

FRANÇOIS TADDEI

# LEARNING IN THE 21<sup>ST</sup> CENTURY



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with Emmanuel Davidenkoff

# LEARNING IN THE 21<sup>ST</sup> CENTURY

*Translated from French  
by Timothy Stone*



*To all those who have taught me so much.*



If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea..."

Antoine de SAINT-EXUPÉRY, *Citadelle*

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## Prologue

Where are we going? I couldn't tell you any more than the next person can. But my life has been one of asking questions, drawing parallels, and forming hypotheses. Contained in the following pages are what I imagine an expert in comparative evolution would have to say if he or she were from another planet.

For perhaps the first time in the history of humanity, there's growing collective awareness that we're living through an evolutionary transition, like any one of the transitions that occurred dating back to the primordial soup from which life emerged all the way to when *Homo sapiens* first appeared.

And in this way, we're extraordinarily lucky.

The more of us there are addressing the questions that this new transition presents, the better we'll be able to mobilize our collective intelligence along with the intelligence of machines and other living organisms; the more likely we'll be to come up with the right answers to these questions and construct a brighter future than the one some are predicting or that certain tech experts are actually creating.

Who knows? Perhaps humans will in fact be able to progress at the same rate as technology, and a better world will emerge in which progress will actually serve humanity and nature.

That's my hope, anyway.

May this book, along with all of you, be a part of making this a reality.

## Introduction

I had just gotten to sleep after a long night of jetlagged insomnia when I was forced awake by the unmistakable, ear-splitting wails of the sirens of New York City firetrucks. I opened my eyes. The clock showed 9:30 a.m.; that was 3:30 p.m. in France, where I had been the previous morning, dropping off my son at preschool before catching a plane to New York.

After landing, I went to stay with my friend and colleague Stan Leibler. He was the head of a laboratory at Rockefeller University, where I had been invited to give a seminar. I had also been thinking about spending a sabbatical year there, that world-renowned institution famous for its Nobel Prize winners in biomedical research.

Stan gave me a tour of the campus, right on the banks of the East River on Manhattan's Upper East Side. From the top floor of the tallest building on campus, we took in—as one must—the fabulous New York City skyline, the steel geometry of the skyscrapers cutting up the horizon as we looked to the south of Manhattan Island. After that we ate dinner, and then Stan showed me to one of the

single rooms reserved for visitors, who come from all over the world. I tried in vain to fall asleep until finally, just as the sun was rising, I began to doze off.

Awoken by the sirens, I tried against all hope to get an extra half hour or so of sleep while the hubbub down in the street continued. It kept growing louder. Eventually the sound had invaded the entire room, and I dragged myself out of bed to go look for Stan. Passing someone in the hallway, I heard him mutter that *something* had happened at the World Trade Center, but I couldn't quite make out what it was. Then I found Stan.

"Come on," he said. "We're going upstairs."

Just as we had done the previous evening, we went up to the top floor of the tallest building and looked to the south of the island. But the fabled skyline had changed. My brain refused to comprehend it.

"Unbelievable," someone said. "One of the towers fell."

I still didn't believe it.

"No, no, there's just a lot of smoke," I said. "It's hidden by all the smoke."

At those words, the second tower fell. It was September 11<sup>th</sup>, 2001. The course of history was changing before our eyes.

There were Israeli researchers with us. They were used to living in a place under threat of terrorist attack.

"We can't let terrorists scare us," they said. "We must continue our work."

I recalled my own experiences with terrorism in an effort to match their resolve, that we can't shy away the face of terror. My family is from Corsica and I often visit there. Nationalist bombings have rung out through the "blue nights" there for decades. In Paris, 1986 was a

year of attacks; I was 19 and going to college there. In February of that year, there were attacks on the shopping arcade beneath the Claridge Hotel, the popular Gibert Jeune bookstore, and a FNAC-Sports retail store in a busy shopping district in the center of Paris. In March, the Point Show shopping arcade on the Champs-Élysées was attacked. In September, the post office in the Hôtel de Ville, a police headquarters, the Renault pub on the Champs-Élysées, a Tati department store, and a super-market food court in La Défense, the financial district just outside Paris. In 1995 and 1996, there were attacks on Paris subway stations Port-Royal, Maison-Blanche, and Saint-Michel, parts of town I went to almost every day.

Nonetheless, we found it impossible to get back to work. We went down to give blood, but the waiting line was three blocks long, and on top of that, they weren't accepting blood from Europeans for fear of spreading mad cow disease. Back at the university, we tried to talk science, but everything brought us back to what had happened. A colleague told me about an experiment on predator-prey relationships, which showed that even when predators are rendered harmless and don't attack, their presence still scares their prey and decreases their fertility. His conclusion was that fear has the same impact as real danger. We can't give in to fear.

While we were trying to focus on other things, my wife and children back in Paris were worried sick. I had sent them an e-mail letting them know I was fine, but it had been blocked and wouldn't get to them until a week later. All telephone communication had been cut off. It would be three days before I could get in touch with them and reassure my distraught wife, who for some reason had

been convinced I was out buying shoes at the World Trade Center the morning of the attack. My son, who was only 3 years old at the time, was under the impression that all the buildings in New York were falling, not understanding that it was just the same footage being replayed over and over on television.

It just so happened that the return flight I had booked for a week later would be one of the first to receive authorization to take off from New York City after the airports had been closed. Before takeoff, I bought the weekend edition of the *New York Times*. It's known for being dense, but that day, it was as thick as a book and contained hundreds of eyewitness accounts of the attacks.

It was only then, reading those eyewitness accounts during my return to Paris, that something hit me. I had been in New York City only a short distance from the disaster, yet I hadn't been able to really understand it. I didn't have access to television—the broadcast antennas were on top of the World Trade Center, so the entire city was without television—and my hosts had done their best to distract us to keep us from panicking.

I passed yet another sleepless night on the flight, and it occurred to me suddenly that, there, 30,000 feet above the Atlantic Ocean, I was no longer a microbiologist who marveled over the curious behavior of bacteria; rather, I was a global citizen who had been thrown unwittingly into the epicenter of history, a history in transition. My brain swarmed with questions. What kind of world do I want to see my kids grow up in? What kind of a world will I leave for them? Will I continue to be a powerless bystander as I had been throughout that week? Or can I be a changemaker? If the world was headed off the rails,

what should we do? Migrate to another planet? Face the inevitable? Try to build a better world? But how do you work toward a more humane...humanity?

To add to the shock of the attacks, I learned the following week that terrorists were making use of biological weapons in letters containing anthrax. As a microbiologist, this affected me directly. I remembered when I was a child how my father, who had also been a university professor, once described his job as an elected official. He said, “There are problems in the world. I think up solutions, and the government puts those solutions into action.” I don’t know why, but until then I had never let go of the idea that everything would always be under control, that if the world was in trouble, my dad would take care of it, and I could keep playing. At the turn of the 21<sup>st</sup> century, he was going into retirement, and I had become a father myself. I could no longer be the child. Now I was the parent. What would I do for future generations? Would I be content raising my children to do the best they could, or would I contribute to building broader ecosystems that would benefit them and their whole generation?

When the airplane landed at Charles de Gaulle airport in Paris, the idea of what I would do was beginning to take shape, although it would further solidify over time. I wouldn’t be just a scientist, striving for advances in knowledge and improvements in medicine in isolation from the world in an ivory tower. What mattered was the here and now and how we prepare for tomorrow’s world. We can’t stand idly by as our society undergoes major changes that have global impacts.

Watching the Notre-Dame Cathedral fire with students and colleagues on the rooftop of the Center for Research

and Interdisciplinarity (CRI) in central Paris, I felt once again that feeling of incomprehension in the face of destruction, of shock and horror at our inability to save what was in this case a symbol of French history. But the next morning, we saw the cathedral still standing, and hope was renewed. Of course, the cathedral would never be the same; it would evolve, but it would still be there for future generations. This is non-utopian optimism. I believe that, even though our forests are burning from the Amazon to Corsica and our planet continues to get warmer, we can still act. Young people, as they always have throughout the history of civilization, refuse to stand by, and young people today are taking action against the overwhelming challenges posed by climate change. It's the responsibility of every parent, scientist, teacher, politician, etc., to do everything they can to support the "Greta Thunberg generation," the first generation of global youth activism in the name of science. Collectively, they're working to overcome today's and tomorrow's challenges. The 21<sup>st</sup> century's first generation is showing us that they're willing to fight for the future, and it's our duty to provide them with the latest developments in science and innovative education so that, instead of being mere bystanders in the face of imminent catastrophe, they can be change makers and authors of a history that's yet to be written.

Prior to 2001, I had spent 12 years studying how bacteria cooperate and exchange information in order to adapt. On my return to Paris in 2001, I decided I would focus my energy on fostering cooperation among humans while keeping in mind in those early days of the digital revolution that digital would exponentially accelerate,

profoundly and rapidly changing the outlook of my task. We won't learn in the 21<sup>st</sup> century the way we have in centuries past. Why not? And how will we learn?

These are the questions addressed in the following pages. First, I'll take a more in-depth look at them by fleshing out the reasons why we will learn differently in the 21<sup>st</sup> century. Then I'll take a slight detour, relating my own experiences to share where I'm coming from and what I've learned at various points throughout my journey. Then I'll concentrate on what takes place on the individual level—our ability to understand ourselves and the importance of not only learning how to learn but also learning how to unlearn. This section will take us through the complex inner workings of the brain, which plays a dual role of our best friend and worst enemy in the learning process. After this, I'll look at how to learn with others the way living organisms have done since life first began. Then we will explore the best ways to learn how to ask if not the right questions, then at least good questions. Lastly, I will share with you some concrete solutions that can transform our globe into a learning planet.



## Why will we learn differently in the 21<sup>st</sup> century?

Aristotle said there were three types of knowledge: *epistêmê*, *technê*, and *phronesis*.

*Epistêmê* is knowledge of the world, thus the word *epistemology*, the study of knowledge.

*Technê* is knowing the practice of a craft in the world, thus the words *technique* and *technology*.

*Phronesis* is the least well-known of the three. It's often translated as *prudence*, but not the kind that tells us to be cautious. Rather, it's the ethics of our actions. In Aristotle's time, the word essentially was used to refer to the impact our actions had on ourselves and others. Today, it doesn't just apply to the here and now but to everywhere and in the future. If we want to tackle the crises of this century—which are global crises, be they climatic, environmental, economic, or geopolitical—we must make *phronesis* a pillar of knowledge as solid as *epistêmê* and *technê* are. And this we must do as much in our collective

and political action as in our individual behavior as responsible global citizens.

It's a shame that nearly all education systems put science at the top of their priorities, with engineering next in importance, while the ethics of our actions are studied only minimally and at a later stage in education. Worse still is that in certain fields, medicine for example, it seems that one's ability to empathize—a dimension of ethics—diminishes with each year spent in school.<sup>1,i</sup> The same phenomenon was observed in major business schools: The higher the level of study, the less students were cooperating. In engineering programs, what decreases with time spent in school is the ability to take an ethical look at a given subject. It's as though the more knowledge and skills we gain, the less we take into account the values and ethics of what we learn and what we do with what we learn.

Today, science and technology no longer simply tell us what the world is like; rather, they tell us how to live in the world, and their impact in this regard has been considerable. Our blind spot on ethics thus becomes even more critical in all learning processes, and this is very new.

## ALL LIVING ORGANISMS LEARN

Since the first cell appeared, the complete set of genes of living organisms—the genome—has evolved tremendously.

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<sup>1</sup>All footnotes marked by Arabic numerals appear at the end of this book. They do not provide any additional information, only relevant sources and references.

But for billions of years, this genome remained unaware of its own evolution.

This is what Henry Plotkin showed so remarkably in *Darwin Machines and the Nature of Knowledge*<sup>ii</sup>, an essay published in 1994 that brought together biology, psychology, and philosophy. He says that Darwin could have been a zoologist, microbiologist, immunologist, psychologist, epistemologist, computer scientist—the list goes on—all due to the simple fact that each of these fields operates according to evolutionary processes similar to those Darwin illustrated. They are variation of a gene, selection for that variation, and retention of the new gene, which usually then gets propagated in the species. Note that the retention stage is often a form of learning.

To use an example, our brains are theaters of multiple random phenomena taking place in our neural circuitry. When randomly crossing neural connections get stabilized, those connections can be memorized. That's how we learn.

And this phenomenon of learning is universal. What's true of our neural networks is true of all cells, from bacteria to multicellular organisms, whether they have brains or not. For example, a given bacteria knows how to break down a sugar because a few of its ancestors happened by chance to find the right genetic combination that made it possible for them to consume sugar as food and thus continue to reproduce. According to Plotkin, these Darwinian processes for acquiring knowledge can be traced back to the dawn of life. The first self-replicating systems, which allowed the first forms of life to develop, must have operated this way. These processes have made all the great evolutionary transitions possible by providing

successive forms of life increasingly elaborate ways to acquire knowledge about their environment.

A very interesting book by Christopher Wills called *The Runaway Brain*<sup>iii</sup> describes how, when an innovation of this kind emerges, an evolutionary arms race takes place. Predators with a larger brain will have an advantage over their prey, creating selective pressure so that, in turn, the brains of prey will develop in order to survive and reproduce. There are also selective pressures between sexual mates. In the same way that a peacock's tail is used solely for the purposes of seduction, it's not unlikely that part of our brain function could be solely reserved for seducing a mate. Learning how to perform a courtship ritual or a ceremonial nesting can be necessary for reproduction, which explains the unmatched flair of so many animal artists in their courtship displays (to say nothing of humans). Such selective pressures between mates may have shaped not only our artistic abilities but our moral values and ability to cooperate as well. This is what Matt Ridley investigates in his book *The Origins of Virtue*.<sup>iv</sup> Anthropologist Robin Dunbar<sup>v</sup> has even posited that morality could be one of the factors behind the emergence of language, as cooperation among members of a community is better enforced when they can exchange information about one another's reputations.

Bees, ants, birds, and marine mammals can communicate to those around them about where to find food, how to avoid a predator, a threat, etc. Plenty of organisms transmit information and therefore knowledge to others. It's an ability that's absolutely crucial for survival, as it provides a considerable competitive advantage. I'll come back to this later.

Thus the dominance of the human race is due primarily to our extraordinary ability to exchange information and cooperate with fellow humans. Language provides us with the tools to describe an infinite number of situations, and as Yuval Noah Harari points out in *Sapiens*,<sup>vi</sup> humans have a much more developed capacity for cooperation than other species do. If you pit one human against one chimpanzee, the result could go either way. But if you pit 1,000 humans against 1,000 chimpanzees, the humans are much more likely to win because they can communicate more effectively and work together more easily.

It doesn't matter if learning is done intentionally, say, to resolve a given problem at a given moment or if it's done blindly. As it so happens, many major scientific discoveries came about completely by chance. What's special about humans is that, at least in principle, we know which innovations are important and can then pass these on. Each time we learn something, we can teach it to someone else, who can then go deeper into that knowledge and enhance it further before teaching it to someone else. In many of the hunter-gatherer tribes we've been able to study—and this was likely true among our ancestors as well—children are educated by one another, through playing, exploring, and imitating, and all this without an organized education system or adults having the least say in what they learn. Needless to say, they learn a lot through game playing. It goes to show that, like our ability to laugh, our ability to learn and teach is unique.

What's new in the 21<sup>st</sup> century is that digitalization lets us go even further by allowing us to create artificial intelligence, which itself will be able to create new

knowledge. Or for those who feel “artificial” and “intelligence” can never go together, digitalization allows us to create machines that on their own can discover new relationships between data in massive databases that the human mind is not able to process and analyze.

As I said before, since life appeared on Earth, living organisms have invented numerous and varied ways to acquire knowledge. What’s unique about humans is that we’re not only a living organism but a conscious organism too, and as far as we know, we’re unlike other animals in that we are conscious of being conscious and capable of articulating this thanks to language.

Therefore, we know that we are consciously living through a new, major evolutionary transformation characterized by the creation of new forms of intelligence. As far as I know, this is completely unprecedented, at least in our part of the galaxy.

A second revolution is taking place at the same time, still thanks to technological advances, this time fostering progress in genomics. We’re now able to modify the genomes of other species. Here as well, the fact of modifying the genome isn’t new; it’s that we can do so deliberately. All forms of life are constantly evolving by way of random mutations, but they are never conscious of the fact that they are evolving. Consciously rearranging a genome is radically new—all the more so as we can now envision modifying our own genome, and this would be a major leap into the unknown. We cannot leave these developments to *epistêmê* and *technê* alone. We must involve *phronesis* to try to understand where such a step would take us as a species.

## TRANSITION ALWAYS CREATES CONFLICT

These transitions—we could even say upheavals—are not the first of their kind in history, of course. What have past transitions taught us? We'll see that periods of evolutionary transition have almost always engendered conflict among those involved.<sup>vii</sup>

It's thought that life arose from what biologists call the primordial soup, an environment rich in organic molecules and energy that brought about the emergence of self-replicating molecules, i.e., molecules that were able to synthesize identical copies of themselves through a process called autocatalytic replication. What were these first molecules that both carried information and replicated this information? We don't know. DNA can be replicated, but not on its own. RNA, however, is capable of replication and at the same time it is capable of catalysis, meaning it can accelerate chemical reactions, including those that transmit information. It's a better candidate for the original self-replicating molecule, even if today we don't know of any self-replicating molecules that are completely independent.

In any regard, all it takes is one self-replicating molecule to set off the process of Darwinian evolution in which every error in the replication process creates variation and that variation gets passed along. It's thus likely that evolution began even before the first cell ever came into being, more than 4 billion years ago, shortly after the Earth was formed.

Still today, researchers are trying to understand the composition of this primordial soup. They take nitrogen, carbon, oxygen, and hydrogen and heat them up and

try to see if any slightly more complex molecules get created in the process—these hypothetically being the first building blocks of life. Scientists are also looking in space, where these molecular groupings appear to form to synthesize relatively complex molecules such as amino acids. Panspermia, an old and well-known theory, posits that life was brought to Earth by comets. The comets “inseminated” Earth by not only bringing water to it but also providing it with the elementary building blocks of life. This is why we are trying to identify all the different molecules that make up comets. There are still many mysteries to uncover in this part of our biological history, and this is only one hypothesis that still doesn’t answer the question of what took place to bring self-replicating molecules into being.

The period after this one is a bit better understood. As soon as the first self-replicating molecules evolved into cells, the second evolutionary transition began. What’s a cell? It’s a unit of life surrounded by a membrane, and it contains within it resources and carries out certain life processes. Cells produce the molecules they need in order to replicate. The organisms are selected in order to be replicated, produce “good” molecules, and expel toxic ones when it needs to. Here we see the notion of an internal and an external begin to emerge, almost of a molecular or cellular “me.”

And at the cellular level, the struggle between the various “me”s can be violent indeed! Some molecules such as virus genomes self-replicate very well, while hindering the replication of other molecules. In a way, these are selfish molecules, refusing to cooperate. Of course, they can’t have empathy in the sense of an ability to consider

another's point of view, but they can take up too much space and eliminate other molecules, causing replication of their host cell to stop. Evolution has therefore favored cells containing molecules that are able to cooperate in the replication processes of all other cellular components. These cells can accomplish things together that they would not be able to do on their own, such as—and this is the third evolutionary transition—form groups of cells and, from there, form multicellular organisms.

Within multicellular organisms, there are germ cells, which pass on genetic material to progeny (e.g., eggs and sperm in humans), and there are somatic cells, which make up the body. Multicellularity has evolved many different times on Earth, giving rise to animals, plants, fungi, etc. Their cellular replication mechanisms often undergo conflicts among multiple cells working together and “selfish” cells that refuse to get along with the others, which is what tumors are, for example. Who will survive? And more critically, who will have more offspring? It's the organisms whose cells work together the best. In a way, these are constructions of cellular societies in which we can see conflicts between those that get along with one another and those that don't.

## COOPERATING AND TEACHING

Within these societies, the next stage of evolution was the creation of cultures, meaning group behaviors that are acquired and not innate. Transferring information among individuals allows them to adapt more quickly. Scientists can already observe the exchange of genetic information

at the bacterial level. We see it, for example, when billions of bacteria cooperate to fight an antibiotic. Tatiana Dimetriu,<sup>viii</sup> whose doctoral dissertation I had the pleasure of advising in the Frontiers in Life Science doctoral program, showed that the collective ability of bacteria to cooperate in order to create common goods evolves simultaneously with the ability to exchange information. Bacteria cooperate to exchange information and exchange information to cooperate, all without a centralized system coordinated by a larger organism. Natural selection simply selected for bacteria that could cooperate, exchange information, cooperate to exchange information, and exchange information to cooperate. This was what allowed them to overcome the challenges they faced.

Bacteria can cooperate in many ways. Sometimes a bacterium will emit a signal, a bit like an alarm. If the bacterium is alone, nothing will happen, but if enough other bacteria are around, something called quorum sensing takes place. Then the population of bacteria, like a population of humans, can decide to change their behavior once a certain threshold is reached. They essentially wait until they are numerous enough for it to be worth it to work together. Like us, they cooperate on a conditional basis.

These cooperation mechanisms are not studied by biologists alone. Mathematicians and economists who study what's called game theory<sup>ix</sup> also try to find what situations will prompt human beings to choose cooperation over selfishness. The perk of working with bacteria is that we can conduct experiments on them on a massive scale, as it takes bacteria about 20 minutes to reproduce. If you put one of them in a culture before you leave your lab at

night, you'll have billions to work with when you return the next morning.

So, these are living organisms together in a society, and in certain instances, they will change their behavior based on the behavior of others and choose to cooperate. We see this in ants, bees, whales, birds (both whales and birds communicate through song), etc. Diverse cultures can coexist in the same space; for example, some groups of chimpanzees break nuts while others use the long stalks of plants to fish termites deep in their nests. These behaviors in general are not spontaneous but have been transmitted and acquired through observation and imitation. Some even use the word *teaching* to describe these forms of transmission, although this teaching is not done consciously necessarily in all animals. In humans, the creation of language gave way to the emergence and development of extremely elaborate cultures.

Since life began, the ability to cooperate was a basis of evolution and, in most cases, the best way to gain an evolutionary advantage. Brute force on its own was not enough.

What is cooperation? In game theory, it's defined as an act that represents a loss for oneself and a gain for another. This definition works the same way in microbiology. From an evolutionary perspective, we don't often choose something that doesn't offer at least a small benefit for ourselves, even if the benefit is indirect. For example, when you cooperate with members of your family, you increase the likelihood that your family's genes, i.e., the genes you carry, will get passed down. The natural world is replete with examples like this. Ants cooperate in all aspects of life because only the queen reproduces.

The others help their sister or their mother reproduce and thus to pass on their genes under the best possible conditions. The probability of their genes being passed on is increased by their behavior. Evolution selected for altruistic behavior (I help the queen) that also represents a gain for the individual (I contribute to passing down the genes that I carry).

When can we use the word *teaching* with regard to living organisms? If an animal observes another and learns something from the other's behavior, this doesn't necessarily constitute teaching. An animal may certainly learn things from another animal, but the other animal didn't *teach* these things in any intentional way, unless we can prove that it was acting in a way that represented a "loss" for itself. For example, it's teaching if the other animals repeated or slowed down the demonstration of a certain technique that it wouldn't have repeated or slowed down were it not being observed by the other animal. Certain ants leave chemical trails when they find food so that other ants can find their way to the food. We also observe in certain species that they adopt distinct behaviors that are easier to follow when being followed by kin so the others don't get lost.

Meerkats are another example of a very cooperative species. For instance, they make an alarm call when they detect a predator, which represents an obvious "loss" for the individual making the call, as in doing so it renders itself more vulnerable to the predator. Yet this is a gain for other meerkats nearby who can then quickly go into hiding. Meerkats are also able to teach their pups how to eat scorpions, one of the few sources of protein available to them in their natural habitat of the Namib

desert. As we all know, the sting of a scorpion is lethal, and the reason for this is obvious: Scorpions don't want to be eaten. But adult meerkats have perfected a process for catching a scorpion, dismembering it, and removing its venom to make it safe to eat. Except early on when they feed their young on hunted scorpions, adult meerkats teach their young the process by slowing it down and going about it step by step. This is certainly a process of cooperation and teaching, as the "loss" for the adult meerkat is considerable: It's not only risking its life by walking around with a live scorpion in its mouth, but to top it off, it doesn't even eat the scorpion in the end.

Plant species can also change their behavior in order to protect themselves. In South Africa, acacias have been shown to collectively defend themselves against antelope by producing a toxin that makes their leaves indigestible. When antelope begin munching on the leaves of an acacia, the tree under attack emits ethylene molecules into the air, which other trees can detect as a signal to beware. When an acacia receives the signal, it starts producing toxins in order to protect itself and emit its own ethylene molecules in turn to warn others.

Are there commonalities among all these different evolutionary transitions, from the primordial soup to the cell to changes in cultural behavior? This is something Eörs Szathmáry and John Maynard Smith<sup>x</sup> have investigated. Their conclusion was that conflict will arise in the transition between the two when there's evolution from one state to a more complex state. In other words, conflict is an intrinsic part of evolution, and that's as true of cells as it is human organizations. Conflict is, in a way, natural. And the best way to overcome it is to cooperate.

So, why out of all the other species did *Homo sapiens* triumph? Because it was the species that was able to cooperate on the largest scale, as historian Yuval Noah Harari shows in his best seller *Sapiens*.<sup>xi</sup> Bacteria cooperate in great numbers (in the billions!), but only for very simple tasks. Ants cooperate for slightly more complex tasks, but in fewer numbers. Only *Homo sapiens* brings the two features together, cooperating in ever-increasing numbers to accomplish increasingly complex tasks.

How are we able to do it? Through the strength of belief. We cooperate on a large scale, Harari says, because we believe in things that are meaningful only because a large number of people believe in them—the value of money or a diploma, for example. We’re prepared to do things chimpanzees would never do, such as trade a banana for a sum of money or force ourselves to learn something in exchange for a piece of paper called a diploma. This appears to be what sets us apart: this ability to believe in something whose meaning is contingent on others believing in it.

Harari shows us that the greatest transitions in human history were marked by conflicts, just as John Maynard Smith does, although I’ve met both and learned that Harari had not read Maynard Smith. By separate paths, one by history and the other by biology, they both converged on the importance of cooperation.

## THE NEW FRONTIERS OF EVOLUTION

What will the next phase of evolution look like, when biology fuses with digital?

Machines do not have consciousness, but they do have the capacity to know what affects them. A computer knows when its memory is saturated, for example, or when its battery is low. Is that what it was programmed to do? Sure. But we can say the same of bacteria when they react to the temperature rising: that they were programmed by evolution to do so. It's the same thing that happens when you realize you're hungry. One of your genes was programmed by evolution to decipher a molecule as a signal that your blood is low on glucose and that it's time to have lunch.

One of the new scientific frontiers of our time is fusing biology with technology. You likely know of Elon Musk because of his electric cars (Tesla) or his rockets that land back on Earth rather than get discarded in space (SpaceX). What you don't know perhaps is that he has invested in a company called Neuralink, which seeks to drive the development of human enhancement through technology, perceiving in artificial intelligence an existential threat to humanity. Specifically, it wanted to increase the speed of information processing in the human brain. For now, our ability to interpret information is superior to that of machines. But we convey information much slower. We are held back by the speed of oral communication and typing on a keyboard, as well as by our listeners' or readers' ability to understand what we are conveying. If you were to speak 100 times faster than normal, no one would likely be able to understand you.

That's why Elon Musk, as well as the Defense Advanced Research Projects Agency (DARPA), which invented the Internet in 1969, is working on developing technology that

enables direct brain-to-brain connections. The possibilities of such technology in the medical field would be enormous. Imagine being able to give sight to a blind person by connecting her brain to light receptors outside the eye. Yet in military applications, the possibilities would be more frightening. There are already helmets fitted with electrodes to help increase focus and reduce stress on the battlefield. British journalist Brian Viner tested one such device and was amazed. He experienced such intense concentration, the likes of which he had never known before, and it even continued after the experiment. “Shortly after leaving the laboratory, I parked my car, with consummate ease, in an impossibly tight spot,” he said.<sup>xiii</sup>

Similar, though more sensational, experiments have been carried out on rats. In one experiment, two rats had electrodes implanted into the motor cortices of their brains and successfully communicated brain-to-brain. The experiment was conducted by Miguel Nicolelis, professor of neurobiology at Duke University in the US. He and his colleagues connected the rats’ brains to a common computer, and together the rats worked on a simple task. Separated from each other, they were each placed before two levers. The first rat, the so-called encoder rat, would see a light appear above one of the levers. If it chose the correct lever, it received a reward. Its brain activity was recorded by the computer and then transmitted in a simple pattern to the second, so-called decoder rat. The decoder rat had no visual cues, only the signal sent to its brain. Through rewards as well, the decoder rat learned to decipher which signal meant for it to choose right or left, and its success rate was 70 percent. The rats received a bigger reward when they both chose the correct lever, and researchers

eventually observed that the encoder rat adapted its cerebral activity to make it easier to decode. They made faster decisions in clearer ways.<sup>xiii</sup>

We can see the advantages of these (r)evolutions from the points of view of fundamental, biomedical, and military research. We can try to imagine the unbelievable things our collective intelligence would produce if we could forgo cell-phone keyboards and simply remain connected brain-to-brain. But having a background in evolutionary biology and virology (the study of viruses), I know that viruses are always ahead of security systems. I'd be worried about the viruses that could spread via these new brain-to-brain channels. But such is the story of life. In prehistory, the emergence of cells prompted the emergence of viruses.

Every time we invent a new way to communicate and share information, whether it's among cells or humans, there arise ways to contaminate those communication channels and new risks of misleading information. Technology offers incredible potential for positive cooperation, but potential benefits must be carefully weighed against potential risks.

## TRANSITION = CONFLICT

As we see our current transition through, are we noticing there's more and more conflict of various kinds? Very much so. And there's nothing surprising about that. That's how it's been for billions of years.

We see in our current transition that there are winners and losers, namely in the job market, as both physically

and mentally repetitive tasks continue to be taken over by machines. That's why it's so urgent that we place ethics at the center of our discussions. Ethics can help us make this transition beneficial for everyone and not just certain players, whether human or artificial.

It's a challenge that touches upon global economic inequalities. How do we better distribute wealth? It's by further developing education and guaranteeing that it benefits everyone. The more educated that people are, the better they do in life; and on a national scale, the more a country educates its population, the better off it is economically, as we see on the two maps below. They show not only rising education levels but also the concurrent ascendancy of certain countries among those with the top economies and education systems, namely Japan, South Korea, and Russia. As such, it is our collective responsibility to share the fruits of knowledge as widely as possible.

Furthermore, the current transition is characterized by its overwhelming scale, which is in contrast to the Industrial Revolution, a term coined in 1837 by Adolphe Blanqui referring to all the societal changes that had taken place in England since the late 18<sup>th</sup> century. During the Industrial Revolution, England would transform its agrarian and handicraft society into one driven by industry and trade. Already in the early 19<sup>th</sup> century, competition between humans and machines provoked violent protests, particularly in the 1810s with the birth of Luddism, a movement that took its name from a likely mythical workman named John Ludd. In his name, textile workers, i.e., weavers, knitters, etc., destroyed power looms that they felt threatened to put them out of

work. Indeed, their professions effectively disappeared within a few decades.

## SEQUENTIAL TO EXPONENTIAL

Similar worries are felt today. The most in-demand jobs now didn't really exist 10 to 20 years ago, and we all sense that this trend will continue, if not accelerate, as artificial intelligence makes spectacular progress in very little time. A few months before the AlphaGo computer program beat the world's best Go player, Chinese 19-year-old Ke Jie, experts were saying it would take 10 years for artificial intelligence to beat a human at the game. It was presumed that the game was too complicated and that algorithms couldn't yet outwit a human brain. In a way that's both funny and a little scary, the AlphaGo program, developed by Google subsidiary DeepMind, won after making moves we could not understand.<sup>xiv</sup>

Why did people think it would take artificial intelligence longer to catch up with us? Because artificial intelligence has an exponential rate of growth, and we're not used to thinking in such terms, if not incapable of it altogether. The legend of Sissa is an oft-told fable for illustrating mind-boggling exponential growth. Sissa was the Indian sage who invented chess as a way to keep King Belkib from getting bored. Out of gratitude, the king asked Sissa how he could repay him. Sissa took the chessboard, put a grain of rice on the first square and two on the second, and asked the king to complete the 62 remaining squares, doubling the amount of the preceding square each time. Belkib agreed to it, unable to foresee the outcome.

For those who have studied math, the total number of grains on the chess board is  $2^{64}-1$ , as:

$$1 + 2 + 2^2 + \dots + 2^{63} = 2^{64}-1$$

That's more than 18 billion billions of grain, or, if each grain is 0.04 g, 720,000 million tons of rice, more than 1,000 years of global production.<sup>xv</sup>

## TECHNOLOGY WINS IN THE LONG TERM

The legend demonstrates how difficult it is for us to grasp exponentials. At first it doesn't seem to increase by much, but before long it starts skyrocketing. Another well-known example, one directly related to the digital transition, is Moore's law. This is a term often misused in common parlance; it's supposed to refer to the prediction made by engineer Gordon Moore in 1965 that the power of microprocessors would double every 18 months.

It was Bill Gates who said we overestimate technological progress in the short and medium terms and underestimate it in the long term. We overestimate it in the short and medium terms for several reasons, some of which have to do with the speed of adoption and maturation of a given technology, while others are due to the defenses that societies put in place to resist technological progress. Societies build these defenses for obvious reasons, as no government wants to create masses of unemployed people overnight. But in the long term, technology always won. That's what history has taught us.

Where are we in the exponential increase of these transformations? Well, it took 8,000 years to go from the Agricultural Revolution to the Industrial Revolution,

100 years for the Industrial Revolution to produce the electric light bulb; 90 years after that, we sent someone to the Moon; 22 years after that, the Internet was created; and 9 years after, that the human genome was decoded.

In the 20<sup>th</sup> century, education helped ease the threat that technology posed. Since the end of the 19<sup>th</sup> century, the mean years of schooling in advanced countries has risen about one year every decade. When my grandfather got his high school diploma a century ago, 1 percent of his generation had a high school diploma. Today, that number is 80 percent, and about 1 percent of people per generation get a PhD. The mean level of education has gone up substantially, yet all the while, the number of available places in elite universities around the world has not adjusted proportionally. In my grandfather's time, it was much easier for someone with a high school diploma to get into these elite institutions than it is today. This kind of meritocratic competition is putting a terrible strain on the education system and on learners and their families. The system is more concerned about where to place students than it is with providing high-quality education distributed equally across socioeconomic classes and geographic regions.

Yet the education system was nonetheless able to withstand the changes brought about by the Industrial Revolution and the challenges of the 20<sup>th</sup> century. In the past, new jobs were largely in manual labor and resembled the previous jobs they were replacing. One didn't have to pursue continuing education throughout one's life. If I was good enough with my hands to repair a wagon, I could learn to repair an engine easily enough.

## RETHINKING THE FOUNDATIONS OF THE EDUCATION SYSTEM

Today's cars are so full of electronic components and computer systems that getting them repaired requires knowledge and skills that certified mechanics don't necessarily have. In the future, when machines will program themselves, who's to say they won't replace humans in these lines of work? If machines are better at the job and can reorient and retrain themselves faster, it's not just a question of rethinking how we get trained or even training for longer. We have to rethink the foundations of the education system.

The purpose of the education system is changing.

The Industrial Revolution generated all kinds of changes: cultural, technological, social, etc., but unlike today it did not coincide with biological changes, a stage that's now only in its infancy. Gene therapy seeks to treat disease by delivering DNA and RNA into our somatic cells, which make up our bodies. We're not yet at a stage where we can engineer the human germline, i.e., edit someone's genome such that the change gets passed on to progeny. We are now able to, technically speaking; it is not too complicated for leading laboratories, even if there still remain some challenges. Regardless, what this means is that ethical considerations are more important than ever. The ethical training required for those experimenting with these new techniques is nowhere near where it should be considering the potential repercussions for the entire species, and we have to ban unethical experiments.

As of right now, our school curricula and education systems have not fully taken into consideration the

impact artificial intelligence will have on the ways we live, work, consume, cohabit, interpret laws, and—sorry to keep coming back to this, but it’s an obsession—maintain ethical standards.

Meanwhile, the people driving advances in artificial intelligence seem to be giving us an idea of what’s at stake. Google has talked about its “big red button,” the switch that they reserve the right to use at any time should they feel the need to turn off any AI that begins to perform operations they don’t understand. They’re particularly trying to prevent cases of machines reprogramming themselves autonomously or requiring so much energy for their operability that their energy needs would come in conflict with our own.

## ETHICS AND THE FUTURE OF INTELLIGENCE

To put it simply, scientists know that, even if they’re still a long way off, *Terminator*-like scenarios are no longer something merely out of science fiction. There was a sign of hope when Google created an AI advisory council, essentially a private ethics board, meaning no one outside Google could know the decisions it made. Then Google disbanded its advisory council.

The issue is so serious that even the United Nations (UN) has addressed it. It’s considering moving to implant UN representatives on the ethics boards of major tech companies and within the partnership deals these companies create among themselves when AI is on the table. How can we guarantee that technological advances truly benefit everyone and not just some, if not the machines them-

selves? Can we program ethical standards into robots? If so, can we be sure the robots won't one day discard them or come up with their own ethical standards?

The technological developments currently underway are so complex that only a few people in the world understand them. Be that as it may, we still have time to prepare for them. For now robots continue to do what we program them to do. Artificial intelligence remains dependent on the human intelligence that programmed it. But for how much longer?

The latest developments in genetics raise questions that are equally bewildering. We learned in June 2016 that American scientists had been meeting secretly at Harvard University as part of what they called the Human Genome Project-Write (HGP-Write). The project had one question in mind: Might it be interesting from a scientific standpoint to synthesize the human genome?<sup>xvi</sup> They were no longer interested in reading the sequence of the 3.3 billion base pairs—the immense chain of the letters A, T, C, and G that make up the alphabet of the genetic heritage of each and every one of us—but rather in writing it, synthesizing it, and producing its expression in cells. To be clear, HGP-Write was not trying to create a human being. Rather it was interested in “growing transplantable human organs; engineering immunity to viruses in cell lines via genome-wide recoding, engineering cancer resistance into new therapeutic cell lines; and accelerating high-productivity, cost-efficient vaccine and pharmaceutical development by using human cells and organoids.”<sup>xvii</sup> Concern was of course raised over the secrecy of HGP-Write's first meetings as well as over the fact that, as some in the scientific community have said,

an ethical debate should precede such a project rather than take place alongside it. After all, some people may be tempted to edit the human genome simply to improve certain traits, namely our intelligence, as a means to “stay in the race.”

In that same month, June 2016, a study was published about robots that could not only produce other robots autonomously<sup>xviii</sup> but do so in a way that combined the genomes of two parent robots. There were two parent genomes and these two genomes randomly combined, just like in animal sexual reproduction, to create offspring that didn't have the same features as their parents. This way, they could evolve according to laws similar to those that govern human and animal evolution.

And to be clear, I'm not talking about virtual robots. The sexuality of algorithms has existed for decades. I'm talking about physical robots that reproduce using a 3-D printer. Here again, the scientific intrigue of this study is clear: We can envision designing robots that adapt to complex environments. But no one could predict how these robots would evolve.

Developments of this kind are the fruit of four traditionally isolated fields now coming together under one field known as NBIC. N stands for nanotechnology, or extremely small technologies (one nanometer is one-billionth of a meter, i.e., the width of a strand of hair divided 10,000 times). B stands for biotechnology, i.e., analyzing our genomes, redesigning them, and synthesizing them. I stands for information technology, which is both a tool for increasing understanding in the other fields as well as a science in its own right. C stands for cognitive science, or everything that goes on in our brains.

## VIRUSES ARE ALWAYS ONE STEP AHEAD

Their next frontier is in developing brain-machine interfaces, or in other words, connecting our brains directly to computers.

I remain firmly convinced that if our brains are directly connected via electrodes, in no time at all there will be people using these channels to manipulate us. Just as biological viruses can enter the brain and alter its behavior, new forms of viruses that spread through this network could do likewise. Just look at the forms of manipulation that have spread on Twitter and Facebook since the dawn of social media, namely “fake news,” or false news stories meant to change how we see and think about the world. We can also look at how Hitler, Mussolini, and Stalin were able to create revisionist histories and manipulate the masses wielding nothing more than rudimentary analog technology. Terrorists as well recruit young people by operating on their cognitive biases and using social media as a manipulation tool. If in the future our brains are directly interconnected, how will we know if a given idea came to us out of the blue or if it got planted in our brain by some transgressor looking to manipulate us? With social media we can use our critical-thinking capacities to challenge manipulative forces, but this won't be the case if our brains themselves are online. There would be no disconnecting.

As a biologist, I can assure you that viruses are almost always a step ahead of our defense systems. This is true of both living and technological defense systems. You need only read the newspaper for weekly examples of the latter. Networks thought to be essentially impenetrable

are broken into by hackers who steal the protected data and share it.

What was true in the past will not be true in the future. Failing to understand this would be a tragedy on the magnitude of the evolutionary transition that lies ahead. Being aware of its potential risks can help us avoid such tragedies. We're more aware of this new transition than our species has ever been during previous transitions, and these were nonetheless major, such as generating oral speech and writing, etc., saying nothing of the transitions that took place before conscious beings existed, i.e., the appearance of life on Earth, the evolution of neurons, and the formation of our brains. These transitions may seem far in the past, yet so too did Sissa's reward seem modest to King Belkib. What's unique to exponentials is their explosive progression. Take for example the film *Gattaca*, which depicts a world in which eugenics shapes everyone's destiny from the moment they're born. When it came out in 1997, it was purely science fiction. Today, we're capable from a technical standpoint of all the genetic manipulation we see in the movie.

I would know. I've seen it firsthand. When I started getting interested in biological research in the early 1990s, scientists were still having trouble trying to understand any number of things that today are common knowledge, such as what factors make us more susceptible to certain cancers or the evolution of antibiotic resistance, and we had only just started to produce genetically modified organisms (GMOs). When I first heard about the convergence of NBIC, I didn't really believe it, as the sciences were still highly partitioned back then. Yet only a few years after hearing about it,

researchers started coming to my lab from backgrounds in nanotechnology and computer science, and together we did biology. Let's look again at the decoding of the genome. In 2013, the Holy Grail for scientists, even those in Silicon Valley, was to be able to sequence a genome for \$1,000. The very first sequencing of the genome must have cost somewhere in the billions, but today it costs \$300, with that number continuing to plummet faster than the rate of Moore's law. It's hard for us to know what kind of impacts certain technological advances will have because they undergo exponential rates of change while we're accustomed to linear change.

This is something discussed by director of engineering at Google and Silicon Valley guru Ray Kurzweil. He predicts that computers, namely quantum computers, will continue to make such substantial progress that by 2045 (quite a precise time frame), computers will have attained a power of calculation superior to our own as individuals and will later trump our collective powers as a species. He refers to this moment of surpassing human intelligence as the "singularity,"<sup>xix</sup> and he and a few other Silicon Valley heavyweights have cofounded Singularity University, a school for instructing entrepreneurs and academicians in exponential thinking. Their message smacks of the end of days prophesying that flies in the face of Cartesian rationalism, and the fact that it's a private school incorporates a business component that runs counter to the principles of the public good and disinterested knowledge. Nonetheless, they're at least clear about the urgent need to understand the major technological transformations currently underway.

Personally, I think we're in need of a Plurality University rather than a Singularity University—plurality in the sense of multiple perspectives on technological advances and the increasing number of spaces in which we'll need to discuss *epistêmê*, *technê*, and *phronesis*. Plurality University would create courses, programs, and tools that truly benefit everyone and would be a breeding ground for transparent and democratic debate on issues that involve all disciplines. Today interdisciplinary debate is rare because the various fields of knowledge taught in universities are very partitioned, and many are reticent about breaking down these barriers. But make no mistake, it will require contributions from everyone in order to prepare for the world to come, one in which computers will surpass us in so many ways, in which people will be tempted to “download” their brains onto computers in order to live forever. That world is on the horizon.

It goes back to our fantasy of becoming God, or *Homo Deus*, to use the title of another of Yuval Noah Harari's books.<sup>xx</sup> What is the god of the Abrahamic religions? What are the gods of antiquity? First omniscient, then immortal. Thanks to technology, we're zeroing in on omniscience. Once technology allows us to become immortal, humans will be fully omnipotent.

After creating gods, some people want to become God.

