Liber Amicorum
Cristian S. Calude 70

Editors
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Preface

Cristian Calude is currently chair professor at the University of Auckland and the founding director of the Centre for Discrete Mathematics and Theoretical Computer Science (CDMTCS). Cristian is also Member of Academia Europaea since 2008. His academic career started at the University of Bucharest, under the supervision of Grigore C. Moisil; he received his Ph.D. at the age of 25, under the supervision of Professor Solomon Marcus. Cris's research is vast, although most of his results focus on theoretical aspects of computing, algorithmic information theory, quantum computing and randomness, philosophy, and the history of mathematics and computing.

Over time, Cris has received several awards and recognitions for his long-term research career in Theoretical Computing Science, such as the ACM "Computing Reviews Award" in 1986 and the Mathematics Prize "Gheorghe Lazăr" Mathematics Prize from the Romanian Academy in 1988. It must be noted that The President of Romania, Klaus Johannis, has awarded him the Romanian National Order of "Faithful Service" in the degree of Knight in June 2019. This order is honorific, initiated in 1878 by the first King of Romania, Carol I. Only about 150 Professors in Romania have this order, out of 1000 other recipients holders. Last year, the most recent prize awarded to Chris was the "EATCS-IPEC Nerode Prize".

We celebrate our friend and colleague with this volume for his 70th birthday anniversary. The book contains a collection of non-technical contributions, stories, philosophical thoughts, congratulations, birthday wishes, and recollections from the past. The contributions are included in alphabetical order by the first author's name.

On this occasion, we all wish you Happy 70th Birthday, Cris!

Cezar Câmpeanu,
Michael J. Dinneen, and
Karl Svozil

An academic father who has never stopped questioning

I first encountered Cris when I was a BSc student in Auckland studying both Computer Science and Physics around 2008, still very uncertain of what I wanted to do with my life. I enjoyed physics hugely but saw it largely as a "personal interest" major, while in Computer Science, I was interested in AI and imagined I would probably be heading towards a path as a software developer. I don't think it's an understatement to say that Cris is largely responsible for completely upending that state of affairs and setting me on the path to where I am today. As an attentive lecturer and, subsequently, supervisor, Cris first awakened an interest in computability theory and then opened up the world of quantum computing and information to me. I suddenly realised I didn't need to choose between Computer Science and Physics but could have the best of both worlds, setting in motion the path that brought me to be a researcher in the field.

Throughout the years that I was Cris' student – first for an Honour's year project, then an MSc, and finally a Ph.D. – I could hardly have imagined a better mentor. Even as a fresh student, Cris had me presenting my work at international conferences and immediately made me feel at home in the community. The impression was all the more vivid given the interesting conference locations Cris had us running to: from travelling 40 hours to get to the Azores for my first conference (to find it resembled a smaller version of where we started from – volcanoes, mud pools, bush and all) to a conference on the Nile (a venue which will be hard to ever top), around which Cris kindly invited me to visit some spectacular sights in Egypt.

In subsequent years I had the pleasure of spending several prolonged research visits with Cris, notably in Vienna and Paris. I have warm memories of long summer walks with Cris and Karl Svozil in the Vienna woods (at least when we weren't caught in unexpected thunderstorms on hilltops) or around the streets of these cities, where our conversations drifted from incomputability and randomness in physics, to family, books (his recommendations of which have never disappointed), politics, and back again. I can't thank

Cris enough for providing me with such a stimulating environment and for his warmth and humanity, welcoming me into his scientific family.

Although Cris readily admitted to lacking a physicist's intuition and having a mathematician's view of the field, he has never been afraid to challenge prevailing wisdom on a topic. In our long collaboration on quantum randomness, we regularly ran up against a refusal to accept the established mathematical notions of randomness. We persevered and were able to make some important contributions at the intersection of computability and quantum information. This ability to challenge ideas, despite how loudly their proponents shout and ask difficult questions, is a rare but essential quality for interdisciplinary research, and Cris always has an excellent historical anecdote on hand to reinforce the importance of doing so. It is something I have particularly taken to heart from our time working together.

Since finishing my Ph.D. and moving to Europe to pursue my research career, I have had far fewer opportunities than I would like to see Cris. I sincerely hope that changes soon and that we will find many more opportunities to discuss.

For the occasion of Cris' 70th Birthday, I wish him the very best of birthdays and that there may be many more of them to come, of time to be spent with families, and many stimulating discussions with friends and colleagues!

Manuel to Cris Calude

Dear Cris,

During 2018, an event marked the beginning of a new stage in my life and would lead to a friendship I cherish and an exiting view towards the future. Month by month, I was steadily losing motivation to learn, but one day, I enrolled in the most enjoyable course I have taken during my academic life: Mathematical Foundations of Computer Science. Suddenly, the tedium of the bachelors curriculum was transformed into an inquisitive narrative that captured my imagination, and rekindled the curiosity that had once steered me into this little corner of the world.

My now favourite lecturer gave me a great gift; he helped me regain the passion for learning that was slipping away from me. Then, my teacher became a mentor that guided me and helped me explore the fascinating world of randomness and quantum phenomena. During the process, I was given the opportunity to know the remarkable person that I admire and am proud to learn from.

I always enjoyed our conversations from sharing about our families, cultures and views on life to receiving valuable advice and discussing research topics; I have fond memories of walking together, sharing a nice coffee and being warmly welcomed every time. My mentor became my friend.

I wish you to enjoy every moment and continue building wonderful memories.

Sincerely,
Manuel

Carpenter Thoughts on Cris Calude

In 2007, the year when I came to live and work in Auckland after a career at CERN and IBM, I was asked to teach part of a course on "Data Communications Fundamentals" and found that one of my new colleagues would be covering the real fundamentals: coding, Shannon's theorem, compression, and the like. This was just as well, since I am a poor mathematician. Of course, I soon discovered that the colleague in question, Cris Calude, was a highly accomplished mathematician and theoretician of computing. I could digress here to debate whether either what he does or what I do (Internet protocol design and standardisation) deserves to be called "computer science", but that is the banner under which we met. Those who know Cris will not be surprised to hear that he was most welcoming to me as a newcomer, and thanks to his native modesty, it took me some time to realise how eminent he is in his own field. What did strike me very quickly is how his undergraduate teaching matched the students' needs and abilities, whereas his own research was at a level of abstraction that would escape most of his colleagues in Auckland. I was also impressed when he was elected to the Academia Europaea, which is a somewhat unexpected honour in New Zealand (he is one of three). Previously, the only Academicians I had known were high above me in the CERN hierarchy, but now, I had one as a colleague.

Cris did me the honour of interviewing me for his series that eventually became The Human Face of Computing. The whole book perfectly illustrates his widespread interests, well beyond the arcana of computability and algorithmic information theory. Furthermore, his mind is far from closed to new topics and new thinking, and he is always willing to listen to crazy ideas, and explain in the kindest way possible why they are crazy.

Cris Calude, and Elena Calude, who I have also had the pleasure of meeting professionally, both have the Erdös number 2. Everyone who has published with either of them owes them for bestowing the Erdös number 3.

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To Cristian Calude on his 70th Birthday

Dear Friend and Colleague, my very best wishes for your 70th birthday!

Allow me to recall some of our many highly pleasant interactions.

First of all, it was always very stimulating to visit you in Auckland or to host you in Yorktown Heights; we visited each other many times. On one such occasion, we went on a pilgrimage to Princeton, New Jersey, where we found Einstein's former home, the Kurt Gödel and John von Neumann gravesites, and then Gödel's former home. I would never have done that without you!

Another fun project, which I was peripherally involved with, was your paradoxically successful calculation, together with Michael Dinneen, of a good approximation to a halting probability, later to find its way into a medallion struck by Wolfram Research in honor of Leibniz's discovery of binary arithmetic.

Still, another joint project was putting together two World Scientific volumes in 2007, when I happened to be sixty, which volumes you and I had the pleasure of launching together at the University of Vienna.

May I add that I admire your excellent tennis and the fact that you were able to learn to play the piano at an age that most of us have stopped being so adventurous?

Finally, I am most grateful to you, Cris, for encouraging me to complete an autobiographical essay, "A Life in Mathematics," part of which will appear in the October 2021 EATCS Bulletin, and the rest of which has just appeared as an Auckland University CDMTCS research report, in both cases, thanks to your good offices.

Gregory Chaitin, 4 October 2021
University of Buenos Aires
https://uba.academia.edu/GregoryChaitin

Make me a perfect scientist

I met Professor Cristian Calude (simply Cris) in 2006 in York, during one of the conferences associated with his name, at the time, the 5th International Conference on Unconventional Computation (UC), chaired by Susan Stepney. It was really Cris Calude seated at the back of the amphitheater, full of participants (later on, I had never seen so many participants at the UC Conferences). I introduced myself, thinking that before me was a scientist who promoted scientists and science. In the space of a year, almost without noticing, I was involved in program committees and scientific events organization. It was not the very first time, but certainly the first time I had seen my name prominently on the posters. That was how, anyhow, my humble project came into discussion in international terms. In 2007, the 6th International Conference on Unconventional Computation, Queen's University, Kingston, was chaired by Selim G. Akl, and I was already in. On that occasion, it occurred to Cris during a coffee break that he should restart the old dream of an international workshop involving Physics and computation, something like to be called "Physics and Computation" (P & C). Cris asked me to organize the workshop together with him as a satellite event of the 7th International Conference on Unconventional Computation, TU Vienna, chaired by Rudolf Freund. It was a very interesting meeting participated by most well-known researchers, running projects in the field, from Quantum Computing to Relativistic Computing, from Analogue Computing to Chemical Computing. With the resurgence of the workshop emerged the possibility of publishing journal issues addressing the subject of Physics and Computation. In 2009 the Workshop P & C received a new edition, this time in Ponta Delgada, Azores, organized by Olivier Bournez and Gilles Duwek, while a very few Ph.D. ex-students and I, myself, were organizing the 8th International Conference on Unconventional Computation, Ponta Delgada. Cris Calude, representing the Steering Committee, was invariably present, suggesting how to give more and more emphasis to the Conference and the workshop, selecting places to host UC conferences that covered the world, from New Zealand and Tokyo to Arkansas and Western Ontario (by the way Antarctica was promised, but it is still missing ...).

But, that big event I should recall took place in 2010, one year after, when Cristian Calude, Walid Gomaa, Hélia Guerra, Karl Svozil, and myself organized the 3rd International Workshop on Physics and Computation,

Egypt,... just one week aboard one of those Nile cruises. Unbelievable for many. It looked like a fraud .... The visiting tours were done early in the morning and at dusk. Nevertheless, in the very hot hours, say between 10 AM and 4 PM, the Workshop could be carried out very successfully in the large room at the top of the vessel, a place prepared for the purpose by the Egyptian company. The idea was so crazy and involved so many top researchers in this world of ours that, to this day, I am still stunned by the success of the mission. Some researchers took some family members. That is when I met Elena, Cris Calude's wife and their daughter. Small talk here and there made me understand that, although always keeping some distance and dignity proper to researchers who took on a large number of organizational, editorial and scientific research responsibilities, Cris Calude was friendly, although too formal with me, in such a way that I never had a real conversation with him that evaded matters of organization and science. After Egypt, we met again in Tokyo the same year. Somehow, I was suggested as a guest speaker for the 9th International Conference on Unconventional Computation, UC 2010, Tokyo, organized by Masami Hagiya. Observing from a distance the stage of Conferences and Workshops, we could see how protective Cris Calude was of our deviations from the mainstream of conventional computing in the course of successive meetings. (Cris' respect for some masters became obvious, whose names I will avoid pronouncing, except for one, Gregory Chaitin, with whom he was a close friend. He was convincing in scientific politics... so that, among my students, I usually spoke of Calude as the Southern Hemisphere master of Kolmogorov Complexity. One day I asked him what name I should give this discipline. He answered "Plain, plain complexity, just that". End of discussion.)

Having passed through Lisbon, in 2010, on his way to Ponta Degada, Azores, we took Cris Calude to a place called Cascais, not far from Lisbon, and we had dinner in a German-style restaurant. Cris declared himself tired, and to be retired from some of the editorial and steering committees. Shortly, he would abandon part of this burden. Cris Calude was absent from the 16th International Conference, UCNC 2017, Fayetteville, AR, USA, organized by Matthew J. Patitz. (Unconventional Computing had its name changed to Natural Computing and Unconventional Computing at the 2011 edition.) The 2017th edition also coincided with my departure from Cris's world. As I felt more and more involved in Conferences and Workshops from 2006 to 2012, the pressure on my institution against these activities increased and,

consequently, my ability and competence to serve as an organizer or as a program committee member ended. It became clear that this life was not compatible with what was expected of a very humble mathematician...

I have been with Cris Calude eight times in programme committees and seven times as co-editor of Applied Mathematics and Computation, International Journal of Unconventional Computing, Lecture Notes in Computer Science, and Natural Computing. I was a member of the Steering Committee of the Workshop on Physics and Computation, together with Caslav Brukner, Cristian Calude, Gregory Chaitin, and István Németi (for the events of 2008, 2009, 2010, and 2012). Cris Calude is certainly one of the persons who helped other researchers and me to enter this international world of scientific activity, to meet other researchers who have supported my work and, above all, to visit the intricacies and backstage of conferences and journals. I think if the conditions were met in my institution, he could have made me a perfect senior scientist.

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Random Predictions

I met Cris Calude for the first time as a second-year student in the Faculty of Mathematics at the Univerisity of Bucharest. Before that, I heard about him several times from my high school teachers, mainly from Nediţa Neculai and Gheorghe Ianuş. Although Cris was only an Assistant Professor at that time conducting the Foundation of Computer Science Lab, he managed to be a great source of inspiration to many of my colleagues. Surprisingly, in that lab, I found the answer to my idea that we could prove all mathematical statements starting from axioms by using the rules of deduction. The answer was actually false, and it was solved by Gödel many years before I was born. That was a great revelation for me at that time.

