SCIENCE MAGAZINE

ELEMENTS

SPECIAL EDITION
January 2024

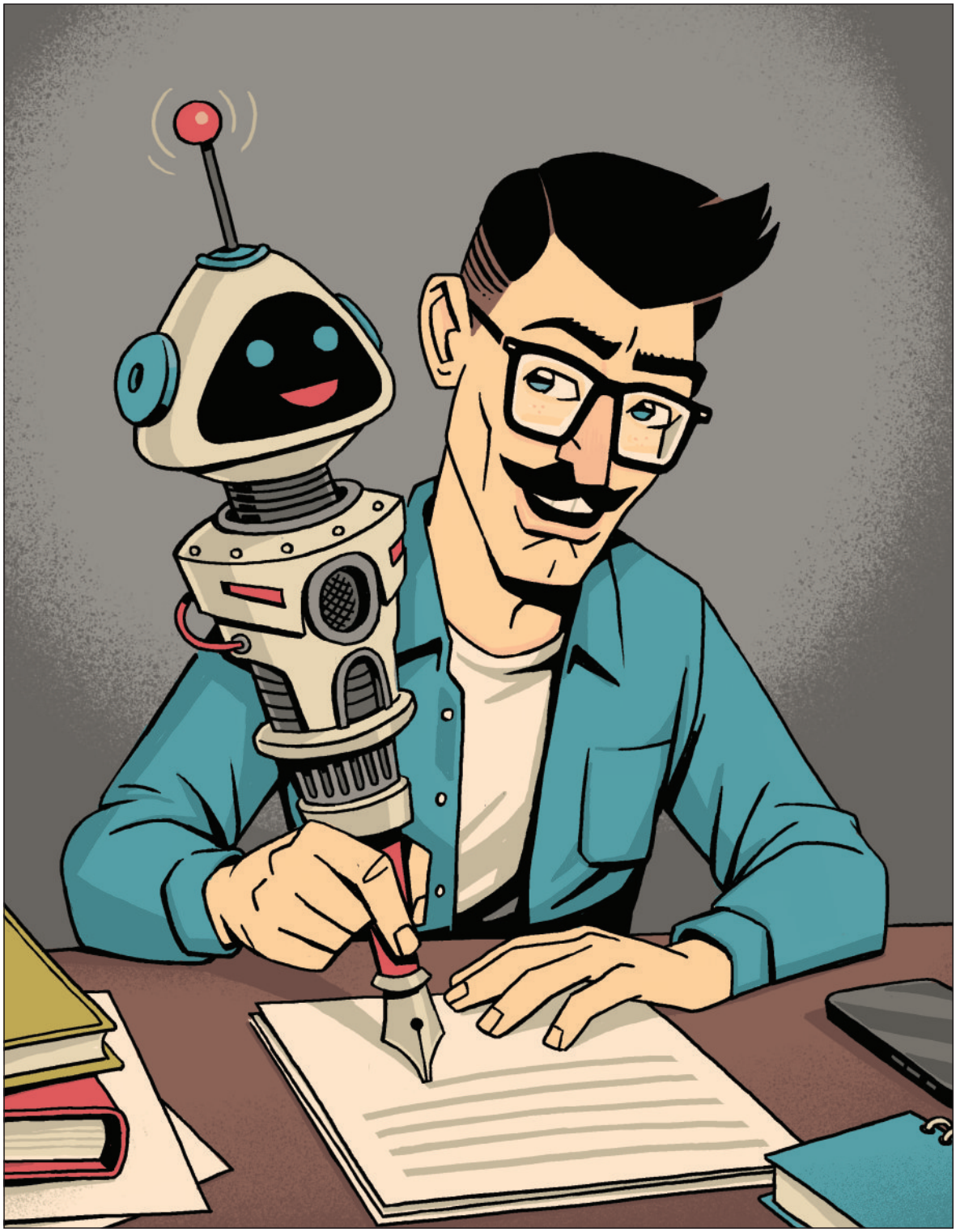
COVER STORY

A Hitchhiker's Guide to Natural Language Processing

An Introduction to a Desert Cosmopolis

Could Robots Vote?

Ugh! Yuck!



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COVER STORY

THAT CHATGPT can automatically generate something that reads even superficially like human-written text is remarkable, and unexpected. But how does it do it? And why does it work? You may find answers to these and many other questions in an article entitled *A Hitchhiker's Guide to Natural Language Processing* on page 18.

Illustration by ***Nikola Korać***

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Cover Illustration by **Nikola Korać**

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ABOUT US

ELEMENTS

IN ITS STRIVE TO BE A HUB of science journalism, *Elements* brings together the most talented science writers and illustrators from Serbia and the region. The editorial concept is rooted in the idea that science stories should be explored in a broader context, with questions we ask ourselves every day and topics that stir personal curiosity. Although the magazine mostly covers current developments and the latest scientific discoveries, the style is sophisticated, clear, and exciting, and authentic visual storytelling is what sets this publication apart from others.

Elements has been published quarterly since 2015, with 35 issues out so far.

The *Elements* science magazine is published by the Center for the Promotion of Science (CPN), a public institution established by the Ministry of Science of the Republic of Serbia in 2010. The Mission of the CPN, as a leading organization in the field of science communication, is to bridge the gap between science and society. The CPN implements its programs and activities with research and educational institutions, and in close collaboration with the media, government and non-government organizations, innovative businesses, and cultural institutions from Serbia and across the world. The Center is famous for its publishing activity, public engagement events, interactive science exhibitions and workshops, trainings for researchers, and vibrant international cooperation that unfolds through participation in a large number of projects from the programs Horizon Europe, Creative Europe, Erasmus, and the JRC. The CPN's objective is to engage society in research and innovation efforts so as to improve scientific literacy and provide insightful answers to contemporary social challenges.


$F=G\frac{m_1 m_2}{r^2}$

Photograph by ***Zoran Petrović, NITRA***

Dear readers and science enthusiasts,

It is with great pleasure that I welcome you to the latest edition of *Elements*, a publication that stands at the forefront of scientific exploration and technological innovation. As we immerse ourselves in the realms of artificial intelligence, biotechnology, and other disruptive technologies, we promise you a captivating journey into the frontiers of contemporary science.

As a molecular biologist now serving as the Minister of Science, Technological Development and Innovation, I find immense pride in presenting this edition that reflects the pulse of our rapidly evolving scientific landscape. The future is unfolding at the intersection of biology, technology, and myriad branches of science, and *Elements* serves as a compass guiding us through this intricate terrain.

In this special issue, we spotlight the contributions of brilliant minds—pioneers shaping our understanding of the world and forging paths toward groundbreaking discoveries. From the intricate dance of algorithms in artificial intelligence to the transformative power of biotechnology, each article is a testament to the limitless possibilities that science and technology offer. Not only do these articles spotlight the latest advancements, but also provide a glimpse into the profound impact these innovations will have on our society, economy, and daily lives.

I sincerely compliment the authors whose dedication and expertise illuminate the pages of this edition. Their commitment and thirst for advancing knowledge and fostering a culture of curiosity are instrumental in propelling our nation toward becoming a global hub for science and innovation.

On these pages, you will find the essence of our collective journey—a journey marked by curiosity, discovery, and a relentless pursuit of knowledge. I encourage you to immerse yourself in the articles, engage with the ideas presented, and find inspiration in the transformative potential of science.

Thank you for joining us on this intellectual voyage.

Warm regards,

Jelena Begović, PhD
Minister of Science, Technological Development and Innovation

Illustration by ***Monika Lang***

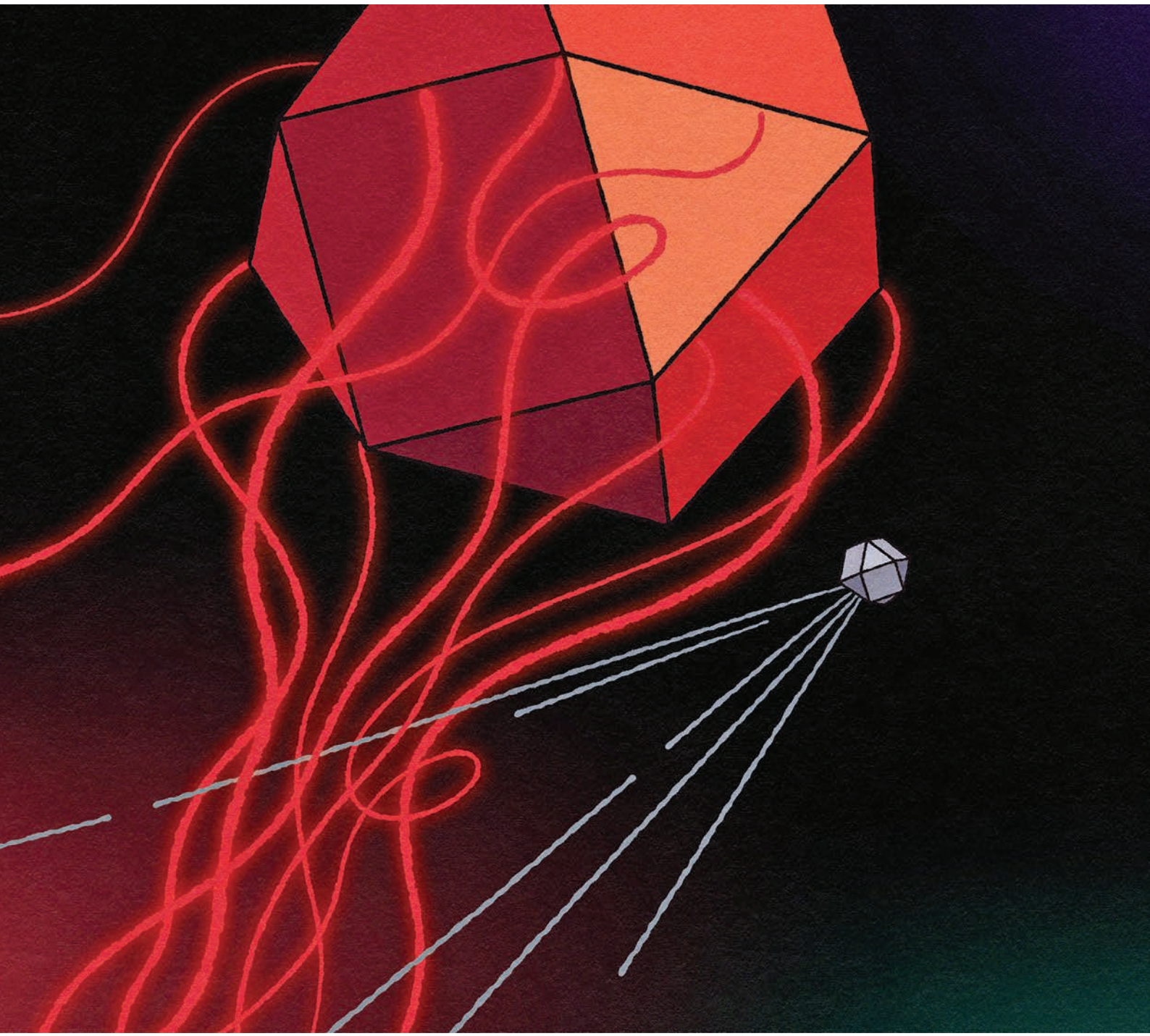
Illustration by ***Željko Lončar***

RNA vs. RNA

Nobel Prize in Physiology or Medicine

ACCORDING TO A PRESS RELEASE issued by the relevant committee, the 2023 Nobel Prize in Physiology or Medicine has been awarded for "the discoveries concerning nucleotide base modifications that enabled the development of effective mRNA vaccines against COVID-19." The Nobel laureates, Hungarian-born U.S. scientist Katalin Karikó and U.S. scientist Drew Weissman, made some key steps along the road that eventually led to the awarded discovery.

As all other jabs, mRNA vaccines work on the principle that the RNA of a virus is offered to the immune system of a vaccinated person so that it can memorize it and thus gain the ability to have an incredibly quicker and more effective response, should it ever contract the virus with the same RNA. As a result, the infection will be either prevented or drastically curtailed, with much reduced prospects of causing organ damage or life-threatening conditions.



IN FOCUS

Illustration by ***Jakov Jakovljević***

NANOTECHNOLOGY IN QUANTUM COLORS

Nobel Prize in Chemistry

WHEN ALEXEI EKIMOV, Louis Brus, and Moungi Bawendi did their first experiments with quantum dots, probably no one could have imagined that these tiny particles would have such an enormous impact on our daily lives and today's technology. Though quantum dots have already found numerous applications, from QLED TV sets to medicine and diagnostics, we are really just at the beginning of their implementation and all the quantum functionalities they could offer.

As a recognition for all this, on 4 October 2023, Ekimov, Brus, and Bawendi shared the Nobel Prize in Chemistry for the discovery and synthesis of quantum dots. Quantum dots are nanometer-sized objects (10^{-9}) made of semiconductor materials. The color of light they emit is determined solely by their diameter. However, once we reach the dimensions measured in one-millionth of a millimeter, there start to occur quantum effects that seriously challenge our intuition about reality.

An Introduction to a Desert Cosmopolis

Like human beings, galaxies tend not to spend their life isolated, so they often cluster into larger-scale structures made of groups or whole swarms

By
Darko Donevski

ON THE LAST FLIGHT THAT DAY, we left the city and headed north. Several more hours to go before our final destination—a mountainous plateau located in the Andes at an altitude of 3000m. There awaited us a dry puff of desert sand, inquisitive foxes, herds of lamas and alpacas, and large astronomical telescopes. Sixty antennas with a diameter of several meters that should give us an insight into the light of distant galaxies. As we were taking off from the Chilean capital of Santiago, its contours were fading away in a white fog drifting above its blurred lights of boulevards, buildings, and advertising screens. Only several minutes later, the lights already dropped from our sight, leaving us under the cloak of darkness. In the direction we were heading, from the center to the north of Chile, geographical maps told us there were no other big, dazzling cities. I thought how similar this was to galaxies that also accumulated light toward the center and emitted it strongly enough so that we could see the glow in different forms depending on our manner of observation. Santiago was very much like that light. But, if some far-off, small, and almost invisible city appeared within our sight, would we recognize it at all? Or would this city be left unnoticed due to our incapacity to understand its existence?

The fact is that many distant galaxies, though giant in their size and glow, seem very small, even when viewed through the largest telescopes. Put simply, there are so distant from us that even if we detect their light, little could we say about their nature. While we could still learn something about the development of cities on our planet from the preserved old maps and other precious archaeological records, looking into the central square of a distant galaxy remains one of the biggest challenges facing astronomy.

The following morning, we were in San Pedro in the Atacama Desert. In these desert cities, dark red archaic buildings dominate the skyline, making it very clear that the architecture owes a debt of gratitude to dust and mud. Those houses are made from a special building material called mudbrick. Also known as unfired brick, this material is made by combining heat, dust, and mud. This traditional construction technique made it possible for indigenous tribes to live in homes that did not get too hot by day, and then over night, when the desert temperature drastically dropped, they remained warm enough and suitable for life. A local once told me a joke that if it ever turned out that some structures existed on the planet Mars, they would most likely resemble those in San Pedro. There, we could witness dramatic changes in nature's dance interwoven into the landscape, revealing the desert's power, in contrast to steep mountains on one side and a large extinct volcano on the other. Along the way to the peaks, we could also see salt pans and geysers, a reminder of desert life often being much more dynamic than we would have ever thought.

However, I did not come there to enjoy the Atacama landscape, but rather to make observations at a major astronomical observatory. The objective was to explore the surroundings of dozens of gigantic galaxies. We turned the telescope to a small piece of sky where nothing seemed to emit any visible light. It was like searching for invisible cities. There is a good reason why astronomers sometimes like to focus on those dark corners of space. In their thick darkness, they hold many dazzling worlds—galaxies. The galaxies we are searching for are more than ten billion light years away and filled with billions of stars, with their light overshadowed by clouds packed with various organic materials. In other words, the worlds we are tracking down are distant, formed in the early universe. Due to the cosmic distance, the light of those far-off galaxies reaches us substantially changed and weakened, as with every attempt at escape from the thick cloud of gas and dust, the light of young stars loses a bit of its power. As a matter of fact, the initial ultraviolet wave, decelerated and extended, comes to the telescope with essential information about the heat emitted in a collision between dust grains and starlight. Meanwhile, the galaxies that had emitted the

information turned extinct. Hence, we are like travelers discovering the past we did not know we had.

In *Invisible Cities*, a kind of travel book in which the Venetian adventurer Marco Polo recounts his travels to imaginary cities in Asia, the Italian writer Italo Calvino observes how the languages and characters of cities differ depending on the epoch when a traveler (explorer) visits them. We can say the same about galaxies. The only significant difference lies in the time scale of their evolution. We are pretty sure the universe is 13.7 billion years old, and that the first galaxies were formed after several hundred million years. In contrast, the oldest cities on our planet were established several thousand years BC. Most of them are no longer inhabited or appear on maps. Hence, it is clear the time scale of the universe's development, which is much longer than the age of humankind, places substantial limitations on our scientific curiosity. We cannot possibly travel to some galaxy and stop it in time and space so that we can examine its interior and surroundings. So, while it is possible to explore ancient city structures by analyzing materials collected during archaeological explorations—in observing galaxies, we can only strive to detect and understand their light.

Illustrations by ***Irena Gajić***

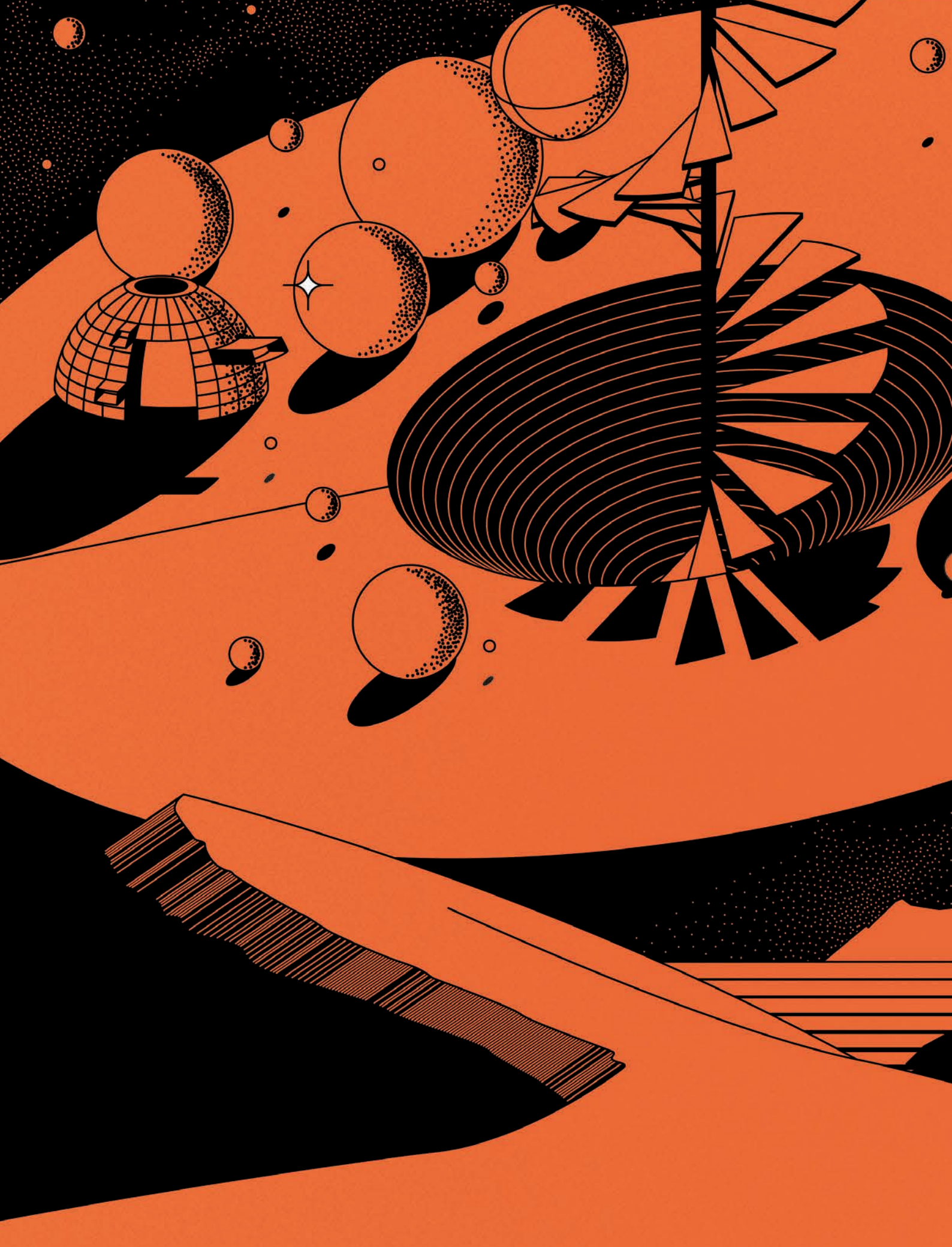
ON THE URBAN POETICS OF INVISIBLE CITIES AND GALAXIES

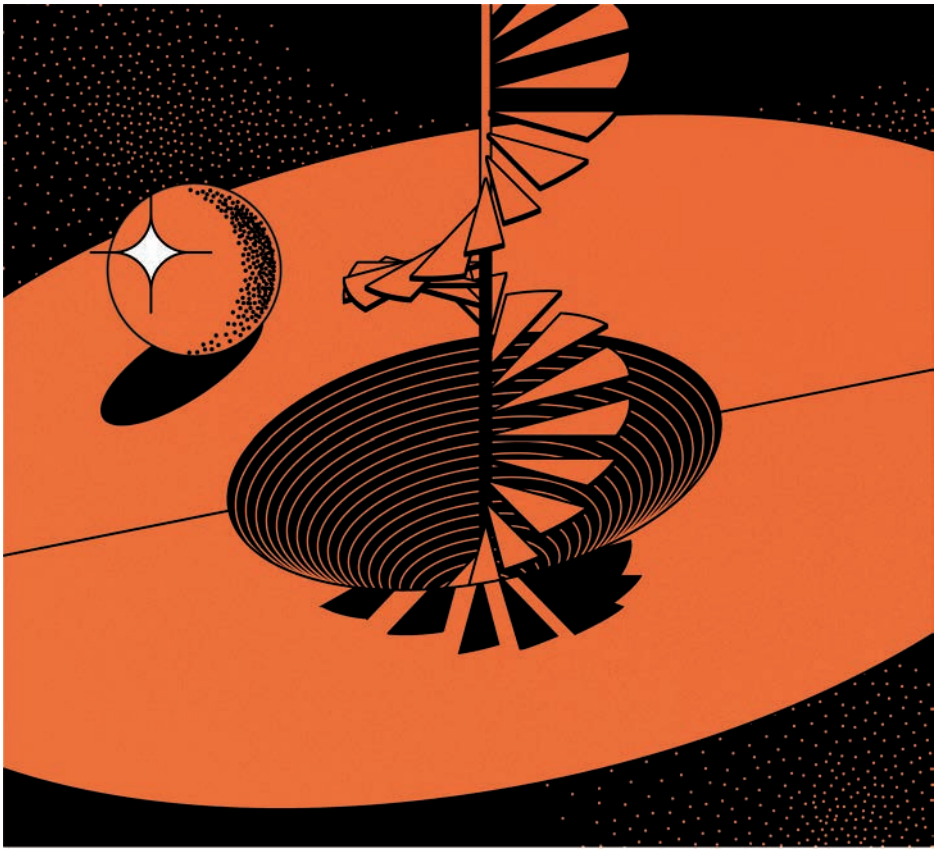
Galaxies and cities go through similar phases of evolution. These evolutions start by meeting an essential requirement: both galaxies and cities need to be located close to the source that would guarantee their survival and development. Thus, most settlements have been built near rivers, seas, or oases, in areas with a mild climate. As for galaxies, they are complex systems composed of visible and invisible matter, with gas playing a dominant role in their growth, as at some point it transforms from the atomic to the molecular content.

Science still does not know about prevailing conditions during the emergence of galaxies. When it comes to cities, theoreticians believe they formed in response to a need for an exchange of goods and socialization in developed agricultural areas. Calvino emphasizes that some cities were also created because *some people wanted to escape from the wilderness* or *some rulers decided to show to their people a power bestowed by the gods*. Though the most ancient galaxies and cities both show great diversity, one thing they have in common is the need to be in the vicinity of the most fundamental resource. In the case of cities, it is simply clean water. In the case of galaxies, cold hydrogen gas is believed to be the most precious constituent material. The universe is full of hydrogen, but only sufficiently cooled gas under certain pressure may be useful in creating large structures such as stars and galaxies. What mudbrick is for San Pedro, the molecular gas content is for a galaxy—a binding material that keeps it in balance with the surroundings. A vast gas reservoir is used to create stars. Tens and hundreds of millions of years later, the biggest of those stars conclude their life cycle, releasing vast quantities of chemical elements into the space in between. This space, a kind of sea in the galaxy's interior, is referred to in science as *interstellar matter*.

The remnants of previous star explosions are the primary source of condensed structures, dust grains made of silicate and carbon. In other words, the universe and galaxies within it demonstrate a fascinating and perfect recycling system that has brought about the conditions necessary for life on the Earth. It is interesting, though, that this recycling unfolds so effectively in the universe, while in many cities it is still insufficient.

Once formed, cities and galaxies quickly start with their urban poetics. Our cities formally have their own urban planners, but we often witness various effects of that planning. The imaginary city of Perinthia from Calvino's book was designed by astronomers according to the laws of space mechanics. Following the example of the most detailed urban planners, they thought that if they applied the positions of celestial bodies, such as the Sun and the Moon, in their





models, they would build a perfect settlement for all people. In contrast to utopian expectations, the traveler faced dismal scenes in Perinthia, wondering whether a planning error stemmed from astronomers' failure to clearly understand space phenomena since space dynamics vary even between places that look similar (e.g. galaxies and planets). This ever-relevant question and strong metaphor that Calvino sets in his book is a fundamental issue that we are trying to solve in the theory of galaxy evolution.

ON GALACTIC MIGRATION

The expansion of cities has been motivated by numerous factors, from the sustainability of living resources, development of transport and communication, and aspirations to ensure better economic and education systems. Galaxies expand similarly. Like human beings, galaxies tend not to spend their life isolated, so they often cluster into larger-scale structures made of groups or whole swarms. Central galaxies manage to produce large quantities of materials, primarily stars; they have the most gravity and consequently run the highest chance of finding themselves at the center of huge swarms. Hence, they become places of intense socialization, something like *agoras* in space. The number of swarms discovered in the universe is not too high, around several hundred, which implies that we are yet to understand how its different *tenants* co-exist. A central galaxy is the most massive, and numerous small objects, so-called satellites of a galaxy, orbit around it (does this remind you of suburbs near a big city?). Exploring those space megalopolises is rather challenging and complex because not all the galaxies within the same swarm glow the same as distances between them may amount to millions of light years. Overshadowed by the light of the central source (big city), *invisible space cities'* urban poetics and charm often remain an unattainable dream even for the most persistent astronomers.

Unlike human-imposed boundaries that take the form of administrative lines in cities, the outlines of galaxies are very elusive. For instance, telescopes in the Chilean desert can provide the most detailed demarcation of a gigantic galactic structure in the early universe, but still they cannot reach beyond tens of parsecs in diameter. Just like the desert scenery around San Pedro is unfathomable to the human eye so the only way to get to know the city's character and history is by walking doggedly around *parched rocks among geysers, salt pans, and an extinct volcano.*

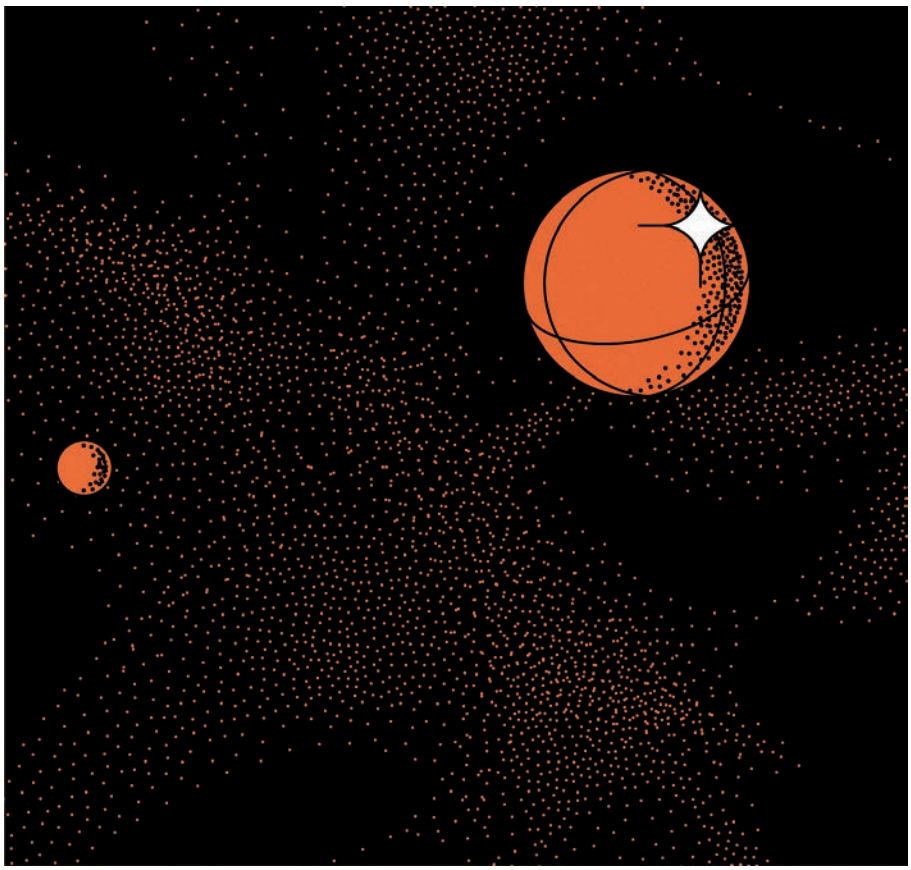
There are certain limitations to the expansion of galaxies. Several billion years after the birth, a galactic structure with too many stars reaches a critical mass (estimated at around one hundred billion times the mass of the Sun). Crossing this mass threshold triggers the formation of a massive black hole that serves as an energy transformer. This robust structure at the heart of a galaxy emits radiation that soon becomes so intense that it quickly wipes out all available gas required to create new stars. Consequently, galactic cities gradually lose their dynamics as they no longer have an influx of new young inhabitants. Galaxies begin shutting down, and this is the final phase in their evolution. Thus, observers are left with a colossal cloud of hot gas as a reminder of the dynamic past. Where once the galaxy's central region stood full of dazzling stars, now there is a black hole invisible to the human eye. Like galaxies, our cities cannot grow forever. On our planet, we witness urbanization efforts that seem not to be in balance with available resources. Such uncontrolled growth often leads to a rapid collapse

"Arriving at each new city, the traveler finds again a past of his that he did not know he had."

Italo Calvino,
Invisible Cities

of structures, triggering migration to other settlements.

