



André Ourednik

# ROBOPOÏÈSES

LES INTELLIGENCES ARTIFICIELLES DE LA NATURE

NOUVELLE ÉDITION REVUE ET AUGMENTÉE

**Abstract.** Artificial intelligence, as we understand it today focuses on “machine learning”, whereby an isolated program evolves to make increasingly “correct” decisions with a predefined objective in mind. Its myth feeds on the ideology of the *self-made-man*, seen as a model of intelligence by the major investors in the AI field. While starting to display a creative potential, this kind of intelligence lures our imagination to the gravity centres of established systems of thought, whom it contributes to immobilise. To escape from its pull, we need broader perspectives. This essay examines AI in the perspective of a long tradition. Its history begins with the emergence of spoken language, and is materialised in writing and in the urban structures of antique cities. Ourednik reveals AI as a *set of symbolic and functional systems* that mediate our relationship to the uncontrollable, the unnameable, the elusive, in other words: to nature. Linking the law tablets of the city of Ur, the Vedic meganumbers, the automata of the 18<sup>th</sup> century, cybernetics and generative algorithms, this is the story of the growing autonomy of thinking devices. What role will humans play in their creations in the future? Does artificial intelligence that escapes human control become “nature” again? With what consequences? Can AI help us in our relationships with other living beings, with our own subjectivity and with our natural environment?

**André Ourednik** is a researcher, writer and lecturer at the Swiss Federal Institute of Technology (EPFL) and the University of Neuchâtel. Trained in geography, philosophy and the digital humanities, he is the author of a doctoral thesis on algorithmic modelling of the inhabited space, as well as numerous articles in newspapers and specialised journals in geography, social science, and human-computer interaction. Since over ten years, he is teaching on the concept of nature to an interdisciplinary audience of polytechnic students, and has worked for several years as a *data scientist* for the Swiss Confederation.

His publications include the hypertext *Wiki-tractatus* (book, Hélice Hélas, 2014, and digital creation<sup>1</sup>), *Les cartes du boyard Kraïenski*, a philosophical journey through spaces, borders and maps (novel, La Baconnière, 2016), *Omniscience*, a metaphysical satire of the data civilisation (novel, La Baconnière, 2017) and the essay *Hypertopie* (La Baconnière, 2019), presented at the CERN Globe in 2022.

# ROBOPOIESIS

Artificial Intelligences  
of Nature

**André Ourednik**

Translated from French by the author

Foreword by Nicolas Nova

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## Foreword to the Second French Edition

In a poem entitled *All Watched Over by Machines of Loving Grace*, published in 1967, Richard Brautigan described a future utopia in which humans, machines and nature would coexist in gentle harmony<sup>2</sup>. Three stanzas composed the text. The American writer evoked a “cybernetic meadow where mammals and computers live together in mutually programmed harmony” and a “cybernetic forest populated by pines and electronics where deer stroll in peace past computers”. However, the final lines made it clear that our place in this “cybernetic ecology” would be ambiguous: we would certainly be “free of our labors and joined back to nature”, but there would be a price to pay: that of being “all watched over by machines of loving grace”.

While literary critics have argued over the interpretation of these few lines, some convinced by Brautigan’s critical irony, others by his blissful utopianism, the merit of this poem is twofold. Firstly, it links com-



puter science and artificial intelligence to the a priori remote subject of nature; and, secondly, it shows the author's desire to take a poetic approach to a technical subject that is generally left to scientists and engineers.

Even if the purpose, aim and tone of Robopoiesis are different from Brautigan's, it was this poem that came to mind when I read André Ourednik's work a few months ago. In particular, for the shared desire to deal with advanced technologies from a literary point of view that captures the nuances and richness of the phenomena, and, in essence, by not detaching them from the ecosystem in which they hatch and unfold. Ourednik is not the only one to have tackled this aspect recently. Robopoiesis is one of a number of publications to have appeared in recent years exploring these issues. In addition to the plethora of texts on the environmental impact of the digital sector, there is more specifically the work of James Bridle. In his opus on animal, plant, fungal and machine intelligence<sup>3</sup>, this English artist and writer sets out to identify how the cognitive or physiological capacities of a number of living beings might suggest alternative ways of thinking about and designing less utilitarian and alienating artificial intelligence systems. We should also mention the philosopher and ethologist Dominique Lestel, who is seeking to show how robots and artificial intelligence are not a form of simulated life, but rather another

singular and unprecedented register of non-biological animation<sup>4</sup>.

Despite this thematic convergence, Ourednik's argument is different, and even more subtle. In defending the idea that artificial intelligence "is not a recent invention, but rather the continuation of a long tradition of creating artificial systems that mediate our relationship with nature", and which aims to "externalise our thought processes", the author is, in his own way, part of another, older current of thought: that of "cultural technology". Originating in the French-speaking anthropological tradition, this movement is interested in the study of material cultures, based on two characteristics that correspond well to what is expressed in Robopoiesis. On the one hand, it describes objects, whatever they may be, as the result of the transformation of matter; in other words, in direct relation to so-called natural elements: from minerals and other metals to plants and animal remains. Whether we are looking at the most minimalist prehistoric bifaces, the most complex smartphones or decorated yams from Papua, the creation and use of these artefacts are the result of processes of action on these materials. Ourednik also reminds us of this, highlighting the importance of critical metals such as Congolese cobalt and those with the "-ium" suffix, such as indium, germanium and cerium. Like this current of anthropology, Ourednik's work does more than simply present the material

underpinnings of digital technologies. He also highlights the ways in which the physical characteristics of our world, and the way in which human collectives think about them to create languages, churches, kitchen utensils, tools and artificial intelligences, “do” something specific to our social relations<sup>5</sup>. This is why Robopoiesis rightly insists on the metaphorical thickness of the digital terminology of recent decades. What is it telling us? What does this profusion of more or less organic expressions commented on by the author practically tell us? What does it mean to live in a world where “random forests”, “trees”, “neural networks”, “cellular automata” and “genetic algorithms” are commonplace?

A second point of connection between Ourednik’s work and the “cultural technology” movement is the idea that human beings, and a few other animals such as primates, extend their gestures and cognition by delegating them to things. In 1964, it put forward the principle of a progressive externalisation of muscular, sensory and then cerebral functions, first in gestures and language, then in technical objects<sup>6</sup>. Without saying that these are “of the same nature as my fingernails”, as Leroi-Gourhan put it, we can follow Ourednik’s lead in understanding how the externalisation of thought processes in thousand-year-old tablets, Vedic meganumbers or post-cybernetic generative algorithms is part of a growing autonomy. This is where

the notion of “-poiesis” in the title of the book comes into its own, since it underlines the unexpected, the surprising and the unthought of these devices. This externalisation is also singular, as the author expresses it, in the sense that technologies such as artificial intelligence systems mediate our relationship with nature, a nature that has itself inspired and constrained the creation of these devices. Here we return to the logic of co-evolution described by the same André Leroi-Gourhan, and above all by his predecessor Marcel Mauss, who reminds us that human beings “create and at the same time create themselves, they create both their means of living, purely human things, and their thoughts inscribed in these things”<sup>7</sup>.

If we find an echo of this anthropological thinking in André Ourednik’s argument, we should not see in this work a single illustration of these two thematic axes, technology as action on natural matter, and as externalisation of the human being. To this type of perspective, and this is his great originality, Ourednik combines other reflections and references drawn equally from philosophy, literature, the natural sciences, mathematics and history. It is this combination, which is as generous as it is intellectually fertile, that allows the subject matter to spill over into considerations that cultural technology rarely addresses, due to its difficulties in grasping industrial objects. It should as well be noted that the quality of this work undoubtedly

also rests on the freshness of the language, the clarity of the progression of the text and the range of cases and fields covered... in the body of the text or in the treasure trove of notes at the end of the volume. This literary dimension of Robopoiesis inevitably gives rise to innovative, hard-hitting thinking, compared with the poor standard of the profusion of essays published in recent years on the subject of artificial intelligence. Unlike this book, which should be read over and over again to discover its many implications, or to ponder the trajectories we might adopt in the face of this “second nature of our thinking exceeding our thinking”, watched over or not “by machines of loving grace”, as in Brautigan’s poem.

It’s up to us, because in most cases, mastery of these technical devices is more a matter of gigantic undertakings over which we have little control than of harmonious coexistence.

Nicolas Nova

## Two Fundamental Melodies

If we try to perceive our century with our ears, we will hear a deafening blare, composed of the drumming of a hundred billion fingers on ten billion touchscreens; the clicking of their fingernails; the suction of their wet fingertips. We will hear the friction of rumours spread across social networks, punctuated by distant explosions, the roar of burning forests, raging rivers and cracking ice floes. And in the lower frequencies, we will hear computer servers trying to hum the sacred syllable *om̐* in the alveoli of the *datacaves*<sup>8</sup>. ॐ

At first, this symphony will sound like a disorderly cacophony. But we have been listening to it for decades, now, and two major musical themes, two fundamental melodies, are starting to emerge: that of the *degradation of the natural environment*, and that of the *emergence of artificial intelligence*. If

everything goes wrong, these two processes will culminate in a stereophonic disaster. It might sound like this:

*The automation of production, distribution and retail will lead to the elimination of more than two thirds of jobs, including in the service sector and the creative industry. Lower wages will reduce production costs, but not prices<sup>9</sup>. Capital will concentrate exponentially in the hands of a few individuals. Isolated citizens will lose their ability to organise as a society to resist the process. They will be divided into competing factions by the lies of content-generating bots on social networks. Prosumers will work for free on corporate farms and pay for the results of their own efforts at automated counters. No longer able to pay their debts, they will be enslaved and become the playthings of the powerful. We will be living through the 120 days of Sodom on a planetary scale<sup>10</sup>. The planet devastated by extractivism will be nothing but dead-land-dead-water<sup>11</sup> with the exception of a few heavenly gardens inhabited by the winners of the process<sup>12</sup>. The immortal Jeff Besos, the three clones of Elon Musk and the neuromorphic blob<sup>13</sup> imbued with the mind of Travis Kalanick, surrounded by their closest system designers and robot trainers, will recline on giant ot-*

*tomans amidst a menagerie of peacocks and transgenic antelopes; they will invite their manager of Asian sweatshops Terry Gou. Jeff, the three Elons, Travis and Terry watching a gladiatorial game with a million protagonists in suits and ties. Drones filming the details of the fights and broadcasting them live. The luckiest of the slaves, among us, will oversee video editing...*

Of course, it doesn't have to come to that.



