of stone to yield a useful tool. The relevant skills, embedded in a heterogeneous ensemble of other practices and opportunities specific to particular times and places,

would have been passed on from generation to generation without either having been completely “pre-programmed” genetically or requiring language or music as we know them today. Indeed, far from presupposing language, such skills might be better regarded as underpinning it in terms of biosocial evolution. Yet in some sense the associated bodily movements would have been directed toward the finished tool rather than being just mechanical reflexes (Rouse 2000).

Retrospectively, such rhythms can be described using English phrases like “repeated performances of the same movement.” But concepts like *repeated* and *same* wouldn’t have been present at the time. Just because today we can map rules onto such such rhythms does not quite imply that the Acheulean toolmakers themselves were following such rules (Shanker 1998: 8). Rule-following would have unambiguously emerged only when compositional, combinatorial linguistic structures developed on top of earlier, more intrinsically-contextual gesture-vocalizations (Tomlinson 2015). That’s when it would have become possible for one hominin to ask another something like “Are these motions the *same* as what you’re doing?” – and, eventually, “Are these movements *correct*?” and “Am I following the *rule*?” To put it another way, the tightly-knit cluster of concepts that encompasses *same/different*, *correct/mistaken* and *obeying/disobeying* came after, and is in some ways derivative of, rhythms that were already present. The same goes for other members of this conceptual cluster including *repetition*, *regularity*, *replication* and *duplication*, as well as later additions including linguistic *rules*, legal *contracts* and scientific *laws*, mathematical *recursion*, culinary *recipes*, computer *algorithms*, and so forth.

To switch the focus from archaeology to child development, a baby can teach herself and be taught to sharpen her entrainment to regular beats long before she learns language. Her subsequent acquisition of the additional ability to handle concepts centering on the notion of “the same beat” is a matter of progressive “triangulation” (Davidson 2001) among the antics of an active external nonlinguistic world that includes all sorts of such rhythms, the performances of her own organism in animate motion, and the antics of her language-proficient elders.

What stays constant between rhythms and rules is that both revolve around “sameness-that-is-not-sameness.” Rules, like rhythms, represent unfolding variation inside constancy and of the “differences induced or produced by repetitions” (Lefebvre 2013 [1992]: 17). No one can predict all the ways in which rules will need to be reinterpreted and reapplied in future socionatural circumstances (Wittgenstein 1953, Collins 1985), any more than they can predict the exact trajectory of each of the next of a series of repeated strokes that a skilled carpenter will need to make with a saw (Ingold 2006). Small wonder that no sooner had the early Soviet psychologist Nikolai Bernstein (1967) pointed out that the “same” rhythms into which athletes or workers were trained could never really be the same in their physical measurements than Ludwig Wittgenstein added that something similar applied to the interpretation of the “same” rules.

For sure, most people today have the feeling that a rule must be something at once firmer, more autonomous, and more private than that. For example, they feel that the rule “add 2 to the previous number” compels them from within to produce the single determinate sequence “2, 4, 6, 8, 10, 12, ...” rather than, say, “2, 4, 6, 8, 10, 10, 10, ...” (Kripke 1985: 21-22). They resist out of hand alternative interpretations of the rule – such as, for example, “add 2 to the previous number (until you get to 10, obviously, then add nothing).” Over the last few hundred years, amid the fitful development of what the historian of science Lorraine Daston (2022: 273) calls “islands of uniformity, stability, and predictability” in society (in part to make machines and divisions of labor work for the benefit of elites), it has become possible for the first time in history for people to believe that there are such things as “rules that follow themselves, everywhere, always,” and that such rules can be put inside the brain through some mysterious process, as well as built into machines.

Such intuitions pave the way for the theory that cognition must be a sort of “digestion” (Shanker 1998) or computation carried out by a “language module” or even “master algorithm” (Domingos 2015) built into individual brains (Ibbotson and Tomasello 2016). The extent of this variant of machine fetishism (Hornborg 2023) in contemporary society can’t be underestimated. It pervades science, science fiction, and the “scalability” and “singularity” assumptions of many AI mega-investors. Only when confronted with the infinity of possible ways of obeying any rule or “going on in the ‘same’ way” (Wittgenstein 1953) does this pseudo-science collapse (together with some of the most fundamental assumptions underpinning AGI research programmes at firms like Meta, OpenAI, Google, Amazon, Microsoft and Apple). Only then does it become obvious that it is necessary to “place,” rather than simply accept at face value, the ingrained modern intuition (Dennett 2013) that a rule is a rigid inner mechanism giving us incorrigible, final first-person authority over its future interpretation.

