# Chapter 1

# Laying Bare the Device: Computer’s Modernist, Literary Roots

“The weakest point in our present day universe is the incapacity of man to meet the machine, the cultural conserve, or the robot, other than through submission, actual destruction, and social revolution.”[[1]](#endnote-2) So wrote the Austrian-American psychiatrist, Jacob L. Moreno in his idiosyncratic, sprawling, and now seldom read volume, *Who Shall Survive?[[2]](#endnote-3)*

Humanity, according to Moreno, faced two major threats: one, human aggression, and two, the aggression of robots: “cultural conserves” and “zootechnical animals.” When Moreno referred to robots, he meant all devices, social structures, and products of the mind which persevere autonomously to compete for attention. Conserves, Moreno thought, diminish the human capacity for cultural production. Robots create the illusion of “finished, perfected product[s],” which substitute for creativity.[[3]](#endnote-4) In this way, musical records obviate musicians, just like books do authors.

An “avalanche of ghosts” from the past enters into an evolutionary contest for survival.[[4]](#endnote-5) Unlike speech, which is extinguished as soon as conversations end, written words past persist and proliferate. They survive and continue to shape the social and the mental worlds to come. “[T]he author is immaterial,” Moreno wrote:

the book goes to all places and to all people, it does not care where it is read and by whom. Many robots have further in common the attribute of comparative immortality. A book, a film, an atomic bomb, they do not perish in the human sense, the same capacity is always there, they can be reproduced *ad infinitum* […] Our human world is increasingly filled with robots and there seems to be no end to new forms and new developments.[[5]](#endnote-6)

The musician and the author struggle to survive in competition with historical records. The conserve reduces humans to “machine-addict[s]” who reside in a “jungle of robots” that suffocates spontaneous activity.[[6]](#endnote-7)

Similar to king Thamus from Plato’s *Phaedrus*, Moreno thus distrusted rote mechanization of thought. In the name of comfort, safety, and prolonged life, technocracy disempowers, Moreno believed, the very subjects whose lives it claims to preserve. The zootechnical animal exchanges human capacities for self-determination for promised certainty of a better future. The eugenic dreamer and the technological dreamer have this one idea in common:

to substitute and hasten the slow process of nature. Once the creative process is encapsulated in a book it is *given*; it can be recapitulated eternally by everybody without the effort of creating anew. Once a machine for a certain pattern of performance is invented a certain produce can be turned out in infinite numbers practically without the effort of man. […] Once that miraculous eugenic formula will be found a human society will be given prefect and smooth at birth, like a book off a press.[[7]](#endnote-8)

Knowledge, in Plato’s terms, is thereby replaced with the simulation or imitation [*homoiōmata*] of knowledge.[[8]](#endnote-9) It is given and received passively, bypassing the critical faculties. Robots appear to us in their perfected state, whereby the labor and struggle for their production is elided.

Instrumental and institutional mechanisms alike fell under Moreno’s suspicion: the plow, pen, book, gun; central planning, corporate governance, and legal codex.[[9]](#endnote-10) All robots in that sense constituted a species of autonomous agency, a problem long in the background of Western liberal thought.[[10]](#endnote-11) For Moreno, books and bombs resembled one another because they both embodied volition detached from its human sources. Once in motion, both books and bombs seem to act in the world autonomously. The projectile acts at a distance; once launched, it completes its grim mandate even if the command to act is withdrawn. Technology of the word similarly decouples readers from writers. Books persist to mean in the absence of their authors. Once decoupled, seemingly autonomous paper agents—folders, novels, contracts—clutter the social sphere, continuing to structure human experience in the absence of the originating accord. Agency so detached operates without consensus or comprehension. Books are “robot[s] par excellence,” Moreno wrote.[[11]](#endnote-12) They elongate agency’s causal chain to effect change in mental states across time and space. Yet books and bullets are not social actors in a true sense. One cannot assign blame to them. They do not figure independently in our models of justice and responsibility.

Moreno’s claims and his language might seem curious today, but they were not unusual in the larger context of early twentieth century post-Kantian humanism. In Moreno’s work one discerns the influence of Marx’s critique of the fetishism of commodities, a dynamic by which “definite social relation between men” assumes “the fantastic form of a relation between things.”[[12]](#endnote-13) Moreno arrived at a similar conclusion by another logic. In creating some of the earliest examples of social network graphs, he found (and objected to) the presence of things in the position of social actors. His objections to the automatization of human experience echo also those of his near contemporaries like Viktor Shklovsky, Martin Heidegger, Walter Benjamin, and Hannah Arendt.

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Moreno helps us see the book in a new light. If it was always, as he suggested, a robot for enacting action at a distance, it is all the more robotic as a device that draws electricity, an electronic book. When, in the 1930s, one could view Moreno’s rhetoric about books and bombs as fanciful, technophobic even, a century later his concerns appear prescient. The unintended consequences of automated and disembodied agency, from artificially intelligent personal assistants to market trading algorithms, worry contemporary scientists, legislators, and philosophers.

Today, a machine that looks like a book can also function as a gun or trigger. Electronic books read on mobile phones, tablets, and personal computers comprise a part of the same digital framework that powers drones and aircraft carriers. Computers in the service of the world’s largest purveyors of literature are also used by air traffic control and covert intelligence agencies.[[13]](#endnote-14) Cellular phones, once devices for voice telecommunication, are now used both to read books and to detonate remote explosives.

These conditions compel us—historians, philologists, et al.—to reconsider the cozy relationship we have had with books since Gutenberg. My task in this chapter will be to illuminate the blueprint of computation within electronic books and thereby make them strange again. In a reciprocal movement, I aim also to place modern computers within the long history of the book; to view them as technique for literary and not just mathematical symbolism. To do this, I will construct a short prehistory of the literary device, based on materials drawn from the first half of the twentieth century. I am interested here broadly in the concepts of device and technique which emerge in the thought of Russian, German, and English philologists, whose work I will cover in the first section of this chapter. Subsequent sections trace the concomitant emergence of literary device in another sense, as a thought experiment staged by Ludwig Wittgenstein and completed by Alan Turing in the 1920s and 1930s. These experiments lead us to consider a number of fantastical broken reading and writing machines that define the limits of symbolic thought. They culminate in the schematics for a specific mechanism, which lies at the modernist roots of contemporary computational culture.

## Technique

What kind of a *thing* is a literary *device*? The formalist concept of a device is in part an artifact of an unfortunate translation from the Russian *priem*. The word would be better translated as “technique,” in the sense of “method,” “approach,” or “procedure.” Device contains these meanings as well, but in modern usage, it often carries a more concrete connotation, as an “object, machine, or piece of equipment that has been made for some special purpose.”[[14]](#endnote-15) “Laying bare the device,” for Viktor Shklovsky, who coined the phrase, meant making explicit the implied mechanisms of a literary trope, particularly in cases where such tropes turn “stale,” “automatic,” and “naturalized,” that is, bereft of their evocative power.[[15]](#endnote-16)

Vladimir Nabokov, a writer conspicuously aware of his literary-theoretical heritage, used the formal technique of “laying bare the device” often and with relentless clinical precision. In the short story “A Guide to Berlin,” to which D. Barton Johnson attributes our first glimpse at Nabokov’s “mature virtuoso style,” Nabokov wrote:

In front of the house where I live, a gigantic black pipe lies along the outer edge of the sidewalk. A couple of feet away, in the same file, lies another, then a third and a fourth—the street’s iron entrails, still idle, not yet lowered into the ground, deep under the asphalt. For the first few days after they were unloaded, with a hollow clanging, from trucks, little boys would run on them, up and down, and crawl on all fours through those round tunnels, but a week later nobody was playing anymore and thick snow was falling instead; and now when, cautiously probing the treacherous glaze of the sidewalk with my thick rubber-heeled stick, I go out in the flat gray light of early morning, an even stripe of fresh snow stretches along the upper side of each black pipe […] Today someone wrote “Otto” with his finger on the strip of virgin snow, and I thought how beautifully that name, with its two soft o’s flanking the pair of gentle consonants, suited the silent layer of snow upon that pipe with its two orifices and its tacit tunnel.[[16]](#endnote-17)

This tightly wound vignette dramatizes a distinctly formalist concern. The pipes embody the literary device. Usually found beneath the street, they now sit idle and visible above the surface. Even when exposed, the structure fails to captivate for long. Disused, it once again passes out of sight, covered in snow. Concerned with surfaces, the narrator “probes the glaze” of the street and finds a palindrome written in snow. The inscription “OTTO” not only resembles the pipes visually, but is in itself a surface-revealing inscription that makes the pipes visible again. The mimetic surface inscription draws attention to the word’s visual shape and acoustics. It invites readers to perform the symmetry of its consonance as they pronounce the word. The round vowels and the interrupting obstruents of “OTTO” contort the body in accordance with the sound image: reverse mimesis, the body as sound pipe. The moment of corporeal reenactment transcends the representational and paper-bound confines of the medium. The pipes reach beyond page. The performance makes the “making of the literary technique obvious,” obvious. The metaphor implicit in the idea of “laying bare the device” is thereby revealed. In this lies the prevalent characteristic of Nabokov’s mature work, which often seeks to transcend the diegetic, fictional world through sheer recursion of literary technique, where each successive turn of abstraction pushes the buried symbol closer to the reader.

Despite such emphasis on devices, formalist poetics (both in art and in scholarship) fell short of producing an explicit theory of technique. In this section, I will attempt to reconstruct the notion of technique in the thought of three major literary theorists of the interwar period: Viktor Shklovsky, Percy Lubbock, and Mikhail Bakhtin. I do not mean to suggest that the group amounts to a coherent school of thought. Rather, I am interested in observing the development of technique as a concept in parallel traditions at a formative time in the history of literary technology. I am consequently going to do something unusual in this chapter, namely juxtapose relevant patches of literary theory and material culture, which converge on a mechanistic view of reading, writing, and interpretation. These observations evidence fragments of a larger history. The reader should not mistake them for a complete canvas. I arrange them in this way to provoke a response and to find curious early intersections between disparate intellectual traditions—literary theory, philosophy, and electrical engineering—which intertwine to form the fabric of contemporary computational culture.

Viewed in the context of technological development, the emergence of technique as a critical category illustrates the broader concerns of the machine age. The notion of technology itself does not fully find its place in the critical literature until the 1950-1970s, judging by the rash of titles like Martin Heidegger’s *Die Frage nach der Technik* (1954), Jacques Ellul’s *La technique ou l’enjeu du siècle* (1954), Lynn White’s *Medieval Technology and Social Change* (1966), and Viktor Fekiss’s *The Technological Man* (1969). Calling for the institution of a new field in 1959, editors of the inaugural issue of *Technology and Culture* wrote about the “neglect of the study of technology” amidst a body of extant work that has “scarcely constituted” a systematic scholarly discipline.[[17]](#endnote-18) “*Technology* is a word whose time has come,” Langdon Winner would still write in 1978 in his influential *Autonomous Technology*.[[18]](#endnote-19)

Seen in this light, the pre-WWII concern with literary technique anticipates the post-war turn towards technology as a field of cultural analysis. Before technology, there was technique.[[19]](#endnote-20) The formalist period in literary theory signalled a turn away from history and philosophy of literature towards the mechanics of literary production. The technical turn entailed a mechanistic understanding of language, in which linguistic phenomena was viewed as a system of moving parts, whose relationship to one another was determined by discoverable laws. The turn to technique also meant that the mechanisms of meaning production, on the sides of both authorship and apprehension, were made accessible to a mass audience. Russian formalists in particular understood their task as one of radical democratization of the literary sphere.[[20]](#endnote-21) High literature, once the purview of a select few, could now belong to the proletariat at large. This also meant that literature was *composable*: it could be distilled into discrete and reproducible rules—technique over art—to be learned and shared widely.