## Handling the Unspeakable

At eighteen months, a toddler suffers from night terrors induced by the development of her neuronal system. From the middle of the Pleistocene, the hominid species underwent an accelerated process of encephalisation. The first humans must have been afraid of their own brains. They were taken aback by the *hypertrophy* of their thinking organs, who created images that tormented them even in their sleep. Even in broad daylight, they saw new, eerie, imagined things. Everywhere, they guessed ominous agreements between blurred beings. Shadows of rocks and tree trunk hollows harboured illegible threats. The first humans grappled to bind this raging world; to interweave its elements into a coherent idea, in other words, to make intelligence of their environment.

The Latin word *intelligentia* would later describe the ability to make sense of expe-

rience in two movements: *legere* (choosing, selecting singular elements in the environment) then *inter-legere* (establishing relationships between these elements).

Early humans struggled to make sense of the images of the outside world that their brains gathered inside their skulls. The conscious mind of the average human being cannot hold on to a single thought for more than seven seconds<sup>14</sup>. But they could talk<sup>15</sup>.

Like many animals, they were able to export their consciousness into their environment to share it with their peers. Like ants mapping their world with a network of pheromone trails. Like honeybees performing waggle dances until the entire hive knows the locations of food in its vicinity. Like birds transforming the air into a world of song. Like prairie dogs, who modulate their barks to warn each other about the size, shape, and colour of approaching predators. Like whales and dolphins swimming in an acoustic ocean of shared destinies. Like elephants stomping ground to keep track of their mates across the vast distances of the savannah. Most of these exchanges vanish in the moment, others persist: notches, broken branches, pheromones, urine, excrements...<sup>16</sup>.

Never is animal communication limited to information exchange about food and reproduction. Prior to any pragmatic concern, it conveys a sense of community and belonging; a sense of fear and joy of living in a world perceived by the animal's senses. Like most of our neighbours on the phylogenetic tree, we are a "semiotic animal, a species whose individuals are kept together and apart by their use of signs"<sup>17</sup>.

The first humans talked not only to organise themselves in pursuit of an objective, but to reassure themselves, like the child singing a nursery rhyme before falling asleep<sup>18</sup>. Their words made things and beings recognisable. They gave a direction to isolated perceptions; they merged words into a narrative thread that made sense<sup>19</sup>. Pains and pleasures, fears and certitudes, began to alternate in a memorable progression.

Humpback whales teach their offspring songs that vary from community to community and evolve over time. Species of sparrows and parrots use distinct regional dialects in their vocalisations, which they learn from other members of their group. From one generation to the next, elephants pass on their knowledge of water sources and migration routes.

Over the generations, the first hominids developed complex symbolic communication to give shape to the intricate ideas that fogged their brains.<sup>20</sup> They spoke to reassure themselves. They danced to reassure themselves. They sang, they sculpted objects, they determined the perimeters of sacred groves, they built megalithic sites to give shape to the universe of their perceptions. They shaped objects outside their human bodies. Their shared words made the air vibrate to the rhythm of a common thought.

The fantasies of their overgrown brains became a system of things and verbs: an experience they could share. Let us recollect that, for millennia, the starry night sky was the only nocturnal spectacle available to human eyes. Looking at a cloud-covered moon, some thought, perhaps, they saw for instance the pupil of the eye of a gigantic face.

— *It's the face of a god! said one.*

*And some got afraid, for they thought the eye was staring at them. Others laughed.*

— *An eye that size cannot stare at you! Such an eye never looks at any of us in particular. The scope of its concern is far wider than the life of the best of us, wider even than this plain we have never left.*

*Hearing that, the frightened ones felt like children who realise that the gaze of their parents was never intended entirely for them, but in truth embraces the whole world.*

Members of a community who use the same language see identical things, experience similar feelings<sup>21</sup>, share the subjects of their dreams and express fears that others understand.

The intelligence of the language is not the intelligence of the individual. Intelligence is not a quality, an aptitude or a faculty specific to any single human being. You cannot *possess* words. Their only value lies in the fact that others understand them when you speak them out loud. Language is a collective intelligence<sup>22</sup>, a collective object, a collective creation, an intelligence objectified in a system of sounds and signs. Language is a human creation, a product of human action, a fact of art, an artefact<sup>23</sup>.

*Language is the first form of artificial intelligence.*

## The Urban Artefact

Eleven millennia have passed, since thousands of hunter-foragers gathered in the Harran Plain to erect T-shaped stone pillars carved with animal forms<sup>24</sup>. The site belongs to the first *material incarnations* of collective human thought; to the first *devices* of artificial intelligence.

Much separates the sculptures on the Harran plain from the immediate, immanent world. The separation remains tenuous, though, if we compare it to the gap that more recent thinkers dug between reality and the imaginary. The first humans hardly theorised about the distinctions between body and mind, or between signifier and signified. They did not yet erect an otherworldly realm of metaphysics. People, animals and spirits inhabited a common world<sup>25</sup>. Yet, a human intelligence outside of human intelligence took shape; extracted from the chaos of the

brain, extracted from the raging ocean of unstable ideas, and from the *flowing thisness* of immediate experience<sup>26</sup>; an intelligence rooted in words, symbols and artefacts.

Such artefacts required the collective effort of vast populations, and formed urban archetypes: seeds of a collective imagination that laid the foundation for the growth of early cities<sup>27</sup>. As the cities grew, so did the scale of artificial intelligence.

Chance alone does not explain the resemblance between the shapes of urban structures and those of computer motherboards. Both proceed from a similar effort to organise the reality of our world. Imagine an archaeologist from the future discovering a motherboard! She'll think she's dealing with a scale model of a rational city<sup>29</sup>, very similar to the chequerboard plan conceived by Hippodamuses for the city of Miletus in the first century BC, or to that designed by Simeon de Witt and John Rutherford for the city of New York in the 19<sup>th</sup> century. Urban architecture and computer design share common principles of organisation and intelligent planning.

Computers are machines for thinking the world in terms of functions. Cities are existential machines; machines for thinking about common life in terms of functions.

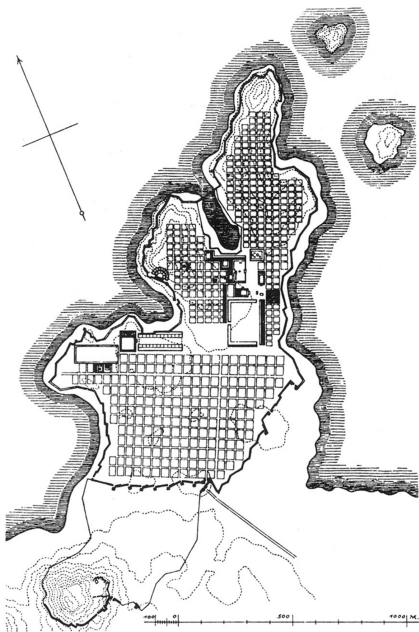


Figure 1: *Urban plan of Miletus designed by Hippodamos, 450 BC<sup>28</sup>.*

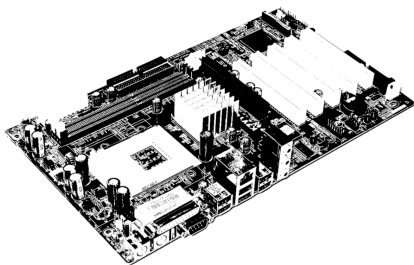


Figure 2: A city ?



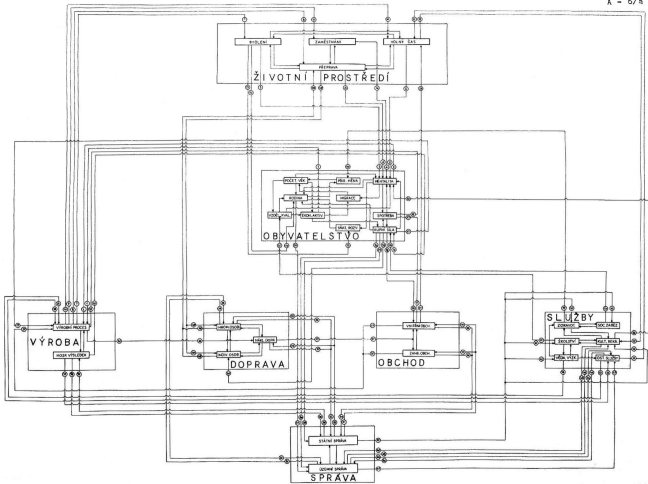


Figure 3: Functional block diagram of the city Etarea, by Czechoslovak architect Gorazd Čelechovský, planned for the Prague region and presented at Expo '67 in Montreal<sup>30</sup>.