During our classes, Professor Calude asked several interesting questions, and I answered one of them; that's how I got the subject of my first student paper. After that, the second paper came almost immediately, solving another challenge proposed by Cris. In my fourth year, I took a course with Cris on Computability and Complexity, and that was the one that convinced me to pursue my research in the theory of computing field. It was only natural that my Honours and my Ph.D. Thesis were under Cris' supervision.

Later on, there were a few moments when our roads had crossed again. Each time it happened to be at moments when I needed a piece of advice, an idea, or simply somebody to share my ideas. I will mention next only the most important ones:

- the Conference in Mangalia, Romania in 1995, where I could meet Helmut Jürgensen and Greg Chaitin;
- the CIAA 1999 in Potsdam, Germany, where Cris and George Păun have convinced me to attend the first edition of DCGARCS, now the DFCS conference;
- the DCFS 2008, in Charlottetown, PEI, where his talk was a source of inspiration for all the participants, and
- the International Workshop on Theoretical Computer Science dedicated to Prof. Cristian S. Calude's 60th Birthday, in 2012.

For each of these occasions, to name just a few, I could produce new results and directions in my research, which put a new milestone in my journey.

Figure 1: Cris Calude, Cezar Câmpeanu, Auckland, May 14, 2016

Now, looking back to these events, they were pure randomly in my life, as I could have had someone else as a professor in the second year, I could have had a different supervisor for my honours thesis, and I may have never thought of a Ph.D. in mathematics. The same I can say about the other happenings: without meeting Helmut and Greg, I could have never thought about complexity gaps and all the results related to infinite random sequences. Without attending the DCAGRS conference, I would probably never have returned to Canada and written all the papers on descriptional complexity, which is now my main area of research. Finally, without our meeting at DCFS 2008, I would probably never dug up my then-buried idea of uniform complexity measures and brought it to life at the workshop for Cris's celebration of his 60th Birthday.

Figure 2: Cris Calude, Elena Calude, Cezar Câmpeanu, Auckland, May 14, 2016

Quoting Greg, "Randomness is the true foundation of mathematics."

Cris, for all these random events that have changed my life, I can only say to you a big "Thank you!"

Wishing you a very Happy 70th Birthday!

Cezar

Cezar Câmpeanu
School of Mathematical and Computational Sciences,
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CANADA

Professor Cristian S. Calude at the 70th Anniversary

As my time horizon becomes less generous, as twilight penetrates deeper and deeper into my soul's room, writing becomes an increasingly difficult undertaking. The statement is true when writing mathematics, but also at times (increasingly rare) when I try to revisit my past life to write about a person who means something to me and whom I admire. In any of these situations, I must first of all overcome a psychological barrier: I remember the French poet and critic Nicolas Boileau (1 November 1636 – 13 March 1711) who, in his famous "Art Poétique" published in 1674, told aspirants to glory in poetry:

> Avant donc que d'écrire, apprenez à penser.[1]

Here is another quote from the same Boileau:

> Ce que l'on conçoit bien s'enonce clairement.
> Et les mots pour le dire arrivent aisement.[2]

Not everyone who writes meets Boileau's requirements. In France, readers and many critics have called them not "écrivains" (writers), but "écrivants".

When I am in a position to write about a person, another major difficulty arises. Indeed, when you write about someone, you are implicitly writing about yourself. That's because writing about her or him, you say how you see them. But "how you see" depends upon your axiological criteria, your sensitivity, your culture. It is one of those situations where the usual word seems irrelevant and the right one, too loud.

The following lines should be considered in this key. These are a person's thoughts about another, hence they need order and structure. If someone finds here inspiration for a portrait of Cristian, they are free to use it.

First thought: about how we live our birthdays. As time goes on, I wonder, more and more often, if birthdays are just a matter of joy. The

[1] So before you write, learn to think.

[2] What is well known can be clearly stated. And the words to say easily arrive.

answer is always the same: no, they are, equally, occasions of remembrance, of nostalgic retreats, attempts to stop time, at least for a moment, from its unstoppable flow:

> If ever I to the moment shall say:
> Beautiful moment, do not pass away!
> (Goethe, Faust)

We find this idea in Eminescu too:

> Nu e păcat / Ca să se lepede / Clipa cea repede / Ce ni s-a dat?[3]
> (Eminescu, Stelele-n cer)

From a book by Milan Kundera, entitled *Ignorance*, I got a deeper understanding of nostalgia. Following the beginning of Kundera's book:

> Reîntoarcerea, în greacă se spune *nostos Algos*, înseamnă suferinţă. Nostalgia e aşadar suferinţa provocată de dorinţa neostoită de a reveni acasă: lângă bătrâna-ţi mamă, lângă iubita de lângă care te-a smuls o soartă crudă, la casa părintească şi la poteca pe care ţi-ai purtat, cândva, paşii copilăriei.[4]

The founding epic of nostalgia is the Odyssey, and Odysseus, the greatest adventurer of all time, is also the greatest nostalgic. Nostalgia appears to be suffering from ignorance: I am far away from my country, I do not know what is going on there and I am suffering. Exile is not easy and no matter how much Eliade says it is an initiation experience, exile often remains traumatic for an intellectual who changes culture and language. Cristian settled in New Zealand in 1992. Of course, in his case there is no such thing as exile. But by changing culture and language, I am convinced, nostalgic feelings could not be avoided.

Second thought: about the date and place of birth. A human is the shortest way between life and death. But no one can choose the time when

[3]It's not a sin / To give up / The quick moment / What was given to us? (Eminescu, The Stars in the Sky).

[4]Returning, in Greek, is called *nostos Algos*, which means suffering. Nostalgia is, therefore, the suffering caused by the relentless desire to return home: to your old mother, to the beloved who a cruel fate took away from you, to your parents home or on a path you once took as a child.

this journey begins (that is, the date of birth) or the place from where it starts (that is, the place of birth). The person we call today Professor Cristian S. Calude was born on April 21, 1952, in a house located at number 50, Lăpuşneanu Street in Galaţi. Then God shed a tear of light that has fallen upon this house from which an important mathematician emerged. Among the numbers that determine the date of his birth, 21 is odd. I was glad to see that because

> There is divinity in odd numbers, either in nativity, chance or death.
>
> (William Shakespeare, *The Merry Wives of Windsor*)

In a remarkable 2018 interview Professor Calude said

> From my mother's grandfather I got interested in reasoning (through chess), from my father (lawyer) the passion for argumentation, and from my mother the emotion caused by beauty (a theorem expresses a feeling).

In a world where there is time, nothing comes back. The pure present is the advance of the past that swallows the future. In fact, the whole perception is already memory (H. Bergson). And the man, the poor man, no matter how hurtful, needs a place to return to. That is, a place worth returning to. For many people, this is the place where they were born.

To a certain extent, people are shaped by the place where they were born and raised. The way they feel and think is related to the topography of the place, the temperature, the direction in which the wind blows (Haruki Murakami, *Kafka by the Sea*).

Third thought: about success and merit. According to Rimbaud, in life you go where you don't want to go, you do what you don't feel like doing and you die completely differently than you imagined. Through all that he has lived and done so far, Cristian contradicts Rimbaud's first two statements. He went on a path chosen in high school, and since then, he walked firmly and steadily on this path, overcoming failures without losing his enthusiasm, considering successes only delayed failures and thus becoming himself a successful person. This is because the One who shed a tear of light over the house in which he was born sent him to read two books: S. Marcus, *Notions of Mathematical Analysis. Their Origin, Evolution, and Significance* (1967)

and Gr. C. Moisil, *Elements of Mathematical Logic and Set Theory* (1968). Two books that presented a living mathematics, a mathematics in its development, that excited him and determined his professional development. A road permanently lit by two great mentors: Gr. C. Moisil and S. Marcus.

Many signs of success can be cited for Cristian S. Calude. I mention a few, without claiming to be the most significant: PhD in Mathematics from the University of Bucharest at the age of 25 (advisor Solomon Marcus), researcher with international recognition in algorithmic theory of information, quantum calculus, discrete mathematics, history and philosophy of calculus, holder of prestigious awards such as the Romanian Academy "Gheorghe Lazăr" Prize (1988) and EATCS-IPEC Nerode Prize (2021) for the work "Deciding parity games in quasi-polynomial time", *SIAM J. Computing* (2020) written with S. Jain, B. Khoussainov, W. Li and F. Stephan, member of the European Academy (2008), decorated by the President of Romania (2019). The list goes on and on, but what I want to emphasise is that for him, success and merit converge. It hasn't always been that way. Let us think only of the obstacles which the French Impressionists encountered in recognising their merits, and of the role which that picture dealer named Ambroise Vollard (July 3, 1866-July 21, 1939) played for the artistic destinies of the most important of them. Things are not even better today: many deserving people are waiting tired of injustice for their value to be recognised.

Fourth thought: Sapere aude! (Dare to know). In 1967, the High School V. Alecsandri from Galaţi (today, V. Alecsandri National College) was celebrating its centenary. Representatives of three generations of Calude participated in the festivities: Cristian, as a high school student, his father and grandfather, as former students. In 2019, preceded by the fame of an important mathematician, Professor Cristian S. Calude had a meeting with students from the same high school. He told me that he was impressed by the way the 11th grade student Luiza Irina, a student in humanities, answered a question he asked. Here is the story (the questions are his and the answers are Irina's):

Q. Is the set of all finite sets finite?
A. No.
Q. Why?
A. Because the set of natural numbers is infinite.
Q. What does this have to do with my question?

A. It has, because the set of natural numbers 1, 2, 3, ... is the set of finite sets.

The story led me to think of a programmatic article that Kant published in 1784 in a Berlin magazine, entitled "The Answer to the Question: What is Enlightenment?":

> Enlightenment is man's emergence from his self-incurred immaturity (Unmündigkeit).

Being immature comes from the lack of courage to use one's reason, intellect, and wisdom without the guidance of another. You find yourself guilty of this condition not because of lack of intelligence but from the absence of firmness and courage to use your intelligence without being led by someone else. Sapere aude!

Through his ability to stimulate young people to think freely, to wander the world of ideas, to argue confidently in their own judgment, Professor Cristian S. Calude paved the way for Enlightenment. He follows the line marked by his great professors Gr. C. Moisil and S. Marcus.

At the other end of the spectrum are those who inspired S. J. Lec (a Polish poet and aphorist) to write

> I would have understood many things if no one had explained them to me.

Fifth thought: disciple's tribute. In March 2010, at the Symposium dedicated to S. Marcus 85th Anniversary at the Faculty of Mathematics and Computer Science of the University of Bucharest, Professor Calude presented a lecture entitled *Arithmetic Progressions with Primes*. The presentation was calm, in a slow rhythm, without excess of technicalities, putting the ideas in the foreground. It reminded me of Professor Marcus' own mathematical analysis lessons, which I attended as a student in the 1960's. The crux of the lecture included two results: Marcus Theorem (1963), "There is no infinite arithmetic progression of primes" (see Automates finis, progressions arithmetiques et grammaires a un nombre fini d'etats. *Comptes rendus de l'Academie des Sciences*, Paris, vol. 256, 1963, nr. 17, 3571–3574), and, Green-Tao Theorem (2008), "There are arbitrarily long progressions of primes" (see, B. Green and T. Tao, The primes contain arbitrarily long arithmetic progressions, *Annals of Mathematics* 167 (2008), 481–547). The statement of each

of these theorems is presented "as an August text, as an inscription whose laconicism is itself the guarantee of its sustainability", giving that impression of "maximum thought in a minimal expression". Noting that the result of Green and Tao counted for Tao's Fields Medal, Cristian discussed the merit of Marcus' result obtained 45 years earlier using completely different mathematical tools. Emotionally, I perceived the whole lecture as an "exercise of admiration" in the sense of Emil Cioran, the disciple for his master.

Sixth thought: a few key words about the personality of Cristian. In June 1994, we found ourselves in the same train compartment which took us to Sinaia to participate to the Symposium "Romania and Romanians in Contemporary Science". I talked a lot with Cristian and I unraveled the following. He is sober – without being rigid, dignified – without being proud, communicative – with caution. He is a good man, and kindness is a form of intelligence. Intelligence helps you see the essential in a matter. And the nuances around the essentials. It can be said that intelligence is the expression of the goodness of the spirit (Eugen Simion).

Professor Gr. C. Moisil once said: "A theorem is a letter to a stranger who can discern not only its meaning but also all its implications". In view of the above, we deduce that the theorems are made for intelligent people. What about those who make theorems? Professor Calude is one of them.

How did I comprehend all of this? Judging with the mind and seeing with the heart.

> One sees only with the heart; the essential is invisible to the eyes.
> (Antoine de Saint-Exupèry).

End:

> And now these three remain: faith, hope, and love.
> (from Epistle I to the Corinthians of the Holy Apostle Paul).

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Cristian Calude

Cristian Calude has made many contributions to science. While it is not my place to talk about his long career, as many aspects of it are beyond my ken, I would like to talk about his vision. Cris has always had a great eye for what is, or will become, important in mathematics and theoretical computer science.

His work in algorithmic randomness is one example. Here we give a mathematical theory giving a meaning to the intuitive notion of randomness for an individual sequence. Whilst the notion is quite old, going back to Borel and von Mises in the early 20th century, the actual theory really only came to maturity later in the century and the early 21st. Cris was highly active in this area, and one of his questions to my ex-postdoc Coles was the catalyst for my own work and that of my co-workers and postdocs. Cris wrote a book in the area and further popularized it as part of his work as the director of the logic institute at Auckland, something he has done since 1995.

I am sure that he also influenced both Khoussainov and Nies in that role. We also see his vision in suggesting that methods from algorithmic randomness could have applications in quantum mechanics, and this is now something of great interest and activity worldwide.

Lots of good people have visited Cris in Auckland, and this is partly because he has good ideas, but partly as he is a very nice person to be around and work with. It also helps if you play tennis at a reasonable standard.

From afar (at least from Wellington, which is 9 hours away by car), it has always been obvious the energy Cris brought to Auckland and the logic institute. This is not something many have. A willingness to organize, a drive to make conferences (some quite major), and the like to happen; to be a driver is something hard to maintain for a long period and if often not recognised. In my own experience, I have always found him uniformly helpful, a good referee, a great organizer and generally a champion of the parts of logic and computing he works in.