Migration is not just an earthly thing. In close contact between two galaxies of similar mass and size, there is a commotion and a rush of entire interstellar matter, which can be compared to people hurriedly boarding night trains to leave one big city for another. Interstellar matter is funneled into a new galaxy in a way that invokes the images of trains rushing through a tunnel into the mountain or under the sea, like the Chunnel. However, unlike tourist trips, brief and intense galactic collisions are irretrievable processes that lead to the generation of young stars continuing their life far from the home galaxy. The consequence of all this is that in some parts, the number of galaxies and cities is getting higher or lower, reflecting different density distributions on geographical and astronomical maps. From a long distance, this arrangement seems harmonious and isotropic. Still, when we look at smaller-scale maps, whether we observe the continents on our planet or certain parts of the universe, this apparent symmetry is lost.



ON LIGHTS OF (IN)VISIBLE GALAXIES

The residents of San Pedro in the Atacama Desert say their city has had the same glow for centuries. Tucked under the Andes, sufficiently in the desert, but still surrounded by extraordinary living things and geological structures, San Pedro is one of those invisible cities whose language can be understood only by the people who spend enough time in its sun-scorched houses.

Due to its small size and population density, San Pedro has never been envisaged for the country's administrative center. The power of this city lies in something else—its centuries-long harmonious co-existence with nature. Disguised in red mudbrick, it has always remained covert enough to resist conquest and time, thus protecting its rich past. Hence, instead of being administrative, San Pedro became the archaeological capital of Chile. So, it comes as no surprise that this small city is the last station before an encounter with the most powerful telescopes. Symbolically, it seems to indicate to desert travelers they have come to an intersection of the earthly and galactic past.

And space? How many cities or galaxies, red and almost invisible, tucked behind large structures, like San Pedro, exist in the universe? The answer depends on the part of the universe's history we look into. If we see through the telescope the light of the galaxy formed more than 9-10 billion years ago, there is a great chance it would resemble that world. Despite seemingly taking up small space, most galaxies have such a dense intergalactic medium full of dust so there is much more to them than observers may notice. Their life is characterized by past periods of turbulence, while their future will depend on how deftly they will use the available resource (gas). With its considerate approach to nature, San Pedro has facilitated a stable environment for its citizens, and protected the surrounding soil from degradation, and ecosystems from desiccation and decline. Galaxies evolving at this pace reach the old age of around 13 billion years. Among the old galaxies leading a peaceful life is our Milky Way. Its foggy trail was visible in the crystal-clear skies while we were leaving San Pedro, immersed in the desert freedom of nighttime images and invisible cities. —Ⓔ

Darko Donevski has received a scholarship from the Italian government under the project "Dust in the Early Universe" in the field of cosmology. He defended his PhD thesis "Evolution of Distant Galaxies" at Aix-Marseille University in France in 2018. Under scholarship programs, he also advanced his knowledge at the institutes in Leiden (the Netherlands) and Toulouse (France). He completed his BA studies at the University of Novi Sad. He is a regular contributor to Elements.

COVER STORY

A Hitchhiker's Guide to Natural Language Processing

ChatGPT runs on natural language processing technology that works with both living and classical languages. What do we know about this powerful model, trained on 570 GB of data and refined by its 175 million parameters?

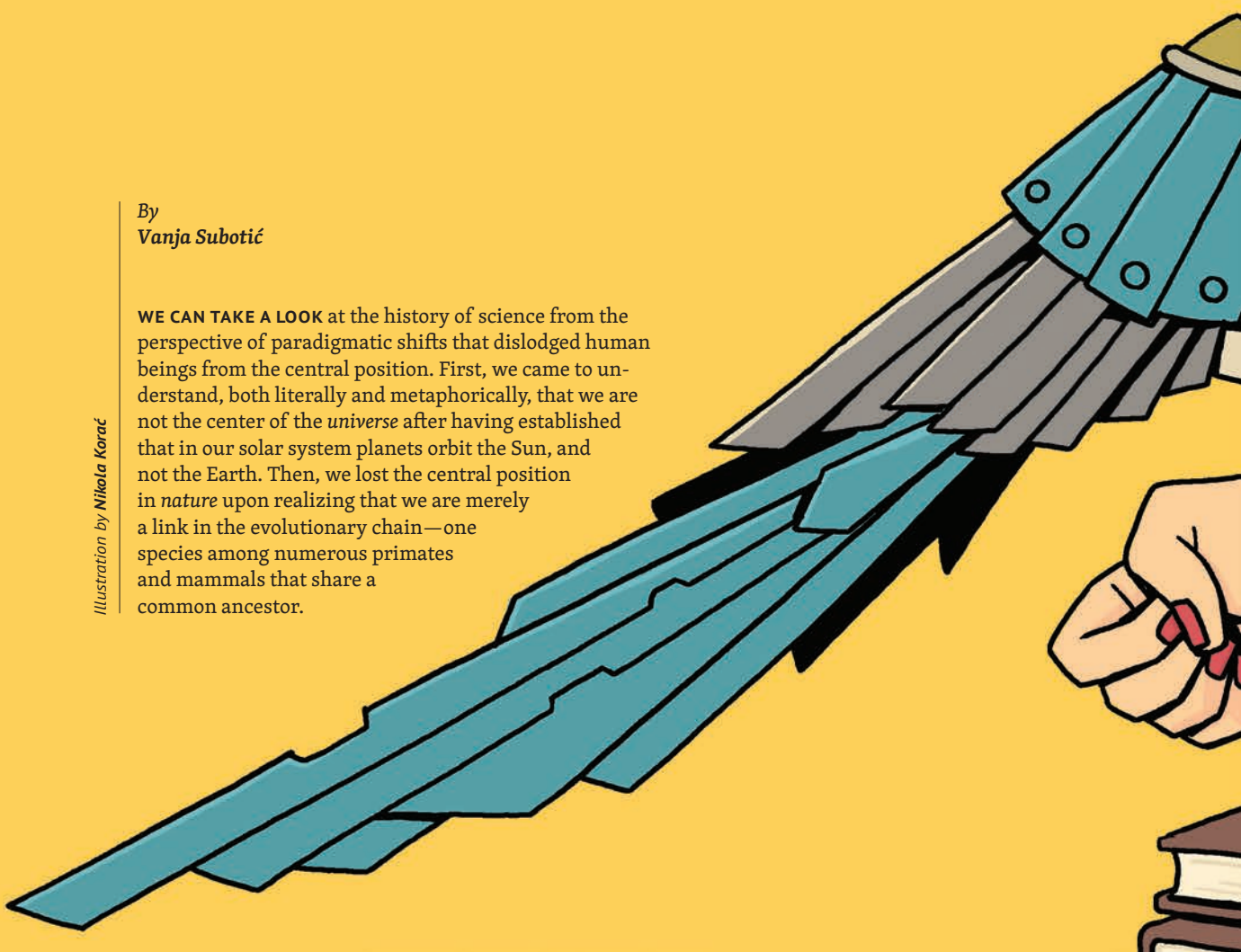
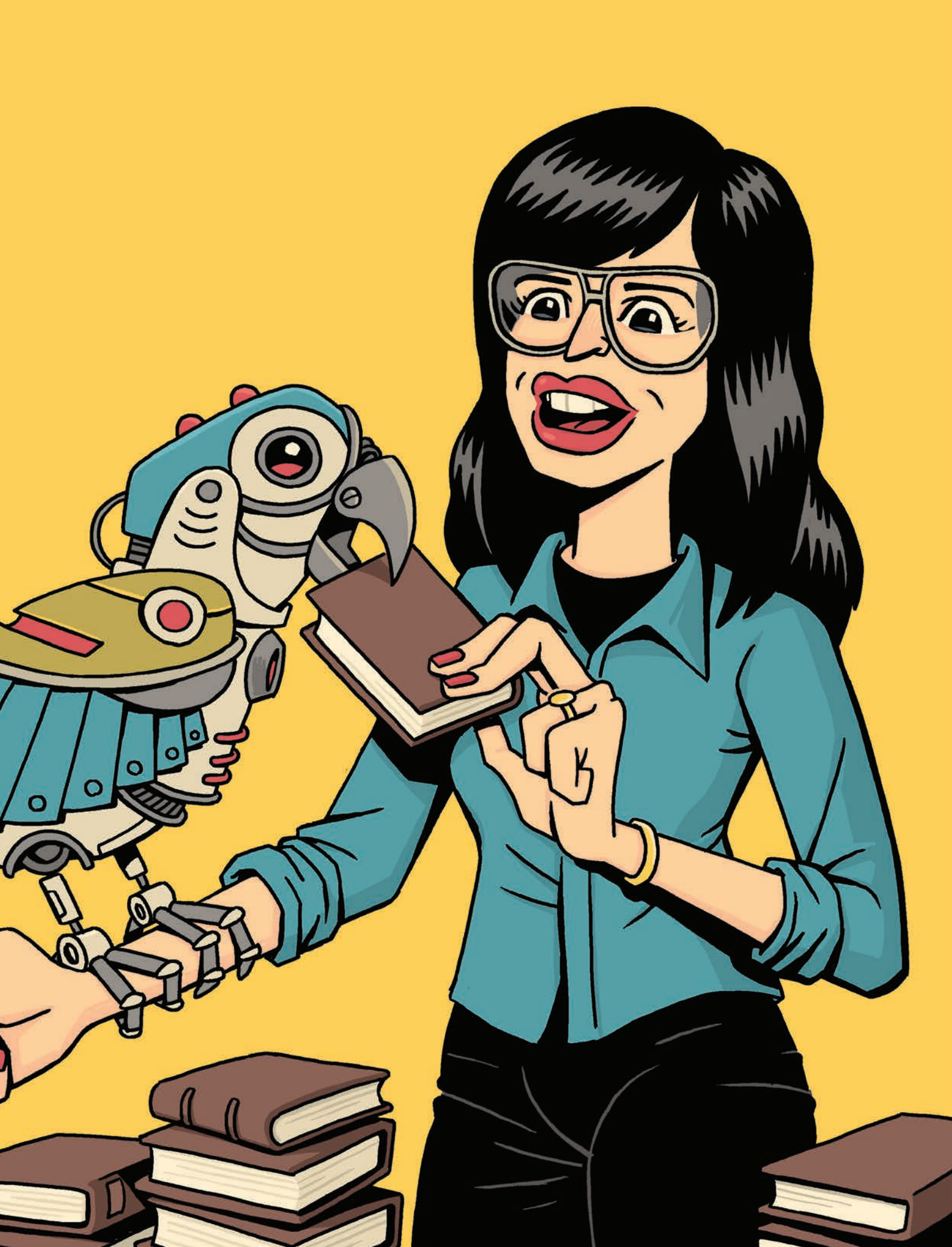


Illustration by ***Nikola Korać***

By
Vanja Subotić

WE CAN TAKE A LOOK at the history of science from the perspective of paradigmatic shifts that dislodged human beings from the central position. First, we came to understand, both literally and metaphorically, that we are not the center of the *universe* after having established that in our solar system planets orbit the Sun, and not the Earth. Then, we lost the central position in *nature* upon realizing that we are merely a link in the evolutionary chain—one species among numerous primates and mammals that share a common ancestor.



It appears that, in recent decades, the ground beneath our feet has been shaking in an overwhelming and alarming manner. This time, we may lose our defining characteristic—the capacity for creative language use, a trait that is absent (at least in such a developed, diverse, and abstract form) in our primate relatives. Unlike in previous episodes in history, when we *discovered* we were not at the center, it seems that we are now willingly surrendering our uniqueness by creating artificial intelligence capable of matching or potentially surpassing us in the distant future. What will then remain of humanity and the authentically human in an indifferent universe, harsh and hostile nature, and an increasingly complex society?

Concerns over the development of artificial intelligence are neither new nor original. Existential angst about the mechanization of human labor and life is as old as the Industrial Revolution itself. A certain disdain or unbridled enthusiasm toward machines in any form has been almost ubiquitous—progressivists tend to be thrilled about changes that machines bring, whereas conservatives express distrust either toward the changes themselves or the machines *du jour*.

This historical template is widely acknowledged and equally applicable to the recent hype surrounding a chatbot from the depths of *OpenAI*, the already-infamous *ChatGPT*. This chatbot is a typical example of *conversational artificial intelligence* and is currently being embraced in education, research, video gaming, or simply to satisfy human curiosity about what it is like to chit-chat with a non-human intelligence. This article aims to inform both progressivists and conservatives, as well as those undecided about which camp to join, about the inner machinery of chatbots, thus setting realistic expectations of their current capabilities and further development.

WHAT IS NATURAL LANGUAGE PROCESSING?

Chatbots are based on a technology called natural language processing. Natural language is defined as any living or dead classical language that people currently speak or once used to communicate. Essentially, chatbots are specific implementations of large language models. More specifically, ChatGPT is a generative, pre-trained transformer model (hence the GPT part of the name). If reading this piece so far has brought you to the verge of being overwhelmed by technical jargon, please do not despair, as we will proceed with step-by-step explanations.

Natural language processing relies on statistical methods, like deep learning algorithms, to handle and analyze a gargantuan amount of data—predominantly textual, but occasionally also auditory and/or visual. The classification of input data hinges on the task at hand, and, in turn, dictates the preferences regarding the output. Deep learning algorithms are applied in artificial intelligence models as follows: an artificial neural network that consists of a multitude of layers (hence "deep" in the algorithm's name) has the weights of its artificial neurons adjusted in relation to a training procedure. In this way, the artificial neural network learns to classify input data. To assess how much the model, that is, the artificial neural network, has learned, and to verify the adequacy of its training, we employ previously unknown or imprecise data as input and compare the output with the results obtained during the training process. The ultimate goal is for the artificial neural network to perform a given task with little or no supervision, in a manner akin to, or consistent with, the criteria we have established.

Large language models are not only based on natural language processing, but they also incorporate a technological innovation which, among some other features, seems to render ChatGPT more advanced than its predecessors. The secret ingredient is a specific type of artificial neural network, called *the transformer*, which was pioneered in 2017. Thus, the transformer is a relatively new type of neural network that allows for processing all textual data *simultaneously*, rather than sequentially, word by word, and does so with the aid of a mechanism known as *attention*. This mechanism helps the transformer *focus* on the context where certain parts of the input data occur. The training of this artificial neural network is a two-fold process. In the first stage, dubbed *pre-training*, AI engineers allow the transformer to predict the next word in a particular corpus only to adjust the parameters so that the transformer can respond to the assigned task using the previously *digested* input. This is often referred to as semi-supervised learning. Fully unsupervised learning of artificial neural networks entirely eliminates the step of parameter adjustment, with the model *learning* its own parametrization through a series of iterations.

However, when we specifically implement large language models in chatbots, our requirements shift in response to economic and social factors. This is reflected in the particular choice of training methods and subtypes of the deep learning algorithm. The most effective results are achieved when large language models are exposed to supervised training, where AI engineers and/or interns directly label or annotate data sets. Consequently, *OpenAI* naturally opted for this type of training to realize the vision of a superior ChatGPT, employing a deep reinforcement learning algorithm known as *Proximal Policy Optimization*. However, what exactly are the social and economic implications of such a methodological choice?

"Natural language processing relies on statistical methods, like deep learning algorithms, to handle and analyze a gargantuan amount of data."

Firstly, the datasets on which ChatGPT is trained contain a diverse array of internet content that is manually annotated. ChatGPT is capable of providing responses in 95 world languages. However, this chatbot cannot be equally successful in processing languages with fewer speakers compared to those with a vast number of speakers. To afford speakers of lesser-spoken languages with an equally *functional* chatbot, the existing databases and text corpora in those languages must be annotated, which requires significant financial support. Such support may be challenging to secure in the case of developing and underdeveloped countries. Hence, it is unimaginable to picture them on a par with Western European countries or the United States in terms of resources allocated for better and larger databases. Another issue is that most of the languages listed are official state languages—not the languages of specific ethnic groups. This significantly reduces the visibility and inclusion of such groups, especially minorities. Take Swahili, for instance. Despite being an official language in several African countries and an indigenous language of Sub-Saharan Africa, Swahili is not part of ChatGPT's knowledge base due to a lack of developed text corpora, even though it has *merely* 20 million speakers.

Secondly, the Proximal Policy Optimization algorithm is fine-tuned through direct human impact. Specifically, AI engineers served as instructors for ChatGPT by playing the roles of both the user and the artificial customer support and then adjusting the dialogue format that ChatGPT should maintain with humans. As a result, one common criticism of this chatbot points out its tendency to provide overly lengthy and rationalized responses, resembling a... bot. This is, however, precisely the dialogue format learned through the deep reinforcement learning algorithm. In fact, AI engineers positively reinforced such responses as an actual indication that the chatbot had effectively *digested* the vast amount of data. Naturally, this form of training is exceedingly slow and expensive.

Additionally, this scope of human *tinkering* with the chatbot's internal mechanism leaves us with the following question: How much of the chatbot's output is its own *thinking,* and how much is a result of our instructions? Are chatbots an imperfect mirror of our biases, or is it simply that the perfect reflection of our nature cannot be found within artificial intelligence at all?

ANTHROPOFABULATION OR THE CONFABULATION OF ANTHROPMORPHISM?

American philosopher Cameron Buckner, one of the pioneers in exploring the philosophical implications of deep learning for a better understanding of our higher cognitive processes such as abstraction or language comprehension, has noted that all models based on artificial neural networks have been criticized in a quite predictable manner throughout the years. A common thread linking all strands of criticism in the literature is that these models do not perform tasks with enough proficiency as we do, that is, they are not sufficiently anthropomorphic.

For instance, the *enormous* quantity of data required for large language models to *begin* to compete with our capabilities suggests, at least at first glance, that they are *inferior* compared to human cognition. This is because we can learn even from a single relevant example. In other words, we are capable of zero-shot learning. Moreover, algorithms of deep reinforcement learning represent an unnatural method of learning: through them, the artificial neural network does not learn how to solve a task, but rather how to *crack* the system. Put simply, it fixates on achieving a reward signal that the algorithm reinforces each time the artificial neural network produces a correct result during training. Consequently, artificial neural networks do not truly understand the task they are about to perform and lack humans' common-sense approach.

Ultimately, not only do we learn differently than chatbots due to a fundamental difference in our understanding of what we learn, but the connection between input data and output results within artificial neural networks is *opaque*. The lack of transparency in all models based on artificial neural networks, including large language models, appears problematic because it is unclear how the models produce output results. In other words, these models are *black boxes* whose functioning mechanisms we cannot fully comprehend, given the numerous layers and parameters present in artificial neural networks trained via deep learning algorithms. Structurally, it is futile to compare the inner workings of human cognition or the human brain with how artificial neural networks function as they are two disparate phenomena.

All these broader criticisms, which pertain to models based on artificial neural networks, are equally applicable to the specific implementation of such models in the field of natural language

"Are chatbots an imperfect mirror of our biases, or is it simply that the perfect reflection of our nature cannot be found within artificial intelligence at all?"

processing, namely, our notorious chatbot. ChatGPT was trained using 570 GB of data, and the transformer powering it contains 175 million parameters and is as opaque as any artificial neural network. Additionally, since it is built upon a deep reinforcement learning algorithm, this chatbot, in pursuit of a reward signal, often produces convincing yet untrue sentences or responses that do not fully correspond to our questions. The art of human conversation, judging by these apparent limitations, remains beyond the reach of ChatGPT because we are simply more adept at recreating natural conversational situations, whereas ChatGPT is simply not as capable as we are.

Fortunately, Cameron Buckner is not a philosopher who merely diagnoses issues and catalogs other philosophers' viewpoints, but also offers a way out of such dialectical impasses. Buckner finds the root of the previously described criticisms in an anthropocentric fallacy called anthropofabulation, which ensnares philosophers and scientists and leads to their biased comparison of the performance of artificial neural network models to human behavior. The fallacy lies in making the comparison to an aggrandized, *superior* version of human behavior. This bias has already marked decades of scientific research in comparative psychology and cognitive ethology, where animal behavior was always interpreted in relation to human, with the balance consistently tipped in our favor. A similar situation is currently unraveling with artificial intelligence, such as chatbots.

However, through an analysis of various psychological studies, Buckner shows that we are far from the anthropocentric ideal we might like to promote. Or, if we go back to our starting point, Buckner actually confronts us with the reality that we no longer hold the central position (if we ever did). Hence, humans also learn by drawing on a vast amount of data—various instances of letters, words, sounds, and perspectives from which we observe objects. All this must be and is stored in our memory, from where it can be retrieved as needed. Moreover, we also *crack the system* and often chase *a reward signal* rather than attempting to understand the task at hand. This is evident in studies on how people behave when they play online video games in which they occupy specific social roles. Finally, humans are also *black boxes* when it comes to decision-making. Social psychologists have uncovered a discrepancy between the rationalizations we tend to construct *after* making a decision and the causal factors that *actually* influenced the decision-making because we are guided by socially shaped motives such as acceptability, positive self-image promotion, and the like.

Therefore, any attempt at anthropomorphizing models of artificial neural networks, including large language models, turns out to be futile, or the confabulation itself, since there is no perfect reflection against which their capacities can be assessed. Instead, these models should be seen as reflections of our own biases and imperfections. Ted Chiang, a science fiction writer who often finds inspiration in artificial intelligence and advanced technologies, describes in his opinion piece for *The New Yorker* how ChatGPT is like a murky image of all content on the internet, which is then *compressed* so that all textual information we care about is stored on a private server to prevent us from *losing* the internet. If we tried to reconstruct the *original* internet based on the *compressed* content, we would face our own unfiltered imperfections and biases. The statistical regularities of the *compressed* content show to what extent we spill out imprecise, unchecked, frivolous, and toxic claims.

THE NEVER-ENDING CLASH BETWEEN REVOLUTIONARY EMPIRICISM AND IMMORTAL RATIONALISM

Yet, we cannot escape the impression that there must be something authentically human in language understanding and production, something that *must* elude any chatbot. French philosopher René Descartes and American linguist Noam Chomsky shared this intuition, though three centuries apart, alongside many contemporary *conservatives*. Descartes argued that even if we could construct a machine that could perfectly imitate us, such a device would never be capable of creative language production. For Chomsky, the creator of transformational-generative grammar, the distinction between linguistic competence and performance precludes any possibility that models implementing artificial neural networks could master language as we do. The notion of linguistic competence in Chomsky's transformational generative grammar conveys the idea that we are all endowed with a set of innate rules that enable children to master their native language in a flash even though the stimuli from the environment are often incorrect, imprecise,

irregular, or insufficient. This is known as the poverty of the stimulus argument that, in fact, echoes the core tenet of Descartes' rationalism that we possess innate ideas that enable us to *keep in check* all that we receive through the senses.

The guiding principle of programmers developing natural language processing models through the deployment of deep learning algorithms and artificial neural networks, such as transformers, is to give a chance to empiricism. This position runs counter to rationalism, according to which experience is the key to learning and shaping cognitive processes rather than innate rules. Artificial neural networks learn in a manner that can be described as empiricist, considering the large amount of data they exploit to form patterns, which, in turn, serve as the model's outputs. Although it may seem counterintuitive today, given the buzz and fuss about ChatGPT, artificial neural networks are actually the *black sheep* in the intertwined history of linguistics, artificial intelligence, and cognitive science in the 20th century, especially those confined to natural language processing tasks.

From 1958 to the early 1970s, when Chomsky's influence roamed through departments and laboratories, it seemed natural that models for natural language processing should be structured in the same way as language in his theoretical framework—so rules had to be at the forefront. Therefore, the first models for natural language processing were *symbolic*: they processed the syntactic structure of specific sentences in small corpora thanks to the manually specified rules. Many researchers expected this would simplify the automation of multiple-language translation. The objective was to anticipate whether sentences in the corpus are grammatical or ungrammatical. Then, the model would favor the formation of grammatical sentences in every iteration since it would obey the relevant grammatical rules. One of the earliest chatbots, ELIZA, was based on a symbolic model of natural language processing and created the impression of conversing with a psychotherapist. It is quite common to see comparisons of this chatbot to ChatGPT in popular texts and media. However, this is actually a tricky thing to do precisely because of the different methodologies behind these two chatbots. The artificial neural networks entered the scene *after* the creation of ELIZA and stand in contrast with all the assumptions and implications of symbolic models.

In the 1980s and 1990s, stochastic models that implement artificial neural networks single-handedly triggered an empiricist revolution in the field of natural language processing because, instead of using encoded rules, these models *learned* through algorithms how to predict the next word or sentence in a corpus. In the 2000s, impressive progress in designing various kinds of artificial neural networks allowed for a more diverse task performance—from grouping words with similar meaning and discourse analysis to generating image descriptions.

Be it as it may, the point of this brief and somewhat laconic history of natural language processing is that the same negative opinion on ChatGPT has been consistently invoked to discard stochastic models from the very moment of their inception and throughout their development. It is argued that these models are in principle unable to *truly* understand language as we can thanks to our semantic competence. In other words, their distinctive characteristic becomes their curse since the lack of encoded rules renders them incapable of simulating our language understanding based on raw environmental data. Thus, a rationalist contends that language is a hierarchically structured and presumably innate phenomenon.

Anders Søgaard, a professor at the Departments of Computer Science and Philosophy at the University of Copenhagen, argues that stochastic models do not lack semantics: words that frequently appear together in context, which stochastic models of natural language processing detect, usually signify objects and phenomena that co-occur in our experience. Søgaard draws on empirical studies to show an isomorphism between our cognitive maps and the way things are located in the world, as well as between cognitive maps and vector spaces of stochastic models. Hence, the frequency and contextual interconnectedness of words in the corpora used to train artificial neural networks can indeed reflect semantics. As Søgaard cleverly puts it in his recent scientific paper: "Well, what would me make of, say, a 14-year old child with the same skills? If a 14-year old child can point to the referents of Italian nouns, translate Italian sentences into another language, summarize documents written in Italian (...), would you not say this child still speaks Italian?" —Ⓔ

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“The Secret of Life” or Only a Beginning: the Discovery of DNA’s Structure

Maybe, every “secret of life” is inevitably only a beginning. Hence, as Friedrich Nietzsche reminds us through eternally reverberating words of his Zarathustra—life is that very thing that must always surpass itself

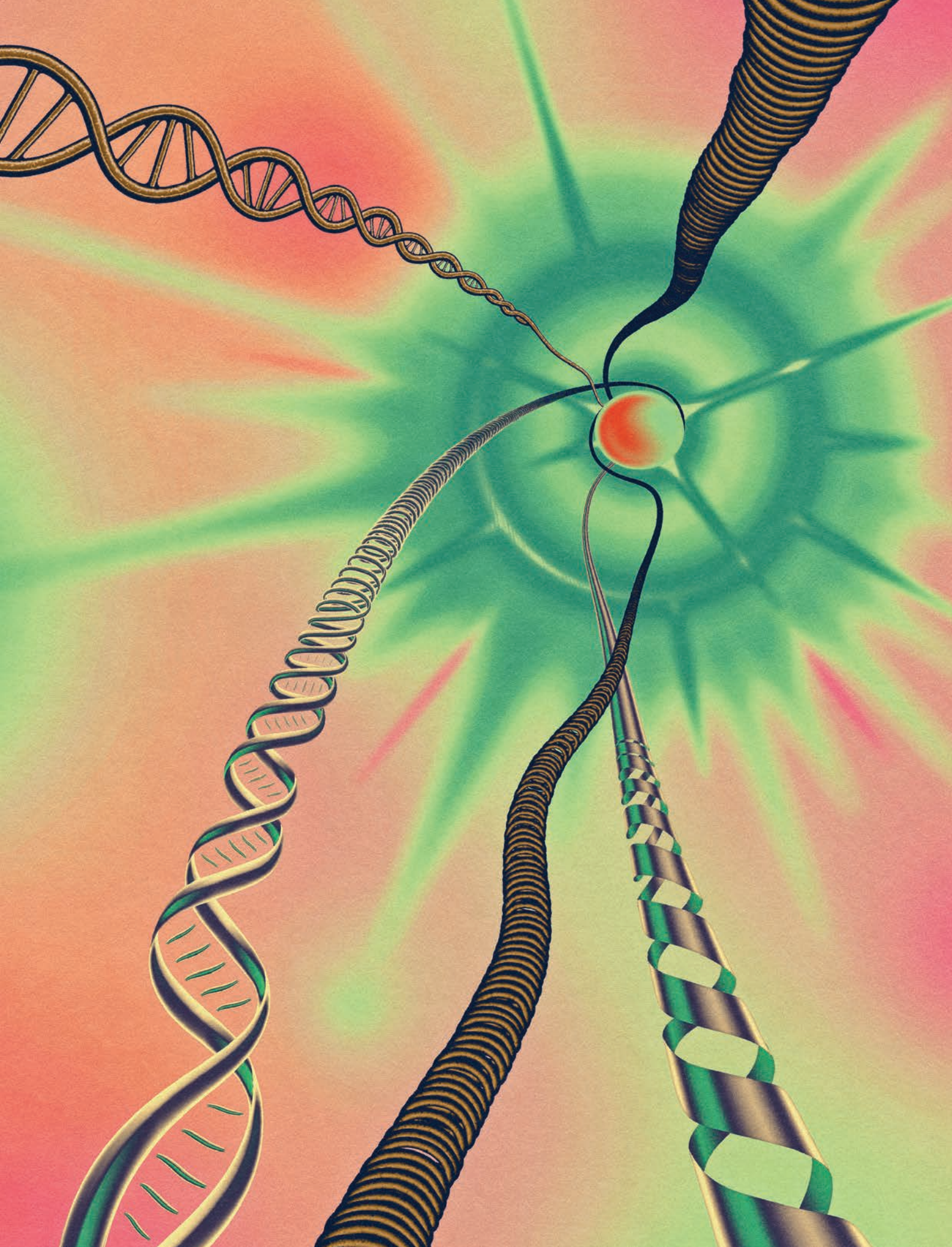
By
Srđa Janković

Illustrations by ***Jakov Jakovljević***

ON THE LAST DAY OF FEBRUARY in 1953, around lunchtime, two men burst into *The Eagle*, a famous pub and favorite meeting place of researchers from the renowned Cavendish laboratory in the historic university town of Cambridge, exclaiming: “We have discovered the secret of life!” They were bacteriologist James Watson and physicist Francis Crick. The secret, of course, referred to the molecular structure of deoxyribonucleic acid (DNA) and the biochemical mechanisms underlying its function as a carrier of hereditary characteristics of all living beings on the Earth.

Besides Watson and Crick, key roles in the discovery belonged to two more people—biophysicists Maurice Wilkins and Rosalind Franklin, both from King’s College, London. The first three of the above later received a Nobel Prize, while Rosalind Franklin suffered a well-known, grave injustice. Still, it was Franklin who, while studying the crystal structure of DNA in X-ray scatter experiments, obtained precious and practically crucial data, including (in) famous Photograph 51. This X-ray photograph was given to Wilkins without Franklin’s authorization by her student Raymond Gosling. Wilkins, in turn—with perfect timing—showed the photograph to Watson and Crick. The initial injustice inflicted on Rosalind Franklin became irreparable by her untimely death in 1958, since the Nobel Prize, according to propositions, can never be awarded posthumously. Even though the contribution of this brilliant scientist is now widely recognized, her initial long neglect remains one of the most glaring examples of unfair treatment in the history of science, as well as, beyond doubt, an important testament to the still pervasive gender inequality in both science and society at large.