They embody the physical laws of human coexistence. They are ritual texts inscribed in the material substrate of our inhabited space<sup>31</sup>.

The first cities gave new meaning to human itineraries, through their walls, their selective gates and doors, their staircases and their secret passages. The first cities were artificial ways of understanding and inhabiting space<sup>32</sup>. Their builders separated the outside from the inside, the without from the within, the organised part of space from the part they did not control. This other part of reality, they named “nature”<sup>33</sup>.

## The Idea of Nature

To say “nature”, Sanskrit offers the word *prakṛiti* which refers to a primordial, cosmic substance from which all things arise. Prakṛiti is the fundamental force underlying the material universe and encompasses the physical and metaphysical aspects of reality. It is associated with the cycle of creation, preservation, and dissolution and is characterized by transformation and proliferation<sup>34</sup>.

प्रकृति

To say “nature”, Japanese offers the word *shizen* which refers to the idea of spontaneity and self-determination<sup>35</sup>. Shizen embodies the idea of the natural world as it is, untouched and unaltered by human intervention. It emphasizes a harmonious relationship between humanity and the environment, recognizing the inherent beauty, interconnectedness, and balance of the natural world.

自然

φύσις To say “nature”, ancient Greek offers the word *physis*, which refers to the idea of arising, pushing, growing. *Physis* designates all living things while also designating the primary cause of their existence. The word *physis* describes anything that is the first cause of its own existence.

*zihunlail* The ancient Yucatecan Maya offers the word *zihunlail* to say “nature”. *Zihunlail* refers to the idea of birth<sup>36</sup>.

*natura* The Latin word for “nature” is *natura*. *Natura* refers to the verb *nascor*, which means “to be born”.

природа To say “nature”, Slavic languages offer the word *priroda* which means “to add to what is born by being born oneself”.

For all these languages, nature is a reality that gives birth to itself. Nature is born of nature. No one can create it, by definition. Nature is opposed, by nature, to the artificial and the artefact.

טבע There is one exception among the ancient languages: to say “nature”, Hebrew uses the word *tiv’a*. *Tiv’a* refers to the idea of a first imprint, a seal, an informed form, the imprint of a first idea. The printer of the imprint *tiv’a*, the author of nature, is God<sup>37</sup>. God is the first form of intelligence which is distinct from nature insofar as it decides on its own<sup>38</sup>. In the Abrahamic religions —

including Judaism, Christianity and Islam — God’s intelligence subdues nature, and the human being is the heir to this intelligence<sup>39</sup>. Insofar as it is only humans who think of God, insofar as only humans form an intelligence of God, the intelligent God and creator of nature is a human artefact.

God is an artificial intelligence of nature.

— While God calculates and reflects, writes Gottfried Leibniz, he makes the world<sup>40</sup>.

Continuing the Hebrew tradition, the Arabic language uses the word *Tabi’a*, derived from *Taba’a*: “to create” or “to fashion”, to say “nature”. *Tabi’a* represents the natural order and innate disposition of things as they were created by God. It encompasses the laws and principles that govern the functioning of the natural world, seen as a manifestation of God’s wisdom, design and purpose in the world.

طبيعة

طبع

For thousands of years, those who believe that nature creates itself have opposed those who believe that nature is created by a creator. Those who believe that nature should be explored have been at odds with those who believe that nature should be subdued

to human will, heir to the will of the Creator, or be cared of in His name only.

But all merely invented names to master the *unnamable*; they confined the *unspeakable* in what they could say about it. They all put nature at a distance; they erected between themselves, and the untold, the artifice of speech that says “nature”. Even the *physis* of the ancient Greeks is an artificial way of making intelligence of nature.

On the contrary, there is no word for nature among the Schuar of Ecuador or among the Arrernte of Australia. In civilisations that built themselves without building cities, “nature” merges with the “world”<sup>41</sup>. Whoever doesn’t try to keep it at a distance has no reason to name it.

## Law Against Arbitrariness

The first city builder, in the first fictional text that humanity has preserved to date, called himself Gilgameš. The brave Gilgameš who loved Enkidu. The brave Gilgameš who killed Humbaba to take possession of the Cedar Forest. The brave Gilgameš who cut the wood of the Cedar Forest to build the city of Uruk. The brave Gilgameš who defeated the barbarian being Humbaba. The brave Gilgameš who subjugated the Freudian *it* to rules. The brave Gilgameš who submitted to civility through the intervention of Enkidu. The brave Gilgameš who, by civilising himself and the Cedar Forest, became civil, and founded *civitas*, the city.

Building a city is a way of subjugating nature to reason: by appropriating its resources, and by subjugating everything in ourselves that contradicts the city, living together.

What we call *artificial intelligence* reflects a millennial aspiration to endow thought with rules.

Four thousand years ago, a Sumerian scribe engraved the code of King Ur-Nammu on a clay tablet using a stylus, then dried it in the sun. The artefact hardened and fixed the laws of the city of Ur<sup>42</sup>. Its code replaces *spontaneous intelligence*<sup>43</sup> of a judge, subject to the arbitrariness of his cruelty or clemency. It has a casuistic form: *if* a man is accused of witchcraft, *then* he must undergo trial by cold water; *if* his innocence is proven, *then* his accuser must pay three shekels, and so on.



## Renaturing Intelligence

Law is an intuition turned into discourse; a synthesis of what *has been said* and what, now, must be *done*<sup>44</sup>. Law is the armed wing of language; it is a program executed by the legal apparatus of a society. Like a computer code, a law seeks to regulate as many actual situations as possible while remaining as concise as possible<sup>45</sup>.

But a law is always dogmatic, since it is limited to imposing its decrees without proving their justness. The meaning of the law and its *raison d'être* are not contained in the law itself. They come from an upstream reasoning; often from a simple tradition whose origin faded in oblivion, or from the feverish whim of a king. No legal system contains a law that is self-sustaining. No law is its own creator. No law gives itself birth. No

**From Rule to  
Proof**

law contains a life of its own. The law is not *physis*. The law is not *natura*. Every law is an artefact. There are no natural laws.

Are the laws lifeless? Or can we inject life back into a way of thinking that has been broken down into precepts? How can we ensure that our words continue to carry the life that led us to utter them, when all that remains of them are scratches on a smooth surface? What *shem* is there for our *golem*<sup>46</sup>, for our formless, our unfinished thought? How can we find nature in the artefact of law?

Should we start by creating a thought capable of proving its own dogmas?

आन्वीक्षिकी  
हेतुशास्त्र  
न्यायशास्त्र  
A shift from prescription to demonstration occurred three millennia ago. In the seventh century BC, appears *ānvīkṣikī*, the science of reasoning<sup>47</sup>. *Ānvīkṣikī* includes *hetu-śāstra*<sup>48</sup>, the theory of reason, which the venerable Medhātiti Gautama (~550 BC) develops in a “science of right and true reasoning”. The *Nyāya-śāstra*<sup>49</sup> logic emerges at the foot of the Himalayas. It defines, among other things:

प्रत्यक्ष	<i>Pratyakṣa</i> , the science of perception,
उपमान	<i>Upamāṇa</i> , the rules of comparison and
अनुमान	<i>Anumāṇa</i> , the rules of inference <sup>50</sup> .

A century later, the sophist Protagoras distinguished the modalities of speech between *questions*, *answers*, *prayers* and *injunctions*. As in India, the rules of Greek logic were linked to those of grammar, imposed by the written word.

After one more century, Aristotle called “syllogism” a way of reasoning by linking a series of premises to a conclusion<sup>51</sup>:

συλλογισμός

— Socrates is a man; all men are mortal:  
Socrates is therefore mortal.

In the 13<sup>th</sup> century, Ramon Llull — Catalan soldier, priest, mystical writer, missionary, erotic poet, charlatan, genius and martyr of his enlightened faith — proposed a language of symbols to express syllogisms. He fancies a formal system whose universalism would lay the foundations of consensus amid wars of faith. He imagines a mechanical artefact capable of giving substance to such a language. Inspired by the *zā'irjah* of Arab astrologers, he conceives *Ars Magna*, a machine for discerning the truth “by giving reason to all things”<sup>52</sup>.

ذايرجة

In the 19<sup>th</sup> century, George Boole regretted that the symbolic language of mathematics reduced it to a “science of magnitude”

## Notes

1. Ourednik (2009–2023).
2. Brautigan, R. (1967). *All watched over by machines of loving grace*. The Communication Company.
3. Bridle (2023).
4. Lestel & Killoffer (2021).
5. Lemonnier, P. (2012). Des objets pour penser l'indicible: La nécessaire convergence des théories de la culture matérielle. N. Schlanger & A-C. Taylor Inrap & Musée du quai Branly. *La préhistoire des autres. Perspectives archéologiques et anthropologiques*, Paris: La Découverte, pp. 277-289.
6. Leroi-Gourhan (1964).
7. Mauss, M. 1927. "Divisions et proportions des divisions de la sociologie". *L'Année sociologique*, (2): 87173. [author's translation].
8. A *datacave* is a cavern housing computer servers.