The philosopher Wilfrid Sellars (1997 [1963]) has sketched an account that helps explain how such intuitions might be diagnosed and contextualized as belated overlays on historical or prehistorical intercorporeal practices in unpredictable environments in which final authority for how rules were to be followed were rooted in social, public contingencies. In some ways, this account chimes with the reconstructions of the archaeology of tool-making mentioned above. It suggests a material genealogy for linguistic notions of *same*, *correct* and *rule* that connects ultimately to the nonlinguistic “same-but-not-the-same” rhythms of evolved hominin animate movement. It reminds us that, despite modern intuitions, meanings of words, too, are derivative of social practices of translation rather than the other way around (Quine 1960). Acts of translation or interpretation are instances of living labor in that they consist of historical, political events that are “in time” rather than being infinitely accelerable in the manner of dead labor (Liu 2019, Sakai 2009).

One upshot is that there exist many forms of compulsion indispensable for capital accumulation that are present in living but not dead labor. Naturally, living and dead labor are equally subject to the type of energetic compulsion that drives a billiard ball away from a collision with another or closes an electric switch. But other forms of compulsion are found only in living labor. These include the compulsions of inherited animate movement and instinct that first came into being hundreds of millions of years ago. Much later came entrainments into rhythms that have components that can be improved through practice in a group. Those date to perhaps hundreds of thousands of years ago. Then there are the kinds of compulsion that derive from social apprenticeship in linguistically-enhanced contexts in which *rules* have become active in governing hands, legs and tongues. These can be traced back perhaps tens of thousands of years. All three forms of compulsion, and others, must be included in the immense ecological heritage that capital seeks to tap for free in its exploitation of workers and appropriation of nature. All three, and more, need to be grasped in detail in order to understand just how fundamental the contradiction is between living and dead labor. This perspective helps expose limitations and points for intervention in AI’s excessive reliance on old notions of prediction and control (Smith 1992) in its approach to capital’s labor challenges.

An up-to-date understanding of rules, for instance, helps bring into sharper definition the reasons why capital accumulation paradoxically depends on resistance to itself (Caffentzis 2013). Business management is “the art of getting others to do things” (Dujarier 2017). But obedience always implies the possibility of disobedience. Lay down any rule for the worker and the worker can find a way to subvert it by reinterpreting it. One example is the protest tactic of “working to rule” – irritating the boss by following his or her rule “too mechanically.” Fitfully, capital strives to halt the never-ending dance of interpretation, reinterpretation and re-reinterpretation by using energy-intensive mechanization. The hidden fantasy is to make its rules uninterpretable – to eliminate

once and for all the worker's interpretive labor. Imagine how streamlined and efficient rule-following would be if it didn't require interpretation at all! If you can recruit the metronome as the basis for correct rhythm, the fantasy goes, you ought also to be able to make the industrial or digital machine into the model for rule-governed behavior.

But this tactic brings new problems. Since machines can't do their jobs the "wrong way," they also can't do them the "right way." They need humans full of historic and prehistoric experience of the fizzy flexibilities of rule-following and rule-flouting to fix them, clean up after them or find new ways of feeding or adjusting them to surrounding socionatures to deal with unanticipated circumstances. They need living laborers who – unlike the "bullshitters" that AI mechanisms are purposely designed to be (Hicks, Humphries and Slater 2024) – can distinguish between real and unreal due to their histories of learning from causal interactions with objects within a community of other human individuals observably reacting to the same objects (Davidson 2001). No capitalist who actually succeeded, *per impossibile*, in mechanizing away the interpretive labor of ordinary workers would ever be able to accumulate anything. Nor, conversely, could any anti-capitalist attain a world of "luxury automated communism" (Bastani 2021) by offloading human subsistence-oriented activity onto machines. Far from replacing living labor, machines only increase capital's desperate need for it – and, ironically, for the ever-shifting wellsprings of defiance that come with it. As noted in the introduction to this chapter, what is popularly called automation is always, in fact, the highly-unstable hybrid of living and dead labor that Ekbia and Nardi (2017) term *heteromation*. Under racial capitalism, this often amounts to what black auto workers in Detroit once called *niggermation* (Georgakas, Serkin et al. 1988).

