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# FROM GOLEM TO CYBORG: A NOTE ON THE CULTURAL EVOLUTION OF THE CONCEPT OF ROBOTS

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**Dedicated to the 85th anniversary of the birth of robots.**

During the 20th century, the concept of the machine in science, culture, and human society changed almost completely. Starting from the time of myths, this contribution sketches two important trajectories of this change—traditional culture (mainly literature and the theatre), and science and technology—initiated by highly influential personalities of the 20th century–by the writer Karel Čapek, by mathematicians Alan M. Turing and John von Neumann, and others.

## Prologue

**Brownstone:** [*In a more frenzied tone of voice.*] It's difficult for me to tell you the exact nature of our problem with Max. I've been working with computer systems as a professional for almost thirty years, but nothing like this has ever happened before.

**Worthmore:** Relax, Harry. Take a deep breath.
[*Brownstone sits back and breathes deeply.*]

**Worthmore:** Now tell me exactly what I need to know.

**Brownstone:** It seems that Max – Max – [*with great resolve*] Max fell in love with a beautiful co-ed, and he is suffering because he cannot consummate that relationship.

**Worthmore:** Do that again.

**Brownstone:** Max is completely and totally obsessed with one of our co-eds. Yet, he cannot embrace her because he does not have – he does not have arms. He does not have a body. [*Pause*] Max wants a body. That's what it all boils down to.

This conversation between Mr. Browstone and Mr. Worthmore is taken from Richard Epstein's play *Mad Max–Beyond Turing Drone*, from the end of the last century.[1] It documents both some of the potential present day professional difficulties that may arise from the use of the robots of the future, and the increasing public interest in the topic. Moreover, it is proof of our current embarrassment of how we should continue in this shifting field of cognition and creativity: We have become very good at modeling fluids, materials, planetary dynamics, nuclear explosions and all manner of physical systems. Put some parameters into the program, let it crank, and out come accurate predictions of the physical character of the modeled system. But we are not good at modeling living systems, at small or large scales. Something is wrong. What is wrong? There are a number of possibilities: (1) we might just be getting a few parameters wrong; (2) we might be building models that are below some complexity threshold; (3) perhaps it is still a lack of computing power; and (4) we might be missing something fundamental and currently unimaginable in our models wrote Rodney A. Brooks (Brooks 2001, 401), a top-specialist in the field of robotics and artificial intelligence.

The situation depicted by Brooks is similar to that appearing in many other fields, e.g. in the study of cognition, intelligence, perception, etc. It is time both for a reconsideration of the paradigms that ruled the previous period, as well as for the creation of new ones, and in addition, to suggest qualitative changes in our concept of the machine and its substance. Our contribution will sketch some paradigmatic shifts of this kind.

## A Very Short Prehistory

Our history is full of narratives and experiments dealing with artificial intelligent human-like creatures that are products of the human attempt to discover the miracle of life and human rationality as well as of metaphors of the concept of machines from the relevant period. The following serve as examples:

The idea of a man created by a man occurs in the history of European culture in the first book of the *Old Testament* of the *Bible*, where ... *the Lord God formed the man from the dust of the ground and breathed into his nostrils the breath of life, and the man became a living being* (*Genesis*, 2.7). So, from our perspective, we can consider Adam from *Genesis* as the ideal predecessor of the robot. Moreover, the words of the *Bible* give us an assurance: We—the descendants of the first human couple (Adam and Eve), are capable of and designed for creative acts as well because: *Then God said: Let us make man in our image...* (*Genesis*, 1.26).

[1] R. G. Epstein is a professsor of computer science at West Chester University of Pennsylvania, West Chester, PA, and a playwright. The play in question was first performed after the conference banquet organized during the *Future of the Turing Test Conference* at Dartmouth College, Hanover, NH, January 28-30, 2000.

The idea of machines that can in a certain sense be considered intelligent is also present in Aristotle's *Politics*: *For if every instrument could accomplish its own work, obeying or anticipating the will of others, like the statue of Daedalus, or the tripods of Hephaestus, which, says the poet, "of their own accord entered the assembly of the Gods"; if, in like manner, the shuttle would weave and the plectrum touch the lyre without a hand to guide them, chief workman would not want servants, nor master slaves* (*Politics*, Book 2, Chapter 4, 33-39). Homer in the *Iliad* described a dream about artificial servants as well as god-like, ideal creatures in the following verses: *There were golden handmaids also who worked for him, and were like real young women, with sense and reason, voice also, and strength, and all the learning of the immortals* (*Iliad*, Book XVIII, 415-420).