## TO REREAD AND TO UNITE

It's no coincidence that the digital revolution is occurring at the same time as a rise in religious fervor. Etymologically, the word *religion* has two potential origins in

Latin, both the word *religere*, meaning “to unite,” and *relegere*, meaning “to read over again,” as in “to discern.” Today, science has replaced religion in terms of a legitimate understanding of our world. We have gone from the story of Genesis to a story based on scientific hypotheses, in which the Big Bang took place more than 13 billion years ago, the Earth was formed 4.5 billion years ago, and life began shortly after that. As for our human ancestors, they appeared some 2.8 million years ago, and *Homo sapiens* appeared 300,000 years ago.<sup>xxi</sup>

Science also replaces religion with regard to what unites us. Science has shown us that the genetic heritage we share is remarkably intermixed and similar. We have more traits in common than we do differences, and this is also true of our evolutionary cousins, the great apes. Situating ourselves and reflecting on our place in this history can help us understand its importance. Understanding that all living beings on Earth have a common ancestor can make us see that we all belong to the same family and we should thus preserve biodiversity the same way i we want to protect our extended families.

Something that helps me take a step back and understand our common history and destiny comes from Carl Sagan. In 1990, he had NASA’s *Voyager 1* probe take a now-famous photograph of the Earth. It’s called *Pale Blue Dot*, and he had this to say of the photograph:

“Look again at that dot. That’s here. That’s home. That’s us. On it everyone you love, everyone you know, everyone you’ve ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager,

every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there—on a mote of dust suspended in a sunbeam.

"The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds.

"Our posturing, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.

"The earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand.

"It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our

responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known.”<sup>xxii</sup>

## IS THERE A PLANET OF IDEAS?

When I think of human destiny on the cosmic level, I sometimes ask myself how other forms of life could evolve differently than we did. An interesting way to exercise the imagination and get outside our normal patterns of thinking is to imagine a planet of ideas, where ideas spread, develop, and coevolve in unexpected ways with conscious beings who are unlike us.

We can imagine a futuristic kind of *Persian Letters*—the famous book by Montesquieu, who offers us a frank description of the reality of his time by observing 18<sup>th</sup>-century France from the perspective of a traveler from faraway Persia. It's a style of mental exercise that anyone can do, and the results are always illuminating, both for the young and the not so young. Through the eyes of a foreigner, we can analyze how our education systems are organized, among other aspects of our societies. High schoolers from the Science Ac' (a program we'll talk more about later) took part in such an exercise and wound up writing theatrical scenes and a musical about the history of ideas on our planet seen from a different perspective.

It would be interesting to create a kind of “citizen science of potential futures” based on young people conducting this exercise. They can try to imagine new utopias in which, like Thomas More before them, we

come up with new forms of organization to help us collectively shape the future.

It's of course very difficult to predict the future. If we look at how the future came to be in the past, we can glean from this exercise a few lessons that may shed light on how the future will shape up. The world to come is likely already here in part, only spread too far and wide for us to notice, with only a few gems dwelling here and there, whether they're ideas in people's imaginations or initiatives that most of us haven't heard about yet. We'll need to figure out how to unearth these gems, gather them together, and adapt them to new environments so they can flourish.

These citizen scientists of the future will not have been the first to ponder other worlds and question our own. Humans have always needed to unite and legitimate their history, whether it's through creation myths or scientific data. As knowledge about our history has progressed, *epistêmê* has called into question the narratives that religions have offered and in some cases imposed, and with this it discredited the ethical foundations (*phronesis*) underlying the moral precepts prescribed by these religions. While the creation myth is no longer credible, can ethical laws found in religion still be legitimate?

No doubt you've seen firsthand when knowledge and rationality in our age of reason have been rather dubious. American psychology professor Jonathan Haidt<sup>xxiii</sup> has studied the diverse range of moral thinking in humans and its origins in evolution. He has found that while we are moral beings, we nonetheless can't seem to bear it when others practice a different morality than our own. This can be explained by the work of two other

researchers, Hugo Mercier and Dan Sperber, who found that what spurred the evolution of human reason wasn't an interest in reason itself but rather a need to advocate for our own beliefs, whether personal or collective.<sup>xxiv</sup>

In summary, whether it involves God or not, we need religion in the etymological sense, i.e., knowledge that unites us and allows us to legitimate our history, both individual and collective. This is one of the predominant ideas that Harari develops in *Sapiens*.<sup>xxv</sup> Our species can cooperate better than any other, and thanks to our highly developed capacity for language, we can cooperate on things that are meaningful only because a large enough number of people believe in them too, e.g., businesses, nationhood, institutions, diplomas, religion, and money.

These things are endowed with meaning through narratives, which a large number of people can believe in. This is likely why some people are so attached to versions of history seen as part of a “national narrative.” For example, in France many insist that, whether you've newly arrived or your ancestors were born here, in order to be French you must feel that you share ancestry with pre-Roman Gauls. And this is despite the fact that Gaulish history was completely rewritten in the latter 19<sup>th</sup> century for the sole purpose of arousing national sentiment and in a way that completely disregarded historical sources.

How can we (re)establish a balance between *epistêmê*, *technê*, and *phronesis*, with a particular emphasis on *phronesis*?

Before answering that question, I'd like to take a moment to introduce myself a little more in order to share with you where I'm coming from.

## 2

# What I've learned

The ideas in this book are drawn from the experience of its author, which is the case for all books, whether the author is candid about this or not. I'm writing this as a former child and student, as a current parent and researcher. All four are intimately related, to the point that I feel there has been a common thread running through each chapter of my story. It's a story marked by pivotal moments that I feel the need to share with you, so crucial has their influence been in determining the course of my life and in strengthening the beliefs that underpin this book. At the time I was experiencing them, I didn't know that together these moments would inspire me to undertake what I now strive to do, of which this book provides a partial account. Throughout my life, I have learned through research and experience, fostered dialogue across barriers, explored ways to recompose existing forms—whether it involves our understanding of bacteria, designing university courses, defining research objectives, etc.—and sought the freedom to think and

act in systems that aren't bogged down by dogma, be it administrative, historical, political, or religious.

From my experience, I have drawn a number of lessons that have stuck with me throughout my life. To illustrate the ideas in this book, please allow me to share them with you now along with how I learned them.

#### FROM PRIMARY SCHOOL THROUGH UNIVERSITY, FOLLOWING CODES OF CONDUCT IS AS VALUABLE AS WORK ETHIC AND INTELLIGENCE

I was always a good student, but never top of the class. I spent four years at a secondary school in an area that would be designated a Priority Education Zone, part of a public program for allocating greater resources to schools in underprivileged areas. The school was eventually closed for safety concerns. It was in a district south of Avignon, France, called Monclar. My family moved there when I was 8 years old. Getting shaken down for money or beaten up were common occurrences, and I was targeted in particular because I was enrolled a year ahead. I started at the school at age 10, and some of the other kids in my class were 14. Despite all this, I came away with two positives. First of all, that was where I formed my closest friendships; second is that the teachers there were excellent. On top of that, I came to understand kids and adolescents from underprivileged areas, and this has stayed with me throughout my life. I experienced how sad it is to see students rejected by the system, not because they were less capable than other students but because they didn't adopt the code of conduct that the school upheld.

I then went to Mistral High School, also in the beautiful city of Avignon where popes once lived, because my parents kept to school-district boundaries. Among my battle scars from there was a behavior grade of zero in math for incessant talking during class. Factored into my overall average, it almost kept me from being eligible for preparatory courses for trying to get into a good science program at the university level. In the end, I figured out what boundaries not to cross and managed to jump through the hoops of the system, which rewards those who submit to it over those who demonstrate a proclivity for invention or thought-provoking discussion.

Some of my classmates in high school, just like those in secondary school, did not develop this particular social skill, and they paid for it. That left a lasting impression on me.

## THERE'S NOTHING MORE SERIOUS THAN PLAY

Playing chess was really the only intellectual activity I pursued seriously from age 8 to 16. I managed to win the regional championship for my age group every year. A friend of my parents named Jacques Montaignac introduced me to the game. He was a former France Junior Champion. Very quickly, chess became my primary source of intellectual stimulation, so much so that I soon started getting invited to chess clubs for adults. I even took part in adult competitions, which was a crucible for my developing the skill to stay focused on my objectives and not let my opponents distract me. One woman I played against kept blowing her cigarette smoke in my face during the

match. I called the arbiter over to make her stop, and that caused her to lose her composure. She wound up losing the match. In another competition when I was 16, I had to play against my French teacher, Mr. Savolle. We played to a draw! The atmosphere of the match was incredible, especially with my classmates wanting to know who would win.

I didn't discover until around the age of 15 the symbolic weight of that game, as much with regard to war strategy as psychoanalysis: killing the king father, the importance of the queen mother, all that. I was also playing during an era when the big international matches made front-page news, with the likes of such colorful characters as Bobby Fischer, who later went mad. Perhaps you've perhaps seen his story on the big screen in the movie *Pawn Sacrifice*.<sup>i</sup>

## HUMANS CAN DOMINATE MACHINES

Chess also provided me with precious opportunity that would be hugely important for me: It introduced me to the computer. I'll remind the younger readers that at that time, in the mid-1970s, personal computing was only in its infancy. My grandmother bought a computer, and it had on it one and only one chess software program, Chess Challenger, and I was able to beat it. What a privilege to have lived at a time when a human could outplay a software program! Unlike my father who, the university professor that he was, had a very methodical approach to chess—he read books about chess, filled pages with notes on various kinds of opening sequences—I had a more intuitive approach.

I had internalized the notion that a computer won't necessarily win every time, and so, in 1997 when Russian grandmaster Garry Kasparov lost to IBM's chess computer Deep Blue, I reflected perhaps longer than most on the implications of his loss.

After my final year in high school, I was accepted to a prestigious and very challenging program for prep classes at the Louis-le-Grand college. That would unfortunately put an end to my chess adventures. I had seen very high-level players try to go professional, and I knew that the path was narrow and that I didn't want to have to work giving chess lessons to make money. On the bright side, I had finally found a subject in school that exhilarated me as much as chess: science.

But there was another game that taught me a lot because it was a team, as opposed to chess. I played handball in gym class, but I really found a love for it with friends. One day, we were down by the gymnasium at the end of my street in Avignon and peeked inside. A women's team was playing, and we got to talking with the coach, who agreed to coach us if we wanted, so long as we got a dozen boys together to make a team. We did just that, and I remain close to these people. When I was 15, I was playing well enough to be recruited to join a sports-study program in Marseilles, but I didn't like the idea of having to live away from my family. When I was 16, I suffered two back-to-back fractures in my right thumb and had to stop playing. I couldn't even write. I had to rely on notes taken by a kind soul who was willing to share with me, but I discovered then that there are other ways to learn than just copying down what's on the board. A Danish friend who was with us in that final year of school explained to

me that in Denmark, students don't have to copy what the teacher writes on the board or text from their books. Instead, they're simply given opportunities to apply what they learn in class and discuss it.

## OVERLY COMPETITIVE ENVIRONMENTS DON'T NECESSARILY PRODUCE BETTER RESULTS

When I moved to Paris at age 17, I lived in the dormitories at Louis-le-Grand. Like many other students preparing for the exams to get into the *grandes écoles*, France's most prestigious universities, I had to put everything else on hold. More than 30 years later, I still remember getting the result of my first math test: a crushing 4 out of 20. I walked down the stately rue Soufflot to the Luxembourg gardens at the bottom of the hill, laid down in the grass, and spent an hour wondering what to do with my life. Was I ready to sacrifice so much for this? To become a willing participant in this humiliating system that gave such demoralizing grades to students generation after generation, and this despite their level in high school? In the end I decided there was nothing more important I could be doing with my time, and I walked back up the hill and got back to studying. Yet I still refused to put real pressure on myself. It would take a friend's knocking some sense into me four months from the exams for that to happen. My math teacher had tried during my first year, saying, "If you don't get down to some serious work right now, what's the point of even being here?"

I was willing to listen to my friend because major shifts were happening in my personal life.

My mother had fallen very ill two years beforehand, and my father was getting ready to undergo major surgery. I was 18 and suddenly pictured myself having to take care of my three little sisters Antonia, Angela, and Julia, ages 16, 14, and 8, should things ever take a turn for the worse. That's what motivated me to want to get into a school that offered students a stipend. If the worst were ever to happen, I would need to start making money immediately.

## A GRATEFUL PLANET HONORS ITS COLLECTIVE INTELLIGENCE

Over the course of those years, the Panthéon formed part of the background of my life. I often pondered the famous inscription above the portico: *Aux grandes hommes la patrie reconnaissante* (“A grateful nation honors its great men”). My first moments in Paris were spent visiting that triumphant landmark of French history. In it you learn about the French Revolutionary era, which sought to pantheonize the nation's most accomplished citizens within a “secular temple.” Of course, you question the strikingly small number of women buried there, which is by definition a lack of recognition for women's contributions to French history. It seems to me that if we had to do it over again and build a modern Panthéon, we should expand the scope of the inscription. “A grateful planet honors its collective intelligence,” it should say, underlining both that most major breakthroughs come from collaborations between women and men and that the real challenges of our time are to be considered on a global scale.

## I AM INCAPABLE OF SUBMITTING TO DOGMATIC AUTHORITY

To get into the Ecole Polytechnique, a military academy and France's most selective engineering schools, I had to take a portion of exam that has since been done away with, a kind of preliminary oral exam for applicants who did well on the written exam but not well enough to pass directly to the main oral exam. I went in, introduced myself, and held out my ID for the proctor to take. He didn't move. Looking me square in the eye, he said, "Sir, you're taking an oral exam for the Ecole Polytechnique. Don't look so laid-back." I didn't understand. He repeated it one more time, this time louder. It then occurred to me he must have been talking about the fact that I had my left hand in my pants pocket. Just like in chess, I tried to keep my nerve and tucked my left hand squarely under my right arm for the whole hour of the exam, and I did my best to solve the equations he gave me. Once again, even at the highest levels of academia—if we believe in such a hierarchy—candidates are selected in part based on how well they submit to authority and respect codes of conduct, not solely on their abilities. In my case, it was solving math problems.

Based on that episode, I should have been more wary for what was to come. I would graduate from that esteemed military academy with 45 days of confinement to quarters to my name, the record in my class.

Just like in preparatory classes, I often felt I didn't belong there. Classes started on the Plateau de Millevaches in central France, and right away there were problems. I was reticent about having to stand at attention all

the time. I then spent four months at the artillery school in Draguignan, in the Provence region, and there too I ran into trouble with authority. Once, I even got called in to the colonel's office for refusing to buy the badge of the school insignia.

I'll never forget the conversation we had. We just couldn't see eye to eye.

"Colonel, it's clearly written in the rule book that purchasing the school badge is optional," I said.

"Everyone buys it. It's not good not to have it," he replied.

"Perhaps. But it's nonetheless optional, and I don't see the point of spending money for one," I said.

"You can afford it! You have a stipend!" he said.

"Yes, but it's the principle of the thing. This way, students who perhaps can't afford one won't have to follow the tradition," I replied.

"That's the word: tradition! It's tradition. And tradition is important in the army," he said.

"But this is tradition is... optional."

I wasn't put in confinement that day, but that little quarrel earned me a reputation.

The point of the system of rank is to get us to bend to authority, and I had to admit after a months at school that it was rather effective. Most of my classmates made up their minds to climb the ranks, and some of them are still doing so! The ones who seemed at first the unruliest became the staunchest advocates for military hierarchy once they became officers.

What I learned above all from that year of military service, and in my time at Ecole Polytechnique in general, was that I have a major problem with dogmatic authority.

When we first got to Polytechnique, we had to take a slew of psychological tests. I later learned the purpose of these tests. Because the school system inflicts such heavy psychological damage on students, from preparatory classes to the academy, suicide rates were rather high, so students were monitored very closely. Being curious by nature, I asked the psychologists what my test results were. Compared to my classmates, I had an average profile in most criteria, although slightly more literary than most. Then again, in the kingdom of the blind, the one-eyed man is king. The only thing that really set me apart from others was how I questioned authority. Perhaps I had understood intuitively something French philosopher Michel Serres once said: True authority is whatever causes us to grow. I realize that I never rebelled against my parents as a teenager because they never really gave me orders. They always took the time to reason things out with me, and in that way they provided me with both love and freedom.

This book comes from a similar place of questioning authority, for in my time as an educator, I have endeavored to establish teaching methods that help both free individual potential and create collectives that can be sources of growth.

WE SHOULD LEARN TO ASK THE RIGHT  
QUESTIONS RATHER THAN MECHANICALLY  
MEMORIZE ANSWERS

Fortunately, despite its being a military school, Polytechnique was capable of being open-minded. First off, it

forced us to take breaks from math and physics, as indeed some students got sick with studying for exams. We were forced to study other subjects, and not only were we able to venture outside the so-called hard sciences, i.e., math and physics, but the teachers in the other subjects were outstanding. I studied history with Marc Ferro, psychology with Elisabeth Badinter, and demography with Hervé Le Bras. I got to study Hitchcock's art of suspense in English class. And little by little, I would make my way toward what would become my forte: biology.

I heard in my first year that the French Ministry of Defense, under which Polytechnique is technically placed, was looking to start a biomedical program. I got accepted to it, and for one month, I and some 20 of my classmates went around to different military hospitals in Paris. We spent our mornings in hospital wards and our afternoons in research laboratories. I wasn't even 20 years old, and I was discovering the major focuses in research at the time, things that today are common knowledge but were completely new in the 1980s. For example, we looked at the prion, which was an acronym that had been coined five years earlier for a pathogen causing an unheard-of epizootic disease referred to in the mainstream as mad cow. We also looked at AIDS at a time when the retrovirus that caused it had only just been identified. Magnetic resonance imaging, or MRI, was extremely expensive back then and not as ubiquitous as today; in 1983 my mother had to go to New York to get an MRI scan, as the technology didn't yet exist in France.

It all fascinated me. The researchers who hosted us in their labs made themselves available to us and were enthusiastic. We bombarded them with questions, and

when they didn't know something, they had the guts to say as much. They would essentially say, "We don't have the answer to that question, but we need young people like you to help us so that one day sooner or later we can find the answer." Although the academy subjected us to heavy doses of math and physics, I knew that I was a far cry from being able to do high-level foundational research in these areas, and here these researchers were welcoming us with open arms and pushing us to get involved in biomedical research, to which we had only just been introduced.

By going down that path, I had to stop thinking like an engineer and learn how to think like a researcher. An engineer looks for the right answer; a researcher looks for the right question. An engineer laments when an experiment goes wrong; a researcher loves it, so long as the problem encountered is new, signaling new possibilities at hand, new fields of knowledge to be investigated.

Unfortunately, learning to ask (oneself) questions is not a sought-after trait in the French education system. I'll share two short anecdotes that illustrate my point.

My son went to the same kindergarten that I did. Like a salmon, I returned to where I grew up to become a father. He ran into the same problem that I did there that got me held back a year: He wasn't demonstrating good enough motor skills in handling scissors in arts and crafts to begin writing lessons. When I was a kid, the teachers got my mother so worked up about it, she felt the need to sign me up for extra arts and crafts classes so I could get used to handling pens and paintbrushes.

Thirty years later, I relived the same scenario, this time in the role of the parent. I tried to downplay the impor-

tance of the issue. After all, my career hadn't suffered because of kindergarten arts and crafts. "You didn't struggle during your later schooling?" the teacher asked me. I didn't dare impart to her the knowledge that there's no scissor-cutting portion to the exam to get into engineering school. I saw once again how quickly we get stigmatized when we deviate from the norm.

When my son was 6, I attended the first parent-teacher conference of the year, a few days after school started. His teacher said to me, "He's a nice boy, but he asks questions." As a researcher, I'm inclined to think that's an asset, perhaps the most important asset. I didn't like that she said the word "but." My son isn't as nice as the other boys because he asks questions? I tried to understand.

"Are the questions off topic?" I asked.

"No, no. They're questions about the lessons," she said.

"And he asks them to his friends? He's a distraction in class?" I asked.

"No, he asks them to me," she said.

"OK. So, what's the problem?" I asked.

"Well... he asks questions," she responded.

At the time, I gave the teacher the benefit of the doubt. Maybe he goes too far with his questioning. Maybe the teacher is sick of being interrupted by him. I gently suggested to my son to keep his questions to himself and bring them to me at the end of the day. I tried to convince myself he was nonetheless fulfilled there and enjoying the school he was in, but that little episode, along with a few others, helped me realize the absurdity of any system that finds asking questions to be a problem. Asking questions is the answer!

On their own, however, these stories aren't enough to condemn the whole system.

Of course it's important to learn how to write legibly, and despite low marks I've received because of it, it has never improved. Similarly, a teacher has every right to want to get through certain sections of a lesson without being constantly interrupted. But in the long run all these little things start to add up. Contrary to what we're told in school, both as students and as parents, there isn't a single path to knowledge, and plenty of educated adults seem undertaught and totally ignorant of how complex learning is.

This wasn't a problem back when the world evolved slowly, but as the world now changes at lightning speed, the old way is no longer going to cut it, especially as access to education and information has increased so significantly. I doubt that anyone, French or otherwise, still believes that an education-based meritocracy is the best way to run a country and that the educated elite should be given responsibility to make informed decisions on their own. I can't imagine that in the past anyone apart from the educated elite believed in such an illusion.

This is not a new idea. Socrates was its first and perhaps best advocate. And the way he defied authority through asking questions did not do him any favors. Already in Antiquity, authority and asking questions did not mix. We see as much in Genesis, when in the Garden of Eden, the first thing God forbade Adam and Eve was to eat the fruits of the Tree of Knowledge. Our conventional wisdom also reinforces our aversion to questioning: "Curiosity killed the cat," we tell our kids.

## WE ALL NEED CARING MENTORS

After graduating from Polytechnique, I got into the French National School of Rural Engineering. Through the program I wound up going to some 40 different research laboratories, not including the ones I had already been to when I was at Polytechnique. The reputation of Polytechnique opened every door to me. Rightly or wrongly, heads of labs figured a Polytechnique-trained engineer could adapt to any discipline. I went to talk with historians, economists, hydrologists, geneticists, etc., and at the end of each meeting, I would ask, “Apart from your lab, what other labs do you recommend I go see?” I kept hearing the same thing: “You have to go see Miroslav Radman.” I heeded their advice and met Radman, whom I would call Miro, as did everyone. He would become my mentor.

In 2011, 20 years after meeting him, I described him in an interview with French daily *Le Monde* as a “mythical, quantum being who has a certain probability of being in a given location, but never where you expect him to be.”<sup>ii</sup> The article was an overview of his career, describing him as someone “on the hunt for the secrets of DNA, uncovering the mysteries of evolution.” His discoveries in DNA repair systems are in every biology textbook. He’s particularly well known for his work on SOS response, which is how cells repair DNA damage to then undergo mutation. He also did notable work studying the mismatch repair system, which repairs errors in DNA copies in organisms ranging from bacteria to humans.<sup>iii</sup>

## SCIENTIFIC TRUTHS ARE ONLY TEMPORARY

Before beginning my doctoral dissertation with Miro, I got a master's degree in cellular and molecular genetics at Paris-Sud University. The program style there was totally different from anywhere else I knew. It didn't matter that I had never studied genetics. I was told there would be no classes in the traditional sense; instead, students did three internships in three different settings. There was also a lot of analyzing articles, which was an exercise I had become familiar with at Polytechnique and was one of the few things we did in which my penchant for critical thinking was encouraged. Every time I do it, I like it a little more. It's an exercise in sniffing out guesswork and logical errors based on what's known in a given field. Along with sports, it's an activity that helped me excel not only at Polytechnique but in biology in general and in analyzing political economy. When you do it, you see firsthand that science isn't simply a matter of summarizing what everyone knows. Rather, scientific truths are only temporary, especially in the experimental sciences. You tinker, make mistakes, and start over. You investigate and you're constantly reformulating your questions. My love for this aspect of research continues to grow to this day.

## BARRIERS BETWEEN DISCIPLINES ARE MADE TO BE BROKEN DOWN

My first research project dealt with AIDS. At the outset, what struck me most was the hermetic seal between key

players who were taking up the issue. When I attended my first international conference on AIDS, I started up a conversation with some South American activists, as thanks to some training I had done in Latin America the previous summers, my Portuguese and Spanish were in good enough working condition. And I was the only scientist who talked to them! I understood that if I wanted to save lives, I had three options: creating a biotech start-up where I would be dependent on shareholders who would make all the decisions, doing public-sector research where I would be at the mercy of regular budget cuts, or getting into activism and passing out condoms in Rio and elsewhere. From then on, I have been unrelenting in every field I've worked in to try to create ways to cut across these barriers.

As a researcher, I am so grateful to have discovered interdisciplinarity.

I changed my research topic four times in four years, which I wouldn't recommend to anyone. Be that as it may, however, I managed to write a dissertation of reasonable quality, no more and no less. But in the process, I uncovered several other directions for research that piqued my interest considerably. I pursued them, and two years later, in 1997, I got published in major international reviews, namely *Nature* and *Science*. This doesn't happen to everyone, and it hasn't happened for me since. Yet I didn't come to my findings on my own. I had formed an interdisciplinary network that brought together experts on antibiotic resistance, bacterial virulence, evolution, medicine, bacteria in the food chain, genetics and phylogenetics—and the list would grow.

## MISTAKES ARE NOT (ALWAYS) BAD

During the course of our research, we looked at how bacteria evolve, or in more concrete terms, how they become more harmful and more resistant to antibiotics. We showed that their speed of the evolution itself fluctuates, especially in periods of stress such as when bacteria are exposed to antibiotics. Widespread use of antibiotics makes it more likely for bacteria to become resistant to treatment, and the traits that generate greater resistance will be selected for such that efficacy of antibiotics will decline the more we prescribe them. Bacteria are more adaptive than your doctor tells you, which is why you shouldn't take too many antibiotics. At play here is what's called second-order selection. First-order selection selects for resistance to antibiotics, whereas second-order selection selects for "evolvability," i.e., an organism's ability to evolve. Second-order selection selects for increased speed at which resistances emerge, spurring the evolution of resistant bacteria.

So, how do bacteria go about ensuring their survival and finding new resistance mechanisms? Through mistakes in their reproduction. If they reproduce in exact replicas, antibiotics can wipe them out. In order to survive, they must change. In order to change, they must deactivate the molecular mechanisms for high-fidelity DNA replication—the mismatch repair mechanisms Miro had discovered in his research. In humans, mutations caused by these molecular mechanisms are at play in hereditary predisposition to certain cancers.

In short, bacteria need to make mistakes in order to evolve. In order to evolve more quickly, they need to make

more mistakes. It's a bit like when you play the lottery: You raise your chances of winning the more tickets you buy.

### "IT TAKES A VILLAGE TO RAISE A CHILD"

I wound up winning a few awards for this research. Back then I was 35 years old and a young father to my son Bosco, age 4, and his sister Sophia, age 2. I mention this because, as I stated, I'm also writing this book as a parent. Had I not had kids and been at their side throughout their education, I wouldn't have started reflecting on my own education. Their mother Angèle, my wife, is Chinese and studied interculturality and Asian languages to become a Chinese teacher. She has introduced me to many new ideas, needless to say.

Our children are very lucky to grow up in two cultures. Their cultural diversity begets many questions: What should take priority? Why are attitudes so different from one country to another, one culture to another, or one family to another? Our family trips to Asia have given them opportunities to discover the similarities and differences between how children are raised in Asia and Europe and how schools, universities, and families function. It made me reflect on my own schooling and realize the importance of culture and family. How lucky was I to have loving parents, and sisters who helped me grow even though they were younger than me? I was also lucky to have so many caring cousins, aunts, uncles, and grandparents. They have taught me so much, and I continue to learn from those who are still with us today. Grieving losses of family members are of course devastatingly sad

moments, but these are also occasions to look inward and be in communion with yourself.

My Corsican family and Angèle's Chinese family are two big tribes where our children can play with their cousins and learn from their experiences, both their successes and failures. It's just like when I was growing up. Uncles and aunts can be mentors who help them overcome difficulties and discover new ways of seeing the world and working. The African proverb "It takes a village to raise a child" captures so well the contributions of every family member. Now that with the Internet the whole globe is one big village, we can all teach and learn from one another online.

Since we can learn so much in every setting, including the professional setting, why don't we place more value on it? How can we make formal and informal education complement each other? Informal education encompasses everything we learn in our free time, at work, with family, and at school. What role should these places have in our world as change takes place more and more rapidly? These are the questions I've asked myself over the years as I watch my children get educated. This book offers a few answers to these questions.

## THERE IS A NEED FOR ETHICS EVERYWHERE

In the late 1990s the Chairman of Inserm (the French National Institute of Health and Medical Research) named me to its ethics committee. At first I turned it down. I felt that my bacteria did not present ethical challenges of the kind that would make me a worthwhile

contributor to the committee. I wasn't cloning sheep like the team of Scottish scientists who created Dolly in 1996. I had no position on those questions, or at least my positions didn't seem to me to be sufficiently informed or developed. The chairman insisted, saying, "It's because you don't see the role your bacteria play that I want you to be a part of this. The more you resist, the more I'll insist." I gave in and proceeded to submerge myself in the literature on ethics. It wasn't long before my stomach was doing turns. The entire biomedical field was rife with serious ethical risks, including microbiology, which could be harnessed to make deadly biological weapons.

Until then I had thought of scientific research as a kind of game, a natural continuation of my childhood and teenage fascination with chess. I enjoyed both of these activities because they stimulated pleasure zones in my brain to the point of being highly addictive. I realized then that scientific research was not a game. It could influence the world for the better, but it can just as easily influence it for the worse.

I wouldn't figure all this out that day. Like all scientists, and I hope like all global citizens, I have thought a good deal about the ethical ambiguities of the atom, which can both cure diseases and destroy our species. This was one of the reasons why I, unlike many of my classmates at Polytechnique, had never wanted to go into the field of physics lest I make a discovery that "improves" nuclear-weapons capabilities. As far as I was concerned, biology had nothing to do with killing. It was all about life and improving health. I hadn't thought about, or hadn't wanted to think about, biological weapons.

## UGLY DUCKLINGS NEED A DUCK POND

Without my being aware of it, all these experiences would take me from being a “simple” researcher to being a social entrepreneur and starting the CRI (*Centre de recherche interdisciplinaire*, or the Center for Research and Interdisciplinarity). In the autumn of 2018, the CRI moved into a superb, 7,000-square-meter location in the heart of the historic Marais district in Paris, where we welcome any and all people looking to reinvent how we learn, teach, research, and mobilize collective intelligence. Our building, which we’ve nicknamed the crossroads of research interests, is where projects can get off the ground and continue developing as they go. Among the hundreds of students and researchers who have joined us since we started, many of them have one thing in common: They think outside the box. To some, they can even be considered “ugly ducklings.”

Hans Christian Andersen’s tale<sup>iv</sup> is universal because we all aspire to be different, even if only briefly, but pressure to conform doesn’t always allow us to develop our individuality. The story shows very well how, even though the situation may be only temporary, the solitude and sometimes rejection that go along with developing our individuality are nonetheless painful experiences when we don’t have at least one companion who understands what we want to be or what we want to do. There’s a TED Talk you can watch online titled “How to Start a Movement”<sup>v</sup> that underlines how important that first show of support is for innovators who are isolated in order for their ideas to become recognized as legitimate. It opens the gates for others to join.

French writer Daniel Pennac was a terrible student and was held back repeatedly in school. Later in life, he became a professor and renowned writer. He has said that Andersen's tale affected him more profoundly than any other in his childhood because he suffered so much in solitude. In his autobiography,<sup>vi</sup> he shares the story of one of his teachers who was able to understand him when others didn't, helped him overcome his hardships, and encouraged him to write. Writing for him was an invitation to use his ripe imagination, which was the reason he said he never did his homework, to create material for writing stories. Like many professors who are able to draw from their own past hardships, Pennac put himself in the place of his struggling students when he became a teacher and could try to help find the missing piece of the puzzle, the way his teacher had done for him. In an interview,<sup>vii</sup> he shared his enthusiasm for group projects and the importance of curiosity for overcoming isolation and fear of failure in order to enjoy learning and understanding.

Like Pennac, many young people feel isolated within education systems that don't allow them to be different, and because of this, they get discouraged and in their work they don't develop the full potential of their intelligence. In order for them to spread their wings, just like in Andersen's tale, to become swans, novelists, people capable of inventing other worlds, or simply themselves, we need more spaces for people who want to try new things. The CRI aspires to be one of these spaces, and it's also as a cofounder and director of the CRI that I am writing this book. The founding of the CRI is illustrative of the point I mean to make in this book and conveys the overarching principles that define what it means to learn in the 21<sup>st</sup> century.



## 3

### New ways of teaching

The story of my involvement in innovative methods of teaching begins with an improvised teaching experience I had. Miroslav Radman, my doctoral-dissertation adviser, always had a million things to do. One night, he asked me to fill in for him at a three-hour lesson he had promised to give students at the Institut Pasteur the next morning. With so little time to prepare, there was no way I could plan a traditional lecture. So I decided to do what I like most and what I believe I do best: I took the lesson topic and analyzed it from a bunch of different perspectives.

I enjoyed it immensely. Some of the students did as well. They were even asking to do a multidimensional reflection on the lesson! But other students didn't like my lesson at all, and for a long time I received very mixed evaluations of my proficiencies as a teacher. Not all students are used to taking the road less traveled. Thankfully, among those who liked my teaching style were members of the management at the Institut Pasteur, and

they kept inviting me back. Soon students were asking to join my lab, and my lab team was growing rapidly.

I also taught at the ESPCI Paris, the science and engineering institute where the Curies—Marie, Pierre, their daughter Irene, and son-in-law Frédéric Joliot-Curie, all Nobel Prize winners—studied and worked. When I taught there, the director was Pierre-Gilles de Gennes, the winner of the Nobel Prize in Physics in 1991. I had gone to hear him speak at the Sorbonne shortly after he won the prize. He criticized the French propensity for doing too much theoretical work and not enough experimentation and the American propensity for doing the opposite. Good research must balance the two, he said. Message received.

At the same time, students from the department of mathematics at the ENS (another *grande école* in Paris) had wanted the administration to create a biology course. At first I was asked to be minimally involved, then later was asked to teach it. I discovered that students of the *grande-école* caliber can pick up biology very quickly. I used the same method that I had enjoyed at Polytechnique and later with Miroslav Radman, encouraging them to visit as many laboratories as possible. Just like at Institut Pasteur and at the ESPCI, students soon wanted to join my lab, and before long I had no more positions left to fill. I tried to convince them that there were dozens of other labs that would be just as interesting for them to be in, and their response was that while I was right about that, they worried that they would get bored in a traditional lab setting. They figured they would be asked to carry out menial tasks devoid of the interdisciplinary approach that I had introduced them to and that

they had incorporated into their daily lives, practicing discussion in the university cafeteria and on the Web.

This was back when the Internet was really taking off. I set up a meeting with the Chairman of the Inserm at the time, Christian Bréchet, and told him that I was encountering a whole generation of young people who learned via the Web and wanted to break down barriers between disciplines and combine them. This was an approach that helped them grasp themes and ideas that were too complex to be sufficiently addressed in monodisciplinary approaches. Like Miroslav Radman a few years prior, he didn't need a lot of time to think it over. "Keep trying new things," he said. "You have my support."

So Ariel Linder, who was then a postdoc in the lab, and I were able to find a handful of students who were interested together with a few other researchers who had experience breaking down disciplinary barriers.

A few of us got together once a year for an "interdisciplinary spring school,"<sup>i</sup> a chance for us to meet and exchange for a few days over spring break on a little island called Île Berder off the coast of Brittany. Communing at the island's only hotel, we discussed in total freedom, far from the madding crowd. I had two key takeaways from those experiences. First was that I wasn't the only ugly duckling who wanted to break down barriers between disciplines. Second was that I wasn't the only person there who had received prizes and honors for his interdisciplinary work. It showed that you can be rewarded for being disobedient after all, or at least for being curious and escaping traditional curricula! I concluded that while interdisciplinarity wasn't an abso-

lute guarantee of success every time, it was certainly a way of exploring knowledge that was worth the trouble.

To satisfy the students who had gotten hooked on interdisciplinary discussions, we organized our first workshop in Paris. It was in the small room adjoined to our lab where the coffee machine was kept. The agenda was not very academic; we stated that we wanted simply to do things differently, such as discuss topics that weren't being taught because they were too-recently published to be on the radars of most programs.

A little community of students and researchers started meeting regularly. Because we had chosen at the outset to speak English, we had international students and researchers joining our group as well. But by the end of the first year of meeting, the students were disappointed because they found our discussions so much more enriching than what they did in their traditional, confined disciplines. "Why don't you create a degree program?" they asked. I went to see mathematician Gabriel Ruget, then director of the ENS. He suggested trying to start a master's program. "Write up a proposal," he told me. That's just what we did.<sup>ii</sup> We named the program "Interdisciplinary Approaches to Life Sciences."

Despite our interdisciplinary aim, we had to become affiliated with a specific department. That's how universities work. Yet that was impossible for us, as we didn't function via the traditional channels. Nonetheless, in each department Gabriel Ruget was able to find at least one researcher to take part in the program and at least one student interested in enrolling. Despite skepticism on the part of some, he sent our proposal to the Ministry of Higher Education and Research to get our master's

program authorized. And we got lucky. The person in charge of reviewing our proposal was open-minded. She acknowledged that, while the program was unlike anything then in existence, if she were a college student she could only dream of enrolling in a program like ours. Jackpot! Now we could issue diplomas. We were an official program.

## NOT TAKING RISKS CAN BE RISKY

We then started longing for a permanent location for our interdisciplinary discussions, a place where students and researchers could come to learn from one another. The CRI was in its embryonic stage, although neither I nor my cofounding partner, Ariel Lindner, knew it at the time!

We were eventually given a decent locale at the Cochin site of the Faculty of Medicine of Paris Descartes University. Until then, we had been based out of go-between spaces: the coffee break room attached to our lab, the cafeteria at the ENS (between meal services from 3 p.m. to 5 p.m.), and even a room adjoined to the morgue of Necker Hospital in Paris. In our new location, we had some 100 square meters at our disposal. A major, global symposium was going to be taking place at the French Institute for Higher Scientific Studies (IHES, which hosts some of the best mathematicians in the world), and Ariel and I had the idea of inviting participants to our new location for discussion sessions in the days preceding it. Just before they arrived, Ariel had the brilliant idea of printing *Centre de Recherche Interdisciplinaire* on a

sheet of printer paper and taping it to our door. And so the CRI was born, albeit informally, but our little group had an identity and even the start of some international notoriety with the eminent researchers we hosted.

This introduction to the world turned out to be crucial for us: First of all because it was an immense pleasure to share the space with great scientists and see them interact so enthusiastically with our students, and second of all because it helped us dispel the notion that we were somehow illegitimate, which is what always happens when you try to do something that's never been done before. When the biggest names in science from all over the world write a letter of recommendation in support of you, it quiets some of your critics.

Word about us started to spread. Within the few months following the CRI's opening, dozens of researchers and students came to see what we were up to. At the French National Assembly, there was a conference on the future of higher education and research, and there I bumped into Paul Friedel, then director of research and strategy at Orange Labs, the R&D division of France's biggest telecom company, Orange. He had just come from the US, where he had been visiting the famous Bell Labs. Bell Labs understood all the way back in the 1920s how important it was to bring together researchers from different disciplines in order to drive knowledge forward. The list of innovations coming out of Bell Labs is enough to make you dizzy: the first color fax transmission in 1924, the first long-distance television transmission in 1927, the artificial larynx in 1929, along with numerous advances in telephone communications; later on they invented the transistor, the laser, and solar cells and made

a host of discoveries in foundational research that would have applications in all kinds of different fields. “The way you describe your program,” Friedel said to me, “sounds like what I saw at Bell. Can I come see it? We can maybe talk some things over.” He came by, and we talked. We wound up creating a research chair, which is a program in which a researcher gets funding to be the chairholder at a university to both teach and drive research in a given field. Ours was called the Orange Research Chair at Paris Descartes University, and it focused on interdisciplinary research in mathematics, biology, and technology.

Then I went around to all the departments at the ENS to recruit students to be the first to enroll in our brand-new master’s program. I tried to make them understand how important interdisciplinarity would be for research in the 21<sup>st</sup> century and that if they kept themselves isolated in their partitioned disciplines, they risked getting left behind. I acknowledged that they would be taking a risk by being part of a program that had never been tried before but that remaining within the old-fashioned framework was also taking a risk—the risk of not letting their curiosity grow in unexpected directions. Livio Riboli-Sasco, one of the students I spoke to, summed up my argument perfectly when he said, “So, you’re telling us that we’re taking a risk by not taking risks.”

The master’s program was launched, and it went so well that students wanted to continue on our path and do a doctoral dissertation. But back then it was extremely difficult, if not impossible, to find funding and an institutional framework in France for interdisciplinary dissertations. That was a shortfall in the French system that directly benefited American universities, which every year would

pluck from us a few more of our most promising early-career researchers, who often would never return to France after getting their doctorate. Our little bubble wasn't enough. We needed to expand our community and anchor that community in a doctoral program. For research institutions, if you don't have a doctoral program, you don't exist. The awards I was receiving back then opened some doors for me: the Inserm Research Prize in 2002, the Liliane Bettencourt Prize For Life Sciences in 2003, and the European Young Investigator Award in 2005, among others. The European Young Investigator Award, created by the European Heads of Research Councils, was back then given out only to 25 young researchers throughout Europe in all research domains. Along with the funding they provide, prizes like these establish you in the scientific community. I was still an ugly duckling, but an ugly duckling who was gaining legitimacy.

In 2005, I had to share how I was spending the money I had won from the Liliane Bettencourt Prize for Life Sciences, and I mentioned to Armand de Boissière, then the new secretary general of the Bettencourt Schueller Foundation, the difficulty we were having starting a doctoral program. The obstacles and pushback I was getting were essentially the same as what we experienced starting the master's program. More than anything, we kept hearing, "It's never been done before," which for me was the best argument for supporting our project and the reason why I'm still motivated by it. Meanwhile, in the US, there were more and more interdisciplinary programs cropping up every year, namely the Stanford d.school opened the previous year by David Kelley and MIT's Media Lab,<sup>iii</sup> which mixes and matches different areas

of tech research and is also where physics and computer science researcher Neil Gershenfeld started his famous class *How to Make (Almost) Anything*. That class led to the creation of the first fab lab, the Center for Bits and Atoms.<sup>iv</sup> “Fab lab” is short for “fabrication laboratory,” and it’s a workshop that’s equipped with computer-guided tools that can turn data into things. These programs were attracting young people from all disciplines, including art, architecture, and design.

## TAKING TALENT TO THE TOP

The Bettencourt Schueller foundation asked us to make a budget in the spring of 2006. When we presented it to them, they told us, “This is a very innovative project, but if we really want to take talent to the top, which is what we love to do, you’ll need to design an organization that’s built to last. And we’re ready and able to work with you to come up with the best path forward for your ambitious project.”

Their unprecedented financial backing, expert advice, and the positive working relationship we’ve enjoyed together was a huge game changer. Thanks to the foundation, we received authorization to start a doctoral program. As I’ll be describing in the following pages, the foundation has been an extraordinary partner through every stage of the CRI’s development. Shortly after it would fund the interdisciplinary undergraduate and master’s degree programs we had started at Paris Descartes and Paris Diderot universities. We could offer thorough interdisciplinary training from high school graduation to the PhD level. A few years into our collaboration, the founda-

tion had the idea of building a research center that would be unique in the world. It soon began visiting other innovative centers all over the world and taking stock of what they offered. Meanwhile, we received visits from such forward-thinking notables as Helga Nowotny, the first female president of the European Research Council; Bruce Alberts, former president of the National Academy of Sciences in the US; Robert Tjian, then president of the Howard Hughes Medical Institute in the US; and David Botstein, then director of Princeton University's genomics institute.

Our reputation would grow abroad even more quickly thanks to our students themselves. A handful of them got together on their own to put together a team in order to participate in MIT's premier International Genetically Engineered Machine Competition, or iGEM. The competition can be described as playing with biological LEGOs. Teams come from all over the world, and in the summer before the competition, they receive a kit of standard biological parts called BioBricks. The teams then come up with the best way to use these parts and have them operate in living cells to create genetically engineered systems.