Hence the fatuity of the self-serving claim, still prevalent today in AI circles (OpenAI 2026; Ji, Qiu, Chen et al. 2025) and among political elites (Politics UK 2026), that the dead labor represented by an automated, predictive large language model (LLM) might someday be able to regulate itself – that is, take on living labor's ability to "align [LLM] outputs with human values." Marcus Arvan (2025: 3769) has formally proved that it is in fact impossible to know whether an LLM has "learned any particular function at all before any of an uncountably large number of unpredictable future conditions obtain." The probability of LLM "misalignment" is, "at every point in time, given any arbitrarily large body of empirical evidence," always "vastly greater than the probability of 'alignment.'"

### *What structures dead labor?*

The previous sections have argued that understanding what capitalists exploit when they exploit living labor (and thus how they accumulate value) is in part a task for what might be called *prehistorical materialism*. Investigations of the role of dead labor, by contrast, are more a matter for classical *historical materialism* in the tradition of Marx. The time scale is on the order of 10 million times shorter: centuries as opposed to billions of years.

Yet dead labor – at least as represented by the example of industrial machines – has its own expansive conditions for existence whose study has also been neglected. Machines don't appear out of nowhere any more than do sentient beings. Nor can their functions for capital be sustained in isolation. Through an exploration of its historical, geographical, ecological, political, social and ideological preconditions and accompaniments, the concept of dead labor needs to be fleshed out in the same way that the notion of living labor was made more concrete using up-to-date understandings of animate movement, rhythms and rules.

The operation of industrial machines, including digital machines, is invariably preceded, accompanied and followed by the re-engineering of territories. Industrial machines aren't of much use in unpredictable environments, where they can become like the broom in the tale of the sorcerer's apprentice. Those environments have to be made over. Dead labor needs deadened surroundings. In factories, machine use presupposed an ongoing programme of dividing labor, fragmenting tasks, and disassembling worker life-rhythms that had hitherto oriented themselves more around communal obligations and multiply-interlocking "in-time" processes (Smithers 1998) than around wages and clocks. There existed an "industrialization before industrialization" (Kreidte, Medick and Schlumbohm 2008). Sylvia Wynter writes that New World plantation slavery in particular was actually the "first large-scale intensive attempt at the mechanization of human existence" (n.d.: 107). Similarly, increased regimentation of the labor of groups of human computers preceded serious mechanical AI (Grier 2005, Riskin 2016). By the same token, the large-scale assimilation of trains and cars into society presupposed and fostered sprawling infrastructure networks in which complications like unlucky turns in the weather, locally-variable ways of marking time, or cows crossing the right of way were systematically minimized (Schivelbusch 2014). Today, so-called self-driving vehicles require even more thoroughly simplified or "deadened" landscapes. Further elements of the backstory of such machines include the simplified landscapes of colonial and neocolonial monoculture plantations (Wynter n.d., Scott 1999, Fiori 2020, Whittaker 2023, Mintz 1985), whose soils become progressively deadened in "green desertification" processes (World Rainforest Movement 2022) analogous to those that Marx found to degrade workers' vitality (Marx 1990 [1867]: 376-378).

In this process, entire territories, and not just the industrial machines sited in them, become increasingly caught up in the "production" (Lefebvre 2013 [1992], Arrighi 1994, Schivelbusch 2014) of the type of time marked by repetitions that can be speeded up indefinitely. This is part of the process through which capital enlists machines to reduce the "socially necessary labor time" (Marx 1990 [1867], Postone 1993) needed for the production of various commodities. This transformation of landscapes inevitably comes at the cost of exacerbating tensions between "over-time" and "in-time" processes (Smithers 1998) – that is, between machine capabilities and the non-accelerable biological and social repertoires of "same-but-not-the-same" behaviours that constitute part of the "free gifts" (Marx 1981: 745) bestowed on capital by a nature that has evolved over billions of years.