A medieval legend has survived in Prague that embraces both of the above mentioned and related ideas: the idea of an artificial human-like being whose existence documents human control over the secret of life, as well as the presence of artificial slaves in our cultural history. According to this legend, a famous Prague rabbi from the turn of 16th and 17th centuries, Judah Loew ben Bezalel (buried in the Old Town Jewish Cemetery in Prague), constructed a creature of human form—the Prague Golem. He proceeded in two significant phases: First, he and his collaborators constructed an earthen sculpture of a man-like figure. Second, he found the appropriate text, wrote it down on a slip of paper and pushed it into the Golem's mouth. As long as this seal remained in Golem's mouth, the Golem could work, do the bidding of his master and perform all kinds of chores for him, helping him and the Jews of Prague in many ways, etc. The Golem was alive (if we can call such a state alive).

The legend about the Golem, an artificial servant and protector, reflects the level of technological skill of the period (pottery was the highest technology of the time described in *Old Testament*) as well as the belief in the magical and creative power of symbols which is also relevant to the period when another significant book was written—the *Sefer Yezirah* (the *Book of Creation*).

Since the time when the medieval technologies evolved from ancient pottery and smithery were replaced by different new technologies helping us to embody machines, the traditional and broadly accepted definition of the machine has been and still is related to physics. Machines of the previous centuries have been considered to be man-made physical systems working deterministically in physically well-defined cycles to concentrate the dispersion of energy in order to carry out economically meaningful (valuable) physical work. A well-known example of such a machine is the steam-engine which predetermined the evolution of 19th century industry.

The industrial revolution of the 19th century accelerated during the 20th century as a result of the emergence of machines intended for information processing. This technical development brought about dramatic scientific as well as social and cultural changes, and also considerably influenced the self-image of western man.

This (albeit briefly) illustrated developmental line of the culture of the west leads us to completely new and fundamental problems associated with our present critical thinking, technical creativity, and new and different forms of our artistic expressiveness. *Am I a man or am I a machine?* the philosopher Jean Baudrillard asked his colleagues at Ars Electronica in Linz (Austria) on September 14, 1988, to which he immediately replied: *Virtually and physically we are approaching machines*; cf. Baudrillard (1989).

Where do Baudrillard's ideas (and the many other similar ideas expressed by so many western intellectuals during the 20th century) find their roots? We will focus on this question, and explore at least two of these ideas, one in the arts of the last century, namely in literature and drama, and the second in the field of science and engineering (of computing and computers).

Considering the human-machine relationship, we can propose that the emergence of cybernetics was a turning point dividing the history of this relationship to the pre- and post-cybernetic period. In the pre-cybernetic period, technology was generally understood in terms of mechanics and an interchange of power. Cybernetics and developments within the field of computer science, technology, and engineering significant altered human attitudes and feelings toward machines. Since this shift in the understanding of machines we cannot think about them as if they were simply tools (or slaves) but rather as if they were our partners, colleagues and soon possibly (alien) citizens with their own rights. This substantive change in the way we see and treat machines will, we suggest, be significant for the coming age of post-humanism and for post-human or knowledge societies as such.

## Birth of Čapek's Robots

It is commonly known that the word *robot* appeared first in the play *R. U. R.* (Rossum's Universal Robots) by the Czech writer and journalist Karel Čapek (1890-1938). He wrote *R. U. R.* during a vacation he and his brother Josef (1887-1945) spent at their parents' house in the spa town of Trenčianske Teplice (now in Slovakia) during the summer of 1920.

As Karel Čapek mentioned, the first name he gave his "artificial workers" was *labori*. But he wasn't satisfied with this word—it sounded too academic to him—and he asked his brother for help. Josef "in passing" suggested the word *robot*, derived etymologically from the archaic Czech word *robota*, which means—as it does in modern Slovak—the *serfs' obligatory work.*

The official first night of *R. U. R.* was held in the Prague National Theatre on January 25, 1921 under the direction of Vojta Novák. The costumes were designed by Josef Čapek, while the stage for the performance was designed by Bedřich Feuerstein. The first night was a great success. Many theatre critics commented on the play's cosmopolitan character, the originality of the theme, and anticipated the play's world-wide success.