9. On the impact of intelligence on employment, particularly in the service sector, see Frey & Osborne (2017). According to their estimate, almost fifty per cent of current jobs in the United States will be lost to automation in the next 10 to 20 years. This would particularly affect the public administration, service and sales, and transport sectors. However, some researchers are critical of their statistical prediction model.
10. For 37 days from October 1785, locked up in the Bastille, the Marquis de Sade copied his drafts of the *120 days of Sodom* onto a scroll twelve metres long and eleven centimetres wide. The text describes a sequence of tortures and murders inflicted on a group of young people for the pleasure of four notables of the age of our boomers: the duke, the bishop, the president and the financier. The sadistic device has a fastidious numerological structure: 8 beautiful girls and 8 beautiful boys taken from their families, 4 wife-daughters (the notables marry their respective daughters), 8 valets “fouteurs” chosen for the size of their penises, including 4 “*fouteurs principaux*” and 4 “*fouteurs subalternes*”, 4 ugly maids, 6 kitchen wives, including 3 cooks and 3 cook’s helpers, 4 “historians”, former prostitutes, to recount the sexual excesses grouped into 4 acts, each lasting 30 days for a total of 120 days (Sade, 1904). The sadistic imagination thus honours structural rigidity and symmetry, a notion found in many rational attempts to describe — and master — nature, as well as to explain its beauty.
11. Cf. Sassen (2014).
12. A few weeks after writing these lines, I learned that Amazon’s new headquarters were indeed laid out like paradise greenhouses. The architectural project inaugurated in January 2018 is called “*Spheres*”. It consists of three hemispheres

filled with more than 40 000 plants from 50 countries. For details of the survivalist fantasies of computational technology billionaires, see Rushkoff (2023).

13. Kaspar et al. (2021).
14. Graeber & Wengrow (2021, 94) point out that dialogue is the most effective way of breaking out of this seven-second “window of consciousness” limit into which neurologists would lock our minds. “In conversation, we can hold thoughts and reflect on problems sometimes for hours”.
15. According to current knowledge, the anatomy of *Homo ergaster* and *Homo erectus* already enabled them to produce and understand phonetically articulated speech Habermas (2019, 229). Ancient thinkers would one day link this proto-language faculty to the concept of discernment (*legere*), i.e. to the foundation of intelligence. Etymologically, the Latin *legere* derives in effect from the ancient Greek *λέγειν*, which also meant “to choose, select, gather, enumerate” in Homeric Greek, but whose meaning extended to “say, tell, speak, declare”. From the outset, intelligence was linked to language.
16. The philosopher and communication theorist Jürgen Habermas distinguishes human symbolic communication from generic animal communication by the presence of symbols exported into the environment: “Die Innovation besteht nicht in der Adressierung von Zeichen und Artgenossen, die wir auch bei Primaten Beobachten, sondern in der reziproken Verwendung von Symbolen, die für die Gruppenangehörigen dieselbe Bedeutung annehmen. Die Errungenschaft besteht in der kommunikativen Erzeugung eines Raums intersubjektiv geteilter semantischer Inhalte.” (Habermas, 2019, Band 1, 227). However, he

refrains from naming the substratum of this space. Is it a semantic space or a physical space? Are the signs ephemeral like sounds or more persistent? Whatever the case, even Habermas' anthropic exceptionalism wavers in the face of advances in our knowledge of animal and plant communication.

17. Olson (1993). The geographer Gunnar Olson seems to reserve this semiotic faculty for humans alone. Our knowledge of animal consciousness has come a long way since the 1990s.
18. Many authors have put forward the hypothesis of speech as a coherent shaping of reality prior to any practical use of it for predetermined purposes. Among them, the urban planning theorist Lewis Mumford: "Language was an instrument that reflected life, that enhanced life, long before it could be fashioned for the limited purposes of intelligent communication." (Mumford, 1964). Composer and acoustic ecologist David Dunn agrees with this hypothesis: "Language is perhaps the most physical thing, because it requires the participation of the whole organism to be produced. Nevertheless, the screen onto which consciousness projects meaning and intentionality is a very narrow field. The complexity of the mind, as an interactive and cybernetic system, is certainly closer to an environment that lies beyond the conscious vision of the organism that possesses it... Many animals present numerous and varied examples of fanciful acts carried out out of double necessity. They extract from everyday activity the substance of the mime, and re-enact skills useful for survival, in order both to exercise them and to derive deeper satisfaction from them. Since I see such satisfaction as the result of a wider systemic link with the environment, it may well have given human rituals their origin and their necessity. This biological necessity for play was undoubtedly the

impetus that gave birth to art and music.” (Dunn, 2011, 38–40). It would obviously be an aberration to assert the precedence of this explanation over others: the world is criss-crossed by multiple logics, none of which constitutes anything more than a linear sequence of thought inscribed across a complex reality. To look for the true beginning of the word — of any phenomenon, for that matter — would be as idiotic as looking for the centre of the universe. A story is only as interesting as the sequel it allows us to imagine.

19. The French term “sens” renders well the polysemy of the term “meaning” and reveals a basic intuition. Before it began to denote a “metaphysical meaning”, the word “sens” simply denoted the “direction of a movement”. This reduces the great metaphysical systems to hypertrophied narratives; and ideologies to mere consequences of their drifts.
20. TODO Habermas 1991 p. 227 says: “Die Innovation besteht nicht in der Adressierung von Zeichen und Artgenossen, die wir auch bei Primaten Beobachten, sondern in der reziproken Verwendung von Symbolen, die für die Gruppenangehörigen dieselbe Bedeutung annehmen.”
21. Feelings and emotions are transdisciplinary concepts. Depending on the focus of the research, their expression in words and actions is triggered by a somatic event, emerges from the depths of the individual psyche or crystallises in a given sociolinguistic environment. Emotions do not have a single origin; they emerge at the interface of a plurality of origins and scales of reality, ranging from the individual to the global context, from the immediate event to the long time scale of biological evolution. For a more in-depth development and a case study based on this conviction, see (Ourednik et al., 2018).



22. Maclure (2021) which underlines the social and institutional dimension of human reasoning processes.
23. For a phenomenological analysis of the notion of the artefact and the artificial in its opposition to nature, see in particular Waldenfels (2008, chap. 9). This opposition distinguishes what happens spontaneously from what happens in a planned way; what is occasional and random from what is subject to a reproducible methodology; what is *anchored in an environment* from what is *independent of the environment*, i.e. *abstract*; what is *immediate* from what is *mediated*. Waldenfels goes on to explain the limits of these distinctions: "The artificial emerges when bodily faculties detach themselves from the body to form a world of tools, symbols, masks and means of communication, which slip between seeing and seeing, between saying and saying, between communication and message, between action and action, between emotion and its expression. Images, words, letters, glasses [...] are the product of artificial production. By contrast, what has not been artificially produced appears natural to us. Yet even the simplest instruments and media have a weight of their own, a materiality that resists. Waldenfels also links the notion of the natural to phenomenological *epoché*, i.e. to a pre-reflexive experience of reality: "Natural experience refers exactly to what I am already doing when I ask myself what I am doing and how I am doing it. Natural experience is equivalent to the patient's suffering, which no health expert can dissuade; it is equivalent to the dream, which no dream expert can undo. Natural experience is certainly not, in this sense, a secure foundation, but it remains nonetheless *what we start from* when we question or doubt experience, and what our artificial experiences detach from." [translations by the author].

24. Archaeological research recently revealed these monuments at the Göbekli Tepe and Karahan Tepe excavation sites.
25. In the absence of written traces of Palaeolithic civilisations, we can, of course, only speculate about their thought systems. Nevertheless, the writings of anthropologists such as Descola (2005) suggest that a separation between the ontological domains of body and mind, physics and metaphysics, etc. only occurs in the “naturalistic” systems of later urbanised societies.
26. The philosophical concept of “flowing thisness” is an accepted French translation of Edmund Husserl’s *fließende Jeweiligkeit*. My description of the evolution of human thought at the beginning of the Palaeolithic can be understood as a “state of nature” model of Husserl’s *epoché*.
27. Jane Jacobs or Lewis Mumford, in particular, argued that ritual sites preceded the first cities, and identified them as the *raison d’être* of early urban development.
28. Archaeological reconstruction by Gerkan A. V. (1924). *Griechische Städteanlagen: Untersuchungen Zur Entwicklung Des Städtebaues Im Altertum*. Berlin, Leipzig: Walter de Gruyter. Cited by Vance (1990).
29. The “Futur antérieur” exhibition presented from October 11<sup>th</sup> 2002 to April 21<sup>st</sup> 2003 at the Roman Museum of Lausanne-Vidy, invited visitors to imagine such an archaeological interpretation of a motherboard. In 2016, the artist Christoph Morlinghaus devoted a photographic series to microcircuits, noting their resemblance to aerial photographs of cities (<http://www.morlinghaus.com/computerwelt>).