In the first year the CRI's Paris Bettencourt team participated, under Ariel's excellent coaching, it won the competition's Foundational Research prize. We organized a small reception to congratulate the students, and the presidents of Paris Descartes and Paris Diderot universities came. The fearless young people these students were, they told the university presidents that, while a cocktail hour was nice and all, what they really would have liked was a degree for the work they did. We got the message,

and we incorporated the iGEM program into the first year of the master's degree, which earned students an M1 degree, the first part of the master's. A little later, we finished setting up our undergraduate degree, the first in France in which students are taught through research. Again, this was possible thanks to the help of the Bettencourt Schueller Foundation and the governing bodies of Paris Descartes University. Thus our degree offering was complete.

Soon after, we started developing programs for youths, particularly for those from underprivileged backgrounds. When in 2005 I was invited to the World Science Forum in Budapest to receive the European Young Investigator Award, I followed online the riots that were shaking several low-income urban areas throughout France in the wake of the deaths of two teenagers, Bouna Traoré and Zyed Benna, who had a deadly run-in with police in the Paris region. Rarely had the contrast between the “winners” and “losers” of globalization seemed more apparent to me. My personal experience ties me as much to the first group as to the second. I have never forgotten my adolescence in Monclar, which wasn't in the news that year but which had been affected by rioting in 2003.

## A COOPERATIVE, EVOLVING ECOSYSTEM

Is it possible to build bridges between these two so seemingly different worlds? At the forum I debated this question across the aisles of the auditorium with Gaëll Mainguy, then president of the World Association of Young Scientists (WAYS), and the great Hungarian biochemist Péter

Csermely, who had launched an initiative 10 years prior that gave 10,000 Hungarian high schoolers opportunities to conduct scientific research. Péter talked to us about some of the problems specific to Hungary, starting with the educational segregation of Roma children. As it so happens, the issue has since worsened. The Council of Europe even felt the need to issue a statement affirming that school segregation had become increasingly widespread over the course of the past few years.<sup>v</sup>

The following summer we invited Péter Csermely and two of his high schoolers, one of which was Roma, to visit the ENS. We wanted to set up a program in France similar to Péter's in Hungary. The Association Paris Montagne was thus founded thanks to the work of dozens of students and researchers, and Paris Montagne started the Science Ac', a program seeking to open the doors of laboratories and (hopefully) the whole world of research to high schoolers, particularly those from low-income backgrounds. The president of the association was Livio Riboli-Sasco, another ugly duckling whose doctoral dissertation no one wanted to supervise because it was too out of the ordinary. He would eventually find a place to pursue it at our brand-new graduate school, the CRI.

We were becoming a cooperative, evolving ecosystem covering a lot of ground. In a vertical sense, we had programs available to students from secondary school to the PhD level (and soon we would get involved in kindergartens and primary schools), and in a horizontal sense we took in researchers from across all fields, although most were in the sciences. And all this was thanks to the bacteria I had been observing for 15 years, who didn't need ministers or centralized governments in order to get organized.

## FAIRY GODMOTHERS

The Romans had a god of opportune moments: Portunus. Portunus is the god of keys, doors, ports, encounters. When he opened a door for you, you had to use time to the fullest. In this way he's similar to the Greek god Kairos. Kairos' single lock of hair hung in front of his face, and you had to seize it when he was coming toward you, otherwise once he passed by it would be too late.

I'm an agnostic, but I think that if there had been gods looking over our shoulders during that period, it would have been the gods of opportunity. In our changing world, there are so many opportune moments that arise, and students know better than anyone else how to seize them. We constructed a place where they could maximize opportunities, and they did this with some pretty amazing results, starting projects for which the CRI is still known to this day and which continue to inspire students to want to join us. Indeed, the students have been the engine of our exponential growth.

We've also been fortunate to have had a few fairy godmothers along the way, most importantly the Bettencourt Schueller Foundation, with its motto "taking talent to the top." Françoise Bettencourt Meyers, the daughter of its founders, supervises the foundation, and Olivier Brault now runs it together with Armand de Boissière. Without the foundation, the CRI could never have become what it is today. Until 2003, I had never heard of the foundation and didn't know anything about the family's history, but that year I got a call from the eminent microbiologist Pascale Cossart delivering a message that wouldn't give me much time to think. When I got the call, I had

just gotten back to France from the US and was horribly jetlagged. In my stupor I could barely make out what he was saying: “François, are you free tomorrow? You and your colleague Ivan Matic are going to receive the Liliane Bettencourt Prize for Life Sciences.”

The next day we received the prize and a large grant. The prize has been awarded since 1997 to researchers under the age of 45 who have begun promising initiatives in the field of science. Why is the foundation interested in the sciences? We heard at the ceremony the story of the foundation’s legacy, of Eugène Schueller, born in 1881, the son of a modest baker. He had come to Paris in the late 19<sup>th</sup> century and was fortunate enough to be able to study chemistry and conduct research in a nascent cosmetics industry. He developed the first hair-color formula that wouldn’t get washed out in the rain. That was in 1907. Two years later, he founded the *Société française de teintures inoffensives pour cheveux* (“The Safe Hair-Coloring Company of France”), which would later become L’Oréal. Schueller’s work would produce a considerable fortune for his family, and it was in his honor that his daughter, Liliane Bettencourt, wanted to use the family fortune to create grants to bolster young scientists.

Former French Prime Minister Pierre Messmer was a member of the foundation’s board of directors. When they later decided to go ahead with funding the CRI, he shared with the family his thoughts that neither the public nor the private sectors would be able to get something like the CRI off the ground, and he congratulated their efforts to help young people go exploring off the beaten path. I share his point of view. It’s uncommon in France, but my

multiple stays in the US have accustomed me over time to the idea of research being funded by philanthropy.

The CRI's journey may have begun in a coffee-break room with a handful of pioneering souls, but our evolving, innovative project has seen exponential growth, doubling in size on average every 18 months since its inception. We've consistently changed our structural framework to meet the expectations of the ever-increasing number of students. And their ages and disciplinary backgrounds continue to diversify more and more. I am beyond grateful to our teams, which have been able to offer students the freedom they need, and I congratulate them for persisting through the challenges that come with the CRI's constant evolution. It's never easy to make the everyday function properly when you're always thinking about the future, but we've been able to do it only because everyone has been on board from day one.

## SOCIAL ENTREPRENEURS ARE HERALDING THE WORLD TO COME

It was through the Science Ac' that I met Arnaud Mourot, codirector of the European branch of the international organization Ashoka. Ashoka was founded in 1981 by American Bill Drayton.<sup>vi</sup> He worked for the US Environmental Protection Agency during Jimmy Carter's presidency and the global consulting firm McKinsey & Company, and he has also taught at both Harvard and Stanford. Many credit him with popularizing the term "social entrepreneur," a term that Ashoka defines as an individual "with innovative solutions to society's

most pressing social, cultural, and environmental challenges.” After 35 years, Ashoka’s network includes nearly 4,000 social entrepreneurs in 93 countries. On Ashoka’s website, I read that the inspiration for the name comes from the Sanskrit word Ashoka, meaning “the active absence of sorrow,” and from the Indian Emperor Ashoka, who was one of the earliest great social entrepreneurs. “After unifying India in the 3<sup>rd</sup> century BC, Emperor Ashoka renounced violence and became one of history’s most tolerant, global-minded, and creative leaders, pioneering innovations in economic development and social welfare.”<sup>vii</sup>

Ashoka is also based in France, and codirector Arnaud Mourot came to visit the CRI. I shared with him our young history. He quickly came to a conclusion, saying, “You’re a social entrepreneur.” Later he would ask me to become a part of the Ashoka Fellowship and partner with their global network, which seeks to create of a world in which everyone is a change maker. I was grateful, but I didn’t even understand what it meant to be a social entrepreneur. “If you want a better understanding, read *How to Change the World* by David Bornstein,”<sup>viii</sup> he told me. The book’s subtitle alone seemed like the title of a major action plan: *Social Entrepreneurs and the Power of New Ideas*.

In the book, I read about Brazilian Fabio Rosa and his low-cost technology for providing electricity to rural areas; Indian Jeroo Billimoria’s Childline, an initiative for improving street children’s access to emergency telephone services; and South African Veronica Khosa, who created a nursing service for AIDS victims in poverty-stricken areas.

Reading the book, I noticed a common feature between these initiatives and those of—you guessed it—bacteria.

Similar to humans, when they're not adapted to their environment, they have a few options. The easiest is to migrate and look for an environment more conducive to their survival, although that's not always possible—especially in the case of humans. It will be hard to change planets once we wreck our environment beyond repair. The second option, the most dangerous, is to mutate. Like a lottery, random mutations only rarely land on the winning combination that allows the organism to survive in its new environment. The third option, which the book illustrated over and over again, is adapting the environment to your needs. In biology it's called “niche construction” and “ecosystem engineering.” Humans do this very well, as do bacteria, but the best example comes from beavers. Lakes are their preferred habitat, not rivers. In the absence of natural lakes, they build dams as a way to engineer the ecosystem, not only for themselves and their offspring but for the neighboring species as well. I began to think about the beaver as a metaphor, wondering how one might go about re-engineering the learning ecosystem. This is a key piece to the larger puzzle this book hopes to convey.

## WE ARE LIVING THROUGH A PARADIGM SHIFT

But I didn't realize its importance at the time. It still wasn't clear to me if the signs of change I was seeing more and more of weren't merely evidence that there can be exceptions to the rule while the rule remains nonetheless the rule. But perhaps a new paradigm was appearing, a transition moving toward a new worldview. The American philosopher and historian of science Thomas Kuhn<sup>ix</sup>

popularized the term *paradigm shift* and demonstrated very well how difficult it is to know when such intellectual crises are occurring in real time. He showed that when a prevailing worldview generates contradictions, those who ascribe to that worldview will simply ignore the anomalies. Eventually, however, a free thinker will come along and attempt to reproduce the anomalies. When it turns out that they can be reproduced, these are no longer considered anomalies, but rather evidence that a new paradigm is emerging.

In the early 1960s this idea was revolutionary, and indeed it remains troublesome for those who still want to believe that science is somehow objective. Kuhn argued that, more than the results of lab experiments or new emerging theories, the predominant paradigm that a scientific community ascribes to will determine what questions it finds worth considering. Are the new ways of learning and researching anomalies? Or will digitalization bring about a new paradigm?

I wanted to find out for myself, so in 2011, the CRI organized the first NightScience event for discussing new ways to learn through research. *Night science* is a term coined by French biologist François Jacob, winner of the Nobel Prize in Physiology or Medicine in 1965. He discussed two different cultures in science. He said science in the works has two aspects, what could be called day science and night science. Day science employs reasoning that meshes like gears; its results that have the strength of certainty. Night science, on the other hand, wanders blind. It hesitates, stumbles, recoils, sweats, wakes with a start. Doubting everything, it is forever trying to find itself, question itself, pull itself back together. Night science is a sort

of workshop of what's possible, where what will become the building material of science is worked out.<sup>x</sup>

There are examples of night science throughout the world, and you will read about them throughout these pages. Indeed there are too many of them to pass them off as mere anomalies.

## WE'RE BORN SCIENTISTS, YET SO SOON WE FORGET

Also in 2011, American psychologist and philosopher Alison Gopnik gave a brilliant TED Talk called “What Do Babies Think?”<sup>xi</sup> based off her books *The Philosophical Baby: What Children's Minds Tell Us About Truth, Love, and the Meaning of Life* and *The Scientist in the Crib: What Early Learning Tells Us About the Mind*.<sup>xii</sup> Its main message is one I now live by, and it can be summed up in a few words: “We’re born scientists.” She shows that child brain development occurs the same way scientific understanding does, i.e., through experimentation on the surrounding environment. If this is innate behavior, it’s what surrounds us that can help us harness and develop our potential as scientists.

In science journals as of late, more and more articles are being published by children at younger and younger ages. That’s certainly an anomaly that should make us reconsider the prevailing worldview. Also regular people, sometimes referred to as citizen scientists, are publishing more and more in science journals. This was an anomaly too, but over time it has become something of an established practice. It’s part of a movement that’s considered a new branch in research called citizen science. We would

soon do our part in contributing to this paradigm shift when we created a program that it's my great pleasure to describe to you now.

Here again, the genesis of this initiative was contingent on a very important encounter with Ange Ansour, a translator-turned-schoolteacher in a Priority Education Zone school outside Paris. I passed along to her an article about bumblebees from the British Royal Society's biology journal. The article had been written by 8-year-old students in a science class.<sup>xiii</sup> "It would be great if our kids could have the chance to work with bumblebees," she said. "But French national education would never allow bees in the classroom. We could try ants though." Laurent Keller, a world-renowned myrmecologist, or ant specialist, put me in touch with two of his colleagues from Pierre and Marie Curie University: Thibaud Monnin and Mathieu Molet. They agreed to get on board and be available to Ange's students via e-mail to answer questions they may want to ask (themselves) throughout the year. Then we built an ant habitat in Ange's multi-age classroom.<sup>xiv</sup> At the end of the year, we had the students present their observations and findings, each reporting two things they learned, similar to how scientists present at symposiums. It lasted an hour, and my colleagues from the CRI and I were astonished. Tamara Milosevic, a biologist and education pioneer interested in learning through research, took the floor.

"I have learned so many things from you today," she said to the children. "How were you able to ask yourselves so many questions?"

"The first question we asked ourselves at the beginning of the year was whether or not we could ask questions," the students answered.

“You didn’t think you could?” Tamara asked.

“No,” the students said. “Grown-ups are always saying, ‘Curiosity killed the cat.’ At home, too, some of us have parents who say it’s not good to ask too many questions. So, when the scientists told us it was good to ask questions, we were confused. We talked it over, and we decided that when it came to the ants, we could ask all the questions we wanted.”

“So, then you made your observations and wrote to the scientists when you didn’t understand something?”

“No, first we looked in the books at the library, and then on the Internet, but eventually we figured out we couldn’t find all the answers in books or believe everything that we found on the Internet. We found Vikidia [like Wikipedia but for children] and we added things to the article about ants. We wrote to the myrmecologists only when we really couldn’t find an answer.”

“Do you have an example?” she asked.

“Like how does the queen eat? Because she never leaves the ant colony.”

“And what was the scientists’ answer?”

“The ants use their ‘crop,’ a second stomach in which they can store food for the ants who never leave the colony. But first it took us a month to understand all the myrmecology vocabulary.”

At first, the students reproduced laboratory experiments that researchers had already done. They did this until one day they came up with results that didn’t match those of the researchers. Specifically, the ants had built a wall that barred entrance to the ant colony. They wrote to the myrmecologists about it, and they responded that they didn’t know why the ants had built the wall.

Their hypothesis was that the ants were perhaps depositing things from within the colony. The children had their doubts about that hypothesis, however, because it didn't fit with their observations. So, they tested it out. They did an experiment in which they took down the wall and scattered little scraps of paper and leaves and things throughout the habitat. The ants responded by building an even bigger wall with the debris the children had deposited, disproving the scientists' hypothesis. The children understood that, while scientists know a lot, they don't know everything, their explanations aren't always right, and you can test the different hypotheses.

That has been one of the most successful and enriching experiences we've had, and I love sharing it. I did just that with a journalist from the *New York Times* on a plane trip back from the World Innovation Summit for Education (WISE), and the story piqued his interest. He wound up coming to the CRI and to Ange Ansour's classroom, and he wrote an article about the students. Our young scientists had made waves all the way across the Atlantic!<sup>xv</sup>

I was also invited on French public radio to share the story on a segment called *Les Savanturiers*, a portmanteau of French words *savant*, meaning intelligent, and *aventuriers*, adventurers. The adventurers of intelligence. The knowledge explorers. The kids really liked it as a title, and French public radio eventually let us use it as the name of our new education program.

Ange's class had a Twitter account with hundreds of followers, and eventually even the City Hall of Paris heard about her class. The city was reforming school extracurricular activities at the time and was looking for new ones. We wanted to spread the program to schools all

throughout Paris, and although it was painful for Ange to part with her students, she agreed to join our team to help set up identical programs in 20 afterschool workshops. We then found 20 PhD holders from different fields to lead these groups in 20 different research topics, spanning from astrophysics to botany to myrmecology.

And it was a huge success!

The kids learned to love the scientific method, and their teachers sat in on our workshops, stayed throughout the sessions to learn about what we were doing, and some even asked us to take over science classes in their schools. We of course refused. We could work with them, we said, but never replace them. Little by little the *Savanturiers* started programs in preschools, then branched out to high schools, including vocational and technical high schools. The program even got certified as part of President François Hollande's social-reform initiative *La France s'engage* ("take action France"). This made it easier for us to set up even more workshops and get recognition from bigger institutions.

Just like the CRI itself, the *Savanturiers* grew from just one classroom, developing rapidly by taking on more and more opportunities.

A good example of this is the teaching innovations we helped start in Paris suburb Gennevilliers in partnership with the local city government and French electronic-systems company Thales, which has a site in Gennevilliers. The project shows how a research center can catalyze an educational ecosystem that's local, challenging, and innovative, serving the high standards of the public school system and located in an area seeking improvements in education. Since September 2015, this partnership between the Thales Foundation and the *Savanturiers*

has created a virtuous cycle that benefits the entire city. Dozens of classes from primary school through secondary school undertake various learning-through-research projects, with the *Savanturiers* helping with lesson plans and engineers from the Thales company volunteering to provide scientific input.

The success of the *Savanturiers* is based on how beneficial it is for students as well as teachers, as they derive professional development from the program as well. The *Savanturiers* won over the City Hall of Paris, which offered its support and agreed to expand the program throughout the city. Thales also plans to implement the program at its other sites, both in France and abroad, and other regions of France and other companies have also reached out to create similar partnerships that they see as positive for their employees, teachers, and of course, students. The boost that the *Savanturiers* helped to provide has turned into an empowering program for everyone involved.

At the last *Savanturiers* conference at the Thales site, where students were presenting their findings, three of the mothers of students who themselves had found out they could become scientists also got on stage to share discoveries from their investigations.

## TRAVEL BROADENS THE MIND, BOTH FOR THE YOUNG AND THOSE WHO STAY YOUNG AT HEART

One of the great advantages to going to the Ecole Polytechnique is using the officer stipend to travel during vacation periods. After a short time, I had traveled throughout

Europe before venturing out to other continents. I learned so much. There's a common French expression that goes, *Les voyages forment la jeunesse* ("Nothing shapes a young mind like travel"), and European study abroad programs such as Erasmus, trans-European internship programs, and interim years for traveling are looked upon as real advantages for students.

The Chinese have another way of expressing the same idea. They say that if you're familiar with only one way of doing things, you'll have difficulty imagining another way of doing things. If you have the opportunity to experience other ways of doing things, you can keep imagining more possibilities. French philosopher and expert on Chinese culture François Jullien demonstrated the same notion through philosophical concepts. He compared the way the Chinese and the Greeks understand the certain ideas in completely different ways. For example, in Chinese, the word for "crisis" has two meanings. One means something dangerous, the same meaning we have, but another means opportunity, or a chance to change the way people think about a given situation.

For children (and adults) who grow up in two or more cultures, encouraging them to reflect on these diverse ways of perceiving things can help them understand the complexity of the world. It can help them be aware of the importance of cultural context and language in one's outlook. Migrant children, for example, will construct a "third culture" that is neither the culture of their parents nor that of the country of refuge. These children are sometimes called third culture kids. Culture for them takes on a meaning that is very subjective and specific. While we need to be prepared to help these children

through identity crises they may face, their third culture makes them more open, adaptable, and more suited than most to understand globalization and its challenges.

International studies have shown that Australia and Canada are two countries better equipped than France at helping immigrant children succeed. These countries welcome them by celebrating their culture of origin and inviting them to be ambassadors of that culture so as to share it with others. When they travel elsewhere throughout their lives, they'll then share the culture of their country of adoption.

In Singapore, a rich cultural melting pot, heads of companies and especially schools are sent around the world to observe how colleagues in other countries do the same work. Their duty is to learn from others, be it through their successes or their failures. This open-mindedness has contributed to the success of both the Singaporean economy and particularly the education system. We could learn something from this system, sending around the world the members of our “learning society,” which has so much to learn from other cultures, saying nothing of how much we learn about ourselves when put in role of the outsider.

## COLLECTIVE INTELLIGENCE IS MORE POWERFUL THAN ARTIFICIAL INTELLIGENCE

When I think of the CRI's history and all the projects described in this book, I get very optimistic, or perhaps more than optimistic. I like to think that the historical moment we're living through is similar to the one in the

18<sup>th</sup> century that produced the Enlightenment thinkers. In just a few decades, they invented the press, science, publishing, science journals, and modern democracy. At the outset, the Enlightenment thinkers were an extreme minority, but then they all began talking to one another, setting up an informal network or “invisible college,” to use British chemist Robert Boyle’s term from the 1640s. At that time, it took several generations for anything to change, both because cultural transformations take a long time by nature and because the technology they had for exchanging information, i.e., the printing press, was very slow. American historian Elizabeth Eisenstein dates the start of what she called the unacknowledged revolution with the invention of the printing press.<sup>xvi</sup>

Today’s technologies are much faster, and our revolution isn’t based on one technology like the Enlightenment was. Rather, it’s based on a galaxy of interconnected technologies: genetic, biological, cognitive, nano, and so on. And we have more and more access to these technologies on more and more devices, namely our smartphones. We are still a long way away from being able to fully imagine, let alone analyze or really understand, the impact our phones have had on our lives, so numerous are the potential ways they have changed how we live. We lack spaces for thinking about our future, and similarly, spaces where foundational and applied research aren’t opposed to each other. They can help us assess the ethical and social implications of the technological advances we’re seeing.

We have to lead a collective reflection on these issues and mobilize collective awareness, both with regard to major technological transformations and the great chal-

lenges our planet faces, i.e., biodiversity loss, climate change, etc. We won't be able to meet these challenges without collective action. We should mobilize collective intelligence in all spaces where humans come together, starting with classrooms, businesses, and government bureaus, and we must reorient these spaces toward these goals. These spaces as they are currently were designed with implements and organizing principles dating from the 19<sup>th</sup> century—mostly hierarchical, small-scale, and for the purposes of control. All information rose to the top so that those at the top could remain informed and send decisions back down for everyone to follow.

WHERE THERE IS EVOLUTION,  
THERE IS TENSION—AND THAT'S NORMAL

Let's come back to Socrates. The charges condemning Socrates to death are revealing. Not only was he accused of introducing new gods, but more importantly he was accused of corrupting youth. His prosecutors could foresee political fallout from his teachings. Should education based on curiosity take precedence over education based on allegiance to institutions, the city-state was at grave risk. Socrates' defense for his actions was meek. He admitted that what he was doing was not allowed or acceptable. He did not deny the accusations, and he would die for it.

That age-old tension still exists between, on the one hand, those who submit to institutions and mechanically repeat lessons based in outdated knowledge, and on the other hand, those who believe in a system based on the capacity to wonder, question everything including the

rules, and create the world of tomorrow. This tension is also political, which is important to keep in mind when trying to understand the fierceness of debates on education policy. We're seeing a confrontation between two systems that seem to be diametrically opposed to each other, and when their proponents face off, the sparks fly. That's how it is in any transitional period. The Athens that condemned Socrates to death was the same Athens that produced the West's first philosophers and invented the first forms of democracy, science, secondary schools, institutional education, etc. The Renaissance witnessed similar tensions because of the major technological advance that was the printing press. In our own time, with the birth of the Internet and the digital revolution, we see similar tensions. These tensions are sometimes better understood by the avant-garde, the artists at the cutting edge of these changes. That's why the CRI seeks to be a middle ground, or an intermediary space that catalyzes interactions between the "upper ground" (institutions) and the underground (innovative individuals who are blazing new trails but who are often left isolated and even marginalized).

### THREE IDIOTS TRYING TO DREAM UP THE FUTURE OF EDUCATION

Although I am by far the least artistic member of my family, the community I grew up in placed art at the center of culture and life. Art allows us to explore other ways of seeing the world and can take us beyond what we'd be capable of experiencing if we didn't have it. J.

Roger Hollingsworth, an American historian and sociologist, showed that the best researchers are very often artists, as they are able to break down barriers, move freely between different worlds, and play with one realm of imagination or another.<sup>xvii</sup>

From a very young age, I was always a big reader. I remember at the age of 6 reading my first novel while my parents were asleep. At the library, I read everything I could get my hands on that had to do with mythology and legends from different cultures. I was extremely fortunate to grow up in Avignon, a city with lots of festivals and a major mecca for theater. I learned a lot from the performances and the discussions we'd have afterward in the narrow streets and cobblestone plazas of that old papal city. When I got to Paris, I went to a lot of art exhibits and discovered the richness of cinema in movies from every era and from all over the world. On occasion I would even go into a movie theater for the first showing and not leave until the last showing. There too, discussions between friends after the movie was always enlightening.

My favorite movie is *3 Idiots*, an Indian movie that didn't get distributed much outside Asia, which is unfortunate, as it was number one at the box office in several Asian countries. I first heard about it from Filipino and Chinese students of mine, and I've watched it a total of five times already. It's a window into how the Indian higher education system works. The system is even more competitive and ruthless than most, with bullying and family and social pressures that push many young people to commit suicide.

But the film is profoundly joyful and funny. The leader of the three idiots, Rancho, is unerringly creative and

funny. He winds up becoming the top student in his class while he actively denounces the limits of the system. He even woos the daughter of the school's very traditionalist dean. Drawing from his experience, he goes on to start a school in the foothills of the Himalayas. There, children can exercise their creativity by solving problems and patenting their solutions. The movie is partly based on true stories, for example that of Sonam Wangchuk, an Ashoka Fellow. He began a school where students find solutions to the challenges they find in their communities. He also leads interesting debates on the values and structure of education systems.

I would love for everyone to see this cinematic jewel that demonstrates in the funniest of ways the paradigm shift and tensions covered in this book. The film forces us to ask how we got to this point in our education systems. Are young people trying to find what's right for them really idiots? If that's true, then there are countless idiots out there who want to infect everyone with change. I've never seen a movie or even documentary on the impact of a given film, but I really want to see one about the effect *3 Idiots* can have on young people (and everyone else for that matter). It's all the more worth it if helps us realize that what we see in the movie is a reality and that indeed there are spaces, more and more of them around the world, where we can learn differently and help build the future.

In its ability to move us in the most profound ways and have an impact on millions of people at the same time, cinema represents an opportunity to develop awareness and change our collective culture. I bet that the impact of cinema could be even greater if we gave ourselves opportunities at the end of the movie to meet the other

moviegoers, who like us were so drawn to the emotions of the film that they literally “got in motion” when they saw it. Discussing with people other than those in our close circles, expressing our reactions, and cultivating our reflections with others can be impetus for starting collectives that can move toward action in ways that people individually either can’t or won’t do.

Every era has had a space to debate things. The Agora is where the Greeks talked over the issues that worried them; Parisian salons and cafés are where the Enlightenment thinkers met for discussion; many television programs played a similar role hosting moderated debates. I’m not sure that talk shows and social media handle debate quite as well. Debate should help both the debaters and the viewing audience to grow. We’ll likely need to find a new way of having open discussions in the digital age.

Art can open our imaginations, and discussion can help us understand where others are coming from. There are people at the CRI and elsewhere who are passionate about both. I think these are essential for the health of our democracies and our capacity to think about the world to come. Cinema lets us see through the eyes of another, and by analyzing the emotions we felt during the experience, we can know both ourselves and others better.

## “KNOW THYSELF”

More generally, what I want is for schools to reconnect with the Socratic teaching “know thyself.” It’s an imperative that should be at the heart of the education system. What do you know about yourself? What do we know

about ourselves? As technological advances continue and computers know more and more about us—at least things about us that we can't know or would rather forget—I think we have an increasing need to ask ourselves what it means to be human, what it means to be oneself, and where we want to be in this rapidly evolving world.

Young people are more motivated than anyone to look for answers to these questions. And innovations rarely come from those already in power.

Now that you know me a little better, let's continue our journey and take a moment to talk about a central issue, which is that in order to learn, you must start by unlearning.



## 4

# Before you can learn, you have to unlearn

There's a story, perhaps you've heard it, that illustrates how hard it is to give up old ways of beliefs and ways of doing things. It's the story of the macaques on Koshima Island, Japan. To attract the monkeys out of the forest for observation, scientists came up with the idea of placing sweet potatoes on the island's sandy beach. This trick made the potatoes hard to eat, though, as the potatoes got covered in sand that ground on the monkeys' teeth. An adolescent macaque named Imo came out to the beach, pulled a potato out of the sand, then washed it in the ocean before eating it. Her friends came by, and she showed them how to wash the potatoes, and then all the adolescent females adopted the behavior. Next, the adolescent males picked it up, and then the adult females, then the alpha males. Sometime later, the scientists placed rice on the beach instead of potatoes. The exact same sequence occurred. Clever little Imo found a way to get the sand off the rice. A brief aside: Getting sand off rice is

not as easy as you may think. Since one of the aims of this book is to motivate its readers to wonder about the world and do research, I'll let you figure out how to do it. And don't just look it up online. Once you figure it out, you'll admire the ingenuity of this not-so-distant cousin of ours.

Anyway, the exact sequence occurred of transmitting the new skill within the troop. It goes from adolescent to adolescent, then from mothers to alpha males.<sup>i</sup>

Japanese macaques are not the only species in which the alpha males have trouble questioning old habits and adopting new ones. The history of science is full of discoveries that took years to be accepted as fact simply because the alpha males—in this case the researchers with the most power—refused to admit that their vision of the world was wrong.

One of the most famous is a tragic case, that of Ignaz Philipp Semmelweis (1818–1865). By the way, his story is exceptionally retold in the book *Semmelweis* by French writer Louis-Ferdinand Céline.<sup>ii</sup> Semmelweis was a German Hungarian physician who specialized in obstetrics. He noticed that women preferred giving birth with midwives rather than with doctors, not simply because the women liked consulting with other women over men, but because women felt survival rates were higher with midwives. Semmelweis looked into the phenomenon and found it was true. Mortality rates in the clinic where student doctors performed deliveries were higher than in the clinic where midwives worked. He then observed the differences in practices between each clinic. Each clinic followed the same procedures except for one important difference: The student doctors went directly from autopsying cadavers to delivering babies without washing

their hands. It's one of history's most tragic ironies. The student doctors were autopsying women who had died of childbed fever in the hopes of finding a cure to childbed fever, meanwhile it was the doctors who were infecting them with the disease by not washing their hands before going into the delivery room.

Semmelweis then published his findings, making the case for the correlation between hand washing and mortality from childbed fever and recommending that doctors wash their hands. No one believed him except for one doctor, a man who had delivered his beloved niece without washing his hands, and his niece later died from the disease. Upon learning that it was he who had caused her death, he committed suicide. For Semmelweis, it's perhaps his great tragedy that the only person who believed him wound up killing himself. After years spent struggling in vain to get the medical community to take his findings seriously, he suffered a nervous breakdown and died shortly after, dejected in a mental hospital. It wasn't until Joseph Lister and Louis Pasteur understood the mechanisms of infection that hygiene would gradually become standard practice. Today, Semmelweis is recognized as the father of the fight against nosocomial, or hospital-acquired, infections, although there are still those who don't wash their hands as often as they should or think critically about their own behavior.

Semmelweis may have lived 150 years ago, but humanity is still far from immune to repeating such tragedies. Someone can be right about something, but it still takes a number of people (hopefully influential people) to agree with her for it to be considered right. It's not hard to imagine that Semmelweis's colleagues were not

brutes but rather honest doctors who wanted nothing more than to save lives, and for that very reason they were unable to accept the notion that they had involuntarily caused the deaths of so many.

It's also the case that scientists who make important discoveries that challenge orthodoxy will have the hardest time accepting subsequent paradigm shifts, in which they themselves are being challenged by the younger generation.

## OUR BRAINS WILL HAVE US THINK THE MOON IS MADE OF GREEN CHEESE

If you type “rabbit-duck illusion” in a Google image search, you'll see a well-known optical illusion that was first published in a German magazine in 1892.<sup>iii</sup> It's a classic optical illusion in which some people who look at it see a rabbit, others see a duck, and some see both. This particular optical illusion became popular in 1899 thanks to American psychologist Joseph Jastrow. He used it to show how our culture acts on our brains in the production of representations. Social media loves these brain-bending images, and if you type *optical illusion* in an Internet search, you'll find dozens of other examples: figures that start to move when your eyes move, identical faces that seem to express different emotions depending on the image's heading, etc.

The fundamental idea behind them is that our brains interpret signs from the physical world. Nothing is fixed. Everything is filtered. This function in our brains gives us a considerable advantage and has done so for a long

time. Our remote ancestors could distinguish between predators and prey just from a few visual clues thanks to this capacity in the brain. We're fortunate that we can produce sense out of very complex data in the world, and this has given us an undeniable evolutionary advantage throughout history.

## THE ALLEGORY OF THE "ALLE-GORILLA"

I thought these little optical illusions were all fun and games until I looked at one in a scientific context. It was during one of our stays on Île Berder, the place where the CRI in part started. One day, one of our colleagues showed us a video of an experiment in which a team in black T-shirts and another in white T-shirts intermingled while passing basketballs back and forth to the other members of their team. We were told to count the number of passes the team in white made.<sup>iv</sup> It's actually a difficult exercise. Each one of us had a different answer by the end. We were then asked if we had noticed anything strange during the video. I hadn't seen anything except that at a certain point something was trying to get in the way of my concentrating. Our colleague then had us watch the video a second time, this time without counting the passes. We saw, right in the middle of the passing exercise, someone in a gorilla costume walk to the center of the frame, do a bit of chest-pounding, and walk off. It should have been impossible to miss, right? I couldn't believe my own inattentive blindness.

I spent the rest of the day thinking about how many gorillas I had missed throughout my life, including in my

life as a scientist. When scientists focus all their energy on a single phenomenon, we're really just counting the number of passes. The gorilla video was a revelation for me, as I realized that in science we can get so focused on one thing that we miss the blatantly obvious. I now refer to this experience as the allegory of the alle-gorilla.

Cognitive scientists have identified dozens of our cognitive biases, which affect how we process information.

An example of one of these is backfire effect, also called boomerang effect. This was at the center of a much-talked-about study in the US in which Republican voters were presented with factual information that contradicted what Republican candidates at the time were saying. Not only did the facts not change the minds of the voters, but the facts further entrenched initial convictions.<sup>v</sup> The findings are somewhat unreliable considering that the most talked about of these experiments couldn't be reproduced. Nonetheless, a potential hypothesis is that, when challenged, people will seek above all to defend themselves and the group they feel they belong to.<sup>vi</sup>

Another very common cognitive bias, one which goes hand in hand with backfire effect, is active information avoidance. It posits that I will avoid not only the information that challenges my beliefs and threatens my identity but also the information that could be potentially beneficial to me. Heavy smokers don't read many studies on the link between cigarettes and lung cancer, just like how alcoholics don't read studies linking alcohol to various liver diseases. They're vaguely aware of the truth, but they don't want to look further into it.

Huntington's disease, which progressively breaks down nerve cells in the brain, was also looked at from a cogni-

tive bias perspective. It's a potentially fatal disease and one that we still can't cure. Worse still is that it's an autosomal dominant disorder, meaning that you as someone with Huntington's disease have a 50 percent chance of passing on the disease to your child. Economists will tell you that if you know you're at risk of dying 20 years earlier than the average life expectancy, you'll plan your life differently. You won't save up for retirement, perhaps you won't have kids so as to avoid the risk of passing on the disease. In short, you'll take a different approach to life. Rationally speaking, you have every reason to find out if you have the disease, but the psychological cost of finding out is so heavy that only 5 percent of those at risk get tested.

This is one of many limits to the rationality of *Homo economicus*. For those who haven't taken economics, *Homo economicus* is the theoretical human being who behaves with strictly rational self-interest. We all manifest the limits of our rationality to varying degrees. At some point, you've likely objected to going to the doctor for tests or avoided opening an envelope containing the results of an important medical test. If this doesn't sound like you, then it probably sounds like someone you know.

## THE POWER OF COGNITIVE BIASES

Another amusing test that confirms the power of this cognitive bias is the following: Ask a bunch of people if they think they're smarter than the average person. The majority of them will respond yes, but statistically

speaking that can't be the case. This is the same answer you get when you ask people if they feel they're better drivers than most. In a formal experiment, some of those interviewed were told that people close to them had also been also interviewed, and they agreed he or she was above-average smart, attractive, etc. "But we didn't ask your friends why they felt that way. Would you like us to find out?" Yes, of course! Find out as much as you can! Ask them more questions! Tell me everything!

Another group was told that people close to them were interviewed and felt he or she wasn't above-average intelligent or beautiful. "But we didn't ask them why. Would you like us to find out?" Uh, no. "What if we paid you?" Absolutely not.

Results of these kinds of experiments are always the same, whether it's a question of health, beauty, intelligence, or social standing. The fact is we don't really want to know what others think of us, especially if we think their responses will be negative ones. Don't believe me? You don't need a PhD in behavioral science to prove it. Your Facebook account will tell you. How many of our "friends" think or speak poorly of us? How many have a completely different point of view from us? The answer is not many. By contrast, how many of them affirm our beliefs? How many of them are part of the same tribe we're a part of? The answer is the majority.

## POPPING OUR FILTER BUBBLES

Facebook's algorithm, like all social media algorithms, aggravates the effects of our cognitive biases. It suggests

to us friends and shows us news and opinions that are in line with what we have already liked based on previous Internet activity. There's no question: It's the cross-fertilization of cognitive biases and the prejudice of algorithms that makes it so hard to pop the filter bubbles that form around us on the Internet, making it easier for fake news to gain traction. After all, isn't it so nice just to preach to the choir?

The filter-bubble phenomenon existed before the Internet and social media. Throughout history, anybody who has ever wanted to push the human race toward more rational beliefs, more rigorous science, or more open, democratic debate has had to face impenetrable filter bubbles. Read or reread the early Greek philosophers, the first democratic thinkers, the Enlightenment thinkers of the 18<sup>th</sup> century, even the founders of the Internet. The Internet founders were brilliant minds convinced that mass circulation of information, rationality, and scientific proofs would foster democratic debate the likes of which had never been seen before and, in the long run, improve how democracy functions. But it hasn't gone that way, which is in large part due to the power of our cognitive biases and our need for recognition within our tribe.

However, there do exist situations in which we're better able to bear disappointing news or question our own beliefs. This happens when we feel supported, cared for, listened to, and in a way, loved. No matter what age you're living in, that takes time.

How can we create such an environment in an age of mass circulation of information? How can we start to value reason over emotion? Since the 1970s, the late

French urbanist and philosopher Paul Virilio had been warning us about the global accelerations technology would set off. Something he said in 2010 remains a scalding truth: “We’re experiencing a synchronization of emotions, a globalization of affect. All at once, anywhere on the planet, we can all feel the same terror, the same worry about the future, or the same panic. It’s pretty incredible. We’ve gone from synchronizing our opinions—made possible with freedom of the press—to synchronizing our emotions. For example, emotional communities now rule where common-interest groups based on social class once used to define the political left and right. Our societies used to be based on common interest; now they’re based on a communism of affect.”<sup>vii</sup>

How do we rebuild the discussion forum? How do we go back to considering other points of view? Where can we go to move beyond our usual ways of thinking? This is perhaps one of the greatest challenges facing humanity. It’s all the more complicated when, after we recognize cognitive biases in others, we have to acknowledge our own cognitive biases. How will I conquer my own refusal to learn? How will I overcome my own active information avoidance?

## (UN)LEARN FROM EXPERIENCE

Today, eliminating cognitive biases should be at the heart of all education-policy proposals. We can and must come up with exercises that help us change our points of view and see things from the point of view of the other, and we should implement these starting in preschool.

The French foundation *La main à la pâte* does just this. The French expression “*mettre la main à la pâte*” literally means “get your hands in the dough,” illustrating their core mission of getting children actively involved in science curricula through hands-on activities, which are complemented by reflection, group work, etc. The foundation strives to promote and develop science and technology education starting at the primary and early secondary school levels, both in France and abroad. Interestingly, those who work with the foundation don’t champion the importance of science as a first argument. Whether it’s astrophysicists Pierre Léna and Yves Quéré or Georges Charpak, winner of the Nobel Prize in Physics, they all stress the value of scientific experimenting as a way to help kids bridge the disconnect between how they think of the world and the world as it is. When you do an experiment and write down every step of it in a notebook, you start to realize that the world can be counterintuitive. When you’re the one confirming the results of an experiment, it’s worlds more enriching than when the teacher simply describes to your class the past results of the experiment—it doesn’t matter how brilliant and persuasive the teacher is.

Chemist Richard-Emmanuel Eastes, who also has a PhD in cognitive science, got involved early on with *La main à la pâte*. He later created another association called *Les atomes crochus* (“atomic bonds”) and designed for science classes a series of experiments meant to surprise and amaze, e.g., showing that water can start on fire.

According to Eastes, conducting scientific experiments can even change the structure of our neural networks.

He explains this using as an analogy of something called allostery. Allostery is a way of altering protein activity in the body. Our neural networks are a bit like networks of protein reactions in that they can get stuck in a certain configuration, and to change that configuration, a lot of energy is required. In the case of changing a network of protein reactions, temperature change provides the necessary energy. For neural networks to change, it takes curiosity, i.e., positive motivation. This is the neurobiological explanation for why it's so hard to change our minds or see things from a different perspective.

When we find ourselves in stress-filled environments, we feel threatened and we conform more easily to the status quo, especially if everyone else feels the same way we do. But when we find ourselves in more comforting environments where we can own up to our misinterpretations or even change our opinions altogether if we so choose, then it's easier to be curious. Then we see that we start at a certain point in our thinking, accept being challenged in that thinking when contradictions become apparent, and eventually, modify our thinking.

## IN SEARCH OF PLEASURE, HAPPINESS, AND MEANING

We're also victim to various physiological biases because we are programmed to seek out things that give us pleasure, namely food, which we need to live, and sex, which is essential for reproducing as well as recognition, which we need as social beings.

The environments our ancestors evolved in lacked foods that were rich in sugar, salt, and fat, which is why we now devour foods that are sweet, salty, and fatty whenever we can. The neural networks that fire when we eat such foods use a neurotransmitter called dopamine, and dopamine can have adverse effects. American pediatric endocrinologist Robert Lustig, who has long studied obesity and diabetes, talks about this phenomenon in his book *The Hacking of the American Mind*.<sup>viii</sup> Pleasure-seeking, which is controlled by dopamine, is the enemy of happiness, which is mediated by serotonin. From using social media to eating lots of sugary and processed foods, cheap pleasure has never been so easy to come by thanks to a host of new products and services that are marketed as *the missing piece to our happiness*.

Pleasure and happiness are at the center of Lustig's book. In addition to being a doctor, he's a professor at the University of California, San Francisco. He explains the science behind his findings very clearly, and likewise he makes clear the gravity of the potential implications for modern society at large. Not only is happiness not the result of so many accumulated pleasures, but our mad pursuit of pleasure can actually inhibit feelings of fulfillment and contentment.<sup>ix</sup>

Lustig illustrates that many addictions, i.e., to alcohol, tobacco, drugs, and gaming, all involve much of the same neural circuitry. He's critical of corporations that take advantage of our pleasure-seeking biases to maximize their profits despite detriments to our health and, ultimately, our happiness. He wants to make us conscious of these biases while also calling for regulation to protect us. He also encourages us to spend more time with those

we love, e.g., by doing more cooking and eating together, activities that are more likely to make us truly happy. Another book, this one by French psychologist Jacques Lecomte,<sup>x</sup> works in tandem with Lustig's book, as it's all about things that help us give purpose to our lives, which include, as Lustig recommends, prioritizing time spent with those we love, doing something creative, and getting involved in projects that have an impact beyond ourselves.

## EXPERIMENTATION BEATS INTUITION

When you satisfy your curiosity through scientific experiments, you may feel little sensations of happiness as you stimulate the neural networks that interpret the world more scientifically. That's what the *La main à la pâte* and *Savanturiers* programs believe can happen, as does every person who feels that a scientific understanding of reality can make us better citizens. This is because our societies are becoming more and more based in science, and through science we can go from false convictions rooted in intuition to other ways of thinking. Over time science helps inhibit our mistaken beliefs.

The major benefit of a scientific approach is that it's the best deterrent against yet another bias: ideology. It's harder to agree with someone else when our own values are at stake, which explains why scientists usually agree more often than politicians do. The best known example of this concerns the atomic bomb. In the 1940s and 1950s, American and Soviet intellectuals were in absolute agreement on one issue: that so much progress had been made in harnessing the destructive power of

the atom that a nuclear holocaust would be imminent if the wrong button was pressed. These experts concurred that everything should be done to keep either superpower from doing just that, which led to the start of the Pugwash movement, among other initiatives. In 1995, the Pugwash movement won the Nobel Peace Prize for its contribution to diminishing the role of nuclear weapons in international politics. While scientists in the Pugwash movement did not see eye to eye on politics, they could at least be of the same mind when it came to the destructive potential of the atomic bomb.