Through his play Karel Čapek opened up perhaps two of the most appealing topics of 20[th] century intellectual discourse—the problem of human-machine interaction and the problem of human-like machines. Reflecting the social and political situation of Europe immediately after the end of the First World War, he intended, first of all, that the robots be seen as a metaphor for workers dehumanized by the daily grind ofl work, and consequently that they were an easily abused social class.

From an artistic point of view, the artificial humanoid beings used by Čapek in his play may also be understood as his humanistic reaction to the fashionable concepts dominating the modernistic view of human beings in the first third of the 20th century—the concept of a "new man"—e.g. in symbolist theatre conventions, in expressionism, in cubism etc., and most significantly in futuristic manifestos yearning for the mechanization of humans and their adulation of the "cold beauty" of the machines made of steel and tubes often depicted in their artwork as well as the political implications of futurism. In such an intellectual climate, contemplating the way in which machines work, Karel Čapek expressed in *R. U. R.* his misgiving on what may happen to human beings and mankind.

So, when Wiener gave Ampére's "cybernétique" its contemporaneous meaning (Wiener 1948), the *word* robot was already an accepted attribute of our future, at least in some cultural circles (see, for example, probably the first use of the word robot by Wiener in Rosenblueth, et al. 1943).

## Turing's Hypotheses on Machines and Humans

The considerable paradigmatic shift in scientific and technical understanding of machines consists of a movement away from viewing machines as physical systems intended to perform physical actions in the physical world towards their being understood as universal symbol-manipulating systems for storing and retrieving information coded (represented) in suitable ways. Hodges (Hodges 1983, Chapter 2) informs us of the first steps towards this new image of machines as executed by Alan Mathison Turing (1912-1954).

Alan Turing, after finishing his dissertation and as a King's Fellow at Cambridge University, attended a course on the foundations of mathematics delivered by M. H. A. Newman in the spring of 1935. Newman concluded his course by outlining Kurt Goedel's proof of his famous undecidability theorem, which did not rule out the possibility that there was some way of distinguishing provable from non-provable statements. Newman put the following question to his students: Was there a *mechanical* process which could be applied to a mathematical statement, and which would come up with the answer as to whether it was provable? The phrase "mechanical process" revolved in Turing's mind and led him to a challenging question: What would be the most general kind of machine that could deal with symbols? Inspired by a mechanical typewriter, Turing invented and described with all the necessary mathematical rigor the idea of such a machine, which he called an *automatic* (or *a-*) *machine* (Turing, 1936-7), and which is now generally known as the *Turing machine* (a name suggested by Alonzo Church).

In layman's terms, the Turing machine consists of two basic parts: the control engine, and the writing hand. The writing hand is able to read and (re)write symbols appearing on bi-directionally potentially infinite tape. It is able to write a specific symbol (say symbol 1) on a square above which it hovers or withdraw the symbol from this square. The control engine governs the actions of the writing hand using four commands: write, erase, move one square to the right, and move one square to the left. Alan Turing invented an abstract "mechanical" (mathematically well-defined and rigorously constructive) method (an abstract "machine") and he proved—in general terms—that this "machine" is the most universal one for dealing with symbols. Moreover, he proved that from the perspective of this "machine" the answer to Newman's question outlined above is definitely "no". In other words, he provided exact mathematical proof for the statement that there exist mathematically well-defined functions for which their values cannot be effectively computed from the values of their variables.

The invention and further study of the universal Turing machine provide the basis for the formulation of at least two fundamental hypotheses related to our understanding of machines and their capabilities. *The first Turing hypothesis* concerns the capabilities of machines, and is known as the *Church-Turing Hypothesis* in the literature (for more details, see e.g. Sieg 1999). The hypothesis states that all that is intuitively computable in any realistic sense, can be computed by the universal Turing machine. What we call *The Second Turing Hypothesis* is known as the *Turing Test*, particularly in the literature on Artificial Intelligence, (see e.g. Pfeifer, Scheier 1999). The test was first published in (Turing, 1950), and compares the ability of machines (computers) and human beings with respect to the way in which they are capable of performing tasks that are associated with intelligence in human beings. If the test proves that the behavior of the human beings and the computers are unrecognizable to a human observer, then the computer might be considered intelligent. So, in other word, the test leads us to the general hypothesis, that human intelligence is expressible by a collection of computable tasks.