The turn to technique gains significance in its instrumental context. The rise of formalist and consequently structuralist thought—along with philosophy’s linguistic turn, which saw language as a system of rule-based games—parallels the rise of rule-based programmable media: punch cards, magnetic drums, and ticker tape. That is not to imply that thought and technology stand in a reductive causal relationship to one another. Rather, they form a feedback loop, in which instruments, practices, and explanatory models evolve through mutual reciprocation. Locating the literary-theoretical construct of the device within its technological context allows us to witness the contemporaneous evolution and mutual interdependence between art, engineering, and philosophy. The origins of computer science and literary formalism can be traced back to shared theoretical assumptions and technological contingencies coming to the fore of telecommunications in the first few decades of the twentieth century.

It is at this time that the formalist concept of technique began to abstract the idea of literary production from its irreproducible contexts. The emphasis on craft over art implied primarily a change in the artist’s relationship to labor. Walter Benjamin had this view in mind when he wrote, decades later, about works of art that could no longer be thought of as “rigid, isolated object[s].” Rather, they had to be “inserted into the context of living social relations,” determined by their relation to literary production.[[21]](#endnote-22) Technique, for Benjamin, made literary works “accessible” to materialist analysis.[[22]](#endnote-23) Where the artistic genius was unique, craft carried with it a model of inheritance. Where genius was born, technique was shared. Where artists labored alone, craftsmen learned their trade in workshops, as part of a collective.

In a more general sense, the turn to technique could be seen as a rejection of Romanticism: Schopenhauer’s aesthetics for example, which emphasised individual creative genius that reached “beyond the objects which actually present themselves” towards the transcendent ideal.[[23]](#endnote-24) Formalism dispelled the myth of lone genius creators, orienting artists instead towards discovery through handicraft. In his “Art as Device,” Shklovsky wrote:

The work of poetic schools amounts to the aggregation and the discovery of new devices/techniques [*priem*] for the arrangement and the processing of linguistic material, and, in particular, more so with the rearrangement of figure [*obraz*] rather than with its creation.[[24]](#endnote-25)

Influenced by Herbert Spencer, the formalists imagined language to comprise a a natural, physics-based system, which tended towards the conservation of energy.[[25]](#endnote-26) In his influential 1852 essay on the *The Philosophy of Style*, Spencer wrote about the limited reserves of the “recipient’s mental energy.”[[26]](#endnote-27) “A reader or listener,” he wrote, “has at each moment but limited amount of mental power available,”

[h]ence, the more time and attention it takes to receive and understand each sentence, the less time and attention can be given to the contained idea.[[27]](#endnote-28)

The ideal writer thus strove to minimize reader mental exertion, following the law of what Spencer called the “economy of composition:” to say as much as possible in the most concise and direct way possible. Poetry for Spencer was exemplary in that regard: it habituated those “symbols of thought” and “methods of using them” that have proven themselves to be most effective through continuous use.[[28]](#endnote-29) Spencer’s ideal of literature was of the most thrifty, economical kind.

Shklovsky agreed with Spencer about the dynamics of everyday language, but not poetry. Poetry does not facilitate communication, he argued, it disrupts it. Poets “arrange and process” habituated material with the view of “resurrecting” the vitality of the word lost to everyday habituation. The “de-programming” of received trope constituted for Shklovsky the primary technique of aesthetic language. Poetic estrangement counterbalanced prosaic habituation, by which complex things and ideas were replaced by shorthand. Thus, where everyday language followed the laws of energy conservation, poetic language, according to Shklovsky, expanded energy. It literally belabored [*zatrudnenie*] and made language difficult again. It prolonged rather than shortened apprehension [*vospriiatie*].[[29]](#endnote-30) If, for Spencer, language was a labor-saving device and poetry its most economical expression, Shklovsky’s idea of poetry was labor-intensive and extravagant.

Any literary innovation was, in the formalist view, bound to follow a cycle of habituation and renewal. With time, images once able to capture the imagination lost their vitality. Consequently, the evolution of aesthetic periods followed a course of arbitrary differentiation, in what Jean Moréas (a symbolist poet and art critic important for the history of formalism) called a “cyclical evolution” [*évolution cyclique*], by which dominant tropes in one period become clichés in the next. Art depletes itself, Moréas wrote, “from copy to copy, from imitation to imitation.” What seems fresh today “dries up and shrivels” tomorrow.[[30]](#endnote-31) Technique in that sense was seen by the formalists as a kind of information processing at the meta-linguistic, social level. The mechanics of “arrangement and the rearrangement of figure” produced new meaning within habituated contexts. Such give and take powered the engine of literary development.

In the 1920s, reflecting critically on Shklovsky’s “materialist aesthetics” Mikhail Bakhtin would write that such overly formal, according to him, model of aesthetic genre formation was capable only of establishing a “chronological table of variance in the evolution of technical devices,” because “in isolation technique cannot have a history.”[[31]](#endnote-32) The formalist model of literary development seemed to the more teleologically oriented critic meandering and meaningless. Bakhtin was also less inclined towards materialism. He was, for example, careful not to reduce technique to questions of “material arrangement” alone, independent of the aesthetic idea. “I am quite ready to join in the sentiment that ‘in art technique is everything,’” he wrote, “provided we understand that the aesthetic object cannot exist independent of the artistic work.”[[32]](#endnote-33) For Bakhtin, the work existed neither in the mind nor in matter’s configuration alone. Any immanent volume of text, an edition of Shakespeare’s *Hamlet* for example, could not, for Bakhtin, exhaust the possibility of *Hamlet* as a transcendent work of art. Neither could works be reduced to their pure ideas. Any notion of *Hamlet* the play must rest on firm material foundations—the textual witness—be it an original folio or critical edition. “In art, technique is not mechanistic,” he wrote. Rather, “technique animates and motivates the aesthetic object at every point.”[[33]](#endnote-34) In effect, Bakhtin denies the dualism between ideational content and physical form. Idea and objects enter into a continual dialectic.

For Bakhtin, technique was that force which at any point of a text was capable of translating ideas into things and things into ideas: where the mental conception of the word materialized into a specific arrangement of ink and paper. Within the ontological indeterminacy of art, which exists simultaneously as an object and idea, Bakhtin approximated the following formula: “audiences are equivalent to creators, minus technique.” Alternatively, authors “equal the audience plus technique.”[[34]](#endnote-35) Audiences experience art’s coming into being, though they lack in craft. Technique in that sense is a “method of processing content through material.”[[35]](#endnote-36) We return to the notion of labor or procedure, which transforms raw material—things—into art, no longer mere objects limited by their physical manifestations. In this light, the goal of poetics became, in Bakhtin’s words, the analysis of the “technical apparatus of aesthetic creation:” the movement between works and objects of art and back from things to ideas.[[36]](#endnote-37) Hence, aesthetics as dialectics: the study of transformation.

Even as formalism flirted with the idea of a materialist poetics, the “matter” of formal analysis was limited to the abstract notion of language, which, as is the case with any abstraction, can exist only in a categorical sense: in a way that all whales are mammals, for example. Mammals are not a thing in that sense. The category of “language” similarly comprises a theoretical aggregate of specific vernaculars. In giving names to literary phenomena—genres and periods, for example—literary critics similarly move from material specifics to categorical abstractions. We can thus view Nabokov’s recursive meta-poetics as a response counter to the critical method of induction. His prose works deductively, in that it attempts to convert ideas back into things. It reifies. His pipes and surface inscriptions protrude through the diegetic limits of the fictional world.

On the way to becoming things, words necessarily encounter the medium’s physical confines. Whatever the diegetic limits of fictional worlds, they are firmly constrained by paper. Nabokov’s prose often reveals the book’s outer-most conceit. Devices in their ideational sense meet devices in their material. Fictional worlds bump against the real at a page’s bounds.

Recall, for example, the conclusion of Nabokov’s 1936 *Invitation to a Beheading*, which ends with the imagined dissolution of diegetic boundaries. Readers glimpse the material reality “on the other side” of the page. “Everything was falling,” Nabokov wrote:

A spinning wind was picking up and whirling: dust, rags, chips of painted wood, bits of gilded plaster, pasteboard bricks, posters; an arid gloom fleeted; and amidst the dust, and the falling things, and the flapping scenery, Cincinnatus made his way in that direction where, to judge by the voices, stood beings akin to him.[[37]](#endnote-38)

Nabokov gestures towards the real, arresting mimesis. He exposes the literary incapacity to actualize, to assume physical form. A book’s physics constrain the novel’s. Nabokov drew attention to that boundary throughout his career, often creating meta-literary characters that understand their predicament and struggle hopelessly to escape.

Similarly, the material contexts of literary production escape from a reader’s view. Critics struggle to articulate the transition from thought to object. Technique, the linkage between pen and paper, disappears in reception. Echoing his Soviet colleagues in his influential *The Craft of Fiction*, the English critic Percy Lubbock, himself a formalist of sorts, wrote:

To grasp the shadowy and fantasmal form of a book, to hold it fast, to turn it over and survey it at leisure—that is the effort of a critic of books, and it is perpetually defeated […] Nothing, no power, will keep a book steady and motionless before us, so that we may have time to examine its shape and design.[[38]](#endnote-39)

The author’s use of object-oriented vocabulary does not however quite refer to objects. Lubbock’s “grasping,” “holding,” and “keeping the book motionless” are metaphors. The reader holds and keeps the thing before the mind’s eye. Books escape the reader’s mental, not physical, grasp. Nor do his “books,” “forms,” “shapes,” and “designs” refer to the outward, material aspects of the literary artifact. These are again mental constructions, not material. When he mentions the book he usually means the novel.

The confusion underscores his thesis. Our unfamiliarity with what Lubbock calls the novel’s “technical aspects” hampers our ability to understand how it comes to present itself to the mind in its entirety.[[39]](#endnote-40) Viewers grasp other more plastic art forms like sculpture or painting whole and at once.[[40]](#endnote-41) These exist synchronically, in space limited to their physical dimensions. Narratives, by contrast, unfold in time, diachronically. To perceive a book, to read a novel, we must therefore abstract from the physical object and extend it in working memory, past immediate perception. Meaning-making of the sort involves the mental assemblage of linguistic minutiae, which eventually constitute a literary whole.