## SHEDDING YOUR OWN IDEOLOGIES

While not all confrontations among human groups are as radical as the standoff between the Eastern and Western blocs after World War II, humanity has deeply divergent views when it comes to values. In his books and TED Talks, American psychologist Jonathan Haidt offers very lucid analysis of these divides. He identifies five moral foundations in every human society.<sup>xi</sup>

The first moral foundation is care, i.e., protection and concern for others. It's what pushes a mother to protect her children or makes us feel compassion for our kin or people who are suffering. It's the reason why we feel animosity toward those threatening people dear to us.

The second foundation is fairness, concern for reciprocity and equality. It's the foundation of a just society.

Third is loyalty. This is the reason why humans have been able to form the largest communities in the history of the animal kingdom. Cooperation between groups of

other animals can reach only a few dozen, and only the parents in the group are able to cooperate. This is something Harari talks about also, particularly in *Sapiens*.<sup>xii</sup> Haidt ponders the irony of the fact that loyalty finds its most enthusiastic expression in both fighting (mounting an army to go to war) and playing (supporting a particular sports team). But which group should we be loyal to: our friends, family, tribe, neighborhood, city, region, country, continent, or planet? Why must we choose?

The fourth foundation, authority, is also inherited from our evolutionary past. But who or what has authority? Whoever or whatever causes us to grow, said Michel Serres. He came to this conclusion after looking into the etymology of the word. It comes from the Latin word *auctoritas*, which is derived from same root as Latin *augere*, meaning “to augment,” “to grow.”

Lastly, the fifth foundation is purity, and what people find pure they tend to consider sacrosanct. It’s different for everyone but always something at the center of our lives.

The most bitter conflicts are fought over values, what we mean when we say equality, community, authority, or sanctity. And we consider to be unmoral those who have different morals than we do.

In Haidt’s view, how you vary with regard to these moral foundations will give a pretty good indication of your political leanings. You can test it out yourself on the website Haidt created, <http://www.yourmorals.org> (not available in Europe at the time of publication). On the website you’ll respond to a series of questions, and the results will show you what percentage of people fall in the same place on the political spectrum as you. The most valuable takeaway from Haidt’s work is how

difficult it is to step outside of our points of view and come to terms with the fact that how other people see the world can be no less grounded or legitimate than our own. We're trapped within our neurons, cognitive biases, and moral values too.

Education can help, though, which is why biologist Livio Riboli-Sasco, cofounder of the Association Paris Montagne, created a program called the *Atelier des jours à venir* ("the workshop of days to come," from a line in the Pablo Neruda poem *Esperemos*). At the outset, the program was interested in introducing young people from low-income areas to the sciences. Eventually, the program began conducting science-communication sessions in conflict zones around the world, such as in Palestine, Israel, and the former Yugoslavia. He's someone who's honest about the limits of his program and others like it: "If you were to have kids in these divided communities play a match soccer against one another, it could either be aggressive and full of fouls due to nationalist rivalry or unifying and sportsmanlike. The same goes for science."<sup>xiii</sup>

Finding neutral ground in science is a chance to learn how to work with others and realize they too are rational people. Once this is established, then the more difficult issues can be examined. Anything is possible, even the best possible outcome, when the starting point is seeing that the other is not dumb, ignorant, or purely wretched. Anything is possible when we realize that we can disagree with others and still find common ground in scientific truths, which I remind you are themselves only temporary. They too will be called into question as we discover more and more about the world.

## LEARNING TO SAY “I DON’T KNOW”

There’s a preliminary step to integrating scientific methods into education, and that is training teachers. I don’t mean educating them in the sciences, although they should have a minimum of science training. I mean developing their ability to say “I don’t know” to students, to make discoveries with the students during experiments, and to come to terms with the fact that cognitive biases can also lead teachers astray.

When it comes to education, certain cognitive biases can be quite terrifying when we consider their impact on a large scale. The Pygmalion effect is one of the most famous. At the beginning of the school year, if you point out a few students to a teacher and tell him these students are really excellent, whether or not it’s true, these students will have shown the most progress by the end of the year.<sup>xiv</sup> The way teachers view their students has a major effect on outcomes. The teacher will hold higher expectations for these students, be warmer to them emotionally, give them more feedback about their work, teach them more extensively, introduce more difficult material, and give them more opportunities to answer and ask questions.<sup>xv</sup>

A more well-known phenomenon is that how students think of themselves is also a cognitive bias. In one experiment, a teacher told students they were all getting the same test when in fact half of the class got an easy test and the rest got an impossible one. The first half passed and the second half failed. This was repeated once more with the same students in the pass and fail groups. It was then repeated a third time, but this time the exer-

cise, a relatively easy one, was the same for everyone. Those who passed totaled only 80 percent, meaning 20 percent failed. The 20 percent who failed were all in the fail group for the initial two tests. When you're used to passing, you have a better chance of passing again. When you're used to failing, you're likely to fail again, and this for "no apparent reason."

It's likely that a significant number of the successes and failures we experienced in education were linked to cognitive biases such as these. Generally speaking, we misunderstand how the brain works. It's still something of a black box for most people.

## I THINK LIKE THEY DO, THEREFORE I AM

Our brains also get tricked by social biases. Social biases are tied to what group we belong to, what ideology we identify with. A study about attitudes toward climate change was carried out in the US, and the purpose was to find out what kinds of people believed global warming was real. I'll take this opportunity to remind everyone that global warming is a scientific truth, based on well-established evidence. Level of education was not a determining factor among those who did not believe in global warming. Politics was the key. Among those with lower levels of education, Republicans and Democrats had the same percentages of people believing as not believing. What's interesting is that as level of education rose, the more Republicans denied climate change and the more Democrats were convinced of it. This is social bias. Individual biases get amplified by the biases of the

group. If you believe that all the members of your group think a certain way, then you'll be partial to reasoning that leads you to the same conclusions as them.

This is what the argumentative theory of reasoning demonstrates, developed by Hugo Mercier and Dan Sperber.<sup>xvi</sup> French psychiatrist Guillaume de Lam erie had this to say about the theory: "It makes the hypothesis that decisions are most often made based on intuition, as reason is used only afterward to justify why a given decision was made. The primary goal of reason is not to improve knowledge, find truth, or make better decisions, but rather to persuade others in debate and undermine those who would try to tell us otherwise."<sup>xvii</sup>

When the Internet is used correctly it can help combat biases, but social media pushes us toward yet another bias: confirmation bias. We tend to select channels of information that confirm what we already believe. When we stumble on a website that challenges what we believe, we're not likely to visit it again. What an immense privilege to be afforded unlimited access to information, yet we don't venture outside what we already believe, confirming the legitimacy of what we think and therefore the legitimacy of who we are. Open-mindedness is an illusion. We only reinforce what we already believe.

The good news is that there's an antidote, even in the case of the American study I described above. There's a small minority of people who don't follow the dominant behaviors in their communities. What do they have in common? Curiosity, that nasty flaw that could be the greatest personality trait of the 21<sup>st</sup> century. Those who are more open to doubt are constantly on the lookout

not to be misled, thus they seek out information that challenges their opinions to perhaps change their minds.

I'll say again that everyone, both children and adults, people with no degrees and those with too many degrees, can have difficulty handling information that startles our brains. A cognitive-science experiment was conducted on psychology students in which the students were shown data that contradicted something that had just been explained to them. Specifically, they were being shown what's called genetic regulation, discovered by André Lwoff, Jacques Monod, and François Jacob, which won them the Nobel Prize in Physiology or Medicine in 1965. The genetic-regulation model was such a profound break with what we knew about genes, it can seem counterintuitive. It's a bit like the rule that throws off so many students when they learn relative numbers: more multiplied by more and less multiplied by less both yield more. Those conducting the study asked the students to try to reason it out aloud. The only ones to figure it out were those whose first reactions were along the lines of, "That's interesting—it's not going the way it should." This was only 10 percent of them. The rest were stuck in the mind-set of "It's not working" and "It doesn't make sense," which kept them from being able to dig deeper.

To show you to what extent it's difficult for us to accept scientific paradigm shifts, Thomas Kuhn, whom I've already mentioned,<sup>xviii</sup> based his findings on another famous experiment carried out by Jerome Bruner and Leo Postman in the late 1940s. If you type "red spade experiment Jerome Bruner Leo Postman"<sup>xix</sup> in a search engine, you can try out the experiment yourself on YouTube before reading on.<sup>xx</sup>

If you didn't do it, I'll explain it. Playing cards are dealt out at a very fast pace, and you have to name each card. Almost no one realizes that something is off when shown the cards at high speed; for example, a 4 of spades will be red and a 3 of hearts will be black. Everyone simply says 4 of hearts and 3 of spades and moves on to the next card. Then the speed slows down, and the more it slows down, the more the participants see the discrepancies. Yet even at a very slow speed, some participants still don't notice the discrepancies, and they get mad when it's pointed out to them. "I've had enough of this!" they say, or "I need to go to the bathroom," "I need a drink of water," "I want to do something else," "This test is dumb," etc.

What these experiments show is that we all have cognitive biases, but some have more than others and are less capable (or totally incapable) of changing perspective when faced with something that does not fit within their preexisting frame of reference. Kuhn used anomalies to prove that even scientists, who are supposed to be open to doubt, have difficulty changing perspective. Most of them think, "This anomaly is useless; it doesn't fit within my paradigm, so I won't spend too much time thinking about it because I have other things to do within the dominant paradigm." And don't get me wrong: A lot of the time they're right not to waste their time with anomalies. Anomalies can arise from statistical or experimental errors and not be worth our time. But if we never investigate them, we'll miss paradigm shifts.

To put it another way, when something doesn't add up, should we automatically think it's merely an exception to the rule and the rule is by no means in question? Or

should we give ourselves the opportunity to look into it further to try to figure out if, by chance, a new rule is emerging?

## SO MANY WHYS

Curiosity is like a muscle: You have to work at building it. Having children and teenagers recite ready-made answers to old questions breaks down their desire to discover new things. Let's encourage them to ask questions. Let's stimulate their curiosity. Then they'll be able to challenge their own beliefs. But we have to start now.

Kids begin asking a lot of questions around age 4, and it's likely that this is closely tied to curiosity. If you've ever had a 4-year-old child or spent time with one, then you know this. What should we do when kids start asking a lot of questions? Should we say, like my son's teacher, that he is asking "too many questions"? An education system that evaluates students based on their ability to answer old questions is missing something, I think, especially since we can find the answers to those old questions on the computer. In the past, it was helpful to know the answers to the questions of the past because the world at any point in history was similar enough to what came before it that the old answers remained relevant. In a world in which everything changes so rapidly, however, and in which computers store all the answers to the old questions, we need to be able to find new answers and ask new questions. If not, we'll miss out on something that's key to understanding and thinking about the transition we're living through.

Certain experiments show children the effects of representation biases and the importance of asking questions. One such experiment was carried out in several schools throughout the world. It took a familiar object to the children—it didn't matter what it was—and asked kids to study it closely. Then the object was taken away, and the kids were asked to draw it from memory. Once their drawings were done, the object was brought back out, and children were asked to comment on the differences between the object and their rendering of the object. Then they were asked to reflect on why there were differences. The children slowly caught on to the idea that it's not easy to remember all the details of an object. They realized also that representation on paper and representation in the brain are two very different things. In essence, the children discovered subjectivity.

They were then asked to look at the differences between each of their drawings. They noticed each one was very different. Why? Again, there were several possible answers. Perhaps it was because they each had a different point of view when drawing the object. Perhaps also it was because the children were influenced by an archetypal model of that object from their home life, and at home the object was different. Again they discovered, perhaps without even realizing it, that the way we look at objects is biased due to both point of view and personal experience. We have to consider also the fact that some are better at drawing than others.

What's most interesting is that Gilda Darlas (another Ashoka Fellow), who designed this experiment and others like it, observed that children who took part in these kinds of exercises were then less violent at recess.

Her interpretation is that when children later disagreed about other things, rather than think the other was dumb or mean, they were able to take into account that the other had a different point of view, a different take, and that through dialogue, they could find ways to work through the disagreement instead of pound on one another.

## THE FABLE OF THE BLIND MEN AND THE ELEPHANT

Gilda's experiment reminds me of a fable that I enjoy telling from the Indian subcontinent.<sup>xxi</sup>

*One sunny day, six blind men from India, all inquisitive men of learning, sought out an elephant in order to learn more about it.*

*The first man touched the elephant's broad, robust flank, and exclaimed, "God help me, the elephant is like a wall!"*

*The second man, feeling the tusk, cried out, "No, no! It's cylindrical, smooth, and pointed! The elephant is like a spear!"*

*The third man approached the animal, took its squirming trunk in his hands, and said, "In my opinion, the elephant is like a snake."*

*The fourth man reached his hand out and patted the huge leg, thereby concluding that the elephant was like a tree.*

*The fifth man stretched out his hand and, happening to grab the elephant by the ear, said, "Even the blindest of the blind would deduce that the elephant is like a fan."*

*The sixth man felt around, seized the swinging tail swatting the air, and recognizing it immediately, he said, "The elephant is like a rope."*

*The six blind men debated passionately at length, each going to every length to try to convince the others that his was the correct interpretation.*

*It seemed they would never agree, when a wiseman who was walking by overheard their argument.*

*“What has you so worked up?” he asked.*

*“We can’t agree on what the elephant looks like!” they said.*

*Each man then stated his argument. The wiseman smiled slightly.*

*“Each of you has told the truth,” the wiseman said. “You each have a different description of the elephant because you each touched a different part of the animal. The elephant indeed has all the traits you describe.”*

*“Ooooooh!” they exclaimed.*

*And the discussion ended there. Each of them was very pleased to have provided a right answer, as each one had found part of the truth.*

This fable applies as much to the children mentioned in the previous experiment as it does to scientists coming from different disciplines who believe that their discipline alone has a monopoly on the truth of a given issue. In fact, we need input from all disciplines.

If you try to understand from a historical perspective the Spanish flu pandemic that struck just as World War I was ending, you’ll see that the outbreak was the result of poor living conditions and mass migrations taking place at the end of the war. If you approach it from the point of view of molecular biology, you’ll know that it was a mutation of the flu virus. In my opinion, these two perspectives complement each other, and if we really want to understand what took place, we need both

perspectives. Each discipline narrows its focus to one part of the reality without seeing the other parts, and they miss the gorilla pounding its chest right in front of their eyes.

Take the example of carbon. We can study it from the point of view of chemistry and try to understand the bonds of a CO<sub>2</sub> molecule. We can take the biological perspective and ask why carbon is essential to life. We can also adopt the perspectives of climate change or energy consumption or even the arts, as there are ways of sculpting with carbon and using carbon to draw. We can even write poems and read novels about carbon and diamonds. Some children may be more interested in one perspective on carbon than another perspective, but it's very likely that in the end, they'll understand it's really all the same thing. They'll see that while its impacts are different depending on different contexts, each discipline offers only one facet, and that some facets aren't the reality but rather convenient ways of representing the reality. In countries such as France, however, each discipline continues to carry on like the blind men in the fable.

I've shared the fable in so many different encounters that, for a symposium in the south of France, creativity consultant Rémi Sabouraud sought out artist Thibault Franc to make a sculpture inspired by it.

It's a sculpture of an elephant made from various assorted objects, including even a few elephants. Also for the symposium, Rémi made a video of me blindfolded and discovering the sculpture for the first time. I felt around all the parts but was completely unable to figure out what the object was made of. The video was

called “*Défense d’y voir*,” which means “no seeing” and in French is pronounced the same way as “ivory tusk.”<sup>xxii</sup> On stage at the symposium, Rémi had six people from the audience do the same thing, thereby playing the six blind men. Since then, I have had more than 100 people do this exercise when they visit the CRI. The funniest of these was when Rob Lue, a personal friend and professor at Harvard, thought he had the answer. “It’s a palm tree!” he shouted. Once the blindfold was off, he came to terms with his limitations, saying, “I truly am a biochemist.” What he meant was that analyzing a purified protein, for example, is only one way of understanding the complexity of life. He then took the exercise to his students, and only one of them understood what fractal nature of the object represented. That student happened to be both a pianist and scientist. While he explored with one hand the smaller constituent parts, with the other he assessed the overall structure. In the end, everyone understands the fable and the need to work together in order to better understand how different perspectives can complement one another.

## GETTING OUT OF YOUR SILO

The way education and research functions at universities in most countries makes biases stronger. Each discipline is stuck within a silo that has little communication with the other silos. This practice is not inherently ridiculous or unproductive; in the past this was essential for scientific progress because it brought together lots of researchers who all knew the same things and worked the same way.

That way of doing things can always help you go far. The problem is that we're never encouraged to leave the silo. To get a job, you have to excel in your discipline, i.e., your silo, and gather a team around you that you get along with, which is the silo within a silo.

In France, secondary school teachers are trained in these same silos, unlike primary school teachers. It's to the point that when you try to get them to think differently, it's very difficult for them. Their angry reactions every time the Ministry of National Education tries to introduce a bit of interdisciplinarity in the curriculum is evidence enough that these silos are heavily reinforced structures. Apart from a few zealots, most teachers aren't against interdisciplinarity in principle, but many of them weren't raised with the opportunity to do experiments at a young age, so they think that interdisciplinarity should exist only in higher education, after the basics in each subject matter have been fully mastered.

The problem with having to master one discipline before you can use it in combination with other disciplines is that this takes a long time. I know this from experience. It was my studies in engineering, math, and physics that got me interested in bacterial evolution, and after I began studying genetics I got interested in evolutionary biology. Up to that point, I hadn't encountered any resistance. It wasn't until I wanted to start studying evolution and ecology that I was told, "No, going from molecular to evolutionary biology is something you can do only toward the end of your career." So you have to win a Nobel Prize in molecular biology before you can start studying evolution? I ignored what they said, convinced that molecular biology and genetics were understandable only from an

evolutionary biology perspective, whereby you see that organic compounds evolve in response to evolutionary challenges. If we're able to discuss with molecular biologists, experts on antibiotics, and evolutionary scientists all at once, much more thorough work can be achieved.

## THERE'S NO AGE REQUIREMENT FOR INTERDISCIPLINARITY

Some countries are less rigid than France in this regard. In the French education system, you choose the general field you want to specialize in at age 15 and continue specialized studies from there. Other countries continue to offer general education in the sciences and humanities through secondary school and into undergraduate studies. I think this is the right approach. There's even something more to be gained by implementing this approach as early as primary school and to develop it further in secondary school. It will help children understand the different facets of an issue, not confuse them. When they create different dots surrounding an issue, they can then connect them to form a truly robust understanding. We have to show them how each discipline works on its own while at the same time make them aware of how complex each one is in combination with the others.

I'm not alone in thinking this way. This is exactly what the countries do that score highest on the PISA (Program for International Student Assessment) test.<sup>xxiii</sup> They are Finland, Canada, South Korea, and Singapore, among others, and they obtain the highest scores in reading, science, and math. They understand that there's no age

requirement for interdisciplinary learning, all while not skimping on the fundamentals, “reading, writing, and arithmetic,” as people say.

Research has shown that an important key to success in education, in no matter what subject, is motivation.<sup>xxiv</sup> Reading, writing, and arithmetic become much more interesting when we’re motivated to understand these subjects and communicate with others about them. To see concrete examples of ways we can implement these interdisciplinary approaches with children, check out the *Savanturiers* website.<sup>xxv</sup> There, you can discover how, inspired by their work with ants, students in Ange Ansour’s classroom composed poems and songs about ants, studied the importance of ants in Australian aboriginal culture, and even learned about ants in English—all while fulfilling to the letter the requirements of the French national curriculum. On the website, you can also read about how Amélie Vacher’s 9-year-old students in the Bordeaux region studied the brain by combining sports and neurobiology.<sup>xxvi</sup> With a ball-passing exercise, they demonstrated how nerve impulses get transmitted across the synapse. There are lots of other examples that show the benefits of what Americans are calling T-shaped learning, the vertical stem of the T symbolizing depth of learning in a field, and the cross stroke of the T symbolizing the ability to collaborate across disciplines.

Throughout the world, communities are getting together to create alternative research environments based in the benefits of collective intelligence and breaking down disciplinary and institutional barriers. If you don’t mind, I would like to share a few of them with you.

## IMPATIENT PATIENTS

Temple Grandin is an American scientist and researcher in animal science. She was born in 1947, and when she was 3 years old, her parents were told that she suffered from irreversible brain tissue damage. They were told she would never be able to read and couldn't do anything productive with her life. What she actually suffered from was difficulties with autism, but very little was known about autism in those days. It was often misdiagnosed and no treatment existed at the time. Temple's own mother had to come up with various solutions that she found to work, and later in her life, Temple would say that her mother figured out on her own the standard autism treatment that doctors use today. It would be Temple herself who would document and analyze her autism the most extensively, however. Take 20 minutes to watch the TED Talk she gave in 2010 called "The World Needs All Kinds of Minds."<sup>xxvii</sup>

Based on her experience with autism, she wrote a book called *Thinking in Pictures*<sup>xxviii</sup> in which she explains how her mind works. Likewise in 2010, a film by Mick Jackson tells Grandin's story performed by Claire Danes. Grandin doesn't believe that all people with autism will become high-level scientists or genius programmers in Silicon Valley. She simply says that autism has a vast spectrum, which means that while some people with autism lack the ability to speak, others will excel in certain fields, namely those in which being detailed-oriented or having intuitive understanding of complex systems are particularly valuable. She also draws important lessons from her experience, lessons which can benefit everyone that touch

namely on the benefits of stimulating children's attention and putting greater emphasis in school on subjects that develop hands-on and artistic skills and not just abstract-thinking skills.

Temple Grandin was a patient...who was impatient. When medical facilities could neither treat her nor take a deeper interest in her condition, she explored her pathology and made groundbreaking advances.

## SOCIAL SCI-ENTREPRENEURS

Sharon Terry is a mother of two patients who likewise were impatient. She told her story in a TED Talk in 2016.<sup>xxix</sup>

Her story begins in 1994, two days before Christmas. Sharon was concerned about rashes she had been noticing on the side of her daughter Elizabeth's neck. Elizabeth was 7 years old then. Sharon took her to see a dermatologist, who looked briefly at the little girl's neck and diagnosed her with pseudoxanthoma elasticum (PXE), a rare genetic disorder that causes vision loss that can result in blindness, as well as many cardiovascular problems. It's a premature-aging disease that causes some to die in their 30s. To top it all off, the dermatologist looked at Sharon's other child, Ian, age 5, and diagnosed him with the disease as well.

Researchers from Boston came to draw blood from the whole family as part of a research project to try to identify the PXE gene. A few days later, researchers from a second medical center in New York came asking for blood samples as well, and this surprised Sharon. She

told the researchers to share samples with the Boston research team. The researchers from New York laughed. That's when she realized a sad fact in research, which isn't limited to biomedical research: Teams of researchers work in competition with one another. It lit a fire under her and her husband, who decided they were going to change the rules of the research game.

What does research on PXE need to advance? DNA and clinical data. So, she and her husband created a nonprofit organization that collected blood samples and medical histories and made these available to scientists for no cost on the condition that they share their findings. Realizing this wouldn't take research far enough, they borrowed bench space at a lab at Harvard and learned how to extract DNA. After a few years they found the PXE gene, created a diagnostic test, organized a research consortium, and carried out studies. They joined forces with the Genetic Alliance, a network of advocacy groups and research organizations that build resources for research on all diseases, not just PXE.

This is just one of many successful examples of citizen science. Sharon and her husband, despite their lack of initial training in biology, were able to generate advances in science by breaking down barriers that were thought to be impenetrable. She speaks about then President Barack Obama's championing of citizen and open science at the time. Obama was a staunch advocate of such initiatives, holding ceremonies at the White House for distinguished individuals and organizations who promoted open science. Sharon Terry is the perfect example of a social entrepreneur of science, or a "social sci-entrepreneur."

And she's not the first. The French Muscular Dystrophy Association (AFM), famous in France for its annual telethon, was created in 1958 by Yolaine de Kepper, mother of seven children, four of whom were boys with Duchenne muscular dystrophy. In 1987, Bernard Barataud and Pierre Birambeau, also parents of children who suffered from muscular dystrophy, got French public television to help the AFM put on a national telethon, a fund-raising practice started in the US in 1966. Thanks to this annual telethon, the AFM runs one of the world's largest facilities for developing gene-therapy products for rare diseases, and it funds the four laboratories included in the Biotherapies Institute, a world leader in research. It took nearly half a century for the AFM to get to where it is, but today, thanks to technology and open science, we can now create robust citizen-science ecosystems in the span of a few years.

## SERIOUS GAMES

Foldit is what's called a serious game. Serious games help people, myself included, understand the new path of education in the 21<sup>st</sup> century.

This particular game was born out of an interdisciplinary encounter at the University of Washington, in Seattle. It was between biochemist and protein expert David Baker and computer-graphics and game-design expert Zoran Popović. Were these two in France, it would have been hard for them to meet, as games are not taken seriously in France, or rather, where games are taken seriously in France, you're not likely to run into biologists there.

At the time, David Baker was interested in digitally modelling proteins, which is difficult to do and requires a lot of computing power. His first idea was to borrow computing power like SETI@home, a network of Internet-connected computers that collects and analyzes radio-telescope data. People who participate in the network leave the SETI@home program running on their computer while the computer is not being used, and this provides a massive computing-power network.

David Baker used the SETI@home network, changing the name of his software to Rosetta@home. Its function was to perform trillions of calculations in order to predict the shapes of folding proteins. A few participants Rosetta@home network were curious about the program as they watched it working on their computer screens. They wrote to Baker, telling him that they thought his algorithm could run more optimally and that they wanted to help guide it. So Baker went around talking to people, trying to find ways to make the network more interactive. A friend put him in touch with Popović, who helped Baker turn the network into a multiplayer online game. Thus Foldit was born.

To train players, they have them predict protein structures that are already known to science. This helps players gain an understanding of the nature of these structures for them to develop a solid working knowledge of the rules of protein folding. Over time, the game will begin introducing folding problems that science has yet to solve, and usually from there players get sucked in. It's not just learning about protein folding that players love. The game adapts to the players, figuring out how to present problems to them in ways that kept them interested and

thus helps them get better. There's another reason why it developed the following it has: Playing the game has a bigger purpose. Predicting protein structures contributes to research in medicine. For example, players figured the structure of an enzyme involved in the reproduction of HIV. The hundreds of thousands of Foldit players<sup>xxx</sup> together possess a collective problem-solving power that surpasses both the automated software and the scientists designing the software. And the scientists who design the technology must in some small way be victim to cognitive biases, as they're typically worse at the game than the non-scientists. The non-scientists are able to think outside the box, a box they didn't even know existed.

The game is constantly being improved. By collecting data on player performance, the developers found that some players are better at the start of the game, others in the middle, and others toward the end. Based on this finding, they made it so that teams could be generated automatically based on skill sets, and they also found ways to let players automate their approaches. In 2010, an article was published in the science journal *Nature*, and among the listed authors of the articles are ">57,000 Foldit players," recognizing their contributions through their play.

## IN FAVOR OF PARTICIPATORY SCIENCE AND CITIZEN SCIENCE

The Genetic Alliance, AFM, Foldit—you can say that these examples aren't fundamentally changing how things work, that participatory and citizen sciences

are exceptions to the rule, and that the fundamentals of knowledge continue to be produced by traditional institutions. My feeling is that the many examples are too numerous to consider them anomalies and that we can head toward a new perspective. Digitalization is bringing about a paradigm shift, and it's making us rethink everything. One of the best Foldit players is a child, and another—you can't make this up—is a secretary at a research lab!

I'm very happy to find that some of the larger institutions are starting to incorporate some these methods in their research projects. Every year, the Inserm trains hundreds of patients and family members of patients to help them develop of new treatment protocols. Since 2012, the Institut Curie has supported the *Seintinelles*<sup>xxxii</sup> (“breast-cancer fighters”), a cancer-research initiative that's not restricted to investigating breast cancer, cofounded by French surgeon Fabien Reyrol and breast-cancer survivor Guillemette Jacob. The group's goal is to speed up cancer research using digital means to recruit study volunteers, and rather than run clinical trials, they want to hear stories, be it of surviving cancer or caring for a loved one affected by cancer. Their research is thus sociological as well as biological and epidemiological.

If you are in France and would like to participate in what the *Seintinelles* are doing, you can visit any one of the sites they operate out of, for example La Paillasse<sup>xxxiii</sup> (“the lab bench”), which is one of the largest open-community labs in the world. The lab was cofounded by Thomas Landrain, a CRI alumnus who was a member of that first synthetic-biology team to take home a prize at MIT's iGEM. At the lab, you can learn how to extract

your own DNA—which today is child’s play really—and perhaps be inspired to go even further.

Other games allow us to push advances in sciences and can be used as much for contributing positively to change as for helping young people acquire life skills and knowledge. Games for Change<sup>xxxxiii</sup> was founded in 2004 and seeks to empower game creators throughout the world to design games that have a real-life impact. As we talked about previously, movies get us to empathize with someone else by placing us in the skin of a character, changing the way we look at the world as we live through that character’s experiences. Games go even further because they make you a player rather than a spectator. You’re made to live through the various game scenarios, be it as yourself or as another character. In games we further develop the essential skill that I keep stressing, i.e., being able to see things from someone else’s perspective, keeping us from being prejudiced and seeking more creative solutions than those that reinforce our own biases, be they cognitive, social, moral, etc.

## COMPETENCE WITHOUT ETHICS IS ONLY RUIN OF THE SOUL

Games can also force us in often striking way to ask questions about the ethics of our actions. Why should we keep improving on things? What’s the meaning of progress? I remember a game I discovered through Games for Change in which players had to improve a railway network. When they reached the finish line of the game, it was then revealed to them that the railway

network they had worked to improve was taking Jews to Auschwitz. There are few ways as striking and unforgettable as that to show you that before we act, we should think about the ultimate aim of what we do and what the consequences will be. Competence without ethics is only ruin of the soul.

Katie Salen founded a secondary school in New York City called Quest to Learn where curricula are centered entirely around games. Curriculum designers partner with game designers to develop lessons. I sat in on a middle-school-level introduction to genetics class. They didn't use the typical method of using blue eyes or brown eyes to explain variation and how genes get passed on. Instead, they played a game in which students built monsters as a way to look at how a phenotype from a recessive gene can skip one or several generations.

The first generation of monsters had a certain number of genetically inherited traits, e.g., running faster or being a tougher fighter, coded in dominant and recessive alleles (the kids used all the correct genetics terminology, only in the context of a game). From each successive generation of monsters, the kids had to pick which monsters would reproduce, i.e., the faster runners or the tougher fighters. The kids were also asked at the end of each class what ideas they had to help improve the game. The purpose of this was not only to make the game more fun but also to get the students to think about all the different aspects of the game, which was a way to help them think more systematically.

Students from Quest to Learn won the math competition at the New York City Olympiad Tournament, which is all the more remarkable considering that most of the

students came from low-income backgrounds. It's worth noting that they did particularly well on sections that required teamwork.

If you're worried that your children play too many games, read Katie Salen's book *Quest to Learn: Growing the School for Digital Kids* or Peter Gray's book *Free to Learn*<sup>xxxiv</sup>. Peter Gray is a researcher in psychology who was curious about how his son's chances of success may vary due to the fact that he was enrolled in an alternative school where students from ages 4 to 18 choose their own activities. He compiled a lot of anthropological and ethological evidence showing how young mammals and humans develop numerous skills through unsupervised game-playing. His conclusion was that, for our ancestors, the most important things to learn were learned in informal settings where kids of different ages and skill levels learned together in total freedom. He also looked at the success of alumni of democratic schools where children and adults make decisions together. He showed that students from these schools did better in college and excelled in their jobs because they matched their interests. By learning through games and hands-on activities, they could explore their interests and develop the ability to learn from others. This is what our ancestors did before formalized education, and kids in these schools appear to learn all the skills necessary to lead successful lives as adults of today.

In *Free to Learn*, Peter Gray encourages children's freedom to pursue their own interests through games, showing that they do acquire all the knowledge and skills they need, but do so with more energy and passion than traditional students. To help children grow in this

constantly changing world, we have to trust their ability to teach themselves and undertake their own self-development. Basing his ideas in psychological and historical anthropological research, Gray argues that play in total freedom is the best way for kids to learn to manage their lives, resolve problems, live in their community, and be emotionally stable.

If you're someone who excels in a game that draws on working in teams and thinking systematically, always remember to put it on your CV. Job recruiters talk about hiring certain candidates because they were top players in *World of Warcraft*. Their reasoning is that, if the candidate has experience managing a team online, she's very likely capable of doing so in real life, as work teams interact more and more online.

Let me just be clear about one thing though: I don't believe all schools should resemble Quest to Learn and democratic schools.

## TO FLOW OR NOT TO FLOW

The reason why it can be difficult to understand all this, and get others to understand it as well, is because the benefits of so-called informal learning haven't been sufficiently studied and because any learning implies a stage of awareness. It's not enough that I simply learned or understood something. I must also be aware of it, especially if I plan on implementing that knowledge or skill in the future. In order for a game to teach me the basics of genetics from a made-up example—monsters and dragons, etc.—I first have to believe that I can learn through games,

i.e., that the genetics of mice and humans are based on the same principles.

Along with their teachers, kids have to convince their parents and friends as well that these methods can work. Yet there are so many people who believe that if education isn't in some way boring or even painful, then something's missing. This belief is as common as it is false. Scientific research shows that we never learn better than when we feel motivated and enjoy what we're doing.

Hungarian psychologist Mihaly Csikszentmihalyi interviewed hundreds of successful people in various lines of work, namely in the arts and sciences, in an effort to find out what it took for them to be at their most creative and productive. Everyone described the same phenomenon at work, which was almost like a state of mind. It's when they stop feeling hungry or tired, no longer feel like they are "working" with all the constraints that come with work, and they even forget they're working altogether. At its best, this phenomenon feels like a moment of ecstasy that they're not necessarily aware is taking place. In fact they feel as if they didn't even exist anymore. Mihaly called this state a flow experience,<sup>xxxv</sup> and according to him, this is the state in which we learn the best.

Flow is typically a state in which we forget about ourselves when we're doing something we enjoy, namely playing. Anyone who has tried to get the attention of a child—or if you yourself have been or continue to be this child—who is completely engrossed in a particularly enthralling game. Reading a novel or watching a movie can also move you into flow. Teaching as well, if you have the right personality for it, can get you in flow, that is until that bell so unnecessarily interrupts your

flow. A slight tangent on that point: There's no biological or man-made law that requires classes to last one hour. Studies on attention span say that classes that involve passive listening should be much shorter, and classes that involve something particularly enthralling should have no predetermined length at all. The hour-long class is something we inherited from an age when the day was divided up by prayer times and when we had only clock towers to tell us the time.

This is why some teaching methods that try to get students into flow start by reforming the class schedule in order to do away with the counterproductive system that's so common. While it is after all necessary to implement a bit of organization, these programs find a middle ground where the day is divided up into more optimal time slots. If we shortened lessons to 45 minutes, we'd have 15 minutes left over at the end of the lesson, time when our attentional resources are greatly reduced anyway. Those 15 minutes can be carried over to the end of the day, week, or quarter to be used in ways that optimize students' ability to get into flow, e.g., developing their own projects.

## THE TEACHER-RESEARCHER

Whether it's Finland, Canada, or certain countries in Asia, the countries adopting these approaches all have one thing in common: They have invested heavily both in education research and teacher training and have even combined the two.

Research is a record of reality. It gives us facts. Once I gain awareness of the fact that stress has a negative effect

on learning and I measure the impact of that effect, I'll then take more care to create a classroom environment that eases stress. Once I gain an understanding of the brain mechanism responsible for consolidating memory during sleep, I can better explain to children (and parents!) why it's so important not to go to bed late and avoid stimulating activities right before bed.

I'll share an example from a symposium at the Collège de France, France's free, no-enrollment, no-degrees higher-education institution based in Paris. Mélanie Strauss, a neurologist who got her PhD at the CRI, gave a lecture on the benefits of napping in children ages 3 to 6.<sup>xxxvi</sup>

She discussed an experiment published in the science journal *Proceedings of the National Academy of Sciences* that measured these benefits<sup>xxxvii</sup>. Specifically, researchers measured the accuracy of children's recall of how to perform a visuospatial task depending on whether they had napped and how long after the nap. Recall was tested immediately after they were taught to perform the task, later in the day after some children took naps while others didn't, and then the following day. The difference the following day was up to 20 percent, which should lead us to conclude that midday naps are very important.

The contrast is just as stark for teenagers. Adolescence is another crucial development phase in which our neural circuitry needs lots of sleep for optimal brain function.

These data are very important and transcend the usual heated debates in France and elsewhere about school curricula and teaching methods. Whatever your style of teaching is, biological laws will get the best of your students, and this will impact how effective your teaching is.

The other benefit of combining education research and teacher training is that teachers learn the scientific process. They're encouraged to think of themselves as education researchers in the classroom and to evaluate their teaching practices. Ideally, this will inspire teachers to enter into dialogue with their colleagues in order to discuss the latest in education research. This is actually already happening in many schools around the world. In a similar vein, it motivates teachers to attend education symposia, just like professional researchers whose job it is to try to test their theories against scientific doubt.

## THE SINGAPORE METHOD

This method is beneficial at every level of education. We can take inspiration from a model used in the English-speaking world called Scholarship of Teaching and Learning (SoTL). With SoTL, teachers gain professional recognition for not only creating and sharing valuable research resources for the education community but also developing real improvements in their classrooms with students achieving higher rates of success.

These are the principles at the heart of Singapore's incredible education system. The Singapore method has been explained incorrectly by some in public discourse, so I would here like to set the record straight. The success of Singapore's education system isn't just based on the connection it establishes between theory (I learn a rule) and practice (I solve a problem using the rule). The real secret of the Singapore method is that since the 1980s,

the country has made education research the focus of the teaching profession.

It's almost hard to believe, but two-thirds of schools in Singapore have teaching and learning centers in-house that help teachers examine the effectiveness of their methods and work with other teachers to solve problems and learn from one another. The Singapore method is a lot of trial and error, observation, and adjustment. There is no prominent educator, all-powerful minister, or luminary education researcher dictating instructions from the top to be implemented down the chain of command. Singapore has created a system in which teachers improve their methods themselves and then share these innovations with colleagues.

## ACTION-RESEARCH

Japan has developed a similar approach called Lesson Study (*kenkyu jugyo*) in which a school's teachers, often accompanied by researchers, will study, plan, teach, observe, revise, and share lessons in various curriculum areas.<sup>xxxviii</sup> There's an initial test phase in which teachers sit in on their colleagues' lessons, not to observe them so much as to observe how their students do in the lessons. Usually each teacher will observe a specific student or group of students and to try to identify what happens for them when they finally understand a lesson or, to the contrary, what goes wrong when they feel they don't understand. Teachers then meet to share their observations in an uncritical dialogue that's open to the trial-and-

error process. Little by little, they put together the lessons in a given subject that fit the needs of their school.

This approach is similar to what American social psychologist Kurt Lewin in the 1940s called action-research, which has seen renewed interest over the years. In Lewin's own words, action-research is "a comparative research on the conditions and effects of various forms of social action, and research leading to social action[, as research] that produces nothing but books will not suffice."<sup>xxxix</sup> It's not enough simply to base teacher training on research findings, although this practice is all too uncommon in its own right. Teachers also need to be trained in research methods and get introduced to the differences between methods, e.g., that research methods in sociology are different from those in cognitive science or computer science.

Once we're able to adopt the mind-set of a researcher, we'll likely carry out experiments with our classes all the time, establishing control groups, observing, quantifying, comparing, etc. Teachers should have the ability to adopt an approach that's not just self-reflexive but critical of their own methods, and teacher training should focus on developing this ability. Then when teachers are faced with students who are having difficulty with a lesson, they're less likely to fall back on a one-size-fits-all solution that in terms of sheer probability is not likely to be very effective. While it is partially true that, as a French expression goes, "education is turning repetition into a form of art," lessons shouldn't be repeated identically in every context.

1%

Without the necessary resources allocated to education, implementing these approaches is unrealistic. We would need more extensive teacher training and more time, both in classes and schools. This is what Singapore understood so well when it made the decision to invest more in education research. And yet education in most countries is one of the few major sectors in which there's not enough investment in research and development, while in the other sectors promising the jobs of the future we invest heavily in R&D. If countries were to invest only 1 percent of their education budget in research and development, education would be revolutionized within a few years. It is my firm belief that research and development in education would have a much clearer impact on quality of education than if we were to, for example, reduce class sizes by 1 percent, which is a widely discussed measure.

## TAKING CHILDREN SERIOUSLY

Why aren't education-research approaches more widespread in schools? I think one of the primary reasons is that we don't take children seriously. And that's a mistake.

When my daughter was 8 years old, she placed a book in my hands one day and said very earnestly, "You're going to love this." It was the life of Louis Braille told by Margaret Davidson in *Louis Braille: The Boy Who Invented Books for the Blind*.<sup>x1</sup> And my daughter was right. I loved it. If you're not aware of who Louis Braille is, you've at least heard of braille, the tactile writing system

he invented, which millions of visually impaired people today use throughout the world. He invented the system when he was a teenager.

He was born with sight but blinded himself at age 3 playing with an awl in his father's harness workshop. His parents wanted him nevertheless to have an education and were able to get him into the Royal Institute for the Blind, in Paris. Other tactile systems for reading were already in existence, but the most common one was not very useful. It was easy enough to read but you couldn't write in it, as the alphabet could be printed by machine only. Another system existed that was a cryptography used in the military, but it was not very efficient. Besides, why would young Louis, hungry for books, have any interest in reading about moving three cannons here, five there, etc. At the age of 12 he started work on the system that would make him famous. His system consisted of cells of up to six raised dots in two parallel rows, making for 64 different possible combinations. The free-spirited and avid learner he was, he completed his school's curriculum and was asked to stay on as a teacher's aide. Eventually he was made a teacher and taught a diverse array subjects: grammar, history, geography, math, and music!

Nonetheless, Louis's writing system was initially met with hostility by school administrators. They felt that if children spent time learning his new system, they wouldn't learn the standard alphabet they used and would thus lack the skills necessary for the outside world. Louis shared his invention with his peers at night in the dormitories, and they loved it. Even after teachers began seeing children using Louis's system, they remained doubtful as to whether the children really

could read with it or, since blind children often have an excellent memory, whether they had already known the books by heart. A public demonstration was eventually held. Adults chose a book at random, encoded it using braille, and gave it to the children to read. The children could read it perfectly.

It would take another decade for Charles Barbier, the inventor of the military cryptography, to acknowledge not the superiority of braille—that would have been too much to ask—but its practicality. In an address given in 1833, Barbier commended the reduced size of Louis's symbols and his writing system based on the use of a slate and stylus, saying for these innovations Louis was owed a debt of gratitude.<sup>xli</sup>

Forty-seven years later, Helen Keller was born in the US. At the age of 2, she was afflicted with an illness that left her blind and deaf, thus she would have more difficulties than most children combatting her isolation. She was unable to communicate with others except through touch. Her parents eventually came across Anne Sullivan, someone who would be an extraordinary teacher for Helen and who was herself visually impaired. With extraordinary patience, Anne Sullivan got Helen to realize that she could in fact communicate with others. She had Helen touch water, then she traced the word *water* in Helen's palm. This is when everything opened up for the little girl. Until then she had been a difficult child, but she suddenly became well-behaved with an enormous appetite for knowledge. She learned braille and sign language and became the first deafblind person to earn a Bachelor of Arts degree. Later in life she would become a public speaker and an activist for socialism,

feminism, and pacifism. She told her story in her autobiography *The Story of My Life*,<sup>xlii</sup> which became the inspiration for the 1962 film *The Miracle Worker* directed by Arthur Penn. If you have children, I highly recommend having them read another of Margaret Davidson's biographies, simply titled *Helen Keller*.<sup>xliii</sup>

The legacies of Louis Braille and Helen Keller united in 1952 at the centennial of Louis Braille's death. The French government decided to honor him by moving his remains for burial in the Panthéon joining the great men. For the occasion, Helen Keller was invited to Paris to be made Chevalier of the French Legion of Honor. She gave a moving speech, which she wrote in French, at the Sorbonne, and in it she stated that the blind are as indebted to Louis Braille as the human race is to Gutenberg. One quote from her has always stuck with me: "The only thing worse than being blind is having sight and no vision." There's a video<sup>xliv</sup> of some of her speech as well as of the hundreds of blind people who processed arm-in-arm through Paris following Louis Braille's remains to the Panthéon.