Turing's idea (expressed in Turing 1936-37) and the results he proved using it, revolutionized mathematics and—two decades later—provided the basis for the rapid development of theoretical computer science. His paper (Turing 1950) is considered to be akin to the founding manifesto of Artificial Intelligence research (at least during the 1960s and 1970s). First of all, Turing demonstrated that the idea of a machine is important not only from the perspective of physics. It is a general idea, which provides for the rigorous study of not only the physical limitations, but also the limitation of our efforts to express procedurally certain symbol-manipulation concepts, as well as our own intellectual limitations. Beginning with

Turing, the idea of the machine started to serve not only technological progress, but it was also a critical self-reflection of mankind's own abilities and intellectual boundaries (of mathematics and the application of computing).

## Alquis, von Neumann, and the Origin of Artificial Life

In the third act of *R. U. R.* robots ask Alquist, the last living human being on the island where the R. U. R. factory is located, for the secret of reproduction: *Teach us to make Robots. We will give birth by machine. We will build a thousand steam-powered mothers. From them will pour forth a river of life. Nothing but life! Nothing but Robots!* Alquist answered: *Robots are not life. Robots are machines.* John von Neumann was the first to try—approximately 35 years after the first night of *R. U. R.*—to create this kind of recipe for reproduction.

In 1912, when Alan Turing was born, Margittai Neumann János Lajos[2] (1903-1957) was a nine-year old boy living in Budapest as the son of a prosperous Hungarian banker. In late 1944—as a US citizen and already a distinguished theoretical physicist and mathematician– he joined the development team of one of the first electronic computers in the world —the EDVAC Project—as an advisor. The project was to a certain extent inspired by the idea of the 19th century English mathematician, Charles Babbage, as expressed in the design of his planned *Analytical Engine*. The *Analytical Engine* would be able to ingest an unlimited number of instruction cards for its control (programming) using instruction cards. One of the earlier 20th century computers, Howard Aiken's MARK II, solved the same problem using a kind of pianola roll. However, the EDVAC Project was intended to improve the existing idea of the ENIACZ—an *electronic* computer whose development had begun in the spring of 1943 at the University of Pennsylvania. The operations of the ENIAC, being electronic, would be so fast as to make it impossible to supply instructions mechanically. With the ENIAC the instruction supply for each job was arranged using a system of external devices similar to a manual telephone exchange. The advantage of this solution was that the instructions would be available instantaneously, once the plugging work had been done. The disadvantages were twofold: (1) the sequences of instructions were limited in length, and (2) it would take a very long time (a day or so) to do the plugging.

Joining the EDVAC Project, John von Neumann proposed that the original idea that the data (numbers) and the program (the stock of instructions on how to operate the data) were entirely different kind of entities was erroneous. Instead ,the *Draft Report on the EDVAC* dated June 30, 1945 and signed by von Neumann

[2] This is the original, albeit relatively rarely used and unknown, Hungarian form of the name of John von Neumann.

suggested the following important steps that form the core of the idea of the von Neumann computer architecture: *The device requires considerable memory. While it appeared, that various parts of this memory have to perform functions which differ somewhat in their nature and considerably in their purpose, it is nevertheless tempting to treat the entire memory as one organ.* John von Neumann, in his search for a means of arranging the sequences of acts performed with data in computers, was perhaps inspired by the introspective evidence that both the methods and means of processing the data in our minds are located somewhere within the brain alongside the thought processes that led the mind to select a particular approach. In Neumann's posthumously published book (Neumann 1958) the notion that the computer and the human brain display similarities (and differences) is explained in certain detail. In accordance with the plausible hypothesis that the human memory is not passive, but that it is completely involved in organizing human (intellectual) activity, he applied this hypothesis to the construction of machines, and the hypothesis held. By figuring out how the human mind works von Neumann was able to improve the abilities of machines.