Probably the most understudied aspect of this geography of dead labor and its mechanically accelerable motions is the geography of thermodynamic energy, which was developed together with modern industrial engineering during the 19<sup>th</sup> century (Smith and Wise 1989, Smith 1999, Porter 1994, Daggett 2019, Lohmann 2025). The territorial entailments of energy-related extractions of coal, uranium, wood, copper, lithium etc. are already well-known in their various specific respects. So, too, are those of various networks that transmit or transport electricity, cocaine, LNG or electronic signals (Anusas and Ingold 2015, Ensmenger 2018, Blum 2013). But the post-1800 remodeling of landscapes by abstract energy *itself* needs a separate, independent analysis that has only recently been undertaken (Lohmann 2025). No more than any of its predecessors can this new geography be treated as a mere "background" to the antics of an invariant "human species" (Leroi-Gourhan 1993 [1964]: 247, Wynter 2003). Rather, it is part of its continuous re-formation.

The energy in question is "abstract" because digital and other industrial machines can't carry out their accelerable motions unless the "little" concrete energies of the commons used for cooking or keeping warm or growing crops, together with the diversity of the universe's biological, geological, hydrological, stellar and other energetic relationships, are detached to a greater or lesser degree from previous contexts and subordinated within a single overarching "fuel" for capital accumulation (Caffentzis 2013). From around 1800 on, what had been largely incommensurate realms of muscle

power, charcoal fires, wind, magnetism, waterfalls, oil and so forth had to be mobilized globally as a single economic force (Mokyr 1999: 20) driving mechanical repetitions taking place “over time” (Smithers 1998). Disciplining, concentrating and boosting the productivity of labor worldwide in the new age of machines meant not only finding the mechanical “equivalent” of heat, the electrical “equivalent” of magnetism and so forth. It also meant making all these forms of energy materially “the same” in millions of specific locations via conversion engines, motors, boilers, coal barges, dynamos, heating markets, pipes, wires, crankshafts, batteries, flywheels, transatlantic cables and cellphones. Traditional weavers, farmers, cooks, or blacksmiths would not necessarily have known what to do with this abstract energy. They might also have found their traditional sources of wood, water or muscular strength indirectly threatened by it.

In terms of energy physics, the driving force of this transformation can be expressed as the technical requirement of industrial machines to be located on, and continually relocated to, figurative “slopes” where properly unimpeded “flows” between low entropy and high entropy can be ensured for reasonable lengths of time (Carnot 1988 [1824], Deacon 2011, Rovelli 2016, Lohmann 2025) before the slopes flatten in accord with thermodynamics’ Second Law. That entails continual, wide-scale, centralized, colonial management of the entropy borders where the machines are sited in order to dispose of high entropy, import low entropy and hence curb trends toward local thermodynamic equilibrium. As Alf Hornborg (2001) has emphasized, low entropy must continually be metaphorically shipped toward the “technomass” located disproportionately in the global North while high entropy is shipped away. Either that, or the technomass itself must be moved to find new entropy slopes before they get flattened. That kind of organizational process, based around devices whose “home state” is thermodynamic equilibrium, tends to give rise to a landscape of restless frontiers of extraction and massive waste disposal that are in many ways antithetical to the complex biological membranes that make life possible. Whether the industrial “fuel” sources in question are solar, wind and geothermal or coal, oil and gas, the structural contrast between dissipative structures and equilibrium-tending digital or other industrial machines activated by humans for capital accumulation is given more and more room to extend itself. AI contributes its own graphic, up-to-date illustration of this old industrial dynamic in its hopeless, unending mission to substitute gigantic applications of thermodynamic energy for billions of years of biosocial evolution. The accompanying accelerated flattening of entropy slopes requires the appropriation of enormous quantities of pure cooling water (Starosielski 2021) required for community life – a consequence that has proved to be a key flashpoint for popular resistance (Hao 2025).