I have been so pleased that he has won some deserved recognition for all this energy and his work in recent years.

Cris, I wish you well in the future and am certain you will keep doing things with energy, talent and good cheer. Happy 70th.

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New Zealand

Teammates in Mathematics

On March 27, 2008, Professor Solomon Marcus gave a memorable speech at the Romanian Academy about "the loneliness of the mathematician" (Singuratatea matematicianului). The spiritual loneliness is generated by the limited awareness of the connections between mathematics and other sciences, as well as by the special identity of the mathematical language. Besides this spiritual loneliness, mathematicians can also face social loneliness in the work environment. Cristian Calude, one of the most famous followers of Professor Marcus, has learnt the art of doing research from his mentor. He has learnt it so well, being very gifted for it! Over time, Cris has developed valuable skills that allowed him to conduct top quality research. I would like to underline one special gift that he has: to overcome loneliness through his ability to bring researchers together, in the service of science. He is concerned with:

(a) expanding up-to-date knowledge about the mathematical domains and their connected fields;

(b) identifying challenging problems, promising topics, with theoretical and/or applied valences;

(c) formation and harmonization of the appropriate research team;

(d) allowing full access to information for all teammates, equal rights and total freedom to exert their specific competencies, for the success of the research.

And I have benefited from all these! I remember that in the fall of 2004 he visited me at the Faculty of Mathematics and Computer Science in Bucharest. By simply telling me "I need a statistician!", I became one of his teammates. Allow me to mention three of the teams I belonged to:

- 2006 team: Cristian Calude, Cezar Câmpeanu, Monica Dumitrescu, leading to a paper published in Fundamenta Informaticae;
- 2010 team: Cristian Calude, Michael Dinneen, Monica Dumitrescu, Karl Svozil, leading to a paper published in Physical Review A;
- 2012 team: David Bailey, Jonathan Borwein, Cristian Calude, Michael Dinneen, Monica Dumitrescu, Alex Yee, leading to a paper published in Experimental Mathematics.

It was a beautiful experience! It was interesting! It was challenging ! It was not easy! It was great ! I am proud and grateful to Cris for "recruiting" me. Cris, let us see many new, beautiful mathematical results! I wish you success in teaming up for research for many years to come! Happy birthday Cris, and many happy returns of the day !

My Professor, Cristian Calude

Profesor Calude brought me not only a low Erdös number (3), but more importantly, the passion for thinking about challenging information and randomness-related subjects and the courage to tackle difficult and open problems (together with another favourite professor of mine, Prof. Ioan Tomescu).

He introduced me to other researchers (including the famous Gregory J. Chaitin) in a Summer School in 1995 that gave me the chance to ask a question that found then two different proofs right after in [2]. Once again, a chance for me to see that research is not finished, that my own questions can touch areas not completely explored, and that I could be part of that research.

An important milestone Prof. Calude helped me through was my first research article [1]. This continued with him being my Ph.D. advisor until I defended my thesis successfully in 2003.

Covering the time past since, I admire the way he seeks and succeeds to address interesting questions in hot fields, such as machine learning/inference and quantum computing, focusing on the crucial questions and often limitations, in a nice contrast to the empirical trend that tends to dominate the machine learning and quantum machine learning, fields with relatively minor improvements in accuracies and arbitrary architectures proposals.

References

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Being a Postdoc with Cristian Calude in Auckland

After finishing my Ph.D. dissertation in 1996 in Germany, from January 1997 until July 1998, I worked as a Postdoc in the Computer Science Department of the University of Auckland, being invited by Cristian Calude. It was a great time in my life; I still have very fond memories of that time. Scientifically, it was a very productive period. Cristian's enthusiasm for questions in algorithmic randomness was infectious. Several people, Cristian Calude, Bakhadyr Khoussainov, Yongge Wang, and I, later also Richard Coles, met frequently to discuss questions in algorithmic randomness, producing several papers on this topic. Actually, this was the time in which the interest in Martin-Löf random real numbers grew rapidly among computability theorists.

Nevertheless, Cristian was also interested in other topics. Discussions with him and the physicist Karl Svozil about quantum logic got me interested in this topic as well, and that led to several joint papers on this topic. It was remarkable how Cristian managed to bring people from different areas together. Another interest of his was in unconventional models of computation. Cristian organized the First International Conference on Unconventional Models of Computation, which took place in February 1998 in Auckland. Since then, this conference has evolved into a whole conference series taking place regularly in different parts of the world. Again, Cristian was committed to this wholeheartedly. I remember that he was classifying machines and gadgets as to whether they were conventional or unconventional. For example, he classified a toaster as conventional.

I also enjoyed the nonscientific aspects of life in Auckland and New Zealand, among many other things, the excursions organized by Ulrich Günther and the events organized by Cristian, his wife Elena, and his daughter Andreea. They always made their friends and visitors feel welcome. I wish Cristian all the best for his birthday, and I hope that he will enjoy the years

to come together with his family and friends and with the same enthusiasm that he has always shown.

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Is biological randomness just noise?

Introduction

I would like to focus first, here, on the role of the mechanical vision of nature, the passage that was made between nature and machines in the scientific revolution, of which we are the heirs. I will frame this in an understanding of randomness in terms of unpredictability in relation to the intended theory. That is to say, it is necessary to place oneself in a theoretical framework and to speak of the unpredictability by the intended theory to speak of randomness. As a matter of fact, there is no absolute randomness. This understanding is at the core of a joint paper with Cristian[5]. I will then compare randomness to noise. My presentation will all be very informal, but there is a rigorous theoretical, even mathematical framework as for what I will say.

I consider randomness to be an absolutely central issue. It is so in classical physics, quantum physics, in biology. That is to say, we can ask someone: "tell me what your vision of randomness is" and add: "I will then tell you which is your philosophy of nature". First of all, for me, randomness is not intrinsic to the world, nor to the process. If you are asking to a dice, "where are you going to go?", the dice would answer,

> I am going to follow a geodesic, the only one possible optimal path, perfectly determined by the Hamiltonian. If you are not able to know and take all required measurements with perfect accuracy, it is your problem.

Classical randomness is a problem of knowledge. Even a river, if you ask a river "where are you going to go in a very irregular and hilly landscape", the river will follow an optimal path to the sea, there is no doubt. The stone falls straight down, just as the river will follow a geodesic: the never go wrong – in contrast to this, I will stress, organisms' phylogenetic trajectories go wrong most of the time. And however, the river's path can be completely unpredictable if the course is complex. There are frictions,

[5]Calude C., Longo G. (2016) Classical, Quantum and Biological Randomness as Relative Unpredictability. Special issue of Natural Computing, 15 (2):263–278. This paper contains the references not given here for sake of simplicity; the interested reader may download it: https://www.di.ens.fr/users/longo/download.html

minor variations in shape... that we do not know. So randomness emerges at the interface between a theory that tries to predict and the world, a friction produced by measurement which is the only form of access we have to the nature, in science - you have to measure with an instrument, your fingers, in some way, this the "access" to the world - therefore randomness pops out at the interface between theory and reality, it intervenes through measurement, which I will explain. For that, I said that randomness is the unpredictability compared to the intended theory and therefore if we change the theory, we have a different randomness. Since four centuries, we are in a framework of research which has been formidable, that of the scientific revolution, but which is not an absolute. A framework in which, for the founding fathers, randomness disappears from nature, it belongs to activities created by man (finance, dice, cards ...). Mechanical accuracy, machines are projected onto nature. But it was not so a little before. I learned it, I must say, from my daughter Sara, an art historian. I wrote with her on Leonard, Mantegna and then for my part, Cardano (see our joint papers on my web page): their scientific framework is different. That is to say, in the 15th and 16th century, these thinkers of nature in Italy had a view of immanence and contingency of great interest. Leonardo is interested in complex disordered structures, in "ephemeral phenomena" as he says. He makes hundreds of drawings, not for artistic reasons, as he wants to know, understand nature by drawing. For example, he makes this absolutely extraordinary drawings of the turbulences of air and water, these ephemeral phenomena. He is interested in it from the point of view of knowledge. He considers their contingency and makes an extraordinary remark: "these phenomena, these movements of air and water must be similar since to draw them, I made the same gestures". The great painter understands nature by his drawing motion. Most of his drawings concern these complex, ephemeral structures, or shall we say "chaotic" in modern terms? They are at the centre of his attention, as an immense naturalist. In the middle of the XVI century, Cardano has the same attitude. He is a doctor, a scientist, he loved Leonard's stress on movement in paintings and is interested in the movements of clouds, the random distribution of beans falling in a disordered way, but, obviously, also dice, cards, as he was a great dice and card player. His book on probability was a seminal work – after inventing the complex numbers, the imaginary "i". The situation changes completely fifty years later. There is a birth of extraordinary mathematics and physics, but scientists are doing celestial mechanics. It's a time when there are more and more complex clocks, mechanical pumps to

push water, extraordinary progress and above all, there is a new synthesis between theory, observation and practice. For example, for Galileo, the practical experience of the craftsmen of Venice is essential for the construction of machines, but for him, as it is the animal and human body for Descartes and Bacon, nature itself is understood by looking at these machines. Let's say, instead of looking at the turbulence, he looks at the machines and to stabilities in nature; by this, he proposes the first fundamental physical "mechanical" invariant: inertial movement, an invariant w.r.to transformations of reference systems. And modern physics, in particular the physics of "rational mechanics" will start. To put it briefly, Leonardo, when he makes machines, he does something different from nature and he is aware of this. He draws an helicopter, a bicycle, (working!) machine-guns ... very few are nature inspired; he makes funny and working machines and he makes a difference between the two activities. He invents the technical drawing which is very precise, very rigorous, it is the opposite of this turbulence, he shows the elementary components of a machine, then draws the hole and its sections. The scientific revolution will take a completely different way, I insist, and identify the two, machines and nature. Also probably because of the progress of these machines, but especially for a new dualism which emerges, a dualism which was not there. For example Cardano said "I know that the soul is immortal, but I don't understand how it works". For him who saw this immanence of God in nature, the disaggregation of bodies as a medical doctor, dualism is inconceivable, while it will be at the heart of the later mechanical vision. The understanding of nature will then be based on the "mechanicality" of the organism, of nature in general, and then by dualism, on the radical separation of the soul, in the case of man at least. So for Descartes, the Universe is a machine where there is nothing else to consider except the composition of elementary and simple components and movements. This is the heart of machine vision. We compose with the elementary and the simple and we obtain the very complex. This is how any machine is built. Leonardo knew it already. Bacon makes an even starker case. For Bacon, not only is nature a machine but we must control it completely, which is why it will be a great reference for biotechnology champions, even today, for GMOs etc.

In summary, Galileo, Descartes, Bacon no longer look at these phenomena which so interested Leonardo and Cardano, clouds, flows, hurricanes, irregular movements. They just don't consider them. They think about stable and invariant phenomena, and they do two absolutely amazing things. They do it

in a radically dualistic framework that was not the previous norms and they do mechanics. Galileo is the least radical, since he is also great humanist, he is very sensitive to the diversity of living things, for example. But he doesn't work on it, he's a real physicist. The only thing he does in biology is a very nice physics of biology. He invents allometry. Allometry is the remark that if you make the bones grow in length, the section of the bones should not grow like the square but like the cube since it must hold the weight which grows like the cube. It is a very nice remark with applications, but it is mechanics for an organism. When he talks about randomness, Galileo writes a very nice book on randomness in dice and card games, he thinks that randomness is created by man. It is man who plays dice, but nature is mechanical.

So in order to talk a little bit about what is very complex, that is to say randomness in biology, I must first talk briefly about randomness in physics since, in biology, it is also based on random in physics. I'll tell you about the classic randomness in a few lines, classic and epistemic physics. First I insist though that mechanical thought against Leonardo, against Cardano, which is developing during the scientific revolution, is rooted in this history of the composition of the elementary and simple. As we do computers, when we put a lot of very simple and elementary little things, we make computer networks of great complexity. And this is really the mathematical perspective of Lagrange, Laplace and Fourier. The determination according to these three big names, who do great things with this idea, is the fact that any system of equations which describes physical phenomena must be approachable in a linear way, by "Fourier series", we will say later. And Fourier will do amazing work with it. The three of them think that any mathematizable system must be approachable in a linear way, that is to say by the sum, the linear composition of elementary and simple components. That is the heart, the mathematical expression of mechanicity which is at the centre of the scientific revolution. Well, Poincaré will prove, within mathematical physics, "no, it's not true". Even if we take a system as simple as a sun and two planets, the gravitational interferences between the planets destabilize the system. From a mathematical point of view, it is because these equations which are nonlinear (nonlinearity is a way of expressing interactions with several bodies, several interacting entities) are enough to make the system unapproximable in general, in a linear way, almost everywhere. That is to say, this hypothesis, the mathematical translation of the mechanistic vision - the linear composition of the elementary and simple will give us the global

- is mathematically shown to be impossible. Or, in an intrinsic way, there is a non-integrability and non-approximability almost everywhere in a system as simple as the three gravitational bodies as proposed by Newton. And Poincaré gives the first analysis of what classical randomness is: it shows up in physical processes, possibly represented by a nonlinear mathematical system of equations or evolution functions, where, following the measurement, the classical approximated measurement, there may be small fluctuations below the best possible measurement, these are "amplified" by the non-linear dynamics and produce the unpredictability of the deterministic system, even in systems determined by a modest number of equations. As I observed, to talk about randomness we need a theory and a measurement,

So once again, we have an analysis of randomness which is not only probabilistic, which was the case before this time - that is to say that we had probabilities but not an analysis of what is randomness: Poincaré definitively defines the classical framework for what randomness is. It means to have a theoretical proposition, which from the mathematical point of view is expressed by nonlinearity, which assumes in theory also the fact that the measurement is intrinsically approximated and always in intervals. And therefore we will not be able to predict because a small fluctuation below the measurement will create bifurcations, trajectories which are between a stable and an unstable manifold, called homocline, two notions that Poincaré invents, which demonstrate the unpredictability of the system facing a bifurcation or along a homocline trajectory, where a small fluctuation can lead to one side or another, and this is unpredictable.