The general-purpose von Neumann style digital computers provided an excellent opportunity for the studies anticipated by the late von Neumann, who pointed out (Burks 1970, 3) that *while the past science has dealt mainly with problems of energy, power, force, and motion, the future science would be much more concerned with problems of control, programming, information processing, communication, organization, and systems.* This conviction was very similar to Norbert Wiener's. However, von Neumann wished for a common theory of man-made as well as natural systems with more emphasis placed on logic and computation (an automata theory), while Norbert Wiener's cybernetics was oriented more around physiology and control engineering. One of the most important properties of living systems that distinguishes them from non-living systems is the ability of living systems to reproduce, and von Neumann's big dream was to propose such an automaton. Starting from the idea of the Turing Machine he worked on the notion of an automata that produced not sequences of 0s and 1s on a tape, but new automata that in terms of their complexity could be considered equivalents of their "parents". Its design consists—in brief—of the following three phases (Neumann 1951):

a) An automaton **A**, which is able to construct an arbitrary well-described automaton. However, the description is not found in the form of symbols on tape, but in the form of a combination of basic construction elements in the environment. Let this description be denoted by **I**.
b) An automaton **B**, which is able to make a copy of **I**.
c) Let **A** and **B** combine with a control unit **C** thanks to which **A** will construct an automaton according to description **I**, **B** will then produce a copy of **I**, and finally, **C** will put the newly produced **I** into the automata constructed by **A**. Finally **C will** separate the "newborn" automaton from the systems **A+B+C**.

It follows then that **A+B+C** can be denoted by **D**. In order for it to work, it is necessary to implement the process described in c) into part **A** of **D**. So, let us construct a description **ID** of **D** and implement it into **A**. Let the resulting automaton be denoted by **E**. Von Neumann concluded that from the point of view of Turing-computability **E is** a realistic and *self-reproducing* automaton, although he never proved the result with mathematical rigor..

John von Neumann proposed his self-reproducing automaton in the form of an artificial multi-cellular system: an artificial organism composed of different types of "organs" formed of different types of "cells" with simple computational properties and whose production required 29 possible internal states of a "cell". However, he never completed the written proof of the properties of the proposed model. The complexity of the description of the subject was greater then he had anticipated, and he shelved it when he was appointed to the U. S. Atomic Energy Commission. When his health was failing, he allowed John Kemeny (the later inventor of the programming language BASIC) to write an article on self-reproducing cellular automata.

In order to make the theoretical analysis of the idea of cellular automata and the process of the self-reproduction of computational systems possible, von Neumann's original highly complex and technically demanding idea had to be simplified. This simplification was undertaken by E. F. Codd, by reducing the "cells'" internal states from 29 to 8 in such a way that the resulting self-reproducing cellular automata model preserved their computational universality as conceived of by Turing. The proposed model was systematically studied and then presented in the form of a monograph (Codd 1968).

Further simplification of the model was carried out—in order to program the first computer simulation of self-reproducing cellular automata—by Christopher Langton. Langton's intention was not to preserve the computational universality property of the model. He was looking for the simplest implemented cellular configuration that could reproduce itself not only theoretically, but also in its computer simulated form, and in this he was successful. Moreover, the proposed and implemented model—*life, as it could be*—contains some significant similarities to real living systems—with *life, as we know it*—e.g. the genotype/phenotype distinction and others.

The italicized phrases are from Langton's pioneering paper (Langton 1989) which initialized the new branch of scientific and engineering activities now known as *Artificial Life* (AL) which is concerned with (complementing traditional biology which analyzes living organisms in order to understand life) synthesizing life-like behaviors. The key concept of AL is emergence. It is taken for granted that natural life emerges out of the interactions of nonliving molecules with no global "controller" of the behavior of every part. Rather, the behavior of the whole system emerges from local interactions of the parts.

**Towards a New Concept of the Machine**

In the Prague newspaper *Lidové noviny* (June 9, 1935) Karel Čapek expressed his own opinion concerning robots: *...robots are not mechanisms. They have not been made from tin and cogwheels. They have been built not for the glory of mechanical engineering. Having the author in his mind some admire of the human mind, it was not the admiration of technology, but that of the science. I am terrified of being responsible for the idea that machines may replace humans in the future, and that in their cogwheels may emerge something like life, love or revolt.* Čapek's statement regarding the machine is artistic even though he was inspired by science. He recognized that robots were a metaphor for a simplified man not for a sophisticated machine.