30. Translation of the diagram: *životní prostředí* = environment, *obyvatelstvo* = citizens, *výroba* = production, *doprava* = transport, *obchod* = trade, *služby* = services, *správa* = management. Source: Krivy (2019, 9). Original source: Čelechovský, G. (1967) *Etarea. Studie životního prostředí města* [Etarea. Study of the urban living environment]. Prague: Státní komise pro techniku & Pražský projektový ústav. Image A6/a.
31. On the subject of “urban semiology”, derived from linguistics, which suggests interpreting the city as a text, see Barthes (1971) and Choay (1971).
32. I discuss the relationship between models of space and the phenomenological notion of “inhabiting” in more detail in Ourednik (2010).
33. Cf. Ourednik, 2009–2023, “nature” <https://wikitractatus.ourednik.info/nature>.
34. The word *prakṛiti* is used in particular by the Samkhya school, one of the *āstika* (ontological schools) of Hindu philosophy. *Pra-*: equivalent of Russian *при-*; *kṛ-*: to act; *-ti*: equivalent of Greek *-sis* or Latin *-tion*. *Prakṛiti* designates all living things, as well as the cause of their existence.
35. The word *shizen* can be broken down into *shi* ( 自 ), oneself, and *zen* ( 然 ), to be so, as it is, unchanged, right, correct. It derives from proto-huan *zì ràn*.
36. Ducarme (2015) uses the spelling *sijnalil*. We also find *zihnal* for the adjective “natural” and *zihunlail* for the natural being or thing, in Pérez, J. P., & Beltrán, P. (1898). *Coordinacion alfabetica de las voces del idioma maya que se hallan en el arte y obras del padre fr. Pedro Beltran de Santa Rosa, con las equivalencias castellanas que en las mismas se*

hallan. Mérida de Yucatán, Impr. de la Ermita. <http://archive.org/details/coordinacionalf02beltgoog>.

37. This vision of a printed world perhaps reached its apogee in the 18<sup>th</sup> century, when Carl von Linné contrasted the ancient and medieval metamorphic chaos with a supposedly exhaustive description of the species created by God at the origin of the world, with their eternal characteristics. Charles Darwin — following pioneers such as Jean-Baptiste de Lamarck — in his turn opposed Linnaeus' model by postulating the constant evolution of species, in a nature comparable to an endless race with no goal other than itself, hardly compatible with Abrahamic creationist cosmology.
38. Cf. "Only the human, who participates simultaneously in the divine through his soul and in nature through his body, can make the link between these two kingdoms." (Maris, 2018, 42).
39. On the subject of this subjugation of nature, many authors note in particular Genesis 1: 28: "And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth". In a much-quoted article, White (1967) points to the emergence of Abrahamic monotheisms as a cause of the collapse of natural systems.
40. "*Dum Deus calculat et cognitionem exercet, fit mundus.*" Marginnote by the philosopher and mathematician Gottfried Wilhelm von Leibniz in "Dialogus", A VI, 4-A, 22, in *Philosophischen Schriften* (Gerhardt), VII, p. 191.
41. The linguistic analyses of Hindu, Mayan, Greek, Latin and Hebrew concepts of nature in this

chapter are based mainly on Ducarme (2015) and Ducarme & Couvet (2020), which also argue that there is no equivalent of the word nature in non-urban societies. The anthropologist Philippe Descola, in particular, explains how the very concept of nature is linked to a cultural stance that he calls “naturalism”.

42. Writing was born of the desire to impose functional rules on reality centuries before any attempt at literature. Even the priests did not begin to use it until after the merchants and civil servants. In this respect, it seems wrong to stipulate — with Nassehi (2019) — that a “digital society” only emerges with the beginning of industrial modernity. A data society emerged with the very first clay tablets. A Romanesque form of writing only emerged with its popularisation. Archaeologists date the first example of writing to the “ostraca” of Deir el-Medina in the New Egyptian Empire (1539-1075 BC). The inhabitants of ancient Thebes learned to write here and used it to exchange lists, letters and gossip. Cf. McDowell (1996).
43. As mentioned earlier, spontaneity is an essential characteristic of nature. In this sense, “spontaneous intelligence” becomes synonymous with “natural intelligence”. Other terminologies could be used to distinguish between what I propose to call “natural intelligence” and “artificial intelligence”. Aristotle, for example, contrasts *noesis* [νόησις], (“intuitive” intelligence) with *dianoia* [διάνοια] (discursive intelligence). Here again, language allows us to move from a natural intelligence to an artificial intelligence.
44. The Latin *lex* (law) derives, by etymology, from elements taken from a commonly experienced reality (*legere*) and articulated in discourse (*lexis*).

45. Contemporary legal texts contain a variety of forms of linguistic action: prohibitions, permissions, authorisations and threats of sanctions, as well as preambles, objectives, objects and provisions for coming into force. The concrete linguistic realisation of these linguistic actions influences the understanding of a decree and its ease of acceptance by citizens. (cf. <https://www.ds.uzh.ch/de/projekte/gesetzensprache/>).
46. The word *shem* refers to the ineffable name of God, *HaShem* (the name [ הַשֵּׁם ]). In the legend of the Golem, the *shem* inserted in the golem's mouth endows it with the ability to come alive, i.e. a *âme* (from the Latin *anima*). The golem ( גולם ) is the formless creature, the embryo, the unfinished thing. The golem is born from clay after four wise men, representing the four elements, have endowed its formless matter with their attributes; on its forehead is the word *emet* ( אמת , “truth”) which, when its first letter is erased, becomes *met* ( מת , “death”), returning artificial man to dust.
47. This science includes logic and epistemology-logy.
48. From *Hetu* ( हेतु ), cause, object, motive and *Śāstra* ( शास्त्र ) the discipline of thought, in other words, the suffix *-logie*.
49. From *Nyaya* ( न्याय ) law, justice; and from *Śāstra* ( शास्त्र ), In the classification of systems of thought, Nyāya is atomistic, pluralist and realist.
50. Vidyabhusana (1920). The *anumāṇa* already take into account the uncertainty of thought, i.e. the idea of probability ( *śāmbhava* – संभव ) which will one day become essential to machine learning algorithms.

51. In the West, Aristotle is still presented as the demiurge of this type of logical inference. In fact, Aristotle inherited an environment of thought of which the notion of syllogism is merely a synthesis; the only open question is whether he inherited Indian logic directly. We know that the historian Callisthenes (360–327 BC) accompanied Alexander on his Asian campaigns, but it is only stipulated that he reported texts from *Nyāya-sāstra* to his nephew Aristotle (384–322 BC). This hypothesis is attractive in that it allows us to imagine a continuity of ancient thought across Eurasia. Kak (2005) and others cast doubt on it. Whatever the case, Aristotle's thought took an extraordinary route; it was notably through translations into Syriac and then Arabic that Aristotle's writings returned to Christian Europe under the name of Imam Arastu. The Aristotelian syllogism was later called the "logic of terms".
52. Llull's "machine" consists of four schematic figures, one of which is made up of three concentric paper discs. Two of them, which rotate, illustrate concepts in the form of letters. Turning the discs allows linguistic symbols, terms and letters of the alphabet to be combined and correlated. Llull assumed the unity of the different learned disciplines of the time. Through his deductive logic, argumentation and dialogue, he wanted to bring peace between religions by convincing Muslims of the logical necessity of Christianity. See in particular Gardner (1982).
53. See Boole (1847). Today, we call this algebra of propositions "Boolean". If  $x$  is true and  $y$  is false, is it true to say that " $x$  is true or  $y$  is true"? To express this idea, we would write  $x = 1; y = 0; x \vee y = 1$ . Boole wrote " $xy$ " to express the conjunction " $x$  and  $y$ ",  $1 - y$  for the negation "non- $y$ ", and  $x + y - xy = 1$  for the disjunction " $a$  or  $b$ ". Later authors simplified

# Mediagraphy

- ABRAHAM D. S. (2015). *The elements of power: gadgets, guns, and the struggle for a sustainable future in the rare metal age*. Yale University Press.
- AIELLO L. C., WHEELER P. (1995). The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution. *Current Anthropology*, 36(2), 199–221. <https://www.jstor.org/stable/2744104>
- ANSERMET S. (2006). *Xyloglossaire artistique*. Castagniéé.
- ARADHYE H., TODERICI G., YAGNIK J. (2009). Video2text: Learning to annotate video content. In *IEEE International Conference on Data Mining Workshops, 2009. ICDMW'09.*, (pp. 144–151). IEEE.
- BAREIS J., KATZENBACH C. (2022). Talking AI into Being: The Narratives and Imaginaries of National AI Strategies and Their Performative Politics. *Science, Technology, & Human Values*, 47(5), 855–881. <https://doi.org/10.1177/01622439211030007>
- BARNESLEY M. F. (1988). *Fractals everywhere*. Academic Press.
- BARTHES R. (1971). Sémiologie et urbanisme. *L'Architecture d'aujourd'hui*, déc. 1970 - jan. 1971(153), 9–10.