The contradiction between living and dead labor, in short, continually permeates deep into the landscape itself. The spaces and times of rural commons are confronted by the hierarchy of thermodynamic energy on which industrial machines in data centres and other factories depend for their capacity to produce super-fast, accelerable, repeated motions. In the case of AI, this hierarchy integrates *forward* into a social regime characterized by increasing reliance on mass production of statistical predictions and the belief that, if their numbers can be “scaled up” enough, such predictions can be identified with intelligence and social planning (Wong 2026; cf. Knight 1921, Ascher 2016, Doganova 2024). At the same time, the hierarchy of abstract energy on which AI and other industrial machine networks are built integrates *backward* into catastrophic processes of degradation of soil fertility, biodiversity, climate stability and human resilience by plantation and other extractive, polluting economies (HM Government [UK] 2025).

Both aspects of this deteriorating landscape provoke Sisyphean struggles to locate an in-principle infinite amount of cheap living labor to clean up the endlessly accumulating mess. On the one hand, billions of low-paid or unpaid humans must be found who can take on the rhythmic, rule-governed, fatiguing machine-care labor that encompasses what sociologist of science Harry Collins (Collins and Kusch 1998: 123-125) calls “RAT-work” (“repair and attribution and all that”). RAT-work

includes fixing and preparing data for AI models; interpreting, anthropomorphizing or censoring computer outputs (Dennett 1978; Collins 1990); cleaning up “AI slop” (Niderhoffer, Kellerman, Lee et al 2025) and “AI bullshit” (Hicks, Humphries and Slater 2024); and otherwise adapting AI machine repetitions to human society and vice versa. One of the most important functions of RAT-work is to hide, in classic 19th-century Industrial Revolution fashion, how much living labor is going into machine-human interactions. That makes it easier to hype AI as doing it all by itself (Carbonell 2025), thus reinforcing capital’s double propaganda strategy of threatening workers with redundancy while simultaneously promising a new age of “full automation” featuring leisure for all (Bastani 2001). It also conceals how little AI machines are actually contributing to productivity (Mazeika, Gatti, Menghini et al. 2025; see also Gray 2019, Ekbia and Nardi 2017), facilitating the wild speculation that is the mark of AI investment in an era of wholesale financialization. And it aids the mass production of military targeting lists and the indefinitely accelerated mechanization of “kill chains” (Baker 2026, Jones 2020, Lindsay 2020), accustoming the public to a new stage in the heteromation of war (Gvoryahu 2026). At the same time, billions of humans must be recruited to absorb AI wastes that they are evolutionarily unequipped to deal with; to try for as long as they can to adapt to environmental stresses; and to labor to “offset” or delay the effects of the accelerating ecological disruption that is inevitable with AI (Beuret, Fitzmaurice and Harvie 2025; Lohmann 2017; Lang 2026; Kratli 2026).

### *From Marx to AI and back again*

Artificial intelligence is a subject of great political controversy. Its colonization of energy, water, minerals and unpaid labor provokes resistance around the world. Its effects on employment, productivity and the future of work are topics of hot debate. Its use in surveilling citizens and listing military targets is widely criticized. Its role in the plans of the world’s largest corporations is a matter of global concern, its potential disruption of the world economy a subject of great apprehension. Its racial and gender biases are often challenged, its effects on education denounced, and its claims that combining big data and statistical prediction can translate text or drive cars often questioned. Its growing scale has been accompanied by popular, often sensationalist scare stories about its threats to social goals or even the survival of humanity.

This chapter is based on the conviction that it will not serve popular democratic movements well to frame such manifestations of concern as if they were unrelated to one another. For example, to advocate responding to AI by “seizing the means of computation”, redistributing them and ensuring that their impacts fall within expert-delineated “social and planetary boundaries” (Kwet 2024: 200, 212) is to risk encouraging a reactionary machine fetishism (Hornborg 2023) that overlooks the complex, history-laden structure of AI that this chapter has stressed. By the same token, to fail to explore fully the connections between the threats of AI surveillance (Zuboff 2019) and the “data colonialism” (Mejias and Couldry 2024) that exploits the unpaid labor of billions would be to pass up rich possibilities for movement alliances. And to ignore the contrast between the long-evolved biosocial “same-but-not-the-same” and the “mechanical ‘same’” that has been a focus of this chapter would be to miss one key root of the coming AI-driven global economic crash.