## CONFIDENCE AND TRANSMISSION

The stories of Louis Braille and Helen Keller, who are both in my personal pantheon, contain morals that, in my opinion, should be at the foundations of the education system. We should have confidence in our children's abilities to find ways to pursue their own interests. We should believe that they can be taught, even when everything seems like a lost cause. And lastly, we should

ensure that the discoveries of one generation are passed on to the next.

You find very similar morals in the story of Babar Ali. His is a story I first read about in a BBC article in 2009. The article dubbed him “the youngest headmaster in the world,”<sup>xlv</sup> as at the time he was only 16 years old and seven years prior he had begun giving classes in his backyard for kids in his neighborhood.

He came from a middle-class background and could afford to go to school. His neighbors, on the other hand, didn’t have the \$40 per year necessary to pay for school in that part of Bengal. So every day after school, Babar taught them what he learned and did that day. Not only did the children keep coming back every day, but they brought their friends, too. Babar’s parents saw no problem with letting their son transform their backyard into a school. Some of the first students he had would later go on to start their own schools. When the BBC filmed him seven years later, he had 800 students!

In a way, Babar Ali and his friends gave new life to a system that was relatively popular in the 19<sup>th</sup> century called the monitorial system. In the very first public schools in the 19<sup>th</sup> century, it was not uncommon for one teacher to have hundreds of students. The schools implemented a pyramid structure for mentoring. As soon as one student understood something, that student would then transmit that knowledge to other students, who would transmit it to others, and so on and so forth. It’s a method that’s at least as effective as our traditional education methods. It certainly doesn’t instill in students the same respect for authority that traditional education does. In a few cases, some monitorial systems became

breeding grounds for seditious and revolutionary ideas. Since most nations back then valued respect for authority over the most quality education method, they turned away from that system, even though it works wonders. As proof, today Babar Ali is invited all over the world to share his experience, and we even invited him to the CRI. He attended a conference of ours in which children were the only ones on stage explaining to us what it is to learn in the 21<sup>st</sup> century.

Today, digitalization and social media are making it possible for hundreds of Babar Ali's to step forward all over the world in all different kinds of contexts.

In the US, Sylvia Todd is one them. She has a show, *Super Sylvia's Super-Awesome Show*,<sup>xlvi</sup> and it's outstanding. When she was 6 years old, she and her father went to the Maker Faire Bay Area, a festival for DIYers ("do-it-yourselfers") and beloved by the hundreds of makers who flock to it every year. For those who don't know, makers are people who, with only their hands and a bit of help from 3-D printers, make objects, reconfigure and improve objects, or invent whole new objects.

Returning to the Maker Faire for the third time, Sylvia began filming her YouTube show. "Me and my dad just wanted to do something fun," she says in her TEDx Talk.<sup>xlvii</sup> As an aside, her father was a school dropout who became a programmer. At just 8 years old, Sylvia was handing out business cards to spread the word about her show. It was the beginning of what would become a soaring success that would get her on stage at several TEDx Talks.<sup>xlviii</sup> By the time she was 12, her videos had been watched by nearly 2 million people. Every video ends with the same line, a kind of mantra: "Go out there and make something!"

The Obama administration, which also advocated for makers,<sup>xlix</sup> eventually heard about her. She was invited to the White House Science Fair,<sup>l</sup> where she presented to the president a watercolor painting made by a robot she created.

One of the inventions she's most proud of is a pendant that changes color based on the heart rate of the person wearing it. Making it required a good deal of knowledge about the physiology of the heart, technology, and art. She's another example of a child who learned how to do pretty extraordinary things and share what she learned to help others learn.

"TRUST US AND EXPECT MORE FROM US!"

Again in the US, Adora Svitak, born in 1997 in Springfield, Oregon, learned to write at age 4, and at the age of 6 her mother got her a computer with a word processor. By the age of 8 she had written 300 stories on it, and she decided she wanted to get published. Her first book, *Flying Fingers*,<sup>li</sup> contains a few of these stories with advice for young writers. With the help of her sister Adrianna, she wrote a follow-up to the first book called *Dancing Fingers*<sup>lii</sup> that was published in 2008. And so, by the age of 11, she was one of the youngest writers in history. Three years later she became the youngest person to give a TED Talk, titled "What Adults Can Learn From Kids."<sup>liii</sup> With her dry sense of humor, she makes the case that adults should listen more to children because unlike them, children still dream about a perfect world, undeterred as they are by the weight of humanity's past failures. "We love challenges, but when

expectations are low, trust me, we will sink to them.... Trust us and expect more from us.” At the age of 16, she was accepted to the University of California, Berkeley.

Crossing the northern border of the US into Canada, we meet Craig Kielburger. Born in 1982 in Thornhill, Ontario, Craig read about the murder of a Pakistani boy named Iqbal Masih, 12 years old, the same age as Craig at the time. Iqbal had been a slave in a textile factory since the age of 4 and was assassinated for being an outspoken activist against child labor.<sup>liv</sup>

Craig was devastated by Iqbal’s tragic death and decided to act. He began by asking permission to raise awareness about child labor at his school. He founded a group with 11 of his friends called the Twelve Twelve-Year-Olds, which later became Kids Can Free the Children. The charity continued to grow, eventually shortening the name to Free the Children, and their first major action was getting 3,000 signatures for a petition that was sent the prime minister of India calling for child-labor activist Kailash Satyarthi to be released from prison. At age 16, Craig published his book *Free the Children: A Young Man Fights Against Child Labor and Proves That Children Can Change the World*.<sup>lv</sup> Free the Children is now called the WE Charity and has lifted one million people out of poverty in 20 years. Craig Kielburger has received just about every humanitarian award imaginable for the fight he has led.

When we hear so many stories of young people taking action, common sense would tell us that these are no longer exceptions to the rule. I think these young people are the sign of a paradigm shift, one we should follow as we redesign the education environment for the 21<sup>st</sup> century.

Of course, children didn't wait until the 21<sup>st</sup> century to dream big dreams and fight to make them a reality against all odds. It's the Internet that has changed everything. Now the barriers to knowledge have been taken away, and knowledge can go anywhere in the world. This is the new paradigm. In it we have to draw on children's curiosity, enthusiasm, and generosity, much more so than we did in the past.

## UNLEASHING CHILDREN'S CREATIVE POTENTIAL

I'll share three modern-day examples of education programs that have had an impact on thousands of kids and that demonstrate the power kids can harness with just a little bit of direction from adults.

The first started in Venezuela, known as *El Sistema*<sup>lv</sup> ("the system"). It all started in 1975 in the garage of the late economist and pianist José Antonio Abreu. He began offering music training to children from poor families. His goal was not to turn them into virtuoso musicians, but rather to teach them to listen to one another, which is one of the greatest gifts that playing music has to impart. As many musicians say, you can't go to the beat of your own drum. You can't play too loud when the rest of the band is playing quietly, or vice versa, and you can't suddenly change tempo in a song. A band is in its very essence a school for listening.

More than 40 years later, *El Sistema* has provided music training to 400,000 children from underprivileged backgrounds, and some world-renowned musicians have come from the program, namely Gustavo Dudamel, who has

been music director for some of the most prestigious orchestras in the world. And the *El Sistema* program has spread all over the world, with teaching locations on every continent.<sup>lvii</sup>

Any way you look at it, *El Sistema's* results are overwhelmingly positive. Many of the children have found in music an activity in which there's no limit to their growth. They gain self-confidence and develop healthy relationships with themselves and others. Students even find ways to convert their music skills into learning skills at school. For example, they realize working with fractions is the same thing as dividing quarter notes into eighth and sixteenth notes. This first example is of a movement that draws on children's limitless desire to learn despite the difficult environment in which they may be growing up.

The second example comes from India, specifically from the Riverside School in Ahmedabad. The school was founded in 2001 by Kiran Bir Sethi on the principle notion that the best way to learn is through action, and the best way to inspire people to take action is to get them to improve their immediate surroundings.

The school has kids follow four steps. The first is to identify a problem that affected them personally; second, think of a solution; third, test the solution; fourth, write down observations to then share. Each step draws on essential skills. In the first step, empathy; second, creativity; third, action; fourth, sharing.

This education method draws on design thinking, a collaborative creativity approach used in the world of design. Kiran tested her unique curriculum first with the 200 students at Riverside School but was soon bringing her empowerment thinking to the 30,000 children of

Ahmedabad by convincing the city to organize a children's day once every two months. The busiest streets in the city get blocked off, and kids and teenagers fill the streets to play and create. It was during one of these festivals that Ahmedabad created the first child-friendly street crossing in the world. To mark the street crossing, kids got to paint big, colorful flowers on the pavement to make drivers aware that children were present, no doubt more effective than simple white lines.

Two years later, Kiran Bir Sethi would bring her education to 100,000 children throughout India. The kids from Riverside wrote to 32,000 schools, challenging students to identify a problem that affected them personally, told them to pick a week to dedicate to finding a solution, and then implement it. One-hundred thousand children answered their call. They started literacy classes for their parents, found ways to eradicate plastic-bag pollution, launched a campaign against child prostitution, and created fundraisers to buy hearing aids, among other great ideas.

“BE THE CHANGE THAT YOU WISH TO SEE IN THE WORLD”

In her TED Talk, Kiran Bir Sethi says that contagiousness is a good thing.<sup>lviii</sup> She says we need to spread the “I can” virus, and to do just that, she created an initiative that goes far beyond the Riverside School. It's called Design for Change, a program to help kids develop 21<sup>st</sup>-century skills through design thinking, and it has chapters all over the world,<sup>lix</sup> including one in France

called *Batisseurs de Possibles* (“builders of possibility”), run by Florence Rizzo.<sup>lx</sup> If this all sounds to you like a nice idea but perhaps a bit cumbersome and a hindrance to academic learning, I would like to point out that the Riverside School is ranked among the top 10 in India with regard to scores in math, English, and the sciences.

There’s no age requirement for getting involved in programs like this. The *Batisseurs de Possibles* even awarded an honor to a project done by 4-year-olds at the Saint-Joseph de Yaoundé school in Cameroon. The problem these children had identified was that one of them had been seriously injured in the eye while playing soccer with a plastic bottle—the school could not afford an actual soccer ball to play with at recess. A possible solution could have been banning soccer at recess, but with children in Cameroon that’s not very realistic. Instead, they decided to make balls out of recycled plastic. And if you think that sounds easy, it’s not. They had to collect plastic bags and learn a lot of complex science to find ways to get the bags to stick together to form the ball.

My third example is that of the website of the World’s Largest Lesson,<sup>lxi</sup> started by Project Everyone and supported by UNESCO and UNICEF. The website lists the United Nations’ 17 global goals for sustainable development to eradicate poverty, protect the planet, and guarantee prosperity for all.<sup>lxii</sup> They are:

1. No Poverty
2. Zero Hunger
3. Good Health and Well-Being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation

7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation, and Infrastructure
10. Reduced Inequality
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace and Justice Strong Institutions
17. Partnerships to Achieve the Goal

To tackle each goal, the World's Largest Lesson offers multimedia education resources in nearly 40 languages for both children and adults.

Just picture fusing this awareness-raising project with a program like Design for Change, which tries to highlight the fact that global issues all manifest themselves at the local level. You could put millions of minds and imaginations to work throughout the world to solve these major problems.

This is very similar to the method used by scientists to tackle problems. To me, there's no difference between kids doing research to find solutions to problems in their immediate environment and children being researchers, period. But here again, it's the reductionist view that adults tend to have toward children that stands in the way. We should listen to children, provide a space for them in which they're free to learn and develop, where they can explore issues that affect them, ask questions about things they're interested in, find answers to these questions while learning at the same time, and perhaps

even make an impact on the world along the way. And all this without any pressure from adults. Then anything would be possible.

## WHEN CHILDREN SEARCH—AND FIND

This is what French-British astrophysicist Rodrigo Ibata did. He works at the Strasbourg Astronomical Observatory, in Strasbourg, France, as well as at France's center for scientific research, the CNRS. Rodrigo let his son Neil, then 15 years old, work with data the Observatory had gathered on the satellite galaxies surrounding the galaxy Andromeda, the nearest galaxy to our own. Scientists at the Observatory had been trying unsuccessfully to find the logic behind the configuration of these galaxies. So they concluded that the galaxies were independent of one another. On the Saturday afternoon before Neil started school again, his dad asked him to develop a computer program that could help him visualize the galaxies' positions and rotation speeds. At first, he was just applying knowledge that his dad had taught him, but by the next night, he had found an answer to the problem by using vectors he had studied in math class. Neil's dad had been guiding Neil along during the two days Neil spent on the computer program. They eventually both noticed that the satellite galaxies were in fact rotating around Andromeda.<sup>lxiii</sup> Neil coauthored an article with his father that was published in *Nature*. The CNRS formally recognized Neil's contribution to their research, stating that it was he who was the first to

prove the rotation of a disk of satellite galaxies around Andromeda.<sup>lxiv</sup>

So discoveries can be collective, too.

Beau Lotto is a neuroscientist and a parent. Like a lot of parents, he agreed to participate in career day at his son Michael's school, Blackawton Primary School, in Devon, England. When Beau asked the children if they liked science, their response was, "kind of." Beau said to them, perhaps you haven't been told this yet, but science is actually a game—the point of science is to understand what game nature is playing. He talked to them about his work with bumblebees and how he was convinced that bumblebees play tons of games. He asked them what games they thought bumblebees played and what were the kinds of questions one should ask to find that out. The children were enthralled. What if bumblebees can think? How do they adapt? According to Beau, five of the fifteen questions that the kids came up with on the spot were questions scientists were trying answer in science journals. It's proof that kids aren't as naive as one might think.

The children under Beau's supervision came up with a design for an experiment that would answer their questions. It was already known that bumblebees recognize colors, but could they recognize patterns? The children conducted their experiment, analyzed the results, and showed that in fact bumblebees do recognize patterns. They then wrote an article that was published in *Biology Letters*, the biology journal of the British Royal Society, the world's oldest science academy. The children coauthored the article with Beau.<sup>lxv</sup> The last sentence of the article is fantastic: "Science is cool and fun because you get to do stuff that no one has ever done before."

## WE NEVER SEE WHAT'S THERE; WE ONLY EVER SEE WHAT WAS USEFUL TO SEE IN THE PAST

Two years later, Beau did a TED Talk called “Science Is for Everyone, Kids Included” alongside one of his students from Blackawton, Amy O’Toole. By then she was 12 years old.<sup>lxvi</sup> The talk begins with a funny game that harkens back to our discussion of cognitive biases, i.e., the duck or the rabbit and the “alle-gorilla.” He has the audience read aloud what they see on the screen behind him. One slide shows: “W at a ou rea in,” and everyone in the audience reads in unison, “What are you reading?” Why didn’t they read out what was written—that is, “W at a ou rea in”? Beau explained:

It’s because perception is grounded in experience. The brain takes meaningless information and makes meaning out of it, which means we never see what’s there, we never see information, we only ever see what was useful to see in the past....We’re only ever responding according to what’s been done before. But actually, it’s a tremendous problem, because how can we ever see differently?

Beau then makes the case for playing games as a method of scientific inquiry through the story of the Blackawton bees project. He says the purpose of the project was to get children to see differently and change their relationship with the world, not just to understand the behavior of bumblebees.

It was in part thanks to Beau’s story that the CRI was inspired to create the *Savanturiers* program.

Beau’s story illustrates the well-established fact we’ve already mentioned: that we are all born scientists. Let’s

look back to the work of American psychologist and philosopher Alison Gopnik, a professor at the University of California, Berkeley. She established a poignant parallel between the way we discover the world in childhood and the rule for judging probabilities developed by 18<sup>th</sup>-century British mathematician Thomas Bayes. The Bayes Rule is a way of sorting through possibilities in the world based on one's prior beliefs and what one judges to be likelihoods based on patterns of evidence.

Without being aware of it, a baby thinks according to this rule:

$$p(H|D) = p(D|H)*p(H)/p(D)$$

The rule is also the model for the reasoning doctors use to establish diagnoses and that e-mail filters use to sort spam out of your inbox. This is an innate process, and Alison Gopnik shows that essentially from the moment of birth we begin to formulate hypotheses about the world, test our hypotheses, and adapt them until we find a satisfying result. Furthermore, we do this unencumbered by cognitive biases, which build up over time in our brains. Quite comically, she proves this through experiments she conducts in which 5-year-olds solve problems that stump her students at Berkeley. "Babies and children are like the research and development division of the human species... and [adults are] production and marketing," she says.<sup>lxvii</sup> A publication of hers in the *Proceedings of the National Academy of Sciences*<sup>lxviii</sup> showed that preschoolers and adolescents are the most flexible learners in terms of ability to grapple with unfamiliar hypotheses that are consistent with new evidence. It's important to take this into account if we are to maximize their development so

they can reach their full potential, and this is both for their own good as well as for the good of anyone who may one day benefit from their creativity, which could be all of us.

Another important point she makes is that humans take more time for cognitive development than any other species. A newly hatched chick is able to stand immediately, while it takes humans several months. Likewise at birth, chickens learn everything they need to know for their survival, without learning much of anything else after that. By contrast, humans have an extended childhood in which we learn to strike a balance between exploration and exploitation, or in other words learning and making use of what we learn. Our exploration is hindered by adults, oftentimes just to keep us from putting ourselves in danger. Yet whether it's at home or in school, the more free, experimental spaces we're offered as little scientists, the more effective our exploration will be.

I agree that it's justified to prohibit children in some measure. But I've found that when children are given more freedom and their curiosity is encouraged, their growth is immense. It's necessary to let children explore and discover new things so that throughout their lives they can continue developing the most significant of their discoveries as children.

### *ERRARE HUMANUM EST*

The tension between exploration and exploitation is nothing new. Whether you're a bird looking for a place to build a nest, a prospector looking for gold-bearing

deposits in the earth, someone doing research on the Web, a CEO on the hunt for new markets, or just someone trying to plan your future, you can ask yourself how much time you should spend exploring and how much you should exploiting what you've found. The Latin maxim *Errare humanum est* ("it is human to err") can be interpreted two different ways depending on how you define "to err," which means both "to make mistakes" and "to wander." Both seem pertinent to me. In order to make progress, we need to be free to make mistakes and to wander and explore. Machines will be delegated more and more exploitation responsibilities in society, i.e., doing repetitive tasks we already know how to do, leaving humans to do more exploring. Since exploring can be difficult and frustrating, we need to learn how to explore well. Being able to explore will be an increasingly important skill in the future.

In the past, once we found our niche in society, we'd spend our lives exploiting or making use of everything we had learned up to then in order to fulfill our role. In our rapidly changing world, it seems clear to me that we need be able to do more exploring, as resources can dry up, gold can get depleted, markets can shift, and changes in the environment can render our exploitation strategies obsolete. For the explorers of the past exploring unknown territories, their success and even their survival could depend on how well-prepared they were, if they had a map and the appropriate gear, if they had a team of experienced explorers alongside them, and if they'd read works written by the explorers who came before them.

In all societies, there will be those who exploit what has already been explored, and there will be those who

continue exploring. This is who researchers are, equipping themselves with scientific methods to make themselves as effective as possible while exploring the unknown. They have fine-tuned their techniques and can explore anything and everything, no matter how small, large, or complex. They're constantly pushing their research further by making use of new instruments and approaches that offer new possibilities. We can also discover new ways to explore, but we have to be prepared to stray from the beaten path. One way of doing this is by cutting across disciplines, asking new questions, catalyzing diverse new collectives, and mobilizing collective intelligence.

As an explorer, you must be prepared to ignore those who don't understand what exploration is, i.e., that you won't simply be exploiting the discoveries of the past as they do. Your discoveries as an explorer may even call into question the discoveries of the past. Young people are always looking for new ways to explore, and while intergenerational conflicts can be difficult, it's the best prepared among the younger generations who are sure to have a bright future. This is likely why Helga Nowotny, who studied the sociology of science before becoming the first female president of the European Research Council, encourages young people to become competent rebels, to develop their skills without losing their sense of rebellion, to continue exploring new possibilities. In the world of business, exploitation would be the short-term strategies, i.e., managing in a way that maintains discipline and limits risk. Exploration then means taking risks, making room for mistakes, experimenting, and having long-term vision. For businesses in the changing world, striking a balance between exploitation and exploration in strategy

is one of the keys to survival, especially for businesses that tend to stick to the exploitation side of things.

It's likely that the *Homo sapiens* of the past often had to ask themselves, "Is it better to continue exploiting the land we have or explore new lands?" Today, we're realizing that we must both explore new ways to exploit and exploit new ways to explore. To do this, I think we have to create open platforms for innovation and creativity and make these platforms available to everyone motivated to explore new possibilities, whether that's in education or the professional world. We should especially encourage children to learn to explore in a safe environment where they have the freedom to make mistakes. The trust we confide in them as children will stay with them for the rest of their lives.

## YOU SAID "NEW" TEACHING METHODS?

What I'm saying is not in itself revolutionary. I'm always bothered when I read or hear people talk about "new" teaching methods when talking about experimental education practices, the kinds that create these sorts of free spaces that draw on children's innate curiosity, love of games, and ability to cooperate.

In the late 19<sup>th</sup> century, Italian physician Maria Montessori began to take an interest in education philosophy, and in 1907 she opened her own school. Montessori was one of the first women in Italy to become a doctor. She started at a psychiatric clinic and there became interested in the educational problems of intellectually disabled children. The first school she would open was for

slum children of normal intelligence, and in it she implemented methods she had developed working at the clinic and through research. She organized lessons around using concrete materials for the children to manipulate, and soon she discovered that the children were able to do much more than anyone else thought they could. She taught them to read, write, and do arithmetic and even took them to sit for the national standardized tests. Her students would up scoring better than most children from more privileged backgrounds in Rome. While her alternative methods didn't always earn her many allies, she certainly left a lasting impression on everyone who knew her.

She would go on to open other Montessori schools and spend 40 years of her life traveling throughout the world to lecture on the benefits of her methods and to train teachers in these methods. Today, 100 years later, many of her methods have been integrated into traditional education without teachers' being aware they were developed for intellectually handicapped and slum children. Apart from her innovative approaches to teaching, what I like most about her is that it was through experimenting, documenting, sharing with others, and training others that she created her revolution.

According to the International Montessori Association, there are more than 20,000 Montessori schools throughout the world. The Montessori method seems perfect for preparing young people to meet the challenges of this century. I base this both on scientific studies of Montessori classrooms and the stories of certain Montessori alumni who happen to be the greatest innovators in our time, Google founders Larry Page and Sergey Brin

and Amazon founder Jeff Bezos, to name only a few. Both of these tech companies have been very innovative, founded on the principles of using and sharing machines and having greater access to knowledge. These are skills at the heart of the Montessori method. Page and Brin have credited their years at Montessori school more than their time at Stanford with teaching them to be self-motivated and independent, which they say helped them to create Google.<sup>lxix</sup>

Like Maria Montessori, Célestin Freinet also had a very prolific career in education. In 1920, Freinet was returning from the battlefields of World War I to south-eastern France where he became a teacher. There he developed a free, experimental school founded on the idea that kids should be active in class rather than passive sponges absorbing information dictated by the teacher. Just like Montessori's students, Freinet's students overcame the odds to score very high on standardized tests.

One of the key aspects of his method was communication. Freinet felt that we're more inspired to write if we're writing to someone and for a specific purpose. Thus he had installed school printing presses for correspondence between schools in which editorials on the various projects children were involved in would be published. It makes sense that, 75 years later, the first teachers in France to experiment with using Twitter in the classroom came from backgrounds in free experimental schools.

Like many innovators, Freinet and Montessori faced many difficulties, combatting the naysayers, challenging conservative attitudes, and constantly defending the cause of educating all children, including the poor, marginal-

ized, intellectually handicapped, etc. For a wonderful film based on Freinet's experiences, I recommend watching *L'école buissonnière*, which means "skipping school," directed by Jean-Paul Le Chanois.<sup>lxx</sup>

## INNOVATING FOR EVERYONE OR CREATING AN ELITE?

Is it possible to move beyond these few small success stories and scale experimental education?

In the wake of World War I, many educators tried to do just that. You can learn all about them in a wonderful television documentary called *Révolution école*, directed by Joanna Grudzinska.<sup>lxxi</sup> The film uses archive footage and photos, much of which have never been seen before, to tell the story of dozens of educators—not only teachers but also doctors, philosophers, etc.—who tried to create a school that would work toward building a peaceful world after the carnage of the war. Swiss education reformer Adolphe Ferrière was able to bring together these educators under the New Education Fellowship, formed in the period between the two wars.

The documentary shows brilliantly how their pacifistic dream of "never again" was shaped in the trenches of World War I only to be smashed to pieces when World War II swept Europe.

Among them were many thinkers whom you may know, including Maria Montessori and Célestin Freinet. Others were Rudolph Steiner, who developed the philosophy of anthroposophy, based on the idea that the human intellect can come in contact with the spiritual realm, and

this in the underlying philosophy of Waldorf education. British educator A.S. Neill ran a free self-development school called Summerhill School, which you can read about in his book *Summerhill: A Radical Approach to Child Rearing*.<sup>lxxii</sup> There was Belgian education pioneer Ovide Decroly, whose Decroly method is still followed by schools in Europe. German education reformer Paul Geheeb established two progressive boarding schools, in Germany and Switzerland respectively, that applied his methods of employing both students' intellect and motor skills in education. Polish doctor Janusz Korczak refused the sanctuary offered him by the Nazis and followed the children he worked with at his orphanage to the death camps.

There was a good deal of conflict within the movement. Members couldn't decide whether to try to form an enlightened elite who would guide the people toward the light of peace or if they should try at all costs to build a system that was open to everyone, although the undertaking would be so enormous it could never really be carried out. These questions remain relevant.

Can we repeat their experiment? Can we apply ideas discussed here on a large scale?

I believe we can.

We can start with what Beau Lotto did with the students at Blackawton Primary School, and you can look at what biophysicist Samir Brahmachari is doing with the thousands of students who participate in his Open Source Drug Discovery program.<sup>lxxiii</sup> Its aim is to research neglected diseases that affect mostly poor countries, as market forces in the West make it unprofitable to pursue research and development in these

fields of research. The program's biggest undertaking was creating a computer simulation of the tuberculosis genome in order to understand the functions of all its biological parts. There are thousands of research articles on tuberculosis, but due to a lack of funds, no one had ever made the effort to compile all their data to create a systems-biology model of its genome. Only 50 percent of the tuberculosis genome had been understood until then.

It occurred to Samir Brahmachari that he could crowd-source Indian students to read the scientific literature on the subject. They would extract all the information on tuberculosis genes they could find in the articles, map the genome in a database, then build a model of it to be able to run genetic and systems-biology tests on it. He had several students work on each article so as to cut down on the workload for each student, and eventually, they succeeded in creating the first ever systems-biology model of the tuberculosis genome. He uses the model to identify all the different genes, the proteins that play the most important role in causing illness, and then finds new targets for drugs, and the students themselves try to synthesize these drugs.

At every step of the way, Samir Brahmachari crowd-sourced students from all different disciplines, be it chemistry, genetics, genomics, etc. His program won him the Open Science Prize from *Science* magazine, and he really earned it. He was able to bring together citizen science, open science, and the collective intelligence of young people in order to face a global challenge. I hope to see more and more Samirs in the world as time goes on.

## BETTER ACKNOWLEDGEMENT

I'm happy to say that today, several major global institutions have taken a big step forward and acknowledged the incredible accomplishments of young people. The most illustrative example the 2014 Nobel Peace Prize being awarded to Malala Yousafzai. She was 17 at the time, the youngest Nobel Prize winner to date.

Six years before winning the prize, she was speaking out against the Taliban's prohibition on educating young girls in the rural region of Pakistan where she lived. She then began blogging for the BBC about her daily life among school closings. Not only did she live in the region, but her father had founded and ran the school she attended. She wrote using a pseudonym in her blog, but the Taliban found out who she was anyway.

On October 9, 2012, members of the Pakistani Taliban stopped the school bus Malala was in on her way home from school and attempted to kill her. She was shot in the head but miraculously survived, later to be flown to England for an operation. After months of treatment and recuperation, she took back up the cause of education as a right for young girls, later to tell her story in her book *I Am Malala: The Story of the Girl Who Stood Up for Education and Was Shot by the Taliban*.<sup>lxxiv</sup>

The corecipient for the Peace Prize that year was Kailash Satyarthi, the prisoner whom, if you'll recall, Craig Kielburger petitioned to have liberated. The Nobel committee's message was clear: that they were supporting "the struggle against the suppression of children and young people and the right of all children to have an education."<sup>lxxv</sup>

While remarkable progress has been made since the year 2000, especially with regard to educating girls, nearly 60 million children still don't have access to education, namely children in war zones. There are also millions of children in refugee camps whose parents must prioritize food and health over education, although organizations such as Libraries Without Borders<sup>lxxvi</sup> are hard at work to combat this. They've tried to bring digital education to children with the portable multimedia center they've designed called the Ideas Box. The Ideas Box contains "satellite Internet connection, a digital server, a power generator, 25 tablets and laptops, 6 HD cameras, 1 large HD screen, board games, arts and crafts materials, hardcover and paperback books, and a stage for music and theatre," all in a highly durable and energy independent case.<sup>lxxvii</sup>

It's true that behind all the initiatives we've been talking about are truly exceptional teachers, researchers, and young people—who often have the help of extremely supportive and encouraging parents. But what they're doing are things anyone can do. Even if the person who started a given initiative is exceptional, reproducing the ideas and adapting it to other contexts is something anyone can do. If you look continent by continent at the countries whose students score highest on the PISA test, they have all put in place reforms that support observation, experimentation, learning through trial and error, and cooperation. The countries in question are Finland, Singapore, and Canada, among others, i.e., countries that are very different from one another in terms of political and social organization. Interestingly, what they also have in common is that they invest substantially in learning-science research.<sup>lxxviii</sup>

## GETTING AWAY FROM HIERARCHY

France is still trying to understand what's needed in order to implement dynamic education methods such as the ones we've been discussing. And it's not for lack of trying. Rather, France seems unable to throw off the system it's had for years, one that's far too hierarchical. To offer an example, the Ministry of National Education did understand that making it easier for teachers to communicate with one another was an important part of stimulating innovation. Of course, this isn't a question of reinventing the wheel, neither in the classroom nor in the school; it's just about teachers communicating with one another, exchanging, seeing how other teachers came up with solutions to similar problems that they have. What did the ministry do to facilitate the exchange of information among teachers? It created a completely new social network, ViaEduc, and it was entirely closed... even though we know the engine of innovation is openness. As a result, teachers interested in education innovation get in touch on Twitter and Facebook rather than ViaEduc.

As it so happens, these kinds of gaffes don't happen just in France. Before Wikipedia was the top Internet encyclopedia, there were two competing Internet-encyclopedia projects. One wanted to create the greatest encyclopedia by bringing together the best researchers in world. The other believed in crowdsourcing intelligence and wanted to open the project to everyone, while of course following a set of best-practice guidelines and establishing a fact-checking system. After a few months, the first project

had written a few hundred articles, while the second had thousands.

I hold Wikipedia in the highest regard, and in a similar vein I have tremendous admiration for the French education system. But being a meliorist (someone who believes the world can be made better through human effort), I try to practice constructive criticism as a means to move things forward. With regard to Wikipedia, I have just one criticism. In English, there are often two versions to the same article: the regular article and a version of the article in simple English for those who have less mastery of the language. A simple version in every language would be extremely useful, and not least for children. But this doesn't exist. Simpler encyclopedias do exist, such as Vikidia,<sup>lxxix</sup> mentioned previously, but they are less well-known and thus receive fewer contributions. Just as there are simplified dictionaries, there should be large, collaborative encyclopedias accessible for people of all ages who could, for example, select their level of difficulty using the same color-coded classification system you'd find at a ski hill, i.e., green, blue, red, and black.

This isn't just for the purpose of making knowledge accessible. It's about getting young people to contribute, which can help them understand how knowledge is created. I'll share a brief anecdote from my own family life. At age 7, my daughter Sophia loved whales. After reading every book on whales that she could get her hands on at the library, she went online to see what more she could find about them.

"Dad," she called out to me one day. "I think there's a mistake. On Vikidia it says that whales eat only plankton."

I didn't see what the problem was.

“You know as well as I do that killer whales eat other things. I saw a video of killer whales eating sea lions.”

So, I showed her how to use the editing function to correct the information, and then showed her how to create a new page if she wanted. The following year, she did just that, writing the page on orcas.

This made an impression on me because when I was growing up in the 20<sup>th</sup> century, I would never have thought that a page in a dictionary could have been wrong, and even less so that I could have contributed to editing it. If we could get every young person today to contribute information to open-source articles at their language level, we would have a lot more content and numbers of contributors, and we could show young people how consensus is created. Going further, in language class, students could compare the same Wikipedia article in different languages. This is something I do as a way to see the different points of view of different cultures. It can help students see that consensus is not always universal—not by a long shot. If you’re fortunate enough to be able to read in different languages the articles on love, Napoleon, or Crimea, you’ll see that certain concepts and ideas about history are not at all seen the same way around the world.

## THOUSANDS OF HUMMINGBIRDS

Have you heard the legend of the little hummingbird and the forest fire? A forest fire swept across the land, and while all the other animals were fleeing the fire, the little hummingbird, thinking, “I’m going to do something

about the fire!” flew over to a nearby stream, grabbed a drop of water in its beak, and flew over and dropped it on the fire. It did this over and over again, saying to itself, “I’m doing the most I can do.”

The hummingbird in this story represents meliorism, which, as Wikipedia tells us, is not mere optimism. Rather, it’s the belief that our efforts can create a better world than if natural processes were left to their devices. The world is not perfect, but we can continue to work toward making it better. This is what Voltaire’s *Candide* means when he says at the end of the book, “We must cultivate our garden.” French philosopher Alain put it another way: “Pessimism depends on mood; optimism depends on sheer will.”

In the education field, there are thousands of hummingbirds. British journalist Charles Leadbeater wrote a fascinating book about them.<sup>1xxx</sup> He didn’t want just to describe a series of education innovations taking place around the world. He wanted to uncover the logic underlying all of them and show how to go from a single hummingbird with a drop of water to systemic change. That means organizing with different communities, working with institutions without getting swallowed up by them, etc. After all, what’s difficult for most people is not innovating; it’s getting things done on a massive scale.

## HUMANIZING THE SYSTEM

Some countries, France among them, have difficulty with hummingbirds. In the French education system, everything is supposed to be uniform. All programs

are the same everywhere: Teachers and other education staff are placed here or there based on their credentials, with no regard to where they may be a good fit given the particulars of the school in which they're placed. For school principals, however, it's the opposite. If they want to get anything done, a charismatic personality is the only way forward. The worst part is that in many teachers' lounges throughout France, even talking about wanting to do things differently is generally frowned upon. Should any teachers be ever so unfortunate as to garner media attention for new ideas, they'll be subject to scorn.

And yet, behind any innovative program anywhere, and behind any school that has been able to adopt new methods, there are innovators. French audiences discovered in 2017 a host of innovative French educators in the documentary *Une idée folle*, which means "a wild idea," directed by Judith Grumbach. The teachers featured in it were from nine different French schools both public and private, and they are the heroes of this truly feel-good movie about education methods centered around empathy, creativity, cooperation, self-confidence, and taking initiatives. It's not a film about schools that are struggling; rather it's one about children who are happy, teachers who are fulfilled and engaged and who show that caring for students and having high expectations for them are not mutually exclusive.<sup>lxxxii</sup> What's the difference between these schools and others? It's that these teachers want to find paths for their students to succeed, no matter what criticism they may encounter.

There are wonderful people behind education innovations everywhere. Columbia's *Escuela Nueva* ("new school") model was generated in large part thanks to

the work of Vicky Colbert,<sup>lxxxiii</sup> the daughter of educators and who herself studied the sociology of education and comparative education. Her model has spread to 20 countries and has changed the lives of 5 million children.

At first, her goal was to design a system that was adapted to children in rural areas. These kids often have to work on their families' farms to contribute to family income. At Vicky's school, kids can progress at their own pace, which keeps them from dropping out because they never have to repeat grades. It's not the teacher who's the center of the lessons, but the children themselves. Children are also encouraged to be "participative, democratic, [and to know] how to share and work in teams."<sup>lxxxiii</sup>

Vicky Colbert doesn't claim to have invented a new method or consider herself on the level of Montessori, Decroly, Steiner, and Freinet. She was simply able to bring progressive education ideas to Columbia's national education policy. Typically, only wealthy children have access to progressive education, and this despite what these education reformers had envisioned. Vicky was able to make progressive education low-cost, effective, and available to everyone.<sup>lxxxiv</sup>

Here as well, we notice a common thread among the most effective teaching methods. They put faith in the ability of the students to contribute to solving complex problems and have an impact in the community. At the outset, the idea was to provide an education solution for marginalized sections of society, and Vicky's school wound up creating a modern education model fit for our time.

In Port-au-Prince, Haiti, the incredible success of Catts Pressoir school is indistinguishable from the ambition of its director Guy Étienne and his family. From primary

school through high school, the 650 students at the school focus on observing the world around them and identifying problems in their communities. They pick a problem that matters to them and then work together toward a solution by doing research. At the end of the year, they share their results in a science fair.

For example, after the 2010 earthquake, traffic lights stopped working and streets became dangerous places for pedestrians, especially school children. Students from Catts Pressoir primary school invented a way to fix the traffic lights that was more economical than the system in place. They took their idea to city hall, proposing that it would likely be useful in other parts of the country as well. Other students from Catts Pressoir created their own SMS gateway for sending text messages, as the general cost of sending text messages was too high. A major undertaking at the primary school level is a mass reforestation project of Haiti, which has already planted 1.2 million trees. The Haitian president has publicly stated he took inspiration from this Catts Pressoir project in developing his own reforestation program. The students were interested in understanding earthquakes that plagued their country and studied them, connecting with other schools and researchers abroad. They wound up winning medals in international Olympiads of geology.

## LEARNING TO LEARN

Just like Vicky Colbert, Guy Étienne is implementing an approach that focuses on the importance of learning to learn. This will prove to be a major education idea in

our time because it brings together fundamental learning, technical skills, and the major social questions that coming generations will have to face. A brief anecdote: The students at Catts Pressoir were one day working on robots, and one of them, a primary school student, gave his robot a number. Guy asked him why, and the student told him that, this way, if the robot did something bad, the student would know which one it was. This student understood on his own the ethical risks in robotics, and these ethical questions are currently at the center of a lot of high-level legal battles going on around the world, whether it's dealing with liability in accidents caused by self-driving cars or the use of military drones.<sup>lxxxv</sup>

Another hummingbird, Shrinath Kalbag, established in 2002 a fab lab at Vigyan Ashram in Pabal, India. This was the same year that MIT's Media Lab opened its first fab lab. Kalbag's Vigyan Ashram is part of the Indian Institute of Education, housed in a low, 40-square-meter building located about a four-hour drive from Mumbai.

The fab-lab philosophy was developed by physics and computer-science researcher Neil Gershenfeld in two legendary MIT classes, the first of which I've already mentioned: "How to Make (Almost) Anything" and "How to Make Something That Makes (Almost) Anything." Gershenfeld was inspired by maker culture in California and familiar with the ethics of hackers. He took these ideas and implemented them at one of the best universities in the world.

A fab lab is a great example of the kind of place I've been talking about where people can learn and create freely. There you find digital tools for working on all kinds of materials, and at its best, people are granted access to the

fab lab so long as they let others see what they've made so that they in turn can learn from it. Essentially, a fab lab is perfectly adapted to teaching methods that encourage “doing” and crowdsourcing solutions to problems.

The Vigyan Ashram fab lab, established with the support of MIT, was the second in the world. Kalbag brought in young rural dropouts and sent them to nearby farms to learn about the problems farmers were having. Then, working together in the fab lab, they would try to build something to solve a given farmer's problem. Once they came up with something, they were then encouraged to start their own businesses with their inventions, as it was very likely that other farmers were having the same problem. We see here how solutions can be transformed into products and services.

The same thing happened when the CRI's *Savanturiers* program began working with students from vocational high schools. When students found solutions to the problems they were working on, local entrepreneurs offered to partner up with them to file patents for their inventions. From Mumbai to Paris, hundreds of thousands of inventions are just waiting to be made. All we have to do is show people the ways of learning differently and free them from passive learning in the classroom.

Putting innovative teaching methods to practice is not a matter of working miracles. It just takes paying close attention to students to try to combine our observations of the students with what scientific data say. That's how we can bridge ethics and science, the scientific method and the needs of the local communities. This is also how we educate conscientious citizens ready for the challenges of this century. The skills that Catts Pressoir focuses on

are skills that most schools don't spend much time on: understanding yourself, empathy, organizing a work team, gaining a sense of responsibility and initiative, having a scientific mind-set, being creative, having the skills necessary to be a change maker, respecting established guidelines, and leadership.

## HUMANITY AT THE CORE

I just want to be clear: The purpose is not to create a class schedule with one hour of building empathy, one hour of respecting guidelines, etc. It takes methods that can teach effective math, language, and history skills in order for these personal skills to develop. What's important to keep in mind is that the ultimate goal is larger than each individual subject area, that formal academic skills should never be prioritized over non-cognitive skills and social skills.

The *Escuela Nueva* and Catts Pressoir are two schools that focus on humanizing the system and allowing students to make their own choices. The countries that are able to apply these teaching methods at the national level, such as Finland, Singapore, and Canada, are able to make the institutions themselves less top-heavy. According to international comparisons, they are better at reducing inequalities than French schools, even while French schools bear proudly above their doors the national motto *Liberté, Égalité, Fraternité* ("liberty, equality, fraternity").

## EMPATHY IN THE EDUCATION ENVIRONMENT

Changing attitudes and introducing a culture of questioning doesn't have to come at a significant cost. It would be easy, for example, to carve out regular times for teachers to discuss innovations that are being tested elsewhere in the world. What should we take from the examples of Catts Pressoir and the *Escuela Nueva*? Ignore them because our specific context is different? Or can we borrow from these approaches and adapt them to our context? But notice that doesn't mean adapting it to the top-down model. The simple fact of teachers' working together as a learning collective, or even better a learning collective with ties to other learning collectives, is enough to spark positive changes. That's because learning collectives build trust, at least so long as the members of the learning collective feel that administrators are genuinely looking out for their best interest and that administrators are willing to listen to them when needed. Having inspectors come to schools goes back to the days of Napoleon, which is why we should change the name of that job title, as the word carries with it a connotation of control and punishment, and school-inspection practices are getting better, though slowly. Teachers need mentors, not police officers. They need people to listen to them rather than enforce arbitrary rules on them. They need empathy, not judgment. Contrary to what some teachers may have been told by their higher-ups, it's not just children who deserve empathy.

You'll have understood by now that throughout the entire world, there exist real education models that meet the needs of this century. We need to foster them, facili-

tate communication between them, and legitimize them. How can we know which ones they are? We notice that each one of these innovative systems reject rote learning and embrace the ability to formulate new questions.

Geoff Mulgan, CEO of the National Endowment for Science, Technology, and the Arts (NESTA), started a network of innovative schools called Studio Schools,<sup>lxxxvi</sup> “studio” to harken back to the studio system of the Renaissance, when young people learned by working and worked while learning. Geoff’s definition of what a school of this century will look like is very clear. For him, putting knowledge to use involves three types of “loop learning.” First-loop learning is fitting new data into existing models. This, according to him, is what most mainstream education does. Second-loop learning generates new concepts and categories. This kind of learning is better adapted to the new millennium, but it doesn’t address the complexity of our world. Finally, third-loop learning is developing new ways of thinking.

The first form of learning won’t have much more of a future, as this learning will be taken over by artificial intelligence. The second and, above all, third forms of learning should last much longer. It may be that no one knows how the world will change, but we know at least that the ability to adapt to change will be one of the most important skills to have.

Those with experience in innovative learning will be much better prepared.

## 5

# Learn to ask (yourself) good questions

How will we learn in the 21<sup>st</sup> century? We don't need to wait for the next big trend innovation in education to know the answer. We need only look back to the method Socrates developed in ancient Greece that he called the maieutic, which is the Greek word for midwifery. Indeed, he saw as a form of midwifery his duty as a philosopher, i.e., drawing out people's ideas and understanding through questions and dialogue. "Maieutic" comes from the name of the Greek goddess Maia, synonymous with the earth and growth, and we can see why Socrates was drawn to this comparison, as Socrates' own mother was a midwife.

As we saw in the last chapter, we've made a lot of advances in cognitive science and our knowledge of the brain since Socrates' day. Similarly, digital technology and artificial intelligence have revolutionized the way knowledge is produced and spread.