Critical reading in Lubbock’s sense entails an account of the transformation from things to ideas: from words and sentences to stories, novels, and verse. Echoing Boris Eichenbaum in “How *The Overcoat* is Made,” Lubbock was interested in the mechanics of literary craft—how the thing is made. He promised to view “a few familiar novels […] with some particularity,” but without judgement or critique. “How they are made is the only question I shall ask,” he wrote.[[41]](#endnote-42) The book’s author is “craftsman,” he wrote. It is therefore the critic’s role to “overtake him at his work and see how the book was made.”[[42]](#endnote-43) Books however “vanish” when we “lay our hands” on them.[[43]](#endnote-44) Critics must therefore choose to see either trees or the forest. As the totality of the work comes into view, the technical details of craft—books as objects—disappear. Conversely, when viewed up close, technical particulates obscure sight of the work as a whole.

“The real heart and substance of the book,” Lubbock wrote, “stands out more clearly for the obscurity into which the less essential parts of it subside.”[[44]](#endnote-45) To read in this mode is to deny books their materiality. When reading for pleasure, lay readers lose themselves in the elements of narrative immediately available for observation. To read novels for pleasure for Lubbock is to “forget, if we can, that the book is an object of art.”[[45]](#endnote-46) By object of art he means the transcendent idea of the novel as opposed to the immanent work itself. To “objectify” elements of the novel that “strike us more keenly,” as Lubbock phrases it, therefore means for him quite the opposite of what is usually meant by objectification. The complete mental idea of the novel congeals only at the conclusion of reading, that is, at the limits of the book as a thing. “[F]ar from losing ourselves in the world of the novel,” Lubbock argued, “we must hold it away from us, see it all in detachment, and use the whole of it to make the image we seek, the book itself.”[[46]](#endnote-47) But to hold books away in that sense means also to internalize them completely. And by “books” he means the idea of a novel, not at all the thing itself. Thus to read critically is, paradoxically, also to arrest the coming-into-being of the work. The difficulty of materialist poetics reflects in its language, which continually conflates mental and physical constructs.

*The Craft of Fiction* ends on an ambivalent note. Lubbock sensed the inadequacy of his materialism: “if only there were one single tangible and measurable fact about a book,” he wrote. If only it could be “weighed like a statue” or “measured like a picture—it would be a support in a world of shadows.”[[47]](#endnote-48)

I want to end the section here, with a momentary failure of materialist poetics, to pick up another concomitant thread, one that will take us through some of the same concerns about the nature of symbolic representation and its relationship to the physical world. My aim in this disruption is to disconnect the history of modern computing from its expected contexts of calculating machinery and to join it with literary theory, where as we will see, it also finds a measure of congruity. I do so in the absence of direct evidence for an explicit intellectual connection.[[48]](#endnote-49) My goal is not to prove that such a linkage exists, but rather to irreparably entwine the nominally discordant intellectual and material genealogies in a way that sheds light on our modern predicament, where books and guided missiles indeed share the same semiotic infrastructures. Along with critics of contemporary computational culture like Bernard Harcourt and Frank Pasquale I would like to ask: How did we get here?[[49]](#endnote-50) The thought of Ludwig Wittgenstein and his student Alan Turing reveals, along with a number of broken reading and writing machines, a possible answer to the quandary of materialist poetics, posed in the liminal space between thought and thing.

## Thought Experiment I

Modern computers—and by extension the electronic book—harken back to a cluster of related thought experiments prevalent in the philosophy of Ludwig Wittgenstein and subsequently Alan Turing, his long-time student and colleague. The story of Turing machines has been told before in many contexts, but never with an eye towards literary machines. The history of literary interpretation nevertheless occupies a central place in the early development of modern computing. To confront computers as literary devices one must first understand their peculiar relationship to universal Turing machines. I would like to frame that discussion by drawing two further as yet unexplored historical genealogies that lead to Turing’s seminal essay on computable numbers: the first intellectual, which stem back to his tutelage under Ludwig Wittgenstein, and second, material, which highlight the physical similarities between Turing’s design and a number of attendant developments in printing and communication.

To read Lubbock, Turing, and Wittgenstein together is to recover a legacy of humanities computing that often gets overlooked in the history of computer science and software engineering. The literary perspective is important because it allows us to see the computer in a new light: more than a byproduct of quantification, a metaphor machine. Turing machines should interest literary scholars because they embody a minimally viable model for generalized symbolic manipulation: reading and writing. Poetics should interest electrical and software engineers for the same reason, because it grounds computation in the long history of the written word. Turing’s thought experiments were meant to solve a mathematical problem, but their pedigree lies also in the study of textual meaning-making and interpretation. Wittgenstein and Turing pose a problem similar to that of the formalists, and arrive at a similar conclusion: a generalized algorithm for language manipulation.

In his seminal 1936 paper on computable numbers, Alan Turing proposed a peculiar (for a mathematical treatise) thought experiment that addressed a problem in the field of elementary number theory.[[50]](#endnote-51) His solution involved more than a formula. Instead, he imagined a machine that would substitute for calculation. Ultimately, Turing described a device that was meant to embody the symbol: it transformed external abstractions into physical states, internal to the device. In doing so, his imagined machine breached the boundary between idea and matter. It was exactly an instrument for transforming thoughts into shapes, of the kind approached by formalist poetics. In that sense, Turing’s hypothetical machine represents an advancement in the development of a long-standing thought experiment concerning the nature of human understanding and the beginning of a new, machine-assisted philological practice.

The question of an “automated” hermeneutics echoes through the canon of Western philosophic tradition. What does it mean to read and to understand something? Is it enough to repeat another’s words, as Phaedrus did in response to Socrates? Could students be said to possess reason when they merely parrot thoughts, without actively thinking on their own? Would we make the same conclusions about the possibility of animal or machine intelligence? The question was posed already by Descartes who wrote that it would not be sufficient for the “rational soul” to be “lodged in the human body like a pilot in his ship, except perhaps for the moving of its members,” but that intelligence must be “joined and united more closely with the body in order to have sensations and appetites similar to our own.” Magpies and parrots can appear to speak, Descartes wrote, but can they show us that they understand?[[51]](#endnote-52) And what would that “showing” entail?

Recall also the experiments with combinatorial poetics of the 17th century German Jesuit scholar Athanasius Kircher, the inventor of *Arca Musurgicae*, a music composition device, by which a composer not versed in music could combine predetermined musical phrases written on wooden planks to compose a score. In correspondence with Kircher, the German Baroque poet Quirinus Kuhlman argued that using a similar instrument to compose poetry would amount to *sed versus, non poema* [mere versification, not poetry]. Would we call a naive child using such a contraption a composer or a poet, he asked? And answered:

*Sed lusus est ingeniosus, Ingeniose Kirchere, non methodus, prima fronte aliquid promittens, in recessu nihil solvens. Sine cista enim puer nihil potest respondere, & in cista nihil praeter verba intelligit; tot profert, quot audit, sine intellectu…*

But [the poetry box] is just an ingenious game, *Ingenious Kircher*, not a method, promising something on the surface, but solving nothing deep down. For without the box the boy can answer nothing, and with the box he understands nothing but words. He produces whatever he hears, without understanding, like a parrot.[[52]](#endnote-53)

The child cannot create without mechanical assistance. Like the parrots of Plato, Kuhlman, and Descartes it mimics creation on the surface. Nothing in an automaton’s mind corresponds to the outward appearance of thought. The child composes poetry without thinking—that is, without the appropriate deep structure that should accompany proper poiesis. If technique alone is to guide the creation of poetry, in a way that was suggested by the formalists, would we recognize purely formal creation as art, or thought, or language even? Or would it be also for us mere versification? Does technique matter in other words? Do we care how the thing is produced—by machines or aliens—or do we care only about its effects?

The philosopher John Searle would later pose a similar question in his famous Chinese Room thought experiment.[[53]](#endnote-54) Can a contraption be said to “speak” a language if inside it contains only a dictionary for looking up the correct answers to any given query? A man inside the room sorts the answers blindly. He does not understand the language, yet the contraption appears to respond appropriately. Is it again enough to appear to understand, or should we say that understanding must always involve an analogous inward movement?

Searle argued that his room, a kind of a robot for automated responses in a foreign language, could not be properly said to speak a language in the way a fluent speaker can. For Searle and other so-called “internalists,” the external signs of whatever is meant by “speaking” and “understanding” must correspond to some appropriate internal mental states.[[54]](#endnote-55) Plato, Descartes, Kuhlman, and Searle all pose a variation on the same thought experiment, which, in opposition to mere functionalism, aims to identify deep structure that characterizes cognitive phenomena, apart from its surface manifestation. Reading and writing should, these thinkers intuit, leave something behind. Functional, outward appearances are not enough. A text is ingested. It leaves a trace. It is “joined and united” with the body, to paraphrase Descartes. Moreover, the trace must correspond, in some way, to the originating inscription. The two achieve a measure of structural accordance.

Recall the famous *pharmakon* passage from Plato’s *Phaedrus*, which explores the relationship between writing and its impression on the mind. At the conclusion of the dialog, King Thamus objects to the technology [*ta tekhnēs*] of the written word, as he believes it will foster forgetfulness in the people who use it. Plato writes: “Their faith in extrinsic writing [*graphō exōthen*], by means of foreign impressions [*allotrion tupōn*] will diminish their intrinsic [*endothen autous*] capacity to remember.”[[55]](#endnote-56) Plato thus contrasts the exterior figure of the inscription with memory, an intrinsic cognitive ability. The Greek *tupōn*, related to the English “type,” literally means an impression. It is, in this case, also “foreign” or “othered” [*allotrion*]. It comes from without. Like Moreno after him, Thamus finds thought externalized through typography problematic. True memory and thought for him comes from within. It is once again properly internalized.

For this reason, in the beginning of the dialog Socrates asks his young collocutor to stop reciting a speech that the latter learned by heart. Recitation is worthless for him. He wants Phaedrus to think for himself and not merely regurgitate another’s ideas. The student must not perform, in other words, as a mere parrot would or an automaton. To truly comprehend something and to make a show of it, readers internalize and make their own. Much can go wrong in that process. We expect for reading to ultimately leave appropriate impressions [*tupōn*] on the reader’s mind. These typographic imprints presumably correspond to the stamp. For understanding to take place, writing must produce “true,” in Descartes’ words, feelings and appetites. But what is true, appropriate, or proper? What shapes does type [*tupōn*] impress onto the soul? It cannot be a letter’s literal form. How does one then convert external images [*graphō exōthen*] into internal [*endothen*]? How can we incorporate foreign [*allotrion*] to us states of mind? How does one ingest inscription in a way that leaves an appropriate trace? Even the most mundane acts of reading contain such profound mysteries of comprehension.