Now, Lagrange, Laplace, Fourrier also knew very well that the measurement is approximated, but believing that everything is approximated in a linear way, they thought that measurement is approximated but the approximation can grow linearly, so the initial approximation will roughly be found in the final approximation of the dynamics. This is Laplace's predictable determinism. It is not true that it is his sentence we hear all the time "the infinite being who knows all the points of the Universe, knows perfectly the future and the past". As for this remark, he is right, the good Lord knows all the points of the Universe, he knows the present and the future and everything, there is no problem, that's the job of the Lord. The mistake of Laplace, Lagrange and Fourier, while doing some fantastic mathematics in the context of their mistake, is to believe in the possibility to linearly approximate any reasonable system of equations and then any physical or mathematical

process. And so, the central questions that arises here is the theoretical proposition and then measurement, the confrontation with reality through the measurement. From the combination of the two, i.e. nonlinearity and approximated measurement, the demonstrable unpredictability follows that is the randomness as Poincaré put it very well in 1902.

Quantum randomness is of a different nature. It is objective in the sense that it is intrinsic to the theory. Why? Since the fundamental Schrödinger equation is an equation of a predictable deterministic trajectory, in some form also linear, the trajectory is perfectly given, but a trajectory of what? Of a probability law. It is a probability value that changes over time and therefore, when we take the measurement, we will have the probability. That is, randomness is integrated, made intrinsic to the fundamental equation of quantum physics. Moreover, the measurement is undetermined and not commutative, therefore a measurement of the position then of the momentum, according to the order of the measurement gives different results: there is an indeterminate difference which emerges from the act of the measurement itself. Finally, the spin-up/spin-down of an electron is an intrinsic randomness, in the interpretation that I prefer, the standard one. There are those who look for the hidden variables, we heard it in the presentation earlier, that would cause the spin to be up or down, but it does not work since the hidden variables are not local, they may depend on remote events, like in entanglement – I do prefer the pure contingency, just no causes, of the spin at measurement to referring back to the Big Bang in search for the causes of everything. Mathematics separates the two types of classical and quantum randomness since there are equations called Bell's inequalities, which give different probabilities in classical and quantum frameworks, I will not go into details. So we have two theoretical propositions, which, with a simple for a change of scale, propose a structure of determination, and therefore an analysis of randomness as unpredictability within the theory, which differ in the classical and quantum frameworks.

Obviously, all of this is different from noise - I will come back to it. Why is it different? Since randomness is analyzed in the theory, as we hinted; that is, when you do a quantum measurement of the spin-up and down in a lab, you analyze the nature of the randomness that you face. Then, if there is a truck passing in the street, it makes noise, that's another thing. As in the classical framework, the theory which analyzes in its interior randomness, will tell you "if you take this measurement, there will be unpredictability

(by spontaneous fluctuations below measurement, say). Yet, if there is a truck passing, that is noise". It is another thing then. Physics can separate randomness from noise. So unpredictability, in synthesis, in physics is at the heart of randomness: in order not to "pre-dicere" someone has to say ("dicere"). As I said earlier, the dice, a river ... know very well where they are going to go. They are going to do a geodesic, there is no doubt. But if we try to say, therefore to predict, the theory shows that the sensitivity to the initial or border conditions, therefore at the time of measurement, the approximation does not make it possible to predict the evolution of the dynamics. And there is the difference between randomness and noise.

In physics, there is a great fundamental unity, despite the differences we get through: by changing the scale, we change the theory, but there is a basic unity. These are the great principles of conservation as symmetries, which makes it possible to unify the discipline, once again despite the great audacity of physicists, who change theories as they change scales or observables. We go from the classical to the micro-physical scale, they change theory. Some do hydrodynamics: the equations for incompressible fluid cannot be understood in terms of particles. There are partial results which make links, etc, but again, the mathematical analysis of incompressible fluids cannot be developed in terms of molecules, though we all know very well that water is also made of atoms and molecules. So, to the physicists who analyze the El Niño Pacific current, if you tell them "listen, do that in Boltzmann or Schrödinger's terms" (statistical or quantum theories of particles), they burst out laughing, they don't care at all, they work in an incompressible fluid dynamic, with its own level of observability, its own theory, its own internal unpredictability within the theory, in continua. Indeed when I am told that we are going to understand everything in terms of particles and molecules as for the living state matter, my answer is at least to say "there is a lot of water in a cell and it plays a major role, since in terms of particles we do not understand the dynamics of water ... well, tell me how we can understand the behaviour of a cell globally?". Obviously, biological properties must be compatible with physics (which theory, though, exactly?), but not deductible, that is the fundamental difference.

And then there is information theory. As I said earlier, noise is independent of what spontaneous fluctuations are, as we call them in physics, and this in both classical and quantum cases. Noise is different from the intrinsic randomness of quantum physics and from epistemic randomness, as

it is called in classical physics. Instead, in information theories there is only noise. Why? Because there is no problem of measurement. Information theory is based on discrete data. There are two of them: Turing's "information elaboration", and Shannon's "information transmission". The two are based on sequences of letters, of 0 and 1, finite sequences, to which the access is exact, there is no problem of measurement. So any dynamics is Laplacian, that is any deterministic process is predictable. Turing says it clearly: "my machine is Laplacian" in the 1950 article. That is to say, given the initial conditions, since there is no problem of measurement, the most chaotic of dynamics is predictable. If you implement the most chaotic turbulence of the atmosphere on your screen, you press restart, it will do exactly the same chaotic dynamic. It is perfectly predictable. Restart, it looks the identical. Why? Since the initial conditions are exactly given, pixel by pixel, and you may restart with the exact same initial conditions. It's going to make exactly the same most chaotic dynamic in the world – a physical nonsense. You take a double pendulum, which is highly chaotic, a real double pendulum, you simulate it in a computer – one may download nice implementations from many web pages, you will see, it iterates identically. This has no physical meaning and is due to the discrete structure of this Laplacian Discrete State Machine, as Turing calls it in 1950. Likewise the theory of transmission, it must be exact. Yes, there is noise for sure and Shannon does a lot of work to figure out what to do with the noise. In both cases there is noise, even on these machines there is noise, but there is no randomness. Shannon is precisely focused on the question "how to avoid and reduce noise?" And today it is the work of colleagues working on networks who make it a "do not care", as they say – a difficult task in space-time networks. In networks there is a lot of noise: there are fluctuations of all kinds, electrical, magnetic, the dynamics of access to nodes ... even due to the shape and oscillations of the Earth. But the discrete state nature of the nodes allows to eliminate or heavily reduce noise. That is to say, you open a web page a thousand times, in Japan, it always opens identically. If it doesn't work, you are very upset. We are so used to the exact Laplacian nature of these machines that we want it to work. If you open your file 10,000 times, if there is a comma missing, you are furious, it is inconceivable. Indeed, it is claimed even on the network, and there, it is a real job, since there is a lot of noise, as I said. But the plurality of possible tools, with a whole bunch of techniques of which I know some champions, very good mathematicians, we manage to avoid the noise. So there is no randomness, it is forbidden (or largely hidden). There

is none in theory and when there is noise, we try to avoid it at all costs. And globally, we manage.

Let's move on to biology. Darwin has an absolutely terrific page on randomness. He doesn't call it like that, he has a different terminology. I am going to read you only the last lines. " induced variability, partly due to the fact that the system is extremely sensitive to changes in conditions." He uses a terminology, 120 years in advance: extreme sensitivity to the environmental conditions. It is the terminology of Ruelle, said in 1970's, to the point that Boltzmann, to talk about randomness in physics, refers to Darwin. It's absolutely incredible, normally biologists have to refer to physicists all the time, the converse never happens. Again, that's not Darwin's terminology, but what's his point? He stresses that the first principles of heredity, of evolution, is "variation at each reproduction". For Darwin, even the breeders who have a species that satisfies them, the cow that makes a lot of milk, cannot manage to stabilize the variety of that species. No matter what, with each reproduction, there is a change. This is the first principle, about 4 out of 6 chapters from Darwin's Origin. He does not know the reasons but he understands the phenomenon at the level of the phenotype and the organisms. Then comes the theory of information in molecular biology, totally missing the point. They even manage to say that "biological specificity" (the DNA) is "written not in ideograms but in exact alphabetic writing", as in information theory (Jacob), a program in the sense of Turing. I was telling this remark in China and we found a compromise: "their DNA is in ideograms", otherwise I would have been in trouble.

What arises from this informational vision? A structure of determination. Clearly, Monod in this book derives the necessary fact that the macromolecular interactions are stereospecific, exact: this is necessary to be able to transmit and elaborate the information. Yes, if we want it to act like a computer, it gives a Boolean algebra, like in a computer. In fact, "the cell is a Cartesian mechanism", according to Monod. We come back to what I was saying earlier about evolution: inevitably, at this point, the evolution is due to noise, it's not even randomness, it's noise. It's malfunctioning, something's gone wrong in a Cartesian machine. So when we take this attitude which is quite common, and when the organism is the result of a program and elaboration or transmission of information with some noise, here are the consequences: a parody of evolution. I would like to quote Maynard-Smith, an article from 1999 called "the notion of information in biology" which is

one of the few that tries to clarify this notion of information and refers, as I have done here, to two information theories on discrete data, Turing and Shannon, say elaboration and transmission of information. He analyzes some examples and he gets it wrong. This is the only article in biology where it is spelled out what information means and he confuses the nature of the two theories which are different in comparing entropy and complexity, for deep reasons which I will not detail here, but which I've detailed in some articles: for Turing-Kolmogorof complexity/information is co-variant with entropy, for Shannon-Brillouin it is contra-variant – information is negentropy – and this duality has good internal reasons, in the two theories. We inevitably find everywhere this vision of the randomness as noise, when we talk about information in biology, against the mathematics of randomness in our robust theories of information.

On the contrary in biology, not only is there a randomness specific to the theory, but also it is a very rich and very functional randomness. This is the radical difference. Randomness is not only to be distinguished from noise, in analysis, in experiments, in measurements, but it is also functional, since it is an essential component of adaptation and the production of diversity, and contributes to stability. Stability comes from diversity, in a species, in a population ... if you have a thousand individuals of a species in a valley, this population is more stable if it is diverse and this diversity is one of the results of randomness. Within an organism, the immune system is a permanent producer of variability. It works because it produces variability that makes it possible to cope with the diversity of foreign bodies that come in. Even the liver, which, if you look at it, it is so dull at the butcher's, it's all the same, well no! About 50% of liver cells are aneuploids, which means they don't have the right number of chromosomes. They have a lot of mutations, about 50%, and this is functional, since this diverse production of enzymes makes it possible to cope with the diversity of toxic shocks we have every day. So, here are some feature of randomness, whether at the level of the species, population, and organism. But there is something deeper. Physical randomness has a theoretical advantage. In physics, in order to write the equations it is also necessary to first give the pertinent observables and the parameters, that is to say what is called the phase space, which contains all the possible trajectories. It can be a very large space, even infinite dimensions, such as diverse spaces in quantum mechanics, but its symmetries allow us to define it in a finite number of words. So there is a

stability of the space of possibilities which is presupposed, in each theory of physics. It changes from one theory to another. As I said, physics has been extremely rich in the invention of the diversity of theories, but nevertheless, the method stays the same. We take the phase space as given, possibly a different one for each theory, but it is the pre-given uniform frame for each theory. There are also major principles of conservation that dominate - conservation of energy, of momentum... They are beautifully stated in terms of "theoretical symmetries", related to the very structure of the mathematical equations.

The problem which arises in biology, on the contrary, is radical. If one is situated at the Darwinian level, one takes as relevant observables the phenotypes and the organisms, which change during the evolution. Evolution produces new possibilities. We are in a historical science, in which we cannot give the probabilities, as also in history, human history or any other history. A story is a change in the space of possibilities. To give ourselves probabilities – probability is a measure – we must give the space of possibilities and then a measure on it. That's why in an ecosystem, there are other concepts that enter: the historical dynamics creates new phase spaces, new spaces of possibilities, of pertinent observables and parameters. Changes enable or make possible the reconstitution of new niches and other phenomena on which I cannot dwell, and which make me say that biological randomness is more radical and is built on physical randomness: in a cell, there are Brownian motions, there are quantum phenomena with phenotypic effects – but at the evolutionary level, the level of the history of organisms and phenotypes, the very space of pertinent observables and parameters does change. In short, I wrote an article with a plant geneticist, starting from photosynthesis where quantum physics take part to make it intelligible, to tunnel effects, to effects which are located at the epigenetic level, massively quantum phenomena, with their own randomness, which mixes with classic randomness. They are superimposed, both of them appear in a cell – I wonder if current physics can handle such a superposition. But there is something more radical, which is to say that there is an unpredictability at the level of the possibilities of phenotypes: the evolving phase space is unpredictable. So not only, we don't know what will happen, as in a dice roll, which is paradigmatic for physics, or the spin-up/spin-down for quantum physics, but we don't know what could happen.

And then there is the role of rare events. There is a whole branch of

physics called "the large fluctuations" which considers rare events. But precisely, they admit that it is rare that in a physical trajectory, a rare event might have a role. However, any phylogenetic trajectory is marked by rare events. So if they happen often, why are they rare? This is the type of event that happens often, but every event is rare. When the placenta is formed in certain mammals 100 million years ago, it was the infection of a retrovirus which passed to the germ cells and which gave this protein, the syncitin, which was transmitted, a fundamental glue and filter in cells interfacing the mother and the embryo. It is an incredible cascade of rare events that resulted in a phenotype and which, like almost all phenotypes, was unnecessary. You could very well be a mammal that is not placental – like kangorros. Again, this is the other radical difference, most of the phenotypes are not necessary. A turbulence, a hurricane is necessary. There are probabilities that it may or may not form, but there is a constitution, an environment that makes you conceive the need for a process that may be chaotic and unpredictable in its evolution, but certain border conditions make a hurricane, a flame necessary. I hope the nuance is clear. There is a determination that can allow to speak of a necessity, even if it does not happen because of some low probabilities. On the other hand, there I am going forward, I say something very strong: "almost all the phenotypes are not necessary". We could very well not be there. This is historicity of life.