However, the author is never the owner of his work and ideas. The way in which the *R. U. R.* robots in general were understood in two cultures with different social, economic, and historic experiences—the European social and artistic experience after the First World War, and the industrial experience and expectations of the USA at the same time—has been substantially different. It can be proved very simply by comparing the costumes of the robots from the first nights of the play *R. U. R.* in Prague (1921), in New York City (1922) where we notice the attempt at industrial unification, and in Paris (1924) which reflects the esthetical influence of futurism (see Fig. 1), for instance.

In the European context, Čapek's robots were—and still remain—a warning against the dehumanization through "mechanization" of human beings. In the USA the idea of the robot was understood in a different way, as an appeal for progression in industry, and, consequently, for making machines increasingly clever. As the result of this "industrial" mechanistic tendency, for engineers of the pioneering years of American cybernetics the only way to build robots was to combine metal-based mechanics with electro-techniques.

Methodologically, the attempt to construct robots according to the dreams of cybernetics has been based on the significant progress of the computer science and engineering pioneered for example, by Alan M. Turing and John von Neumann. Midway through the last century an ambitious journey of human professional curiosity was started off by Turing's famous paper (Turing, 1950), and named in 1956 as *Artificial Intelligence* (AI). The main goal of the newborn discipline consisted (and in a sense has consisted up until now) of *...finding useful mechanistic interpretations of* [...] *mentalistic notions that have real value* [...] and *...is associated in its most elementary forms with what we call cybernetics, and in its advanced forms with what we call artificial intelligence*, according to one of the cofounders of AI, Marvin Minsky (1968, 2). Decades of research led to the discovery of two means of achieving this goal – the *top down* approach analyzing the human mind from the position of the computational paradigm, and then trying to (re)construct it step-by-step on the base of its computationally precise understanding.

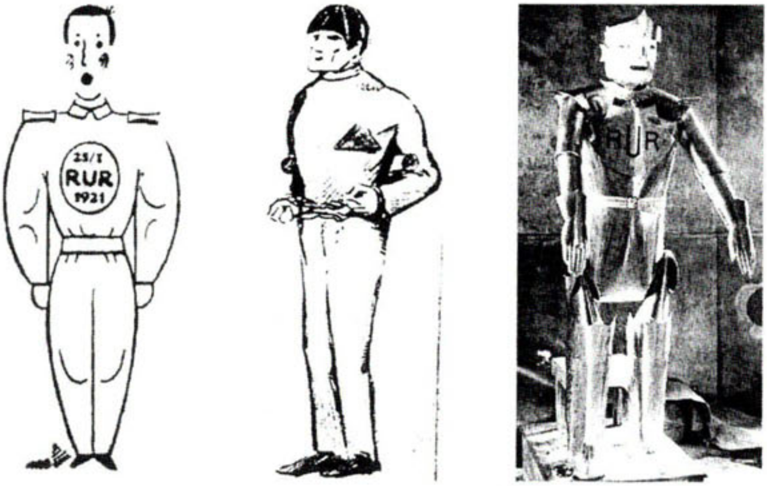


**Fig. 1.** Costume design of robots (and a caricature of K. Čapek) by J. Čapek for the Prague first night of *R. U. R.* (left), a drawing of a robot costume from the first US run (in the middle), and a robot (as part of the props) from the first night in Paris (right).

Minsky outlines the concept in the Prologue of his *The Society of Mind* (ibid., 17): *What can we do when things are hard to describe? We start by sketching out the roughest shapes to serve as scaffolds for the rest...Next, draw details to give these skeletons more lifelike flesh... in the final filling-in, discard whichever first ideas no longer fit.* The alternative approach proceeds from the *bottom up* synthesizing increasingly clever machines. It is supposed that the robot does not need a coherent concept of the outer world. Instead, they must have efficient opportunities to learn directly from their manifold interactions with their environments. A famous project of this kind—the Cog project Cog—has so far resulted in an upper-torso humanoid robot which approximates human movements, and visual, tactile, auditory and vestibular sensors (Brooks et al. 1999).