## Thought Experiment II

Turing machines, which will come into view shortly, embody a stark solution to the problem of appropriate comprehension. I propose now to consider them first within the above broad tradition of formalist poetics and second, more narrowly, in response to a series of thought experiments proposed by Ludwig Wittgenstein in the 1930s at Cambridge, where Turing studied in his early career and later taught.[[56]](#endnote-57)

Wittgenstein broached the problem of reading machines and comprehension in his *Blue and Brown Books* and *Philosophical Grammar* (all compiled in the early 1930s), then in his lectures and remarks on the foundations of psychology and mathematics from the late 1930s, and finally in *Philosophical Investigations*, written between 1945 and 1949. The earliest of these documents, *The Blue Book*, opens with a question of semantics. “What is the meaning of a word?” Wittgenstein asks and cautions his students against choosing the easy answer, which holds that meaning resides in the head. “It is misleading then to talk of thinking as of a ‘mental activity’”, he writes:

We may say that thinking is essentially the activity of operating with signs. This activity is performed by the hand, when we think by writing; by the mouth and larynx, when we think by speaking; and if we think by imagining signs or pictures, I can give you no agent that thinks. If then you say that in such cases the mind thinks, I would only draw your attention to the fact that you are using a metaphor, that here the mind is an agent in a different sense from that in which the hand can be said to be the agent in writing.[[57]](#endnote-58)

Wittgenstein explains that when we see a sentence on paper we assume that some structure analogous to that sentence exists in the mind. Perhaps, he speculates, we could even observe the brain directly, in the process of writing, to check whether mental states correspond to the inscription, as a sort of a linguistic Magnetic Resonance Imaging (MRI) machine. Both thought structures, mental and written, embody thought. Yet neither exists in isolation.

Rather, we are witnessing the workings of a metaphor: the transference of properties between two distinct physicalities, one in the head and one on paper. Neither physical nor mental descriptions alone are sufficient for Wittgenstein to locate cognition. The subject escapes depending on our point of view. When the hand writes, it is the brain that thinks. But when the hand thinks, it is the brain that writes. Meaning thus lies in the transition from hand to head and from mind to paper. We might say that thinking takes place “on paper, in our head, in the mind,” Wittgenstein writes, but crucially, “[n]one of these statements of locality gives *the* locality of thinking.”[[58]](#endnote-59) Thought is rather distributed throughout the body and among its extensions. We think by the sign, head, hand, and pen.

“Could a machine think?” Wittgenstein asks later on in the first notebook.[[59]](#endnote-60) The challenge, as he explains it, is not one of finding a machine that can do the job—of manipulating signs, for example. It lies in the ability of the machine to enact both sides of the metaphoric equation. “Doing the job,” to manipulate external signs for example, must correspond to something else. Severed from its analogical structure, the “blind” manipulation of signs is a meaningless activity. Meaning, Wittgenstein suggests, resides in the metaphorical transference between something (symbol) and something else (machine state). “Can a machine hold private mental states?” is therefore a better question. Can it feel pain in the sense of pain being the state of internal affairs not accessible to others?[[60]](#endnote-61) If we believe machines to be capable of holding intrinsic states, we can then imagine something akin to machine intelligence, by which a spoken word or letter finds the appropriate inward representation for the machine. Understanding, in that sense, lies simply in the structural accord between something internal and external.

Wittgenstein engages the question of semantics again in his *Brown Notebook.* He first defines reading mechanically, as an activity devoid of meaning which involves “translating script into sounds,” “writing according to dictation,” or “copying in writing a page of print.” What happens when a naive child reads a newspaper? Wittgenstein asks, echoing Kuhlman and Descartes. The child’s eyes, he answers, “glide along the printed words, he pronounces them aloud or to himself,” but “other words he pronounces after having seen their first few letters only, others again he reads out letter by letter.” Children act as “reading machines” when they pay no attention to what they read. A child reads “faultlessly like a reliable machine,” Wittgenstein repeats, emphasising the mechanical property of colloquially “mechanistic” reading.[[61]](#endnote-62) Another hypothetical child merely pretends to read. It guesses at the words and on occasion repeats things “by heart,” without actually seeing them on the page.[[62]](#endnote-63) Would any of these hypothetical scenarios rise to our conventional understanding of reading?

Wittgenstein continues to complicate such edge cases. He considers the case of a hallucinating patient, who “reads” what to us looks like gibberish. Another fakes reading Cyrillic by memorizing the lines phonetically. He thinks of machines too which produce random sounds that occasionally, by accident, correspond to some existing texts. In each case, we envision two mechanisms, Wittgenstein writes, one visible and external and one hidden and internal. The reader eventually does more than mimic the mechanical motions of reading. Outward signs are insufficient to indicate comprehension. The motions—of gliding one’s eyes across the page and saying the words out loud—must connect in some way to appropriate internal, mental representations.

We are tempted then to privilege the inward-facing signs of comprehension as the “real criterion for a person’s reading or not reading.” However, no such internal mechanisms can be known to us or communicated to others properly.[[63]](#endnote-64) We can only intuit a reader’s intimate experience of reading. Absent the ability to convey private mental states directly, reading pupils must convince their teachers that the scanned sign had the intended effect through language. This requires even more words. The hermeneutic circuit is perpetually frustrated. How can Phaedrus convince Socrates? How can he explain that he understands? Texts beget texts. But what if the explanation is memorized as well? What can be done to convince others definitively of our having understood a text properly?

Wittgenstein finally describes something akin to affective hermeneutics—an “indirect way of transmitting [a] feeling.” Communication, we would say today, is always mediated. In the conclusion of his notebooks, Wittgenstein imagines the possibility of “direct” modes communication, capable of transmitting feelings immediately from one person to another, in a way that “obviate[s] the external medium of communication.”[[64]](#endnote-65) Barring that possibility, we are ultimately limited by our private sensations of knowledge. “Something which we can never know happens at the end end,” Wittgenstein writes.[[65]](#endnote-66) Any sense of affirmation, the phatic utterance—Can you hear me now? Did you understand?—comes through further expression, entailing further uncertainty.

*Philosophical Grammar,* written around the same time as the *Blue and Brown Notebooks*, develops the reading experiments further. It begins again with a problem of “understanding” and “not understanding.” “To understand a language,” Wittgenstein writes, means “to take in a symbolism as a whole.”[[66]](#endnote-67) A word is always a part of a larger system. Similarly, a pass in football (soccer) also only makes sense as part of the game. It is meaningless in isolation. From the start, Wittgenstein envisions “understanding” as a type of trans-mediation. In comparing the understanding of language and music, he writes: “For explanation I can only translate the musical picture into a picture in another medium and let the one picture throw light on the other.”[[67]](#endnote-68) And elsewhere: “How curious: we should like to explain the understanding of a gesture as a *translation* into words, and the understanding of words as a translation into gestures [emphasis mine].”[[68]](#endnote-69) In conclusion, he again describes what we mean by “understanding” as a “process of translation from one symbolism into another; tracing a picture, copying something, or translating into another mode of representation.”[[69]](#endnote-70) To understand something said is thus akin to modeling it in clay or drawing it. Similarly, we imagine explaining basketball rules to someone who only knows how to play hockey by analogy: pucks bare grammatical resemblance to balls, goals to basketball hoops. The symbolic grammar of one game explains the other.

It is insufficient however to merely paraphrase: to show understanding one must “draw a picture” or “model” in a way that reveals a correspondence of equivalent structures. Language cannot, in this view, be explained by more language. We must trade symbolisms to create a model that explains one representational system in terms of another. The symbolisms cannot diverge completely either. There must be some productive overlap to account for the structural similarities between balls and pucks. We would have to explain: take note of these similarities, but not these—these are incidental. Language cannot be modelled like clay exactly. The rules of one game unfold by logics connected to its distinct physicalities: air and clay, ice and asphalt.

In thinking of the various ways in which the translation between divergent symbolisms breaks, Wittgenstein continually returns to the pianola, a type a player piano. The pianola joins music score to mechanism in a rigid way. Mechanism and symbolic notation become one. The machine does not “interpret,” in that sense. Perforated paper physically actuates the appropriate pins and gears and always in the same manner, leaving no room for interpretation. As long as the mechanism functions properly, musical notation and internal arrangement of instrument parts stand in perfect accord. The connection’s rigidity assures a symbolic correspondence. The machine enacts an exacting translation from one medium to the next by mechanical means, as the actuating mechanisms of the player piano fit into the grooves of a music roll (Fig 1.1).

**>>> Insert Figure 1.1 here <<<**

The idea of a rigid correspondence seems to bring us closer to solving the challenge of “proper” comprehension. What if reading could become similarly rigid, in a way that is impossible to misinterpret? But, like other, less exacting, mechanisms of comprehension, pianolas too break. Early in *Philosophical Grammar* Wittgenstein explains: “Aren’t our sentences parts of a mechanism? As in a pianola? But suppose it is in bad condition?”[[70]](#endnote-71) “The sentences that we utter have a particular purpose,” Wittgenstein writes:

they are to produce certain effects. They are parts of a mechanism, perhaps a psychological mechanism, and the words of the sentences are also parts of the mechanism (levers, cogwheels and so on). The example that seems to illustrate what we’re thinking of here is an automatic music player, a pianola. It contains a roll, rollers, etc., on which the piece of music is written in some kind of notation (the position of holes, pegs, and so on). It’s as if the written sign gave orders which are carried out by keys and hammers.[[71]](#endnote-72)

As was the case with reading automata in *Blue and Brown Notebooks*, Wittgenstein again substitutes a physical mechanism for the process of symbolic interpretation. Words and music notation alike contain a “purpose,” in his words. They elicit specific “effects” in the mechanism.

But as before, we cannot always expect the mechanism of interpretation to function properly, nor do we have a reliable way to verify its correct operation. “But suppose the pianola is in bad condition,” Wittgenstein repeats. The notation could produce “hisses and bangs” instead of music, for example. One could object that notes are always “meant” to play on a mechanism in perfect working order. But to explain what is meant by “perfect working order,” we would need to draw yet another diagram or build another machine. Wittgenstein resorts to yet another analogy. The “sense of an order,” he writes, lies in its “effect on an obedient man.”[[72]](#endnote-73) We are not able to escape subjective hermeneutics. Mechanical sense seems to again lie within “reasonable” interpretation of the instructions.

When drawing analogies between mental and mechanical processes, Wittgenstein explicitly rejects the model of language as a “psychophysical” mechanism.[[73]](#endnote-74) Rather, as the title of the work suggests, Wittgenstein is in search for “grammars” governing the engagement: between speakers and listeners, readers and writers, player pianos and musical scores. By the end of the work, grammar emerges as a cheat-sheet, a conventional protocol: recall the dictionary inside of Searle’s room. It contains the “smarts” of the system. Neither the room nor the person inside speaks a foreign language. If anything “knows” the language, it is the dictionary, which allows the system to function.

Wittgenstein thus complicates his mechanistic model by imagining a layer of rules that mediate between symbol and machine or mental state. We can agree upon a convention formally, by transcribing into a protocol: a chart of appropriate correspondences that describes the exact rules of engagement. It would be then possible to imagine a “part of the mechanism which resembles the chart,” Wittgenstein writes, “inserted between the language-like part of the mechanism and the rest of it.”[[74]](#endnote-75) Such instructions could enforce compliance. One could imagine a warning bell that sounds, for example, when a musical score falls out of alignment.