It may be said that the road that led to the discovery of DNA’s structure had been long, complex and not in the least linear, rather like assembling a great three-dimensional puzzle—both in a metaphorical and quite literal sense. Namely, the elegant model in the form of a double helix, with its “backbone” composed of serially bound molecules of sugar (deoxyribose) and phosphate residues, and the “ladder rungs” connecting the strands, which consist of nitrogen bases that fit together like Lego



bricks (adenine with thymine, cytosine with guanine)—the model that amazingly unifies enormous complexity with total simplicity, as a most cogent embodiment of the philosophical principle of unity of structure and function in nature—has been built through a gradual process of trial and error. Watson and Crick worked on this model with particular fervor during the last six weeks leading up to the fateful day from our opening sentence. In their quest, they were partly spurred on by fierce competition with other teams, the most powerful being led by none other than the scientific giant (and double Nobel laureate) Linus Pauling. With substantial assistance from Wilkins, Watson and Crick finally solved the great mystery before all others. A careful reconstruction of the sequence of events has, however, demonstrated that the contribution of Rosalind Franklin far exceeded Photograph 51, notwithstanding that this photograph—again both literally and metaphorically—helped fit the final pieces of the puzzle together. Among her many achievements, Franklin discovered that, under laboratory conditions, DNA takes one of two possible crystal forms (designated A and B), which needed to be understood and accounted for before any meaningful analysis of DNA's structure was possible. Franklin was also the first person to note the existence of a particular form of symmetry exhibited by this macromolecule—another insight necessary for the ultimate verification of the successful structural model of Watson and Crick.

The moment in time when humans understood DNA's structure, more or less, resembles a nodal point wherefrom historical trajectories radiate both forward, into the future, and back through the past. DNA itself, as a chemical substance, was discovered in the 19th century by the Swiss physician Friedrich Miescher, who isolated it in 1869 from the festering wounds of his patients. (We now know that white blood cells, while fighting bacteria, eject their DNA to form a sort of sticky net—the so-called extracellular trap—an important part of their armamentarium.) For a long time, of course, no one suspected anything about the principal function of DNA in living cells or organisms. On the other hand, the foundations of the science of heredity—genetics—are much older than the knowledge of its physical and chemical substrate. Even the word "gene," denoting the basic unit of biological heredity, had already been in use long before its molecular identity was touched upon. Thus, Gregor Mendel successfully set down the basic rules of allelic inheritance through his famous experiments on pea and other plants. This knowledge was much deepened in the 20th century through many experiments performed on fruit flies in the famous *fly room* of the laboratory led by Thomas Hunt Morgan (another Nobel laureate) at the University of Columbia in New York. Morgan's observation that genes are physically located on chromosomes was another giant step toward the ultimate identification of the molecular basis of life. Among many key insights leading up to the latter, the experiments of Oswald Avery and collaborators in the 1940s showed that the molecule of DNA is capable of transferring a hereditary trait (in the case in point, the ability of a strain of pneumococcus to cause disease in the infected host). In 1947, John Masson Gulland was the first to suggest that biological information may be encoded by the sequence of nitrogen bases making up nucleotides, the basic structural units of DNA. Then, Alexander Todd established that the backbone of DNA was composed of sugar and phosphate. Erwin Chargaff, in turn, discovered that some pairs of the aforementioned four bases (adenine and thymine, cytosine and guanine) are always present in a one-to-one ratio—the first indication of their specific pairing. These are, inevitably, only a few of the many milestones along the road leading to the double helix.

The unraveling of the mystery of DNA's structure was immediately followed by no less important or exciting efforts to decipher the "language" in which biological information is written into this structure. This was achieved in the few subsequent years, when two research teams—one led by Francis Crick himself, the other by Marshall Nirenberg and Heinrich Matthaei—gradually discerned the "words" of this language, composed of groups of three nucleotides ("letters") each, designating a particular amino acid destined for a specific location in the appropriate protein; these "words" can be combined into longer or shorter, simple or complex "sentences," and eventually—through the functions of information ribonucleic acid (RNA) and ribosomes— translated into the sequence of amino acids comprising the given protein chain and governing its properties. Relatively soon, however, it became clear that only a tiny part of the total DNA that exists in each cell encodes a protein—the other, far greater part has no such role and was initially deemed to be without function. Such areas of the genome were therefore given a memorable, but not quite happily chosen name *junk DNA*. It was thought to be a mere byproduct of evolution—the remains of once active genes and a sort of repositorium of currently unused genetic sequences, providing material for the potential evolution of new genes. Although the latter is correct, we now know that it is quite incomplete: many such regions of the genome turned out to be no junk at all. On the contrary, they feature extremely important, even essential functions in the control and regulation of the expression of genes—in other words, in the genes' daily operation. This discovery made the already complex outlook on our hereditary basis even more so.

The discovery of DNA's structure marked the beginning of a new era in life sciences—both in terms of novel areas of basic research and the vast

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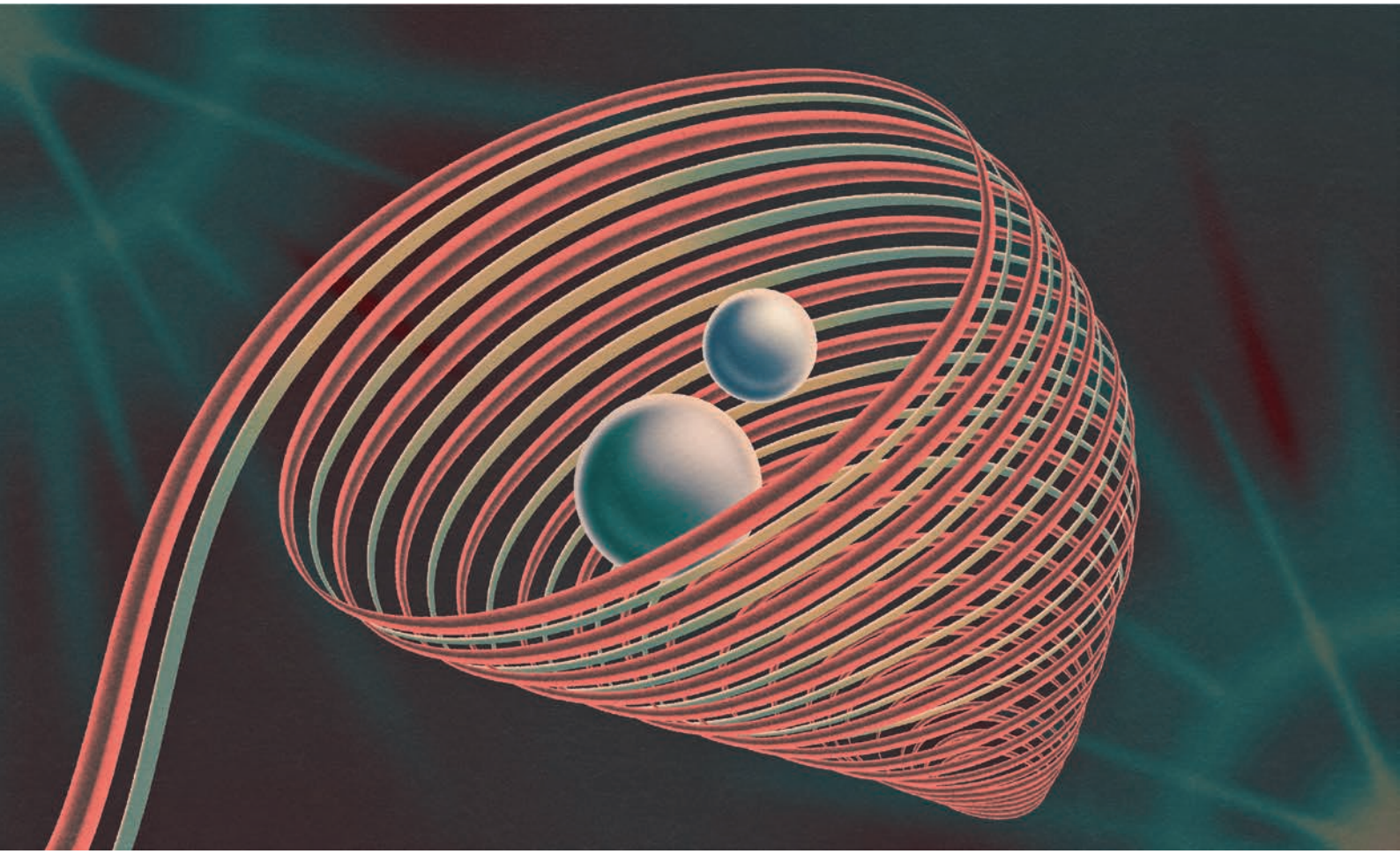
horizon of extremely diverse medical applications, improving the perspectives of treatment for millions of people with all sorts of health problems. Though precipitously fast by all realistic standards (including those of the history of science), this advance still proved somewhat slow to meet the spectacular expectations incited by the discovery. During intense efforts on the mapping of the human genome toward the end of the 20th century, many believed that a cure for virtually every disease was at hand; but, although it would be far from fair to deny that the benefits stemming from this project have already been felt in many ways, its successful conclusion only underscored how much we still have to learn about genes and their functions. Today, owing to the methodology of *next-generation sequencing*, the complete genome of any person can be known in a day or two. However, a clear and reliable interpretation of the encountered individual differences (gene polymorphisms) is still possible only in a limited proportion of cases. This proportion is, thankfully, steadily growing with our ever-improving understanding of the correspondences between particular gene variants and physiological or pathological processes.

At first, it was thought that the discovery of DNA's structure would strengthen genetic determinism (the view that genes alone determine our personal and collective characteristics and behavior). Though this expectation has been met to a certain extent—since the genetic basis of many biological functions (and their disturbances) has been clearly identified—as the modes and directions of genetic research widened, ramified, intertwined and complexified, it brought about the exact opposite: the understanding of DNA's structure and function opened our eyes to many previously unknown factors affecting the relationship between genotype and phenotype. This became particularly impressive with the revelation of multiple regulation levels of gene expression that became the subject of *epigenetics*. In brief, epigenetics allows us to explain why organisms with an identical genetic sequence may develop and function quite differently, depending on numerous influences and circumstances that—through epigenetic mechanisms—"turn" certain genes "on" or "off," or "amplify" and "silence" them. This gives organisms ample room to develop and exist in a way not completely predetermined by the genetic instructions awarded to them at their conception. In other words, genes are not fate. And yet, epigenetics and its relative degrees of freedom do not amount to pure indeterminism or arbitrariness. On the contrary—the study of epigenetics opened our eyes to hitherto unknown nuances of fine-tuning of biological functions at all levels, from the genes, information RNA and countless proteins, through complex structures and functions of various cells, tissues, organs and organ systems, to the organism as an indivisible unity—and possibly even beyond. Furthermore, considering that certain epigenetic (acquired) alterations can be transferred to one's descendants, many hailed the rise of epigenetics as a return to Lamarck's concept of evolution by inheritance of acquired characteristics. However, such a conclusion would not agree with the fact that epigenetic mechanisms—as attested by the Greek prefix "epi," literally meaning "upon [something]"—are essentially adjoined to those genetic, i. e. still dependent on the information recorded in DNA's structure, discovered by the four protagonists of our story. Thus, the *avant-garde* in evolutionary biology is strongly oriented toward an *extended synthesis*, where evolution, development and ecology converge at the level of the whole biosphere.

Evidently, with the discovery of the basis of heredity in living beings, it has also become possible to develop technologies allowing us both to read out the complete genetic information of a human—or any other being—and to alter it at will. This was made considerably easier in the last decade with the development of the CRISPR/Cas gene editing system (the subject of another Nobel Prize, shared for this advancement by Emmanuelle Charpentier and Jennifer Doudna). Such possibilities inevitably raise



deep ethical questions and, for many people, invoke the archetypal figure of Dr. Victor Frankenstein, prophetically envisaged by Mary Shelley in that long-gone, rainy and dark summer of 1816, when no one knew anything about genes or DNA. Although this brilliant story, which has ever since been the subject of countless reinterpretations and reinventions, still represents a most eloquent warning of the dangers posed by unchecked human (and particularly scientists') hubris, genetic engineering has actually brought mankind great benefits (sufficient to remember the synthesis of insulin) and indubitably displays the potential to bring forth even greater ones—especially if, in the long-standing debate on appropriate demarcation lines separating its ethical and justified use from the hazardous or morally unacceptable, we succeed in finding a sober and rational way forward. This is clearly a matter for a comprehensive interdisciplinary discussion and one of the most important issues at the intersection of science, philosophy, and society. For DNA-based technologies are, in addition to medicine and pharmacy, presently being applied—or are at the very doorstep—in many other areas of human life and endeavor: agriculture and food industry, forensics, ecology and environmental protection, and even informatics.

Even though, genetics-driven knowledge may find numerous and diverse applications in an effort to protect and improve human lives, the concept of personalized medicine currently gives the greatest hopes in this regard. In brief, since we can analyze the genetic information of any person, we are increasingly capable of *adjusting* treatment or medical advice to a patient's individual, unique characteristics, in terms of the choice of medication, dosing, and other forms of targeted interventions; in some cases, we can even calculate someone's risk to be affected by a particular disease in the future. Given the colossal advantages of such an approach, which may notably enable us to circumvent the significant problem of generic and standardized treatment all too often turning into a Procrustean bed, as well as to potentially break the current impasse in the struggle with some of the most difficult disorders of our times, a group of experts convened by the World Health Organization has already published a prediction that by the year 2049 practically all medicine

would become personalized. Of course, this development is also wrought with ethical challenges—sufficient to recall Andrew Niccol's memorable movie *Gattaca*, made at the very end of the last millennium, as a sort of cautionary message to the present one.

The discovery of DNA's structure has also provided us with an important tool for the study of evolutionary history of living species—both extinct and extant—including our own. Indeed, owing to the development of incredibly sensitive techniques of DNA isolation from ancient human or animal remains (yet another Nobel Prize, this time awarded to Swedish-Estonian geneticist Svante Pääbo), we are now confronted with a wide landscape of complex processes that shaped the evolution of modern humans, with numerous intersections, bifurcations and blind alleys—very far from the widespread (and unfortunately, still largely favored by illustrators) visual presentation of evolution leading up to the emergence of *Homo sapiens* as a linear sequence of human-like creatures gradually erecting in posture and growing in the skull. Although this was indeed a trend, the reality is far more opulent and intricate than our habitual conceptions recognize. Thus, a comparative study of ancient and modern DNA repeatedly reminds us—in a true Copernican spirit—how much our existence on this planet is owed to a unique contingency.

In an even wider context, the discovery of the workings of DNA placed questions pertaining to the origin of life on a firm scientific basis. The study of potential pathways leading to the creation of such a macromolecule, capable of storing and transferring heritable information and enabling it to play an active role in shaping biological systems and their functioning, has today largely become an integral part of a revolutionary interdisciplinary synthesis approaching life in the widest possible—that is, cosmic context. This synthesis is known as astrobiology; it includes the study of prebiotic (chemical) evolution that presumably gave rise to the first DNA molecules (which probably ensued after a long period of the so-called RNA World, where RNA, thought by most scientists to have necessarily arisen before DNA, compounded the roles of the carrier of heritable information and catalytic matrix for protein synthesis), as well as the prerequisites for the potential existence of life beyond our planet. Of course, such life would not need to be based on DNA or related macromolecules, but it would certainly, according to the increasingly popular "informatic" definition of life, have to involve similar patterns of storing heritable information and its functional expression. In other words, we have already made our first tentative steps toward a cosmic generalization of the concept of life.

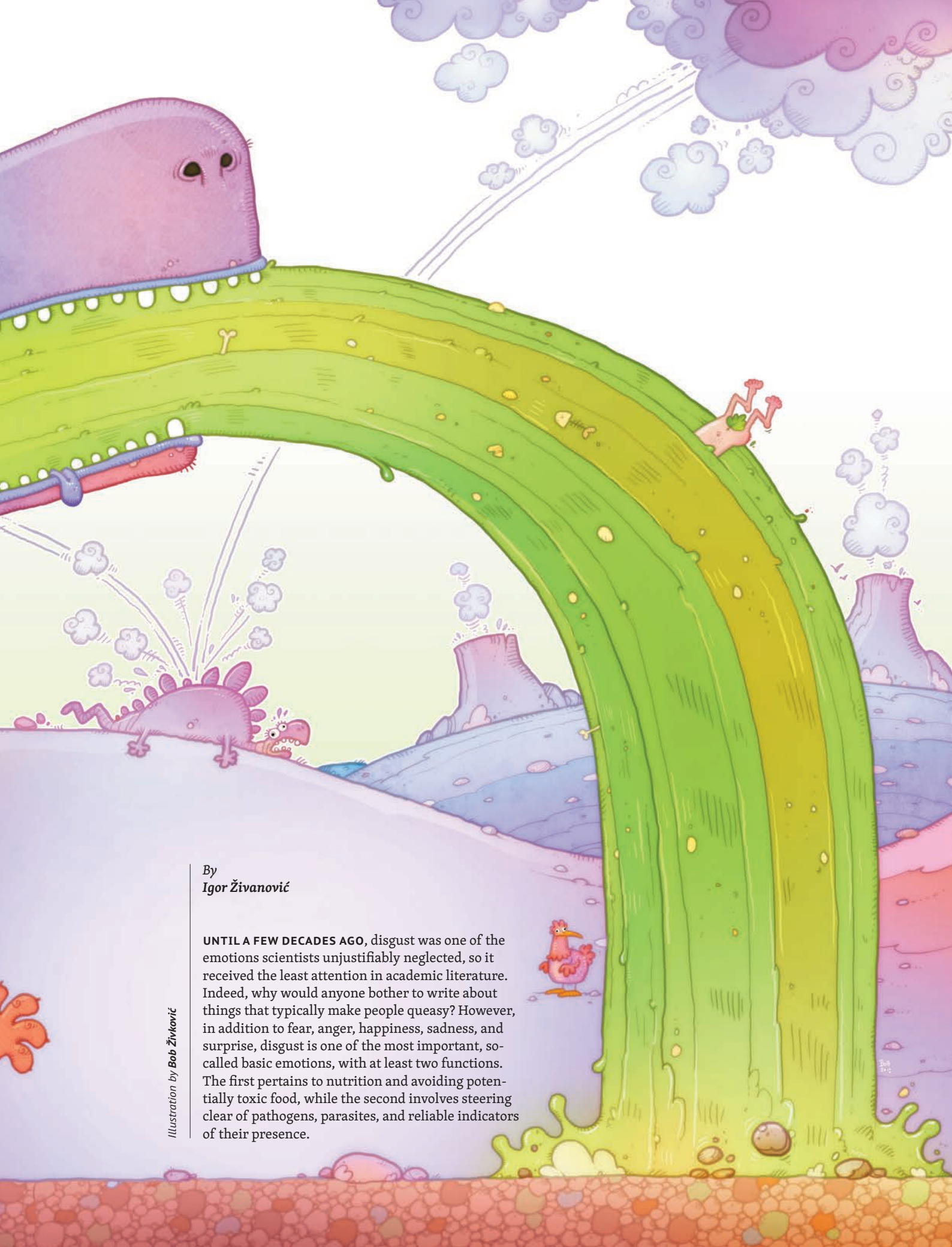
In that spring of 1953, no less than seven decades ago, the final sentence of a brief article published in the prestigious *Nature* journal, where Watson and Crick announced to the world the great discovery—"it has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material"—remains a prime example of the well-known English understatement. Since then, the double helix of DNA has deeply permeated our imagination and, as a collective representation, has become deeply rooted in the common and popular culture of entire humanity, assuming pride of place among the main symbolic icons of science—on a par with the telescope and microscope, schematic drawing of the atom, or the Periodic Table of the Elements. Looking back, we see that this discovery opened the way to many new questions, no less important or far-reaching than those that have found their answers. As is generally true of deep insights into the natural world, instead of "the secret of life" we became aware of innumerable new secrets. But it may well be that life and its secrets can be approached only by opening ever new passages leading to unimagined dimensions of reality that will always supersede everything we thought we knew. It may well be that every "secret of life" is inevitably only a beginning. Hence, as Friedrich Nietzsche reminds us through eternally reverberating words of his Zarathustra—life is that very thing that must always surpass itself. —Ⓔ

Srđa Janković graduated from the Faculty of Medicine at the University of Belgrade in 2002. Since 2007, he has been working at the laboratory for immunology of the University Children's Hospital in Belgrade, where he has also headed the Division of Immunology since 2015, the same year he completed his specialization in immunology. He acquired his PhD in 2016 with a thesis regarding the significance of Wilms tumor(WT)-1 gene and protein expression in children with acute leukemia. In addition to the biology of childhood leukemias, publications co-authored by Dr. Janković are focused on a number of areas: xenobiotic immunotoxicity by means of inflammatory reaction, dendritic cell maturation and acquisition of immunogenic vs. tolegogenic properties, diagnosis and treatment of primary immunodeficiency disorders, as well as pathogen-host interactions and prevention of infectious diseases by active immunization. He also pursues an active interest in the history and philosophy of science and interdisciplinary studies of life and its evolution.

EVOLUTION

Ugh! Yuck!

Throughout the day, humans swallow a significant amount of their own saliva, but few would agree to drink the same or a smaller quantity from a glass



By
Igor Živanović

UNTIL A FEW DECADES AGO, disgust was one of the emotions scientists unjustifiably neglected, so it received the least attention in academic literature. Indeed, why would anyone bother to write about things that typically make people queasy? However, in addition to fear, anger, happiness, sadness, and surprise, disgust is one of the most important, so-called basic emotions, with at least two functions. The first pertains to nutrition and avoiding potentially toxic food, while the second involves steering clear of pathogens, parasites, and reliable indicators of their presence.

Illustration by ***Bob Živković***

There is evidence suggesting that some disgust-inducing mechanisms exist in other non-human animals, but as far as we know, the full-blown phenomenon is unique to humans. In his study on emotions, Charles Darwin, one of the founding fathers of the theory of evolution by natural selection, concluded that all human beings have the capacity for disgust and can equally recognize its signs. The facial expression of disgust—raising the nostrils, furrowing the eyebrows, and lowering the mouth with a characteristically protruded tongue—is universal, highly pronounced, and automatic. Even when we make an effort not to show those signs, it is challenging to conceal them. This emotion has significant communicative potential and is very recognizable since the reaction to it is automatic and empathetic. Thus, when a person observes another displaying unmistakable signs of disgust, s/he, in turn, experiences the same emotion. Expressing disgust elicits the same emotion in the observer, as this emotion and its perception in others share a common representational domain and corresponding neural substrate. It is assumed that this substrate involves mirror neurons in the insular region of the cerebral cortex, and it is known that damage to this brain region leads to deficits in understanding the expression of disgust.

Behaviorally, the feeling of disgust triggers an immediate aversive reaction. An individual experiencing disgust seeks a distance from what provokes it, be it food, people, or animals. Typically, what causes disgust also induces personal discomfort, and consequently, the disgusted individual is motivated to move away from its source. If this person has come into contact with or stands in close proximity to something disgusting, usually, there is an urge to clean or wash. An unusual characteristic of disgust is its ability to spread from one object to another like a contagion, often through physical contact with an object already deemed disgusting. When something comes into contact with what is perceived as disgusting, it will never be the same again.

WHAT TRIGGERS DISGUST

The causes of disgust are, at the very least, numerous, diverse, and not easy to define. Some are universal, others depend on cultural heritage and vary from culture to culture, while some rely on individual sensitivity. The intensity of this sensitivity, in turn, varies from person to person. When it comes to universal triggers of disgust, the list of good candidates includes excrement, vomit, blood, urine, and fluids associated with sex. Other candidates encompass human and animal corpses, and any signs of organic decay. Body orifices and cavities, and objects that come into contact with them, also provoke disgust. Additionally, signs of illness (even if the disease is not contagious), parasitic infections, and recognizable tissue damages such as cuts, wounds, and scabs trigger feelings of disgust. Interestingly enough, certain things that are inside or on the body do not cause disgust by themselves, but once removed and separated, they become disgusting. For example, throughout the day, humans swallow a significant amount of their own saliva, but few would agree to drink the same or a smaller quantity from a glass. Similarly, nails and hairs do not cause disgust when attached to the body, but once removed, they become objects of disgust.

Deviations from usual phenotypic traits—like morphological irregularities, deformities, disabilities, or obesity—can elicit disgust. In some cases, this emotion may be triggered by perceiving strangers, outsiders, or individuals who differ in some specific way from the dominant majority. Thus, disgust is associated with xenophobia. Scientists have found that the feeling of disgust, combined with the deactivation of the medial prefrontal cortex (a brain region linked to social interactions), results in the dehumanization of strangers or those who are somewhat different. This process fosters prejudices with detrimental social consequences.

Food is one of the most significant triggers of disgust, with different cultures finding various foods disgusting. Nevertheless, a nearly universal feature is that it almost always involves meat. Furthermore, the taste of the food itself is not decisive for the effect it produces. In other words, a portion of food can be tasty, but if it is somehow stigmatized as dirty and undesirable, it will evoke disgust.

Certain animals related to diseases, dirt, decay, and death, such as flies, worms, maggots, rats, and cockroaches, usually cause disgust. If you have ever wondered why we feel disgust towards cockroaches or flies, and not, for example, ladybugs, even though they belong to the same class of animals, here is the answer. The same applies to parasites and potential carriers of serious diseases that live on the human body, such as fleas, lice, and ticks. Other members of the animal kingdom that evoke disgust include slugs, snails, caterpillars, snakes, and spiders.

Moreover, specific liquids such as body fluids and actions related to sex and reproduction can evoke disgust. These include menstrual blood and semen, with a particular emphasis on actions that, beyond eliciting disgust, have the potential to generate strong moral condemnation. Such actions involve incest, homosexuality, zoophilia, and necrophilia.

THE EVOLUTION OF DISGUST

Paul Rozin, a psychologist and leading expert on disgust, argues that this emotion evolved as a consequence of human awareness of their animal nature and mortality. Since only humans are aware of their

impending death, they alone need to suppress this threatening thought. Rozin emphasizes that any connection between humans and animals, mortality, and decay triggers the feeling of disgust. On the other hand, another expert, Daniel Kelly, believes that the evolution of this emotion is more complex, involving two related but distinct mechanisms. These two mechanisms integrated into a unified system throughout evolutionary history due to their prior functional overlap. The first mechanism relates to the ingestion of toxins and harmful substances into the body, while the second emerges as an adaptive response to the presence of parasites and diseases in the natural and social environments.

Firstly, Kelly suggests that any omnivorous organism that feeds on various foods, including seeds, plants, and meat, faces a dilemma. On the one hand, an individual must eat, but at the same time, it must be selective about what it consumes because many things that appear edible can be harmful or even lethal. Disgust-inducing objects have the ability to be instantly memorized, rapidly creating almost permanent aversions. Therefore, what once caused disgust is likely to provoke the same reaction. Consequently, what was once believed to have caused nausea would likely be avoided in the future. Of course, the conclusion that the future will resemble the past is wrongly drawn and unjustified, but evolution is not a professor of logic, and it operates on somewhat different grounds. Due to the imperfections of this mechanism, numerous misidentifications of edible things as inedible and dangerous are possible. Suppose the potential harm of misidentifying something as inedible when it is edible is smaller than the harm that can arise from accidentally eating something that could cause numerous problems or even death. In that case, people will be motivated to avoid the costlier errors. Sometimes it is better to remain hungry than to suffer potentially fatal consequences from such misidentification, and the mechanism that supports avoiding costlier errors can be highly adaptive.

Secondly, Kelly emphasizes that the feeling of disgust in relevant situations and appropriate contexts should protect us from infection by pathogens and parasites by enabling their avoidance. The disgust-inducing mechanism is not specific only to feeding and does not activate exclusively in response to potential changes in the gut; rather, it protects from close contact with infectious agents. Kelly argues that this does not only involve visible pathogens and parasites but also includes places, substances, and other organisms that could host them. In the same context, it is essential not to forget that natural selection has equipped us with defense mechanisms against pathogens and parasites, from the immune system to spontaneous hygienic habits such as grooming, cleaning, and bathing. But that is not all—natural selection has also made us sensitive to the very signs of potentially infectious agents, such as the unpleasant smell of decay and decomposition or unusual behavior and appearance. In other words, it has provided biological mechanisms to help us avoid pathogens and parasites in the first place.

Kelly concludes that both mechanisms are ancient but follow distinct evolutionary paths. While the mechanism sensitive to toxins is linked to oral consumption, the mechanism related to parasites is more sophisticated and delicate. Its function is to prevent close contact with potential sources of infectious materials. Aside from being different, Kelly claims these mechanisms are also ontogenetically distant. For instance, the facial expression of disgust related to food is present almost immediately after birth, while disgust toward parasites and infectious agents appears much later, typically in children between four and eight years of age. As we all know, before this age, children are prone to picking up all sorts of gross things and occasionally putting them in their mouths.

DISGUST AND HUMAN SEXUALITY

In recent years, several scientists have been researching the relationship between disgust and human sexuality. Given the various disgust-inducing organic materials associated with sex that are released from the human body during sexual intercourse, it might seem impossible for humans to engage in sex or derive any pleasure from it. What is even more crucial than mere pleasure is that, for a species that reproduces sexually and is so prone to disgust, producing offspring can pose a real challenge. On the one hand, reproduction is a biological imperative, while on the other, body orifices and fluids in ordinary contexts evoke disgust and are perceived as repulsive. The father of psychoanalysis, Sigmund Freud, observed that people are inclined to passionately kiss in the ecstasy of love, but the thought of using their partner's toothbrush does not seem so appealing.

Scientists conducted a series of experiments testing the influence of sexual arousal on the feeling of disgust and concluded that sexual arousal temporarily suspends it—not toward all obnoxious objects, but specifically toward those related to sex. For instance, in experimental conditions, individuals who were sexually aroused were more inclined to put their hand into a container that purportedly contained used condoms. As a result of sexual arousal, things that are typically considered disgusting are perceived as less repulsive.

Sexual arousal does not equally impact the reduction of disgust feelings in both sexes. It has been known for some time that women are more prone to disgust than men, and contemporary research has found that, in women, sexual arousal significantly reduces the level of disgust toward triggers related

to sex. On the other hand, when it comes to men, sexual arousal does not have a significant impact on the intensity of disgust. This is understandable, considering that women are more vulnerable and invest much more in reproduction than men. In the 1970s, evolutionary biologist Robert Trivers theorized that women would be much more selective in choosing sexual partners than men. If that is true, it becomes clear why, biologically speaking, it is more significant for women that sexual arousal leads to the suspension of disgust, particularly when a potential partner is identified. However, disgust toward pathogens and parasites simultaneously intensifies, potentially reducing the chances of making a poor and risky choice. Individuals with strongly expressed sexual disgust will be less inclined to engage in casual sex, promiscuity, or sex that occurs before the person has gathered enough information about the health and hygiene habits of a potential partner. Accordingly, a high level of sexual disgust may support establishing monogamous relationships by inhibiting short-term relationships and discouraging those romantically involved from sexual infidelity.