## The New Concept of Life

In the Prologue of the play *R. U. R.* Mr. Domin—the president of the R. U. R. robot factory—recollects the beginnings of the idea of robots for Helena Glory: *And then, Miss Glory, old Rossum wrote among his chemical formulae: "Nature has found only one process by which to organize living matter. There is, however, another process, simpler, more moldable and faster, which nature has not hit upon at all. It is this other process, by means of which the development of life could proceed, that I have discovered this very day." Imagine, Miss Glory, that he wrote these lofty words about some phlegm of a colloidal jelly that not even a dog would* *eat. Imagine him sitting over a test tube and thinking how the whole tree of life would grow out of it, starting with some species of worm and ending—ending with man himself. Man made from a different matter than we are. Miss Glory, that was a tremendous moment.*

So, as Karel Čapek predicted in his artistic visions, John von Neumann in his scientific writing on the power of self-reproducing cellular automata, and as Luc Steels and Rodney Brooks documented in (and emphasized by the title of) their edited volume (Steels, Brooks, 1995), a collection of recognized papers relating AL with AI, we can follow the trajectory from artificially living to artificially intelligent beings. Perhaps Alan Turing's late interest in the chemical basis of morphogenesis (Turing 1952) was inspired—at least to a certain extent—by his early interest in computational, and later in the intellectual capacity of machines, too.

Computers (machines) are involved in biological research in two principal ways. They are tools for performing traditional computations of output data from an input (e.g. in statistics), and for performing dynamic simulations in order to model well described biological processes similarly found in other branches of science (physics, chemistry, etc.). The role of computers and machines in general in AL is different. In order to understand life AL specialists implement their hypotheses concerning life into machines. The machines with implemented hypotheses then start to behave in certain ways and the specialists have the opportunity (for the first time in the history of humankind) to observe their behavior and compare them with the expectations garnered from the original hypotheses. In other words: they have the opportunity to test their hypotheses. This role of machines in AL is very similar to their role in AI, where the specialists formulate their hypotheses concerning intelligence, and test their hypotheses using machines in a very similar way.

In AI as well as in AL we believe that our hypotheses about intelligence and life will with time more closely match reality. Thank to this progress our machines will behave more and more like intelligent and living entities. However, the question whether they will be intelligent and living or not, is—in our opinion—beyond the scope of science. It is not a scientific problem, but an ethical one, more generally—a problem which must be solved within our culture. The pioneering role of the personalities named in this contribution has been to include machines in the step-by-step process of understanding the miraculous phenomena of life and intelligence connected *prima face* with living and human beings. As a result of these scientific activities, questions concerning our own identity have emerged within our culture such as that formulated rather provocatively by Jean Baudrillard and cited at the beginning of this article.

## Epilogue: A New Concept of Man?

Starting with Baudrillard's questions about the future and the destiny of humankind we have traced a route beginning with the early dreams of artificially created human-like creatures and ending with *robots*, encountering on the way the interests of scientists and engineers in logically understanding the intellectual capabilities of human beings as pioneered by Alan Turing, and then in the context of their attempts to build man-like machines (von Neumann and Turing again) up to the present day efforts of current AI and AL researchers (represented in the this article by Marvin Minsky, Rodney Brooks, and Christopher Langton).

The efforts of both those mentioned above and the many who have not featured in this article but continue to work in AI, advanced robotics, and AL have led to the modification of our view of humankind – to the concept of *post-human*, and to the concept of the *cyborg*. *...becoming a posthuman means [...] envisioning humans as information-processing machines with fundamental similarities to other kinds of information-processing machines, especially intelligent computers. Because of how information has been defined, many people holding this view tend to put materiality on one side of a divide and information on the other side, making it possible to think of information as a kind of immaterial fluid that circulates effortlessly around the globe while still retaining the solidity of a reified concept. [...] Other voices insist that the body cannot be left behind, that the specificities of embodiment matter, that mind and body are finally the "unit" [...] rather than two separate entities. Increasingly the question is not whether we will become posthuman, posthumanity is already here. Rather, the question is what kind of posthumans we will be*, writes Katherine Hayles (1999, 246).

The Czech philosopher, poet and story-writer Zbyněk Fišer (alias Egon Bondy) contemplating the future of mankind sometime at the end of the sixties sketches two possible answers to Hayles' question above: *Emancipation from the biological base, disposing of it, overcoming it, surely does not mean, and cannot mean in any case, the achieving of any immaterial form of the existence of intelligence. [...] It is something which we cannot characterize in any other way than the artificial form of existence, artificial in the sense that it is not biological but fabricated* (Bondy, 1993, pp. 52-53). As a story-writer he sketched the following view: *The man-machine combination is sci-fi.* [...] *Man is a biological unit – a digestive tube plus sexual organs. You may add anything to that, it will remain a hybrid. Biological evolution added the brain. And immediately that the brain becomes productive enough, it starts to collide with the digestive tract and sexual organs. The result is a jewel! Potential aggression is found on one side of the coin, the never-ending feeling of vain boredom on the other. And if you add some machines to all of that, the result will be much worse. So, we must develop a new kind of completely artificial being. Beings which will survive because they will actually re-produce and not because they will increase due to their digestive tracts and their sexual organs* (Bondy 1997, 121).