“Can one say that grammar describes language?” Wittgenstein writes:

If we consider language as part of the psycho-physical mechanism which we use when we utter words—like pressing keys on a keyboard—to make a human machine work for us, then we can say that grammar describes that part of the machine.[[75]](#endnote-76)

The grammar sets up a “connection between a word and ‘a thing’,” in order for the mechanism to function in a certain way. “[T]he definition,” Wittgenstein writes, “can make it work properly, like the connection between the keys and the hammers in a piano.” Crucially, it is that “connection and not the effect which determines the meaning.”[[76]](#endnote-77) A programmer would say that Wittgenstein’s “grammatical layer” resembles modern programming language interpreters and compilers, exactly the parts of the machine that connect codified instructions to their execution.[[77]](#endnote-78) Similarly, Wittgenstein’s grammar “means” in the sense of specifying rules by which meaning succeeds or fails. In this way, we can move away from speaking of “intended effects” or “proper obedience” and rather concentrate on this interpretive and mediating layer, which describes the rules of engagement.[[78]](#endnote-79) To learn a language in that sense is not to learn individual words, but to understand the mechanical linkages of meaning-making.

We say that the mechanism is rigid or the law is inexorable when the results of an action are fixed. Wittgenstein calls such a relationship “super-hardness.”[[79]](#endnote-80) Where a judge can be lenient, he explains, the law is compulsory. What we would now call an “algorithm” compels predictable execution, not subject to the vagrancies of interpretation.[[80]](#endnote-81) The parts of the mechanism subsequently exist in a causal relationship to one another. Pushing this or that lever will always result in such and such movement, because of the way the mechanical parts are connected.

We are tempted, as before, to privilege the inner workings of a symbolic mechanism, also at the core of meaning making in mathematics. “If I show you the mechanism behind the [watch] dial, you will be able to predict the movement of the hour hand for any given movement of the minute hand,” Wittgenstein writes. But once again, how do we know if a mechanism is functioning properly? I may drop the clock, for example, he explains, “so that the machinery is broken, or a lighting may strike it.”[[81]](#endnote-82) To check the mechanism for damage we need “a picture,” a diagram, or schematics that describe what the properly functional mechanism looks like. As a schema, the mechanism is itself a type of a symbol for the perfected behavior of the sort that we expect. We could, to take another example, compare a broken clock with clocks that work. Where we tried to find a mechanism behind the symbol, we found also a symbol behind the mechanism. But again we struggle to complete the circuit of interpretation between intent and effect, which never quite manage to explain and to verify each other. How do we know that our “gold standard” clock schematics are themselves golden, that is that they lead to the construction of properly functioning clocks? We are again faced with a series of receding analogies: a diagram that explains a diagram that explains a diagram.

In his lectures on mathematics, Wittgenstein never finds a way out of this recursive conundrum. The foundations of mathematics rely on some such mutually dependent relationship between the physical and symbolic worlds. Whether it is in math or ordinary language, some magic happens at the coupling of matter and sign. The precise point of contact concerns Wittgenstein in all fields of human activity, from literature to psychology and mathematics. In all of these fields, he finds an implicit analogy between “symbol” and “mechanism.” A type of metaphor, the analogy itself is atomic. It cannot be split further into something like sign and referent, tenor and vehicle, or signifier and signified. Considered apart, the two parts of a metaphor are strictly meaningless. In his lectures on aesthetics, Wittgenstein describes the dependency rather as the “concomitance between mechanism and its trace.” The best we can do in formalizing aesthetics is therefore to “trace [its] mechanism,” Wittgenstein concludes.[[82]](#endnote-83)

Wittgenstein’s thought experiments do not amount to a cohesive model of language, communication, art, or mind. They do however contain the seeds of reading and writing machines later imagined by Alan Turing, at the formative period of contemporary computing. Wittgenstein’s experimental thought machines prefigure a contemporary conversation about machine intelligence. Wittgenstein conjures his fantastical broken mechanisms to test the limits of our intuitions about reading, writing, and comprehension.

## Thought Experiment III

In 1939 Alan Turing attended Wittgenstein’s lectures on mathematics at King’s College.[[83]](#endnote-84) From the notes on Wittgenstein’s lectures complied and published by Cora Diamond, it is clear that Turing was a vociferous presence in the class. His name is mentioned eighty-six times in the text, more than any other student by a wide margin. At some point of the course Wittgenstein concludes his lecture in saying: “Unfortunately Turing will be away from the next lecture, and therefore that lecture will have to be somewhat parenthetical. For it is no good my getting the rest to agree to something that Turing would not agree to.”[[84]](#endnote-85)

One expects Turing’s seminal paper on computable numbers, where he first proposed his universal computing machine, to contain a strictly technical discussion in the narrow field of number theory.[[85]](#endnote-86) Instead, we encounter a number of surfeit features that do not fit neatly into mathematics. These account for the perplexing undercurrent of cognitive theory always present in Turing’s writing.[[86]](#endnote-87) His machines “think,” they are “aware,” and they “remember,” where his humans “calculate” and “compute.” The cognitive language reflects a heritage of Wittgenstein’s thought, concerned more broadly with theory of mind and the passage of inscription into understanding. Turing’s machine thinks in a particularly literate way: by ingesting and regurgitating symbols. Turing inherits these traits from Wittgenstein’s menagerie of comprehension automata in various states of disrepair. In the wilderness of Wittgenstein’s thought he locates the concise coordinates for a universal mechanism, placed at the liminal space between thing and symbol.

Turing machines mediate in the metaphoric transference from intrinsic “hard” states to their extrinsic “soft” representations. Like their predecessors, they concern the grammar of that transformation. They are, ultimately, mechanisms of exacting obedience: fully deterministic systems that nevertheless exceed their formal limitations. “How can the rules of operation of the machine change?” Turing asked in “Computing Machinery and Intelligence.”[[87]](#endnote-88) His answer, which began as a mathematical proposition in the 1930s, by the 1950s developed into a dramatized conversation between a poet and her critic; into the possibility of an evolving artificial intelligence; and into an imitation game, by which computers misrepresent their assigned gender. The very formulation of Turing machines poses a number of questions related to the problem of free will and determinism more broadly. How can a machine escape its programming? How can a poem transcend the rules of its composition? How do humans become more than the sum of their nature and nurture?

Turing’s universal machine finally distills the diversity of Wittgenstein’s experiments into a single concise formula. It needs the following three components to function: (a) a notational system that represents machine states, (b) storage media capable of bearing inscription, and (c) a reading and writing mechanism to transform notation into machine states. Given these three characteristics, the machine becomes a universal mechanism, capable of assuming the function of any other symbolic system.

To understand Turing machines in practical terms, think about the lower limits of computation. A Turing machine can simulate the physics of using a hammer, for example, but it cannot ever become one. A smart hammer is one that contains inscription: rules and instructions for hammering. Turing machines open a space of interiority, by which mechanical actions (hammering, in our case) can be traced into their notational equivalents (instructions for hammering). A smart hammer, or any other smart thing for that matter, presupposes a system of symbolic exchange within the instrument.

Once assimilated in this way, symbols are subject to grammatical transformation. Turing machines unfold the logic of instrument use, that is, their technique. More complicated symbolic logics, which represent higher level activity like solving physical formulas or writing poetry, are similarly amenable to Turing simulation, provided a grammar. Technique, if you recall from our earlier discussion, is a mode of production abstracted from its material contexts. The extent to which Turing machines penetrate everyday life belies their involvement in the general mechanisms of such abstraction, beyond computation. The computer extends its reach broadly not because it quantifies life, but because much of human cultural and cognitive activity is already symbolic in nature. The Turing machine is ultimately a tool for universal symbolic manipulation.

Let us examine the mechanics of a Turing machine more closely. Turing begins his paper as we would expect from Wittgenstein’s student, with a provocative analogy: “We may compare a man in the process of computing a real number to a machine which is only capable of a finite number of conditions.”[[88]](#endnote-89) From the start, Turing treats computation, which we normally consider a complex cognitive process, as a simple mechanism. To these ends, he proposes a machine “supplied with a ‘tape’ (the analogue of paper) running through it, and divided into sections (called ‘squares’) each capable of bearing a ‘symbol.’”[[89]](#endnote-90) Much like a movie reel, the tape moves through the mechanism one section at a time.

At each point only one section bearing one symbol is “in the machine.” “We may call this square the ‘scanned square,’” Turing writes:

The symbol on the scanned square may be called the “scanned symbol.” The “scanned symbol” is the only one of which the machine is, so to speak, “directly aware.”[[90]](#endnote-91)

The scanned symbol becomes a part of the machine’s internal configuration, or, to slide into Turing’s cognitive vocabulary, a part of its “awareness.” The machine can “effectively remember,” Turing argues, the symbols which it has “seen” and scanned previously.[[91]](#endnote-92) Its initial configuration—the arrangement of tape and scanning apparatus—plus the scanned symbol determines its behavior. The scanned symbol becomes a part of machine “memory,” whereby symbols are translated into machine states. Today we would say that the mechanism transforms “software” into “hardware” and the other way around.

We imagine then a device not unlike a telegraph or a film projector, which ingests reels of tape. Unlike telegraphs or film projectors, the ingested symbolic representation becomes, by definition, a part of the machine’s internal state, in a way that telegraph tape or film reels do not when they pass through telegraphs and film projectors. The film reel and the ticker tape do not leave a trace, nor do they signify machine states. By contrast, Turing’s tape alters the machine’s internal configuration in a way that lasts beyond its discharge from the mechanism.

In his earlier thought experiments, Wittgenstein also spoke of humans in the process of reading or doing mathematics as “ingesting” symbols; of the need to internalize external symbolic states; and of affecting a change in mental states, on some real and empirically observable neurological level, which correlates to the symbol. Turing’s machine is capable of such ingestion. It “thinks,” “reads,” and “remembers” to the extent of its capability to scan and internalize symbolic notation. In addition to reading, Turing’s machine also writes. He explains that “[i]n some configurations in which the scanned square is blank (*i.e.* bears no symbol) the machine writes down a new symbol on the scanned square.”[[92]](#endnote-93) It should thus also be capable of erasing and moving symbols to adjacent squares, one square at a time. The Turing machine in effect gives us a concise and minimally viable definition of “reading,” “writing,” and “becoming aware.” These states for Turing involve the appropriate internalization and subsequent externalization of the symbol, for both human and machine.

More than a simple scanner, a Turing machine is also capable of altering the very rules of reading and writing. If we take “reading” to initially entail “moving our eyes from left to right,” we can also imagine notation that stands for directives like “now move from right to left,” or, “skip every other character.” Such directives become a part of the mechanism to determine the movement of the “reading” and “writing” apparatus along the surface of the tape. Unlike an analog watch, the mechanism of the Turing machine is not “set in stone.” It is capable of altering its own inner works, where some of the scanned characters represent symbols to be manipulated and yet others represent machine instructions, which define the rules for manipulation. Data and instructions mix into the same input stream. The instructions are “meant” for the machine, in the sense that they direct the movement of the reading and writing heads, which “write,” “scan,” or “erase” symbols. Today, we would call such instructions “programs,” “applications,” or “software.” Other outputs are meant for the human operator, interested in the functional outcomes of the action.