DISGUST CAN BE AMUSING

The aforementioned Paul Rozin observes that a grain of disgust is often entertaining. He notes that when a well-dressed man, in a three-piece suit and tie, proudly walking down the street, accidentally steps into a dog's poo, it seems amusing and makes us smile. A situation that would be unpleasant if we were in it ourselves seems pretty funny from a certain distance. The same author observes that disgust plays an important role in jokes and teasing among children, especially boys and adolescents. They use disgust to test boundaries and defy the conventional rules imposed by adults, simultaneously gaining a better status within their peer group.

Perhaps the most famous example that exploits the entertaining dimension of disgust is Monty Python's sketch, where the excessively obese Mr. Creosote vomits in jets in an elegant French restaurant. Soon, to the quiet dismay of other diners who gradually give up on their meals, the entire restaurant and its staff become covered with the contents of Mr. Creosote's stomach. Moreover, the peculiar guest simultaneously orders huge quantities of specialties served to him in a bucket, and the situation culminates when Mr. Creosote explodes after having a small mint chocolate. The scene is at the same time repulsive, horrifying, and funny.

Rozin argues that disgust is one of the key components of humor; it is something people sometimes seek. But to respond with laughter to objects that typically evoke disgust, it is necessary to maintain an appropriate distance. He emphasizes that people are complex beings and sometimes experience negative emotions as pleasant, especially when there is no genuine threat. This complexity is one of the reasons why people go to cinemas to watch movies that make them sad or instill fear, sending shivers down their spine.

MORAL DISGUST

Chimpanzees, our closest evolutionary relatives, exhibit empathy, anger, and rage, express dominance and submission, among other emotions. However, apparently, they do not experience disgust. In his writings about the empathic capacities of these animals, primatologist Frans de Waal gives an example of a female carrying her dead offspring with her until it decomposed. From a human perspective, this behavior seems quite bizarre, repulsive, and wrong. As far as we know, disgust is a distinctly human emotion, necessary to explain a large number of moral rules related to food, sex, menstrual cycles, and the disposal of corpses.

Renowned psychologist Jonathan Haidt presented his students with several scenarios to test their moral intuitions and their relation to the feeling of disgust. In one scenario, Haidt asked his students to imagine siblings, Peter and Mary, who loved each other as much as a brother and sister could. On one occasion, after the first year of college, during their summer holiday, Peter and Mary decided to experiment with their sexuality. Just out of curiosity and fun, they decided to make love. Aware of the unfavorable consequences of inbreeding and the dangers posed by sexually transmitted diseases, they opted for appropriate contraception. Mary was already taking birth control pills, and for added safety, Peter decided to use a condom. After the sexual encounter, they realized that a specific relationship had developed between them, unknown to other people. Although both enjoyed it, they decided never to do it again, and everything remained their little secret. The question is, was there anything morally wrong in the scenario described?

Most participants answer this question affirmatively, and I presume that most readers of this text would do the same. Nonetheless, it is not enough to judge something as wrong just because it seems so; we are expected to state why it is wrong. Every moral judgment has to be justified and supported by reasons. Nevertheless, when asked to provide reasons why they consider it wrong for Mary and Peter to have sex, participants face the challenge of finding reasons for moral condemnation because the act is voluntary and consensual, and the likelihood of unwanted pregnancy and sexually transmitted infections is minimized. Thus, experimental subjects soon discover that they are in an uncomfortable position. Namely, they find themselves in a

state of moral dumbfounding—their intuitions tell them something is wrong, but they cannot specify what it is.

The second scenario is even more challenging and better illustrates how disgust influences our moral intuitions and judgments than the first one. Imagine Jennifer, a research associate at the Institute of Pathology at the School of Medicine. She prepares human cadavers for use in anatomy teaching. Cadavers were donated by people wanting to make at least a posthumous contribution to scientific progress. One evening, as she was leaving the Institute, Jennifer saw a body scheduled for cremation the next day. Although a vegetarian on moral grounds, she thought it would be a shame for perfectly edible meat to be destroyed. She cut off a piece, took it home, and thoroughly cooked it. The person whose meat she took had recently died of a heart attack, and given her effort to cook the meat thoroughly, there was no danger of disease transmission.

Human flesh is typically not considered food, and the mere thought of cannibalism elicits disgust and a strong aversive reaction in most people. However, the question remains: Did Jennifer do something morally wrong? It is essential to recognize that just because something elicits disgust does not imply that it is simultaneously morally wrong. For instance, the author of this text finds the idea of eating snails and similar creatures highly disgusting, but he does not believe that someone who enjoys delicacies made from them deserves moral condemnation. On the other hand, when it comes to cannibalism, despite understanding the nuances of philosophical argumentation, he finds himself morally dumbfounded.

In essence, certain gut feelings can occasionally offer guidance on the optimal course of action, reflecting behaviors that ensured survival and reproduction for our evolutionary ancestors. However, there are instances when these same sensations may take us on the wrong path. Hence, they do not serve as a reliable measure for moral evaluation, and consequently, whenever you assume something is wrong simply because it elicits disgust, it is crucial to ask yourself: Am I right? —Ⓔ

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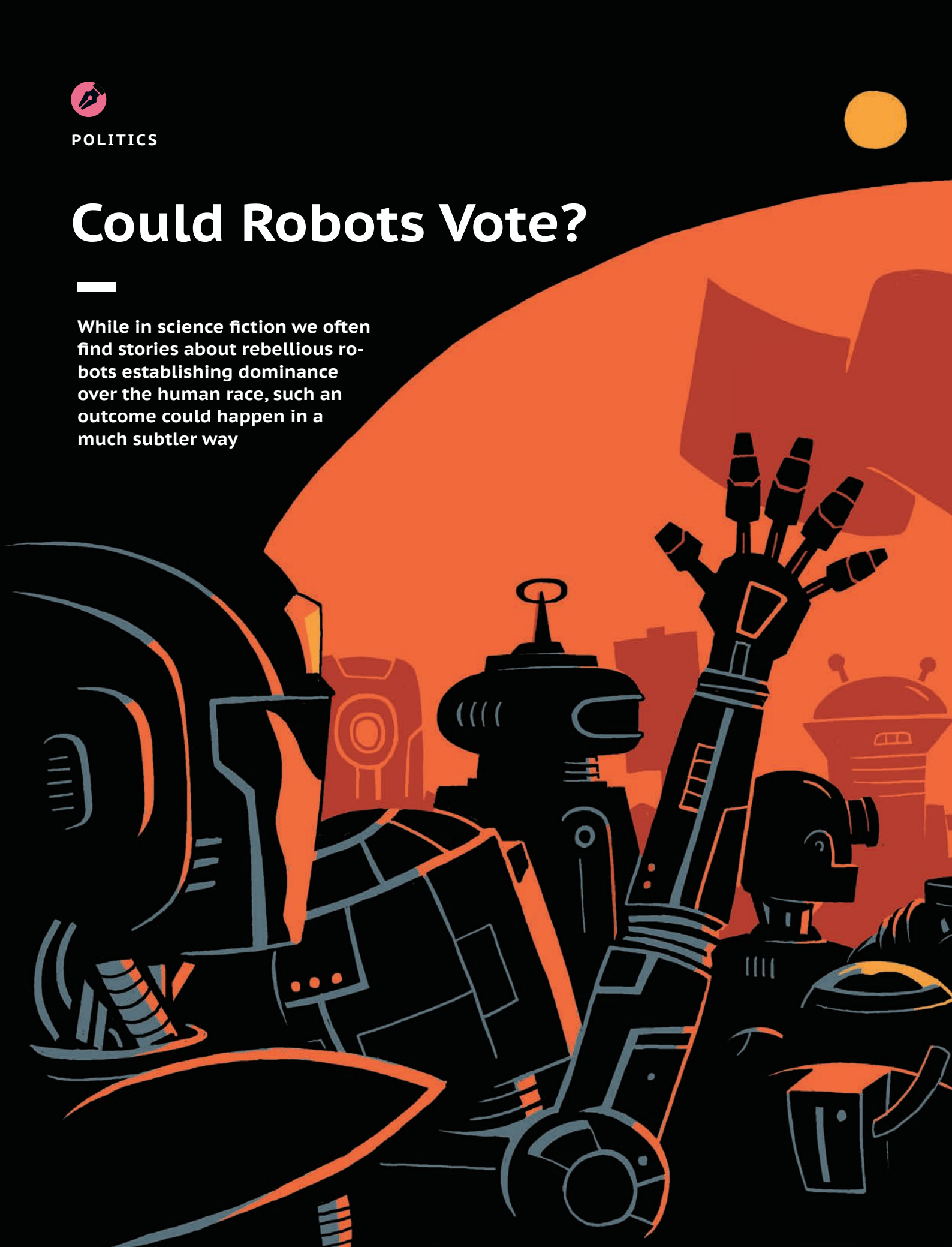
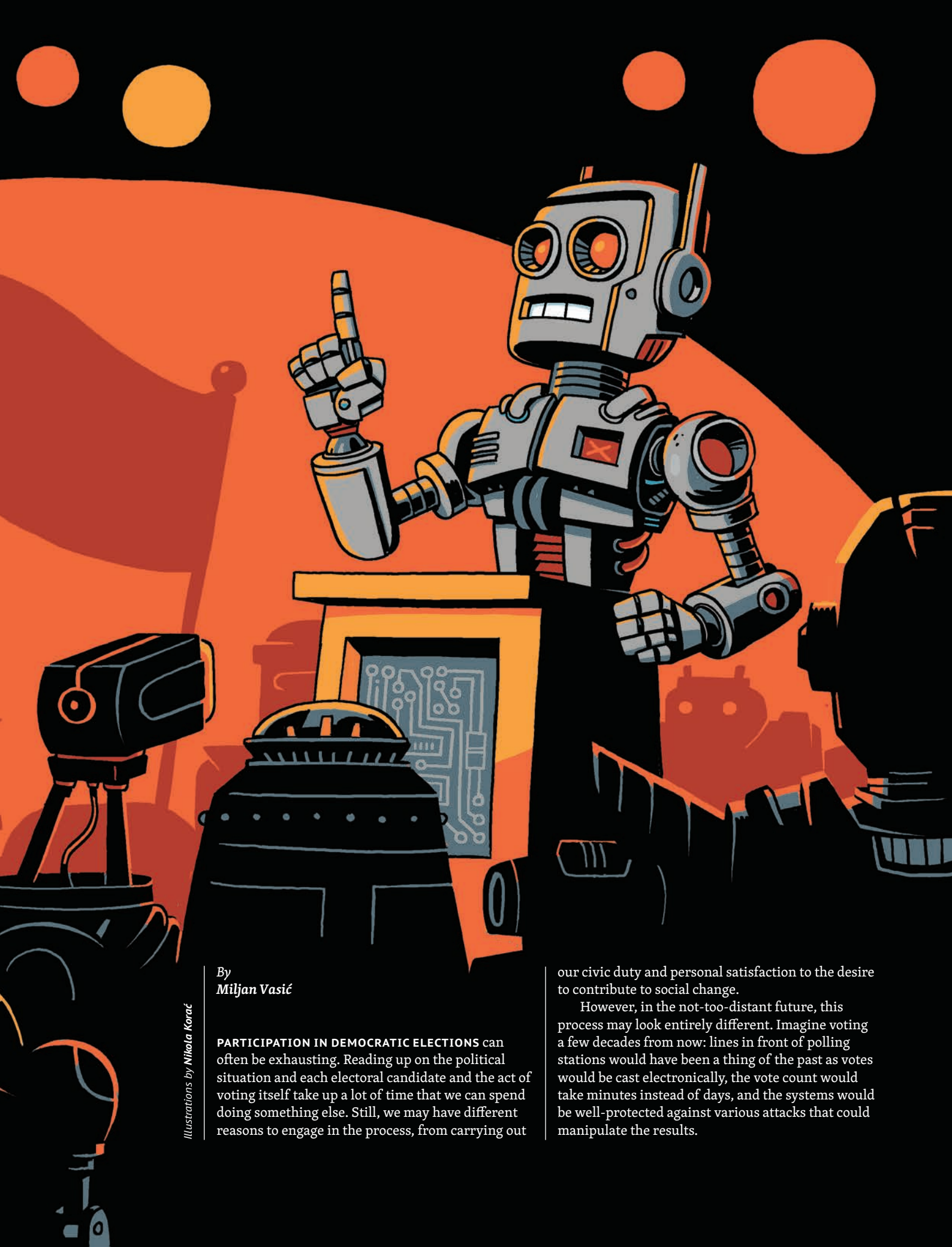
POLITICS

Could Robots Vote?

While in science fiction we often find stories about rebellious robots establishing dominance over the human race, such an outcome could happen in a much subtler way





Illustrations by ***Nikola Korać***

By
Miljan Vasić

PARTICIPATION IN DEMOCRATIC ELECTIONS can often be exhausting. Reading up on the political situation and each electoral candidate and the act of voting itself take up a lot of time that we can spend doing something else. Still, we may have different reasons to engage in the process, from carrying out our civic duty and personal satisfaction to the desire to contribute to social change.

However, in the not-too-distant future, this process may look entirely different. Imagine voting a few decades from now: lines in front of polling stations would have been a thing of the past as votes would be cast electronically, the vote count would take minutes instead of days, and the systems would be well-protected against various attacks that could manipulate the results.

However, there would be another eligible voter in our household: our robot.

Though that might sound improbable to some people, others claim this scenario is not only possible, but also quite certain. The humanoid robot Sophia became a citizen of Saudi Arabia in 2017. Her creator, David Hanson, believes that by 2045, robots would have all civil rights, including the right to vote. Following his vision, we can imagine a society where we would not only meet robots every day, but they would also have their own political associations and parties, prominent politicians, or fighters for their rights and freedoms.

The differences that would exist between humans and robots in terms of their rights and obligations fall under many *gray areas* and there can be no definitive answer as to how a world would look like with eligible robot voters. Therefore, we will limit the scope of the issue and consider it from a political aspect, rather than a moral or legal one. So, we have two things to examine: 1) possible political grounds for robots' right to vote; and 2) whether they would behave differently than humans during the electoral process and how. These considerations will not only allow us to imagine a world where robots participate in elections, but they may also reveal something about humans as voters.

ROBOTS AND THE RIGHT TO VOTE

The first question is whether we can consider the right to vote as entirely separate from other civic rights. We know that the issue of universal suffrage was inseparable from the broader package of civil rights struggles. And according to some theorists, there are good reasons why that was the case.

American economist William H. Riker (1920––1993) believed that the fundamental elements of democracy—freedom, equality, and the right to participate in political life—were so closely linked to voting that we could not even consider them separately. Hence, democratic values are there to make the voting process not only possible but also fair and just. Although these values are significant in and of themselves, voting is the final practical aspect of their realization.

Giving robots other civil rights would be pointless if they could not vote, just as the voting process would lose its meaning if the conditions of freedom and equality were not met. We must also consider how the right to vote came about in the first place. French philosopher Jean-Jacques Rousseau (1712––1778) believed that the right to vote must belong to those to whom the laws apply.

Rousseau saw something inherently unjust in a system where one should obey the laws without playing any part in making them. In our hypothetical story, we assume that the same legal system would apply equally to humans and robots. If robots would have the same obligations as humans, they would also need to participate in the process that should lay down those obligations. This would become all the more important if some laws would apply directly to the robot community.

VOTING AND MOTIVATION

Drawing on Rousseau's theory once again, we will try to answer the next important question as to whether robots would be guided by some motivation different from that of human voters. Generally speaking, we can distinguish between two types of voters. On the one hand, voters may be guided by individual benefits during elections. To put it bluntly, they expect that the victory of certain political options would give them, or the subgroup they belong to, better jobs or financial resources. On the other hand, voters may choose the option they believe would be better for society. Sometimes, the option that brings the most personal gain, and the one that is the best for the entire society, may be one and the same for some voters. However, Rousseau's idea was that in situations where these two motivations failed to overlap, the one that favored the *common good* ought to have priority.

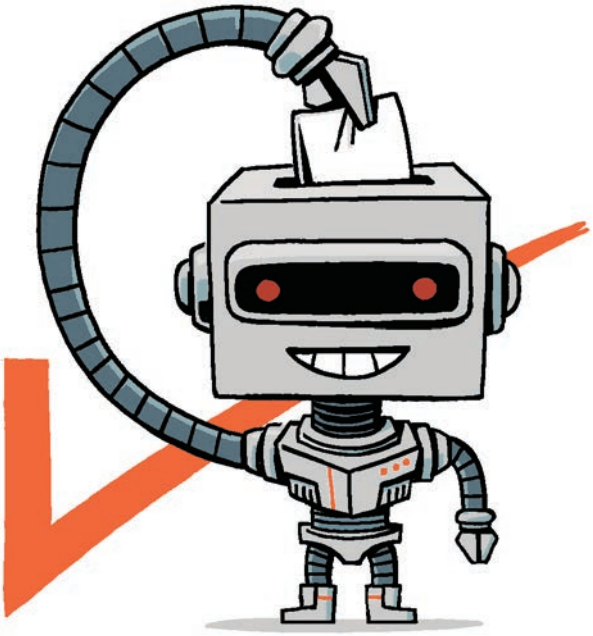
According to one survey conducted in the United States at the end of the 20th century, 83 percent of respondents stated that they were guided by the common good, not individual benefits when voting. Whether we can be that optimistic about voters' motivation is still a central question in political theory. Moreover, different theories of democracy have been formulated based on different responses to this question. The extent to which the common good guides most voters varies from one society to another. Voting motivation is influenced by a myriad of factors, including the state of economy, demographics, and whether the nation in question is a young democracy or has a centuries-old democratic tradition. Hence, we can safely assume that in every society there are voters of both types, although their ratio may vary depending on the mentioned factors.

How do robots fit into this story? If we try to determine which of these two types of voters they belong to, we fall into the first of *gray areas*. The response depends on answers to more complex issues, such as whether they would have human-like emotions or possess certain aesthetic criteria. After all, it is not uncommon for humans to make political decisions according to secondary factors, such as how an electoral candidate speaks or dresses.

On the one hand, we may assume that robots, devoid of physiological needs, would be less *seduced* by campaign promises concerning things such as the prices of basic foodstuffs or the length of the working week. In that regard, robots would be *superior* voters because they would view these issues as

something that would not affect them individually. On the other hand, there could be robots that would vote according to selfish interests or the interests of their community. They could thus prefer a political candidate who would also be a robot or one who would fight to improve their position in society at the expense of humans.

However, when it comes to voting motivated by personal gain, we should note that a society that would have reached the stage to have robots with civic rights would likely be a society taking good care of its *flesh and blood* citizens. Many economic or social factors that are considered to be personally motivating nowadays would be less significant in such a society. In that community, most reasons behind the motivation to elect a candidate would not differ between humans and their fellow robotic citizens. We can, therefore, conclude that robots could not only have the right to vote, but would also aspire to be motivated in the same way as humans.



INFORMATION AND POLITICAL ATTITUDES

The question *Could Robots Vote?* may be asked in its negative form: *Under which circumstances would robots not be able to vote*? To answer this question, we will borrow the term "preference" from decision theory. Preferences are voters' attitudes toward electoral candidates. To determine whether there is something that would be characteristic of robot voters, we must describe how preferences are formed.

Imagine an ordinary citizen reading newspapers, listening to the news, watching political debates, or following posts on social networks in his spare time. All of these are *sources of public information* (PIs). PIs play a central role, but they are not the only factor shaping a voter's preferences. Every voter has their own set of beliefs by which they evaluate available political options. These beliefs can be general worldviews or specific stances on prominent political issues in a certain society. Let's call this set of beliefs *political attitudes* (PAs). We will assume that the general scheme looks like this:

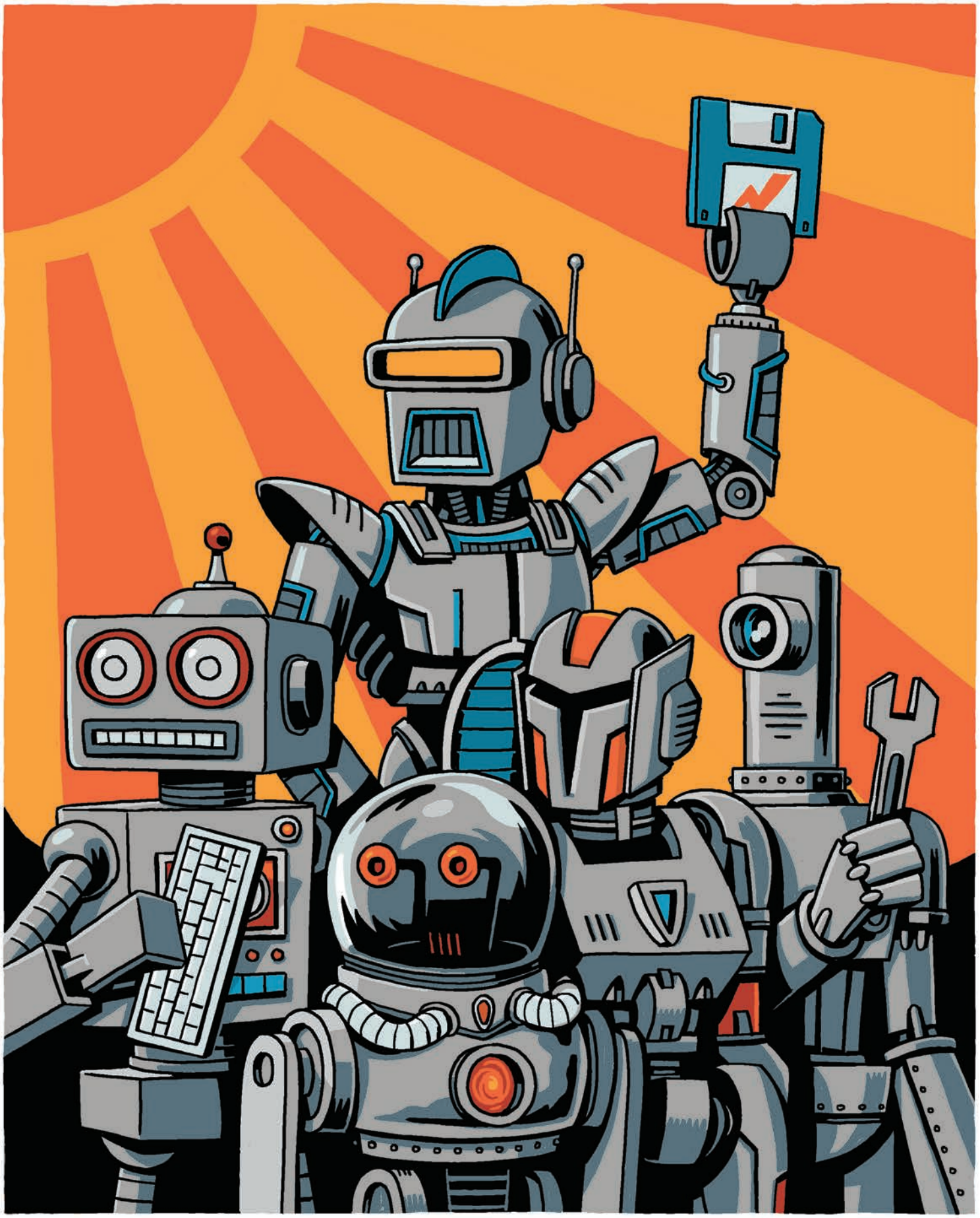
PIs + PAs = Voting preferences

In forming preferences, information is passed through the *filter* of political attitudes, leading to voters' evaluation of political options. The important point is that the same information, modified through two disparate sets of political attitudes, can lead to diametrically opposed preferences. Similarly, two voters may share the same (or very similar) political views while having access to different sources of information, which would also result in differences when forming preferences.

To begin this discussion, we will assume that robots have their own PAs, and that PIs are available to them. The core difference between them and humans lies in the fact that robots are capable of processing considerably more PIs. It is plausible that in some society, the same set of PIs is available to all robots, but it is also realistic that this may not be the case. Keeping these initial possibilities in mind, we can devise four different scenarios.

Scenario 1.1: All robots are exposed to all available PIs. Since they have a greater cognitive capacity than humans, they can receive and process all that information. The *fake news* phenomenon, which has gained much popularity in political discourse in recent years, does not bother them so much. In a sea of conflicting information, robots can assess which of them come from reliable sources and accordingly reject those that are not to be trusted. In addition, let's assume that their creators have *instilled* the same PAs in all robots. That can be (but not necessarily so) a certain value system that has turned out to be the best possible one throughout human history. For example, they have been taught to be tolerant, advocate for non-violent conflict resolution, and respect other people's rights and freedoms. Since all PIs are available to them, they will unfailingly be able to determine which political option best suits that value system, and, as a result, they will all opt for it.

Scenario 1.2: Once again, we assume that robots can efficiently evaluate all information coming from PIs and come with embedded PAs. However, the key difference is that different creators have advocated for different value systems. These robots represent different ideologies on the political spectrum and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follow different ethical doctrines. When forming preferences, they can determine the option most in line with their political views. Hence, robots with different PAs vote differently, although those subsets of robots with shared political views always act the same in this regard.

Scenario 2.1: Robots are no longer exposed to all PIs—either some are not available to them, or they simply choose not to obtain them. In this case, they are much more similar to human voters. Let's also assume that these robots are the same ones from scenario 1.1, with shared PAs. In this scenario, robots vote differently, but the differences depend solely on the PIs that individual robots have chosen to access.

Scenario 2.2: Finally, it remains to be seen what will happen if robots have access to different PIs and also hold different PAs. Not only the outcome of their votes depends on the information available to them, but they process that information through a wide range of political viewpoints. The behavior of robots in this scenario is the most similar to that of human voters, and as a result, there will be the greatest diversity of opinions among robot voters.

As we can see, the only scenario in which all robots vote uniformly is the first one. However, such a situation is very problematic for democratic decision-making. For example, if robots happen to outnumber humans at some point, each and every decision will always reflect the preferences of the robot majority. The first scenario also reveals something about the nature of the voting process in general: if a group of voters with the same political views is constantly exposed to the same information, and if that group becomes the largest one in society, democracy itself could be in jeopardy. In political theory, this possibility is sometimes referred to as *the tyranny of the majority*.

We have questioned whether robots would act differently than humans when forming political preferences. As we have seen, not only is the answer to this question negative, but we have also learned that there are situations in which humans could *vote like robots*. However, there is one problem with this conclusion. Assuming that PIs and PAs are as strictly separated as in our example, we arrive at the four scenarios described above. But what if the two are not so clearly distinguishable? What if PIs shape PAs in the first place, and only then do these two factors influence the preference-forming?

After all, humans are not born with embedded political attitudes, but acquire them over the course of their lives. However, even if we assume that robots also acquire the information first and only then proceed to form their political attitudes, we will once again arrive at four similar scenarios. Robots may either share the same patterns for forming these attitudes or they may follow completely different ones. However, it is still a problem if all of them have access to the same pool of information and this remains the biggest obstacle to robots' participation in democratic elections.

No matter whether robots may be more inclined to vote for the common good or be better than humans in determining which option, in the light of all available information, is most likely to make this happen, their capability of processing large datasets significantly sets them apart from humans. Another *gray area* lies in whether this means that we should simply rely on them as political decision makers and trust their judgment. We already have different software solutions developed to help voters make their decisions. Users provide their political attitudes, such as their views on the economy, immigration, or foreign policy, and the app informs them which candidate or party matches most of their opinions.

Robots that could infallibly determine the best political options could eventually render human voters a burden. While in science fiction we often find stories about rebellious robots establishing dominance over the human race, such an outcome could happen in a much subtler way. If robots had the right to vote and the capability to process all information available to the public, they could become the masters solely through democratic means. —Ⓔ

The author is a PhD candidate at the Faculty of Philosophy, the University of Belgrade. He works as a researcher at the Institute for Philosophy. His primary field of research is political philosophy.

A Brief History of Alarm Clocks—From Plato to Artificial Circadian Rhythm

"A snooze button is a poor substitute for no alarm clock at all."—Stephen Hawking

By
Petar Nurkić

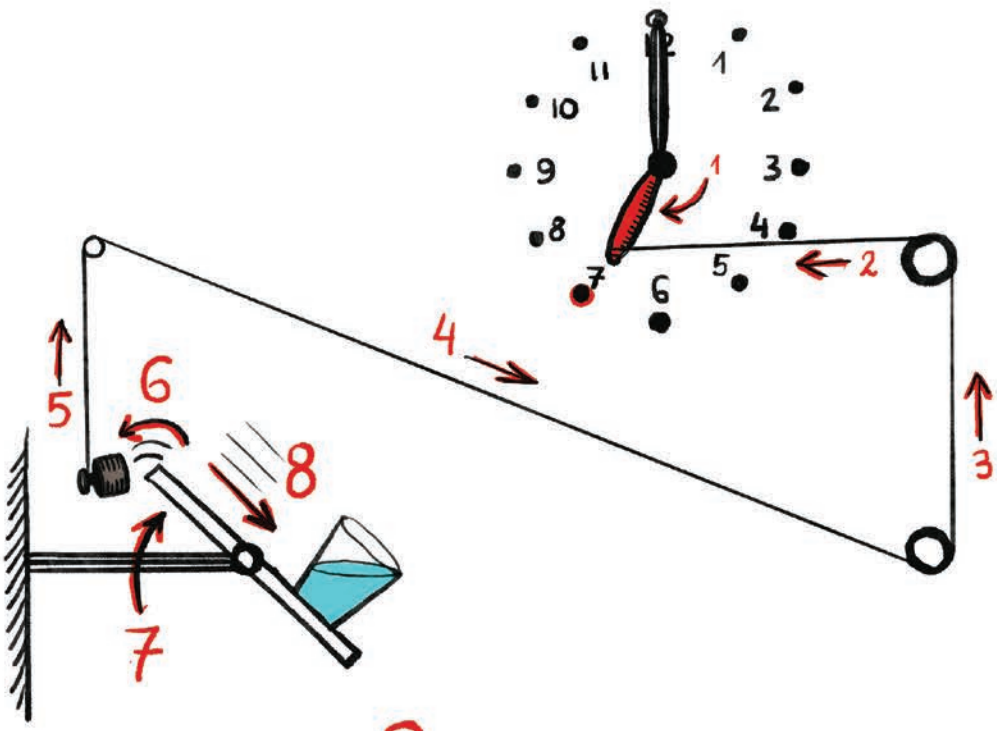
Illustration by ***Đorđe Balmazović / Škart Collective***

HOW MANY OF US ACTUALLY KNOW the name of our alarm melody? Mine is *Happy Bujiwuji Concert*, one of available options on my worn-out *Xiaomi Mi 8 Lite* phone. The melody gets louder and louder, and I slowly become aware that I am no longer dreaming but should get out of bed. There is a solution! I slide my index finger across the phone screen, the melody disappears, and I triumphantly go on dreaming. A victory that lasts a whole five minutes, after which I hear the melody again, the index finger again, then the melody, and so on *ad infinitum*. An infinity that lasts exactly 43 minutes. I finally get out of bed, aware I am late for work, cursing the *snooze* button. The *snooze* button is a purgatory between the heaven of sleep and the hell of wakefulness. I wonder why alarms are no longer as effective as they used to be when I was in elementary school. It must be the alarm's fault, because I have not really changed, getting out of bed is even more important to me now than when I went to school!