*It is no longer meaningful to see the body as a site of psyche or the social, but rather as a structure to be monitored and modified—the body not as a subject but as an object—not an object of desire but as an object for designing* writes the famous Australian performer artist

Stelarc in his manifesto *Redesigning the Body* (more on the *www.stelarc.va.com.au*). There are many different views as to how we—human beings with our mortal bodies and immortal spirits who swapped Paradise for free will—will proceed...

From the position we have reached today, at the beginning of the 21st century, our destiny as mankind can be identified in our cohabitation with the main product of our past, and the basis for our future—with machines.

While in 1963, M. Minsky wrote that ... *we are on the threshold of an era that will be strongly influenced, and quite possibly dominated, by intelligent problem-solving machines* (Minsky 1963, 406), at the present time machines are already our livelihood. We have started to construct them (because we are inventive beings) to make hard physical work for us (because we are weak). Then we gradually passed onto them the routine mental work of which there was too much for us (because we are slow) or which required great precision and attention (because we are inattentive). Now machines are gradually starting to make decisions instead of us (because we are slaves of our own psycho-physical limitations) and they are starting to behave autonomously in the environment they share with us. Is it because we have a feeling of loneliness in the brave new world we have created? In any case, if development continues in the direction and in the way that we have witnessed and participated in over the last few decades, then it can be expected that we will live with future machines in a more or less equal relationship. This relationship—whose examination at least started in *R. U. R.*—will (might be) the crucial ethical base for the coming age of post-humanism and the cyborgic nature of human beings.

The play *R. U. R.* ends with a scene in which Karel Čapek depicted his vision of the destiny of his robots, and which may also be his vision of the future of humankind as well: Two robots (or cyborgs if we are to use our latest favoured expression)—Primus and Helena—are faced with the intention of the last human being on earth, Alquist, who wishes to dissect one of them in order to re-discover the miracle of life—the ability of robots to reproduce biologically. But the robots are against the dissection. Instead of the dissection what might be the first post-human couple has been born...

**Primus:** We – we – belong to each other.

**Alquist:** Say no more. [*He opens the center door.*] Quiet. Go.

**Primus:** Where?

**Alquist:** [*in a whisper*] Wherever you wish. Helena, take him. [*He pushes them out the door.*] Go, Adam. Go, Eve – be a wife to him. Be a husband to her, Primus.

[*He closes the door behind them.*]

**Alquist:** O blessed day! [*He goes to the desk on tiptoe and spills the test tubes on the floor.*] O hallowed sixth day! [*He sits down at the desk and throws the books on the floor, then opens a bible, leafs through it and reads.*] "So God created man

in his own image, in the image of God created he him; male and female created he them. 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 moved upon the earth." [He stands up.] "And God saw every thing that he had made, and, behold, it was very good. And the evening and the morning were the sixth day." [*He goes to the middle of the room.*] The sixth day! The day of grace. [*He falls on his knees.*] Now, Lord, let Thy servant – Thy most superfluous servant Alquist – depart. Rossum, Fabry, Gall, great inventors, what did you ever invent that was great when compared to that girl, to that boy, to this first couple who have discovered love, tears, beloved laughter, the love of husband and wife? O nature, nature, life will not perish! Friends, Helena, life will not perish! It will begin anew with love; it will start out naked and tiny; it will take root in the wilderness, and to it all that we did and built will mean nothing-our towns and factories, our art, our ideas will all mean nothing, and yet life will not perish! Only we have perished. Our houses and machines will be in ruins, our systems will collapse, and the names of our great will fall away like dry leaves. Only you, love, will blossom on this rubbish heap and commit the seed of life to the winds. Now let Thy servant depart in peace, O Lord, for my eyes have beheld – beheld Thy deliverance through love, and life shall not perish! [*He rises.*] It shall not perish! [*He stretches out his hands.*] Not perish!
CURTAIN

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