In addition, activists impressed by industry or academic claims that AI is spearheading a brand-new “knowledge capitalism” may overlook crucial continuities with 19th-century manual labor struggles as well as long-established patterns of falling ecological surplus (Moore 2015). They may neglect illuminating parallels between, for instance, claims that AI can diagnose illnesses or drive cars by itself and older, long-discredited claims that power looms or metal punchers will someday function all by themselves. They may be blind to the way that contemporary AI’s inability to find enough living labor to produce data “big” enough for its algorithms (Shumailov, Shumaylov, Zhao et al.

2024) precisely parallels 19th-century capital's chronic difficulties in finding enough living labor to nurture its own expanding technomass and thereby avoid the tendency of the rate of profit to fall (Marx 1981).

In short, for social movements to treat AI as if it were a neutral “tool” with the “potential to improve human lives” – as if it were an object that has somehow evolved separately from the crises of capital going back to the 19<sup>th</sup> century and before – is likely to result in tactics that undermine the causes of sustainability and nature preservation. Examples include tactical suggestions for “regulating” AI for the public good, sharing AI around more equitably, trying to keep its built-in destructiveness within externally-imposed technical “boundaries,” making it more “accessible,” “mitigating” its “side effects,” and “reconciling” it with “human values.” In addition to being ineffective by themselves, such tactics carry the costs of overlooking the large potential for coordinated resistance that could come with acting on the deeper contradictions and inherent instabilities that characterize AI.

This chapter has suggested that updating Marx's old contradiction between living and dead labor is one way of grasping these deeper contradictions and instabilities. Such an update not only helps identify what the central, underlying, historically-rooted issues are with AI. It also can point toward ways of mapping out popular responses capable of bringing together labor, ecological, feminist, anti-racist and anti-imperialist movements. The most effective resistance strategies around AI are likely to be those that contribute to the questioning of capital itself.

Reciprocally, the experience of AI struggles helps cast the old contradiction between living and dead labor in a new light. Demonstrating that the quest for digital AGI is environmentally unsustainable, as this chapter has attempted to do, is a contribution toward understanding better why classical 19th-century industrial capital was also so ecologically destructive. The obstacles facing today's AGI projects help reveal the core of industrial capital's original “machine problem,” its “worker problem” and its “accumulation problem” alike. Which should be no surprise, since today's AI is rooted in Jacquard's looms (Essinger 2004), Babbage's engines (Schaffer 1994), and other 19th-century innovations in capital's war against labor. The ongoing history of industrial robotics (Brooks 1999), automated image recognition (Jia, Wei, Socher et al. 2009), generative algorithms, and even the remote exploration of Mars (Clancey 2001) continues both to illuminate and to look back toward venerable dilemmas afflicting industrial capital going back more than two centuries.

### *Conclusion: taking life seriously*

“The subversive quality of black popular music has been primarily its ... freeing of time from a market process, its insistence on time as a life process.”  
Sylvia Wynter (n.d.: 199)

“The idea of property, with its metallic threads trapping the earth, was something so alien to our life that we could not understand it.”  
Moira Millan (2024)

If emerging struggles confronting artificial intelligence are to cross-fertilize with old and new labor and ecological movements, it may well be on the ground of what Karl Marx called the contradiction between living and dead labor. In stating this contradiction, Marx might be seen as resisting in advance pressures to squeeze his doctrines into neat straitjackets of conventional economics or positivist science. From beginning to end, he “stayed with the trouble” (Haraway 2016) that always surrounds words like “living” and “dead.” Social movements owe it to themselves to take the

history of thinking about “what makes living things tick” (Riskin 2016) as seriously as he did. To do so, and to go on “integrating ecology into the dialectic” (Moore 2015), means remaining open to new or unfamiliar conceptions of both.

Such conceptions include those that “distance” or take issue with a whole range of standard modern dichotomies: society/nature, discursive/material, information/matter, intellectual/manual, mental/physical, head/hand, human/territory, society/resource, culture/nature, plan/implementation, mind/body, strategy/process, design/execution, subject/object, meaning/substance, in-here/out-there, word/world and so on – all of which continue to be routinely invoked today not only by capitalists but also by most of their educated adversaries. Important contemporary challenges to this assemblage of problematic dualisms are being sharpened by, among other activities, ongoing encounters among various Indigenous and left activisms (Coulthard 2014). Such challenges can be discerned in slogans such as “our *territorios* are not resources but lives that make the *ixofijmogen* of which we are part, not its owners” (De la Cadena 2015) and “to translate is to communicate by differences” (Viveiros de Castro 2004: 10).