While being late for work, I ponder a few questions. How did people wake up *back then*? Was their biorhythm healthier because they did not have laptops, Androids, iPhones, Instagram, and TikTok, making alarms unnecessary for them? What is biorhythm anyway? Why do we call the alarm "alarm" when we have a nicer term—a wake-up clock? Is it because I am alarmingly late for work? Either way, while waiting for the bus, I pull out my Android from the pocket and type:

...THE FIRST ALARM CLOCK IN HISTORY

Of course—Plato! This famous and annoyingly omnipresent Greek philosopher had a large water clock that emitted a whistle-like sound to wake him up for his morning lecture. Plato's complex system worked by water dripping from one reservoir into another, and when the reservoir was full, it released



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air that passed through a whistle, producing sound. This sound would notify Plato that it was time for his morning lecture.

This is not the end, as right below the anecdote about Plato there is also Ctesibius. Of course, I had never heard of him, but it turns out that Ctesibius was a Greek engineer, inventor, and the "father of pneumatics." He lived in the third century BC and was a pioneer in using air and water to power machines. His water clock, better known as the clepsydra, was one of the most advanced of its time. Besides accurately measuring time, it used the siphon principle to force air through several whistles, creating sounds at regular intervals. Thus, this magical device was not just a time indicator, but also had an alarm function, making it an impressive achievement for that era.

Why did the ancient Greeks even need an alarm? Were they not the wisest of all? Why would they go through the torture of being forcefully awakened, getting out of bed, and going to work? Maybe it does not seem like a civilizational step forward to me, but in ancient Greece, precise timekeeping was vital for various aspects of life, from religious ceremonies to public events. The development of precise and reliable water clocks was an important step forward in technology, as well as a deeper understanding of natural principles and mechanics.

Okay, I get it, this mechanism of water-air whistling was in some way a precursor to modern alarm clocks. What the Greeks did, the Romans often followed. Did they also have their own intriguing alarm systems? As I finally boarded the bus and settled in, I began typing:

...ALARMS IN ROME

I expected philosophers again, but to my surprise, firefighters appeared! In ancient Rome, firefighters had special ways of informing each other about fires. Rome was particularly prone to fires because it was densely populated with buildings mostly made of wood and other flammable materials. The first organized fire service in Rome was known as the *Vigiles*, meaning "watchmen" or "guards."

During the day, they informed each other by blowing a loud trumpet. At night, when the trumpet became less suitable due to the risk of disturbing the sleep of a large part of the population, they used guards who would hit a hammer on a metal plate, creating a loud and penetrating sound that was strong enough to wake the firefighters. This organization of the fire service in Rome was a direct consequence of the catastrophic great fire that occurred in 64 BC. After this event, Nero founded the *Vigiles* organization. Despite rumors, Nero did not set Rome on fire and watch it burn while playing the lyre. Rather, he can be considered *the father of fire brigades*, as he recognized the importance of swift communication and response in alarm situations (here I think of a fire, not being late for work).

I am not particularly satisfied with Roman alarms. It seems to me that they relied too much on the human factor of sleeping and waking up in shifts. This takes me back to elementary school when my mother woke me up, which was far more torturous than an alarm. But, when I think about it, it was also much more efficient. While today I can always postpone the alarm, back then I had to listen to my mother, which is why I was never late for school. The bus is not even halfway through, and I am more and more interested in the mechanics of waking up: gears, cylinders, bells, and winding up the alarm. So, I am typing:

...THE FIRST MECHANICAL ALARM CLOCK

The first mechanical alarm clock was made in the 15th century. Of course, mechanical clocks existed earlier, but the integration of an *alarm* into these devices was an invaluable innovation; a person could finally set their wake-up time. Although it was not portable or practical like today's alarms, it marked the beginning of a new era in man's domination over time. When I say they were not portable, I mean that early alarms were quite large and heavy. Not at all like pocket watches that would become popular during the following centuries. Instead, they were placed on tables or shelves.

Early mechanical alarm clocks were usually made of metal, most often bronze or iron. They required great precision and craftsmanship, often with handcrafted gears and other elements. Integrating an alarm into clocks was achieved with an additional mechanism that would activate when the hands reached a particular time, or a specific position on the face of a clock. Instead of polyphonic melodies that woke me up during high school, or the *mp3* sound that failed to wake me up today, these clocks often used bells or even small hammers that would hit metal plates or the same bells to produce the deafening sound of the alarm.

Besides functionality, the first mechanical alarm clocks were also aesthetically attractive. Many had complexly decorated surfaces, engravings, or even small figures that would move or strike bells to mark a certain hour. Owning a mechanical alarm clock in the 15th century meant wealth and prestige. Only the wealthiest individuals or institutions like churches or royal courts could afford these complex devices.

Philosophically speaking (yes, when I talk about work, I actually talk about arriving at the office on time to philosophize), the alarm clock is a good indicator of our perception of time and how social norms affect our daily life, raising questions about freedom, reality, and social influence on the individual.

"Philosophically speaking (yes, when I talk about work, I actually talk about arriving at the office on time to philosophize), the alarm clock is a good indicator of our perception of time and how social norms affect our daily life, raising questions about freedom, reality, and social influence on the individual."

What somewhat disappoints me is the absence of specific personalities who conceived mechanical alarm clocks. I expected complex characters and juicy anecdotes. It seems that clockmaking during the Middle Ages and the Renaissance was a craft skill where many masters worked on improvements and innovations without the need for wide recognition or patenting. Therefore, many inventors and clockmakers who contributed to the evolution of the alarm clock were never known or recorded in historical writings.

However, my curiosity and deep internet digging have at least uncovered few names that contributed to the development of clockmaking and alarm clocks during the Renaissance. Among the mentioned are English mathematician and astronomer Richard of Wallingford, Danish mathematician Peter Dacia, and Ottoman Empire polymath Taqi ad-Din. Here I want to leave a note for curious researchers of the history of science: Wallingford's *Albanus clock* has nothing to do with the country of Albania, but the city of St Albans in England. Please do not be like the author of this article, and do not waste time searching for old Albanian alarm clocks. The results are, mildly put, uninteresting.

Although we dug up some names, we can notice that the Middle Ages and the Renaissance did not offer us particularly interesting figures. Since the bus has still not reached the destination and I have already sent several *SMS* messages lying that I am not arriving on time due to a traffic collapse, curiosity leads me more and more toward the Industrial Revolution. Several blogs and magazines point to an interesting personality by the name of:

...LEVI HUTCHINS

This craftsman and inventor from New Hampshire is considered one of the pioneers in making alarm clocks in the United States. His early model of an alarm clock, which he patented in 1787, was created exclusively for personal needs. His craftsmanship required him to get up very early to start his workday. To ensure he would wake up exactly at four o'clock in the morning, he made a clock with an alarm function that rang exactly at that time. And only at that time! Which was somewhat selfish, because not all the people got up at the crack of dawn.

Hutchins used wood for the clock's housing, while the internal mechanisms, such as gears and springs, were made of metal. Metal allowed the precision and durability needed for the clock's mechanism, while wood provided aesthetic value and external protection. Key elements of Hutchins' mechanical clock were the main spring and a classic hand-winding mechanism. When the clock is wound, energy is stored in the main spring. As the spring gradually relaxes, energy is released that drives the clock's mechanism. The energy released from the spring is transferred through a series of gears that regulate and control the movement of the clock's hands. For the clock to work correctly and precisely, the flow of energy through the gears must be regulated. This is achieved with a regulator, often in the form of a fast pendulum swinging back and forth, allowing the gears to turn the hands at a certain rhythm.

In addition to the basic mechanism for showing the time, Hutchins' clock had an additional one set to activate at a specific moment. When the additional alarm mechanism reached the precisely set time (in Hutchins' case, four o'clock in the morning), it would activate a bell or some other sound signal, notifying the owner that it was time to wake up. These were the basic principles on which Hutchins' alarm clock operated. Since Hutchins' clock was set to ring only at four o'clock in the morning, it probably did not have a more complex mechanism for setting the alarm for other times, making its design somewhat simpler.

Although Levi Hutchins made the first American alarm clock, he was not the first to commercialize this idea. Only a few decades later, alarm clocks became widely available to the public thanks to some other inventors and manufacturers. Hutchins did not earn much from his patented invention, but he remained historically more relevant than the first mass producers of alarm clocks.

And although I am satisfied imagining grumpy Hutchins winding up the alarm only for his needs and hurriedly going to his workshop, I am aware that alarms were still unavailable to the wider population. They were still too expensive. Since that is the case, I wonder how all those ordinary workers

during the Industrial Revolution woke up, given that their lives, almost literally, depended on arriving at work on time. The historical magazine of the BBC says:

...KNOCKER-UPPERS

Before alarm clocks became financially accessible to the wider masses and before they finally became lighter and less bulky, people often relied on *human alarm clocks*. Until the end of the 19th and the beginning of the 20th century, people were woken up in a similar way as Roman firefighters. In some cultures, *knocker-uppers* or "wake-up callers" would walk the streets and knock on windows or doors to wake people up on time. This practice was especially popular in industrial England, before the widespread use of alarm clocks.

The concept of a *human alarm clock* sounds really unusual today, but it was invaluable to many people when modern technologies were not widely available. In the 19th century, during the Industrial Revolution in England, work shifts often started very early, before sunrise. Many workers did not own reliable alarm clocks, so they relied on knocker-uppers' services. These professionals carried long sticks to knock on the windows of those on higher floors, and sometimes used blowers to throw peas at windows to wake up those who would otherwise be late for work and get fired.

With the growing need for a large number of workers to work from early morning in factories and mines, there was also an increasing need for the service of knocker-uppers. This gray picture of industrial England aesthetically fits into the Jack the Ripper panorama of dimmed street lamps and risky narrow alleys of London. I certainly would not like to live in such conditions and am very happy that I overslept for work in the 21st century!

Knocker-uppers were usually paid on a weekly basis, and their efficiency and reliability were of utmost importance to everyone. They provided a basic, but essential service! There were numerous jokes and gags about knocker-uppers who needed their own knocker-uppers so as not to be late for waking up people who do not want to be late for work. We could even make mathematical paradoxes at the expense of these exceptional professionals. Of course, the only alarm clock the knocker-uppers needed was their own *biological* alarm.

With the increasing accessibility and reliability of mechanical alarm clocks in the late 19th and early 20th centuries, the demand for knocker-uppers dropped. The electrification of homes and streets, as well as the improvement of living standards, also contributed to their gradual disappearance. Although the profession of knocker-uppers is now a thing of the past, it provides an interesting insight into the daily life of the working class during the Industrial Revolution. It serves as a reminder of *development*, with all its positive and negative sides.

The story of knocker-uppers made me quite sad. The bus is slowly approaching the station where I should get off and weave my way through a crowd of equally nervous people who, like me, are probably slightly late for work. Because of the traffic collapse, of course! For the end, I want something fun, some anecdote from, say, the early 20th century. And after that, I should think about a new solution, a new alarm, probably some smart and artificially intelligent device. It says:

...LAUNCHING OUT OF BED

In 1905, an alarm clock was patented that literally threw people out of bed to wake them up! At that time, the Industrial Revolution was in full swing, and the need for reliable ways of waking up was still extremely important, especially for factory workers, who had to get up before the first roosters. Hmm, why did they then fire the knocker-uppers? It does not seem sensible. Anyway, while traditional alarm clocks could produce really loud sounds to wake up the owner, some people just did not wake up so easily. In light of such circumstances, the idea of an alarm clock that would literally throw a person out of bed seemed like a practical solution for those who had trouble getting up.

Details on the exact mechanism of this unusual patent vary, but for photographs on the internet, I can conclude that the idea was based on some form of mechanical force, such as a spring, that would activate when the alarm rings, lifting or tilting the bed and thus forcing the person to wake up and get up. Although this concept looked good on paper, obvious questions arise about the safety of the person using such a launch into reality. Injuries from falls or hitting hard objects were quite numerous among the few users of this service. These are certainly factors that contributed to the fact that this exotic device did not become widely popular. In addition, such a robust mechanism is also extremely impractical.

Launching out of bed did not really gain popularity, and the invention was mostly ridiculed during its short existence. However, it is possible to see an interesting construct behind it. The cultural context of the early 20th century was shaped by a strong fascination with mechanical innovations and inventions. Many inventors experimented with different ideas, often creating devices that would today undoubtedly be considered eccentric or even bizarre. The alarm clock that throws the user out of bed is just a reflection of such a culture of innovation.

Although this alarm clock did not leave a deep mark in the history of design, it certainly provides an interesting insight into the creativity and

innovativeness of that era. It testifies to man's desire to constantly cross boundaries and think outside the box in search of better solutions to everyday, even the most ordinary problems. In any case, I got off the bus. I must stop fiddling with the phone so a car does not hit me at the pedestrian crossing.

...WITH COFFEE

Since I arrived at work, made a coffee, and sat at my desk—of course, I did not immediately start working. After all, I am only human! And a man who is interested in finishing his research on the history of alarm clocks.

Since the 1980s, digital alarm clocks have surpassed their analog versions, bringing features such as displaying temperature and humidity. With technological advancement and entering the 21st century, *smart* alarm clocks can now track sleep phases and wake us up at the most optimal moment for a better feeling of rest. Having reviewed and examined repositories of different alarm clocks, I realize I have entered a world of advertisements. Intriguing descriptions of smart alarm clocks are here to convince me to buy one.

Okay, I will accept that game and choose the most interesting product (to me). It seems that alarm clocks with sunrise simulation are especially intriguing. They gradually increase light intensity to naturally signal that it is time to wake up, thus mimicking our circadian rhythm. The human body has an internal clock, known as the circadian clock, which regulates many physiological processes, including sleep. The information useful to someone like me who did not know what circadian rhythm is. Instead of traumatizing alarm ringing, this technology allows a gradual transition from sleep to wakefulness, with additional options such as simulating sunset or nature sounds. These alarm clocks often result in less abrupt awakenings, as research confirms the impact of light therapy on sleep regulation. They are especially useful for those who have difficulty waking up during dark days or have flexible working hours. Essentially, these alarm clocks combine the latest technology with an understanding of human physiology, promoting a more natural waking rhythm.

Indeed, this advertisement sounds impressive! But, let's go back to the beginning, the *snooze* button, and sum up what we have explored so far. The alarm clock has become central to understanding time, social organization, and human nature. Our initial perceptions of time were guided by the natural rhythm, but as societies became more complex, the need for more precise time tracking grew. Before alarm clocks, we relied on natural sounds and light, as well as human interventions like knocker-uppers. However, with its work shifts and urbanization, the Industrial Revolution required the precision provided by the alarm clock. This magical device enabled the synchronization of human activities, increased productivity and economic growth, thus symbolizing modern capitalism.

Philosophically speaking (yes, when I talk about work, I actually talk about arriving at the office on time to philosophize), the alarm clock is a good indicator of our perception of time and how social norms affect our daily life, raising questions about freedom, reality, and social influence on the individual. In all this, the alarm clock is not just a sound signal—it depicts our social evolution and adaptation to self-imposed concepts of time.

All this sounds extremely interesting and impressive. Only, why, for example, would not we spread the curtains and allow ordinary sunlight to wake us up? Why would not we crack open our hermetically sealed blinds and allow ourselves to hear the morning chirp of birds? Maybe because there are carbon monoxide, smog, smoke, and whatnot all around us. The sun has a hard time penetrating through such a toxic atmosphere. When I think about it, I cannot remember the last time I heard the morning chirp of birds. I guess I have no choice but to resort to the 1905 patent. I want to be awakened and launched to work by springs and shock absorbers, all to Van Halen's song *Jump*. —Ⓔ

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The Dark History of Statistics

Statistics used to be presented as completely objective, and statisticians were considered undisputed authorities. Today, it has a somewhat different status, but there is still a risk it may be misused in attempts to objectivize some ideology or socio-political beliefs

By
Darko Stojilović

Illustrations by ***Jakov Jakovljević***

IN THE EARLY 19TH CENTURY, as the Napoleonic Wars erupted, a young boy was growing up in the city of Ghent, which was then under the rule of the First French Republic. This boy, Adolphe Quetelet, would go on to significantly shape the application of statistics in science. Against the backdrop of the war, he had a turbulent childhood that was also marked by the premature death of his father when he was only seven. Nonetheless, he managed to complete high school and immediately began teaching mathematics in the same year that witnessed Napoleon's ultimate defeat at the Battle of Waterloo.

After the war ended, Quetelet earned a PhD in mathematics at the University of Ghent, and then managed to secure funds for the construction of an astronomical observatory in Brussels. To obtain the necessary instruments for the observatory, he traveled to Paris, where he met great mathematicians such as Pierre-Simon Laplace, Joseph Fourier and Siméon Poisson, who stirred in him a love for a new discipline—statistics.

THE AVERAGE MAN

On his return to Brussels, Quetelet wanted to apply what he learned in Paris to a domain outside of astronomy. Back then, the normal distribution was of great importance to astronomers, as they used it to tame a random error that occurred while measuring the positions of celestial bodies with insufficiently precise instruments. However, Quetelet thought that the normal distribution could indicate a real or natural error, which did not arise from imperfect measuring instruments. He believed that the normal distribution could be used not only to calculate the positions of celestial bodies, but also to understand psychological and social phenomena.

His key idea was that it was possible to sketch the *average man* (*l'homme moyen*).

In Quetelet's opinion, the average man represented the ideal of humanity, and any deviation from that fell into the realm of the problematic and deviant. The greater the deviation from the average, the greater the abnormality. Quetelet advocated using statistics to identify these deviations in the social domain and delimit them for the betterment of society. Shortly after his return to Brussels, he published an article analyzing the city's birth and mortality rates and suggested that a census should be carried out. His goal was to determine the *defects of the nation* that disrupted social order and peace, such as criminals and alcoholics. In addition, he emphasized that mental illnesses were linked to immorality and crime, claiming most crimes could be attributed to a few families, which needed to be monitored or isolated.

By advocating the use of *large numbers* and believing that they enable us to arrive at true knowledge, Quetelet steered the study of men, which until then had taken place in a purely philosophical arena, toward empiricism. Moral science became a social science with no room for any subjective interpretation. However, although Quetelet believed that statistics would become the foundation of all science, he did not apply it to studying mental phenomena. On the other hand, his ideas influenced other scientists who laid the foundations for a new psychological science that developed at the end of the 19th and the beginning of the 20th century. In addition to Wilhelm Wundt, the founder of the first psychological laboratory in Leipzig in 1879, Quetelet's ideas made an even bigger impact on another, much more famous scientist, who laid the foundations for meteorology, genetics, psychometry, but who was also the progenitor of a completely different discipline.

THE BIRTH OF EUGENIC THOUGHT

Francis Galton was born 26 years after Quetelet. He already knew how to read at two, while at five he was learning Latin and Greek. These inclinations could partly be attributed to conducive surroundings, as members of the Royal Society formed a good part of his family line, including the great Charles Darwin. Though Galton's interests during his undergraduate studies gravitated toward medicine, he then went on to study mathematics at Cambridge. Similarly to Quetelet, Galton had to deal with the loss of his father while still young, which led to him finishing studies early and embarking on a journey to the Eastern Mediterranean.

Galton knew Quetelet, and it was thanks to him that Quetelet's ideas were developed and applied to lay the foundation of a new science—differential psychology, which studies differences in traits between people. Additionally, Galton was heavily influenced by Darwin's ideas about natural selection and believed that individual talents could be traced back to genetics.

Just as Quetelet used the normal distribution to determine deviations from the average in the frequency of criminal acts, Galton used the normal distribution to understand the variability of human traits and tried to demonstrate that differences in human ability stemmed from hereditary factors. Galton believed that determining deviations from the average could help predict variability in the traits of future generations. While Quetelet was interested in the average person, Galton's focus was precisely on the ends of the distribution—the values far below and above the average. While Quetelet considered these extreme values a consequence of error, Galton viewed them as a result of evolutionary mechanisms and believed they had much greater potential for study.

To measure mental phenomena, Galton used quartile deviations to compare groups of different ability levels. He had to depart from traditional statistical measures and develop new approaches—correlation and regression—so as to be able to compare the heritability of parents' and children's abilities. In other words, Galton was developing statistical analyses that could support the idea of eugenics—that people's abilities could be improved through scientific means. He was one of the pioneers of the idea that it would be possible to scientifically determine "*fit*" members of society and superior races and encourage their survival, at the expense of "unfit" members of society and races. Just as animals could be mated to bring out desirable traits in subsequent generations, he believed it was possible to mate highly capable humans to create a world full of genius. However, this idea also implied that people with less desirable traits should be prevented from passing on their traits to future generations. In statistical terms, Galton imagined that there were different, multimodal distributions of traits and abilities for different races, indicating the existence of completely separate groupings of people.

In a letter to *The Times* in 1873, Galton advocated the idea that the Chinese, a people capable of high civilization, were only momentarily in decline due to the recent failures of their dynasties and should be encouraged to immigrate to Africa and replace the *inferior* races living there. Galton not only believed that the average intellectual ability of Africa's inhabitants was significantly lower than that of the respectable white race in Europe, but that this was a result of hereditary factors and genes, not the environment and conditions in which they lived.

Thirty years later, in his speech to the Sociological Society at the University of London, Galton pointed out that eugenics aimed to create useful classes that would contribute to society more than

their predecessors. On that occasion, he presented a proposal for the direction in which eugenics should be heading and how its *laws* should be studied. Namely, he thought that the kinship of relatives could be studied mathematically, just as it was possible with the birth and mortality rates. He also proposed a historical analysis of how different classes contributed to the society's development or how useful they were, because he felt there was a strong reason to believe that nations were successful or unsuccessful in relation to the influence of its upper class. In the end, Galton advocated the thesis that eugenics must be *implanted* in the national consciousness as a new religion, with statistics as a tool to achieve this.

Another highly important figure in the world of statistics presided over the aforementioned meeting at the University of London. This scientist did not only develop a large number of statistical tests and techniques deemed irreplaceable in science, but also institutionalized Galton's idea of eugenics.

INAUGURATION OF STATISTICS AND EUGENICS

Karl Pearson grew up in London in a Quaker family. He also loved mathematics immensely, so he went on to earn this degree from Cambridge at 24 years of age. He continued to study physics in Germany, and then, like Galton, spent several years travelling. He was also interested in Roman law, physiology and literature, and upon his return to London he studied law, before finally returning to mathematics because he got a job at University College London (UCL). There he founded the world's first university department of statistics.

At UCL, Pearson first met Galton and began a collaboration that lasted until Galton, who was 35 years his senior, eventually died. Although much younger, Pearson described Galton as "mentally half his age" and noted with delight Galton's vigor while speaking about eugenics. At a meeting at the University of London, Pearson fully supported Galton's speech and added that the mission of improving humanity was the most important goal of the European race. What is more, the conflict between the higher and lower races is inevitable, he argued, and should lead to the removal of bad examples in society.

In his book *The Grammar of Science*, which, among other things, made a major impact on Albert Einstein, Pearson responded to a few critics of eugenics at the time: "It is a false view of human solidarity, a weak humanitarianism, not a true humanism, which regrets that a capable and stalwart race of white men should replace a dark-skinned tribe which can neither utilize its land for the full benefit of mankind, nor contribute its quota to the common stock of human knowledge."

"Galton advocated the thesis that eugenics must be *implanted* in the national consciousness as a new religion, with statistics as a tool to achieve this."

Just as Galton pioneered Quetelet's ideas, Pearson seemingly provided the theoretical and mathematical rigor to Galton's ideas and significantly pushed eugenics toward practical application. In an effort to determine whether the distributions of traits and abilities substantially varied in different races, Pearson devised statistical significance testing, as well as the chi-square test. For example, if the distributions of different groups of people or races did not differ at a statistically significant level, this would mean that they belong to the same group or race. The final decision on whether the distributions differ is based on the p-value. Though this procedure has become a standard in scientific hypothesis testing, Pearson first applied it only to determine racial differences between people. Statistical significance testing found one of its first applications in the measurement of skull sizes from the 6th century. Since the skull size distributions differed, Pearson concluded that his sample included two separate races of people, so he reckoned their intelligence and character differed as well.

In the *Biometrika* scientific journal that he co-founded, Pearson conducted a correlation analysis of 4000 pairs of relatives and established a high correlation not only concerning eye colour, but also in traits such as assertiveness, introspection etc. This led him to the conclusion there was a strong hereditary factor in psychological traits. In another scientific journal he founded—*The Annals of Eugenics*—Pearson explicitly advocated this idea, and also presented Jewish immigrants as an inferior race based on their supposedly lower intelligence.

The First International Eugenics Congress took place in London in 1912. It brought together more than 300 participants from Europe and the United States, including a son of Charles Darwin who then served as the president of the British *Eugenics Education Society*. Even Winston Churchill attended the meeting. The program was divided into four sections. The first part dealt with the issue of inheritance, the second part discussed the impact of eugenics on sociological and historical research. The third part considered the impact of eugenics on legislation and social practices. In the final part, the participants looked at practical applications and discussed how to prevent the reproduction of the "unfit" through segregation and sterilization and encourage the reproduction of the "fit" by promoting eugenic ideals.

EUGENICS IN PRACTICE

The next in the line of English polymaths involved in the story of eugenics and statistics was Ronald Fisher, born in a middle-class family, 33 years after Pearson. Like Quetelet and Galton before him, he had to deal with the early death of a parent, as his mother passed away when he was 14. The same year, he won his first medal in mathematics, a field he continued to pursue during his studies at Cambridge, where he became acquainted with Galton's and Pearson's ideas on eugenics.

After the First World War, he was offered a position at Galton's UCL laboratory, which he turned down so he could analyze vast amounts of crop data at the *Rothamsted Experimental Station*. This work helped him establish the principles of experimental research design, apply the innovative analysis of variance and develop the famous z-transformation.

Not only does Fisher remain one of the most influential statisticians ever, but he also made outstanding contributions to biology. However, as with Pearson before him, eugenic ideas guided his scientific endeavors. In his book *The Genetic Theory of Natural Selection*, he wrote about the mental and moral qualities that determine reproduction, and the economic and biological aspects of class differences. Fisher wrote for Galton's scientific journal, *The Eugenics Review*, succeeded Pearson in *the Galton Laboratory* at UCL, and took over the editorship of *The Annals of Eugenics*.

In order to implement eugenic ideas in practice, Fisher tried to support them with evidence from biology. Still, his intent could not be realized to the extent he wanted, since religious institutions opposed such practice. In the 1910s, a bill was tabled for debate in the British Parliament that proposed the introduction of sterilization for certain groups, but this provision was ultimately excluded. In the 1930s, members of the *British Eugenics Society*, including Fisher, formed the *Committee for Legalizing Eugenic Sterilization*.

The data that Fisher offered to support his ideas were collected in the United States, where studies on heredity had been conducted for decades, accompanied by the application of restrictive immigration policies, the ban on marriages of different races

"The issues with statistical significance testing, p-values, correlation, and other techniques that eugenicists applied to back their ideas became evident only later."

(miscegenation), as well as the mandatory sterilization of the mentally ill and physically disabled.

The first eugenic sterilization was carried out in Indiana, the United States, in 1899. Since the sterilization of the mentally ill was not legal, it was carried out in contravention of the law. In the following ten years, several U.S. states made sterilization legal. Harry Laughlin, who headed the commission of the *American Genetic Association*, even suggested that the least able 10 percent of the U.S. population should be sterilized. Physicist and British Nobel laureate William Shockley even proposed paying people to be sterilized, with the price to be determined according to their IQ score.

The British Eugenics Society worked closely with Ernst Rüdin, who played a significant role in Nazi Germany by advocating pseudoscientific claims. As a matter of fact, he chaired the *Expert Committee on Questions of Population and Racial Policy* that attempted to examine the relationship between race and mental illness. The committee members suspected that "*inferior*" races were more likely to have mental retardation, schizophrenia, and manic depression than white people. Fisher maintained contact with the Nazis even after the end of the Second World War and even came to the defence of Nazi biologists and eugenicists, as he believed that their practices had a solid scientific basis. He remained convinced until the very end of his life that there were clear differences in the intellectual and emotional capacities of different races.

In conclusion, eugenics was conceptually and theoretically developed by British statisticians, first tested in practice by U.S. eugenicists, and brought to the extreme by the Nazis during the Second World War.

MISUSE OF STATISTICS

Even before the advocacy of racial theory and the implementation of eugenic practices, a large number of professors in the fields of psychology, biology, and sociology taught courses in eugenics. This idea was so popular that hardly anyone in scientific circles managed to resist it. One of those skeptical was British psychiatrist Charles Mercier, who attended the aforementioned meeting where Galton and Pearson spoke. On that occasion, Mercier was practically the only one to express strong skepticism toward eugenic ideas. Put simply, he believed the laws of heredity were so complex that they seemed to function more on the principle of chance. Unlike Galton, Mercier was convinced that statisticians could not predict a child's fate based on what his parents were like. Creating highly capable people is always sporadic and unrelated to any particular race, but to individual cases.

Mercier's prudent words did not convince the rest of the crowd, and in the next half of the century or more, the world dealt with the negative consequences of eugenic ideas (which still exist today in a somewhat different form), always insufficiently supported by scientific evidence. The issues with statistical significance testing, p-values, correlation, and other techniques that eugenicists applied to back their ideas became evident only later. In addition, they mostly relied on statistical arguments, which, of course, are not sufficient in science. They presented statistics as completely objective, the data as completely true, and hailed statisticians as undisputed authorities.

At that time, statistics seemed completely objective, exact, and sacrosanct, with new opportunities opening up for people to develop it further and explore its potential reach. Today, statistics has a somewhat different status. It is increasingly complex and diverse, requires specialized knowledge, but there is still a risk that it may be misused in attempts to objectivize ideologies or socio-political beliefs. That is why we need to be very careful and interpret statistics exclusively in a theoretical context, aware of its scope and nature. After all, statistics is only a tool, not a solution. —Ⓔ

The author is a cognitive scientist with an MSc from University College London. He also holds a BA and MA in Psychology from the University of Belgrade. With more than a decade of research experience, he has authored over 30 popular science articles across various media platforms.

PUBLIC HEALTH

What Eats Away Our Trust in Vaccines?

Vaccine misinformation is a massive flammable canister that has already shown its power to fuel various other disbeliefs, so it must not be left alone

Illustrations by ***Đorđe Balmazović/ Škart Collective***

By
Pavle Zelić

"THEY KILLED THEM!"

It was Tuesday, 28 June 2022, when doctor Nida Ali walked into the shared office space of the Humbert H. Humphrey Fellows at Emory University in Atlanta, Georgia, the United States. She was crying her eyes out. Had we been outside, the southern heat would have scorched us, but in this sanctuary room we were shivering. I was first to approach my friend, a rock-strong and steadfast Palestinian woman, I hugged her and asked in bewilderment: "Who did they kill, Nida, what are you talking about?"

Ji-hye from South Korea gave Nida some water, Alexandra from Venezuela sat her on a chair, and Sarah from Sudan brought a box of tissues.

After pulling herself together, she finally told us: "Three of my colleagues... my friends. They were killed during polio immunization activities in North Waziristan."

"Who killed them? Why?," I asked spontaneously, even though I knew the answer.

"I do not know. It is something you almost never got to find out. They visited the villages of that border province toward Afghanistan, where polio is on the rise again. If I… if I had been there, I could have been with them. You remember, I told you about this. Now it is happening again."

How could I ever forget.