- BATTY M. (1990). Intelligent cities: using information networks to gain competitive advantage. *Environment and Planning B: Planning and Design*, 17, 247–256.
- BHATTACHARYA A. (2021). *The man from the future: the visionary life of John von Neumann*. Allen Lane.
- BOND A. H., GASSER L. (2014). *Readings in Distributed Artificial Intelligence*. Morgan Kaufmann.
- BOOLE G. (1847). *The Mathematical Analysis of Logic, Being an Essay Towards a Calculus of Deductive Reasoning*. MacMillan and Co. <http://www.gutenberg.org/ebooks/36884>
- BOURG D., WHITESIDE K. (2010). *Vers une démocratie écologique. Le citoyen, le savant et le politique*. Seuil.
- BRIDLE J. (2023). *Ways of being: animals, plants, machines : the search for a planetary intelligence*. Picador.
- BUCHANAN B. G., HEADRICK T. E. (1970). Some Speculation about Artificial Intelligence and Legal Reasoning. *Stanford Law Review*, 23(1), 40–62. <https://doi.org/10.2307/1227753>
- BUCKLEY W. R. (2004). On the complete specification of a von Neumann 29-state selfreplicating cellular automaton. [wrb@wrbuckley.com](mailto:wrb@wrbuckley.com)
- BUOLAMWINI J. A. (2017). *Gender shades : intersectional phenotypic and demographic evaluation of face datasets and gender classifiers*. Phd thesis, Massachusetts Institute of Technology. Accepted: 2018-03-12. <http://hdl.handle.net/1721.1/114068>
- ÇALIŞKAN O. (2017). Parametric Design in Urbanism: A Critical Reflection. *Planning Practice & Research*, 32(4), 417–443. <https://doi.org/10.1080/02697459.2017.1378862>

- CAMMARATA S. J., MCARTHUR D. J., STEEB R. (1983). *Strategies of Cooperation in Distributed Problem Solving*. Rapport technique, RAND Corporation. <https://www.rand.org/pubs/notes/N2031.html>
- ČAPEK K. (1920). *RUR: Rossum's Universal Robots. Kolektivní drama o vstupní komedii a třech aktech*. Aventinum. <http://kramerus5.nkp.cz/view/uuid:31179a10-0e00-11e9-8d10-5ef3fc9ae867>
- CASELL J. (2020). The ties that bind. *Rezeaux*, No 220-221(2), 21–45. <https://doi.org/10.3917/res.220.0021>
- CASTORIADIS C. (1975). *L'institution imaginaire de la société*. Éd. du Seuil.
- CHAN J., XU L. Z., YANG, IZORD C. (2022). *La machine est ton seigneur et ton maître*. Éléments. Agone, 2<sup>e</sup> ed.
- CHAPPATTE P. (2018). *L'autre côté de la Silicon Valley* (2). <http://labs.letemps.ch/interactive/2018/longread-san-francisco-chappatte-ep2/>
- CHOAY F. (1971). Remarques à propos de sémiologie urbaine. *L'Architecture d'aujourd'hui*, déc. 1970 – janv. 1971(153), 9–10.
- CIORAN E. M. (1949). *Précis de décomposition*. Gallimard.
- CLARKE A. C. (1968). *2001: A Space Odyssey*. Hutchinson.
- CREVIER D. (1993). *AI: The Tumultuous History of the Search for Artificial Intelligence*. BasicBooks.
- DELEUZE G., GUATTARI F. (1975). *Kafka, pour une littérature mineure*, vol. 30. Minuit.
- DELEUZE G., GUATTARI F. (1980). *Mille Plateaux*. Minuit.

- DESCARTES R. (1646). Lettre au marquis de Newcastle du 23 novembre 1646. In *Oeuvres et lettres*, Bibliothèque de la Pléiade, (pp. 1254–1257). Gallimard (1937).
- DESCOLA P. (2005). *Par-delà nature et culture*. Gallimard.
- DESROSIÈRES A. (2000). *La politique des grands nombres : histoire de la raison statistique*. La Découverte.
- DILTHEY W. (1910). *Der Aufbau der geschichtlichen Welt in den Geisteswissenschaften*. Suhrkamp. 1970 reedition.
- D'INVERNO M., MCCORMACK J. (2015). Heroic versus Collaborative AI for the Arts. In *Proceedings of the Twenty-Fourth International Joint Conference on Artificial Intelligence*, (pp. 2138–2444). AAAI Press. <https://www.ijcai.org/Abstract/15/345>
- DOCTOROW C. (2022). Revenge of the Chickenized Reverse-Centaurs. *Medium*. <https://onezero.medium.com/revenge-of-the-chickenized-reverse-centaurs-b2e8d5cda826>
- DONZÉ P.-Y., WUBS B. (2019). Global competition and cooperation in the electronics industry: the case of X-ray equipment, 1900–1970. *Scandinavian Economic History Review*, 67(2), 210–225. <https://www.tandfonline.com/doi/full/10.1080/03585522.2019.1583123>
- DUCARME F. (2015). De quoi parle-t-on quand on parle de “nature” ? — une étude comparée. In *Colloque “Penser l’écologie politique”, 5 juin 2015*. Université Paris-Diderot.
- DUCARME F., COUVET D. (2020). What does ‘nature’ mean? *Palgrave Communications*, 6(1), 1–8. <https://doi.org/10.1057/s41599-020-0390-y>
- DUNN D. (2011). *Extractions des espaces sauvages. Cybernétique de l’écoute, écologie sonore, textes 1981-2011*. van Dieren.

- DYSON G. (2020). *Analogia: the emergence of technology beyond programmable control*. Farrar, Straus and Giroux, first edition ed.
- Eco U. (2009). *Il pendolo di Foucault*. Bompiani, 27<sup>a</sup> ed.
- ELIADE M. (1977). *Forgerons et alchimistes*. Flammarion.
- ELSAMANOUDI A., ABDALLAH M. R., ELBADRAWY H. M. (2022). Parametric Hypercell Mechanism for Adaptive Building Skin: A Case Study in New Administrative Capital, Egypt. *Civil Engineering and Architecture*, 10(7), 3046–3070. [http://www.hrpub.org/journals/article\\_info.php?aid=12576](http://www.hrpub.org/journals/article_info.php?aid=12576)
- ENDOH Y. (2023). *Quine Relay: an uroboros program with 100+ programming languages*. GitHub. Open source code. 1<sup>st</sup> commit : 15.7.2013. <https://github.com/mame/quine-relay>
- ETXEBERRIA A., IBÁÑEZ J. (1999). Semiotics of the artificial: The ‘self’ of self-reproducing systems in cellular automata. *Semiotica*, 127(1-4), 295–320. <https://doi.org/10.1515/semi.1999.127.1-4.295>
- FARINELLI F. (2003). *Geografia. Un'introduzione ai modelli del mondo*. Einaudi.
- FATÈS N. (2001). *Les automates cellulaires vers une nouvelle épistémologie?*. Mémoire de DEA, Université de Paris I Sorbone, Paris.
- FORRESTER J. W. (1973). *World dynamics*. Wright-Allen Press. <http://archive.org/details/worlddynamics00forr>
- FOURMENTRAUX J.-P. (2020). *AntiDATA: la désobéissance numérique: art et hacktivisme technocritique*. Collection “Perceptions”. Les Presses du réel.

- FREUD S. (1919). *Eine Kindheitserinnerung des Leonardo da Vinci*. Fischer-Taschenbuch. (2006) original edition: Franz Deuticke, Leipzig.
- FREY C. B., OSBORNE M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, 114, 254–280. <https://doi.org/10.1016/j.techfore.2016.08.019>
- FRIJTERS D., LINDENMAYER A. (1974). A model for the growth and flowering of aster novae-angliae on the basis of table L-systems. In G. Goos, J. Hartmanis, P. Brinch Hansen, D. Gries, C. Moler, G. Seegmüller, N. Wirth, G. Rozenberg, & A. Salomaa (Eds.) *L Systems*, vol. 15, (pp. 24–52). Springer. [https://doi.org/10.1007/3-540-06867-8\\_2](https://doi.org/10.1007/3-540-06867-8_2)
- GADAMER H.-G. (1990). *Gesammelte Werke. 1: Hermeneutik 1, Wahrheit und Methode: Grundzüge einer philosophischen Hermeneutik*. Mohr, 6<sup>th</sup> ed.
- GARDNER M. (1982). *Logic machines and diagrams*. University of Chicago Press, 2<sup>nd</sup> ed.
- GERTIK A., KARAMAN A. (2023). The Fractal Approach in the Biomimetic Urban Design: Le Corbusier and Patrick Schumacher. *Sustainability*, 15(9), 7682. <https://www.mdpi.com/2071-1050/15/9/7682>
- GILBERT S. (2021). *Genetic programming for image classification*. <https://towardsdatascience.com/genetic-programming-for-image-classification-a505950c5467>
- GRACE K., SALVATIER J., DAFOE A., ZHANG B., EVANS O. (2018). When Will AI Exceed Human Performance? Evidence from AI Experts. *arXiv:1705.08807v3 [cs.AI]*. <https://arxiv.org/abs/1705.08807v3>

- GRAEBER D., WENGROW D. (2021). *The dawn of everything: a new history of humanity*. Allen Lane.
- GREENE B. (2019). *The Smart Enough City*. MIT Press.
- GUPTA R. C. (2008). True Laksa-Scale Numeration System of the Valmiki-Ramayana. *Indian Journal of History of Science*, 43(1), 79–92.
- HABERMAS J. (2019). *Auch eine Geschichte der Philosophie*. Suhrkamp.
- HARAWAY D. (2016). *Manifestly Haraway*. University of Minnesota Press. Cited in this book “A Cyborg Manifesto”, first published as “Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s” *Socialist Review*, no. 80 (1985): 65/108.
- HEIDEGGER M. (1976). » ... dichterisch wohnet der Mensch ... « (1951). In *Gesamtausgabe I. Veröffentlichte Schriften 1910-1976 Band 7 Vorträge und Aufsätze*, vol. 7, (pp. 189–210). Vittorio Klostermann.
- HICKMAN L. (2010). James Lovelock: Humans are too stupid to prevent climate change. *The Guardian*. <https://www.theguardian.com/science/2010/mar/29/james-lovelock-climate-change>
- HOBBS OF MALMESBURY T. (1651). *Leviathan or the Matter, Forme and Power of A Commonwealth Ecclesiastical and Civil*. Printed for Andrew Crooke at the Green Dragon in St. Pauls Church-yard.
- HOFSTADTER D. R. (1999). *Gödel, Escher, Bach: an eternal golden braid*. Basic Books, 20<sup>th</sup> anniversary ed.
- HUANG C.-C., ZÜRCHER E. (1995). *Time and space in Chinese culture*. No. 33 in *Sinica Leidensia*. Brill.