Just as Turing machines are able, in theory, to convert extrinsic signs into intrinsic machine states, they can conversely enact the opposite movement, by representing machine states symbolically. This remarkable property allows for what Turing calls a class of *universal* machines, distinct from mere single-purpose computers. Single purpose Turing machines perform singular actions like addition or multiplication. The multiplication machine cannot, however, perform other types of symbolic manipulation—like spell check, for example—because the physical movement of its internals is fixed. An electronic weight scale, to take another example, cannot process text or calculate missile trajectories. The universal Turing machine by contrast has the ability to internalize other machine configurations, wholesale. Such a machine can, in Turing’s words, “compute any computable sequence.”[[93]](#endnote-94) In being able to internalize physical configuration as symbol, the universal Turing machine gains the ability to simulate all other single-purpose Turing machines, as long as the logic of these machines is amenable to symbolic representation. For this reason, Turing computation excludes non symbolic mechanical actions like hammering nails or harvesting grain. The universal Turing machine is a tool for ubiquitous symbolic manipulation; it is a trace of a trace; a diagram of diagrams.

The transition of symbols into machine states (and the other way around) defines modern programming. Unlike other, definitive, single-purpose and limited-state mechanisms (a clock for example), a universal machine contains the ability to take on differing internal symbolic configurations. It can imitate a clock, an abacus, a scale, a book. In a later paper that links computing machinery to intelligence, Turing implied also that his machine could eventually simulate human thought, because he saw the mind as another mechanism for manipulating symbols.[[94]](#endnote-95) Are minds just types of Turing machines or are Turing machines a kind of mind? Turing leaves the door open for either possibility. The universal Turing machine finally encapsulates a model of computation itself. It is capable of computing anything computable. In substituting the concept of computability with “effective computability” Turing’s paper belongs to the annals of mathematical theory. It continues to elicit conflicting responses widely because much of it contains also the excess of symbolic thought, related to our more general sense of it it means to read, write, and think. Besides offering mathematical proofs, Turing’s work embarks on an experimental, ludic even, enterprise in the spirit of Wittgenstein’s playful experimentation, which often involved altered states of mind, drugs, delirium, madness, and outright deception.

## Device

Literature in computer science tends to treat Turing machines as algorithms: logical, not necessarily physical constructs.[[95]](#endnote-96) It is impossible however to dissociate the implementation from the idea. The historian Thomas Haigh wrote that Turing machines “abstract away from the complexity of real computer architectures.”[[96]](#endnote-97) It appeals to the theorist because it is a theory. Haigh notes also that “hardware and software are interchangeable to the theorist, but not to the historian.”[[97]](#endnote-98) In his 1937 review of Turing’s “On Computable Numbers” paper, Alonzo Church, the American mathematician whose work anticipated Turing’s (independently) in several important aspects, would similarly acknowledge the material foundations of Turing computing. A “human calculator, provided with pencil and paper and explicit instructions, can be regarded as a kind of Turing machine,” he wrote.[[98]](#endnote-99) Disregarding the broader, metaphysical implications of that statement, note for now the persistence of two implements required for the minimally viable operation of the Church-Turing human and machine calculators. Pen and paper assert themselves through the abstraction.[[99]](#endnote-100)

To encounter digital books and therefore Turing machines as devices, media and book historians will find that they borrows from a number of extant designs, which, together and incrementally, give universal Turing machines their physical form. What are their technological antecedents? What would happen, for example, if Turing attempted to patent his device? What prior art would he cite in his patent application?

Most of the minimal technical requirements to build a universal Turing machine were within reach in the 1930s, at the time when Turing authored his influential paper. In practice, his proposal would require first an apparatus capable of “scanning” and “erasing” a “finite number of symbols.” Second, it called for what Turing described as “one-dimensional paper,” divided into discrete squares “like a child’s arithmetic book.”[[100]](#endnote-101) Furthermore, Turing specified a mechanism to advance tape through the machine, or, alternatively, to propel the scanning mechanism along a length of tape. Having assembled these elements, our creation would look roughly like a cross between a telegraph, film projector, and typewriter.[[101]](#endnote-102)

Were one to patent the Turing machine in the United States, at the time of its invention, the above elements would find prior art in mechanisms such as the “Numeral adding or subtracting attachment for type-writing machines,” “Combined Type-writing and Computing Machine,” “Computing Attachment for Typewriters,” “Computing Mechanism,” and “Combined Type-writing and Adding Machine” among others.[[102]](#endnote-103) All of these devices contain some combination of reading and writing “heads,” storage tape, and movement mechanism as per Turing’s specifications. A number of inventions at the end of the nineteenth century relate specifically to “circuit-controlling devices controlled by a traveling perforated strip or tape,” as is the case with tape-driven telegraph transmitter filed by Charles Cuttriss in 1893.[[103]](#endnote-104)

Prior to perforated tape, the transmission of messages by telegraph required the presence of a skilled operator, able to transcribe messages from text to Morse code, and into the physical motion of a lever-operated circuit. In the operation of early telegraphy, human operators acted as mute interpreters between text and telegraph. The perforated tape decoupled humans from machines. In US patent #1187035 (1916) on “Telegraphy”, brothers Albert and Ralph Bumstead explain: “the object of our invention is to provide a system of telegraphy which does not require skilled operators for the transmission and reception of messages.”[[104]](#endnote-105) Instead, the message was transcribed into perforation via mechanical means and then fed into the mechanism. Typewriter’s tape movement could then be coupled with telegraph electronics, where perforated tape mediated between the two “worlds” of mechanics and electricity. A number of contraptions emerged at the time with the aim of transfiguring mechanical action into perforation, and, consequently, perforation into script, completing the circuit between automated “encoding” and “decoding.” These included machines for tape-controlled telegraphic transmission, tape-controlled printing, printing telegraphs, and remote broadcast programming devices for radio and television content.[[105]](#endnote-106)

With the invention of punch cards and perforated tape (also used in textile looms, as early as 1725), a message meant for another human became also a physical medium—bumps and holes—used to animate the mechanical movement of the transmission apparatus, the kind of rigid linkage Wittgenstein described in his thought experiments. Indeed, of the 33 asserted claims in the “Telegraphy” patent by the Bumstead brothers, the first 13 relate to the transmission of intelligence:

[…] adapted to initiate a succession of electrical impulses all of which have a character representing significance, a receiver adapted to detect variations in the time intervals elapsing between successive impulses, a plurality of interpreting relays selectively actuated by said receiver, and a printing mechanism responsive to the combined action.[[106]](#endnote-107)

What began as a description of a communication mechanism, concluded with a claim about hermeneutics of control. Starting with clause 14, the brothers describe a telegraph system capable of transmitting impulses at varying time intervals. In the language of the patent, the length of a time interval “represent[s] significance,” involving an automated receiver responsible for “distributing, interpreting, and recording.”[[107]](#endnote-108) The printing mechanism is further “arranged to print the interpretation of the signals.”[[108]](#endnote-109) Interpreting relays thus transform time intervals into typography, representing letters, figures, and other characters, in “accordance with a code.”[[109]](#endnote-110) Initially, the telegraph “interprets” with the aim of “transmitting intelligence.”[[110]](#endnote-111)

Subsequently, the authors understood also that a length of transmitted time interval could also signify information used to actuate a variety of devices. The brothers thus refer to their invention in broad terms, calling it a “controlling medium,” capable of regulating remotely everything from typesetting machines to generic sunflower switches. “Indeed, the detector and interpreting relays could be made to actuate a set of sunflower switches for an indicator […] without including a printer at all,” they conclude.[[111]](#endnote-112) What starts out as a communication device, by the end of the patent is generalized into a universal control mechanism.

Driven by ticker tape and connected to printers, automated telegraphs contained all the necessary Turing features: a discrete symbolic language, removable storage media, and a mechanism capable of altering its physical states according to instruction. These proto-computers read and wrote; they ingested tape and converted extrinsic symbols into intrinsic configurations of the mechanism. By 1905, Donald Murray, inventor of the popular Murray telegraph, could write that “[i]f we disregard the small class of telegrams that merely express emotions, *the essence of telegraphy is control* [emphasis mine].” He stressed that telegraph systems “belong, not to the class of producing or distributing, but to the class of controlling mechanisms.”[[112]](#endnote-113) For the automated telegraph, control code and message are one. The mechanism “interprets” some signals as data to be manipulated and others as control code, the rules for such data manipulation. The first type of code holds significance for humans, where the second for the mechanism itself. The mechanism “transmits intelligence” in the sense of rarefying machine states; it “interprets” in the sense of mechanical embodiment.

Computing scales, dial recorders, electric tabulating machines, and computing typewriters were widely available on the market, made by companies like Underwood Computing Machine, Electromatic, and International Business Machines (IBM). Rather than a single eureka moment, the invention of the computer should therefore be viewed as a gradual historical process that culminates in Turing’s universal and minimally viable specifications.

The limits of physical engineering pull the Turing machine back to the sphere of the applied.[[113]](#endnote-114) What are we to make of universal Turing machines implemented in virtual worlds like *Wireworld* (a cellular automaton simulation), or *Minecraft* (a procedurally generated sand-box world-exploration game)? In the least, we must admit that such simulations do not rest on the immaterial “turtles all the way down,” unless that is, one believes that the universe itself is a type of Turing computation.[[114]](#endnote-115) At some point, the Turing machine in the virtual world meets the material limits of the physical. Simulation engines like *Minecraft* and *Wireworld* do in some sense exist in the abstract, as code or even rules written on paper. In another sense, they do not. They come fully into being when instantiated within first-order physical constrains that involve actual circuit boards and relay switches, or, in the least, pen and paper. For this reason, the performance (in terms of cycles per second, instructions per cycle, or its capacity to hold a number of instructions) of a Turing machine simulated within a virtual world like *Minecraft* cannot logically exceed the performance of the machine running *Minecraft* itself. The physical capabilities of the bottom-most device limit the computational power of all *n+1* order Turing simulations. The bottom-most turtle may have its head in the clouds, but its feet rest firmly on the ground.

The exact plane where the symbolic meets the material is difficult to identify. At some imperceptible point software disappears into hardware. Such ambiguity leads to controversy in the critical literature, as evidenced by Lev Manovich’s playful response to Kittler’s “there is no software” argument, in which the latter posits what he calls the “postmodern writing scene.” “[W]e do not write anymore,” Kittler writes. “[H]uman-made writing passes through microscopically written inscriptions which, in contrast to all historical writing tools, are able to read and write by themselves.”[[115]](#endnote-116) Kittler sees the paper-bound blueprints for the first integrated microprocessor as the last “real” piece of writing. Everything written after that point is hardware, because all digital modes of representation, including text, ultimately rest on physical circuit architecture. The inability to understand hardware, in this view, precludes all higher modalities of reading, writing, and interpretation.