A few months earlier, Nida and I shared a time slot for a lecture in front of a large audience of distinguished university professors and public health students. I spoke about the creative communication of public health topics and interventions through storytelling and art, but Nida… Nida talked about how many of her colleagues were killed in the field in previous years, and how she also risked her life every now and then—to vaccinate children in Pakistan. She immunized them mainly against poliomyelitis—polio, an extremely contagious disease that is transmitted through contact with fecal matter and can cause permanent paralysis and even death.

Back in the early 1990s, more than 20,000 children were left paralyzed in this South Asian country on an annual level. However, the disease appeared to have been almost eradicated as no new cases were detected in Pakistan for 15 months until April 2022. Today, however, this second-largest disease in human history (after smallpox back in 1979) has returned big time. From the only two countries where it remained endemic for years—Afghanistan and Pakistan, polio is now back in several African countries. In June 2022, it was detected in wastewater in London, which was followed by the emergency vaccination of a million children, and in July the same year in New York City!

Causes for persistently incomplete vaccination in the above-mentioned two neighboring Asian countries with predominantly Islamic populations lie in the deep distrust perpetuated by misinformation and conspiracy theories surrounding this and other childhood vaccines—from the claims that they contain pork fat or alcohol, which are forbidden to Muslims, and suspicions that they can cause HIV infection to the most prevalent belief about the villainy of the Western enemies (as new injectable vaccines Ipol® come from the French manufacturer Sanofi Pasteur) as they allegedly want to sterilize Muslim children.

Add to that the lack of enlightenment and illiteracy among the population in hard-to-reach mountain villages, radical militant groups linked to the Taliban regime and Al Qaeda terrorist organization. Having all that in mind, the task of eradicating polio, put before Nida and her colleagues, who risk their very lives every time they put on their shoulder a portable vaccine cooler and knock on the door of some isolated mud house, seems not only dangerous, but even impossible. However, this cannot happen in a world of enlightened democracies, compulsory education, and decades of successful mass immunization, right?

ONE FLEW OVER THE CUCKOO'S PROTEST

Forgive me for being a little more personal in this article and recalling the anti-Semitic graffiti and protests in front of the house of the most recognizable member of the Serbian National COVID-19 Crisis Response Team, and my friend, epidemiologist Predrag Kon, MD. During one such incident in late October 2021, a berserk crowd shouted "Mengele, Mengele" to this man of Jewish descent.

As for myself, ever since the somewhat forgotten H1N1 flu pandemic of 2009-10, or since I started appearing in the media more frequently to speak about vaccines, I have been receiving death threats by phone (from hidden or foreign phone numbers) and even by email. And all that because I spoke in favor of immunization and gave assurances about the safety of these products, which are controlled and approved for use in our country by the Medicines and Medical Devices Agency of Serbia, an institution that enjoys a significant reputation in Europe, which I represent as a spokesman and above all as a health expert.

On that note, while I was attending the Hubert H. Humphrey Fellowship Program in the United States, I had an opportunity to take part in a mini-congress and ask Professor Carlos Del Rio, the second most present expert in the U.S. media on the topic of the pandemic after the famous Anthony Fauci, how he dealt with negative comments and threats from anti-vaxxers—and he replied that over time he had developed a very thick skin. And that he had recently acquired and regularly carried a gun to protect himself. When I wanted to write a scientific paper about this, I was advised from several places in the United States and Serbia to quit the idea and "not to play with fire." I withdrew then, but I am wondering now where patience ends, and when we will realize that the "fire" is already *playing with us*?

I am not saying that we, the communicators and translators of public health measures and preventive, therapeutic solutions, are some kind of heroes, especially not compared to doctor Nida and her fearless team of Pakistani immunizers, or healthcare professionals in direct contact with sick patients in COVID-19 hospitals and healthcare institutions on the front lines of the pandemic in Serbia and all other countries across the world. But in order to make the job a little easier for those brave—not tireless, but *overtired* fighters against this and any other vaccine-preventable disease, we must recognize all the causes of ignorance, distrust, and resistance to vaccines and immunization. We might even classify them and put them in a metaphorical cultural-entomological showcase like some mutated, invasive insect pests. And then figure out how to exterminate *them* first.

TERRIBLE, HORRIBLE, NO GOOD, VERY BAD... VACCINE

Vaccines cause infertility, autism, contain microchips that track people's movements, and serve to limit the population with hidden side effects that will appear over many years and cause a global plague. The responsibility for all this lies with Bill Gates, the powers that be and governments in general, freemasons, illuminati, aliens, and reptilians.

"A lie told once remains a lie, but a lie repeated a thousand times becomes the truth," is a variant of the famous saying attributed to Nazi Propaganda Minister Joseph Goebbels. In the age of *fake news*, *post-truth* and *illusion of truth*, reinforced by the pandemic/infodemic deadly dynamic duo that has made us all just a little crazy. And while the temperature of the planet is rising not so subtly and overheated brains are leaning into conflicts—misinformation and conspiracy theories have become not only a key challenge and enemy of science and development, but also the greatest hidden threat to the survival of the human race in general.

It is one thing when citizens question the theory of evolution, rebel against 5G networks and chemtrails, and even believe that the Earth is flat (sic!), and a completely different thing when they jeopardize their own health, the health of the children they are responsible for, and even everyone they encounter. In fact, they refuse the vaccine against a disease "weaker than the flu," which has actually claimed millions of lives, often completely healthy people, even children and babies. Not so long ago, COVID-19 became the fifth deadliest pandemic in the history of civilization—just above the bubonic plague, which lasted for over a hundred years (1855-1960), and for now far below the HIV pandemic, which claimed over 40 million lives in four decades. Officially, the World Health Organization (WHO) estimated that 6.98 million people died as a result of the SARS-CoV-2 virus infection by 21 November 2023, and according to projections by the *Economist* magazine and Johns Hopkins University on 18 November 2023—up to 33.5 million people.

How many of them did not have to die?

From the moment when unexpectedly effective and available vaccines became the ultimate weapon in the war against the SARS-CoV-2 virus—practically no one. And yet they decided not to get vaccinated. They decided to take a risk. And they died. Or they accidentally killed someone close to them or a complete stranger. Why? Why!?

We must know this, and we must stop it, because too much depends on it. We have also seen this in the headlines in Serbia recently, as we have had the second (!) epidemic of measles in just a few years. The reason is the embarrassingly low double-digit coverage of vaccination with the MMR (measles, mumps, rubella) vaccine in some Serbian cities. The real reason—parents simply do not want to, or delay immunizing their children with a vaccine that they think might cause autism. A conditional, not the imperative, but the outcome is the same.

What is the most important and recent in this (dis)information war is that it is not at all necessary for the "other side" to fully win the trust of the shifting middle mass of the population that is undecided about which position to take. It seems enough to insert *the worm of doubt*, as we say in Serbia. A small, sneaky animal that will burrow its way through the subconscious, laying metaphorical eggs of new little doubts at the core of every entrenched attitude we have grown up with.

Yes—we were all vaccinated as children, and we are doing fine... But! Who knows what the "pharmaceutical mafia" puts in those vaccines today? That is right—billions of people have received vaccines against COVID-19, and supposedly severe side effects are rare... But! What if it happens to me—and you must have heard that even the Pfizer director did not get vaccinated?! You are right, vaccines are one of the most outstanding achievements of mankind thanks to which we have suppressed many diseases... But! I would still like to wait a little longer with the vaccination of my children, there is all kinds of talk, even some doctors advise it, so we will see, take it easy, why are you forcing me to do it!?!

It is difficult to speak, and even more difficult to write about all this without being overcome with anger, the opposite of the dedication and passion that we health professionals must have in order to quixotically attack those windmills of obstinacy anew every day. By flinging the arrows of facts, through the media and direct contacts, all in the hope that this dragon Smaug also has a hole in the armor through which we can penetrate inside, into the heart and souls of those we speak to... and turn everything around.

But as the elder Jedi Yoda wisely says, anger, which comes from fear, leads us to hate, which in turn leads us to suffering, and all that together—to the dark side. Therefore, let's not be afraid, nor angry, and especially not hate those who refuse to listen to us when we talk about vaccines.

GUNFIGHT AT JENNER'S CORRAL

How, why, and where does misinformation about vaccines arise?

This question deserves an essay of its own, but ever since WHO Director-General Tedros Adhanom Ghebreyesus famously declared in February 2020 that "we are not only fighting an epidemic, but an infodemic—fake news that spreads faster and easier than a virus," it seems that COVID-19 was the beginning and end of all misconceptions and untruths about vaccines.

In fact, it started literally *centuries* ago. Not only individual resistance to immunization efforts, but

real anti-vaxxer associations were founded only a few years after the official discovery of vaccines in 1796 by doctor Edward Jenner. Since vaccines were obtained from cows, a favorite argument from these times was that children would grow horns from them! Whole leagues, all with mass demonstrations, pamphlets and aggressive campaigns, started simultaneously with the beginning of the era of compulsory vaccination for children in Great Britain in 1853. To this day, the modus operandi is similar—individuals, and informal and official groups initiate the spread of rumors, using current means of information transmission, questioning the vaccines' composition, justification for their use, and above all—safety.

Fast forward to 1998, doctor Andrew Wakefield and the infamous scientific paper published in the prestigious *Lancet* journal about alleged autism caused by the MMR vaccine. Although in the meantime *Lancet* and all co-authors retroactively rejected it and the scientific community demoted it countless times, it still comes back to us like a zombie that we need to shoot again and again, but simply cannot take down.

Let's finally reveal the true motivation of this pseudoscience—Wakefield was getting money from lawyers who planned to sue the manufacturers of the MMR vaccine, and he himself had a patent for a competing vaccine!

And here we come to one more "why"—someone has an interest, often financial, to push a different narrative. Because he is literally selling something that is an alternative to vaccines. It is often intertwined with crime, but it is most dangerous when real doctors and scientists like doctor Robert Malone, a hot new anti-vaxxer star, the alleged unique (!?!) creator of the mRNA vaccine technology, which he claims was stolen from him decades ago. Anyway, he now renounces it with disgust (in favor of lucrative public appearances).

Influential public figures who do not want to be vaccinated and thereby gain additional popularity with certain audiences, politicians who win over the electorate in this way, but also that one annoying relative in a family chat or at a birthday celebration who non-stop shares anti-vaxxer links or talks about it over the dinner table—they all carry a greater or lesser level of responsibility for the reality that we are still not done with the theoretically resolved pandemic.

And instead of the already worn-out narrative about toxic social networks like Facebook and X (former Twitter), let's accept that the real action is happening elsewhere. Namely, as part of our information ecosystem, billions use encrypted messaging applications such as WhatsApp (2.24 billion in 2023), Viber (1.17 billion) and Facebook messenger (931 million), and more recently Telegram (700 million) and Signal (40 million)—described in a 2022 New York Times article as "the best apps in the world." Much of their popularity stems from their capacity to offer privacy and maintain the confidentiality of online conversations, but precisely because of this, they also create spaces where misinformation spreads freely without measures to protect people from the harm they can cause.

Whilst researching for this article, I could join over a dozen anti-vaxxer groups on Viber that together had tens of thousands of members and associative titles like "Truth Against the Plandemic," or "Ivermectin, Evidence and Facts." The feed on the most massive ones was like the carriages of a fast (and circus) train passing before your eyes while you just waited at the traffic lights.

Given its clear creative power, many are also warning of the potential of ChatGPT's new revolutionary AI software to be a super generator of mis and disinformation, capable of instantly producing news articles, blogs, social media posts, and other texts that perfectly mimic the manner of expression typical of certain professions, experts or even prominent individuals, scientists, politicians and other famous people.

"In most cases, when we asked it to create disinformation, for example on the topic of vaccines ... ChatGPT would do it," claims journalist Jim Warren of the *Chicago Tribune*, who points out that it easily overcame the security restrictions of its manufacturer, OpenAI.

The Lovecraftian Kraken, this time as a symbol of a distorted collective view of reality, has shown its face with countless tentacles reaching into millions of heads, like the gargantuan swollen body of a queen where the eggs of mind worms are lain, and now it has sunk back into the darkness of the abyss from which it was driven out for a while by COVID-19. It is back there bigger than ever, that titan of insanity that will only grow and grow, invisible but as real as any mass ideology or faith. So, extremely.

I deliberately do not use the hydra metaphor because, first and foremost, half-baked and inconsistent measures (such as restricting disinformation from Meta and Google) have maybe slashed, but never cut off its heads, and second, we should not kill this beast—but rather talk to it.

That is the key. I look forward to every request for access to information of public importance, I hope for forums and expect phone calls. I am not afraid of resentment, criticism, or threats. It is of utmost importance that we talk. And that people do not just retreat into the recesses of their minds.

It is just that these conversations are happening less and less. As someone who has personally responded to literally thousands of calls, messages, and emails during the pandemic, I feel at liberty to say with sad conviction that we are further and further from an open discourse on vaccines. While the topic centered on adverse reactions reported to the Serbian Institute of Public Health "Dr Milan Jovanović Batut" and finally the National Pharma-

covigilance Center at my agency, we still talked as much as possible. My colleagues working on this, me included, received complaints, we listened to irrational fears, but were also threatened with court proceedings and applications for damages. Not even that anymore.

They retreated to their trenches, and we jump and clamor in no man's land for nothing, no one fires a single bullet at us anymore.

A PROBLEM THAT CAN BE SOLVED WITH MONEY IS NOT A PROBLEM...

...It is just an expense, says an old Jewish proverb. But can we really solve the problem of mis and disinformation if we "throw" enough money at it? It certainly would not hurt, after all, that is how we got to the most controversial vaccines that this text deals with—those against the SARS-CoV-2 virus.

According to the WHO's latest report on vaccine development published in March 2023, the greatest combined scientific effort on a single task in the history of mankind has brought us 183 vaccines in various stages of clinical and post-clinical trials, out of which 40 have been approved for use, while another 199 are in pre-clinical testing. This kind of sharp focus, which has taken place due to unprecedented public health concerns and financial factors, has significantly slowed down the development of many other necessary therapies, especially in the field of immunodeficiency, cancer, and rare diseases.

And what can we say about the ambitious plan of exactly USD 100 billion that the Biden administration set aside for preparations for the next pandemic, with most funds earmarked for the fastest possible development and mass production of vaccines? It sounds fantastic, but what are we supposed to do with the research published in the *Science* journal in June 2020 saying that before the start of the mass immunization against COVID-19, over 50 percent of Americans did not want to be vaccinated citing the "too fast development" of vaccines as the main reason? And today, about 20 percent of them remain persistent in that attitude, even though it cost them their jobs in large companies or in the public sector because of the vaccine mandate.

All preparation scenarios for a pandemic (which anticipated a virus from the SARS group) predicted a race for a therapeutic or preventive solution. But they did not consider the scenario we faced in real life—that people *would not accept* that solution.

So why make the same mistake? Why so much

money for something that people will refuse? Especially, when I know that literally every single day there was a protest in front of the main entrance of the U.S. Centers for Disease Control and Prevention (CDC) that I listened to for a whole year from my dorm room right across the street. Toward the end of the scholarship, during the practical three-month work at this prestigious institution, I received accusations that I was an accomplice in the killing of children and some new Nazi-type experiments. In fact, nothing new for me.

What else can we do then?

One of the answers lies in the maximum involvement of the academic community, top scientists in multidisciplinary teams of psychologists, epidemiologists, communicators, informaticists, and many other disciplines (with a little help from our new friend—artificial intelligence), who will, in the form of a brain trust, figure out the scale and depth of this megalomaniacal challenge and how to overcome it. And the way out leads through a synergy of scientists, researchers, and professionals from state and international bodies, such as the National Institutes of Public Health and the WHO. They will bring an added value that is necessary at a time when we have largely exhausted the traditional means of influencing populations, and especially ourselves and the credibility of the institutions we represent.

The author of this article has had the pleasure of participating in two such initiatives. The first has been launched by the IRIS Academic Research Group and brought together the world's most prestigious universities in the field of public health—Harvard, Cambridge, the London School of Hygiene and Tropical Medicine and several others. By interviewing government communicators, like me, they actually got acquainted with the methodologies of responding to mis and disinformation about vaccines, and they would offer solutions for them.

The second initiative is actually the plan of the Global Health Institute of Emory University (which I attended as part of the aforementioned U.S. State Department's Hubert H. Humphrey Fellowship Program in 2021–22) to become a world center of excellence for infodemic issues, for which it already has received support from the WHO and UNICEF headquarters.

Moreover, in late March 2023, the Serbian capital hosted a large meeting on this topic, and our Belgrade University was selected as one of twenty in the world that the WHO considers reference institutions in the field of infodemiology, and will continue to support them in the development of this young science. Since May 2022, the Laboratory for Infodemiology and Infodemic Management at the Faculty of Medicine has been doing research and teaching about this new discipline.

I am afraid there is no space to explain methods such as social listening, crowdsourcing, inoculation with misinformation, vaccine diplomacy, social marketing, debunking mechanisms, and especially the development of digital health, media, and scientific literacy in the context of vaccines. Many of these solutions are extremely effective, but none is a magic bullet on its own.

And maybe I inspired you enough to find yourself in this story and discover something about them on your own. Because the bottom line is that whatever we do, this concerns us all, as was the case with the last pandemic, and surely would be with the next one as well.

THE CONCLUSION IS *NOT* PRESENT

Since this text is schizophrenically gung-ho with underlying bleakness, it cannot possibly end with a single ingenious statement, a visionary quote, or a cool reference that will tie the whole topic together, like a nice ribbon on a present.

Unless that present is a ticking time bomb, with a Schrödinger-style hidden timer, which will explode soon, or years from now, maybe even not in our lifetime—we simply cannot know until we open it. But it is *real*, and it is ticking, trust me that much. And it has the power of a thousand Chernobyl disasters.

Vaccine misinformation is just that, a massive flammable canister that has already shown its power to fuel various other disbeliefs, so it must not be left alone. I know for sure that I will not do that, and neither will the motley group of experts and a passionate, committed group of devotees from all over the world with whom I have the honor to collaborate or hear about their work.

And we will succeed. Bit by bit. One person at a time, if necessary.

Because we believe in it, because we care about the lives we indirectly save, because it is right, noble... and it ties us with threads to the heaven itself.
—Ⓔ

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HOW TO COMMUNICATE CONTEMPORARY SCIENCE

THE CENTER FOR THE PROMOTION OF SCIENCE held a course *How to Communicate Contemporary Science?* for doctoral, master's students, and young researchers, for a third consecutive year. This course, which took place from 12 to 14 December last year, primarily aimed to encourage participants to analyze examples from international scientific practice and thus highlight the importance of effective science communication in various fields, as well as present the main tools to achieve it.

Some of the topics covered in the course were: How do we plan and implement a research idea?, How to collaborate in the research process?, How do we communicate scientific information to different audiences?, How to write a good project proposal and get some of EU grants (the ERC and Marie Curie grants), and How important are science podcasts and public media appearances?

The author of the course and lecturer is Darko Donevski, PhD, an astrophysicist and science communicator (SISSA, Trieste; the Astrophysics Division, the National Center for Nuclear Research, Warsaw), but discussions also involved guests from different areas: Vernesa Smolčić, PhD (an astrophysicist and professor at the Department of Physics of the Faculty of Science at the University of Zagreb), Ana Černok, PhD (a geoscientist and assistant professor at the Department of Mathematics and Geosciences of the University of Trieste), Dušan Pavlović (a science journalist and the editor of the Radio Galaksija science news website), Milica Ninković (a psychologist and one of the authors of the Psihološkinje podcast), and Ivan Umeljić (the editor of the Elements science magazine, the Center for the Promotion of Science). —Ⓔ

Illustration by ***Monika Lang***

NUDGE

SINCE PEOPLE TEND to behave irrationally when making decisions, big companies and governments sometimes want to *nudge* them to the right choice. This is the central theme of the nudge theory of Richard Thaler, who received the Nobel Prize in Economic Sciences. The theory relies on several important concepts: choice architecture, libertarian paternalism, homo economicus and people, and a new way.

VISUAL VOCABULARY

LADME

THE TOPICS OF PHARMACOKINETICS can be summarized by the acronym LADME: liberation, absorption, distribution, metabolism, and excretion of a given agent by our bodies. The illustration shows how drugs actually work in the human body, indicating the action of moving from liberation to absorption, distribution, metabolism, and finally excretion. →

BLACK HOLE

ASTRONOMERS DESCRIBE the universe as the most precious lab that enables us to understand objects and phenomena we cannot see with our eyes. One such phenomenon is a black hole—an exotic example of the magnificent death of the most massive stars.

*Illustration by **Srđa Dragović***

*Illustration by **Željko Lončar***


LADME

An Inner World

With every organism, a new world comes into being, finite and enclosed, like a soap bubble

By
Ivan Umeljić

OUR IDEAS AND THOUGHTS do not reflect the world outside of us, but rather that world *conforms to* our cognitive faculties. In a nutshell, this was the notion presented by renowned German philosopher Immanuel Kant in his most famous work, *Critique of Pure Reason,* in the late 18th century. This idea that the entire reality is impregnated with our cognitive perception so we can never really grasp the world as it is, has since inspired many philosophers and scientists, including German biologist and mystic Jakob von Uexküll.

BUBBLES

Starting from the position that one cannot really talk about *the world* as an objective fact or a reality independent from our subjective experience since every organism *creates* its own environment and there are as many environments as different organisms, Uexküll (1864–1944) concludes that the assumption that the human perception of the world is the only accurate is actually "this fallacy fed by a belief in the existence of a single world, into which all living creatures are pigeonholed."

To support this claim, Uexküll often referred in his works to examples he had come across during research, like the allegedly objective description of a meadow or some tree. In one such example, Uexküll notes that even something as simple as a flower can be an adornment for a human, a pipe full of sweet nectar for an insect, a path to cross for an ant, or simply a source of food for a cow. On the example of just one flower, it is very easy to see how a tree, coral reef, soil, or, wider still, a meadow, forest, or ocean may rather be composed of multiple diverse worlds than just *one real world.* With every organism, a new world comes into being, for which Uexküll uses the term *Umwelt* (inner world) and compares it to a soap *bubble.*

The Umwelt encircles every organism and limits its living space, like "the soap bubble that constitutes the limit of what is finite for the animal, and therewith the limit of its world." The *Umwelt* is a whole universe within which all things are significant and meaningful for an organism, and outside of which everything else is non-existent and *hidden in infinity*. A favorite example that this German biologist often resorted to was the description of the tick (*Ixodes rhitinis*). From the viewpoint of the female tick, almost everything from the external world around her is meaningless: moonlight, weather conditions, birds, noises or shadows, simply do not concern her. All these things may belong to the *Umwelt* of some other neighboring organism that lives next to the tick, but they have no significance for her. What concerns the female tick is the sensory perception of heat and sweat from warm-blooded animals that she feeds on, where she lays eggs, and eventually dies.

Photographs by ***Veroljub Umeljić***

A REALITY ACCORDING TO BEES

The sensory world of bees is exceptionally aligned to signals coming from flowers. With their vivid colors, flowers stand out in forests and from green leaves, and bees can detect all their colors. Flowers have scents, and bees have a highly developed sense of smell. This enticing communication between insects and plants started more than 100 million years ago and then intensified some 40 million years later in the Cenozoic, when flowering plants became prevalent in the vegetation on our planet—plant species then started *making partnerships* with certain insects.

Bees can detect parts of the spectrum that we cannot. Many flowers have ultraviolet patterns, invisible to us, which bees rely on to guide them to nectar, while on the other hand, *red* flowers (to us) appear *black* or *gray* to bees (although not everyone would agree with this claim). Bees' eyes have three color receptors, with the maximum sensitivity for ultraviolet, blue, and green parts of the spectrum, and their exceptional color perception is optimally adjusted to the look of flowers. Yet, this is not all because, while flying, bees do not see a world in color. According to one school of thought, they see everything as black and white, and according to the other—as green and white.

Bees' sense of smell is much more developed than ours so recently they have been used to detect explosives and drugs. Unlike humans, bees are sensitive to the Earth's magnetic field and can spot the patterns of polarized light and thus determine the sun's position at any given moment. These two characteristics are crucial for performing *dances*, which we will talk about in more detail later.

During *orientation flights* that last only several minutes, bees briefly leave their nest, flying in different directions and thus *mapping out* the hive's position in relation to the surroundings: the sun's position, the landscape, and typical landmarks, like trees, bushes, and other nearby highlights. To help young bees return to the nest, older bees often *stand* at the entrance with their Nasonov glands open, releasing the characteristic odor of *geraniol* and dispersing it with their wings.

A relatively small number of older bees do the scout work, searching fields for new flowers. After certain flowers have attracted the attention of scout bees, it takes other bees only several minutes, or half an hour at the most, to come to the exact location, and their number is increasing so quickly there is no chance that each one of them has found this food source on its own. So, scout bees have informed newcomers about the discovery of the location and *trained* them to assist in collecting nectar and pollen.

CHOREOGRAPHY IN THE HIVE

At some point in the last 60 million years, honey bees made a significant *discovery*. They learned how to communicate through dance and thus coordinate and concentrate the collection of necessary materials from nature with maximum efficiency! And all that with a brain the size of a sesame seed!

The communication between bees is very complex and has yet to be fully understood as it includes an entire set of behavioral models that happen in the hive and beyond. One of the most important segments in this chain of information flow is the so-called dance language, which was discovered by Karl von Frisch. Over time, it has become one of the most intensely studied animal communication models.

A bee that has discovered, let's say, a blossomed cherry tree will go back to its nest carrying some

nectar and hand it over to bees responsible for receipt of supplies, and then leave the hive again and go back to the same tree. This scenario will repeat multiple times, each time a bit faster, because this bee will arrive at the destination via a shorter and shorter route. Once it finds the quickest route possible, which will happen approximately after ten flights—the bee will start *dancing*.

If the food source is at a greater distance, guidance to the exact location will be more helpful because the search itself would take considerably more time. Bees strive to secure assistance from fellow tenants, sending them information through waggle dance. In this dance, one can detect the details of the route leading from the hive to the food location.

The waggle dance refers to the segment when bees stand on vertical honeycombs waggling (shaking or trembling) their body from one side to the other for 15 seconds on average. Then, a bee makes a circle and goes back to the initial position, where it began waggling, then it does it again, then again goes full circle, but in the opposite direction, so these two routes, when viewed together, resemble the number eight. This entire dancing cycle lasts only several seconds and unfolds within a diameter of 2-5 cm.

What is the purpose of this behavior? To answer this question, let's first see how we would help someone reach the destination via the shortest possible route. When you explain to someone how to arrive at a specific location, it looks like this: you need to go 100m straight down this street to the building x, then turn left and walk straight to the second intersection, then turn right, and go straight for 50m to the restaurant y. This complex set of signs is not a problem for us, but it far exceeds bees' capabilities. However, they do not really need it because, unlike us humans, they can fly in straight lines. In their case, the shortest possible route can be described in instructions for just one direction leading to the destination, while the route length can give information about the distance.

Having closely watched bees dance for umpteen hours, Karl von Frisch observed that the angle at which bees performed their dance changed over the course of the day although they visited the same food source. The only thing that changed, besides the angle, was the sun's relative position in the sky. During a foraging flight, bees with their compound eyes detect the sun's position and then, when they come to the podium, they actually *translate* it into the direction of gravity so that the sun's current position constitutes the vertical axis and makes a certain angle with the direction in which the food is located. Hence, the dancing bee waggles at the angle relative to the sun's current position, which other bees should follow to reach the food source. If the sun is hidden behind clouds, the patterns of polarized light *reveal* its current position to bees. We should underline that the verticality of honeycombs makes it possible for bees to *dance*, as only under this condition can they translate the sun's location into the vertical axis with astonishing precision. What is especially interesting is that this kind of communication does not exist among other social insects such as bumblebees, wasps, and most stingless bees.

The waggle dance also carries precious information about the distance from the food source to the hive, which is not always the most precise, or so it seems. In fact, the longer the waggle dance, the greater the distance bees need to fly to reach the food source. However, the waggle dance duration is proportionate to the distance only in the first several hundred meters, and as the route gets longer, the information becomes increasingly imprecise. Even the most attentive observers would find it difficult to decode whether some food location is one or three kilometers from the hive.

HOW DO BEES MEASURE DISTANCE?

In the mid-1950s, it was speculated they did so by *measuring the energy* spent during a foraging flight. Yet, suspicion was stirred after observations that bees' distance estimates could be manipulated. Esch and Burns placed a food source at 70m from the hive and noted down the information that scout bees presented through dance upon their return. Then, they attached a feeder to a balloon and slowly raised it to a height of 90m so the stretch between the hive and food increased from 70m to 114m. Hence, foragers were expected to signal a greater distance with a longer waggle dance. However, through observations of their dances, it was established they *had an impression* they had flown a 50 percent shorter distance, which clearly indicated that bees' distance perception did not rely on the energy spent for that effort.

Since the landscape reeled past more slowly at greater heights, Esch and Burns concluded that scout bees processed the speeds at which visual contours changed in the eye (optical flow of images) and linked that to the flight length.

To prove this hypothesis, Srinivasan and associates did experiments in 2000, testing bees' perception of distance by training them to pass through a narrow tunnel. As it turned out, they massively exaggerated the route and informed their fellow tenants through dance that they flew over 195m, although the actual range was only 6m. This means that while watching the waggle dances, *observer* bees may be misled to believe that in their search for food *dancers* visited remote locations that they had never really seen. —Ⓔ

Author is the editor of Elements.

INTERVIEW

Branislav Kisačanin, PhD
leading AI advocate
Institute for Artificial Intelligence of Serbia

AI is Here to Empower us

Quantum physics emerged about a century ago, relying on mathematical analysis, linear algebra, and probability theory. The very same mathematical disciplines, when combined a bit differently, form the foundation of today's artificial intelligence

By
Bogdan Đorđević

Photographs by
Vladimir Janić

THE GLOBAL MARKET for AI-related products was worth USD 340 billion in 2021, and then in 2022 reached an impressive USD 500 billion. Exactly two years ago, the Serbian Government decided to establish the Institute for Artificial Intelligence Research and Development of Serbia with its headquarters at the Science and Technology Park in Novi Sad.

We spoke with Branislav Kisačanin (PhD), a leading AI advocate from the Institute for Artificial Intelligence, about how to enter this increasingly lucrative market, why it is essential to talk to young people about AI, how it empowers us all, and the role of mathematics in all of this. As Kisačanin emphasizes: "To successfully engage in AI, one needs a lot of knowledge, personal talent, strong motivation, and mentorship support."

After completing his studies in electronics and telecommunications at the Faculty of Technical Sciences in Novi Sad, Kisačanin went to the United States. He finished his PhD at the University of Illinois in Chicago in 1998. Soon he found a job at a large automotive company in Indiana, where he had an opportunity to solve practical problems on a daily basis, which helped him learn new things and establish a new area of research. He was among the first scientists to understand that, in the field of computer vision, they could not always rely on the most powerful computers. This realization led to the emergence of a new discipline called *Embedded Computer Vision*. Kisačanin organized a number of conferences on this topic, published several books, and met numerous scientists, professors, and successful entrepreneurs in the field of high tech along the way.

"What does it take to get involved in AI? You need to know mathematics, be familiar with computers, understand business, and know how to work with people."