- HUNG W. (2003). Monumentality of time: giant clocks, the drum tower, the clock tower. In *Monuments and Memory: Made and Unmade*, (pp. 109–115). University of Chicago Press.
- HUNYADI M. (2018). *Le temps du posthumanisme: un diagnostic d'époque*. Les Belles Lettres.
- HUTTON T., MUNAFO R., TREVORROW A., ROKICKI T., WILLS D. (2020). *Ready, a cross-platform implementation of various reaction-diffusion systems..* Open source code. <https://github.com/GollyGang/ready>
- IFRAH G., BELLOS D. (2000). *The universal history of numbers: from prehistory to the invention of the computer*. Wiley.
- IMHAUSEN A. (2016). *Mathematics in ancient Egypt: a contextual history*. Princeton University Press. <https://doi.org/10.23943/princeton/9780691117133.001.0001>
- JACOBS J. (1961). *The Death and Life of Great American Cities*. Random House. Republished edition by Vintage Books.
- JARDON Q. (2019). *Alexandria : les pionniers oubliés du web*. Gallimard.
- KAK S. (2005). Aristotle and Gautama on Logic and Physics. <https://arxiv.org/abs/physics/0505172>
- KASPAR C., RAVOO B. J., VAN DER WIEL W. G., WEGNER S. V., PERNICE W. H. P. (2021). The rise of intelligent matter. *Nature*, 594(7863), 345–355. <https://www.nature.com/articles/s41586-021-03453-y>
- KELLER A., GERKIN R. C., GUAN Y., DHURANDHAR A., TURU G., SZALAI B., MAINLAND J. D., IHARA Y., YU C. W., WOLFINGER R., VENS C., SCHIETGAT L., GRAVE K. D., NOREL R., CONSORTIUM D. O. P., STOLOVITZKY G., CECCHI G. A., VOSSHALL L. B., MEYER P. (2017). Predicting human olfactory

perception from chemical features of odor molecules. *Science*, 355(6327), 820–826. <http://science.sciencemag.org/content/355/6327/820>

- KITCHIN R. (2014). *Digital Humanities: Smart urbanism, big data and new ways to know and govern cities*. Friedrich-Alexander-Universität Erlangen-Nürnberg. Video recording of a talk given on le 30.10.2024. <https://www.fau.tv/clip/id/4286.html>
- KLEIMAN K. (2022). *Proving ground: the untold story of the six women who programmed the World's first modern computer*. Hurst & Company.
- KURZWEIL R. (2005). *The singularity is near: when humans transcend biology*. Viking.
- LA METTRIE J. O. D. (1748). *L'Homme machine*. Elie Luzac. [https://fr.wikisource.org/wiki/L%E2%80%99Homme\\_Machine](https://fr.wikisource.org/wiki/L%E2%80%99Homme_Machine)
- LATOUR B. (1999). *Politiques de la nature: comment faire entrer les sciences en démocratie*. La Découverte.
- LAYMAN E. A. (1957). Symbolic Logic: A Razor-Edged Tool for Drafting and Interpreting Legal Documents. *Faculty Scholarship Series*. [https://digitalcommons.law.yale.edu/fss\\_papers/4519](https://digitalcommons.law.yale.edu/fss_papers/4519)
- LEROI-GOURHAN A. (1964). *Le geste et la parole. Technique et langage*. Albin Michel.
- LESTEL D., KILLOFFER P. (2021). *Machines insurrectionnelles: une théorie post-biologique du vivant*. No. 1 in *Traité d'éthologie philosophique*. Fayard.
- LEVINAS E. (1974). *Autrement qu'être ou au-delà de l'essence*, vol. 54 of *Phaenomenologica*. Springer Netherlands.



- LINDENMAYER A. (1968a). Mathematical models for cellular interactions in development I. Filaments with one-sided inputs. *Journal of Theoretical Biology*, 18(3), 280–299. [https://doi.org/10.1016/0022-5193\(68\)90079-9](https://doi.org/10.1016/0022-5193(68)90079-9)
- LINDENMAYER A. (1968b). Mathematical models for cellular interactions in development II. Simple and branching filaments with two-sided inputs. *Journal of Theoretical Biology*, 18(3), 300–315. [https://doi.org/10.1016/0022-5193\(68\)90080-5](https://doi.org/10.1016/0022-5193(68)90080-5)
- LOCKE J. (1689). *Two Treatises of Government: In the Former, The False Principles, and Foundation of Sir Robert Filmer, and His Followers, Are Detected and Overthrown. The Latter Is an Essay Concerning The True Original, Extent, and End of Civil Government*. Anwsham and Churchill.
- LOVELOCK J. E. (1972). Gaia as seen through the atmosphere. *Atmospheric Environment* (1967), 6(8), 579–580. [https://doi.org/10.1016/0004-6981\(72\)90076-5](https://doi.org/10.1016/0004-6981(72)90076-5)
- LOVELOCK J. E. (1979). *Gaia, A new look on life on Earth*. Oxford University Press. 2000 reedition.
- LUDWIG P., PRADEU T. (Eds.) (2008). *L'individu: perspectives contemporaines*. Librairie philosophique J. Vrin.
- MACLURE J. (2021). AI, Explainability and Public Reason: The Argument from the Limitations of the Human Mind. *Minds and Machines*, 31(3), 421–438. <https://doi.org/10.1007/s11023-021-09570-x>
- MAGENTA (2018). *The MAESTRO Dataset*. <https://magenta.tensorflow.org/datasets/maestro>
- MANDELBROT B. B. (1982). *The fractal geometry of nature*. W.H. Freeman.
- MARIS V. (2018). *La Part sauvage du monde*. Seuil.

- MARX K. (1968). Ökonomisch-philosophische Manuskripte aus dem Jahre 1844. In *Marx-Engels Werke. Ergänzungsband. Erster Teil.*, (pp. 465–588). Dietz Verlag.
- MCCABE J., et al. (2010). Cyclic symmetric multi-scale Turing patterns. In *Bridges Pécs Conference Proceedings*.
- MCCARTHY J. (2007). From here to human-level AI. *Artificial Intelligence*, 171(18), 1174–1182. <https://doi.org/10.1016/j.artint.2007.10.009>
- MCCORDUCK P. (2004). *Machines who think: a personal inquiry into the history and prospects of artificial intelligence*. A.K. Peters, 25<sup>th</sup> anniversary updated ed.
- MCCULLOCH W. S., PITTS W. (1943). A logical calculus of the ideas immanent in nervous activity. *The bulletin of mathematical biophysics*, 5(4), 115–133. <https://doi.org/10.1007/BF02478259>
- MCDOWELL A. G. (1996). Daily Life in Ancient Egypt. *Scientific American*, 275(6), 100–105. <https://www.jstor.org/stable/24993496>
- MEADOWS D. H., MEADOWS D. L., RANDERS J., BEHRENS W. W. (Eds.) (1974). *The limits to growth: a report for the club of rome's project on the predicament of mankind*. A potomac associates book. Universe books, 2<sup>nd</sup> ed.
- MENABREA L. F., LOVELACE A. (1843). Sketch of The Analytical Engine Invented by Charles Babbage. In R. Taylor (Ed.) *Scientific Memoirs, Selected from the Transactions of Foreign Academies of Science and Learned Societies, and from Foreign Journals*, vol. 3, (pp. 666–731). R. and J. E. Taylor.
- MERCHANT C. (1983). Mining the Earth's Womb. In *Machina ex dea: feminist perspectives on technology*, The Athene series, (pp. 99–117). Pergamon Press.

- MLYNÁŘ J., BAHRAMI F., OUREDNIK A., MUTZNER N., VERMA H., ALAVI H. (2022). AI beyond Deus ex Machina – Reimagining Intelligence in Future Cities with Urban Experts. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, CHI '22, (pp. 1–13). Association for Computing Machinery. <https://doi.org/10.1145/3491102.3517502>
- MUMFORD L. (1964). *La cité à travers l'histoire*. Agone. 2011 reedition.
- MÖRTENBÖCK P., MOOSHAMMER H. (Eds.) (2021). *Platform urbanism and its discontents*. nai010 publishers.
- NASSEHI A. (2019). *Muster: Theorie der digitalen Gesellschaft*. C.H.Beck.
- NEUMANN J. v. (1951). The general and logical theory of automata. In L. A. Jeffers (Ed.) *1951*, (pp. 1–41). Wiley.
- NEUMANN J. v., MORGENSTERN O. (1947). *Theory of games and economic behavior*. Princeton University Press, 2007: 60<sup>th</sup> anniversary ed.
- NILSSON N. J. (1995). Eye on the Prize. *AI Magazine*, 16(2), 9–9. <https://doi.org/10.1609/aimag.v16i2.1129>
- OLSON G. (1993). Chiasm of Thought-and-Action. *Environment and Planning D: Society and Space*, 11(3), 279–294. <https://doi.org/10.1068/d110279>
- OSHII M. (1995). *Ghost in the Shell*. Kôdansha, Bandai Visual Company, Manga Entertainment. Animated movie, Japan.
- OUREDNIK A. (2009–2023). *Wikitractatus*. A paper sanpshot this hypertext book was published by Hélice Hélas, Vevey, in 2014. <https://wikitractatus.ourednik.info>