Here is the summary. So in physics there is an unpredictability which is in the theoretical framework and the way of analyzing randomness. That allows to differentiate from the noise. In biology there is something different. There is the production of novelties which changes the space of possibilities which is constituted by the very dynamics and within which randomness is an essential component of the very stability of biological dynamics.

(32:05) Member of the public

Thank you very much for your presentation, it was really super interesting. You said that randomness is unpredictability for intended theory. So it's more related to theory, but when you switched to biology, you talked about functions, you talked about randomness in biology being a contribution to stability. So I would like to know if we are still talking about randomness on a side of the theory, where it is necessary to say that randomness is in the cell and it is not really a coincidence at the quantum level or the classical randomness, but really in an ontology of biological randomness, is it possible to find out an ontological space to say that?

(33:09) Giuseppe Longo

Here I do not want to commit to an "ontology". I am not a fanatic of a choice in this sense. I insist that randomness is unpredictability w.r.to a given theory and measurement, it pops out at the interface between a theory and "reality", that is at measurement. For me it is a theoretical question. My theory must integrate randomness as a constructive component of biological analysis at all levels of organization. That's what I dared to say, in analogy to Quantum Physics, where randomness is intrinsic to the theory (Schrödinger's equation is a deterministic dynamics of a probability law (amplitude)). Except that there is a notion that comes strongly in biology, which is a notion of constraint. Constraints are produced by the very biological and molecular processes that canalize them and make them possible. The interactions between macromolecules are stochastic, occur in probability and these probabilities depend on the context which channels them: the large network of macromolecules in a cell are made possible, canalized by the cellular constraints and are there because they are the result of a history – they are physically impossible or have almost zero probabilities – they exist only in a cell, they are not "spontaneous", like hurricanes. In an eukaryotic cell, there are lots of internal membranes, the membrane of the cell itself, there are chemical conditions that are all inherited. This provides a very strong channelling of randomness, and that is what we can make intelligible. We have to understand how it is to channel and play on these massive constraints, one of which is absolutely fundamental, the most important, which is DNA, an incredible constraint, it is inside, in the cell. It's incredible from a physical point of view. The constraints in physics, we see them on the outside, and well no, in the cell there is a constraint also inside, that is to say a structure that constrains the Brownian motion, all the quantum phenomena and all that which arrive at the molecular level – without these constraints most of the molecular networks are impossible. And this constraint, the DNA, is the physico-chemical trace of a whole story. It is breathtaking. But if we see it in this term we understand how the analysis of randomness becomes intrinsic to the theory, is constructive, it makes it intelligible. So we understand that when we modify this constraint, something is happening since it is very important. But believing that we are going to control the organism by dealing with this constraint is madness. It's incredible, we've been told that for 60 years. And we make disasters, like GMOs. We do not really know what is happening in Mexico, India, Latin America, since they kill people

who oppose or tell what is happening on GMOs.

(35:13) Member of the public

You just mentioned at the end that obviously the theory that you are developing for biology, it would be this kind of theory that should apply in the human sciences, therefore in psychology and in others. Do you have any examples of researchers trying to rethink theories in human sciences according to your approach to biology?

(35:37) Giuseppe Longo

I am very careful with theoretical transfers. I dare not suggest that. I'm only saying what is in common, it is historicity. That is to say, the change of the space of possibilities and the role of rare event, as for the title of one of my papers. In this regard, biology being a historical science, and from the point of view of proper sciences, let's say exact sciences, the only historical science. Everything is history, phylogenetic history, history of the organism. The first question the doctor asks me is my personal story, at least ass a patient, otherwise he doesn't understand anything. Obviously, historicity is shared with the human sciences in general, and this is why, it can certainly help to transfer limiting results. So when there is an unpredictability of the space of possibilities, I say in biology, then it applies a fortiori in the historicity of man. But for the rest, a lot of caution, since we are adding symbolic culture.

(36.38) Caroline Angleraux

Thank you very much Giuseppe Longo for your very rich presentation. To try to recollect your words, finally, I think that we could come back to this discussion between the living and the machine, which is ultimately something extremely overused and I think that you have succeeded a little in remobilizing wisely, by showing especially in Leonardo da Vinci, whom we have on the screen: the machine is not alive, but on the contrary, the machine wants to create new things as an aside from the living. Whereas the paradigm from the 17th century, with great figures like Descartes, encourages us to get to know the world, and in particular the living world like a machine. A reductionist paradigm is also being set up according to which, finally, from the simple parts one can gradually get to know the whole complex system. And from there, a method is also given, according to this paradigm, to identify the elements in a linear apprehension of the whole. However, you

said it well, it is impossible. It is rather a question of mobilizing nonlinear systems to be able to really tame the world which surrounds us and to be able to make appropriate models. There is randomness which is impossible to predict as such and any linear apprehension of the system prevents it from being considered as such. So ultimately, one cannot, contrary to what the 17th century hoped, step by step pass from simple elements to the complex system as a whole. There is no simple deduction possible. Finally you made an aside on the question of computer science and you said, what seemed to me very interesting, namely to say that one cannot suppress the noise, one can only counter it, but that this is not "theoretical randomness" in programming: no sequence generated by a program is random. So ultimately it is a kind of way of being able to rebalance things but, in biology, it is quite different. Perhaps a form of reminiscence of this 17th century aspiration to try to understand living things as machines can be found in expressions that are now overused as that of genetic programs, but deny the major role and the functionality of randomness in living things, because it produces variability. As you said, it produces diversity, which is functional to life. And so finally, if we seek to maintain, I think and you will tell me if you agree with that, if we seek to maintain a mechanistic paradigm to apprehend the living, it would therefore be a question of renewing this mechanistic vision for that it fully takes into account randomness, in particular so that it can be read in a probabilistic way and so that it also manages to identify the problem of the reproduction of phenomena to make them understandable. So ultimately, in fact, are the interference in such a system negligible? No, and it is therefore a question of renewing this rhetoric of the living and the machine, which I think was a basic line of your presentation. Thank you very much.

Giuseppe Longo
CNRS and Ecole Normale Supérieure, Paris
https://www.di.ens.fr/ longo/

Talk given on Thursday 1 July 2021 at the CNAM,
Time-World 2021 conference, Paris, France

Transcription and translation made by Florentin Waligorski

Lecture dedicated to a dear friend and major expert on Randomness: Cristian Calude, on his 70th birthday.

In Praise of an Incredible Starry Sky

I like travelling, not so much because of the desire to get to know new places and new people as because of the feeling of free floating. Might there be a better way to make sense of infinity? The feeling of free floating and the freedom to go anywhere are two different things. While the latter relies on the possibility of choice between an infinite number of destinations, the former abides by the vanishing point of all possibilities, in the land of "empty form". So it happened that, during one of my visits to the University of Auckland, Cris Calude invited me to join a small group of colleagues and take a few days off to Norfolk Island, a destination I'd never considered. Then, I asked myself, could this be my chance to go nowhere, to meet with infinity?

On the Diagonal's Edge

Hmm, where is the infinite? Well, one may say, at the crossroads of religion, mathematics, and philosophy. Does it exist? This is a more difficult question. And yet, if religion, mathematics, and philosophy exist, the infinite also exists, simply because it is the main concern of all three. Facing the infinite, Hilbert himself asked Kant for help. The role of the infinite, he wrote in 1925, is "merely that of an idea – if, in accordance with Kant's words, we understand by an idea a concept of reason that transcends all experience and through which the concrete is completed so as to form a totality".[6]

How can the concrete be completed "so as to form a totality?" Hasn't this been a stumbling block to our understanding of the "nature of the infinite" since the time of Pythagoras? Hermann Weyl once stated that the great achievement of Greeks was to make the tension between the finite and the infinite fruitful for the knowledge of reality. "Coming out of the Orient," he wrote, "the religious feeling of the infinite, the *apeiron*, took possession of the Greek soul."[7] Entering the Occident, however, that religious feeling had to square with the philosophical credo in the finitude of Being. The tension between the finite and the infinite was indeed a "problem of measure" which questioned the mathematical mind.

[6]D. Hilbert, "On the Infinite", in *From Frege to Gödel*, edited by J. van Heijenoort (Harvard Univ. Press, Cambridge MA 1967), 392.

[7]H. Weyl, "Levels of Infinity," in *Levels of Infinity*, edited by P. Pesic (Dover Publications, Inc, Mineola, New York 2012), 17.

The discovery of irrationality, i.e., the incommensurability of the side and diagonal of a square, overturned the Pythagorean doctrine that "all is number," as it demonstrated the existence of magnitudes which do not have to one another the ratio which a number has to a number.[8] It was then that the search for a method to secure mathematics from the spell of infinity began. Infinity was allowed as a never-ending process by the Greeks, but such a *potential* infinite is not the "real infinite itself." The real infinite, as Hilbert pointed out after more than two millennia, is the *actual* infinite, the infinite that we have when, for instance, we regard "the points of a line segment as a totality of objects that is actually given and complete."[9] Thinking of the infinity of a continuous line, Richard Dedekind could state "completeness" as the essence of continuity, and hence draw the *continuous* of real numbers from the *discrete* of rational numbers. This allowed a number system without gaps to provide a mathematical model of the line. The hindrance to cope with irrationality was overcome, but the problem of measure was shifted to a higher level. Cantor's diagonal argument showed that one infinite size does not fit all: the set of points on the line (or the set of real numbers) and the set of natural numbers have different sizes. Now, if the never-ending sequence of natural numbers is "countable" in the form of a field of possibilities open to infinity, how can the completed, actual infinite as a closed realm of absolute existence be comprehended by reason?

Yearning for Cantor's Paradise

From a philosophical point of view, if the tension between the finite and the infinite reflected the tension between being and possibility, the contrast between the potential and actual infinite turned the possible into a transcendent and absolute being.[10] Here is "the paradise that Cantor created for us,"[11] and that Hilbert dreamed of making accessible by finite means! Did Cantor "create" that paradise or, rather, give an argument for "showing" its domain? How did he get there? Similar questions may arise as to the mathematician's power to create numbers, argued by Dedekind. How does the mathematician create irrational numbers out of gaps? Are gaps also creations of thought? In line with Kant, Hilbert considered mathematical

[8] Euclid, *Elements*, Book X, Prop. 7.
[9] Hilbert, "On the Infinite," 373.
[10] Weyl, "Levels of Infinity," 20.
[11] Hilbert, "On the Infinite," 376.

cognition as "rational cognition from the *constructions* of concepts;"[12] it is mathematics that builds the connecting bridges between thought and experience. But how can a concept of reason in the Kantian sense "transcend all experience"?

The structure of Cantor's diagonal argument seems to complement and refine the rationale behind Kant's transcendental. The argument is not designed to seize the infinity of real numbers, but rather to demonstrate its uncountability by showing that any countable list of real numbers is incomplete.[13] As for Dedekind's construction of the continuum of real numbers out of "cuts", the key point is well captured by John Stillwell: "Dedekind created a gapless continuum by filling each gap in the rationals, *taking the object that fills each gap to be essentially the gap itself.*"[14] Would this filling up of gaps which, as Dedekind declared, brings into existence "new point-individuals," be possible outside that empty field where the old point-individuals are already emplaced? As a condition of the possibility of "giving form", shouldn't that emptiness be considered a priori?

The overwhelming formative power of that emptiness comes to the limelight through Harnack's "measure argument" for proving Cantor's theorem on the uncountability of real numbers.[15] Since any countable set of real numbers can be covered by segments whose total length is arbitrarily small, this implies that the *measure* of a countable set is zero. The "actual infinity" of emptiness appears to annihilate any potential infinity. Where should we look for "the paradise that Cantor created for us"? How can we reach it?

From Kant to Norfolk Island

Although Hilbert's demand for finite means was motivated by the urge to counter opponents of Cantor's paradise on equal footing, it also encouraged a critical review of the Kantian a priori. According to Hilbert, Kant properly raised the problem of investigating the conditions of the possibility of all conceptual knowledge and of every experience, but he overestimated the extent of the a priori. As for the grounding of pure mathematics, what must already

[12] I. Kant, *Critique of Pure Reason*, First (A) and second (B) editions [1781/1787] (Cambridge Univ. Press: Cambridge 1998), B743-4.

[13] Its constructive character would become even more apparent and 'effective' through the following development of the theory of computation.

[14] J. Stillwell, *Roads to Infinity* (AK Peters, Ltd. 2010), 23.

[15] For more, see J. Stillwell, *The Real Numbers* (Springer 2013), 82.

be given to our faculty of representation, in Hilbert's opinion, is nothing but the concrete signs themselves.[16] By contrast, in a Kantian perspective, for signs (or symbols) to relate to one another and play their game, they ought to stand against a background. In the theater of knowledge, while Kant pointed out the background of intuition, as a necessary stage for the play, Hilbert seems to hold the play outside the scene. Indeed, it is because of its infinity that Kant reckoned space an a priori intuition, not as a concept: "It should rather be thought as a concept containing in itself an infinite number of representations. But no concept can be thought as such" (CRP, B41).

In the Kantian universe, however, the real infinite is not to be grasped by finite means, rather as something immanent within the finite. Following the model of Leibniz's monad, infinity is not to be sought on the side of objective knowledge, it dwells within the invisible self of each monad, hence, according to Kant, in the land of pure understanding. This land, which Kant named the land of truth, is presented as an island "surrounded by a broad and stormy ocean, the true seat of illusion" (CRP, B 295). It is here that the voyager eager for knowledge acquires the instruments to venture out on the ocean and face experience. But there is no need to leave the island to find the infinite.