Manovich inverts Kittler’s argument into “there is only software,” by which he means that in a pragmatic sense, software determines the properties of any media object. The inversion participates in the perpetual dialectics between idealism and materialism: Hegel and Marx, Marx and Gramsci, Gramsci and Kittler, Kittler and Manovich. “[W]hat you can do with the same digital file can change dramatically,” depending on the software, Manovich writes. When it comes to digital photographs, to use his example, one application may allow the photographer to crop the image while another may not.[[116]](#endnote-117) From this property-determining aspect of software (and in reference to the work of Alan Kay), Manovich adopts the concept of the *metamedium*, “a medium that can dynamically simulate the details of any other medium.”[[117]](#endnote-118) Software defines the properties of digital manipulation, determining the physics of all higher-order media it simulates.[[118]](#endnote-119)

Kittler, would perhaps object that all such higher-order, simulated physics rest on the bedrock of silicon. In opening a series of nested software black boxes, the post-silicon writer and scholar of software hits the impenetrable casket of chip architecture. Manovich’s observations hold true for all simulated media, but not for the simulation itself; hardware that gives rise to simulation is not in itself one. Base media ultimately determine the properties of software, their derivative meta-media.

Wittgenstein’s thought experiments do not let us fall definitively into the software or hardware camp. The Turing machine remains in flux, within the transformation of signs into physical states. We return finally to the sheer alienness of the book as a piece of telecommunication technology, captured in the struggle to behold the epistemic object—recall Shklovsky, Lubbock, and Bakhtin, in the earlier sections. Writing already converts mental states into arbitrarily externalized marks on paper. Such inscriptions persist, through time, beyond their biological origin. They are then conveyed remotely and through ingestion, commonly called “reading:” an action that transforms the inscription back into a mental state. The intellectual history of Turing machines leads us to a series of thought experiments about the nature of such transformations. The question of technique continues to haunt contemporary poetics. In the process of reading, the book escapes the interpreter’s grasp as a thing, presenting itself only as an idea.

What does the material history of the computer mean for the history of the book? In viewing the book as a precursor to a generalized machine for symbolic manipulation we discover that it belongs to a class of controlling devices. The very nature of Turing machines implies an irreversible admixture of matter, content, and control structure. When reading a paper-and-cloth book, one can definitively isolate a) the medium from b) content and from c) the legal and political structures governing its production. To separate these components, one could, for example, tear out the copyright notice along with the ISBN number, copy the words into a notebook, and recycle the paper.

The literary device, by contrast, ingests both symbolic representation and control code through the same input stream. Where images of governance (like trademark and copyright symbols) signify control, computed text embodies it. We are not able to fully separate the medium from its message. Mechanisms of copyright enforcement are embedded into the device. The content is inextricably intertwined with the medium. One could copy and paste it, but the action would miss layers of meaning not accessible at the surface.

In asking “How is it made?” we arrest the advance of symbolism in an attempt to find the thing behind the process of signification, which always dissembles to conceal its material foundations. Signification ultimately terminates at the physical boundaries of its establishing medium. Base conditions differ from paper to screen. Paper pages contain no internal states to speak of. The kind of symbolism they supports therefore proceeds from the surface inscription towards the reader. Reading, as Moreno reminds us, is already an invasive procedure. Absent human contact, we take on the mental states of others through a vehicle that conveys a remote kind of agency, displaced in time and space. It should be held in view all the more because the electronic book, unlike paper, does contain internal states of its own which further interject in the process of signification. How is it made becomes a question not only for the poetics but also for the politics of reading.

The question of technique seeks to expose the rules of symbolic transference between at least three discrete systems: one inorganic, the book, one symbolic, text, and one biological, body. There is of course a way in which the three are one: we are all cyborgs in a sense—an assemblage of organs, instruments, and inscriptions. In another sense, poetics asks us to consider the constructed nature of the coupling: the point of contact being governed by rules of engagement, protocols, grammars, and translation tables. These constructed entities grow and proliferate in a seemingly organic, ad-hoc manner. They comprise a part of our received technological a priori. This does not mean however that they should be naturalized or treated with a reverence afforded to endangered species or to nature itself. To decouple ourselves from inscription, if only momentarily—to reject the graft or to let it wither—must remain an option. If poetics lays the grounds for interpretation, we must acknowledge that today, such grounds lie past the digital page’s visible simulacrum.

Where literary technique is concerned with the passage of ideas to ink, computational technique extends the chain of signification also to pixel and transistor. Techniques of the body and literary techniques intertwine in the process of conventional reading. The two couple ever tighter when reading electronically. Miniaturized, the Turing machine passes into the body—think of a digital pacemaker, for example, an inscription within the machine within the body. These linkages are deeply embedded. They require explication, underscoring the continual importance of poetics.

In the process of textual production, printing, and typesetting, it is certain that my message was packaged with control codes that, in turn, have changed the structure of the reading device: in a lap, at hand, near the eye. I could believe that I bear no responsibility for extending the reach of machine languages so close to the reader; I only wrote the content; I am not responsible for those other inscriptions. But that would be factually incorrect. The choice of our writing implements and channels of communication affect deeply the contexts of interpretation. Such choices, in aggregate, define the shared ecosystem of knowledge production. Traditional strategies of close reading which limit interpretation to the parsing of visible content risk missing the concealed machinations of naked circuit control. It looks like we are reading books, but this book may change depending on the reader’s race, gender, ethnicity, geography, or political affiliation. Who authors or authorizes these transformations? Were books also pills or fused with the brain’s neural circuitry, would we know what and whom we were reading?