## FROM MAIEUTIC TO “MAIEUTECH”

How can we marry Socrates’ method with the Internet? We’d need what we could call maieutechnology or socratechnology, i.e., technologies that can help us mobilize both individual and collective intelligence to then develop our intelligence in the tradition of humanity’s greatest thinkers, from Buddha to Confucius to Socrates. Collective intelligence is our best defense against getting surpassed by artificial intelligence, but once again we need to organize collective intelligence a bit more and go further than current collective-intelligence tools such as Wikipedia and Foldit have.

Collective intelligence is not simply the sum total of information on a given topic. Certain opinions and hypotheses on that topic should be given more weight than others. It comes down to the quality of what in the printing press and digital world is called editorialization. Who compiles opinions? Who structures the various opinions? Who’s separating the wheat from the chaff, the good from the bad? To use an example from the chess world, in 1996 Russian chess grandmaster Anatoly Karpov, who dominated chess internationally for 20 years, played a match against the entire world.<sup>1</sup> The world team decided on moves by vote, and Karpov beat them handily. Why? Because there was no system for catalyzing and channeling collective intelligence. People could vote for bad moves. If we have no way to distinguish between good and bad moves, collective incompetence is as likely as collective intelligence!

A much more interesting match was against Garry Kasparov from June to October 1999, two years after his

historic loss to IBM's Deep Blue. The player community was invited to vote on the moves that were suggested by four young, brilliant players: Elisabeth Pähtz, then 14 years old; Étienne Bacrot and Irina Krush, both 16; and Florin Felecan, the oldest one at 19. They were in charge of organizing the collective intelligence of the world team. There was one move made per day, so they had 24 hours to discuss and vote on every option. Kasparov ended up winning, but in his book,<sup>ii</sup> he describes the match as one of the finest and most challenging of his career.

Since then, he has developed the idea of marrying human and artificial intelligence in chess to create “centaur chess,” but instead of meaning half-human and half-horse, he means half-human and half-computer. I support this development. Once we can properly catalyze and channel collective intelligence—and our example shows the important role of young people in this process—we can continue strengthening it with the calculating power of computers.

The great science journals build their reputations on their editorship. When you submit an article, it's read and discussed by peers, then you have to defend your ideas, and in the end an editor will make the final decision to publish you or not. The process is not perfect, as each year journals have to withdraw articles with incorrect information that slipped through the net, yet statistically speaking these journals guarantee the best possible quality of information and help drive scientific progress.

You can also enrich your approach by calling on collectives. Michael Nielsen wrote a book<sup>iii</sup> on new ways to carry out research, and in it he shares the poignant story of British mathematician Tim Gowers. Gowers is a Fields

Medal winner, which is to say one of the best mathematicians in the world, yet a few years back there was a problem that had him stumped. He decided to solicit help from the readers of his blog, and within a few weeks they had helped solve the problem. In the wake of that experience, Tim created Polymath,<sup>iv</sup> an online platform for mathematicians to collaborate on new math problems. Some see Gowers's massive collaboration movement as a sign that the old cliché of the solitary mathematician with only pen and paper to aid her will have to be reimagined in the age of the Internet.<sup>v</sup>

It's also thanks to the quality of Wikipedia's editorship that it has proven to be one of the best encyclopedias in the world. As more and more people become more and more educated, knowing how to mobilize and organize individual, computer, and collective intelligence will become increasingly important.

## KNOWLEDGE AND ACKNOWLEDGEMENT

In order to make the knowledge society a reality, we need to give proper acknowledgement to those who create and share knowledge. And these people are numerous. Diplomas acknowledge that you have acquired certain knowledge. Patents acknowledge the rights of those who have come up with new inventions. Science journals acknowledge contributions to the sciences. All these forms of acknowledgement are relics of the age of the printing press.

Digitalization has come up with newer, faster, and more innovative kinds of acknowledgement. Hundreds

of platforms offer users ways to promote or discourage things, from Facebook Likes to stars on TripAdvisor or more elaborate feedback systems such as those in Massive Open Online Courses (MOOCs). But what most of these systems actually do is create a reputation for the thing being evaluated rather than acknowledge its quality. On top of that, the things being evaluated tend to be limited to recreation activities, services, and products. Nevertheless, acknowledgement in one's field is a strong motivating factor for many people. A 2013 study coauthored by French economist Yann Algan<sup>vi</sup> showed that the most active contributors to Wikipedia were motivated not by altruism but by “barnstars,” i.e., symbolic awards existing within the Wikipedia community that acknowledge important contributions from editors. Wikipedia's editors then showcase their barnstars on their Wikipedia user pages.

How can we bring together the seriousness of the older forms of acknowledgement with the speed and scale of the newer ones? We can't abandon the older ones because not all ideas and knowledge are equal. It's a challenge that I believe should be taken up by the experts who work for the public good. They should draw inspiration from systems already in existence and making the different approaches more effective, as no one system is sufficiently neutral and exempt from bias.

Scientists thought they could judge the importance of a given article based on the number of times that article was cited in other articles. The idea was proposed by physicist Jorge E. Hirsch, so this index for measuring the impact of certain research was called the h-index. Although the index is relatively new, biases appeared very quickly

wherein certain researchers began citing each other as a deliberate means to increase each other's h-index. It was also noticed that interdisciplinary research, which now holds some of the most promise for the future, used to be undervalued, as each separate field preferred to stay in its silo rather than venture outside of it and cite a source from a different discipline.

No index on its own is exempt from bias. Only by aggregating several indexes can we arrive at the clearest possible picture.

And having this kind of clear picture is so important.

For Confucius, there were three ways to attain wisdom. The first is by learning from your mistakes. This way is demanding, painful even, as you need to be willing to face your own fallibility. The second is reflecting on a situation long enough to see every possibility and, that way, avoid making mistakes. It's less painful but even more demanding, as you have to overcome your mental barriers and invest a lot of energy. The third, which he said is the simplest, is by imitating the wisest people around you. This is undeniably the most common, but we have to know who the wisest people around us are. And we have to be careful not to get fooled by those pretending to be the wisest among us. Furthermore, this approach, while necessary, leaves little room for new ideas and new questions.

A second evolution would consist of integrating less formatted knowledge into the notion of knowledge worthy of being transmitted and considering as sources of this knowledge people from different walks of life. As we saw previously, an essential step for avoiding all the cognitive traps that our brains set for us is to try to know ourselves. Supposing we can ever fully know ourselves,

this process can take a lifetime, and yet it's not part of any curriculum recommendations. It is relegated to the private sphere and depends on personal initiative alone.

## CANDLES OF KNOWLEDGE AND ACKNOWLEDGEMENT

In some societies, such as those in Africa, people seek self-knowledge from the old sages. Who are the old sages in our lives? They're likely not the ones claiming to be sages. Why not create a platform where we could collectively identify their practices in order to benefit from their accumulated life experience? In economics, non-rival goods are goods that can be possessed by many people at the same time and consumed repeatedly without ruining their quality or depleting them. Empathy, love, wisdom, and ideas are like non-rival goods. If we call on those who possess them to transmit them, they wouldn't lose anything, and we could all benefit from it. We would even then be able to spread it to others, a bit like when you light a candle from another candle—the first candle doesn't go out.

As in English, the words in French for knowledge and acknowledgement are very similar: *connaissance* and *reconnaissance*. In some classrooms I've visited, children give candles of knowledge and acknowledgement to people in their lives who have helped them progress. The candles were given as often to teachers as to parents who had taught them to ride a bike, for example; to friends who helped them understand a difficult aspect of grammar; or to older siblings who had taught them to be nicer to younger siblings.

We find these kinds of the systems of acknowledgement on sites like Facebook and LinkedIn, but those companies collect data on us for their own benefit rather than our own. Moreover, their systems are still rudimentary and don't provide a particular incentive to share ideas, which is essential in the society I'm calling for: the society of knowledge, acknowledgement, and sharing.

Let's be clear, I'm not trying to make, or not only, a moral argument. My argument is also pragmatic. Artificial intelligence today lets us process unheard-of amounts of data. Take for example a condition we still know little about, autism. It seems autism is due to complex and overlapping factors, hundreds of genetic combinations playing out in thousands of different scenarios. If everyone, scientists and families alike, who knows something about a case of autism were to document it, perhaps we could identify yet-undiscovered correlations and possible therapies that, at least for certain forms of autism, may work better than others. Some researchers are already doing this. I know that because a few of these researchers are at the CRI. What I'm talking about is a massive change of scale, putting collective intelligence in motion at a scale we've never seen.

Behind such mechanisms is the idea that everything must be done to enhance both knowledge and the ability to share and to make information visible in a way that lets us identify those who hold this knowledge, the same way we give out diplomas at schools and universities. Thanks to technology, we can now fuse together on a large the art of creation (Maia) and the creation of fortunate encounters (Portunus).

## WHAT “HANDS-ON” CAN TEACH THE BOOKWORMS

In this regard, intellectuals are far behind those who work using their hands. Maker culture, born on the west coast of the US, was an early advocate of sharing knowledge and tools, as Walter Isaacson describes in a book called *The Innovators*.<sup>vii</sup> Well before Steve Jobs and Bill Gates began their legendary tinkering in garages in Silicon Valley, later to produce the computers that would revolutionize our lives, maker culture was literally taking root in small, isolated farming communities desperate for ways to collaborate in order to solve problems. A bunch of little learning communities cropped up and with them a culture that would later invigorate American industry. This history explains in large part why today California is so innovative. Chris Anderson, a Silicon Valley guru and former editor-in-chief of *Wired* magazine, has said that maker culture laid the foundations for “the new industrial revolution” that digitalization ushered in.<sup>viii</sup>

Just as the teaching methods that respond to the great challenges of our time already exist and are just waiting to be developed and networked, the technical principals and tools that we need to build the society of knowledge and acknowledgement are already out there. They’re called skills portfolios. In them, you document what you’ve learned, meaning not only diplomas but also awards and certificates that show you’ve acquired specific knowledge or skills as well as honors in the arts and sports, certificates and titles you’ve earned over the course of your life acknowledging what you’ve achieved and learned through experience, whether it’s volunteering, political activism,

etc. Skills portfolios draw the map of our knowledge and skills in a way that's incomparably richer, more varied, and denser than diplomas alone. It's a kind of super CV.

Sharing these paths and experiences would also provide an extraordinary guidance tool. Training and career paths are less and less linear as we enter a more dynamic world where professions are constantly evolving. If we could see the paths taken by others in the profession I want to work in or know which professions people with my same background have entered, this could be a valuable guide, for people of all ages but for young people especially.

## A MAP OF POSSIBILITIES

The idea is not to force people in a certain direction or make them feel they have no free will. The current system does a fine job of that already, unfortunately. More than just an assortment of options, it would structure the options to show you a map of all the possibilities, like how a GPS system suggests different possible routes, and it's up to you to decide between a highway jammed with traffic, a dull and direct freeway, or a winding country road.

The map would show you everywhere you've been in the world of knowledge and how much knowledge and skill you've acquired in various areas. And instead of showing the time each route would take, the different routes would show new areas of knowledge you may want to explore and whether you want to pursue them through traditional education, online courses, peer-based learning, a fab lab course, etc. There could also be a geographic map

showing you all the resources in your area, be it people or institutions. In sum, the way we meet romantic partners through Tinder, do ride-sharing through Uber, and find lodging and homestays through Airbnb, these could all be applied to the field of knowledge.

In some fields such as programming, these tools are already in use, primarily because the world of programming is in constant evolution and programmers are always in need of training, and proof of their training, in new computer languages and new versions of existing languages.

Why not extend these tools to everyone? Ideally, this would be done under the aegis of the public service, as with diplomas and health records, in order to protect our privacy and testify to the truthfulness of the information in our portfolios. If necessary, a delegation of different public services could be organized to mobilize the most relevant key players, but on the condition that this doesn't turn into another bureaucratic maze that only they know their way out of. That's how we can modernize the system of acknowledging prior learning, a great idea made somewhat unrealistic given the complexity of its implementation.

## THE MONITORIAL SYSTEM

One of the models that to me seems the most fruitful is the monitorial system, as it provides students the opportunities to grow by teaching other students. And research confirms what one could imagine to be the case: that when we pass on knowledge to others, we strengthen our

own knowledge and even further it through questioning from our “students.” Let’s acknowledge that experience! Let’s provide more incentives than just altruism to get people to share what they know! We can take inspiration from the example of Adora Svitak and her alma mater the University of California, Berkeley, which has programs that let students create their own courses and gives them credit for doing so. Let’s offer financial incentives to those that contribute to creating and maintaining knowledge ecosystems, thus contributing to the building of a learning society or, even better, a learning planet (an idea we will discuss later).

## WISDOM OF THE CROWD VS. COLLECTIVE STUPIDITY

For as much as I believe in the power of collective intelligence and, in some cases, the “wisdom of the crowd,” I’m also wary of collective stupidity, which can itself harness exponential power in the echo chamber of social media, if not degenerate into fake news and the spread of hate speech.

Not all points of view are equal. We need proven processes in place that can take the sum of individual intelligences to produce collective intelligence. Wikipedia was able to do it, thus a public service of knowledge and acknowledgement should be able to do it as well.

This first building block is easy enough to place, and it’s one that brings us back to our discussion of school. A child acquainted with producing collaborative content on Wikidia will be more inclined to contribute to Wikipedia.

A child who was encouraged to ask questions rather than simply memorize answers will have more opportunities to ask more questions. A child who feels empowered to exercise her creativity will have fewer inhibitions when it comes to presenting new ideas. These skills are not difficult to develop, and there are already myriad programs that do so. Yet these programs remain if not exclusive, then on the fringe.

## FAILING TO MOVE FORWARD IS MOVING BACKWARD

There's one place that could and should be at the core of the innovation reactor and a model of a learning system: the university, where research and teaching enjoy equal rank. But universities in most countries progress too slowly. In this rapidly evolving world, that's the same thing as going backward. It's just like that scene in *Through the Looking-Glass* when Alice is running in the Red Queen's race and can't move forward. The Queen says to her, "Here, you see, it takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Lewis Carroll, the man who dreamed up Alice and her adventures in Wonderland, was a contemporary of Darwin. Carroll lived in Victorian England at the height of the Industrial Revolution, and he understood and manifested in his literature the effects of ceaseless evolution such as Darwin had described it in *On the Origin of Species*.<sup>ix</sup> The world is in motion, so failing to move forward is moving backward.

## ON THE SHOULDERS OF GIANTS

Universities are threatened by stagnation, and they face the challenge of going from the age of 2.0, i.e., the birth of digital, to the age of x.0, i.e., organizing learning such that it constantly enriches itself through contributions from both teacher-researchers and students. “We are like dwarfs on the shoulders of giants,” said 12<sup>th</sup>-century philosopher Bertrand de Chartres. A contemporary of his, John of Salisbury, added to this thought, saying, “We see more and further than they did not because we have keener vision or greater height, but because we are lifted up and borne aloft on their gigantic structure.”

This image, later to be referenced famously by Isaac Newton and Blaise Pascal, harkens back to a fundamental attitude that’s widely held in the world of science, and that’s the idea that we don’t do good science if all we do is revere the past. We have to be constantly moving forward to keep the giant growing. This way, future generations will in turn be able see “more and further.” Yet most universities do not produce research on themselves: their own operations, biases, structure, performance, failures, successes, etc.

What is the role of the university in the Internet age? What’s the purpose of having a campus? Do we learn better in a lecture hall among our peers than at an internship, in a laboratory, or taking an online course? How do we articulate knowledge gained in a university setting? What about outside the university setting—in bookstores, coffee shops, cinemas, fab labs, etc.? What synergies are being implemented to get a global vision of student experience?

The answers to these questions do exist in the field, but we must experiment. This is what's being done at the CRI. We should prototype DIY undergraduate and graduate degrees centered around the United Nations' Sustainable Development Goals. It would be similar to what Catts Pressoir is doing with younger learners, and we've been able to test it out in summer schools together with François Grey from University of Geneva, Luping Xu from Tsinghua University, Rob Lue from Harvard, and Yann Algan from Science Po, along with their students. We could mix traditional and *à la carte* styles. Students could get involved in service work for a humanitarian organization, launch a start-up, found a cooperative, go abroad, pursue a sport or artistic activity they excel in—the possibilities are endless. Students would of course have to document what they do with their time and work in reflections on their activities. Their mentors could ask them to complement their experiential learning with more traditional approaches such as taking an online course. In the end, students would acquire the skills that alternative education environments foster much better than the traditional university setting. All this would be recorded in their skills portfolios so that teachers as well as other students would be able to draw from what their predecessors have learned and so that these “dwarfs” can continue “standing on the shoulders of giants.”

## UNSOLICITED-STUDIES MAJORS

At the CRI, we're also developing “unsolicited-studies majors” based on a system that researchers know well,

the “call for unsolicited proposals.” In research, there are two types of calls for proposals. The first are solicited proposals, meaning a sponsor is interested in advancing research on a specific issue. Unsolicited proposals are when researchers submit proposals that the researcher herself judges to be of particular interest to the financial backer. An unsolicited-studies major would work the same way.

I’ll give an example. Let’s say you’re interested in the impact that artificial intelligence will have on society. As it functions today, you’d have a choice to make. A degree in computer science would help you understand the technical aspects of AI. A degree in philosophy would help you dig into the ethical questions. An economics degree would teach you about the impact of artificial intelligence on employment. A psychology degree would get you thinking about the relationship between humans and machines. Studies in art would encourage you to reflect on different scenarios that could play out in society, which you could then draw from to turn into books and movies. But not any one path lets you take up the subject as a whole. Just like in the fable, you have to be just another blind man trying to describe an elephant by touching only one part of the animal.

With the unsolicited-studies track, you can take classes in different departments of your university and even online if certain subjects are not yet taught at your university. The role of the university would be to guide you in your choices and to establish a required number of credits. You would document all this in your—you guessed it—skills portfolio, so that other students who may also want to study AI’s impact on society can glean ideas from

your experience. If after a few years students find they get a lot out of that particular degree and there's rising demand for it, the unsolicited-studies major you created could become an established major. In our example, it would be an Artificial Intelligence and Society degree.

## MORE UGLY DUCKLINGS

Do you think this is all pie in the sky? Think again. I'm speaking from my personal experience at the CRI. Fifteen years ago, we created the master's program mentioned previously called Interdisciplinary Approaches to Life Sciences. Its first students, coming from physics, biology, and engineering backgrounds, worked on the cutting edge in the life sciences. They soon began thinking up all kinds of innovative projects, the most emblematic of which being the one I've already mentioned that took the first Paris Bettencourt team to MIT's iGEM competition, and many more would follow. One of these teams was victorious thanks to outside support from Sara Aguiton, then a student in the second year of her master's degree in history of science and technology at the School of Advanced Studies in the Social Sciences (EHESS) in Paris. I'll share the story of their collaboration, which serves as proof of the need for interdisciplinary approaches and the importance of *phronesis*, the ethics of our actions.

In an interview with *Le Monde*, Sara talked about her four months spent with these students from the fields of physics, biology, computer science, and math.<sup>x</sup> She remarked that their project dealt with fundamental research and thus was far removed from application, the result of which being that

questions of ethics were almost non-existent in the minds of the team members. These same members would later say that it was the ethical perspective that Sara brought to the team that would give the project a whole new dimension and that wound up securing the team's victory in the end. The jury found that the French team was far ahead of the other iGEM teams on questions of ethics and that in order to address those questions, cooperation among specialists from both the humanities and hard sciences was needed. The various specialists must demonstrate mutual respect for one another, and in that regard, the jury said, the Paris team had been exemplary.

Other CRI projects have launched start-ups, advocacy groups, and cooperatives. Students don't necessarily see themselves as entrepreneurs when they first come to the CRI, but many have become entrepreneurs because we provide them with the freedom to create socially engaged collectives. At the beginning of the year they told us what they hoped to achieve for that, whereby we set aside for them a small budget and provided them with access to our facilities. Their projects created fab labs, maker spaces, work in synthetic biology, developments in virtual reality, game-based learning—the list goes on.

Livio Riboli-Sasco, one of our first graduates, created a science and research cooperative within his *Atelier des jours à venir* program.<sup>xi</sup> Xavier Duportet, who was also on the CRI's maiden voyage to the iGEM, started Eligo Bioscience, a company that develops antibiotics and holds the record for fundraising in California by a French biotech company. Xavier also started Hello Tomorrow, an NGO that provides support for deep-tech approaches from science entrepreneurs in more than 40 countries.

Aude Bernheim and Flora Vincent, when they were biology students, started Wax Science and ItCounts. Initially they were part of a club that was interested in science and design. When the European Commission launched its video campaign, which intended to attract more women to the sciences but showed pin-up girls in stiletto heels in the lab, Aude and Flora decided to take action. In the fallout of the EC's campaign, the commission was smart by making a public apology and a call for open submissions for a new video campaign. Aude and Flora put together a team of students from the CRI, and they wound up winning the competition with a hard-hitting video about gender biases in the scientific field.<sup>xiii</sup> The two then started Wax Science,<sup>xiii</sup> which they describe as a “curiosity detonator, a catalyzer for initiatives that seek to tear down stereotypes one by one and effect change.” Wax Science has indeed done just this with both genius and a sense of humor. You can download their app ItCounts,<sup>xiv</sup> developed with students from the E-mma association at the Paris Graduate School of Digital Innovation. The app provides modules for counting the number of men and women in a given meeting or a lecture hall, taking note of who speaks (and who doesn't speak) to then give an estimate of gender biases within the group. Flora and Aude also wrote about the need for AI development that takes into account the necessity of gender policy.

The reason I'm particularly enthusiastic about their initiatives is because at a tender age I was made aware of the issues it's tackling. When I first moved to Paris at age 17, most schools did not make their dormitories available to female students. Later in life I joined a collective called *Ouvrons les portes* (“opening doors”) that led a social

media campaign for equal access to student housing, which is why I started my Twitter account, @Francois-Taddei (which I also use to further explore the ideas I talk about in this book). It's for the sake of gender parity as well that this book does not to follow the grammar rule prescribing masculine pronouns for generic contexts (e.g., "A child who feels empowered to exercise *his* creativity..."), and I'm very thankful that those who helped me write this book understood why this choice was important. I even got publicly involved with other women and men to work toward the joint initiative launched by UNESCO and the L'Oréal Foundation to promote gender parity in the sciences. This is also something I try to engage in every day at the CRI. Thanks to activism by both students and staff, we are making step-by-step advances on this path, which can be difficult to navigate due to differences in culture, attitude, and awareness of these issues. I hope to see more and more constructive dialogue and perhaps even a citizen-science approach develop around questions of gender parity, which could spread to all areas where counterproductive gender biases still exist.

Samuel Huron is someone who came to the CRI after having followed an interesting path in life. He dropped out of school when he was 15 but eventually found his way back to education and came to us because he wanted to study the Internet. This was at the time we had the Orange Research Chair, which sought to combine digital sciences, life sciences, and learning sciences by focusing on interfacing computers with biology. We brought together researchers from Orange and different fields, both academic and non-academic, to work with students

who wanted to explore all the potential the Web has to offer. Samuel wrote a dissertation on data visualization that won the best doctoral dissertation award from the IEEE VGTC Pioneer Group.<sup>xv</sup>

Another student, Antoine Mazières, came to us from an anthropology background. For his thesis he traveled to Brazil, but rather than study indigenous tribes as his colleagues were doing, he went off in search of tribes of programming and IT geeks. His dissertation on artificial intelligence communities cut across the disciplines of digital science, sociology, and anthropology. Like all ugly ducklings that don't want to be confined to one field, he had a difficult time finding people willing to help guide his research. We're glad he found the CRI.

Aurélien Peilloux came from a background in physics and chemistry. He had graduated from the ESPCI, the school where Nobel Prize winner Pierre-Gilles de Gennes was once director. Aurélien came to the CRI to work on a dissertation in partnership with the Institut Curie on interfacing physics with biology. It was just when he had received funding for his research that he came to tell me he had been accepted to the prestigious film school La Fémis and that he wouldn't be doing the physics and biology thesis after all. I suggested he come up with a new research topic that brought together cinema and science. And that's what he did. His dissertation was titled "A film director's search for the dialogical relationship between art and science: from the notion of 'ideas as feelings' in the creative process to an aesthetic approach to knowledge." His work was highly original, as it combined a traditional written dissertation with four films he created that each made reference to one another, entered into

dialogue with each other, and formed a consistent whole. They attempted to respond to the problem raised by his work, namely of creating hybrid objects that interface art with science.<sup>xvi</sup>

Of course, when it came time to put together a committee for the defense of his dissertation, we talked to researchers from various disciplines, and their response was that Aurélien's work wasn't something they were used to seeing in France. So, we brought in a few experts from other universities, namely international universities where arts-based research had been around for 20 years already. These are dissertations in which you have an artist reflect on his or her art by documenting resources and experiments in a way that's similar to scientists. I think Aurélien's thesis was the first of its kind in France.

## THE CRI: THE CROSSROADS OF RESEARCH INTERESTS

The CRI has been the launching pad of so many other projects because the CRI is as much an interdisciplinary research center as it is a crossroads of research interests.

We realized through these various projects that students generated most of our innovations with regard to teaching methods. For this reason, our master's program directed by Sophie Pène, Jean-François Bonnet, David Taresté, and Franck Zenasni now has a new name: "Interdisciplinary and Innovative Approaches to Research and Education." The program has three complementary tracks: Learning Science, Life Science, and Digital Science, and students do three internships

in three laboratories in three different disciplines. One of the only things we require of students is to combine experimentation and theory. We want them to deploy both advanced conceptual thinking skills and experimentation skills. In order to understand the world as it is, friction between ideas and reality is a must. And the program has been successful for them. Graduates have gone on to work in major French and international universities and research institutes or in structures they have created (start-ups, associations, cooperatives, etc.).

I'm not saying that veteran professor-researchers couldn't have innovated in the ways we have. All I'm saying is that innovation comes from CRI students, which is likely due to the fact that they've yet to start obsessing over certain practices or become prisoners of their own habits. A group of students from diverse backgrounds who are both motivated and creative will have an unlimited horizon, and to this day nothing makes me happier than when students come bursting into my office to announce something they found in research or an innovation they came up with that I myself had never thought of. What's more, they're able to take ownership of their discoveries and find ways to go even further.

From a French perspective, these programs can seem very innovative. Internationally—the scale on which universities should measure their achievements—the picture's not quite the same. Many major universities, namely in the US, offer curricula that are, if not just like what the CRI offers, then at least founded on the same principles. All over the US, there are liberal arts colleges where students often have an open curriculum in which they choose the courses that matter to them.

This model does exist in France, but it's in the early phases of development. As a biologist specializing in evolution, I know that a profound change can begin with small changes that are difficult to perceive. I want to believe that this will be the case for the evolution of student practices and that universities will be able to support these practices and ensure the quality of what they can provide. In short, universities should act like caring mentors.

## THE THREE FREEDOMS OF UNIVERSITIES

The principles that gave birth to the modern university at the turn of the 19<sup>th</sup> century in Germany were established by Wilhelm von Humboldt, who wrote that universities should no longer be places where knowledge was forced onto students, but rather a space where caring mentors protect and advocate for students. The modern university is founded on three freedoms: freedom to learn, freedom to teach, and freedom to do research.

## TOWARD A PROJECT CULTURE

In France, researchers have a major role to play in France's state of affairs. Most researchers prefer positions in which they do research 100 percent of the time in a big research institution like the CNRS or the Inserm. They'd rather do this than have a teaching post at a university, and the system encourages this kind of thinking, as being committed to teaching and education innovation is looked down on. And this is despite recent efforts to

promote researchers who use their time and energy to educate students.

The change won't happen all on its own. I have cited some examples in American universities, but the climate in the US is by no means perfect. The tendency to seal oneself off in a disciplinary silo is real there, too. Inter-disciplinarity is by no means second nature, and teachers don't necessarily try to take on a research role in their own teaching practices. There do exist however several incentives to change this, such as Scholarship of Teaching and Learning (SoTL). SoTL is likewise a professional-development incentive that encourages teachers to place equal importance on partnering with students to make discoveries in how they learn, publishing findings, and using these to improve knowledge in the field.<sup>xvii</sup>

Another characteristic of American systems is project culture. Problems are addressed and goals are set by bringing together the multiple areas of expertise. This is particularly effective in the experimental sciences and medicine. Whether you're trying to launch a rocket or treat a patient, it eventually becomes clear whether or not the coalition of different experts was beneficial or not: Did the rocket launch? Did the patient's health improve? In the social sciences and humanities, it's not as easy to judge.

What's even harder to do is apply the first of the Humboldt's freedoms: the freedom to learn. It means totally reversing the prevailing logic and putting faith in students. We saw an example of what this would look like in the unsolicited-studies majors. This reality applies to research as well. In Europe, it's often the dissertation advisers who chose research topics for doctoral students.

At the CRI, we decided to reverse the process and let PhD students lead the way.

I remember the first evaluation committee for the Frontiers in Life Science doctoral program. The evaluators on the committee came from different institutions and couldn't believe that our doctoral students had come up with their research topics themselves. The committee then looked to the students for reassurance: "We were told you came up with your research topics yourselves, but we know that can't be true. Tell us the truth. Raise your hand if what you're doing here goes against what everyone else in France does." All the students raised their hands! And then, after asking to speak in English, the students said, "We came here from around the world in order to do something new; we're sorry. We're going to speak the international language of science, which will allow our work to spread across the globe." The evaluators were stunned. They started by openly bearing their skepticism and by the end were asking how they could do likewise at their universities. This is easier to do today than it used to be, as our latest evaluation of the doctoral program shows. The name of the doctoral program has been changed to FIRE for *Frontières de l'Innovation en Recherche et Éducation* ("frontiers of innovation in research and education"). The new format was prepared with a team that, with director and codirector Muriel Manbrini and David Taresté, will now work with PhD students interested in topics that interface digital sciences, life sciences, and learning sciences.

The freedom to learn, the freedom to teach, and the freedom to do research. With regard to each one of these freedoms, the CRI has proven that it is possible to innovate,

and I hope we will keep pushing the boundaries further and further. But there must be more spaces for experimentation and innovation like the CRI for all those who want to get involved, whether they're researchers, teachers, students, or other key players. This is not yet the case.

Yet I'm not claiming in any way that we need to impose a system like ours on everyone else. While I truly believe in the virtues of bottom-up design, I don't think that this can solve everything. Just as in economics and politics, a changing world needs virtuous incentives from the top and a structure capable of identifying opportunities, seizing on them, and making them available to as many people as possible at a time. It's all about placing power in the hands of individuals who aren't tied down to yesterday's thinking.

## THE MOBILE UNIVERSITY

How can we make room for new ideas in a standardized system that lacks funding? This question is key, yet here again the answers already exist. The one I put the most faith in—open science—harkens back to freedom. It consists of reinventing our processes of discovery and encourages all stakeholders both to contribute to research and to adopt the researcher's approach.

Everyone can pitch in, even if you're not in school. All it takes is a smartphone,<sup>xviii</sup> which holds more computing power than NASA had to send astronauts to the moon in 1969. A smartphone contains an accelerometer, a gyroscope, a magnetometer, a GPS, an audio recorder, a camera—the list goes on. And of course, on your smart-

phone you also have access to the Internet, a global library updated in real time that you could spend a lifetime exploring and still not manage to see everything. Thanks to social media or even e-mail, you can stay in touch with a community of peers and mentors at all times.

In a way, with a smartphone, you have access to a mobile university.

Universities have been successful because they have given a network of scholars and students access both to the technologies they need to do research and to books. For Robert de Sorbon in 1253, it was thanks to his library's 2,000 books, all donations, that his college could become what it is today, Sorbonne University.<sup>xix</sup> For centuries, universities were exclusive and wealthy institutions, the prerogative of elites, but today they are within arm's reach of everyone. It's only major research centers with specialized equipment like the European Organization for Nuclear Research (CERN) that remain out of reach for common mortals. Yet even the CERN is involved in citizen science, inviting the public to contribute to their work.

There are still vast regions of knowledge left to explore. Every one of us has the ability to make brand-new scientific observations and become part of a network for sharing them. If one day you find a species of plant in your garden that you've never seen before, you can take a photo of it and share it online to get help identifying it. If no one can help you, it's easy to solicit help from scientists. And there are questions that you yourself can start to ask. Why has this plant species never been seen before in my area? Could it have something to do with a change in temperature?

Natural history museums from Paris to Los Angeles and beyond also host citizen science programs. The EPFL

engineering school in Switzerland created an app called NoiseCapture that calls on people to make sound recordings in the Geneva area in order to generate a noise map of the city.<sup>xx</sup> Stephen Friend started Sage Bionetworks and Apple's Health Research Kit to empower patients and invite data scientists to contribute to open biomedical research. Scientists started the Safecast radiation monitoring system in the wake of the Fukushima disaster as a way to map radiation levels around Japan, and it has since gone international. In the case of Fukushima, they collected radiation measurements from volunteers and provided open access to the data they gathered. It's worth noting that many people adapted their phones to be able to measure radiation exposure using open-source hardware.<sup>xxi</sup>

Had this kind of movement been possible in 1986 at the time of the Chernobyl disaster in Ukraine, governments wouldn't have been able to cover up radiation exposure. At the time, some claimed that radiation exposure somehow stopped miraculously at the national border. Likewise, we would have known that mushrooms, which absorb radiation and contribute to internal radiation exposure, weren't safe to eat. In a way, open access to data is as revolutionary as open access to information.

## OPEN SCIENCE

Data are the raw materials of information, and with information we can create knowledge. The more we're able to isolate something, break it down to the smallest unit, the better we can understand it. That's why physicists

at the CERN spent months observing the Higgs boson in their particle accelerator. Today, the Higgs boson is the smallest particle we're able to measure. It's the same with molecular biologists breaking everything down to a molecular level, or cellular biologists to the cellular level. The more you isolate something, the more likely you'll be able to understand its properties. Many sciences work in this paradigm, with very reductionist approaches. Scientists rejoice when they isolate something and can quantitatively measure its specific properties.

But when you isolate something, you cut it out of its natural environment and can miss a lot of the picture. The ideal would be working thoroughly on every level—for example, understanding a species on the molecular level as well as the ecosystem it inhabits, along with its cellular function and its anatomy.

Open science, combined with the power of digital, empowers us to do scientific work outside the laboratory. Coming back to smartphones, let's look at another example: sleeping. Until recently, in order to get sleep studies done, you had to spend a night in a hospital hooked up to electrodes. Their measurements are extremely precise, but the data are nonetheless affected by complex exterior factors that have to be parsed through, namely stress from the fact that you're sleeping in an unfamiliar place and your inability to find a comfortable sleeping position with electrodes all over you. Today, there's the "quantified self," which are primarily apps that let you collect data on yourself in the comfort of your own home. An example is iSleeping, developed by a PhD graduate from the CRI, Maxime Elbaz. There are fewer measurements available on these apps and the data are less precise

than what you would get at a sleep center in a hospital, but they do allow us to collect data on millions of people, while a sleep center has only a few beds at their disposal. Also, apps give us immediate feedback, so we can move more quickly from the data stage to the information stage when we compare our data with that of other people. We can answer the question “Is my sleep normal?” We can also read articles or join discussion forums, talk with coaches who can help us get a handle on the information, and so on.

Here we’re seeing another paradigm shift. Just like with majors and research topics created by students rather than imposed on them by professors, here it’s the people providing the data who decide to take part in research. They cocreate with the scientists, who traditionally come to a decision to study a topic without consulting anyone.

The cycle becomes all the more virtuous when the two approaches come together, hence the interest in participatory-science research protocols supervised by researchers, such as we see with the *Seintinelles*.<sup>xxii</sup> That’s how we go from the information stage to the knowledge stage.

As is the case whenever data is being collected, it goes without saying that these measures must be strictly controlled so that everyone’s privacy is protected. You should be able to provide data on your sleep patterns without the whole world knowing about them!

## TOWARD OPEN-RESEARCH COMMUNITIES

Mathieu Cisel was the first scientist in France to do a PhD solely through MOOCs, or massive open online

courses. After that, he became a postdoc collaborator with the *Savanturiers* at the CRI. He once said to me, “Now that there’s the MOOC, we should create MOOR, massive open online research.” MOOR would draw from citizen science and quantified-self applications for the purposes of learning and exchanging with others.

According to a 2016 survey, very few people have heard of citizen science. Only 4 percent of those surveyed had heard the term, yet it was noted that when people learn what it is, most show interest in getting involved, namely to contribute to advances in medicine, knowledge on biodiversity, and the climate.<sup>xxiii</sup>

Even the CERN has launched citizen-science projects. Their HiggsHunters program is an opportunity for citizen scientists to look through the CERN’s images of particle collisions to try to find Higgs bosons. Another CERN initiative resembles that of Foldit. You can install CERN software on your computer so that when you’re not using it the research center can borrow its power to run its simulations. According to the CERN, it needs power from 10,000 computers to match the power of a typical university computing center.

Oftentimes incentives for citizen scientists are financial, but much of the time citizen scientists are willing to take part simply out of an interest to learn. Here again, we can start to see the signs of a burgeoning learning society. More and more, regular citizens are both willing to contribute to research and learning through research. To shift into the next gear, we need to develop in two key areas.

The first one—and sorry to keep coming back to this, but it’s so important—is ethics. Forming ethics committees around biomedical research initiatives has been

standard practice for a long time. We now need these kinds of committees around research in computer science, artificial intelligence, robotics, and education. At the very least, governments need to expand the scope of their national ethics committees, eventually forming more targeted committees, and as well they should create open-participation forums, a kind of “open wisdom” or “open *phronesis*” for citizens. In my opinion, ethical discussion shouldn’t be restricted to groups of experts behind closed doors, regardless of how qualified they may be. This is regardless of whether it’s a public ethics committee or—perhaps all the more so—a private one. Take the case of Google’s ethics committee, which has been dissolved, but regardless, should it really be up to people paid by Google to lead ethics discussions on the future of artificial intelligence? If you ask me, the answer is no.

The second axis is education, and I’ll talk about this only briefly, as I can imagine I may be exhausting you on this topic. Education at every level must prepare us to be stakeholders in the knowledge society and not simply consumers and data providers. Primary school, once it throws off the old rote-learning methods, is in a good position to start guiding children in this direction. The *La main à la pâte* program<sup>xxiv</sup> at the Science Ac’ helped to launch dozens of such projects, the *Savanturiers* among them. Universities by nature have the means do this as well, as they are made up of professor-researchers. What universities need are spaces where people from all disciplines can meet to discuss the impact of the intelligence revolution has on each discipline. Secondary schools and high schools are often on the sidelines of this revolu-

tion—apart from a few exceptions, thanks mostly to the initiatives of some particularly innovative teachers and associations. What’s really a shame is that high schools in France provide preparatory classes for students trying to get into France’s elite universities, and it’s these young people who could really benefit from involvement in interdisciplinary projects, both individually or in teams, just like the best students do in major universities around the world.

## FROM OPEN SCIENCE TO A LEARNING SOCIETY

Moving toward more open science means working to bring about a more open society. Participatory-science initiatives are not the prerogative of elites and offer considerable opportunities to learn. A lot of people miss out on the joys of learning in school but discover them later in life when they decide for any number of reasons to take part in research, whether it’s doing sleep studies, participating in trials for anticancer drugs, etc. These opportunities widen our field of vision because they take us from the specific—my sleep, my illness, etc.—to more general understandings of these issues.

That’s what the learning society is all about. It’s leaving traces of your most original and innovative achievements. You explain to others the path you took to resolving a certain issue. Later on perhaps you create content or technologies that will help others grasp the concepts. You help them learn as well as learn to learn. You empower them and perhaps even instill in them a desire to explore further.

## MAJOR CHALLENGES

How can we keep the virtuous cycle going? What I like to do is name the challenges we face. It's best to start with the big ones, and there's no shortage of them in today's world: challenges of inclusivity, sustainable development, peacemaking, etc. Let's not wait for answers to come from a small group of elites, the people who have excelled since they were teenagers at "beating" their classmates in our current competitive system that rewards students for memorizing yesterday's knowledge. In the learning society, let's get everyone to work together to come up with creative solutions that will benefit the greatest possible number in the future. As news magazine *The Economist* pointed out, more and more universities are changing the traditional education model for a challenge-driven approach to learning.<sup>xxv</sup>

Let's look to China for a moment to get a better understanding.

I've been going to China a lot ever since the CRI worked with Tsinghua University to establish a learning center designed by a CRI alumnus, Luping Xu. Tsinghua University is the 2<sup>nd</sup>-ranked university in China, with its primary location in Beijing and a graduate school in Shenzhen. Shenzhen is where we started "Open Fiesta," from *Open Faculty for Open Innovation, Open Education, Open Science, Open Technology, and Open Art*.

Thirty years ago, Shenzhen was a tiny fishing village, but due to its proximity to Hong Kong, the Chinese government designated it a Special Economic Zone, and after a few years it became one of the most innovative cities

in the world. Its population has boomed, numbering 16 million as of 2016.

Tsinghua University has no problem attracting the best and brightest. Indeed, of China's 3 million first-year undergraduates every year, Tsinghua accepts only 3,000 students. Yet heads of the university noticed that incoming students were lacking the skills that will be most valuable in the 21<sup>st</sup> century, namely creativity and cooperation. In fact, 14-year-old high school students were found to be more skilled in these areas than the 18-year-olds. The culprit was the year students spend cramming to prepare for the *Gaokao*, the national college entrance exam in China. It stifles any creativity the students may have. Yet the *Gaokao* is almost a national ritual, with some students spending 16 hours per day studying for it and some families spending thousands of dollars on tutoring classes.<sup>xxvi</sup>

It occurred to one of the university's vice presidents that the school was accepting students based on *Gaokao* scores despite the fact that the *Gaokao* wasn't perhaps the best evaluation. Thus the university couldn't be sure it was bringing in the best and brightest. Furthermore, it was unclear if the university itself offered the best possible education to students, as the school functioned within the competition paradigm, used the system of separating disciplines to solve problems, and cultivated yesterday's knowledge rather than the ability to be creative and collaborative.

Thinking about how they could reignite creativity in students, they co-established Open Fiesta with us under the direction of Luping, a brilliant researcher in physics, nanotechnology, biotechnology, and education. The

goal is to train students to meet the great challenges of the 21<sup>st</sup> century using open science, citizen science, and the open-source technologies that China champions. Teaching methods are innovative, and social entrepreneurship is encouraged.

Why is China—or anywhere else for that matter—so interested in open innovation? Because it works! Several studies show how effective open innovation is as a complement to internal research and development departments.<sup>xxvii</sup>

This is why platforms such as Kaggle<sup>xxviii</sup> have emerged. Since 2010, Kaggle has been offering businesses the opportunity to post issues they're dealing with on the Internet in order for data scientists online to develop algorithms to solve them.<sup>xxix</sup> General Electric, Tesco, Microsoft, and NASA have all used it, despite the fact that the companies cannot claim ownership of the solutions found using Kaggle. A condition of using a service such as Kaggle is that, while the company's original source code remains confidential, the solution to the problem must be made public. InnoCentive,<sup>xxx</sup> started by pharmaceutical group Eli Lilly, offers the same kind of service.<sup>xxxi</sup>

When open innovation goes hand in hand with collective intelligence, meaning all those involved share their innovations with one another, the result is so much richer than when we just send a problem off to scientists who never leave their labs. Karim R. Lakhani<sup>xxxii</sup> at Harvard Business School demonstrated this with examples from bioinformatics. Regardless of the size or draw of a given organization, be it public or private, there will always be more brains outside the organization to solve issues than brains inside the organization.

These spaces where collective intelligence can be mobilized are excellent for learning. Harvard professor Richard Elmore developed a systemic way to think about our different learning environments. Traditional education is an example of what he calls a Hierarchical Individual environment: individuals learn within a program structured hierarchically. This is in contrast to a Distributed Individual environment in which a self-disciplined person can satisfy her desire to learn on her own, free from structure—at a library or on the Internet, for example. Opposed to individual learning environments are collective learning environments. Take sports, for example. Individuals learn together, but according to rules created by others, i.e. what Elmore would call a Hierarchical Collective environment. Contrary to this is a Distributed Collective environment, where individuals can learn together free from structure, organizing themselves however they please (learn more about Elmore's system in his MOOC<sup>xxxiii</sup>).