Encountering the infinite might well be an unlikely event. As Hilbert remarked, "the infinite is nowhere realized; it neither occurs in nature nor is it admissible as a foundation in our thought without special precautions."[17] But the Kantian attitude to the infinite was more positive. Kant distinguished two levels of infinity, both immediately connected with the consciousness of our existence. The first is disclosed through the starry heavens above us, the second is secured by the moral law within us. The first begins from the place each of us occupies in the external world of sense and extends through the countless multitude of worlds and galaxies. The second begins from the interior self and places each of us in a world "which has true infinity, but which can be discovered only by the understanding."[18] The first defines our sense of proportion to the universe. The second dissolves any proportion.

[16]Which is to say, "certain extralogical concrete objects that are intuitively [anschaulich] present as immediate experience prior to all thought" (Hilbert 1925).

[17]D. Hilbert, "Logic and Knowledge of Nature," in *From Kant to Hilbert*, edited by W. Ewald (Clarendon Press, Oxford 1996), 1160.

[18]I. Kant, *Critique of Practical Reason* (Cambridge Univ. Press, Cambridge 2015), 5:162.

Finally, how might I answer the question whether I managed to meet the infinite? All I can say is that what has inspired the few lines above is the memory of a unique moment of enchantment under an incredible starry sky in Norfolk Island. The conditions of the possibility of "seeing" could not be better, because of the transparency of the air,[19] the rarity of public electric lighting, and the brightness of the empty horizon. Did I really see the infinite? Was it "a religious feeling of the infinite" that emanated from the bottom of that magical heaven? What else could it have been?

To Cris Calude,
As a token of my esteem and in gratitude for his friendship.
With best wishes!

Rossella Lupacchini
Department of Humanities
University of Naples, Federico II

[19] As I was told, one can hardly find another corner on the earth with a lower level of air pollution.

Getting to know Cris Calude

Some 25 year ago, on unpaid leave from Graz University of Technology, I was appointed Full Professor for Computer Science at the University of Auckland.

Actually, the appointment process was very curious, and although it has no direct connection to Cris Calude I think it might be amusing to read about it. At the time I was not happy with the situation in Graz, and as Professor of the Humboldt type (meaning: as government employee, rather than employee of the university) I was entitled for an unpaid leave of up to five years. So I was looking for a position in an English speaking country I did not know yet well, and New Zealand was one of the two possible choices. I noticed that Waikato University (a good hour's drive S of Auckland) advertised a first professor for computer science. I sent an application. The day after I mailed it, I got a letter from one of my brightest students I had had in Canada, Ian Witten, 25 years earlier: He had applied for the position in Waikato and asked me to write a letter of reference. So we were competitors! However, the University of Auckland heard of the fact that two reasonably prominent people were applying for a professorship in computer science at Waikato, so they decided to open also such a position, and invited both Witten and me. After an exchange with Ian Witten we decided to write very similar letters of recommendation for each other. My last sentence was "If I had to choose between Witten and Maurer, I would choose Witten". Witten did the same with Witten and Maurer exchanged. We both were interviewed in both places, and Witten ended up to get the job at Waikato, I the one in Auckland. This made us simultaneously the first two Full Professors for computer science in NZ!

When I moved to Auckland I had a big surprise: Cris Calude was there in a very junior position, very much overqualified! He had taken the positon to leave his then still unbearably communistic home country. After a very short period of getting to know colleagues and the dean of the school it was clearly not just my opinion that Calude should be promoted immediately. I did propose to the dean to make him Associate Professor. The dean made up for first hiring Cris at a level much below his obvious qualifications and appointed him Full Professor for Mathematics.

Cris and I became good friends, despite the fact that he regularly won

when played tennis ☺. During the holidays, when my wife and younger daughter came to visit (not easily possible during the school year) we went to the Yellowstone of NZ together, Rotorua. I believe it was a first for him and his lovely wife.

By then I had started to see Cris as how one has to see him: A true multi-talent, interested (and good) in mathematics, some areas of theoretical computer science and physics (quantum theory) and basic philosophical questions. Together, we managed to invite the most senior theoretical computer scientist of Europe, including at that time public key cryptography, Arto Salomaa from Finland, for a visit— during which our common friend Mike Lennon managed that Salomaa was adopted by a Maori tribe, an honor bestowed on very few Europeans.

The three of us, Cris, Arto and myself decided to start the first truly open scientific journal J.UCS: It is free for both authors and readers (in contrast, most "open" journals are free for readers but not for contributors). J.UCS (for "Journal of Universal Computer Science, i.e. including all research as long as it is valuable), see
`https://www.jucs.org/jucs_0_0/journal_of_universal_computer.html`
for an introduction written by us three in volume 0 in 1994! Now, J.UCS is in year/ volume 26! Some volumes had more than 2.000 pages. When we slowly delegated running the journal to a younger crowd we also suggested to make sure that 12 issues a year with at most 1.400 pages would be enough. This is where it is today, unusual because as mentioned it is completely open (financed by a consortium of research institutes) and because of its high impact factor. For more see `https://www.jucs.org/`.

It was a joy to discuss issues with Cris with his incredible deep knowledge and wide horizons. Who would think that we even worked and published together in the then early days of E-Learning, or that Cris interviewed me and many others for books or for the EATCS journal, see e.g. `https://www.ae-info.org/ae/Member/Maurer_Hermann/OtherInformation/A_dialogue`!

For strange reasons I had to end my involvement as professor at Auckland earlier than anticipated. I still visited a number of times (professionally as research associate), and Cris has been often in Europe (including Austria). So we have been able to stay in close contact, Arto Saloma often as central figure: Celebrations for Salomaa always also meant meeting Cris!

Figure 3: Cris at the 75th birthday of Arto Salomaa in Finland 2009

Let me finish on a personal note: Cris, thanks for your friendship, help and advice over now more than 25 years! All the best to you and your family, and I am sure looking forward to meeting you again when COVID makes this possible again. Congratulations to your many admirable achievements, and now also your great anniversary!

Cordially,
Hermann

Hermann Maurer,
Graz U. of Technology,
hmaurer@iicm.edu

After About Half a Century

In 2020, a Liber Amicorum (referred from now on as LA) was offered to me when entering the Septuagenarians Club, where Cris contribution had the title "After 47 Years" and started with "We met in 1973 as students..." Now, when he also becomes a member of the same Club, I would like to point out sort of correction – which justifies my title above: I knew his name significantly before meeting him in 1973 (but I do not know how much before, that is why I am using the cautious "about"...). Namely, in the group of Professor Solomon Marcus from the Faculty of Mathematics of the University of Bucharest, it was known that there is a brilliant high school student from Galaţi (not even from Bucharest) who is already working with the famous Professor Grigore C. Moisil, the father of Romanian computer science – recognized as such by the Computer Pioneer Award received in 1996 from IEEE Computer Society. Marcus was a close collaborator of Moisil, so it was just natural that, after the unexpected death of Moisil – in Canada, in May 1973 – to have the high school prodigy joining Marcus group. And, the prodigy, Cristian S. Calude by name, confirmed soon: already in 1975 a paper was published (C. Calude, S. Marcus, I. Ţevy, *Sur le fonctions recursives qui ne sont pas recursives primitives, Revue Roumaine des Sciences Sociales, Séries de Philosophie et Logique*, 19, 3 (1975), 185-188) where a rather sound result was reported, eventually recognized by *Historia Mathematica* (6, 1979, 380-384), *The First Example of a Recursive Function which Is Not Primitive Recursive* (a paper by the same three authors, Calude, Marcus, Ţevy): that example does not belong to W. Ackermann, as usually believed, but to Gabriel Sudan, but it remained "hidden" in a paper of the latter one (*Historia Mathematica* declared simultaneous the two discoveries). The "detectivistic-like" story of the research in which Cris was involved is described by Professor Marcus in various places, first time in the book *Din gândirea matematică românească (From the Romanian Mathematical Thinking)*, The Scientific and Encyclopedic Publishing House, Bucharest, 1975 (in Romanian), so I do not recall it here. A natural consequence is that Cris has obtained his PhD title, under the guidance of Professor Solomon Marcus, already in 1977, at only 25 years old – his is one of the youngest doctors in mathematics in Romania. After meeting in the Marcus group, me and Cris remained practically in a continuous contact, with periods of a closer collaboration, but also with periods of separate research directions. We have

even passed together through the boring months of... army service, as usual at that time in Romania – interesting enough, we have succeeded to also write a short popular book at that time. This is mentioned by Cris in his pages from LA, I am recalling it because the memories from the army time are known to be so strong and colorful... Similarly strong and colorful are my memories concerning the looong trip from Bucharest to Turku, in April 1991, by train, crossing the borders of Romania and Republic of Moldova, then the border to Russia, then the border to Finland. Especially the first one was highly carefully watched by the Moldavian (ex-Sovietic) border officers, probably not so much careful because we, me, my wife, Cris and his wife, were looking suspicious, but mainly because the officers had plenty of time to keep us busy, during the time necessary to... change the wagon wheels (the Soviet train rails were, and the Russian ones still are, wider that the European rails). The many tees we drunk and the landscape compensate in a great extent for the almost two days and one night long trip. But, at the destination, the meeting with Arto! In LA, Cris includes a photo from Turku – a "historical" photo, a "historical" meeting, for me, for both of us. I am also adding to these lines two photos, not so expressive, where both of us are present, his wife, Elena, too. I do not know the occasions/places where these photos were taken, it was for sure in nineteenths, it was at some conferences, it was during some parties/special dinners. Of course, we have many other photos where no glass is present, but I am not able to find them now (classic problem of information retrieving...)...

I was always admiring Cris for his open mind, mathematical and human reliability, working power, didactic dedication. After a few years of rather practical computer science (including Cobol programming for real companies), I have chosen to be full time, full energy a "pure" researcher. Instead, Cris has chosen an academic career, first in Bucharest University, after the 1989 changes in Romania, in Auckland University, New Zealand. Completely different "orbitals", to mock a chemistry term. His students, ordinary, master or doctoral, are now spread all around the world, several of them high level professors and researchers themselves. I am also highly admiring people – in general, and also Cris – (let me formulate it in big words...) for transcending the profession, for extending the interests behind the job requests, for *doing* more than prescribed in the (usually minimal) job description. Cris is exemplarily doing that: his book of interviews with internationally renowned computer scientists, cited by Wikipedia as "C.S. Calude (ed.) *The Human*

Figure 4: Elena Calude, Grzegorz Rozenberg, Cris Calude, Alexandru Mateescu, Gh. Păun

Figure 5: Cris Calude, Elena Calude, Gh. Păun, Alexandru Mateescu

Face of Computing, Imperial College Press, London, 2015. *21st Annual Best of Computing*, The Notable Books and Articles List for 2016, Computing Reviews, July 2017", is indeed a *notable* illustration of my point. Twenty six big names of computer science answer Cris questions, leading to "a remarkable collection of fascinating essays by distinguished computer scientists concerning the myriad ways in which computers impact our lives at this time and how they will do so in the future" (from the Amazon presentation of the book). Adding the old interest for tennis playing and the recent interest for piano playing (not tennis watching and piano listening!) completes the proof...

Happy birthday, Cris, and – from a grandfather to a grandfather: best wishes to you and to your three generations family!

Cris Calude: Colleague in Science and Good Friend

We met in Turku in April 1991. I knew already before some of the work of Cris from his papers in EATCS Bulletin and RAIRO. This was one of the earliest times one could travel from Romania. Cris came with his wife Elena and George and Anişoara Păun by a long and tiresome train trip via several Eastern countries.

Cris was not tired, and we started to talk about algorithmic information theory (a few years later Cris published a foundational book in this area), descriptive complexity and various aspects of randomness, a topic Cris approached later from numerous points of view. Later on Cris has dealt with many variegated themes. They will certainly be well discussed in this Liber. I just mention here his many works related to quantum computing, as well as the recent book "To Halt or not to Halt, That is the Question". Somehow the words "contagious creativity" (that appeared in the title of a book edited by Cris) come to mind when one thinks about Cris Calude.

I made my first trip to Romania in 1992. Cris was one of my main guides, especially in the Tomis area. I studied the statue of my favorite poet Ovid. During these years Cris was also active in the launching of the Universal Journal of Computer Science, maybe the first completely electronic journal in Computer science.

I have so far told only about our first common years. Later on our roads have crossed and we have ben longer times together in various places and conferences. Once we had a scheduled meeting at the Toronto air port. Cris started the yearly conference series Unconventional Computing. Because of this I had a memorable trip to Auckland. The 10th conference in this series took place in Turku in 2011.

I introduced Cris to sauna, and he became very enthusiastic. I have avoided this topic because by now I have many sicknesses that prevent regular visits to sauna. Still sauna is a very suitable topic to conclude this greeting.