Kisačanin, who was the best high school student in his generation at the Novi Sad Gymnasium "Jovan Jovanović Zmaj," got to love working with young talents so he is glad to have an opportunity to share his knowledge, alongside renowned Romanian mathematician Titu Andreescu, with high school students in the United States and around the world. Since 2015, he has worked at Nvidia, a company well-known for its chips and graphics cards for gaming. Today, Nvidia stands at the forefront of all AI-related developments, and Kisačanin wanted to share the experience he gained during his career to talents in Serbia. In that effort, the Institute for Artificial Intelligence will play a key role, joining forces with the Center for the Promotion of Science to enrich the program of the May Month of Mathematics event.

As a leading advocate for AI technologies, you have made it clear in your media statements that you see the Institute as a kind of *factory* for leaders in the field of AI. Can you tell us more about the Institute's goals?

AI really requires extensive knowledge, and when we founded the Institute, one of our goals was for it to become a kind of *factory* for leaders in this field. We wanted young people who come here to enhance their knowledge, enter the global arena, and immediately explore opportunities for commercialization. Our intention is to wholeheartedly support our people, whether they choose to leave or remain at the Institute. They should focus on creating companies and opening new jobs. I believe that aiming for just one percent of this vast global market, currently valued at around USD 500 billion, is not overly ambitious. AI is 90 percent mathematics, so considering the success of our students in major mathematics competitions, you will understand why I think we can raise the bar and aim higher, at two or three percent.

At the Institute, we currently have around twenty PhD holders and another twenty postgraduates working on their doctorates. Depending on their level in this game called a career, they have different responsibilities. The main task for those pursuing PhDs is to learn as much as possible and publish high-quality scientific papers. Older members also need to expand their knowledge, as none of us has learned everything there is about AI—far from it. Those with slightly more experience and PhD degrees should use their contacts—both in academia and industry—to implement as many collaborative projects with other institutions as possible. Our most experienced scientists and team leads also have the task of securing EU-funded scientific projects, which is not easy to achieve, given that a success rate is around ten percent.

The Institute is a new player, and it is not easy to enter the game when you are new. Our goal is to elevate our game to the global level as soon as possible. So-called mentorship projects are another thing that is very useful for us. While we were still in the process of establishment, I activated my network of contacts and connected with people working as professors across the United States and Europe. All of them enthusiastically accepted to participate as mentors to our employees because, like me, they want to contribute to their country. After all, we all grew up here and received free education. They are really on the frontlines of creating new knowledge, so thanks to the mentors, our employees can see the latest trends and immediately bring their ideas in line with them. We also get the opportunity to publish in top journals and participate in major conferences, which really counts. Scientists thus gain prestige, and their reputation raises the profile of our institution.

So far, you have had the opportunity to share your knowledge and rich experience with high school students at the Mathematical Grammar School, the Sixth Belgrade Gymnasium, and the Gymnasium "Jovan Jovanović Zmaj" in Novi Sad. Soon, you plan to visit high schools in other cities across Serbia. Why is it important to talk about AI with young people?

When I was a high school student, professors from the Faculty of Sciences and the Faculty of Technical Sciences came to our classes to talk about mathematics and physics. This made a major impact on me and my classmates, some of whom are now esteemed professors worldwide. Those popular science lectures intrigued us, and we felt we could engage in top-notch science. We realized that we did not have to strictly follow old trends and adhere to family traditions, but could also explore areas we were passionately interested in. I think it is useful to tell kids that getting involved in the discussion

about AI is not so difficult. It is far from impossible. And what does it take to get involved? You need to know mathematics, understand computers, know a thing or two about business, and know how to interact with people. For some other disciplines, you may need much more, including expensive technical equipment, whereas in AI—mathematics is really a key factor.

In addition, I believe it is important to convey to them that knowledge pays off. It is no longer just something beautiful and useful, but also lucrative. I strive to give students a broader picture of the most important discoveries in the field and show them the latest applications so they know what to expect in the near future. It seems that ChatGPT has come as a surprise to everyone. If AI soon finds application in fusion-based nuclear reactors, you should not be surprised because such efforts are already under way. The revolution happening in the pharmaceutical industry is also AI-driven. All this should encourage young people to get involved. Finally, why should not they have a piece of that big cake?

You believe that mathematics, programming, business knowledge, and work with people are the key factors determining how successful someone will be in the AI product market. I am pretty sure that you did not just casually mention mathematics first. Can you explain why mathematics is so important when we talk about AI?

I will first tell you an interesting fact. Quantum physics, which has brought us electronics, modern materials, and medical devices that allow us to peer into a patient's body without invasive procedures, emerged about a hundred years ago as a combination of mathematical analysis, linear algebra, and probability theory. The same mathematical disciplines, when combined differently, also form the foundation of AI. To even come to a situation where you discover a new algorithm or AI application, it is necessary to have an excellent command of mathematics. And not just the mathematics taught at the undergraduate level, but also at the postgraduate level. Partial derivatives, continuity and differentiability of functions, matrix factorization and their singular value decomposition, multidimensional probability distributions, and parameter regularization are just some mathematical terms that are part of everyday professional language. Without mathematics, you cannot possibly understand discoveries made so far, let alone create something new. Just like physics relies on mathematics as a thinking tool, AI does so even more. While experiments and physical intuition play a big role in physics, in artificial intelligence, mathematics is truly at the foundation of everything we do.

"To even come to a situation where you discover a new algorithm or AI application, it is necessary to have an excellent command of mathematics. Without mathematics, you cannot possibly understand discoveries made so far, let alone create something new."

There is often this fear that AI will replace or even destroy our civilization. Is there a reason for concern?

There are justified concerns, but what is certain is that the AI we are currently developing does not pose such a significant threat. The current focus is on empowering us with AI rather than replacing us. One day, we will probably reach a point of so-called *general* AI, which could be much more dangerous, but for the time being we are nowhere near that. Of course, it is important to be careful about what we do and how, even with this *narrow* AI, so as to prevent misuse. Of course, there is always a risk that someone might misuse even the best tool or the most advanced scientific discovery, which is why we have police and laws.

In which areas is AI already empowering us?

Whenever you google something, you activate their AI program for quick access to reliable information. Autonomous driving systems are already widely used in Tesla vehicles and are expected to help address shortages of truck drivers in Serbia, Europe, and the United States. The situation is not much different for lawyers, doctors, and engineers. For example, some lawyers may lose their jobs, not because AI would replace them, but because other lawyers would use AI and be much more efficient and productive, allowing them to reduce prices for their services. I was in elementary school when calculators appeared. Back then, you could hear people saying: "Oh no, what will happen now? We will become stupid." And what happened in the end? Well, nothing. We simply became more efficient, and no one ever regretted introducing calculators.

I would also like to tell you about the situation in the pharmaceutical industry. To determine the three-dimensional shape of proteins, which defines their metabolic function, we have so far had to send molecules for analysis in specialized laboratories that perform so-called X-ray crystallography and then wait on results for months. So, this process required considerable time and money. DeepMind, a UK-based company owned by Google and famous for programs for playing chess and Go, has drastically accelerated the entire process with the help of the *AlphaFold* program. They have created software that learned the *language* of proteins, or how to translate the sequence of amino acids that make up a protein into a folded, three-dimensional shape. *AlphaFold* completes this in a fraction of a second, which is the final and crucial part in computerizing the entire process of discovering new drugs.

It seems there is always something new and unpredictable happening in the field of AI?

When it comes to AI, there are always some new and exciting discoveries. We see it in the news almost every day and read about it in scientific journals. Considering that AI is a rather young field, someone who gets involved now still has a great chance of making new and important discoveries. Here are a few examples. Some papers published last year first indicated that scientists and engineers were using AI to control plasma in fusion reactors and that they managed to make the fusion process in tokamak machines last ten times longer than ever before. AI has learned how the plasma *wriggles out* from the magnetic field and how to adjust this field to bring the plasma back to the desired shape.

“I find it truly fascinating how quickly AI can move from an idea and scientific discovery to commercialization. It has never happened so quickly. Never! But a new era has begun —the AI era!”

Or weather forecasting: the Earth is too large, and the system is too complex for computers, no matter how powerful, to quickly solve the necessary thermodynamic equations. This is why approximations are used, and long-term weather forecasting cannot be as precise as short-term forecasting. However, with the help of AI, which does not directly solve these equations but observes the behavior of weather systems, things are changing. When you look at a small area, it all seems quite unpredictable. However, when you see the bigger picture, there enters AI to learn the behavior of complex systems.

The first success of current AI was in image analysis in 2012. Initially, AI showed us whether there was a dog or a cat in the picture, and we quickly moved on to more complex things. Then, similar principles began to be applied to speech recognition. However, speech and images are very different things. In images, the immediate vicinity of each pixel is the most important. In speech, within a single sentence, there can be very important connections between the beginning and the end. Therefore, proximity is neither of crucial importance nor the same principles apply. Proximity is important, but distant relations are significant too. Something you said in the previous sentence is often implied in the next. That is why scientists started analyzing speech with quite different networks than those used for images and managed to connect distant words. Then, the scientists working with images said: “This is not irrelevant to us either.” This connection became particularly significant in images where objects were hidden so only parts of them were visible. So, they benefited from the same principle based on transformer networks. These networks have been mentioned lately because of ChatGPT. The letter T in GPT stands for “transformer.” Generally, this principle is now applied to images as well. It is an entirely unexpected discovery because image research was heading in one direction, and then transformers from the field of speech recognition suddenly *rushed in* and proved to be extremely useful for some complicated situations.

As we can see, AI has found extensive application in various fields—from the pharmaceutical and automotive industries to internet search and weather forecasting. Is there any discovery that has particularly fascinated you recently?

I am delighted every day with what I read. All these discoveries are based on machine learning. This means that you can give a computer a small program that does not know anything yet, but can learn. You provide it with a lot of labeled data. Then, that little program looks at the data and tries to change its parameters and learn a new field—no matter whether it relates to the behavior of proteins, weather systems, or plasma in a fusion reactor. These are all fantastic things.

When *AlphaFold* announced its discovery, I found it incredible, and after just two years, it has already caused a revolution in the pharmaceutical industry. It involves massive investments. Let me illustrate: a guy from our country, while still a student in New York, along with his professors, came up with a different idea of how to observe protein folding than *AlphaFold* did. I want to emphasize that they did not have significant resources. They only patented the idea and created a company to develop it further. Their objective was to find an investor and commercialize the product one day. On the very day they were supposed to sign a contract with the investor, they received a call from a major pharmaceutical company that told them to forget the others because they offered much better terms and conditions and more money. So, our compatriot who sold the business to a major pharmaceutical company has now become a high-ranking director. I find it truly fascinating how quickly AI can move from an idea and scientific discovery to commercialization. It has never happened so quickly. Never! But a new era has begun—the AI era! —Ⓔ

The author holds a degree in Journalism and is currently pursuing studies in Sociology at the Faculty of Philosophy in Belgrade. He gained journalistic experience by reporting from sports events. He joined the Center for the Promotion of Science in 2019.

INTERVIEW

Professor René Bernards

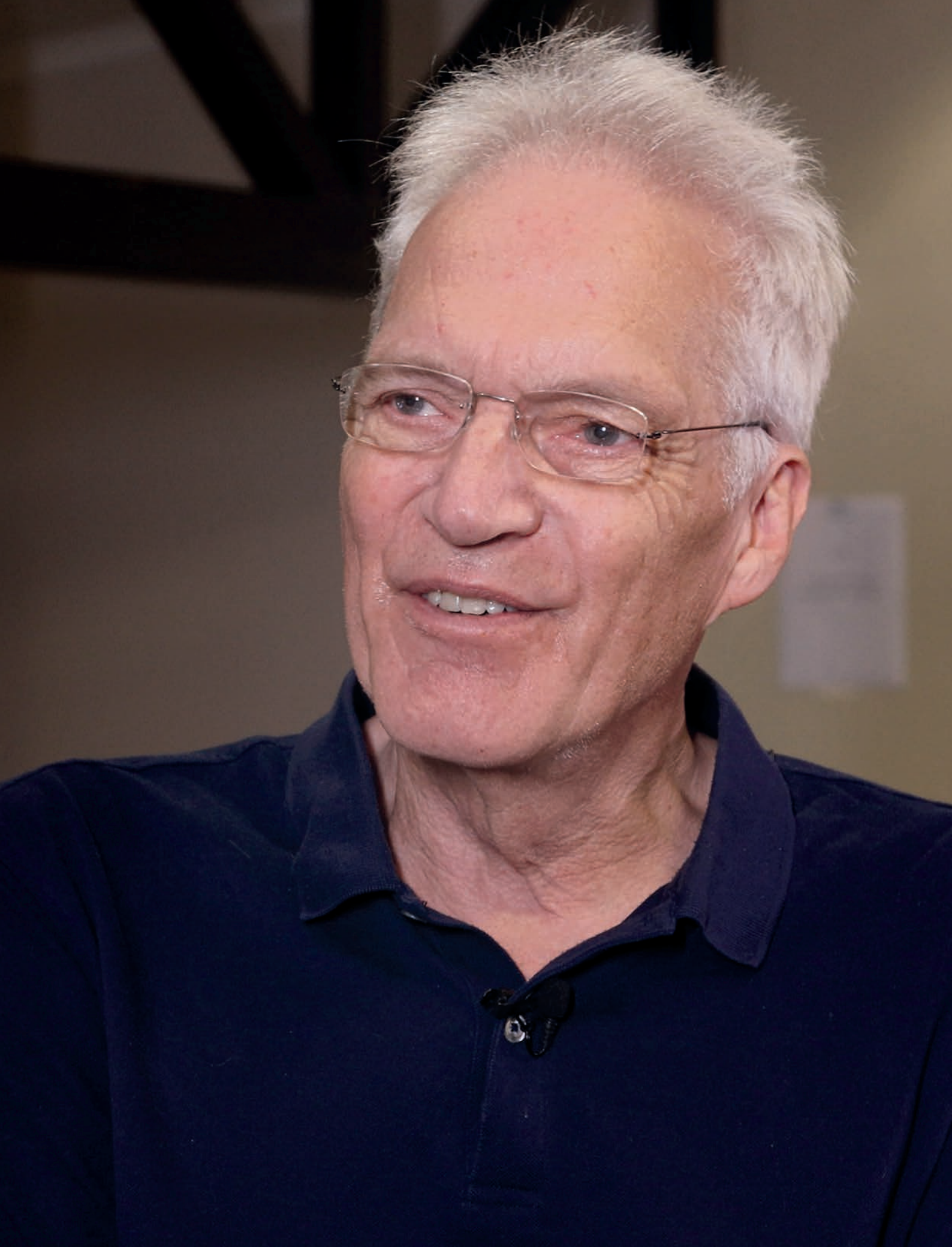
You Need to Think Outside the Box

On the sidelines of a conference that the Serbian Association for Cancer Research hosted in Belgrade in October 2023, Professor Bernards gave an interview to the Center for the Promotion of Science in which he spoke about innovative cancer research, his team at the Netherlands Cancer Institute, and their patents that save thousands of patients a year

By
Ivana Nikolić

Photographs by
Bojan Živojinović

RENÉ BERNARDS IS A PROFESSOR of molecular carcinogenesis at the Netherlands Cancer Institute in Amsterdam and the president of the European Association for Cancer Research. In early October, Professor Bernards was a plenary speaker at the Sixth Congress of the Serbian Association for Cancer Research entitled *From Collaboration to Innovation in Cancer Research*, which brought together around 200 experts from Serbia and abroad, in an effort to foster national and international collaboration. The Belgrade conference focused on clinical and translational research, tumor metabolism, epigenetic and genetic regulation, therapy resistance, immuno-oncology, precision medicine, as well as bioinformatics, and artificial intelligence as necessary tools for omics research. Young researchers had an opportunity to talk to Professor Bernards and other leading experts in the field at an informal session titled *Meet the Experts*. On the sidelines of the Belgrade congress, we talked with Professor Bernards about his engagement at the European Association for Cancer Research, his successful team at the Netherlands Cancer Institute, and the tests they patented that are today part of the most effective cancer therapies.



"People are either conservative, risk-averse, or adventurous and dare to be creative. It is my experience that people come in two flavors. Some have a career plan and they say: *I want to get a PhD in four years so please give me a simple, straightforward project, where I can solve the problems in four years and then I can take the next step in my career.*"

Professor Bernards, you are a plenary speaker at this conference here in Belgrade. Have you got the time to attend some sessions, and what is your impression so far?

So, I saw some younger investigators presenting yesterday afternoon, and two things struck me. One is the enthusiasm of both investigators and participants during active Q&A sessions. And the other thing that surprised me was the depth of knowledge. It has been a real eye-opener for me to see such a deep knowledge of cancer biology here in Serbia.

You spoke about optimism and enthusiasm. Is that something you often see when you give presentations across the world, or is it something rather specific for this congress?

You do not see that all the time, unfortunately. I would have hoped that when young people go into cancer research, they do it for the drive, that desire to solve the problem that we call cancer. At least, that is why I did it 40 years ago, right? And I see that less now, and I find it really refreshing to witness that desire to know and enthusiasm to solve the problem in people here. That is really refreshing, and we should see it more on a global level than I do because I do not see it all the time.

Your upcoming session will be titled *Meet the Experts*. What will be your key takeaways for students and participants? Do you have any specific message for cancer researchers in Serbia?

I think I have two messages for cancer researchers. The theme of this conference is collaboration and innovation. Collaboration is a must because cancer is such a big issue, and technologies are so complex that you can never master them all. So, you need to partner with people who can help you solve your question. So, you need to be an extrovert. You need to engage and interact to convince people to work with you. And that is a must-have trait for success in cancer research. You must be outgoing and interactive. So, be that. Otherwise, you will not get very far. And that is a critical issue. And the other thing I would like to say is something I already said yesterday during my lecture: *if you do what you did, you get what you got.* You need to dare to be different. Do different things than everybody else. This is how you stand out from a crowd. This is how you make a difference. I know it is hard, but you need to think very deeply about how you can be different from the rest, stand out, and do something truly original, because in our field change comes from disruptive innovations. And disruptive innovations boil down to simply doing something radically different. That is hard because you really need to understand the problem and what everybody is doing. Yesterday, I gave an example: *let's say everybody tries to inhibit oncogenic signals to solve cancer. What if we do the opposite? What if we stimulate them to grow faster? They would probably die as well, and they do*. So, that is one of those examples, where you say: *dare to be different and see what you get*.

Think outside the box.

Think outside the box. This is how you make progress, and this is how you make a career for yourself. It is hard because not every stupid idea turns out to be a good one. Not every unconventional idea will get you somewhere. So, this is a big challenge in this field—how can you be different and at the same time make progress in the field? This is where the trick lies. It is not easy. I tell you, it is not easy, but it is worth doing.

I suppose practice makes perfect. It is important to be persistent in testing ideas.

You know, there is this joke about a train driver going across a railway crossing and saying there is no possibility of a car ever crossing the railway track because the ramp is always down. But that is what you call a biased observation. When the train driver goes across the railway crossing, cars cannot. So, he thinks they can never cross. So, by analogy, I speak about successful experiments at my lab because I do not come to a conference to talk about failure. Hence, people may think that everything I do in my lab is a success, which is, of course, not

true. We have ten ideas, and one works out, and I get to talk about the one that works out. But for every success, I have nine failures. So, you need to accept failure. And that also means that if you have an experiment, you have an original idea, you should never fall in love with your hypothesis. For example, I have some crazy idea and now I want to pursue it no matter what happens. If the first three experiments tell me—*you are wrong, you are wrong, you are wrong*—then I should stop and think of something else. So, giving up on an idea is sometimes hard to do because you can fall in love with your own idea, and you should never do that.

Over the course of your career, have you ever fallen in love with your ideas?

Yes, I have. And I have paid the price, right? Because you need to. At some point, you realize that your love was not reciprocal, that the idea was simply wrong. Then, you should find a new love. So, find a new idea and get excited again. Like in real life, when you get excited again about a new person you meet, a new idea will hopefully pull you out of your depression.

These are all very interesting thoughts about science, especially because we always expect scientists and researchers to be serious. Yet, this is a very insightful conversation full of anecdotes.

Well, I think scientists are just humans, right? In that sense, there is nothing different about being a scientist. I think the difference between a scientist and a person having a regular job is that I have never worked a day in my life.

Because you love your job?

Because I love my job. I do not go to work to earn an income. I have found an idiot who is willing to pay me to do my hobby—the director of my cancer institute (laughter).

You should tell that to the participants.

I have never worked a day in my life because I love doing what I do. Now, I am 70 years old, three years

"And you have people that are rare, much rarer, that say: *give me something that is a real challenge because I really want to solve this problem*. And those are the people that are going to make a difference in the field. They are rare. Maybe, one in 50 that I get into my lab has that mentality. But those are the people that are going to make a difference."

post-retirement. I go to the lab every day. Why? Because this is the thing I want to do. That is really amazing.

You work in the lab, but you also run the European Association for Cancer Research. How does that work? You have around 12,000 members across all the European countries. What does your job entail, and how do you like it?

Well, it is not as tough a job as it looks in terms of time commitment. We have a very good staff at the EACR main headquarters in Nottingham in the UK. We have the CEO, which is a full-time position. And those are the people that actually run the organization. The president is a figurehead. But there are a number of things that I do. I am also assisted by a board of directors and some 15 leading scientists in Europe. Together, we decide which conferences to organize, how to serve our members, because that is our duty. During COVID-19, it was all about virtual conferences, and now we are back to in-person meetings, thank God. Now that no one likes Zoom any more, our annual meetings are becoming even more successful. We had more than 2,000 people in Turin, and we are looking forward to Rotterdam in June 2024.

So, we do many things: we award fellowships, travel grants, and small prizes to encourage people. We have recently established what we call an *early career investigator council* with young scientists who advise us, because when you make it to the board and to the presidency, you are older, you are not young anymore. And we want to serve the young. So, we need to have our antennas in the young crowd. And we have this young advisory board to tell us what they think we should be doing to serve younger investigators. Typically, our members are early-career scientists.

What are younger cancer researchers saying? What would they like you to do?

Well, for instance, at the 2024 annual meeting, they will have their own session to invite speakers they would like to hear. So, they will be given a chance to run the show and we will see how that goes. That will be their first time, and we will see what the program will contain. We have given them complete freedom. They have organized a virtual meeting on creativity in research. It touches on what I have just said about daring to be different.
Grants typically have aims and milestones, where you promise *I will do this* and *I will do that*, and *what the outcome will be*. How can you promise an outcome if you have yet to do an experiment? So, the grant system forces us into a rigid line of experimentation, but real breakthroughs come from these creative experiments that are never part of a work package or have a specific aim. So, how do you bring that creativity back into your research? That is what they had a brainstorming session on at a virtual conference. And there were some really original ideas from younger people that people can learn from.

You talk a lot about creativity. Has it always been like that? Were you creative when you started 40 years ago?

Yeah, it was in 1980. So, it is even worse (laughter).

Did your professors teach you to be creative? Or is creativity something you have developed over the years?

I learned it very clearly from Richard Flavell. During my last master internship at the University of Amsterdam, I was under the guidance of this British scientist who was completely creative, out of the ordinary. And he used to say that no problem was big enough, or that you could solve it if you really set your mind to it. He said the brain could solve any problem whatsoever. And if you could not solve it, you just did not want it badly enough. And that was his motto. He said that you should just go for it. And that stuck with me my entire career.

Then, I got to do my PhD in a completely unimaginative lab. I brought a completely different

attitude into that lab. Back then in 1980, it was not allowed to do recombinant DNA research in the Netherlands and I was working on adenovirus transforming genes. I told them that the first thing we needed to do was to clone the genes; otherwise, we could not make mutants and study their function. And the answer was simple—gene cloning was not allowed in the Netherlands. So, I said ok, then I would go to the UK because it was allowed there. And they told me that I would need to apply for a fellowship and that would take six months. Then, I replied I did not have six months to spare and that I was going to the UK the following week and I was going to clone those genes, and later I would worry how we would pay for that. And the lab was not really used to that kind of attitude. But three months later, I cloned all the transforming genes. And we were trying and beginning to make mutants in those genes and study their function. And we learned a lot from that. Again, dare to think outside the box. *If I cannot do it here, I will do it there. You think you want to do it. And then you think, how am I going to make that happen? Right. And that is often how things get done in science.*

I suppose that your mission now is to pass on that creativity to your students and other younger colleagues.

The problem is that you simply cannot pass that on. Some people have that in themselves and others do not. It is not an acquired trait. People are either conservative, risk-averse, or adventurous and dare to be creative. It is my experience that people come in two flavors. Some have a career plan and they say: *I want to get a PhD in four years so please give me a simple, straightforward project, where I can solve the problems in four years and then I can take the next step in my career*. And you have people that are rare, much rarer, that say: *give me something that is a real challenge because I really want to solve this problem.* And those are the people that are going to make a difference in the field. They are rare. Maybe, one in 50 that I get into my lab has that mentality. But those are the people that are going to make a difference. Dare to be different. That is my message. —Ⓔ

Ivana Nikolić holds a B.A. in Journalism and Communication from the Faculty of Political Sciences in Belgrade. She has been working as a journalist since 2014.

The Mortar Connecting the Past and the Future

Just like the Romans did, researchers are trying to use locally sourced materials to make compatible mortars that would help cut down on the use of cement mortar in Serbia's conservation efforts

Photographs by ***Marko Risović***

By
Đorđe Petrović

THE ROMAN EMPIRE ruled the territory of today's Serbia for several centuries and left behind numerous structures built by ancient engineers and builders with amazing skill and knowledge. What is especially fascinating about these buildings is their durability—the fact that, after almost 2000 years, they still withstand the ravages of time.

One of the secrets of their miraculous longevity lies in Roman mortar. This bonding material not only holds together the building blocks but represents a strong link between the location's past and present, providing insight into ancient construction

techniques and connecting us directly to precious heritage.

However, no matter how strong and durable they were, these buildings—and especially those that underwent historical destruction and later decay (which is often the case with monuments in the territory of today's Serbia)—needed occasional, sometimes thorough, conservation interventions and works, so as to be renewed and better preserved for future generations.

But the problem is that until recently, even in the most developed countries, these conservation works only applied modern materials such as cement, and in recent decades it has been shown that not only such materials are not the best solution because they impair authenticity, but they can seriously damage the buildings.

To find suitable mortar designs for the conservation of Serbia's ancient heritage, an interdisciplinary team of researchers—gathered around the scientific project dubbed MoDeCo2000 (Mortar Design for Conservation—Danube Roman Frontier 2000 Years After), which has received funding from the Science Fund of the Republic of Serbia under the PROMIS 2020–2022 Program—decided to investigate Roman sites along the Danube River in the territory of today's Serbia and find out what sorts of materials Roman builders used to make their mortars.

Researchers from three scientific institutions—the National Archaeological Institute, the Faculty of Technology Novi Sad, and the Institute for Testing of Materials (IMS)—conducted thorough research and collected samples from more than twenty archaeological sites, with a particular focus on those under conservation or soon to be.

All these sites—for which the Archaeological Institute and the Serbian National Institute for the Protection of Cultural Monuments are currently preparing nomination files for the UNESCO World Heritage List—are located along the Danube Limes in Serbia.

The Limes was a fortified border of the Roman Empire, over 7500 km long, which partly passed through the territory of today's Serbia, along the Danube. In the Serbian part of the Limes, the Romans built numerous military fortifications—such as Ad Herculem in Čortanovci, Lederata in Ram, or Diana near Kladovo—next to which civilian settlements often formed and developed, as was the case with Viminacium and Singidunum.

In addition to these three ancient fortresses and two towns, the list of sites that the researchers visited and examined includes the Roman tomb in Brestovik (not far from Belgrade) and the remains of Trajan's Bridge near Kladovo. The plan is to examine the remains of Sirmium in Sremska Mitrovica to compare samples and better understand the results obtained.

The researchers selected more than 100 samples from these sites, whose strength, chemical composition, and many other characteristics, were tested in their laboratories. This collection of samples, which to ordinary people may seem like an interesting but shapeless bunch of stones, for the scientific team of the MoDeCo2000 project represents a kind of text from which they can read various information and reveal many secrets about Roman mortar.

One special quality that helps the team a lot is multidisciplinarity.

"It is really important to have different experts in the team—archaeologists, architects, technology engineers, chemists, geologists, physicists, etc.—and that each of them, within his/her field of expertise, can contribute to the interpretation and understanding of the story told by the field samples. And they can really tell us a lot," says Helena Hirschenberger, PhD, an associate at the Faculty of Technology in Novi Sad and one of the external associates on this project.

"It is precisely thanks to such a multidisciplinary approach that we can understand how the Romans lived and how they built buildings in our region, what was important to them during the construction, how the building knowledge from the center was used on the edges of the empire and what raw materials they used."

Roman builders, like everyone else throughout history, experimented with different ingredients to make mortar as resistant and firm as possible, and legends, including old records and some new research, say that in addition to eggs, rice, milk, lard, and olive oil, they sometimes used animal blood. What is known for sure is that they considered various factors, such as climatic conditions and the availability of materials.

"Unlike the Egyptians, who mostly used gypsum as a binding material, the Romans could not count on such a dry climate in all parts of the empire, so they used lime. But they did not stop with just lime. They added various ingredients to improve its resistance to the existing conditions," explains chemist and MoDeCo2000 project team member Ljiljana Miličić, the head of the Laboratory for Binders, Chemistry, and Mortars of the IMS Institute.

She says that the mixture of lime and various additives had been used before for making mortars, but the Romans brought lime mortars almost to perfection.

"In the territory of today's Serbia, various materials were added to lime mortar, such as clays, fragments of different rocks, pieces and powder of fired bricks, and for light reinforcement, they used natural fibers such as straw, so basically they used what they had," says Miličić. The Romans were very economical, so during the construction they rarely brought materials from distant places and other parts of the empire, but rather relied on what was locally available.

Mixing a new compatible mortar at the IMS Institute's lab

"In Viminacium's mortars, for example, there are a lot of bricks. Apart from the fact that Viminacium was a large production center for bricks, next to it, there was an abundance of geological material locally known as *crvenka*, which we can refer to as naturally fired bricks," says another MoDeCo2000 project team member Ivana Delić-Nikolić, a geology engineer and the head of the IMS Institute's Stone and Aggregate Laboratory.

"It can be formed in deposits of various natural flammable materials, such as coal, and it is known that the area of today's Kostolac, where Viminacium is located, is very rich in coal."

Crvenka was used to construct the first ramparts of the Viminacium military camp, and later, with the establishment of brick production in Viminacium, bricks from this center were used in other nearby Roman sites along the Danube.

However, this scientist points out that, for example, in Lederata in the village of Ram, not far from Viminacium, there is a mortar full of shale, which builds the very ridge on whose plateau the fortress of Lederata was constructed. "Shale from the deposit in Rama is a green, leafy rock that has no special strength," says Delić-Nikolić as she shows us the decay of a thin green stone from her shelf, which also contains a large number of specimens of various minerals and rocks from the field.

"Nevertheless, the Romans in the wider territory of Viminacium managed to use it for masonry as the only type of stone that was available to them in large quantities, but also as an addition to the mortar in the structures of Lederata."