The Distributed Collective environment is the least well-known of the four. In it, you find individuals who want to learn from one another, people such as those described by Claire Héber-Suffrin when she talks about reciprocal knowledge-exchange networks. Her thinking is that no one knows everything and everyone knows something, so we can only benefit when we exchange knowledge.<sup>xxxiv</sup> These sharing networks continue to multiply, primarily in communities facing never-before-seen challenges and opportunities, where innovation is a must. We've likely all had experience with each one of these quadrants at one time or another in our lives. In which setting do we learn best? That depends on the individuals involved, the issue

or topic at hand, and the way each of these environments is organized. Whether you're faced with open, complex challenges or simple lists to memorize, different learning environments will be better suited to different needs.

The philosophy of open is not exclusive to ideas and coding. You can also use this philosophy to make objects, such as in fab labs, or make equipment. The most famous open-source community is Arduino, a company that develops, fabricates, and sells kits for building microprocessors and microcontrollers, which are the “brains” behind so much technology.<sup>xxxv</sup> And the processors are low-cost and easy to build. There's even an Arduino Day, celebrated around the world. In 2017, for example, people organized 499 Arduino Day events in 78 different countries. But going beyond how simple and cost-effective the processors are, the real power of Arduino is community.<sup>xxxvi</sup>

At the CRI and in Open Fiesta, we bring together open innovation, open education, open science, and open technology, but these wouldn't be as impactful if we didn't include open art. It's my belief that artists can benefit from the philosophy of open and benefit from what's being done in other communities. We've seen this taking root in recent years in the proliferation of spaces and events that bring together arts and science. We're living in a time when questions of gender, the human-nature relationship, and life and non-life are acutely raised. These questions are too complex for any single discipline to handle. Artists have been questioning the world for a long time, and it's up to institutions to find a way to bring the universe of artists in contact with that of scientists in order to enable them to engage in dialogue.<sup>xxxvii</sup>

Here again, innovation is less unprecedented than one may think. Until the 17<sup>th</sup> century when the big academies were started, knowledge disciplines were not separate. In Renaissance humanist culture, art and science went hand in hand, as we see in the great figures of the age. Galileo and Descartes, not to mention Leonardo da Vinci, were all trained in art and philosophy. Galileo was an illustrator, which aided him in his observations of the sky.<sup>xxxviii</sup>

In the English-speaking world, more and more STEM programs are becoming STEAM programs because science, technology, engineering, and math can harness even more combusive power by integrating art and creativity into the curriculum.

Spaces are being created where artists and scientists can live side by side, such as at MIT, which even hosts magicians, as technology can be inspired by magic and the arts and vice versa. While creating these environments comes down to pioneers doing as much as they can with whatever means at their disposal, these spaces thrive when visionary leadership and a bit of budget come into play. Open Fiesta in Shenzhen was made possible thanks to then president of Tsinghua University Chen Jining, who was willing to believe in a systemic approach to open learning. What he wanted to do was create a learning community, a place where teaching methods could be revolutionized and everyone could live together and learn together. Only a short time into his tenure, he was named Minister of Environmental Protection, a position in which he managed to enforce environmental regulations that none of his predecessors had been able to implement because of powerful lobbies. Later, in 2017, he became the mayor of Beijing, and he

now hopes to create another space dedicated to new ways of learning that's open to all.

## EVERYONE'S A SCIENTIST

As we've seen looking at Alison Gopnik's work, asking questions is natural for children, and it's around age 4 when kids ask the most questions, meaning we're all born scientists. We've also seen that all it can take is an education environment where kids can really thrive, and they can get published in a science journal. The problem is that after childhood not all of us are trained in research, nor are we surrounded by caring mentors or put in situations where we can experiment. How can we cultivate our natural inclination toward research, then preserve it and deepen it? What methods are out there to help us refine and strengthen our gift for asking questions?

These are crucial challenges in today's world, where artificial intelligence provides more and more answers, and the environmental crisis we're living through is making us question our societies and lifestyles. This includes asking questions about how decisions are made, individually and collectively, or how human or artificial entities make decisions for us.

If we compare our time to that of Socrates, it's clear that we have more reason to question ourselves. Athenians must have faced tough challenges, but the planet itself wasn't in danger, and the status of our species wasn't disrupted by discoveries in NBIC. We have more reasons than the ancient Greeks to ask ourselves questions, humbly accept the fact that we don't know everything,

and admit that we live in a world where uncertainty prevails over certainty.

What should we do? Learn to manage transitions, to make decisions despite uncertainty? To say “I know that I don’t know anything” as Socrates did? This statement in Socrates’ time made him a sage of sages. Kant said, “We measure the intelligence of an individual to the amount of uncertainties that he is able to support.” We shouldn’t run from uncertainty, and we definitely shouldn’t deny it. Rather, we should be brave enough to ask questions and say “I don’t know” when indeed we don’t know.

The ability to doubt and question is not easy to assume. Certainty is far easier to bear, but it’s all the more dangerous when certainty turns out to be false. That’s what Socrates understood. He said it’s better to ask questions and be uncertain than hold false certainties as truths. That’s what researchers know. They know their certainties are only temporary. Their certainties are only certain until something else comes along to complement or replace them. This doesn’t necessarily mean the former certainties were invalid. Newton’s laws of physics still hold in certain domains, even though Einstein showed us that we can go so much further than Newton did. Newton’s laws explain the level of our human experience; they just didn’t go far enough.

Moreover, if we take a moment to think about those attempting to impose their certainties on us as absolute and not provisional, we notice that these are people who aren’t necessarily interested in our well-being. In most cases even, they are merely looking to control our brains, to make us docile consumers, if not to lead us altogether into

fatal forms of extremism, as totalitarian regimes try to do, attempting to control those who don't think like them.

Is it reasonable then to keep kids competing against one another? And likewise, is it then reasonable to evaluate students based on their ability to answer yesterday's questions? I don't think so. Memorization and calculation, the two primary abilities on which we test students, are performed much better by machines than us. It would make more sense and be more advantageous for students if we also tested their ability to formulate questions and devise new approaches. Today, curricula like these are only introduced at the master's and PhD level. The question that should underpin all education policy in the 21<sup>st</sup> century is: How can we make students understand that there aren't always definitive answers to good questions?

A good way to teach this lies in considering the same problem from many angles and encouraging students to think about questions as either scientific or not scientific.

What is a scientific question? A scientific question is a question we hope to be able to answer one day. How can we know if a question is scientific? When we come up with a method for finding an answer. To do this, we draw from theoretical corpuses or experimental systems. And this approach doesn't apply only to the physical world. A metaphysical question such as "Does God exist?" can be treated the same way. As it stands now, scientists are unable to answer that question. But they can ask plenty of questions surrounding this question. For example, why do humans believe in God? Since when have they done so? How do some cultures go from belief in several gods to belief in one god? Are these beliefs universal? Do a society's laws change as belief in God changes over time? Are

people who believe in God better off? Worse off? The questions are endless, and that's how science progresses. We keep asking the next question, one to which we don't have an answer yet. In short, even to a question that is not scientific, scientific questioning can offer partial and transitional elements of an answer. This makes it possible to move forward in our knowledge, at any age.

This is how we could create “anti-textbooks,” similar to what *Escuela Nueva* did with its Learning Guide, which resembles a comic book and combines reading, math, social studies, etc., into each lesson. The purpose of such a guide is to look at the most poignant questions being asked currently on a given topic rather than trying to construct the truth in parts. This is a good way to introduce to students the notion of open questions such as those in philosophy. What is beauty? What is truth? What is justice? By their very nature, the answers to these questions are open-ended. Such a guide would also take into account the fact that questions are not all of the same kind. Philosophical questions are different from scientific questions, existential questions different from personal questions, etc.

## MENTOR-TEACHER

Moving in this direction will be possible only if it's accompanied by robust reform in initial teacher training and continuing professional development for teachers. Teacher training needs to focus on the values of adopting a mentor-like attitude. The word *mentor* comes from the character of the same name in Homer's *Odyssey*. When Odysseus leaves for the Trojan War, he puts his son

Telemachus in the care of Mentor, and whenever Odysseus' palace is visited by Athena, the goddess of wisdom and science, she always takes on the form of Mentor.

The mentor-teacher or tutor-teacher is not without experience. It's a professional with a high level of scientific expertise who cares about students and strives to educate them in a way that's stimulating and beneficial to them, without pretending to know more than he does. The Finnish teachers in the documentary *Tomorrow*<sup>xxxix</sup> embody an attitude of mentorship, and we know that the Finnish education system produces the highest international test scores in the world.<sup>xl</sup> It goes to show that mentorship fosters serious learning.

As we've already seen, this mode of operation also implies a complete overhaul of the way education systems are managed. School principals and presidents apply modes of management without direct authority over education practice, and school inspectors enforce it, yet their very job title spells out their mission to police educators rather than collaborate with them.

In a learning society, teachers are not the only professionals who can reflect on their practices and continue developing collectively. Anyone working in any organization can do this. Some businesses in particular are becoming savvier in this regard, as illustrated very well in the book *Reinventing Organizations*,<sup>xli</sup> by former McKinsey & Company management consultant Frederic Laloux (see also a talk he gave in Brussels<sup>xlii</sup>). In the past, if a business wanted to increase its long-term efficiency, it tended simply to create more and more layers of management. This practice made sense in the 19<sup>th</sup> century. It was more difficult for information to circulate, and the

best way to make sure every stage of production was synchronized was to create more and more management outposts. Note that many departments in government, namely education departments, function the same way. The managerial hierarchy would grow bigger, the cost of management would increase and, with it, payroll. Information traveled upward to the top, the top would then make decisions, send directives back down, and the managers at the various levels would see they were carried out.

This management style produced results when the world evolved at a slow pace. Countries like France and England were able to maintain very extensive colonial empires using these principles. You can still see these in practice today in some older organizations formed at a time when information traveled on horseback and steamships.

Today, these management principles leave much to be desired now that information travels much faster and changes, evolutions, and needs are ever increasing. It's comparable to what we see in neurology. You make certain decisions consciously while others, reflex reactions in particular, are made automatically in your spine. When you burn yourself, you react immediately without waiting for the brain to come up with a directive. It's the same for ant colonies. Each ant self-manages going by its genome, which itself is the product of evolution. Essentially all systems of organization face the same kinds of questions: In what circumstances should people make decisions alone, and in what circumstances should information be "sent up"?

With the development of the Internet, e-mail, instant messaging, and social media, the game has changed entirely. Information no longer travels on a vertical axis only. It travels horizontally as well, and it's now possible for us to be involved in an infinite number of information and decision-making spheres in real time.

Laloux created a model to depict the “reinvention of organizations.” It uses the color spectrum starting with red being full micromanagement across intermediary stages to blue for distributed decision-making.

Distributed decision-making replaces the traditional pyramid structure. It's a system of collective decision-making done in smaller teams according to a procedure that's nonetheless systematized. This is to avoid the pitfalls of companies who want to appear non-hierarchical with distributed decision-making but become only lumbering and inefficient organizations where power politics run amok behind the scenes.<sup>xliii</sup>

In biology, we talk about evolvability, which means an organism's capacity not only to adapt to a changing environment and pass on an adapted trait but also—and most importantly—to pass on the very ability to adapt to changing environments, e.g., the way antibiotic-resistant bacteria do.

## MAKING “MISTAKES” IN ORDER TO SURVIVE

The focal point of Laloux's argument is that if everyone understands their organization's overall objective, each team player will be able to act in the most appropriate

way on the small scale, sending information up only when there's a need, thereby reducing the amount of inefficiencies. This structure is possible only in organizations that consider their employees actual human beings and not just cogs in a machine. Such companies don't schedule meetings late at night when employees should be with their families, and there are days when families are invited to visit the workplace so as to integrate work and family life. In short, companies show their employees feel that, in the eyes of the company, no one is reduced because of his status as an employee.

This is what Dominique Pon does as managing director of one of France's best private hospitals, the *Clinique Pasteur* in Toulouse. Hospital profits are invested in research and development, and hospital staff are owners of hospital stock. What's the hospital's secret? According to Pon, investing in humanity does not simply mean handing out end-of-year bonuses. It also means investing in well-being at work, which benefits both hospital staff and patients. *Clinique Pasteur* has 8 nurses for every 15 patients, 4 times the ratio of most other hospitals. Since 2015, the hospital has housed a health-care start-up accelerator, Hi-Lab, which has helped develop, among other things, apps for preventing medication errors and a digital patient space. Patients' families and friends can follow in real time where their loved ones are, if they've been to surgery, etc. Whenever the hospital has the opportunity to humanize the system, they do it, Pons said.<sup>xliv</sup> Taking care of patients and staff should be obvious, but it has become difficult to do in organizations that are too constrained by history and financial and administrative thinking. The more a given

job involves tasks that can be experienced as degrading, the more essential attention to the human being is.

## OPEN PLATFORM FOR INNOVATION AND CREATIVITY

What Frederic Laloux showed to be true in the world of business, the Organization for Economic Cooperation and Development (OECD) has proven true at the state level. It reported a strong correlation between feeling valued, happiness at work, and overall well-being.<sup>xlv</sup> Countries that create open platforms for innovation and creativity contribute to creating a win-win situation at different levels. Individuals are happy, the company is efficient, and the quality of services improve along with trust in the company.

How can we bring small-scale success stories to others? How can we ensure that policy in a hospital in Toulouse benefits others? Why can't experiences in the medical field inspire in some aspects experiences in other fields—education, for example? Learning organizations try to do just this. Digital technology allows these organizations to learn from each other through sharing. Even companies in competition with one another can find solutions together to problems that plague the whole sector, allowing it to progress and adapt to these challenges.

In yesterday's world, only a small, educated elite had access to data and made decisions. Today, we're able to benefit from tools that allow the greatest number to contribute to collective well-being. The more we educate people to contribute, the more people we'll have looking

for solutions, and the more we can hope that our problems will disappear one by one. This is all the more likely if we document the solutions we find, perfect them, and share them.

## LEARNING TO QUESTION YOURSELF AS AN INDIVIDUAL, LEARNING TO QUESTION OURSELVES AS A COLLECTIVE

What we've said about individuals and their capacity to learn, as well as to "learn to learn," can also be said of the collectives to which we belong: family, region, organization, country, continent, etc. All these collectives can be invited to be as learning as possible, and I think this is largely a shared aspiration, as few of these collectives seem completely satisfied with the way that they operate. If you've paid close enough attention to your environment, it's likely you've already noticed signs of a growing learning society in your area. Throughout the world, middle grounds and "third places" are cropping up. "Third place" is a term popularized by American sociologist Ray Oldenburg<sup>xlvi</sup> to describe social surroundings separate from home and work or school where we form relationships and learn.

Libraries and especially cafés used to be the quintessential third places in the 19<sup>th</sup> and 20<sup>th</sup> centuries, before everyone had access to a global library on the Internet. Maker spaces are today's great third place, the most common of these being the fab lab. At its best, maker spaces are open to the entire community, and everything made or created at the maker space is documented so

that future users can benefit from it. Maker spaces, hackerspaces, and hacklabs are designations for neighboring realities, i.e., providing equipment, functioning on a principle of community of practice, and an ethics that values freedom of access, collaboration, autonomy, and solidarity.<sup>xlvii</sup>

These third places also put together sessions in which everyone is invited to work on a project together or find a solution to problem, often one that's real in the community. By nature, these are democratic incubators. You leave your usual circles of friends, environments, and influences, i.e., family, school, or place of work, etc., and the topics addressed collectively are related to citizenship. You participate in solving a problem that perhaps affects one of your relationship circles but is not limited to it. These spaces naturally invite us to move beyond disciplinary boundaries since they are not compartmentalized, as universities can too often be if they are not careful.

These third places are where the learning society finds its best expression. It's the most visible manifestation of a learning society in a given area. It's a place where the hummingbirds carrying drops of water, who along couldn't put out the fire, can meet one another and together implement new, effective strategies. Above all, these third places can also become breeding grounds for starting new associations, teaching innovations, regional projects, etc.

In France, hundreds of these spaces exist, and throughout the world there are thousands. Some are already remarkable (and remarked) reinvention spaces, such as the Woelab in Togo, launched in 2012 by architect Sename Agbodjinou, who made news headlines with

a 3-D printer the lab constructed from European electronics waste dumped in Africa.

But Woelab's purpose goes beyond this. Agbodjinou has stated that everything the Woelab does is driven by an urban project called HubCité ("hub town"). Its premise is that, today, the start-up is the best way to change the face of cities, working faster than an urban planner ever could.<sup>xlvi</sup> Woelab operates as openly as possible, and technology is only part of the wider project. It's an all-inclusive space where everyone can realize their potential. Like in all tech hubs, there's a lot of technology there, but they've also recycled concepts from traditional African society to the tech world, e.g., the initiation enclosure, where young people go in traditional, rural initial ceremonies. They try to create an open community. There are carpenters, fashion designers—there was once even a homeless person. It's really a sociology people aren't used to in that kind of space.<sup>xlix</sup> We can create third places of practically any size and in any environment in order to meet the challenges in a given community.

In the Lorraine region in northeastern France is a fab lab for high school students with disabilities called FabUlis, ULIS being the acronym for spaces in French schools where disabled students have access to inclusive education. Since 2014, FabUlis has been located at a high school in the region. At first it accommodated only students with disabilities, but today all students can have access to the space.

The organizers of the space call this reverse inclusion, meaning that, rather than integrating students with disabilities into spaces reserved for the able-bodied, it invites the able-bodied into a space designed primarily

for people with disabilities. As an example of the space's success, cofounders Baptiste Melgarejo and Alexandre Benassar recount how, after only two months in FabUlis, students with cognitive disabilities put together a video presentation of their special education program, and it was shown to classmates, parents, and others who came to learn about the space.<sup>l</sup> The two have also remarked that, since the program started, attitudes in the high school toward students with disabilities have completely changed. Certain teachers have even changed lessons plan to bring students to FabUlis for class. Other teachers “exchange” their general-education students for students from FabUlis, giving general-education students the opportunity to work at FabUlis and bringing special-education students into the general-education setting.<sup>li</sup>

The total original cost for all tools and materials at FabUlis was only €40,000. How can a space like this transform a region? By being open to everyone, as recommended by MIT's Fab Charter.<sup>liii</sup> Say a local business owner wants to prototype an invention that would require a laser cutter and a 3-D printer, which she doesn't have. She can have access to these tools at the fab lab, get help from some of the young people there if need be, and perhaps along the way even find some recruits for internships or jobs. There's a dynamic that gets created, first within the maker space, then in the community. Over time, this dynamic can expand to the whole region. Other people will hear about it, come check out the space, and be a part of the emerging ecosystem that's centered around what in physics is called a nucleation point, i.e., the point where atoms start to crystalize. These are self-catalyzing and exponential dynamics.

One of the *Savantuiers* projects called *Savanturiers du cerveau* (“*Savanturiers* of the brain”) got to collaborate with FabUlis. The goal of the project was to provide students with an introduction to how neurons work and illustrate the basic principles of brain plasticity, meaning how neural connections rearrange themselves to find alternative solutions. It’s the basis of learning. It helped the students also understand that sleep deprivation, stress, and consuming alcohol and drugs can negatively affect brain function. At the end of the year, students held a conference attended by fellow students in which they discussed the value of the brain and the importance of taking care of it.

This example is a perfect illustration of the incredible dynamic we have yet to tap into in order to “learn” in the 21<sup>st</sup> century. The *Savanturiers* program took inspiration from the mission of the CRI. Reverse inclusion at FabUlis took inspiration from teaching principles developed in the early 20<sup>th</sup> century by American philosopher John Dewey and his method called “learning by doing.”<sup>iiii</sup> Fab labs were invented in Boston by Gershenfeld. The launch of FabUlis was driven by the energy of two teachers in northwest France who placed the well-being of their students above all else. Thanks to digitalization, all these education initiatives can converge and connect.

## A LEARNING PLANET FESTIVAL

Temporary third places can also catalyze these energies. For example, on World Music Day hundreds of musicians in cities all over the world play music on the

same day. Why not create a learning-planet festival? The CRI is working to do just that. We'll talk about it in more detail in chapter 6. There already exist local versions of this throughout the world, both general celebrations of learning and events that target specific sections of society. In Singapore, the Lifelong Learning Festival is a month-long celebration of the joys of learning (#lovelearning).<sup>lv</sup> Every September in the Netherlands, the Van het Leren Festival is specifically intended for seniors, minorities, the unemployed, people with disabilities, and people without high school diplomas.<sup>lv</sup> Australia has the Sydney Learning Festival for 5- to 8-year-olds.<sup>lvi</sup> The Danish Learning Festival brings together 8,000 attendees from the world of education.<sup>lvii</sup>

Let's look at Singapore's festival again. At the 2017 festival, four major themes were talked about: learning for a digital future, learning together, DIY learning with technology, and lifelong learning. All learning spaces were invited to open their doors and present projects they were pursuing. Yet if you think about it, any space can be a learning space. A baker could open up her bakery, a banker the bank's trading room, a nurse one of the hospital's wards or research labs, etc. In Singapore, the festival is family-oriented and intergenerational, which helps the city develop as a learning territory and embodies the fact that learning is a lifelong adventure.

Such initiatives exist everywhere. All that's still missing, unfortunately, are bodies that let us document these disparate projects, to bring together the different initiatives so that other teachers in other regions can duplicate a system like FabUlis without having to start from scratch. We need to create mechanisms that help us create

these kinds of projects as well as give them visibility, make them easy to understand, and give others the opportunity to adapt them to fit different community settings. So far we have observed a state of mind. Now we need to make it a culture that will allow for this revolution to break out of its inner circles.

There are other mechanisms for mobilizing community energy on specific issues. One example is creating prize. In 1919, hotel owner Raymond Orteig wanted to award \$25,000 to the first person to make a nonstop transatlantic flight from New York to Paris. Eight years later, Charles Lindbergh successfully completed the flight in the monoplane *Spirit of St. Louis* and collected the money. More importantly, however, is that a total of \$400,000 was invested in aeronautical research by the nine teams competing to win. This same idea was used by Greek American Peter Diamandis, a successful businessman, who created the X-Prize. In 1996, Diamandis announced he would award \$10 million to the first team to build a space vessel that could take three people 100 kilometers from the Earth and back two times in two weeks. The X-Prize foundation didn't have all \$10 million, so they took out insurance against the risk that someone actually succeed in their somewhat crazy challenge. Eight years later, a team from Mojave Aerospace Ventures did it. Here again though, the important piece is the overall investment. Twenty-six teams from seven different countries took up the challenge, investing a total of \$100 million in research! The X-Prize foundation has launched several other challenges, one of which, currently active, seeks to revolutionize education. The goal is to design autonomous-learning software for chil-

dren in the developing world, where education systems are often unable to handle increasing numbers of children. Five finalists were picked in 2017, each one given \$1 million to prototype their ideas.<sup>lviii</sup> These initiatives could be developed anywhere in the world as a way to face the growing number of challenges in our time.

## WORKING ON TRANSITIONS TO COPE WITH TRANSITION

Third places provide yet another benefit: They can be the place where we work collectively on systemic changes, on transitions, whether these are social or between compartmentalized institutions. In most societies, interfaces between institutions either don't exist or are ineffective, yet often it doesn't take much to make major changes. In the city of Rennes in western France, just as there's the office of the city treasurer, there's an office of time, which sees to efficient scheduling of services throughout the region, namely with regard to the city's transit system. The office found that simply by changing the start times of some classes at one of the major university campuses in the city, rush hour in city could be eased considerably. The start of classes for first- and second-year students was pushed back 15 minutes, and the entire city felt the change.<sup>lix</sup> All it took was creating an interface between the transit company and the university.

And yet, for every successful example, how many examples of dysfunction could we name? And not just in transportation.

Working toward systemic changes is a major challenge in our world, especially as more and more aspects of our lives are systematized by algorithms, reducing us to bits of data to be “processed” in the most rational way possible. The more these algorithms invade our lives—and what we’re seeing now is only the beginning—the more we’ll need places that remind us that we’re not data or mechanical cogs, that we’re multidimensional beings that deserve to have a say.

So, let’s learn everywhere.

And let’s learn at all ages.

We’ve already spoken at length about children learning at school and adults learning in the learning society. Let’s look at two other periods in life that receive little to no attention in education policy debates: preschool learning and learning in retirement.

Preschool is absolutely critical. We’ll come back to psychologist Alison Gopnik, who investigates how babies think. Psychology is not the only science right now that’s confirming how important it is to begin education as early in life as possible. Economics confirms this as well, namely the work of Nobel Prize winner James Heckman and his pilot project in Colorado called the Perry Preschool program. His initiative invested in early-childhood education for underprivileged children starting at birth. Heckman showed that return on that investment was 7 to 10 percent per year, i.e., a \$100 million investment would yield between \$107 million to \$110 million, both in reduced costs in health care, remedial education, and criminal-justice-system expenditures, as well as direct benefits, namely in increased school and career achievements and greater contributions to society through taxes.<sup>lx</sup> The short-term

costs are small compared to mid- and long-term benefits. We need to be able to make that initial investment, which is what social impact bonds, i.e., investors help the public pay for better social outcomes and then receive the savings later on, seek to do, and we're seeing these develop more and more.

Don't think I'm underestimating how difficult it is to really change things. Just in early childhood, the issues to be addressed involve both many scientific disciplines that are each compartmentalized (pediatrics, psychology, etc.) and equally diverse and compartmentalized institutions (health, social affairs, etc.). These formal institutions must be linked with the informal institutions, beginning with the family, the first place where a young child is educated.

Who, for example, informs parents that international studies show that reading stories to children is one of the best predictors for their future educational success? And how do they inform parents? If parents can't read, or read very poorly, who will read to the child? Who explains to parents that screens in general and television in particular are not allies to learning unless their time is supervised and only specific programs and applications are allowed? Who explains to parents that there are addictions to social media and games in the same way there are addictions to drugs? Who informs parents that sleep is essential for learning but that screen-based light affects sleep?

Even though the most dramatic gains in learning are in early childhood, public action in this area is at its most fragmented and least organized. Day cares, for example, could be great laboratories for participatory science on early childhood and contribute to forming a child-centered learning community, with the transfer of informa-

tion between postnatal- and pediatric-care services, the child's day care, the child's preschool, and where appropriate, assistance programs for certain demographics and families. At the CRI, we decided to launch a parents and babies lab, an open third place for drafting new policy ideas in order to allow parents and future parents to contribute to advancing knowledge and technology on these topics.

Retirement is also neglected, even though these days it can last longer than years spent working! Serge Guérin and Pierre-Henri Tayaillot remind us in their book *La guerre des générations n'aura pas lieu*,<sup>lxix</sup> translated approximately as "there will be no generation war," that retirees keep the responsible-citizen machine running. Humanitarian organizations and advocacy groups are largely comprised of people in retirement, a third of mayors in rural areas in France are retirees, and in France four million retirees are caretakers for older retirees. Do our societies invest enough in professional training and support for those who work with children? No, clearly. But they're losing out all the more so by not tapping into what our oldest citizens can contribute. Retirement homes and palliative-care facilities could also be great places for research.

And this would be first and foremost for the benefit of residents and patients in these places. Studies done in these types of facilities show that ideas about quality of life are actually much more subjective than you think when you're in good health. For example, one way of looking at it that you hear when talking to these individuals is lining up what we want with what we're actually capable of doing. Expectations must be adjusted to take

into account limitations, but so long as we can continue to enjoy strong interpersonal relationships, we can have real quality of life despite those limitations.

Sharing these experiences can be beneficial for everyone. People who care for the elderly say that the elderly don't worry over things most people worry about. The elderly don't talk about money or power. They talk about love, values, relationships, even spirituality. How are these people remembered? What are we putting in place to allow them to transmit their ideas, values, stories, and emotions? If, at the end of life, what matters isn't what society pushes us to chase after in our studies and professional lives, then doesn't it make sense to focus on what really matters before reaching the end of our journey?

American author John Izzo documented the wisdom the elderly have to offer. With help from a few colleagues, he asked dozens of people, "Who do you feel is the wisest person you know?" He came away with the names of 235 people ages 60 to 105, each one described by friends and acquaintances as someone who had found happiness and meaning in life. Among them are a town barber, a Holocaust survivor, an Aboriginal chief, a CEO of a company, etc. All 235 of them, with a cumulative 18,000 years of life experience, were asked the same questions: What brings you the most joy? What matters in life, and what's unimportant? Their answers are the subject of Izzo's book *The Five Secrets You Must Discover Before You Die*,<sup>lxii</sup> in which he illustrates five tenets common to all of their wisdom: Be honest with yourself, leave no regrets, become love, live in the moment, and give more than you take.

In the same line of thinking, the Japanese have developed a concept called *ikigai*, a philosophy postulating that your purpose, your *raison d'être* are at the intersection of what you feel for, what you're good at or can become good at, what the world needs, and what can empower you.

Finding the answers to these questions helps us find our passion, mission, profession, and vocation. We can ask these questions individually and collectively, for ourselves or for our organization, the society we're living in, or even the whole planet we're living on. We can consider these questions at any stage in life and help young people consider them as they try to figure out what studies they want to pursue. In traditional societies, elders fulfilled the role of passing down the values of empathy, caring, wisdom, and respect for nature. It was facilitated by the fact that the family unit was the unit of life at all ages. Our societies are no longer organized to allow us to learn from one another, no matter our stage of life.

Some people, such as Mary Gordon, have understood the importance of teaching empathy so that children can learn to take care of themselves, others, and the planet. Her program involves having a local parent make regular classroom visits with his or her young infant, and students learn empathy by observing the little vulnerable being and trying to identify its feelings.<sup>lxiii</sup> International evaluations of these programs have been very positive. The programs can prevent people from experiencing a lack of empathy at school, as one young man described it in a TED Talk that garnered a lot of attention on social media in France.<sup>lxiv</sup> Another approach, developed in Canada, is a school of emotions,<sup>lxv</sup> where the oldest

students look after the younger ones, which teaches older students responsibility and empathy. The Dalai Lama encourages these kinds of educational program that teach compassion. He has been involved in research on understanding the role the emotions and empathy play in brain development and education. In the book *A Force for Good*,<sup>lxvi</sup> *New York Times* journalist Daniel Goleman interviews the Dalai Lama as well as several researchers from around the world who are working on these same questions and creating knowledge on the science of compassion. It's a science that's being integrated in more and more schools today, particularly in Canada.

We also need to be able to take care of those who take care of others, whether they're children or adults. Here, I'm thinking namely of teachers, who, like doctors, are on the front line to help others, which makes them susceptible to emotional exhaustion and burnout. Océane Cordesse is a recent PhD graduate from the CRI who, after going to business school at the HEC Paris and then getting her master's in cognitive science, became a primary school teacher. She wanted to overcome emotional exhaustion in her own way and created an app that aims to provide support for people who work supporting others.

## THE BEST OF ALL POSSIBLE WORLDS

I'm well aware that you probably think I'm naive to say humans are inherently good and wise, especially if you've recently read a newspaper or watched the news. But I'm far from alone in thinking that there are more reasons to

be hopeful than to despair and that it's not in vain to bet on humanity.

Canadian-American psychologist and professor at Harvard Steven Pinker makes the case in his book *The Better Angels of Our Nature*<sup>lxvii</sup> that, contrary to what you may expect, we're likely living in the best of all possible worlds. This is not to say that we shouldn't keep working to improve it, but all the evils that humans have combated since our species first emerged have been on the decline: wars, famine, homicides, poverty, disease, illiteracy, etc.

In his book *Homo Deus*,<sup>lxviii</sup> Yuval Noah Harari makes a similar point when he reminds us, with his typical caustic humor, that today obesity is more of a threat to humanity than malnutrition. The main dark spots in today's world, which are by no means negligible, have to do with our propensity for negatively affecting the planet, whether it's eroding biodiversity, sapping natural resources, or causing climate change. We can no longer ignore the fact that ecological, agricultural, societal, and economic balance is under threat, and we need this in order to survive. As we become aware of these new global challenges, it's my hope we'll be able to face them collectively the way we have faced more personal and local problems in the past.

## FOR A "LEARNING PUBLIC SERVICE"

The fact remains that humanity is better off now than it ever has been and that there are, as I have shown, a wide array of initiatives confronting today's challenges. The learning society is not a pipe dream. Joseph Stiglitz,

winner of the Nobel Prize in Economics, even goes so far as to say that the learning society is essential to economic development and the health of our democracies.<sup>lxix</sup> If the printing press brought about the first phase of the learning society with knowledge circulating in the form of books, a new phase is now on the horizon. How to organize it? By creating a great “learning public service.”

The first pillar of a learning public sector is guaranteeing that everyone can access their own data. Today, the big tech companies, both the GAFAM in the West (Google, Apple, Facebook, Amazon, Microsoft) and the BATX in China (Baidu, Alibaba, Tencent, Xiaomi) know things about us that we don’t even know. The same goes for all the apps that we download on our smartphones because we accept the user conditions that, if anyone ever took the time to read, we wouldn’t agree to. In a world in which algorithms will be making more and more decisions in our lives, it’s essential that we establish easy-to-understand and transparent regulations on the ownership and use of our personal data, and these regulations should be subject to a democratic approval process. We should be the ones looking for relationships between measurements of our sleep habits, eating habits, education, health, modes of transportation, etc.—not the tech companies.

The second pillar should be developing data-processing tools that serve the public interest. Take how we consume culture, for example. Today, Amazon will make suggestions of books we may like based on our online activity and that of “similar” Internet users. But Amazon’s ultimate goal is commercial. Their aim is not to help us to be more cultured, it’s to sell us books and lots of other things. Facebook’s aim is not to bring us more fulfillment

by creating more social bonds, but to collect a maximum of data on us to then sell to advertisers.

These companies will not regulate themselves, as many have pointed out. Sandy Parakilas is among them. She pointed out in a piece for the *New York Times* that a company such as Facebook gains access every day to more and more strikingly intimate personal data, yet the company has no incentive to protect its users or signal abuses.<sup>1xx</sup> “Facebook needs to be regulated more tightly,” she concluded, “or broken up so that no single entity controls all of its data. The company won’t protect us by itself, and nothing less than our democracy is at stake.” I forgot to mention that Sandy Parakilas is not an anti-digital activist. She knows perhaps better than anyone what she’s talking about, as she worked at Facebook from 2011 to 2012.

We also know that, as if making tens of billions of dollars weren’t enough, which is the ultimate aim of a corporation, the GAFAM is determined to pay the least amount in taxes as possible through complex tax avoidance schemes. If there’s one thing that can prove definitively their lack of concern for the public good, this is it.

The learning society must come up with alternatives that takes into account our needs as citizens and respect for our privacy without selling our personal data. The goal should essentially be to increase opportunities for us to learn about ourselves and our environment or about issues in which we have a personal, professional, or humanitarian interest.

Think of a highway system where the only road signs are for private interests. Signs for the nearest shopping center would be very clear, while those for a 12<sup>th</sup>-century

monastery would be less so. This is what today's information highway is like. In the world of information on the Web, we continue to use Google, thereby making ourselves dependent on its goodwill, algorithms, and ultimately the way it decides to make money on a given day. If you're able to find your way to the monastery, it's because either you already knew how to get there or some business enterprise wanted you to find out about it, e.g., a shopping center near the monastery. The road signs on the information highway are set up either by website owners or advertisers. The results are sometimes in our best interest, but our best interest is certainly not at the heart of this system.

Putting our best interest at the center of the system doesn't mean entrusting everything to the government. Education institutions in the 19<sup>th</sup> and 20<sup>th</sup> centuries were primarily public, but the state nonetheless allowed private schools to thrive, subject as they are to certain inspections and regulations. It's perhaps too late to construct an Internet search engine as powerful as Google or a social-media platform as powerful as Facebook, but it's not too late to raise questions about national and European sovereignty when it comes to possession of our data, i.e., our e-mails, private lives, search history, etc. Likewise, it's not too late to create systems for openly sharing knowledge and experience, "maieutechnology" or "socratechnology," as I talked about previously. If civil society and politics don't take up these issues, they'll continue to be debated and decided by the huge Silicon Valley tech companies. And is that really what we want?

I strongly believe that we can and must create alternatives to these commercial services in the form of public

services that are focused on people and our ability to learn. Who knows, one day we may even find ourselves in a position to negotiate with the GAFAM!

Take for example the subject of relevance for content we find online. As more and more fake news proliferates on the web, how can users know how much credibility to give to information, especially if users are young or new to the issue being talking about? Traditionally, we have simply relied on our critical thinking. Yet scientists and journalists over the years have refined the critical approach to an art form, verifying sources, quality of evidence, standard procedure in experiments, and peer review by experts in a given field. These processes of holding information to account are what brought about the enlightenment.

On the Web, it's only a small fraction of users who take the time to verify the truth of what they read before sharing it in one click across social media. This is what creates epidemics of fake news, especially when fake news plays with our cognitive biases and causes us to be blinded by our emotions. Today it's clear that bad actors on the Internet know how to manipulate us, and they're able to undermine democracy, the media, and scientific institutions, relying only on our credulity and the bias of social-media algorithms.

How can we immunize ourselves against these social pathogens without creating another censorship bureau? Let me take another example from our distant cousins, bacteria. They have been fighting against viruses and parasites for billions of years, developing a defense strategy from which we can draw inspiration. When viruses attack bacteria, they introduce viral DNA into the bacteria. The bacteria who survive the infection use

this viral DNA to help them know when a new attack is coming and suppress it, and they pass on this ability to their descendants. The most interesting thing here for us is that the resisting minority of bacteria transmit the information that allows others to resist in turn.

Applying this strategy to the Internet, here's what we could do collectively. Imagine that you have a browser (or a browser extension or plug-in) that lets you flag content that you feel may be questionable. The browser then flags that content and makes the flag visible to others using the browser. This way, we collectively report unreliable content among the content getting the most traffic and, that way, slow down epidemics. We could even alert the people spreading the misleading content to help them to be more wary in the future.

Obviously, this kind of system would take time to refine. Intuition would tell you, especially if you've ever been witness to standoffs at the microscopic level between host organisms and parasites, that bad apples will use the defense system against itself, in this case besmirching the quality of information and jeopardizing the system's effectiveness.

In reality, there is no system that can resist all forms of attack. What we could do, though, is add another layer to this defense system by having users list their full names, professions, education background, and even their CV when they flag content and, along with this, have them present their arguments for why they feel the content deserved to be flagged. For example, they could say, "I was an eyewitness to such and such event, and I can prove it," "I found a fault in the logic," "I found proof that refutes

such and such claim,” etc. We can then hope to have more constructive debates.

Conversely, we can also use this system to recommend good content, e.g., a particular medical article. We can picture a positive form of annotating texts, an idea we’ve discussed at the Faculty of Medicine of Paris Descartes University. The university noticed that, beginning in the second year of study, the numbers of students attending lectures barely reached the 20s out of 500 students in a class. Despite this, however, the majority of students got passing grades at the end of the year. Dean Gérard Friedlander is thinking about closing the lecture halls to save time and energy for both his students and teachers. Along with wondering what to do with the extra time (I think more mentorship opportunities would be beneficial), he wants to know where it is students are learning and how one can be sure, apart from end-of-the-year grades, that the information they’re getting outside the lecture hall is of good quality. Today’s medical students may use handouts just like students in the past, but they likely use digital resources as well. Mapping what future doctors learn on the Web, from their peers, or from patients, doctors, and nurses during hospital internships could help rethink their training.

With the augmented browser I was talking about, a student could point other students to a resource she feels could be helpful to others. Her classmates, as well as their professors and other medical professionals, could then confirm whether or not the content was helpful. If a majority of those involved give their approval, for example giving an A to certain content, we then can have triple-A resources that will undoubtedly be more reliable than

the content patients typically consult, easily influenced as they are. Ideally, among the many resources patients share with one another, medical professionals and researchers will be able to help them know which ones are the most reliable and steer them clear of hacks and quacks.

To give a last example of the benefits of distributed, expert content review online, let's look at education material on the climate. If the same website gets approval from children for its games, teachers for its educational value, and scientists for its accuracy, that's another form of triple-A rating, and the site would then get recommended.

As you can see, this is different from Facebook Likes. On social media, all opinions have the same weight. You can argue that it's better that way because it's more democratic, but in the sciences this is not enough, even though obviously debate must always be a possibility. In the sciences, not all opinions are equal, whether it's the question of if the Earth is several billions of years old or only several thousands of years old or whether a certain treatment for a disease is effective or not. The system detailed above is only a rough sketch, and it would have to be fine-tuned and tested by a scientific trial-and-error process. The ultimate goal would be to take into account the particulars of everyone's opinion without nullifying them by giving them all the same weight and to adapt the system to be able to withstand whatever the next generation of online manipulators has in store.

To create these "learning public services," the best comparison I can think of is transport regulation, ensured by governments, whose necessity it would never occur to anyone to dispute. Transport regulation lets us move about as we wish, so long as we respect traffic

laws—or aviation or maritime laws. And different rules apply for different modes of transportation. A train can travel at 300 km/h whereas a car cannot. Pedestrians are encouraged to use pedestrians crossings, but using them is not mandatory in all cases. Moreover, all these rules are in line with international regulations; for example, flying in international air space requires compliance with international standards for air-traffic control and aircraft operations. All these rules together are meant to make it easier to travel together, which is a key part of living together.

These rules do not mandate how you should travel. You can go from Paris to Stockholm by train, plane, or car, and if traveling by car, you can take freeways or country roads. And of course, you don't have to travel directly either. You can take breaks, stop to take in the scenery, go to a good restaurant, visit a historic site, etc. The learning society should offer such freedom, particularly in higher education and lifelong learning such as the example of degrees in unsolicited majors, which would make it possible to move away from the routes imposed by pre-designed degree programs. As it is today, everyone takes the same train from September to June.

Only this kind of approach would endow our education system with the agility it would need to allow for the emergence of new fields of knowledge, new intersections between disciplines, and new skills. Nonetheless, people tend to think that a uniform system means an equal system. Does uniformity reduce inequality? Not even close. In fact, inequalities have a tendency to grow, certainly when it comes to elite and the underprivileged, as shown by, among others, the OECD's PISA study,

which assesses the skills of students of various demographics across dozens of countries.<sup>lxxi</sup>

Let's look at a comparison. We're all different, thus not identical, based on our genetic makeup. For example, some of us are more at risk of contracting certain diseases than others. Although gene editing could reduce such an inequality, we don't practice it in humans, at least not yet, and this would not be without raising serious ethical questions. Rather than edit our genes, doctors recommend we change certain habits, eat specific foods, take certain medicines, engage in physical activity, etc. Some things the entire population should do to reduce risks, while others specific populations should do.

The learning society lets us apply this notion to education. Technically, teachers can already adapt their teaching methods in the name of their right to "pedagogical freedom," but to what degree can they really exercise that right when their profession is constrained by nationally standardized schedules, class sizes, and curricula that leave little time for anything else?

Did you know that there's no scientific evidence that says learning is more effective in classrooms or, for that matter, in class sizes of 25 to 35 students, or with a single teacher, or for 50 minutes per subject? Did you know this system, standard most everywhere in the world, was developed by Jesuits in the 16<sup>th</sup> century? That is, according to Jesuit Dominique Salin, who says that his religious order created the educative model for secondary school such as it functions in Europe and throughout much of the world today. Students are grouped together by skill level in classes and spend an identical amount of time at school every day going through each subject successively, alternating between

lectures and exercises, and getting graded through a standardized system that was borrowed from the Chinese.<sup>lxxii</sup> Whatever the virtues of this system may be, do you really think an education model that's five centuries old can be so effective and universal that it can meet the challenges of the third millennium?

Let's start really offering teachers the "pedagogical freedom" that the law grants them. But let's document it so that it does not become, as happens too often, a freedom to reproduce forever and ever the pedagogical systems and approaches of the past.

## MAKING THE FUTURE POSSIBLE

I'm aware of the magnitude of the task. Most parents and teachers default to reproducing the system they grew up in, which is tempting not only because it's easier that way but also because for them the system worked. For a long time while the world changed slowly, educating future generations the way previous generations had been educated was an effective formula for meeting the basic challenges of the time. But this is no longer the case. Changes in the world are happening too rapidly now. Perhaps you think rapid change is not a good thing, but do you really think you can stop it? No one has the wrong intentions. Parents want what's best for their children, and teachers want what's best for their students. But in a changing world, the biggest boost you can give students is providing them with the intellectual tools and habits that will allow them to be the change. In the words of Antoine de Saint-Exupéry, "As for the future, your task is not to foresee it, but to enable it."

This change won't come from the top. The educated elite were educated in a system whose aim is to, well, create elites. It's not easy for them to admit that this system is imperfect, as that would call into question their legitimacy. There's a rift forming between on the one hand the elites, who believe they know what decisions to make for others, and on the other everyone else, who are becoming increasingly educated.