Figure 6: Cris Calude, Alexandru Atanasiu, Solomon Marcus, Virgil Căzănescu, Lila Kari(Sântean), Gh. Păun, Arto Salomaa, Alexandru Mateescu, Gianina Georgescu, Victor Mitrana, Sorina Vicolov, Gabriel Istrate

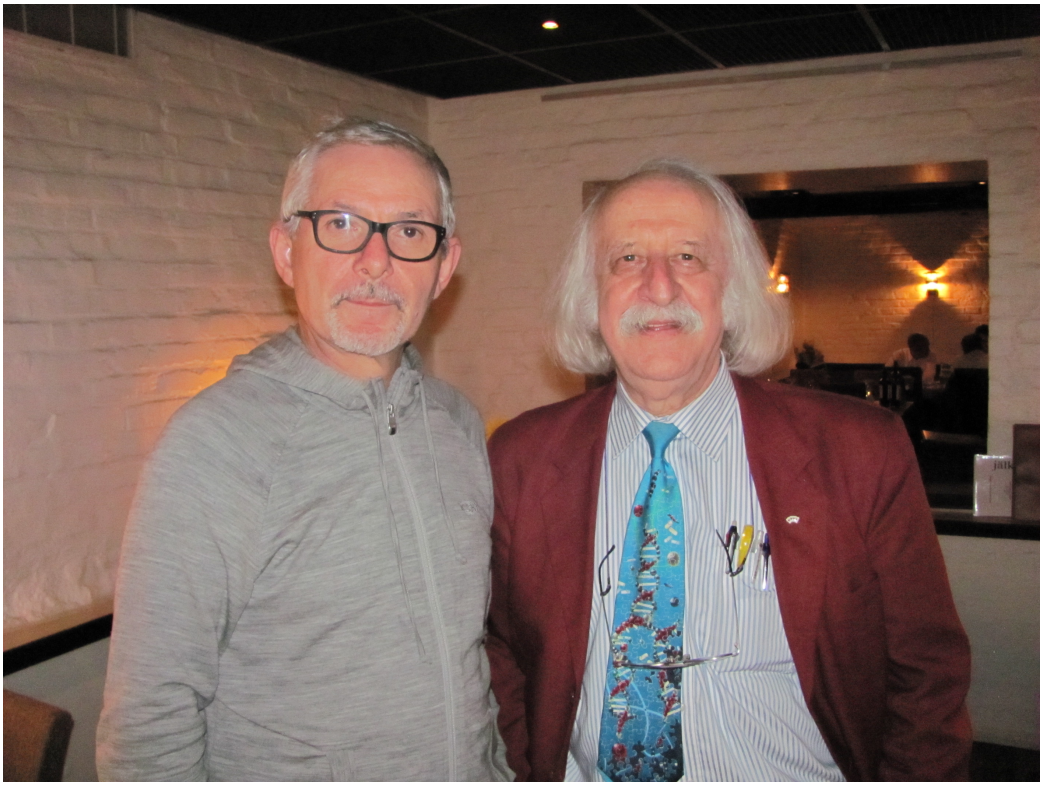

Figure 7: Cris Calude, Grzegorz Rozenberg

Dear Cris! Congratulations because of your birthday! Many Happy Returns! Monia armorikkaita vuosia! I wish you happiness in life and continuing success in science.

Arto Salomaa
Kauhajoki,
Summer 2021

A few words about Cris Calude in the occasion of his 70th birthday

I first have met Cris Calude during the 14th International Conference on Unconventional Computation and Natural Computation (UCNC 2015) that he, Michael J. Dinneen, and their colleagues have organized in Auckland in August 30 - September 3, 2015. I was honoured to give an invited lecture on the Infinity Computer and numerical computations with infinities and infinitesimals at this conference. Before the conference I did not meet Cris personally and new him only through his important papers in theoretical computer science dedicated, in particular, to computability, randomness, and unconventional models of computation.

Already in the first day of the conference Cris has impressed me with his profound questions to the speakers showing a great knowledge in different fields of unconventional computing (this is unusual in our highly specialized world). Even though he was extremely busy with the organization of the event, Cris was able to talk to many participants informally. In particular, we had a long nice talk during the conference dinner. I have discovered that we both have been forced to leave our native countries more or less in the same years and our views on the life and science had a lot in common. Even though this was our first conversation I had an impression to talk to an old friend. This was an amazing feeling.

As I have already mentioned, Cris has impressed me by his broad knowledge and curiosity regarding new ideas. Nowadays many successful scientists look only at their own fields where they have reached a certain success and do not pay any attention to things happening even in close research areas (clearly, in a long run this behaviour is strongly counterproductive for them). Moreover, people of this kind very often allow themselves to express sharply negative assessments about the work of colleagues without understanding well new proposals creating so additional troubles to people proposing unconventional ideas. Well, Cris is a VERY successful scientist in several fields and in spite of this and in contrast to the unpleasant conduct of scientists mentioned above he is very curious and open to new ideas. This is a very precious and rare quality in the contemporary scientific panorama and I appreciate a lot his open mind. He is ready to dedicate his time to study new

Figure 8: Cris Calude and Yaroslav Sergeyev during the conference dinner, September 3, 2015

things coming from various areas. He is a real scientist who works with the wish to create new interesting scientific results and not for money, power, prizes, citations, etc.

After the conference in Auckland we continued our contacts by email and in 2018 Cris has accepted my invitation to give a course on quantum computing for our Ph.D. students. He came with his wife Elena, met my wife and kids and we had a very nice time all together. We discussed a lot about mathematics, computer science, and philosophy of mathematics. These discussions were very pleasant and extremely helpful for me. I am happy and honoured that Cris has dedicated his time to the Infinity Computing paradigm that we develop in our group. In fact, together with Monica Dumitrescu they have published a very deep paper introducing probability

Figure 9: Cris Calude has delivered a course on quantum computing for Ph.D. students at the University of Calabria, Rende, Italy, 2018

theory using grossone-based infinitesimals (grossone is a particular infinite number).

In conclusion, I wish Cris new interesting results in science and all the best to him and his family. I hope that our friendship and collaboration will continue for many-many (possibly grossone) years.

Yaroslav D. Sergeyev
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Rende, Italy
Lobachevsky State University,
Nizhni Novgorod, Russia

Cris Calude

My earliest memory of Cris is from Liverpool in 2008. We came to know each other through serendipity which brought us progressively closer: it began with three successive interviews from June 2011 until September 2018, when I had the pleasure of meeting him in person. In early 2011, Cris sent me a message proposing that we give an interview to the June 2011 issue of the Bulletin of the European Association for Theoretical Computer Science. I was impressed by his open-mindedness and sophistication from the outset. I discovered an extraordinary coincidence of our perspective on matters. Cris did not restrict the interview to technical issues relevant to my research, but embarked on a broader discussion about informatics as a domain of knowledge, the concept of information and their relationship with other sciences.

One year later, because of that interview, ACM approached Cris and asked him to write the entry for Joseph Sifakis for the ACM Turing Award web page [1](1). In March 2014, Cris proposed including my interview in a book he was preparing under the title 'The Human Face of Computing' [2](2) – a proposal I gladly accepted. Cris did a remarkable job updating our past conversation, as my interests had shifted from verification to system design.

Finally, when the ACM History Committee asked me in 2018 to be interviewed in the context of a project to record oral history video interviews of all living Turing laureates, I did not hesitate and chose Cris to be the interviewer. Cris and I agreed to meet and conduct the interview in September 2019 in Athens during my vacations and while Cris and his wife were able to travel to Europe. The Caludes stayed in Athens for a week. Preparing for the interview was a very interesting experience. Cris's comments and acute observations on my career highlighted information that resulted in an exceptionally vivacious two-hour conversation [3](3). Taking walks and going on family excursions during our leisure time, we had the opportunity to get to know each other even better, to share many ideas and thoughts beyond the confines of our narrow interests.

After that meeting in Athens, we remained in correspondence and enjoyed regular Skype chats on issues of common interest, ranging from politics to philosophy of science, artificial intelligence and consciousness. My mailbox had over 65 messages exchanged with Cris in 2021. A remark on the sensitivity of neural networks triggered very interesting and long interactions. This gave me the opportunity to delve deeply into an issue that had long been of

interest, particularly thanks to Cris's technical contribution and unparalleled skill to link observation to theory. Our discussions culminated in a jointly written article, which was published as a technical report and submitted for publication.

They say that there are no coincidences. On the surface, Cris and I are separated by many degrees. He lives in the Antipodes and our areas of research are quite remote from each other. However, a number of events progressively brought us closer to each other. I was charmed by his emotional intelligence, his integrity, his critical spirit and his profound respect for human values. After every conversation with him, I realise I have learned something new or understood something better. On the occasion of Cris's seventieth birthday, I would like to wish him a long and happy life. May his presence and spirit make the lives of his family and friends brighter and more beautiful for many, many years.

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Joseph Sifakis,
Grenoble,
December 21, 2021

Our first joint paper

It was in the early eighties of the last century when I became acquainted with Cris' and Ion Chiţescu's papers [CC82, CC83a] and [CC83b] on Martin-Löf tests and Kolmogorov complexity. Especially, their papers on representable Martin-Löf tests inspired me to add another note [Sta85] on this subject. I wrote a letter to Cris about my results, and he responded with the proposal to work on a joint paper.

In these email-less times collaboration was not that easy as today. In addition, the closedness of "socialist" countries put several restrictions and bureaucratic obstacles into one's way. Today it is difficult to understand those bureaucratic obstacles we had to cope with, e.g. concerning money, visa, permission of leave for a business trip, etc. For me, as an employee of the Academy of Sciences of GDR, to apply for visiting Cris at Bucharest University would have taken a great amount of time and effort. And we had no time, since Cris proposed to contribute to the volume of Professor Marcus' 60th birthday.

So letters had to go to and fro between Bucharest and Berlin, and finally the goal was achieved [CCS85]

Dedicated to Professor S. Marcus on the occasion of his 60th birthday

P. MARTIN-LÖF TESTS: REPRESENTABILITY AND EMBEDDABILITY

CRISTIAN CALUDE, ION CHIŢESCU and LUDWIG STAIGER

REV. ROUMAINE MATH. PURES APPL. 30(1985), 719–732

It appeared that Cris and I were the first foreign co-authors to each other despite the fact that we did not meet until 1993 in Turku at the first DLT conference. Today Cris is my most frequent co-author.

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A Pattern in Cris Calude's Work

Two decades ago, while one of us[20] was a PhD student, I discovered *Information and Randomness* [3]. I wrote to Cris with a question about the book. He was surprised to find out about applications of his work on algorithmic information theory in accounting and economics, far outside his core fields of mathematics and computer science, and corresponded with me at some length. He then agreed to serve on my dissertation committee and generously hosted me in Auckland for a research visit.

During this visit, when we talked shop, our conversations mostly focused on philosophical issues. (When we weren't talking shop, I believe I provided him with an unintended constructive proof about a partial order, demonstrating the existence of a bottom element of any ranking of Ping Pong playing talent.) He shared Calude [1] with me, prompting us to focus on an issue close to his heart: what constitutes a proof? Is it enough to know that something follows from some axioms and rules of inference, or is a proof something that provides deeper insight? In this note, we discuss how much of the body of his work relates to this philosophical question — on this, Paul Pedersen, the second author, joins in on the discussion.

We could go the opposite direction: Is it enough to know something without having any deeper insight? Big Data champions say yes: never mind about the whys and wherefores. Stable patterns tell us all we need to know.

Stable patterns in data are extremely rare. In Calude and Zamfirescu [2, 8], Cris shows us that almost all numbers have no consistent statistical properties. Restricting attention to the numbers in the unit interval $[0, 1]$, expressed in some base b, Cris and his coauthor shows that the $\liminf$ of the probability of any numerical pattern (i.e., word over the base b) occurring is 0, and the $\limsup$ is 1. Because patterns are so rare, they attract our attention.

This does not mean, however, Big Data champions have it right, because they don't. As the amount of data increases, spurious correlations, even stable ones, appear at a much faster rate than correlations reflecting a relationship that occurs for some underlying reason. Cris and his coauthors

[20] Stecher

make this argument precise, using insights from ergodic theory, in Calude and Longo [6], Calude and Svozil [7]. It is not simply that as we get more data, we see more nonsense. As we get more data, almost all of the patterns we see are garbage. As Cris and his coauthor put it: "Too much information tends to behave like very little information" [6, p600].

Cris' argument is reminiscent of one now famous in macroeconomics, due to Lucas, Jr. [10], later expanded upon by Cooley and LeRoy [9]: stable correlations in economic data are not enough for making policy decisions. Consider the relationship between the number of calls to an Auckland Fire Station and the frequency of houses burning to the ground. It would not surprise anyone to find a high positive correlation, one that gets stronger as data sets grow, and that is highly persistent. Without knowing the underlying mechanism, it would be easy to conclude that fire departments recruit arsonists and pyromaniacs; to spare your house, never call the fire department and remove your smoke detectors. A similar example often comes up in econometrics classes: sales of ice cream are said to predict homicides. Surely this is because ice cream sales are more common in weather conditions in which people are more likely to interact. But the relationship is also consistent with an argument that banning ice cream would reduce crime.

So if the numbers can't speak for themselves, who will speak for them? Don't look to observed correlations. Run experiments. The laboratory speaks for the numbers.

Cris uses experiments in several papers; we comment on two of them here. Calude et al. [5] estimates a Chaitin Omega number (i.e., a halting probability). Omega numbers are strongly noncomputable. Nevertheless, using experiments, they obtain an exact initial segment of the Omega number.

Outside of theoretical computer science, Cris has used experimental methods to address problems in pure mathematics. Finding the 6^{th} Taxicab number, for example, is known to be difficult. In Calude et al. [4], Cris and his coauthors propose a candidate for Taxicab(6). Their experiments show that their candidate is the right answer with a p-value of approximately 0.002.

Cris' work spans many fields. All of his research aims to address the questions we discussed during my visit to Auckland as a PhD student. The problems he addresses in his papers are in computer science and mathematics, but his sights are always set on larger philosophical issues.

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The Mosquito incident and the need-(not-)to-know

Abstract

I am reporting here how professor Cristian Sorin Calude, henceforth called Cris, became involved in the "Mosquito incident". More generally, the relationship between the single individual vis-à-vis the state or collective is reviewed, with special emphasis to need-(not)-to-know secrets.

At some point in history, Cris lived in ideological tyranny called "communism". Economically, communism brought austerity, frustration and devastation. Because due to its collectivist economic principles that suppressed individualistic entrepreneurship this totalitarian form of government was unable to provide consumerism and the type of cargo cult which, due to human technologic and energetic advances resulting in huge productivity increases, flourished elsewhere. Communism wasted huge amounts of resources to produce very little goodies consumable by its unfortunate citizenry.

It is my sombre observation that history provides ample evidence that more common equality results in more common misery. Conversely, steepening inequalities—the rich get richer—result in improved living conditions of the poor. Such is the result of compound interest; and, besides catastrophes—some of them economical like communism—and war, there are hardly any means to bring down inequality [15]. The late Dirac's observation on the futility of war [7] adds an impasse by pointing out that there is, in modern terminology, a dilemma between equality of opportunity and motivation for outcome: for, Dirac observed, there are two equally justified socio-political positions—the right of parents to pass on their achievements to their children, as well as the right of every child for equal chances of well-being—that shan't be the topic negotiated by war among conflicting ideologies.

Because of the misery it had instigated, communism had to curb and control the flow of information and people. For it won't be for long that, in a more liberal unrestricted environment, the most gifted and able persons escape to other places where life was better—a kind of osmosis. Who can be blamed for that?