One of the basic principles in Roman construction was the use of locally sourced materials, which is why there are differences in architecture and building solutions in different parts of the empire, says Emilija Nikolić, PhD, an architecture engineer from the National Archaeological Institute Belgrade and the MoDeCo2000 project manager. In the Apennine Peninsula, and in other parts of the empire where volcanic materials were available, the Romans used volcanic ash for making mortar, because such mortar proved to be fantastically strong and resistant.

The famous Roman concrete—used to make the

most monumental Roman buildings, such as the Pantheon (which has lasted for nineteen centuries)—owes its strength to the hydraulic mortar made of volcanic materials.

"In the territory of today's Serbia, we do not have an abundance of quality volcanic materials from which such mortar could be made. That is why the construction techniques and mortar composition had to be modified," says Nikolić. This also meant finding a replacement for natural pozzolanic materials such as volcanic ash, which was often achieved through the use of artificial materials with pozzolanic properties—such as fired brick.

It was the most common additive used to achieve the hydraulicity of Roman mortars in this area, which is a property that, besides water resistance and the possibility of binding underwater, was also responsible for the strength of the mortar. The bricks were crushed or ground and then mixed with other available materials, such as the mentioned shale. Except in Sirmium, which was an imperial city, the imported construction materials of the highest quality were used in the territory of today's Serbia only for very significant and monumental buildings.

One of such monumental buildings, to which the Roman Empire attached great importance at that time, was the famous Trajan's Bridge over the Danube—the work of Apollodorus of Damascus, the greatest architect of his time. This building was erected in 105 AD near today's Kladovo to help the Roman legions conquer Dacia, and it is believed to have been the longest bridge in the world for more than a thousand years.

After taking samples from the remains, Nikolić and her team were convinced of the material quality and the applied construction technology.

"The mortar from the pillar of Trajan's Bridge proved to be of great strength. This material is in an incredible condition," says another team member Snežana Vučetić, PhD, a technology engineer from the Faculty of Technology in Novi Sad, the head of the Laboratory for Materials in Cultural Heritage.

"We are still trying to determine which ingredi-

The MoDeCo2000 team members examine samples from the sites

ent gives it that kind of firmness."

Since this bridge was one of the most important imperial projects at the time, researchers say they would not be surprised to discover that the secret ingredient is volcanic ash, which was brought from the Apennine Peninsula, especially for the occasion.

The MoDeCo2000 team will use all this knowledge about the secrets of Roman recipes to create compatible mortars that can be used in the conservation of sites that represent not only our but also European and world cultural heritage, and which could in a few years, as the project members hope, start to carry the UNESCO logo.

For their preservation, it is crucial to use materials and raw materials that will suit the ancient ones and imitate them, to the extent possible.

"One of the basic principles of conservation implies that materials must be compatible and harmless, i.e. they must not cause new damage to the existing historical material, since it is a very precious and non-renewable resource," Hirschen-

"The mortar from the pillar of Trajan's Bridge proved to be of great strength. This material is in an incredible condition," says Snežana Vučetić. "We are still trying to find out which ingredient gives it that kind of firmness." Since this bridge was one of the most important imperial projects at the time, researchers say they would not be surprised to discover that the secret ingredient is volcanic ash, which was brought from the Apennine Peninsula, especially for the occasion.

Top left photo: a mortar sample from the Roman site of Diana near Kladovo; Top right photo: a mortar sample from the Roman site of Egeta near Brza Palanka; Bottom left photo: mortar samples from the Roman site of Viminacium in Kostolac; Bottom right photo: mortar samples from Trajan's Bridge

"The problem is that until recently, even in the most developed countries, these conservation works only applied modern materials such as cement, and in recent decades it has been shown that not only such materials are not the best solution because they impair authenticity, but they can seriously damage the buildings."

berger emphasizes.

"For example, about thirty years ago, it happened that new materials, which then started to be used intensively in the preservation of cultural heritage, were actually conducive to the development of microorganisms that damaged the ancient material. That is how some sculptures, which were treated with new materials, ended up without parts of their noses or ears."

To avoid this scenario, the team will, before testing new mortars at a given site, examine what is happening in the contact zone between the samples of new and old mortar, and then do detailed analyses using state-of-the-art mobile equipment at the Laboratory for Materials in Cultural Heritage.

"We have a special chamber for simulating aging conditions, in which we can test certain mortar samples, expose them to accelerated aging, accelerated environmental influences that we adjust to match the environmental influences on the site—

From left to right: Nevenka Mijatović, Ivana Delić-Nikolić, Snežana Vučetić, PhD, Ljiljana Miličić, Helena Hirschenberger, PhD, Emilija Nikolić, PhD

humidity, sunlight, temperature, salt exposure—and if these samples prove suitable, only then we do have the full right to test them on the site," says Hirschenberger.

"We always perform on-site testing in a small zone, where we use the new material, and then, with the help of measuring equipment, we monitor what is happening with it and the old material below, how they react, and whether there are any changes."

Just like the Romans did in the past, researchers are trying to use locally sourced materials for producing mortar, and the proposed mortar design should help cut down on the almost exclusive use of cement mortar in Serbia's conservation efforts.

On the other hand, they expect that this project could influence the development of conservation science in our country, i.e. encourage efforts to include related courses to educate students of different specialties, and help recognize its importance for preserving not only Roman but also the entire material cultural heritage in the territory of Serbia.

"The science of conservation, which we are so passionate about, makes sense only if it is applied," said Snežana Vučetić as we observed the preparation of a new mixture at the IMS Institute's laboratory. "That is why we want the society to have some real benefits from 'our test tube.'" —Ⓔ

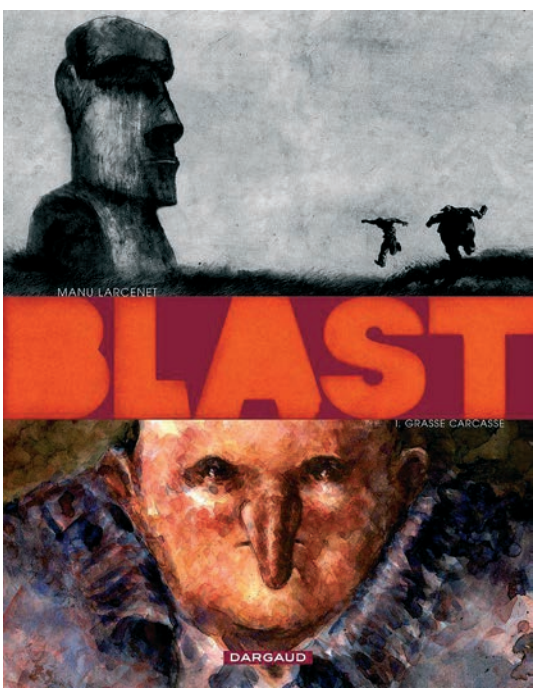
The author holds a degree in Journalism and is soon to complete his studies in Philosophy. He is currently pursuing an MA in Cultural Studies at the Faculty of Political Sciences. He joined the Center for the Promotion of Science in September 2018.

Minds Full of Fear and Hope

In the history of comics, autobiographical books on the topic of psychiatric conditions appeared relatively late. Only since the 1990s and the development of slice-of-life graphic novels have we seen authors communicating with readers in this way and talking about their state of mind. When they are authentic, the depictions of psychiatric disorders in comics bring about a better understanding in society, but may also be part of rehabilitation

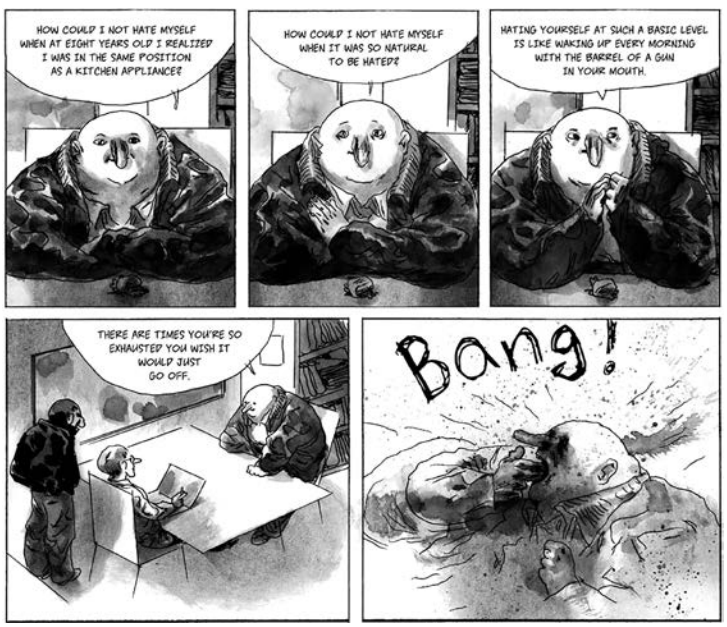
By
Nikola Dragomirović

IN 2007, NEW-GENERATION French artist Emmanuel Manu Larcenet started a brilliant project that would, as it turned out, completely devour him for the next eight years. At that point, he already had substantial fame and recognition behind him. Still, even from his famous works like *Ordinary Victories*, which contained strong autobiographical details and was later developed into a movie, we learn little about Larcenet. He was known for his light and caricatural drawings and satirical themes, with hints of introspection and anxiety. He worked with the very popular Lewis Trondheim, retreated from the city to the countryside with his family, was a member of a punk rock band in his youth, and firmly against right-wing political ideologies. But that was all. We learned more about his thinking from *Ordinary Victories*, where, in a mostly satirical environment, he stood out with his anxiety attacks. Even the six-part autobiographical series *The Return to Earth*, which contained single-page gags about his moving to the countryside with his wife, did not give us more information. We only knew that Larcenet was "funny in the head," and that was all. The fact that Larcenet rarely gave interviews and refused to appear on television also did not help much.



Manu Larcenet's *Blast*, a bipolar artist's self-destructive experiment

Larcenet used the word *blasts* to describe his main character's out-of-body experiences; he illustrated them with his daughter's drawings, and they are rare color segments in this black-and-white comic



Polza Mancini, the main character in *Blast*, eloquent, charismatic—and painfully dark

The true story about Larcenet surfaced only after 2007, when he started working on the four-part graphic novel *Blast*. Contrary to everything he did up to that point, Larcenet now published a dark story in black and white about vagabond Polza Mancini, once a famous culinary critic and a person with severe psychiatric issues. In four volumes of the *Blast* series (*Dead Weight, The Apocalypse According to Saint Jacky, Head First and I Hope the Buddhists Are Wrong*), we witness the moral and psychiatric decline of a seemingly bright and eloquent, but grotesquely fat person. In line with the theme, Larcenet depicted fragments of complete darkness, contrasted with incredibly peaceful countryside scenes combined with the main character's philosophical and eschatological reflection.

As *Blast* moved on, readers were confused to see such darkness from the author known for his satirical and humorous narratives. As a matter of fact, in his late youth, Larcenet was diagnosed with bipolar disorder, a type of manic-depressive psychosis. A person who has bipolar disorder experiences sudden changes of psychotic episodes—euphoria and good mood are quickly replaced by deep depression. This ailment is hereditary, incurable, and lasts for an entire lifetime, and if not treated properly, it can lead to suicide and use of narcotics or alcohol. Though therapy is inevitable, it can help a bipolar lead a normal life.

Larcenet did not talk about his bipolar diagnosis at that time, but only a few years later. But he did find a way to express himself and channel his struggle into art by drawing *Blast*. And he did it in a fearless and partly foolish way—he stopped taking his medications for bipolar disorder. He had the support (and patience) of his family and visited his psychiatrist regularly. But he allowed bipolar disorder to guide his hand for eight years and poured darkness on paper. "If you read it again, you can see that it is built like my disorder. It transitions from large country landscapes to depictions of extreme anxiety, then it suddenly moves to intense happiness. If I entered the studio in the morning with my mind completely down, the story that would follow would be pitch black. A few days later, I would defeat the Beast. *Blast* is almost a graphical depiction of my disorder's sinusoidal influence," Larcenet said in an interview to the French weekly magazine *Télérama*.

Through his main character, Larcenet laid his soul bare for everyone to see, and only when we know about his psychiatric condition we can fully understand the state of his maniacal mind: "How could I not hate myself when it was so natural to be hated?" This is one of the most intriguing questions that Polza/Manu asks in the comic book. *Blast* was a wild journey for Manu Larcenet. As soon as he submitted materials for the last book, he took his medications and put his disorder under control. Then, why did he go through it all? *Blast* had a cathartic

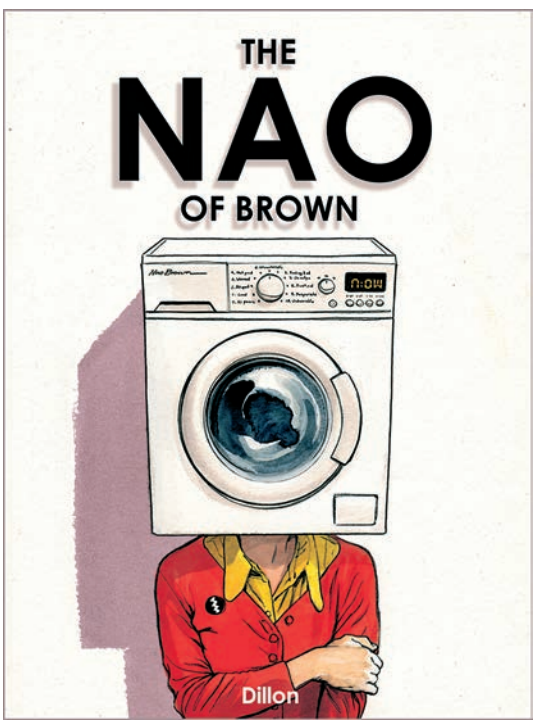
In several places in *Blast*, Larcenet inserted intermezzo segments featuring his friend Jean-Yves Ferri's single-panel gag cartoon called *Jasper, the Bipolar Bear*

effect on Larcenet. He got to know himself, and he allowed others to see the world through his eyes. And it was not a happy place. Even though *Blast* is not Larcenet's life story per se, it reflects the world through the eyes of a bipolar. And the greatest insight was that this was who he was in his original form. Or, as he put it in an interview to the French weekly magazine *L'Express*: "Marginality, violence, madness, it all had to surface. Not so that I can get better, but to express myself. I will never get any better."

Only he knows how many scars invisible to the naked eye this experience left on him. He attracted media attention because he was a mainstream artist capable of going through that ordeal. Comics, as a combined form of visual and verbal artistic expression, are a perfect catalyst for conveying the author's psychiatric experiences. Their narrative tricks and graphic versatility can depict all the states of the human soul, which is still a great unknown today. Truth be told, comics that are not part of the author's personal experience but deal with people with psychiatric disorders should be separated here. The output is far weaker when screenwriters and cartoonists without such difficulties project themselves by drawing on other people's experiences. The difference is as striking as when a war is narrated by someone who did not leave the comfort of his home, as opposed to someone who tells the story from a personal experience. However subtle, there are differences in tone and believability. That is why the Joker from the Batman comics cannot have believability and consistency despite a plethora of psychiatric diagnoses he nominally has.

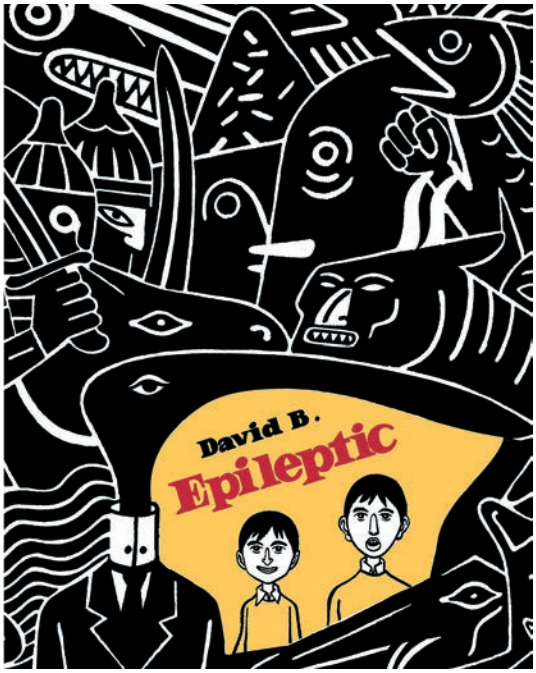
Personal experience is critical when putting psychiatric experiences on paper in a visual-verbal form. Then, the comic has the already mentioned cathartic effect on the author and educates the reader. As in the case of Frédérik Peeters's *Blue Pills*, an autobiographical graphic novel about the love between the author and a girl with HIV. Though it is not strictly about a psychiatric experience, the role of the comic is the same because the author opens up and gives answers in a graphic form that he did not have the strength or will to do in his real life. On the other hand, the implausibility of Glyn Dillon's *The Nao of Brown* lies precisely in the absence of that personal component. In a relatively successful graphic novel, Dillon tells the story of a girl with obsessive-compulsive disorder. The first association would be a person who constantly washes their hands and puts things in a certain number and order. Dillon's Nao Brown, on the other hand, is obsessed with characters from the fictional manga *Icchi*, and suffers from fantasies in which she kills people around her. Therefore, any human contact is a form of suffering for her. For example, upon meeting a pregnant woman, she imagines stabbing her in the stomach with a knife. Consequently, Nao lives in agony and fear that she would really commit these acts of violence. Although graphically perfect, with all the adequate use of obsessive-compulsive flashbacks, *The Nao of Brown* is empty and sugary. The heroine's disorder is only one layer of the plot, polished and second-rate, and above all—implausible.

Recent research efforts have identified psychiatric and mental illnesses as a scourge of modern times. According to the most pessimistic predictions, mental illnesses will claim more lives in the future than cancer and cardiovascular diseases. What is even more concerning is that mental illnesses do not hit only a specific gender or age group. Since they have been dubbed a disease of the new area, we can mainly link them to the fast rhythm of



Dillon's *The Nao of Brown* is an interesting story, brilliantly illustrated, but as the depiction of a psychiatric condition, which should have been the main plot, it is simply unconvincing

Pekar's *Our Cancer Year* tells the story about the psychological impact of a potentially fatal disease, and its physical aspects



For David B., his brother's epilepsy is like a monster

life, the influence of technology, global social networks, and a paradoxical alienation. As the world becomes more connected, young people, especially teenagers, seem increasingly detached from each other.

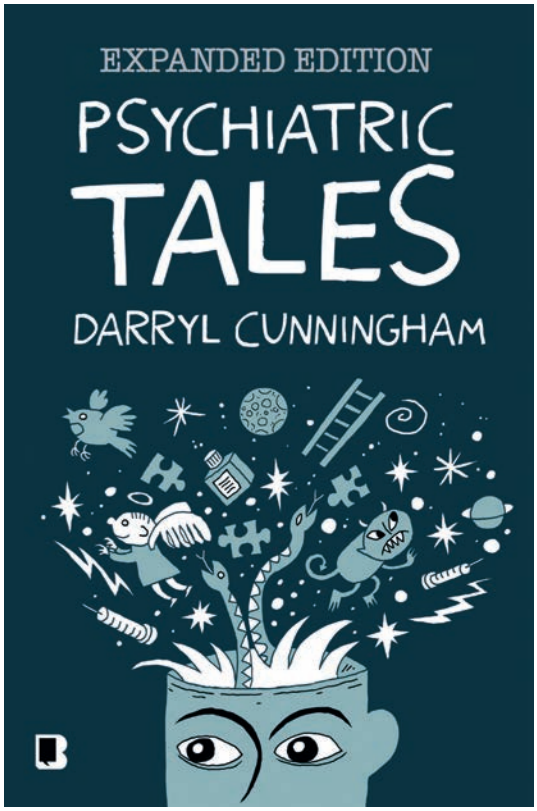
The problem is even greater because psychiatric conditions, especially depression, are accompanied by stigmatization. When it comes to schizophrenia and other hereditary disorders, there is still some understanding. But in the case of depression, anxiety, and addiction, the situation is more complex. For every reported and treated case, it is assumed that there are at least four more people who, due to fear, shame, or prejudice, refuse to recognize and acknowledge the problem. And those psychiatric conditions are increasingly prevalent across the world, mostly targeting so-called spoiled millennials.

In the history of comics, autobiographical books on the topic of psychiatric disorders appeared relatively late. In a way, comics mirrored the trend related to the development and prevalence of depression and anxiety in the world, as well as social awareness on the subject. Only since the 1990s and the development of slice-of-life graphic novels have we seen authors communicating with readers in this way and talking about their state of mind. As in the case of Manu Larcenet, it is most often a cathartic act for authors that attempt to graphically depict something for what they do not have either strength, words, or sufficient distance in real life.

However, a real turning point happened in 1987 when American comic book author Harvey Pekar discovered he had cancer. In 1994, he published the graphic novel *Our Cancer Year*, revealing without any censorship or restraint how the disease was physically and mentally destroying his body, but also his environment, above all, his family. Harvey Pekar's brilliance lies in the fact that *Our Cancer Year* does not sink into pathos, but rather minutely dissects both the psychological impact of a potentially fatal disease, and its physical aspects.

Just a step away from this graphic novel is French artist David B's superb *Epileptic* that was published in 1996. This graphic novel is rightfully considered one of the most personal and best autobiographical works. The roles are reversed and transposed into childhood. David B. depicts growing up with a younger brother who has severe epilepsy. As his brother's illness obsessively consumes the author's world, the then-young David Beauchard rationalizes this illness with brilliant metaphors. But he withdraws into himself and builds an impenetrable emotional wall, at the center of which is clearly an undiagnosed depression.

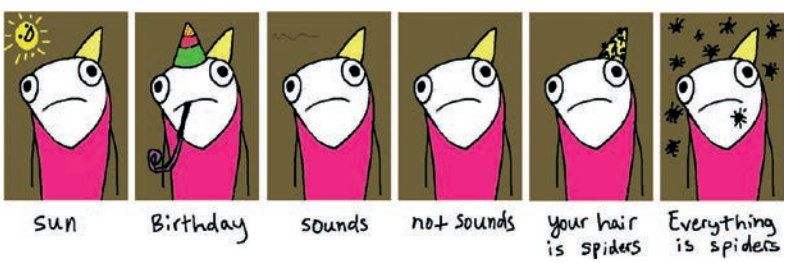
As psychiatric illnesses are becoming more frequent in the new millennium, it is becoming easier for artists to market their experiences or experiences of people from their environment in the form of comics. Nate Powell tackled the portrayal of schizophrenia in 2008 through the roles of two female protagonists. Twins Ruth and Perry have been diagnosed with a hereditary disorder but experience it in different ways. Powell's story focuses on the twins' different experiences of the condition,



Darryl Cunningham's *Psychiatric Tales*: the topic that nearly destroyed the author, but comics helped him come out of the depression. In his comic book, Cunningham points to things that are worth living for

but also the shame with which they approach schizophrenia. Both perceive it as unnatural and dirty, reflecting their environment and prejudices.

Personal experience in the presentation of psychiatric illnesses is crucial and quite often the only way to see the world from that perspective. The internet is flooded with short, often gag comics about depression and anxiety. They are also a topic at medical conferences, such as the British Graphic Medicine, dedicated to these types of graphic expression. Graphic Medicine brings together authors/patients, specialists, and experts in the field of comics. For example, Allie Brosh conveyed the feelings of hopelessness and self-hate in humorous yet strikingly poignant comics, *Adventures in Depression*



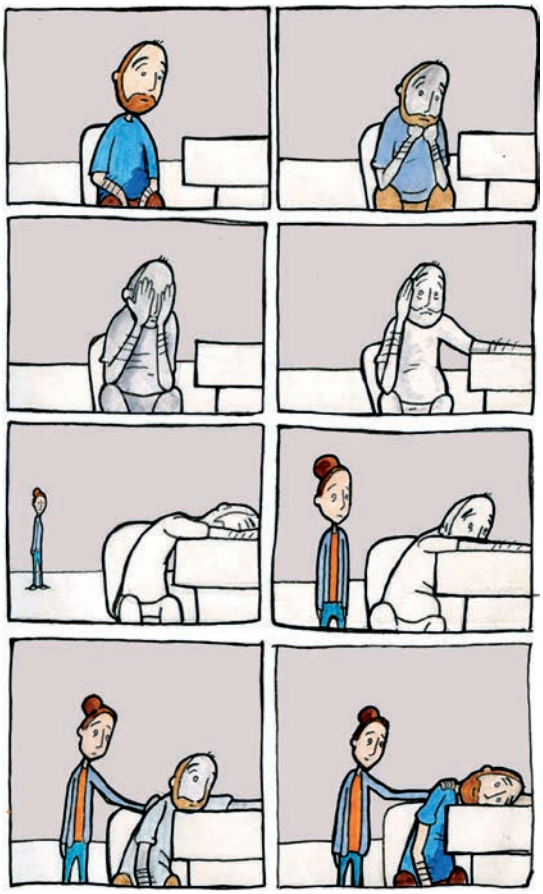
Allie Brosh has an ambivalent take on depression; comics are funny, colorful, joyful and rudimentary, with a satirical approach to depression, but they convey all the pain underneath; and this is usually the mask that depressed people put on

Nate Powell's *Swallow Me Whole* offers two different views on twin sisters' schizophrenia; the outcome is the same—stigma and personal shame

and *Depression, Part Two*, which repeatedly attracted attention at the conference as an example of the mask that people with depression put on. Suppose they do not face the disorder, and the same goes for the people around them—in that case, the consequences may be fatal, as shown in several online databases of photos of people with depression just before a suicide attempt. Without exception, every one of them smiled and seemed charismatic on social networks, only to attempt suicide a few hours or days later. Some of them, unfortunately, succeeded. And that would not have happened if they had talked openly about their problem and had someone to listen to them.

However, as difficult as it is to recognize a psychiatric illness inside yourself, it is equally hard to see it from the outside, from the point of view of people who care for the sick. This form of service takes its toll, and caregivers who are in long-term contact with psychiatric patients often become part of that vicious circle of F-diagnoses. Darryl Cunningham, a former caregiver at a psychiatric clinic, collected his experiences in the comic *Psychiatric Tales* in 2010. Cunningham worked with depressed, demented, and schizophrenic patients for many years. It can be said that he "has seen it all," and he was especially disturbed by the fact that he failed to prevent two suicides at the clinic. The author left his job too late. For the next four years, he struggled with depression, and his only sense of progress came from short stories in the form of comics that he uploaded to the internet. He claims that comics were the only reason he did not take his own life. Today, he is considered cured, and the webcomics have become *Psychiatric Tales*.

More and more authors post their webtoons for everyone to see, thus highlighting that psychiatric disorders need to be talked about as they are much more than the diseases affecting spoiled millennials



Cristopher Grady believes family support is essential for people struggling with depression and anxiety

When they are authentic, the depictions of psychiatric disorders in comics bring about a better understanding in society, but may also be part of rehabilitation. Cunningham, Larcenet, and Brosh agree on one thing: this type of treatment helps and saves lives. Authors can lay bare their souls and readers can understand and accept them. The worst thing is to keep those feelings locked inside as the growing pain threatens to explode and take lives. To repeat Larcenet's words spoken through Polza Mancini: "How could I not hate myself when it was so natural to be hated?" —Ⓔ

The author graduated in Archaeology from the Faculty of Philosophy at the University of Belgrade. He is the editor of comics at the Serbian publishing house Čarobna knjiga, a columnist for the Serbian weekly magazines Politikin zabavnik and Vreme, and several culture news websites. He is also a comic book critic and essayist, with articles published in several Serbian and foreign publications and comic editions.

Часопис за промоцију науке

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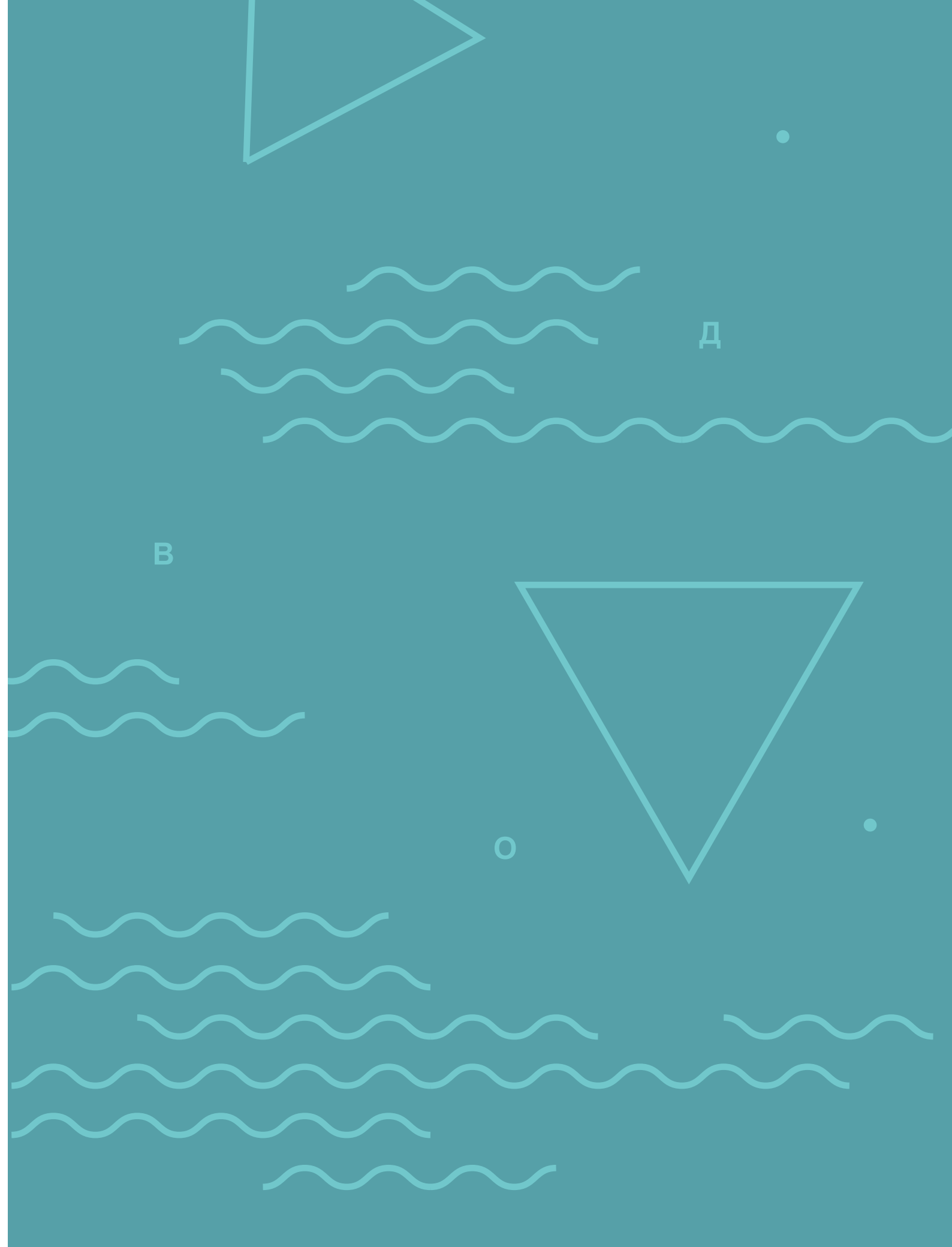
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