This chapter has taken advantage of the rich tradition of struggles surrounding AI to propose an alternative, perhaps complementary, way of setting aside the above dichotomies. In their place it has proposed a less fossilized divide for sustainability movements to work with. This is the divide between the machine/entropy networks of the last few hundred years and the organism/entropy networks that have evolved over the last 4,000,000,000 years. On one side lie the particular class of potentialities for accelerable repetition associated with steam engines, wind turbines, dynamos, SUVs, solar panels and Nvidia H100 GPUs, together with the speeding up of production and circulation of commodities and the evolution of a certain kind of entropy landscape. On the other lie the abilities for another type of repeated action that belongs to manual laborers, musicians, computer scientists, horses, mangroves and agricultural soils, all integrated into overlapping but in many ways conflicting patterns of landscape evolution. From this perspective, the divide to pay attention to is not between, say, society vs. nature or mind vs. body, but between life and the machine/entropy networks of recent industrial revolutions. Unlike the capitalist-era dualisms referred to above, often simplistically labeled “Cartesian” (Riskin 2016), this divide reveals its own historicity in the very way it is stated. In that respect, it avoids foreshortening the prehistory that connects the two kinds of motion that this chapter has distinguished.

In sublimating evolution out of the body, this “Cartesian” foreshortening has also sublimated agency out of plants, animals, microorganisms and the land itself. That has left the body and the rest of nature relatively easy to assimilate to the kind of machines that started arriving *en masse* with industrial capitalism, while continuing to etherealize the equally earthly categories of ancient animate movement (Sheets-Johnstone 2005, 2009) and rhythm (Tomlinson 2015, Iyer 2004) as well as the more recent phenomenon of rule-following (Wittgenstein 1953, Daston 2022). Over centuries, many of the dichotomies listed above have not only become frozen in place but also retrojected to an undefined *illo tempore*. Doubling down on these reifications, some distinguished Marxists (e.g., Malm 2019) have persisted in seeing them as the *sine qua non* of the dialectic rather than something that emerged from it. The same dualisms have also played a part in keeping public debate about AI since around 2010 pretty much corralled inside a fixed set of nonsensical questions. Are machines going to take all our jobs? Will they murder us or instead provide us with lives of leisure that allow us to maximize our creativity? Does AI pose an existential threat to humanity, or will it, on the contrary, save us from ecological catastrophe? Is a singularity coming soon in which mind will suddenly emerge from machine matter? Will we be able someday to transplant our essence into machines? Other, more coherent and interesting questions too often get left on the sidelines. For example, what are the current labor, racial, colonial, gender and environmental politics of investments in algorithmic advances, superfast computer processors, and the energy

conversion engines and data collection devices feeding them? Isn't it a fact that the unlimited pursuit of AGI would necessarily use up all the available energy in the universe, and if so, why? What are the concrete effects of AI's enhanced heteromation of the kill chain (Baker 2026)? Shouldn't intellectuals be updating their understandings of industrial capital and its crises, integrating the insights of evolutionary theory (Wainwright 2025), rather than passively submitting to the dreamy mysticism about AI being promoted by figures such as Sam Altman, Elon Musk or Geoffrey Hinton?

The Archimedean point allowing the greatest analytic leverage against AI hype may well turn out to be a materialist reconsideration of the labor of interpretation (Lohmann 2020) in terms of class and anticolonial struggle (Liu 2000, 2006; Lohmann 2013). As this chapter has argued, interpretation is a necessary component of all living labor that dead labor lacks. Its open-ended procedures can't be made indefinitely fast through turbocharged mechanized prediction operations any more than weaving can undergo unlimited acceleration through power looms. Capital accumulation, like anticapitalist political agitation, is both enabled and constrained by the non-machinic, biosocial rhythms of translation among human individuals and groups. As Marxist thinkers have long pointed out, the cycles of capital, perpetually straining toward an unattainable "bad infinity," are nevertheless forced to touch down again and again in the worldly finite for the sake of their own perpetuation (McNally 2003). The question about AI, as about other manifestations of industrial capital, is how earthly beings can find ways to prevail over this process and come out alive on the other side.

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