These, I kindly remind you, were the times of the "iron curtain" and the "Berlin wall", times of heroes and villains—recall John F. Kennedy's boyish-pathetic "ick bin ein Berlinner!", and his manly stance in breaking the Soviet blockade of West Berlin with a massive airlift. From the communistic inside it was rather obvious who was who; in particular who was the villain—no doubt about that. People suffered through this communist tyranny on a day-to-day basis; their misery was just too obvious and evident. But, of course, it was also the time of Dwight D. Eisenhower's epic "good luck with our military industrial complex" farewell speech.

Coming back to the story, in those times Cris corresponded with a colleague from one of the United States of America's "outremer" colonies, aka "the West". And, as noted by Cristian Terhes, a Romanian member of the European Parliament in an October 28, 2021 press conference about a heavily redacted contract between the European Commission and a big pharmaceutical company [17]: "the difference between tyranny and democracy is very simple: when the government knows everything about you, that's tyranny. I know how it is to live in tyranny. When you know everything about your government, that's democracy." Accordingly, the Romanian government at the time wanted to know everything about the correspondence between Cris and the West; in particular not only the metadata, but also the content. In those days the easiest method for this to achieve was to physically open the correspondence. Knowing this, Cris, therefore, devised an ingenious way of reflection on this eavesdropping: he would write in his letter to a western colleague that it can be easily established if someone had opened and read the letter. For if, upon its delivery, no mosquito could be found inside of the envelope, this would clearly indicate that the letter had been opened, its content compromised, and then sealed and resubmitted before its final delivery.

An easy and at the same time effective way of certification—at first sight. And sure enough, when the colleague in "the West" opened the letter ... out fell a mosquito.

Only Cris had never deposited a mosquito in the letter in the first place!

In that way, the legit sending and receiving parties had, beyond doubt, ascertained that the Securitate—the popular term for the Romanian Departamentul Securitatii Statului (Department of State Security)—had opened, read, and understood the latter in its immediate meaning—and had put in a mosquito upon closing it. It is still is a sarcastic pleasure to imagine those malign bureaucrats at Securitate—maybe feaverishly and desperately—catching

a mosquito, and inserting it into the letter, in their preparation for re-sending it to "the West". Little did they know that Cris had arranged with his colleague this to be a token of authentication unbeknownst to them! As a mathematician you could also say that they made Securitate perform an involutary Cantor diagonalization on parts of the message—metacryptography of sorts.

As far as I know, this was not a single "mosquito incidence" but was applied to each letter of a series of letters, each one containing a properly apprehended mosquito upon delivery. Poor little buggers!

Cris told me that this type of tampering with the powers that be was not entirely uncommon. Indeeed, mathematicians tried various methods to trick the regime without being punished. In this case, Securitate didn't suspect any malicious play and nobody stopped the letters—probably because they thought the outcome might have been worse for them. After all, they lived in that same hermetic tyranny, which threatened all of them.

Other instances involved an internationally well-known political opponent of the regime who was the youngest doctor in mathematics in the country for some time before Cris got his Ph.D. a few months younger in 1976. Cris told me that this person played many intelligent tricks. For example, he knew and told lots of political jokes. One could go to jail for spreading, even for listening to some such jokes. He enjoyed telling them to the big political cats in the university. So these guys tried to avoid him, sometimes in hilarious attempts, because these were no-no situations: on the one hand, listening to them might have turned out to be dangerous; and yet, on the other hand, not listening was kind of embarrassing: well, you cannot even enjoy a joke, mate!

Cris told me that from this person he learned the following dictum: "only those who work make mistakes". (My maybe incorrect reading of this is: those in power are those who work very hard and thereby make huge mistakes.) To understand its context, one needs to know that men in communism could be convicted to jail if they did not work. Such were these times!

As already pointed out earlier, my own judgements about these tyrannies coincided with those who had to bear and suffer through them; the misery and suppression was just to obvious and totally unsophisticated. And yet, I may have been able to afford more nuanced views about western governments. For instance, during my visits to the late Soviet Union in 1986 and 1987, it was obvious that state tyranny was prevalent—evil was easily identifiable, and was commonly acknowledged. For instance, the first thing the Soviet

colleague taking care of me did was to direct me to a little wooded area on the banks of the Moskva river, very close to the Lomonosov Moscow State University, and asked me if I was a member of a communist party. Upon my negation and curiosity, he told me that he just had to make sure that I am no communist cadre sent to spy on him. Caution demanded that he had to be very careful and kept his distance otherwise. I guess the physicists there would have encapsulated me like a tumor, refusing to cooperate. I should point out that the Soviet Russian colleagues I met and cooperated turned out to be the most kind, friendly and cooperative persons I had met thus far. They considered a copy machine as the "most sexiest thing" in town. Maybe I did not get the joke.

Alas, those "in the West" may find it much more difficult to cope with their governments when it comes to the treatment of its citizens. There was no outright, easily acknowledged evil; and "the West" fed its citizens well by implementing a cargo cult-type consumerism. We indulged ourselves in conveniences, travel, and relative freedom of speech—as long as we were not influential and did not stir too much attention. I had even co-organized peace rallies in Vienna before I joined the Department of Energy's Lawrence Berkeley Laboratory as a visiting scholar. But I wonder how much autonomy we really had in all of this. This relates to Zizek's article on WikiPedia mentioned later [19].

There seems to be a prevailing dichotomy between governments and the collective on the one side vis-à-vis its individual constituents on the other side. It would be much to easy—and this has been brought forward by many historic thinkers such as Confucius, Plato, and Rousseau—to assume that governments are "by the people and for the people", and that its subjects should therefore obey its hopefully benign and merciful and wise rulers. Indeed, there exists a long tradition of perceiving rulers and government as potentially malign if not outright bad and dangerous.

Again and again, at issue is the concept of the individual human being vis-à-vis the collective, the state and its apparatus. We find an individual stance, a will, already in the epic of Gilgamesh [10]. Athenians in their short classical democratic period tried to curb government by introducing sortition—that is, elements of the random selection of offices, as manifested in the kleroterion, an early randomness generator [9]—as well as ostracism. The British "Magna Carta Libertatum" commonly called Magna Carta, the United States Constitution with all its Amendments, and the Federalist Papers, as well as Montesquieu's Separation of Powers were inspired by individ-

ual rights and freedom vis-à-vis the collective. Socrates may have thought of this too. In more recent times Popper [14] as well as Berlin [2], Shafarevich [16] and Ayn Rand preferred the primate of individualism with regard to its freedom of expression, self-determination, and autonomy.

And yet, how far should autonomy go? Is there a mandatory, citizen's inalienable rights to know; a desire to know the facts to evaluate a situation that cannot be transferred to others, even by legal procedures and "oversight" by state functionaries and representatives? How extended needs the freedom of information, the people's right to know, be? Is there any reason for compartmentalization and restriction by "need-to-know"? And are there "outer" restrictions to "need-to-know" that curb autonomy?

It is generally assumed that for obvious reasons certain truths—e.g., so-called "state secrets"—cannot be revealed to adversaries. Ernst Specker once quoted similarities with "Jesuit lies"; the sort of allowed "white lies" to (allegedly) prevent greater harm than the lie itself. If, for instance, you told an adversary your line of defense or attack, this would greatly increase his ability to overcome your plans and defeat you. Some of this is reflected in Popper's "paradox of tolerance". Zizek partially agrees and puts forward some anecdotal evidence for nondisclosure also when it comes to politeness and tact that could seriously affect serious politics [19]; yet he also mentions that people's right to know includes revelations of the WikiLeaks story. He speaks of "moments of crisis for the hegemonic discourse—when one should take the risk of provoking the disintegration of appearances", with all the repercussions this might entail. Ellsberg's publication of the Pentagon Papers and other secret material published by Snowden might fall in this category.

So what exactly needs to be kept secret and what has to be disclosed? This is not a question of black-and-white but nuance. Imagine, for instance, it would be revealed that our planet is visited by various alien species and life forms, in particular ones resembling humans, as well as insectoids and reptilians, some of them telepathic; that these life-forms can move in crafts that are unimpeded by our military; that the only time we unintentionally shot down a craft of the "others" was on July 9, 1962, as operation Starfish Prime produced a massive electromagnetic pulse from a nuclear explosion at an altitude of 250 miles above the Pacific Ocean; that the "others" intentions are not always benign, as they abduct humans, mutilate cattle and cause nuclear weapon systems to engage and stop functioning; that even the head of the United Nations, Javier Pérez de Cuéllar, was "ordered" by them not to disclose their existence ... suppose all of this is true [3, 5, 4, 6, 8, 13]—then

what—"how about that" [12]?

Would it not be better to hide these inconvenient truths from the public, and maintain a facade like in the 1998 movie "The Truman Show" [18]? I would like to raise this question, as expressed in the Japanese-Polish movie "Avalon" [11]: "What is the better game, one of which you think you can leave but can't, or one that looks impossible to leave but an exit always exists?" How much need-to-know if that knowledge is harmful or disillusioning? And yet, as noted by Goethe, "No one is more a slave than he who thinks he is free without being so."

Maybe truth is a relative concept depending on context and means, an multi-layered and sometimes even amorphous entity. It varies with respect to the means and purposes available; almost appearing as an epistemic concept. I am well aware that such a stance disputes the "ontic" and "pathetic" conception of truth by, for instance, Hannah Arendt, as "conceptually, we may call truth what we cannot change" [1]. For we have no absolute means, no metaphysical Archimedean anchor, to establish this kind of "truth that we cannot change". Let alone the situation that, in its extreme form, we have no autonomy to commit ourselves to such truth or facts. And we may not even be allowed, neither might we desire, to acknowledge that on a meta-level, so that we may not even want to know what we are not allowed to know. And yet it sometimes helps to keep in mind the unknown unknowns.

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(Dated: January 15, 2022)

Teachers and Students

A full-time Professor, Cristian will always be – in his heart – Professor Solomon Marcus' pupil! I may say this since I know Cristian for more than 50 years: we first met a few minutes after the Algebra thesis during the admission contest for the newly established Division of Computer Science of the Faculty of Mathematics. We had a vivid argument regarding the solution of a cardinality problem.

Then, we worked together at the Division of Systems Studies of the Bucharest University, where Cristian got involved in a very fruitful scientific collaboration with another researcher – who will also become one of his most dear friends: George Păun. Both of them may be regarded as the best followers of their mentor, Professor Solomon Marcus. They were his pride and joy. Their successes were his satisfaction. They learned from him not only to study, to investigate, to teach, to write beautiful scientific papers and books but also to create "a school", their own scientific disciples.

Also like their teacher, they have always loved "The Faculty" and tried to contribute to its scientific progress and prestige. One of the many examples: for several years, the library of our faculty received the full collection of the ACM periodicals because Cristian payed the subscription out of his own pocket. Needless to say that the shelves of our library expose the books and scientific papers that both Cristian and George have written, independently or in collaboration.

Happy birthday, Cris!

Happy Birthday Cris!

It has been over 30 years since I first met Cris during my undergraduate studies in Bucharest. From being my teacher and my mentor to being friends, it would be impossible to count all the ways Cris has helped me in my career and with my personal development. And for all this, I am very grateful.

Happy birthday Cris and all the best to you and your beautiful family!

Figure 10: Cairns, April 2016. May we share many lovely moments like this one!

Cu drag,
Lumi

Luminiţa Simona Vîţă
Wellington, NZ
December 24, 2021

Antipodal Cris

TZ: I have a good friend. With the time passing, he becomes older and older. But somehow he manages to keep remaining eight years younger than me...

Less than three decades ago, he had the fine idea of inviting me to spend a quarter at his University of Auckland. It happened only twice in my life that somebody proposes to me a problem, about which at first glance I think "no chance", but which then turns out to be solvable. One proposer was Cris (the other one, Gerhard Sierksma from Groningen). Cris said I should see via Baire categories if most numbers are disjunctive or not. My goodness! I knew nothing about numbers, except for integers indicating pages in a book... However, I adapted to the situation, and an interesting common paper resulted (even two, if we include a constructive one, which I don't really understand).

We played tennis, of course head down, feet up. This way, he won.

I saw the most beautiful cave, from a boat. The "sky" was full of "stars" (a kind of insects producing light).

The whole place is dangerous: 2000 years ago, a volcanic explosion destroyed most local life (but there were no humans there yet). The sky over Rome became red as a consequence; so, we know the exact date. Now, there is a lake at the explosion site. Around it, lots of warm gas gets out from holes in gardens, parks,...

Cris, come back! Come again to my garden and grill in Bucharest, before the next explosion takes place...

CZ: Of all the schools I had the pleasure to attend, across eight countries on four continents, the best one, by far, was the one in Auckland. Once, from the classroom, we saw towering plumes of black smoke in the distance. As there is no smoke without fire, we all, led by the teacher, went to the rescue!

Getting closer, I exclaimed: "Well, that is exactly where we live!" We hurried up. The fire had already eaten through part of the building, where the owner had assumed to have his superfluous wife before setting the fire;

consequently, my aunt, in the other part of the building, closed her windows to shield herself from that pesky smoke, and locked her door to inconvenience thieves.

Firemen broke everything, and got her out without her handbag, by brute force! My ignorant father was gleefully doing mathematics at the university. Finally, the firemen won, but I don't remember what happened to the owner's wife. She lived happily ever after with her share from the insurance – or she perished. (I hope not, but perhaps she couldn't choose.)

Another memory from Auckland, one that instilled in me an almost Scroogean relationship with money: my father had a nice beige-coloured car. I played a lot in and around it, and I knew of the importance of an unsupervised car being locked. So, when completing my fooling around, I locked all but one door from the inside, got out, pushed the knob down, and closed the final door. I was very pleased with how very locked the car now was.

My father was less pleased. As the attentive reader will have noticed, no key was involved in my locking the car. And so it happened that the only key we had was inside the car. His punishment – as always, swift and just – was for me to use my pocket money to get the car unlocked. I remember paying all these beautiful coins I had amassed, but I had learned my lesson: never tell anyone how much pocket money you have!

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