1. Moreno, *Who Shall Survive?*, 595. [↑](#endnote-ref-2)
2. Moreno is remembered today as a pioneer of group therapy and an early critic of Freud and socialism. Sociologists have also recently rediscovered his formative work on network analysis. His books contain beautiful diagrams, sprouting nodes and edges, with titles like “Structure of a Cottage Family,” “A Handicraft Group,” and “The Civilian Social Atom.” Moreno was also a humanist and a philosopher of technology and culture. In opposition to eugenics, a popular philosophy at the time, his answer to “Who Shall Survive?” was “everyone.” See ibid., , 245. [↑](#endnote-ref-3)
3. Ibid., 595. [↑](#endnote-ref-4)
4. Ibid., 596. [↑](#endnote-ref-5)
5. Ibid., 600–601. [↑](#endnote-ref-6)
6. Ibid., 597, 601. [↑](#endnote-ref-7)
7. Ibid., 598. [↑](#endnote-ref-8)
8. Plato, “Phaedrus,” 482(250a). [↑](#endnote-ref-9)
9. Moreno, *Who Shall Survive?* [↑](#endnote-ref-10)
10. Lapsed consent is a common theme in the works of Thomas Hobbes, John Locke, and John Stuart Mill. To paraphrase, they ask: What makes whatever voluntary compacts made by past generations still valid today? [↑](#endnote-ref-11)
11. Ibid., 600. [↑](#endnote-ref-12)
12. Marx and Engels, *Capital, a Critique of Political Economy*, 72. [↑](#endnote-ref-13)
13. See Soyata et al., “COMBAT”; Logicworks, “Government Cloud on the Rise.” [↑](#endnote-ref-14)
14. “Device, N.” [↑](#endnote-ref-15)
15. I rely on the Russian originals throughout, but will cite the English translations where possible as well. See Shklovsky, *Voskreshenie Slova*; Shklovksy et al., *Poetika*; Shklovksy, “Art as Technique.”. [↑](#endnote-ref-16)
16. Nabokov, “A Guide To Berlin,” 27; Johnson, “A Guide to Nabokov’s ‘A Guide to Berlin’,” 354. [↑](#endnote-ref-17)
17. Kranzberg, “At the Start,” 5–6. [↑](#endnote-ref-18)
18. Winner, *Autonomous Technology*, 4. [↑](#endnote-ref-19)
19. *Technology* overtakes *technique* around 1979, judging by the relative frequency of occurrence in the Google Books n-gram corpus Michel et al., “Quantitative Analysis of Culture Using Millions of Digitized Books.”. [↑](#endnote-ref-20)
20. See for example Osip Brik’s “Against Creative Individualism” and Shklovksy’s “On Authorship and Production” in Chuzhak, *Literatura Fakta*. [↑](#endnote-ref-21)
21. Benjamin, “The Author as Producer,” 87. [↑](#endnote-ref-22)
22. Ibid., 87. [↑](#endnote-ref-23)
23. Schopenhauer, *The World as Will and Idea*, 1:249 and 217-346. [↑](#endnote-ref-24)
24. Shklovksy et al., *Poetika*, 102. [↑](#endnote-ref-25)
25. Ibid., 105. [↑](#endnote-ref-26)
26. Spencer, *The Philosophy of Style*, 7. [↑](#endnote-ref-27)
27. Ibid., 3. [↑](#endnote-ref-28)
28. Ibid., 32. [↑](#endnote-ref-29)
29. Shklovsky, *Voskreshenie Slova*. [↑](#endnote-ref-30)
30. Moreas, “Le Symbolisme,” 150. [↑](#endnote-ref-31)
31. Bakhtin, “K Voprosam Metodologii Estetiki Slovesnogo Tvorchestva (On the Questions of Methodology of the Language Arts),” 270–1. [↑](#endnote-ref-32)
32. Ibid., 308–10. [↑](#endnote-ref-33)
33. Ibid., 310. [↑](#endnote-ref-34)
34. Ibid., 373–4. [↑](#endnote-ref-35)
35. Ibid., 249. [↑](#endnote-ref-36)
36. Ibid., 275. [↑](#endnote-ref-37)
37. Nabokov, *Invitation to a Beheading*, 223. [↑](#endnote-ref-38)
38. Lubbock, *The Craft of Fiction*, 1. [↑](#endnote-ref-39)
39. Ibid., 272. [↑](#endnote-ref-40)
40. Lubbock collapses the difference between painting and sculpture. See by contrast the extended discussion in Herder, *Sculpture Some Observations on Shape and Form from Pygmalion’s Creative Dream*. [↑](#endnote-ref-41)
41. Shklovksy et al., *Poetika*; Lubbock, *The Craft of Fiction*, 12, 28; Eichenbaum, “How Gogol’s ‘Overcoat’ Is Made.” [↑](#endnote-ref-42)
42. Lubbock, *The Craft of Fiction*, 274. [↑](#endnote-ref-43)
43. Ibid., 273. [↑](#endnote-ref-44)
44. Ibid., 4. [↑](#endnote-ref-45)
45. Ibid., 6. [↑](#endnote-ref-46)
46. Ibid., 6. [↑](#endnote-ref-47)
47. Ibid., 273–4. [↑](#endnote-ref-48)
48. Evidence suggests that Wittgenstein read Russian and that he visited the Soviet Union in the 1930s. Both he and Shklovsky fought in Galicia at the Eastern Front. Nothing in the sources suggests that they met or knew of one another’ work. See Moran, “Wittgenstein and Russia.”. [↑](#endnote-ref-49)
49. Pasquale, *The Black Box Society*; Harcourt, *Exposed*. [↑](#endnote-ref-50)
50. Church and Turing, “On Computable Numbers, with an Application to the Entscheidungsproblem.” [↑](#endnote-ref-51)
51. Descartes, Bluhm, and Descartes, *Discourse on the Method; and, Meditations on First Philosophy*, 36. [↑](#endnote-ref-52)
52. Gillespie, “Primal Utterance,” 32. [↑](#endnote-ref-53)
53. Searle, “Minds, Brains, and Programs.” [↑](#endnote-ref-54)
54. Ibid. [↑](#endnote-ref-55)
55. See Plato, *Plato*. I translate the passage into literal English to preserve characteristics notable in the original. In particular, note the parallelism between *exōthen* and *endothen*, the ambiguity of *allotrion*, as a freight other, and the subtle slide between *graphō* (letter, figure, writing) and *tupōn* (type, impression, trace). I extend my gratitude to Stathis Gourgouris, Simos Zenios, and Guy Smoot for their help with Greek translations. [↑](#endnote-ref-56)
56. To give you a sense of the timeline: Turing entered King’s College in 1931. See Hodges, *Alan Turing*, 78. His paper on computable numbers appeared in print in 1936. It is likely that the two philosophers met at the Moral Science Club, where by the 1930s Wittgenstein “monopolized the discussion,” even in the presence of prominent philosophers like George Edward Moore. See Duncan-Jones, “G. E. Moore.”, 25. Turing attended Wittgenstein’s lectures on the foundations of mathematics in 1939. [↑](#endnote-ref-57)
57. Wittgenstein, *The Blue and Brown Books*, 6–7. [↑](#endnote-ref-58)
58. Ibid., 16. [↑](#endnote-ref-59)
59. ibid., , 16. Compare with Descartes, Bluhm, and Descartes, *Discourse on the Method; and, Meditations on First Philosophy*: “If there were such machines having the organs and the shape of a monkey or some other animal that lacked reason, we would have no way of recognizing that they were not entirely of the same nature as these animals; whereas if there were any such machines that bore a resemblance to our bodies and imitated our action as far as this is practically feasible, we would always have two very certain means of recognizing that they were not at all, for that reason, true men.” Also quoted in Dennett, “Can Machines Think?”, 297. [↑](#endnote-ref-60)
60. Wittgenstein, *The Blue and Brown Books*, 16, 46–49. [↑](#endnote-ref-61)
61. Ibid., 119. [↑](#endnote-ref-62)
62. Ibid., 121–22. [↑](#endnote-ref-63)
63. Ibid., 120. [↑](#endnote-ref-64)
64. Ibid., 185. [↑](#endnote-ref-65)
65. Ibid., 185. [↑](#endnote-ref-66)
66. Wittgenstein, *Philosophical Grammar*, 5. [↑](#endnote-ref-67)
67. Ibid., 41. [↑](#endnote-ref-68)
68. Ibid., 42. [↑](#endnote-ref-69)
69. Ibid., 45. [↑](#endnote-ref-70)
70. Ibid., 10. [↑](#endnote-ref-71)
71. Ibid., 69. [↑](#endnote-ref-72)
72. Ibid., 69–70. [↑](#endnote-ref-73)
73. Ibid., 70. [↑](#endnote-ref-74)
74. Ibid., 190. [↑](#endnote-ref-75)
75. Ibid., 187–8. [↑](#endnote-ref-76)
76. Ibid., 190. [↑](#endnote-ref-77)
77. I am forgoing the distinction between interpreters and compilers for simplicity’s sake. See Elbourn and Ware, “The Evolution of Concepts and Languages of Computing.”, 1060; McCarthy, “The LISP Interpreter System.”; Bashkow, Sasson, and Kronfeld, “System Design of a FORTRAN Machine.”; Neuhold, “The Formal Description of Programming Languages.”, 95. [↑](#endnote-ref-78)
78. Wittgenstein, *Philosophical Grammar*, 194–6. [↑](#endnote-ref-79)
79. Wittgenstein, *Wittgenstein’s Lectures on the Foundations of Mathematics, Cambridge, 1939*, 197. [↑](#endnote-ref-80)
80. Ibid., 282. [↑](#endnote-ref-81)
81. Ibid., 195. [↑](#endnote-ref-82)
82. Wittgenstein and Barrett, *Lectures & Conversations on Aesthetics, Psychology, and Religious Belief*, 13–16. [↑](#endnote-ref-83)
83. Not much is written on the intellectual connections between Turing and Wittgenstein. See Copeland and Proudfoot, “What Turing Did After He Invented the Universal Turing Machine.” and Wagner, “Wittgenstein Et Les Machines De Turing.”. [↑](#endnote-ref-84)
84. Wittgenstein, *Wittgenstein’s Lectures on the Foundations of Mathematics, Cambridge, 1939*, 67–68. [↑](#endnote-ref-85)
85. The intellectual history of the Turing machine is well established. It follows works by Diophantus, René Descartes, Georg Cantor, David Hilbert, Gottlob Frege, Bertrand Russell, Kurt Gödel, Ludwig Wittgenstein. See Petzold, *The Annotated Turing*; Herken, *The Universal Turing Machine*; Grattan-Guinness, “On the Development of Logics Between the Two World Wars.”. [↑](#endnote-ref-86)
86. Turing’s later work suggests that his use of cognitive language throughout “On Computable Numbers” was not accidental, and that he meant it to define sentience more generally Turing, “Computing Machinery and Intelligence.”. [↑](#endnote-ref-87)
87. Ibid., 458. [↑](#endnote-ref-88)
88. Turing, “On Computable Numbers, with an Application to the Entscheidungsproblem,” 231. [↑](#endnote-ref-89)
89. Ibid., 231. [↑](#endnote-ref-90)
90. Ibid., 231. [↑](#endnote-ref-91)
91. Ibid., 231. [↑](#endnote-ref-92)
92. Ibid., 231. [↑](#endnote-ref-93)
93. Ibid., 241. [↑](#endnote-ref-94)
94. See Turing, “Computing Machinery and Intelligence.”, 460: “We may hope that machines will eventually compete with men in all purely intellectual fields.” [↑](#endnote-ref-95)
95. To what extent a personal computer is a Turing machine is matter of contention. The Turing machine is a *thought experiment* that imagines a machine. The PC is a machine emulating the thought experiment. See Putnam, *Representation and Reality*, 121-5; Chalmers, “Does a Rock Implement Every Finite-State Automaton?”; Petzold, *Code*. [↑](#endnote-ref-96)
96. Haigh, “Actually, Turing Did Not Invent the Computer,” 241. [↑](#endnote-ref-97)
97. Ibid., 241. [↑](#endnote-ref-98)
98. Church and Turing, “On Computable Numbers, with an Application to the Entscheidungsproblem,” 42–43; also cited in Petzold, *The Annotated Turing*, 63. [↑](#endnote-ref-99)
99. This is a topic of some contention in the literature. James Moor includes software immateriality as one of the “three myths” of computer science: “as a practical matter what we regard as computer instructions, and consequently what we regard as computer programs, is determined by the computers available.” See moor\_three\_1978, 215. Nurbay Irmark argues that software is instead a purely abstract artifact, akin to a musical work. See Irmak, “Software Is an Abstract Artefact.”. See also Turner, “Programming Languages as Technical Artifacts.”; Colburn, “Software, Abstraction, and Ontology.”. [↑](#endnote-ref-100)
100. A true universal Turing machine would require a tape that is infinitely long. See Turing, “On Computable Numbers, with an Application to the Entscheidungsproblem.”, 249. [↑](#endnote-ref-101)
101. Mike Davey built and displayed a similar instrument at Harvard University’s Collection of Historical Scientific Instruments in 2012. He writes: “My goal in building this project was to create a machine that embodied the classic look and feel of the machine presented in Turing’s paper. I wanted to build a machine that would be immediately recognizable as a Turing machine to someone familiar with Turing’s work” Davey, “A Turing Machine Overview.”. [↑](#endnote-ref-102)
102. Daugherty, Numeral Adding or Subtracting Attachment for Type-Writing Machines; Degener, Combined Type-Writing and Adding Machine; Wright, Computing Mechanism; Wright, Computing Attachment for Type-Writers; Ellis, Combined Type-Writing and Adding Machine. [↑](#endnote-ref-103)
103. Cuttriss, Telegraphy. [↑](#endnote-ref-104)
104. Bumstead and Bumstead, Telegraphy. [↑](#endnote-ref-105)
105. Wheatstone, Improvement in Receiving-Instruments for Electric Telegraphs; Murray, Tape-Controlled Telegraphic Transmitting Apparatus; Bumstead and Bumstead, Telegraphy; Creed, Printing Apparatus Controlled by Perforated Tape.; Hallden, Printing-Telegraph System; Vriendt, Program Distribution System; Brown, Automatic Program System; Brown, Selective Program System. [↑](#endnote-ref-106)
106. Bumstead and Bumstead, Telegraphy, 13–14. [↑](#endnote-ref-107)
107. Ibid., 14. [↑](#endnote-ref-108)
108. Ibid., 6. [↑](#endnote-ref-109)
109. Ibid., 13. [↑](#endnote-ref-110)
110. Ibid., 12. [↑](#endnote-ref-111)
111. Ibid., 12. [↑](#endnote-ref-112)
112. Murray, “Setting Type by Telegraph,” 556. [↑](#endnote-ref-113)
113. The institutional distinctions between software engineering and computer science often hinge on the extent to which the discipline pays heed to the physical limitations of computing. As usual the situation on the ground is much more complicated, and the boundaries between software engineering and computer science are fast eroding. Still, North American students often have the choice to major in Computer Science or Software Engineering. It would not be unusual for the one faculty to be located in the School for Liberal Arts and Science and the other in the School of Engineering. Consider also the two major professional organizations: Institute for Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM). See Glass, “A Comparative Analysis of the Topic Areas of Computer Science, Software Engineering, and Information Systems.”; Parnas, “Software Engineering Programs Are Not Computer Science Programs.”; Glass, Ramesh, and Vessey, “An Analysis of Research in Computing Disciplines.”; Vessey, Ramesh, and Glass, “A Unified Classification System for Research in the Computing Disciplines.”. [↑](#endnote-ref-114)
114. Deutsch, “Quantum Theory, the Church-Turing Principle and the Universal Quantum Computer”; Lloyd, “Ultimate Physical Limits to Computation”; Piccinini, “Computational Modelling Vs. Computational Explanation.” [↑](#endnote-ref-115)
115. Kittler, “There Is No Software.” [↑](#endnote-ref-116)
116. Manovich, “There Is Only Software,” 273. [↑](#endnote-ref-117)
117. Kay, “Computer Software,” 59, qtd. in Manovich, *Software Takes Command*, 105-6. [↑](#endnote-ref-118)
118. Ibid., 150–1. [↑](#endnote-ref-119)