- OUREDNIK A. (2010). *L'habitant et la cohabitation dans les modèles de l'espace habité*. Thèse de doctorat, École polytechnique fédérale de Lausanne, Lausanne.
- OUREDNIK A. (2012). L'istinto, la macchina, l'impronta. *Millepiani*, (39). <https://ourednik.info/maps/2020/02/05/linstinct-la-machine-lempreinte/>
- OUREDNIK A. (2016). Autoérotismes et dromomanies. *A contrario*, (22), 83–102. <https://doi.org/10.3917/aco.161.0083>
- OUREDNIK A. (2021). La bifurcation comme vue de l'esprit. In *Bifurcations(s)*, (pp. 287–300). Hélice Hélas.
- OUREDNIK A., KOLLER G., FLEER P., NELLEN S. (2018). Feeling Like a State. The Sentiments-tide of Swiss Diplomacy through the Eye of the Algorithm. *Administrory. Zeitschrift für Verwaltungsgeschichte*, 3(1).
- PASCAL B. (1844). *Pensées, fragments et lettres de Blaise Pascal : publiés pour la première fois conformément aux manuscrits originaux en grande partie inédits. Tome 1, par M. Prosper Faugère*. <https://gallica.bnf.fr/ark:/12148/bpt6k5530213b>
- PAYNE C. (2019). *MuseNet*. <https://openai.com/blog/musenet>
- PLOFKER K. (2009). *Mathematics in India*. Princeton University Press.
- PRUSINKIEWICZ P., LINDENMAYER A. (1990). *The algorithmic beauty of plants*. Springer. An electronic copy of the book, generated in 2004 from the original  $\text{\LaTeX}$  files, is available at <http://algorithmicbotany.org/papers/abop/abop.pdf>.

- RADFORD A., WU J., AMODEI D., AMODEI D., CLARK J., BRUNDAGE M., SUTSKEVER I., ASKELL A., LANSKY D., HERNANDEZ D., LUAN D. (2019). *Better Language Models and Their Implications*. <https://openai.com/blog/better-language-models/>
- REDSTONEBOI (2018). *small-JvN-self-replicator.rle*. Configuration file for the cellular automata simulation software *Golly*. <https://www.conwaylife.com/forums/viewtopic.php?p=62707#p62707>
- RUSHKOFF D. (2023). *Survival of the Richest: Escape Fantasies of the Tech Billionaires*. Scribe Publications.
- RUSSELL B. (1906). The Theory of Implication. *American Journal of Mathematics*, 28(2<sup>nd</sup>), 159–202. <https://doi.org/10.2307/2369962>
- RUSSELL S., NORVIG P. (2009). *Artificial Intelligence: A Modern Approach*. Pearson, 3<sup>rd</sup> ed.
- SACKS O. (1996). *An anthropologist on Mars: seven paradoxical tales*. Vintage Books.
- SADE D. A. F. D. (1904). *Les 120 journées de Sodome, ou L'école du libertinage*. Club des bibliophiles. Published for the first time after the original manuscript, with scientific annotations, by Dr Eugène Dühren. <https://gallica.bnf.fr/ark:/12148/bpt6k5454984c>
- SANTOS G. M. (2023). *A Generative Design Tool for Designing Complete Communities*. <https://storymaps.arcgis.com/stories/7f7eb7e75914433aafe9cc84d89c37e3>
- SASSEN S. (2014). *Expulsions: brutality and complexity in the global economy*. The Belknap Press of Harvard University Press.
- SCHEI T. H. (2020). *iHuman*. UpNorth Film, Think-Film Impact Production, Made in Copenhagen. Documnatary film, Danemark.

- SCHELLING T. C. (1971). Dynamic models of segregation. *The Journal of Mathematical Sociology*, 1(2), 143–186. <https://doi.org/10.1080/0022250X.1971.9989794>
- SEIRADAKIS J. H., EDMUNDS M. G. (2018). Our current knowledge of the Antikythera Mechanism. *Nature Astronomy*, 2(1), 35–42. <https://www.nature.com/articles/s41550-017-0347-2>
- SELIN H. (Ed.) (2000). *Mathematics Across Cultures*, vol. 2 of *Science Across Cultures: The History of Non-Western Science*. Springer Netherlands. <http://link.springer.com/10.1007/978-94-011-4301-1>
- SHANNON C. E. (1940). *A symbolic analysis of relay and switching circuits*. Master thesis, Massachusetts Institute of Technology. <http://hdl.handle.net/1721.1/11173>
- SHUE V. (2022). Regimes of Resonance: Cosmos, Empire, and Changing Technologies of CCP Rule. *Modern China*, 48(4), 679–720. <https://doi.org/10.1177/00977004211068055>
- SIMON H. A., BARNARD C. I. (1947). *Administrative behavior: a study of decision-making processes in administrative organization*. Macmillan Co.
- STANLEY K. O., CLUNE J., LEHMAN J., MIIKKULAINEN R. (2019). Designing neural networks through neuroevolution. *Nature Machine Intelligence*, 1(1), 24–35. <https://www.nature.com/articles/s42256-018-0006-z>
- SÖDERSTRÖM O., PAASCHE T., KLAUSER F. (2014). Smart cities as corporate storytelling. *City*, 18(3), 307–320. <https://doi.org/10.1080/13604813.2014.906716>
- TEXIER B. (2020). Passez à l'écologie numérique. *arbido*, (3). <https://www.arbido.ch/fr/edition-article/2020/vague-verte/passez-à-l'écologie-numérique>

- THOMPSON D. W. (1917). *On growth and form*. Cambridge Univ. Press.
- TURING A. M. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, S2-42(1), 230–265. <https://doi.org/10.1112/plms/s2-42.1.230>
- TURING A. M. (1950). Computing machinery and intelligence. *Mind*, LIX(236), 433–460. <https://doi.org/10.1093/mind/LIX.236.433>
- TURING A. M. (1952). The chemical basis of morphogenesis. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 237(641), 37–72. <https://doi.org/10.1098/rstb.1952.0012>
- ULAM S. M. (1962). On some mathematical problems connected with patterns of growth of figures. In *Proceedings of Symposia in Applied Mathematics*, vol. 14, (pp. 215–224). Am. Math. Soc. Vol. 14, Providence.
- ULAM S. M. (1991). *Adventures of a mathematician*. Univ. of California Press.
- VANCE J. E. (1990). *The continuing city: urban morphology in Western civilization*. Johns Hopkins University Press.
- VARELA F. G., MATURANA H. R., URIBE R. (1974). Autopoiesis: The organization of living systems, its characterization and a model. *Biosystems*, 5(4), 187–196. [https://doi.org/10.1016/0303-2647\(74\)90031-8](https://doi.org/10.1016/0303-2647(74)90031-8)
- VIDYABHUSANA S. C. (1920). *A History of Indian Logic: Ancient, Mediaeval and Modern Schools*. Motilal Banarsidass.
- VON FOERSTER H. (Ed.) (1995). *Cybernetics of cybernetics: the control of control and the communication of communication*. Minneapolis, 2<sup>nd</sup> ed.

- Voss P. (2007). Essentials of General Intelligence: The Direct Path to Artificial General Intelligence. In B. Goertzel, & C. Pennachin (Eds.) *Artificial General Intelligence*, Cognitive Technologies, (pp. 131–157). Springer. [https://doi.org/10.1007/978-3-540-68677-4\\_4](https://doi.org/10.1007/978-3-540-68677-4_4)
- WALDENFELS B. (2008). *Grenzen der Normalisierung. Studien zur Phänomenologie des Fremden 2*. Suhrkamp. Erweiterte Ausgabe.
- WATSON J. D., CRICK F. H. C. (1953). Genetical Implications of the Structure of Deoxyribonucleic Acid. *Nature*, 171(4361), 964–967. <https://doi.org/10.1038/171964b0>
- WATZLAWICK P., BAVELAS J. B., JACKSON D. D. (1967). *Pragmatics of human communication: A study of interactional patterns, pathologies and paradoxes*. WW Norton.
- WEYL H. (2016). *Symmetry*. Princeton University Press.
- WHITE L. (1967). The Historical Roots of Our Ecologic Crisis. *Science*, 155(3767), 1203–1207. <https://doi.org/10.1126/science.155.3767.1203>
- WIENER N. (1961). *Cybernetics or control and communication in the animal and the machine*. MIT Press, 2<sup>nd</sup> ed. (1<sup>st</sup> ed. 1948).
- WILENSKY U. (1999). *NetLogo*. Center for Connected Learning and Computer-Based Modeling, Northwestern University. <https://ccl.northwestern.edu/netlogo/>.
- WITTGENSTEIN L. (1922). *Tractatus Logico-Philosophicus*. Kegan Paul.
- WOLPERT D. H., TUMER K. (2002). Collective Intelligence, Data Routing and Braess' Paradox. *Journal of Artificial Intelligence Research*, 16, 359–387. <https://www.jair.org/index.php/jair/article/view/10303>



YAN H.-S., LIN T.-Y. (2002). A study on ancient Chinese time laws and the time-telling system of Su Song's clock tower. *Mechanism and Machine Theory*, 37(1), 15–33. [https://doi.org/10.1016/S0094-114X\(01\)00059-3](https://doi.org/10.1016/S0094-114X(01)00059-3)

ZASLAVSKY C. (1991). Women as the First Mathematicians. *Women and Mathematics Education Newsletter*, 14(1)(4).