How can we get the system to evolve? We start by allowing those who are already doing things differently to continue to do so, and we invite those who are willing to dare to do likewise. Then we evaluate their work and spread it. From here, virtuous cycles can emerge such as seen in countries that have already successfully reimagined their education systems. International studies have identified constants among all these countries: believing in the innovative capacity of teams and high-quality initial teacher training and continuing professional development for teachers.

I shared my transportation analogy, but we can also look to public-health policy, too. There's a movement in health care that advocates for thinking about action with regard to four P's: predictive, preemptive, personalized, and participatory. In other words: What genetic risks are there for certain individuals? How can we treat the disease before it starts? How can we tailor aspects of treatments to individual patients? How can the community benefit from a specific treatment? In terms of the learning society, I could certainly add two more: peers and permanent progress. *Peers* refers to horizontal collaboration among students, among teachers, and among parents, and among all these groups. *Permanent progress* highlights the fact

that solutions and systems should never be thought of as fixed but always progressing.

By relying on research and cross-fertilization between disciplines, the medical field has been able to inform ambitious public policy hinged on compulsory policy (vaccinations, for example) and large margins of freedom for practitioners. No doctor would recommend treatment to patients without taking into account the latest research findings, and likewise no patient would accept them, especially since with the Internet everyone has access to medical information. Yet this is what we do in education.

Comparing education and medicine can show us three things. First, both fields are as interested in individuals as they are in the community, e.g., both individuals and the community are in jeopardy when it comes to the spread of viruses and fake news. Next, both fields deal both in what's innate, e.g., genetic diversity, and what's acquired in one's environment. Lastly, every international study shows direct, causal links between health and education. The most educated populations have the best health, and vice versa. If you provide an extra year of education to a young girl in a distressed part of Africa, it increases the likelihood of survival of her children.

#### PREDICTIVE, PREEMPTIVE, PERSONALIZED, PARTICIPATORY

Let's see what the four P's would look like applied to education.

Predictive medicine involves looking at epidemiologic studies to try to determine the risks associated with such-

and-such genetic predisposition or environmental factor. This approach should be handled with caution in education, as it carries the obvious risk of stigmatizing some children and suggests that risk factors will prevail in all circumstances. Beyond this, the preventive approach can be extremely effective because it lets us focus on precise risk factors for students.

Preemptive medicine looks at treatments and behaviors that limit risks, e.g., not being a smoker. Education research has already pointed out abundant ways to limit risks. It has showed that encouragement and empathy work better than punishment and humiliation, especially when it's in front of other people. Education research has also shown that, as I've mentioned, high-quality initial teacher training and continuing professional development is the best predictor for a successful education system. Yet both of these examples are still relatively unknown and not widely implemented.

Personalized medicine takes into account the fact that each of us reacts differently to treatments, be they physiological or psychological or depending on how treatment is administered. Applied to education, research confirms what common sense would tell us: We don't all learn the same way and we don't all learn at the same speed.

Participatory medicine means asking patients' opinions and, more and more, inviting them to work with health professionals in participatory research. Participatory research is without a doubt the notion that would seem the most foreign to education systems. While some schools now ask students their opinion on conditions in the school, their teachers rarely ask what students think about pedagogy. Teachers who use digital and online tools

in their classrooms can collect fascinating information on how their students learn, thereby giving themselves the opportunity to then adapt their lessons accordingly. A basic and popular system based on learning-analytics is the Khan Academy.<sup>lxxiii</sup> Depending on the results of your work, the system recommends videos adapted to problems you've encountered. If those videos then help you advance, the platform takes note of this for future reference, as students in the future may encounter the same problems that you did.

As for now, learning analytics is limited but growing fast for predictive and preemptive education. Predictive meaning they can calculate that if a given student comes from such-and-such high school and gets such-and-such grades in the beginning of the semester, that student may be at a high risk of dropping out. Personalized, preemptive education makes it possible to offer mentorship programs catered to his particular situation.

Others will even choose to forgo traditional schooling altogether if they feel the system is defective or doesn't pay sufficient attention to the specific needs of certain students. We can already see this in schooling in the US, where rates of homeschooling have doubled from 850,000 children in 1999 to 1.8 million in 2012. That's 3.4 percent of school-age children.<sup>lxxiv</sup> In France, only 0.2 percent of children were homeschooled in 2014, but that's an 83 percent increase from 2007!<sup>lxxv</sup> Contrary to what was the trend for a long time, homeschooling is no longer chosen for reasons of faith or a lack of alternatives, for example when a child has a fear of going to school or has severe disabilities. And contrary to what you may think, homeschooled children don't necessarily lack social contact.

Parents find opportunities for their children to interact with other children, primarily through sports and cultural activities.

Once the digital tools reach a certain level of maturity, they will be used in private schools both to reduce costs and improve the quality of education. If public schooling doesn't get up to speed with these digital tools and spread them, we'll be looking at a completely different type of learning society, one that's more and more dependent on market forces, offering greater and greater advantages to families that already have strong finances, cultural advantages, and social ties.



## 6

# A how-to guide for a learning planet

The first signs of the learning society, the one I've been calling for, are already here. The preceding pages have offered numerous examples of them. But how can we go take the initiatives of an individual, an organization, or an institution and network all of these? This is the question we try to answer with our plan to cocreate a learning society,<sup>1</sup> which, together with inspiring colleagues Catherine Becchetti-Bizot, Marie Cécile Naves, Gaell Mainguy, and Guillaume Houzel, we submitted in April 2018 to the French Ministry of National Education, the Ministry of Labor, and the Ministry of Higher Education, Research, and Innovation.

We recommended drawing inspiration from the model of the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988 to study the climate and provide the world with scientific consensus on the issue. We proposed creating an IPCC of intelligence, learning, and skills. In the same way that the

IPCC is pursuing the 13<sup>th</sup> sustainable development goal of the United Nations, i.e., urgent action to combat climate change, the IPCC of intelligence, learning, and skills would undertake the 4<sup>th</sup> development goal for the planet: ensuring quality, equitable education for all. As with the other Sustainable Development Goals, we will make that much more progress since we'll be able to draw on the best research and innovation from around the world. Then we can educate today's generation and the next in the skills they'll need to deal with these issues.

The organization's mission will be to think of how to get individual, artificial, and collective intelligence to coevolve. Animal brains coevolved over millions of years, and culture has been coevolving for a very long time thanks to our individual intelligence. The coevolution of various forms of intelligence is happening at an unprecedented rate thanks to breakthroughs in artificial intelligence, and this is as much a source of fear as it is a source of hope for building a bright future that will benefit everyone. As we have seen, the 21<sup>st</sup> century is shaping up to be the century in which artificial intelligence emerges. This will have an impact on all the ways in which people and organizations learn.

By presenting our action plan, we hope to have demonstrated that the experiences, convictions, and thoughts that this book defends can be translated into concrete measures, which we have even calculated.

The learning society is not just a concept. It's a reality that we have to bring about collectively and without wasting time if we want to respond peacefully to the challenges of this century. Inequalities in knowledge and understanding

are widening, feeding fear and rejection of “foreigners,” who have become scapegoats in the political sphere.

We need to unite our strengths, both nationally and with partner countries abroad, those in Europe particularly, so that we can all develop our potential and contribute to co-constructing tomorrow. Our future and the future of our democracies depend on it.

Since the first edition of this book appeared a year and a half ago, I have seen several signs that make me think that creating a learning planet is not as unlikely as it may seem. Several readers have voiced support for the learning planet through posts on social media and messages I have received. We created a MOOC called *Toward a Learning Planet*, and of those who enrolled in it, thousands shared with us how much they loved learning and how they organized their own learning communities. This MOOC was shot as a documentary (MOOD, massive open online documentary), the purpose of which also being to facilitate research (MOOR, massive open online research). These new formats allowed us to gather thousands of testimonies and opinions on the dynamics related to the bringing about the learning planet. The feedback from the first community of stakeholders interested in these perspectives has enriched our perception and we have been keen to integrate their vision into a new version of this more international MOOD, which is available in English.

In the future, we hope to be able to make the content and tools that we develop available to learning communities. Little by little, all those who wish to do so will be able to benefit from the CRI’s GPS of knowledge WeLearn, a database of open-source projects that

enables learners to discover open-access resources to train themselves in the SDGs as well as find peers and mentors to create collectives, places to get involved, and events to meet and celebrate progress. The CRI, with all our partners who wish to contribute to this open project, is already working toward this, and without a doubt the content and tools will improve over time thanks to contributions of collective intelligence. To acknowledge everyone's contribution to this collective intelligence, it's so important at the same time to create new forms of acknowledgement, i.e., open portfolio, open badge, new ways of validating prior learning. Recent pledges from universities supporting the Sustainable Development Goals also moves in this direction, as does the willingness shown by research funders, e.g., the European Union, to support projects contributing to SDGs as a priority. Youth protests for the climate are growing bigger and bigger, and I love how creative their slogans are: "Make the Planet Greta Again," etc., and their taking action in the name of science shows us they won't stand idly by on this issue. The convergence of institutional actors, speeches from certain leaders at the United Nations, more and more business owners, the electorate, and the will of young people prove that awareness is gradually spreading. Nevertheless, this still needs to be amplified and transformed into concrete actions that meet the challenges. One of the challenges is knowing how to take action and getting educated to understand their complexity. Judging by the number of stakeholders at all levels talking about these issues in the media and on social networks, it seems to me that we can find some optimism.

In an effort to mobilize more and more people on this issue, we signed in March of 2019 a partnership agreement with Audrey Azoulay, director general of UNESCO, that lays the groundwork for an open alliance for the future of learning. UNESCO is preparing a new report on the future of education that, like the Faure report in 1972 and the Delors report in 1996, can serve as a reference for rethinking education. Ms. Azoulay has been gracious enough to invite me to contribute to the report. I hope it will help us amplify the voices of people both young and old on the future of education. It would be interesting to have their opinions on the recommendations of previous and future reports as well as current obstacles and ways to overcome them in order to implement the desired transformations. Because it's the people on the ground who are ultimately the actors of change, it's important that they get invited to reflect locally and globally on what they want to do to contribute to the future of education, an education that will empower learners to prepare for the future.

On December 3, 2018, the General Assembly of the United Nations created an international day of education (January 24), and this also is a hopeful sign. We hope to catalyze the organization of a learning-planet festival during that week so that everyone can celebrate what they've learned, document it, and share it. As the festival will likely start very small, we can hope that, like World Music Day, the festival will mobilize more and more people over time. The festival in particular could draw from all the various networks committed to Sustainable Development Goals and education. To go even further, we have begun to discuss how we can highlight the best

ways to overcome the challenges of the Sustainable Development Goals at major international events like world's fairs and the Olympic games. That way, we would celebrate the contributions of teams of young people, educators, artists, scientists, and business owners taking action on these issues and ready to share their progress in open source. As sports championships are the ultimate dream of the young people active in sports clubs all throughout the world and these events mobilize a lot of resources, we hope that the Sustainable Development Games would have the same effect.

In July 2019 at the Learning-Planet Assembly, co-organized with our partners at UNESCO and the French Development Agency, we were able to share the best ways to teach the Sustainable Development Goals. At the event, the CRI and Deputy Director General of UNESCO Stefania Giannini had the pleasure to present awards to students from all over the world who had invested in finding solutions to the challenges of sustainable development. When you see what these students were able to do in the span of a few weeks, you can imagine what they would be driven to do in the span of a few years with support from knowledgeable teachers and drawing on what others who came before them have achieved. To meet the United Nations' 2030 agenda, the sky is the limit if we can mobilize the creativity and activism of millions of young people throughout the world and catalyze and channel those forces.

For example, it would be interesting to collaborate on a list of actions that are good for individuals, good for others, and good for the planet all at the same time. Riding your bicycle, for example. It's good for your health

as well as that of others and the planet, as it reduces CO<sub>2</sub>. We can also look at smoking, which is bad for the smoker, anyone in the smoker's vicinity because of second-hand smoke, and for the planet, as cigarette butts are a pollutant to the soil and water. Fast food is another example. It increases the risk of obesity and contributes to deforestation in the Amazon and methane emission from cows. There are other important topics as well, such as speeding, excessive screen time, addiction to gaming or alcohol, etc., but on the issues listed above we can specifically align the interests of individuals, those around them, and the planet. The only thing left to do after that is gain awareness and change behavior, which is of course easier said than done.

Here again, we would need to be creative and mobilize collective intelligence to grow awareness of SDGs, which are known by less than 10 percent according to a September 2019 survey. As artists are often ahead of the curve and able to mobilize imaginations, I think they have an important role to play, too. A good example is Yacine Ait Kaci, creator of Elyx, who later became digital ambassador to the United Nations. He's able to convey the SDG message through his simplicity and humor. You could go even further and acknowledge the best books, the most emotional films, most inspiring games, and most uplifting songs are on the themes of care for the self, others, and the planet. We can also imagine viral communication campaigns, such as one that was filmed in Times Square in which a teenage girl stood in a wedding gown with a man who was five times her age, or one from Thailand where a child of 6 with a cigarette in hand is seen asking a smoker for a lighter. These videos were made to

speed up consciousness-raising, and they can inspire us to create new campaigns that will facilitate discussions on the transitions we need to undertake. Research also has to be mobilized to understand how end addictions. Drawing on decades of research in the neurobiology and sociology of addictions, we can also develop projects for education-through-research and participatory-science projects in order to understand the warning signs for addiction in young people and help them escape from the trap. Sometimes addiction traps are in fact ambushes, as some companies try to create addictions to their products, something Robert Lustig speaks out against, as we've already mentioned. In an effort to combat these addictions, Lustig is collaborating with the CRI, Cergy-Pontoise University in France, and Tristan Harris's Center for Humane Technology. Tristan Harris is a whistleblower who left his position as a design ethicist at Google to advocate for reorienting tech companies' core values such that they try to help us spend our time well rather than demand more of it.

More and more, businesses want to respect the rules of the game and reflect on their missions. The Pacte law ("action plan for the growth and transformation of businesses") signed by the French parliament in April 2019 calls on businesses to reflect on their core values, their social and environmental impact, and their economic models. There's another law that seeks to ensure that all tech companies, namely the big ones, pay taxes and contribute to the common good. This search for their values, which harkens back to the concept of *ikigai*, shows that deep changes are underway among more and more individuals and collectives.

Confucius said that our second life begins once we understand that we have only one life. As environmental degradation becomes the primary concern of more and more people, we can ask ourselves if awareness of the fragility of our planet couldn't function in the same way. If the citizens, voters, and consumers that we are became aware of the fact that we have only one life and one planet, we would think more about the impact of our choices on ourselves, others, and our earthly ecosystem. Then we would insist that businesses, politicians, and others act as environmental custodians. If on a learning planet we each celebrate and document our growing awareness and transitions and share these experiences, this can facilitate the transformation of individuals, collectives, public institutions, and businesses. It may seem like a utopian idea, but it seems to me that it's a necessary one, as it invites every one of us to live by Gandhi's precept: "Be the change you wish to see in the world."



## Conclusion

### Toward a more humane humanity

We started this journey together in New York City on September 11, 2001, scarred by the attacks, the deadliest terrorist in history. We asked a question that I ask myself still to this day: “How do you work toward a more humane...humanity?”

Throughout these pages I've shared with you my personal journey, how much I've loved exploring and exploring new ways to explore, traveling, reading, discussing, playing, making, researching, sometimes alone, but most often in collectives that have helped us make progress more quickly with all the diverse points of view, the richness of what different disciplines bring, and different cultures as well. I've talked about going from being a scientist specializing in the evolution of cooperation to a mentor to students who aspire to learn through research and work across disciplines to come up with new ways of tackling fascinating problems. I've also talked about how I've gradually understood that if scientists are good learners, all good learners could become

scientists or at least use scientific research methods to progress, no matter what age they are or where they're from, so long as there's a subject in which they're really interested. I've talked about how starting from a young age we can learn faster by satisfying our curiosity. I've talked about how, through researching and cooperating with learning collectives that help us to go beyond our limits and some of our biases, we can make progress more quickly by participating in a collective culture. I've talked about how I convinced myself over time that these collectives could self-organize and teach others to build the learning planet piece by piece. I've talked about how, if we all could come up with new digital tools that could catalyze the emergence of global collective intelligence, each one of us could do our best individually to cooperate and thereby contribute to overcoming the challenges of our time. I've talked about how, if we learn how to unite ethics, technology, and collective intelligence—human intelligence and machine intelligence—together we can build futures in which all of us can benefit from future progress, and we can learn to take care of ourselves, others, and the planet.

I hope I was able to convince you—if you needed convincing—that it's only by revolutionizing our ways of learning, anywhere and at any age, that our collective ambition can take root. We have seen that accelerated progress in technology, genetics, nanotechnologies, and the cognitive sciences have changed the game entirely, for better and for worse.

Worse being the invasion of the Internet with bad actors, the mass diffusion of fake news, radicalization of political opinions, large-scale intoxication of opinions,

threats to democracy, developments in technology that contribute to the destruction of ecosystems and to manipulating life with no ethical consideration—the list goes on.

Better being the thousands of initiatives and examples of awareness-raising, which across the globe give us a snapshot of how to use these same technologies for good. This book has shown only a representative sample, which is nonetheless very small.

It's still to be decided, collectively, what this more humane humanity will look like.

Even in humanity's darkest, most hateful moments, we've been able to work toward a more humane humanity. The first tiny sparks of the Enlightenment shone at a time of religious wars and the Inquisition and a time when there was no structured education system. Gradually, liberating ideas began to emerge, on the fringe at first, but they came to center in a context that were much more difficult than ours today. These brought about the *Encyclopedia, or the Systematic Dictionary of Sciences, Arts, and Crafts*, by Diderot and d'Alembert. A few years later, the monarchy fell, and democracy took its place.

Back then, there was a real dialogue between the different fields of knowledge, what today we call interdisciplinarity. There were networks of informal communication, the “invisible colleges,” third places such as cafés and salons where new ideas would be exchanged and tested. And of course, there were books and printed materials, which American historian Elizabeth Eisenstein<sup>i</sup> describes as so central to the “unacknowledged revolution” that preceded the very open revolutions in the US and France.

Eisenstein explains how Gutenberg's printing press reduced the cost of access to and sharing of information,

which would bring about changes in politics and law. But already back then, like the languages in Aesop's fable, this technology could be used for evil, such as we see in books printed at the time that explained how to prove that independent women were in fact witches. On the Internet today we see an overwhelming amount of sexism being propagated, yet thankfully we also see instances of emancipation such as the #MeToo movement, in which women are encouraged to express themselves and get involved in larger movements that fight for equality and respect for women's rights. The printing press, which at first was a simple communications technology, became over time a powerful catalyst for change. The Internet has the same role today, but to use another example from Eisenstein, whereas in the era of the printing press it took botanists a century to go from 500 classified plants in Europe to 5,000, today it takes only a few years for groups of citizen scientists to mobilize their collective intelligence to chart the earth's biodiversity. And it takes artificial intelligence only a few seconds to process all the data from those efforts.

The same can be said of the possibilities of crossing disciplines, thanks largely to big data, the energy of third places, or the expansion of "invisible colleges." Everything is in place for us to reinvent the Enlightenment for the digital age and answer the three questions T.S. Eliot asks in the poem "The Rock":

Where is the Life we have lost in living?

Where is the wisdom we have lost in knowledge?

Where is the knowledge we have lost in information?<sup>ii</sup>

We know that we have a major asset that's bringing about a paradigm shift similar to what was experienced

in the Enlightenment era. That's digitalization, which is also a communications technology like the printing press, as well as a data technology, one that's autonomous. It can make decisions, model a genome, build robots, etc.

We've gone from a stage in history in which the only way a machine could operate was if a human acted upon it to an intermediary stage where information and action coevolved to now, when more and more autonomous agents use information to make autonomous decisions. And we continue to confer more and more autonomy to them. Prior to machine learning, there was no doubt that a machine would do only what humans had programmed it to do. Now, machines are partially capable of programming themselves. Even prior to machine learning, 7 percent of global financial assets, some \$15 billion, were managed by artificial intelligence.<sup>iii</sup> What will happen in the future when machines set their own criteria for buying and selling? And if their decisions earn more, at least in the short term, we may be tempted to let it happen.

Digital is all about exponential technology. Its impact will be so much greater than that of the printing press, which means that we're facing scientific, social, ethical, and political questions that are, in my humble opinion, unprecedented.

Of course, we can only hope that the more machines can perform repetitive and dehumanizing tasks, the more time human beings can devote to being human, i.e., developing our potential for creativity, empathy, self-understanding, understanding others, searching for meaning in life and what makes life good, caring for oneself, others, and the planet, etc. This is the relatively optimistic view for which we can hope. But it's far from a guarantee.

Other, darker scenarios, the ones Hollywood relishes in, are nonetheless possible. Machines could take control, enslaving or even eradicating humanity. On the table today is the question of rewriting our own genome and thus changing the status of our species.

If T.S. Eliot were alive today, he may have added one question: “Where is the information we have lost in data?” He would likely want us to ask ourselves: How do we stitch back together the fabric of meaning? How can we go from data back to information, information back to knowledge, knowledge back to wisdom? And how can all these benefit life? How can we manifest in everyday life what German philosopher Hans Jonas demanded we do in his 1979 work *The Imperative of Responsibility*<sup>iv</sup>: “Act so that the effects of your action are compatible with the permanence of genuine human life.” This imperative founds the basis of today’s questions of sustainable development. This book proposes ideas for reflection but does not claim to bear any truths. Can it help get people to ask themselves questions and encourage collective debate over what our common future will look like?

## Annex

### CRI ACTIVITIES IN 2020

(to find out more, visit <https://cri-paris.org>)

The CRI develops and promotes new ways of learning, teaching, researching, and mobilizing collective intelligence. Our mission is to help bring about a learning society in which people learn how to learn, both individually and collectively; to care for themselves, others, and the planet; and to confront the major challenges of our time. We're doing this by exploring topics at the intersection of life science, learning science, and digital science. We're developing new education methods rooted in experimentation, digitalization, interdisciplinarity, collective intelligence, learning through research, civic engagement, and serious games. The CRI is an open platform for innovation and creativity where students find peers and mentors as well as a positive environment and a wealth of knowledge. The CRI is a unique space for exploring new ways to explore that's becoming more and more renowned throughout the world.

The CRI has moved 10 times in the past 15 years because we're constantly doubling in size. For the next 50 years, however, the CRI will have its location in the picturesque Marais district in Paris, housed in buildings that are newly renovated and refurbished thanks to the generosity of the Bettencourt Schueller Foundation. The renovation won a prize for innovation, the result of a fruitful and close collaboration among everyone who was involved, i.e., architects, builders, users, and owners. The building is a jewel, drawing in more and more visitors eager to collaborate with us or simply those who are drawn in by the diverse events and projects that the communities at the CRI are undertaking.

As previously stated, the CRI seeks to be a middle ground or an intermediary space that catalyzes interactions between institutions and the underground. What middle grounds have in common is that they are innovation communities in facilities specifically designed to empower change makers, and their members create and learn through projects and organizing events. In order for middle grounds to be successful, they should be like gardens where lots of initiatives can flourish so long as we provide fertile ground for them to take root.

Student initiatives are what drive evolution at the CRI. We encourage students to create clubs for developing projects that are open to everyone, and our degree programs at the undergraduate and graduate levels are open to people of all ages. With the *Savanturiers*, the CRI offers opportunities for education through research from preschool through high school. The *Savanturiers-Ecole de la Recherche* (“*Savanturiers*-research school”) is an education program cocreated with Ange Ansour that

aims to develop a model for education through research with three focuses:

- developing research projects in preschool, primary and secondary school, high school, and in afterschool programs;
- offering professional development for educators;
- and carrying out research and development in education.

The program mobilizes and brings together educational and scientific communities that cocreate and innovate for the benefit of schools. They aim to create rigorous, productive lessons that develop critical-thinking abilities, a desire to explore the unknown, and the ability to work with others. They also seek to develop the expertise of teachers as knowledge workers and education-research engineers within their classrooms.

Behind the *Frontières du vivant* (“frontiers in life science”) undergraduate program are Jean-Christophe Thalabard (who’s also dean of all our pedagogy programs), Vincent Dahirel, Patricia Busca, and Mahendra Mariadassou. Being both a general and interdisciplinary program, this is much more than a biology degree. Its learning-through-research program aims to provide students with solid scientific skills and knowledge, both disciplinary and transdisciplinary, focusing on life science in combination with physics, chemistry, mathematics, computer science, and social science. The three-year curriculum is strongly focused on the Sustainable Development Goals, i.e., learning through research and undertaking research that seeks to achieve these goals. It asks how can we mobilize scientific knowledge

to understand the complexity of the SDGs? And how can we outline innovative solutions that are capable of being scaled up?

Our graduate school, the EURIP (for *Ecole universitaire de recherche interdisciplinaire de Paris*, or “the interdisciplinary research grad school of Paris”) seeks to provide opportunities to students who want to explore the interfaces among life sciences, learning sciences, and digital sciences. Specifically, it seeks to ask questions about how biological, individual, collective, and artificial intelligence will coevolve.

At the heart of the graduate school is the master’s program Interdisciplinary Approaches to Research and Education, directed by Sophie Pène, Jean-François Bonnet, David Tareste, and Franck Zenasni. The program is for students who want to pursue interdisciplinary education at a high level. There are three tracks: Learning Science, Life Science, and Digital Science. The Digital Science track began in September 2019 and has already received praise both from students and several businesses.

The FIRE doctoral program (*Frontières de l’Innovation en Recherche et Éducation*), directed by David Tareste and Muriel Manbrini, promotes projects that require transdisciplinary approaches to problems that bring together questions from life science, learning science, and digital science. These projects cover a large area of study, from molecular and cellular interactions to large ecosystems, including human societies, cognition and the coevolution of different types of intelligence—be it human or machine, individual or collective. It’s a new format for doctoral programs in France. Usually a university labo-

ratory will be designated for one disciplinary PhD, for example, a physics lab for a physics PhD. We slightly modified this rule in order to let, say, a mathematician study in the dermatology lab if she wants to model skin development. PhD projects at the CRI are selected by a scientific committee chaired by Andrew Murray.

The CRI is also a key player in reflections on lifelong learning. We currently offer six university and interuniversity continuing-education degrees. In France, some institutions offer postgrad students the opportunity to pursue certification in the form of what's called a DU (for *diplôme universitaire*, “university diploma”). Unlike master's and doctoral degrees, DUs are not national degrees but rather unique to that institution. The CRI offers several DUs. One of them, called CREER (for *Créativité, entrepreneuriat et recherche*, “creativity, entrepreneurship, and research”), was launched by Vincent Dahirel to meet the needs of those who want to get out of their comfort zone in the context of a learning collective. Another DU is *Philosophie pratique de l'éducation et de la formation* (“practical philosophy of education”), directed by Sophie Audidière, concerned with strengthening educators in their professional environments. This program focuses on sharing resources to create experimental education and training tools. *Acteurs de la transition éducative* (“key players in the education transition”), started by Florence Rizzo and Sophie Pène, is a DU that seeks to give educators the means to innovate in order to build the school of the future. *Médiation scientifique innovante* (“innovative scientific mediation”), a program headed by Jean-Marc Galan, seeks to provide a toolbox full of innovative approaches to mediating scientific

disagreements. *Apprendre par le jeu* (“learning through games”), created by Antoine Taly, seeks to explore the potential of serious games in the areas of education, health, innovation, marketing, civic engagement, humanitarianism, culture, industry, and research. These DUs are complemented by the DU FAIRE (“DU do”), created by Franck Zenasni and Ange Ansour to build bridges between research and teaching.

In France, the basic building block of research is the Joint Research Project, or UMR for *Unité mixte de recherche*. This is an administrative structure created when higher education and research institutions enter into a five-year contract whereby they collaborate by pooling resources and funding. The CRI is part of a UMR between the Inserm and the University of Paris and is directed by CRI cofounder Ariel Lindner. We call it the Collaboratory (collaborate + laboratory), as we bring in researchers who, in the spirit of open source, want to explore interdisciplinary frontiers in a positive research environment where ethics, activism, and mobilizing collective intelligence are the focus. The Collaboratory can host 60 short-term fellows for periods of three to five months depending on their projects. The program allows them to do things that are much harder to pursue elsewhere, as many of the projects are very much in line with ideas laid out in this book. Among these projects is Marc Santolini’s research on the science of science. He has shown that emerging trends in science are often discovered by small groups made up of young, interdisciplinary researchers. Another interesting project is Ignacio Atal’s research to help teachers become more conscious of the fact that teachers, when they conduct experi-

ments and observe the impact of these experiments on their students, are researchers, and they can benefit from networking and adapting methods from other teachers to help their students to progress.

We can also mention the Motion Lab, created by Joël Chevrier. It's a laboratory for experimenting and prototyping ideas in the sciences of human movement, with the potential to benefit areas of general health, rehabilitation, disease prevention, early childhood, and education. Roberto Toro, a long-term research fellow, is working on autism. Anirudh Krishnakumar, a PhD student at CRI Research, worked with the Child Mind Institute to develop apps, wearable devices, etc., that allow citizens to contribute to gathering field data to help assess mental health disorders. The Collaboratory also hosts student research projects, such as the iGEM project we talked about, whose research on tuberculosis is ongoing, now being extended by a team directed by Jake Wintermute. Students can define a collective research project where they can develop their creativity and carry out new experiments. Another example is a project by last year's graduating class that sought to give art and design students an opportunity to envision future applications of their work in biotechnology. Winning teams in the project showcased their work at the Museum of Modern Art in New York. The CRI's research activities have also benefited from an AXA Research Fund Chair called "A systems approach to individual differences in longevity," as well as the Orange Research Chair on finding bridges between developments in technology and biology.

Along with these research projects developed within the CRI, we have also developed participatory-science

projects, such as Doing-It-Together Science (DITOs). This is a project through the European Commission in which 11 partner scientific or professional institutions throughout Europe work to elevate public engagement with scientific research and innovation, namely with regard to biodesign and protecting the environment. At the CRI, the project was coordinated by Imane Baïz.

To make these activities easier and to help catalyze new projects, the CRI hosts labs developed in the framework of the CRI's Institute for Innovative Teaching through Research, directed by Amodsen Chotia, with funding from the Investments for the Future (PIA) program. Game jams and hackathons, which are ways of teaching through rapid prototyping, games, and trial and error, are key components of the institute, which is open to students, scientists, teachers, and citizens. Its labs include a space for developing science and education games. There's a maker space started by CRI alumnus Kevin Lhoste designated for prototyping 3-D and electronic objects as well as developing activities based on development, design, and using low-cost, high-tech sensors for various applications. The VR Frontiers LAB is directed by Philippe Bertrand, a current doctoral student at the CRI, and the lab seeks to develop VR tools with educational applications through serious games. The CRI has a multimedia production studio coordinated by Xavier Desplas in which we develop education tools such as Massive Open Online Courses and documentaries on specific topics we're interested in: education through research, leaders of learning, leaders in health, etc. MOOCs work toward making science and education accessible to the greatest number for lifelong learning via a remote-education plat-

form. To complete this wide range of initiatives, we also have a Health Lab, coordinated by Olivier Bory and Cloé Bami, and a parents and babies lab called *Premiers cris* (“first cries” with wordplay on the abbreviation CRI), cofounded by Lisa Jacquey and Marion Voillot. These are our newest labs, just as hosts of other student initiatives that are now well established were once themselves brand new.

The CRI’s digital team, directed by Éric Chérel, is developing various innovative digital programs like the Augmented Gymnasium, which lets several users interact in augmented reality as a way to learn how to immerse themselves collectively in the digital universe. It mixes innovative pedagogy, technological experimentation, and research on human movement and ergonomics. Led by Jean-Marc Sevin, a data scientist and expert in artificial intelligence, the digital team is also developing the WeLearn platform, a kind of GPS of knowledge that indexes and annotates learning resources to help teachers on their learning paths when looking for reliable pedagogical resources that are relevant to them, as well as to make the skills-learning process easier. Julien Joubin is developing the Projects platform, an online directory of all the projects within the CRI community and outside the CRI with our partners.

New modes of learning must be applicable to everyone in order to be able to slow down, if not stop altogether, the growing inequality that negatively affects certain populations. The Right to Repair project, an initiative started by CRI professors Franck Zenansi and Vincent Dahirel, seeks to lend a hand to vulnerable individuals referred to as NEETs (“not in education, employment, or training”).

The goal of the program is for them to reconnect with the labor market through a sustainable, open-source project for fabricating and repairing objects, offering the potential to eventually start a business.

One of the foundational principles of the CRI is being open to international talent, which adds to our creativity, energy, legitimacy, and recognition. The diversity of the CRI's students, teachers, researchers, scientific advisers, and teams is evident, as 54 different nationalities are represented.

Under the leadership of Gaëll Mainguy, the CRI organizes several international events every year. To name a few, there was the Towards a Learning Planet international conference in 2017, the World Innovation Summit for Education in 2019, and the first-ever Learning-Planet Assembly, organized with UNESCO and the French Development Agency, marking the launch of our partnership with UNESCO to create the *Alliance ouverte pour l'avenir de l'apprentissage* ("open alliance for the future of learning"). This event helped strengthen the CRI's visibility internationally, and we are already developing an annual cycle of interdisciplinary programs during the winter and summer breaks with our international partner institutions: Tsinghua University in China, Tadeo Lab in Columbia, Maker's Asylum in India, the EPFL engineering school in Switzerland, and Paris summer-school program in collaboration with Rob Lue from Harvard University and Yann Algan from the School of Public Affairs at Parisian university Sciences Po. These intensive courses encourage learning through doing and let students develop entrepreneurial projects that try to tackle UN Sustainable Development Goals.

These programs bring together international students from all different academic backgrounds. They are experts in medicine, the sciences, the environment, 3-D printing, or education and come together at hackathons, workshops, and master classes to develop inspiring, impactful projects.

The CRI also supports the development of spaces inspired by its education principles and designed and executed by people who have studied at the CRI. Examples are the Open Fiesta at Tsinghua University in China and the Tadeo Lab in Columbia. We also have a UNESCO Chair for Learning Sciences through UNESCO's initiative to promote interuniversity cooperation, making it easier for us to work even more closely with these partners and with UNESCO. Also through our partnership with UNESCO, we have an initiative led by the CRI's latest staff addition, Olivier Bréchar, to organize the Learning Planet Festival and the Sustainable Development Games for exchanges around new learning pathways and innovative education initiatives that foster the ability to solve the SDG challenges.

To help us recruit researchers and assess their research projects, the CRI has an internationally renowned scientific advisory board presided over by Helga Nowotny, who you'll recall from earlier was the first female president of the European Research Council and is also a professor emeritus of social studies of science at the Swiss Federal Institute of Technology in Zurich. The board guarantees that quality work and science training is done at the CRI, and its other members include Andrew Murray, professor at the Howard Hughes Medical Institute and director of the Center for Systems Biology at Harvard; Leland H.

Hartwell, winner of the Nobel Prize in Physiology or Medicine, director of the Biodesign Institute, codirector of a sustainable health center, and Piper Chair in Personalized Medicine at Arizona State University; Samir Brahmachari, former director general of the Council of Scientific and Industrial Research (CSIR) in India and Chief Mentor of the Open Source Drug Discovery Project; Stephen Friend, former researcher on Apple's health team, and president of Sage Bionetworks; Nadia Thalmann from the prestigious Singaporean university NTU; Stephan Lewandowsky from the University of Bristol; Rob Page, Provost of Arizona State University; Grace Neville, emeritus professor in the French department at University College Cork; and Rob Lue, faculty director of the Harvard-Allston Education Portal and founder of HarvardX and LabXchange.

The CRI encourages students to create clubs, which allow students to:

- discover new fields of knowledge, such as virtual reality with the VR club or cognitive science with the SCALP! club
- take action in concrete, positive ways, such as on energy and climate issues in the group *Avenir Climatique* (“climate future”)
- help train dual professor-medical practitioners in France's university hospitals with the *Association médecine pharmacie science* (“the medicine, pharma, and science association”), which brings together PhD students in medicine and pharmaceutical studies to look into biomedical research
- take up real-world issues such as gender parity in the sciences with Wax Science, or help refugees integrate into society through education with the CRI For All program

— and find purpose, such as with the *Ikigai* club, which educates individuals and collectives to think in terms of the design of their existence.

We also encourage students to adopt a hacker/maker attitude as we guide and challenge them to develop their projects in addition to their class load. Beyond clubs, the *Ecole dynamique* (“dynamic school”), Science Ac’, Rhizi, and the *Atelier des jours à venir* are projects that were started by CRI students. We strongly encourage students to register officially as student-researchers, and likewise, we support all entrepreneurial initiatives, whether it’s finding ways to improve an organization within the CRI or creating a start-up or an association. Numerous start-ups have been created by students at the CRI, some of which have gone on to be very successful. Among these are Unibiome, cofounded by Sophie Gontier; Hello Tomorrow and Eligo Bioscience, mentioned previously, founded by Xavier Duportet; and Just One Giant Lab, PILI, and La Paillasse, founded by Thomas Landrain.

Last but not least, the dozens of dedicated teachers and help from our other fantastic staff members are what make the CRI possible day in and day out, helping run all the CRI’s activities. It’s not like the credits at the end of a movie as I can’t list everyone’s name, but it’s people in our secretarial offices, logistics, accounting, legal, human resources, partner institutions, student services, CRI events, IT, institutional advocacy, and of course the fundraising development. Fundraising is directed by Véronique Giacomoni and is a huge part of the CRI’s success, allowing us to keep developing our programs. We’re preparing our next major fundraising campaign with the support of our experienced adviser Gabriel

Hawawini, a former dean of the INSEAD business school and current trustee of the University of the People. An agile executive team ensures that the CRI runs smoothly. The team includes CRI cofounder and head of research Ariel Lindner, Chief Facilitation Officer Jean Grellet, General Secretary Bénédicte Gallon, who manages the legal and financial aspects of the CRI and was responsible for monitoring the work on our new campus, and Gaëll Mainguy, who works to develop new projects and international relations. In a place growing as rapidly as the CRI, it is a permanent challenge to ensure a balance between existing and emerging projects, and this is possible thanks to passion and know-how of all CRI's actors. The CRI has a role to play as an incubator that must preserve what works and allow for the emergence of new ideas capable of contributing to tomorrow's world.

## Acknowledgements

The reason I dedicate this book to all those who have taught me so much is because I couldn't have become what I am today without them. I couldn't have acquired the least bit of knowledge, wisdom, love of life, or skill, and I wouldn't have been able to write about the topics I discuss in this book, let alone know how to write it or even want to write it.

I will not be able to thank all those who have contributed to my learning since the day I was born, particularly my family and loved ones, but also all of my teachers, students, teammates, study partners, colleagues, mentors, friends, and those who helped create and develop the CRI. There are also many people whom I've never met other than through digital interfaces or through their writings and projects, and I would like to thank them as well.

I did not become a researcher alone, nor did I become one magically. In addition to the episodes I recount in this book, I want to emphasize the role of Miroslav Radman, my doctoral-dissertation adviser, and Ivan Matic. Together, the three of us created the TaMaRa lab,

named using the first letters of each of our last names. I owe them so much for what they have taught me about being a scientist and about being a human. They were the ones who told me to concentrate on research, ideas, experimentation, and results and to not waste time quarreling with tiresome, uninspired people. We worked together for years on the bacteria everyone's heard of, *Escherichia coli* or *E. coli*. For our dissertations, Ivan and I worked on the evolutionary mechanisms of bacteria, he more so on recombination and genetic exchange between bacterial species, and I on mutagenesis. During that time, a new project was created with a postdoc in our lab, Eric Stewart, along with Richard Madden from the French Institute for Higher Scientific Studies (IHES) and Gregory Paul. Using a time-lapse microscope system with automated software that lets you follow and analyze 10 generations of bacteria—i.e., 1,000 individual cells—we detected aging in *E. coli*, whereby we could then explore new molecular mechanisms of aging that were potentially applicable to all forms of life.

Miro would later talk me into testing some of my more far-flung theories, saying, “François, experiments are like love: You can think about it, watch how others do it, and listen to what they say about it, but so long as you haven't tried it, you won't know what it is.” And he was right. What would follow were moments of doubt, of course, and making frequent mistakes, but also moments of pure flow, intense pleasure in science, in searching, discovering, and sharing ideas.

Because I was a pure product of the competition-based system, research was a discovery of both diversity and complementary ways of learning. In research, you're

enriched by everything and everyone, be it interns or Nobel Prize winners, lab technicians or postdocs, bacteria or literature, experiments or failures. You learn by doing, discussing, and collaborating, sometimes alone late at night or in heated debate, at conferences or in lab meetings, at lunch or in the library, in front of a computer or at the lab bench.

Each lesson learned is essential if you want to have a chance of finding a new piece of the puzzle and see a new result, propose a new hypothesis. Every team, every lab is a learning collective, fine-tuning how it learns, learning from other collectives, other labs, whether these are in the same field or not, because in their own way they all help us progress by sharing their discoveries, questions, and results. Learning through research is so enriching and relevant, I wanted to give the greatest possible number of people the opportunity to do it. If learning through research is the secret weapon of the best universities in the world, why not give everyone the chance to partake in it, especially now that technology allows us to break down so many barriers?

This is the core mission of the CRI. It hasn't always been easy for us, and of course we've had to overcome a lot of resistance and entrenched conservatism, so it seems important to me first of all to pay tribute to the courage and audacity of those who joined us at the outset. Namely, I would like to thank those who, like Ariel Lindner, joined us before we had an established name and reputation in the scientific community. Today, Ariel is Director of Research at the Inserm. He trained in Israel, England, and the US, and as a postdoc he joined the lab where I worked after he spent an entire day with Miro-

slav Radman, talking biology, education, and research. I couldn't have known back then that a long friendship was beginning, one that would help us through a lot of difficult times, for him especially during those early years, as most of the adversaries of our unconventional project would focus their attacks on him.

A number of other academics and scientists were also instrumental in helping the CRI see the light of day. Mathematician Jean-Pierre Bourguignon, former president of the European Research Council, was a former professor of mine at Polytechnique. It was he who, with Misha Gromov, suggested that we put together an interdisciplinary conference on innovation in biological systems. This was while Bourguignon was director of the IHES, founded in 1958, of which none other than physicist Robert Oppenheimer was a lifelong member. Among other great scientists who put their faith in us from the very beginning, I must also sincerely thank Helga Nowotny, first female president of the European Research Council; Bruce Alberts, former president of the American National Academy of Sciences; Robert Tjian, former president of the Howard Hughes Medical Institute, the largest biomedical foundation in the US; Leland H. Hartwell, winner of the Nobel Prize in Physiology or Medicine; and mathematicians Cédric Villani, Fields Medal winner, and Misha Gromov, Abel Prize winner. I also can't forget the support of Elias Zerhouni, former director of the American National Institutes of Health, or Éric Karsenti, CNRS Gold Medal winner and researcher at the European Molecular Biology Laboratory. Éric was the first to accept being director of the CRI's international scientific advisory board for our doctoral program,

and similarly I can't forget to thank his successor, now vice president of the board, Andrew Murray, director of a program at Harvard that's similar to our own who also spent a sabbatical year at the CRI. These individuals have made it possible for us to avoid falling into a common trap in French academia: insularity.

But the CRI would of course not exist without its students, all the “ugly ducklings” who have agreed to come splash around in our pond. Some of our very first students have never left, Samuel Huron among them. He's the one who dropped out of high school at age 15 but found his way back to education through a largely underutilized public program in France that lets people earn diplomas by validating knowledge and skills they've acquired in the professional world. Samuel did his master's at the CRI and cofounded our hackerspace Fabelier (fabrication + *atelier*, or workshop) with classmate Antoine Mazières. They acquainted me with the virtues of hacker ethics and have since attracted hackers to the CRI in droves. Kevin Lhoste would later team up with them to create the CRI's first maker space, where I would discover 3-D printing and homemade drones. Samuel Huron went on to defend a prize-winning doctoral dissertation on data visualization, and today he is an associate professor at the engineering school Télécom Paris. And like many of our alumni, he also continues to help us develop new projects. I will likewise thank Pascal Hersen, who joined us as doctoral student with Stéphane Douady, and Amodsen Chotia, who joined us while pursuing two master's degrees in physics and biology. I'd like to thank Gregory Paul for his initiative to organize with friends at the ENS to devise interdisciplinary research projects.

All these first-generation CRI-ers played an important role in the genesis and development of the CRI, especially Stéphane, who continues to aid first-year students to create new projects, and Ariel, Pascal, and Amodsen, who each direct a key program for our activity in research, education, and catalyzing new projects.

But even the strongest motivations are nothing without funding. We receive public funding through the Investments for the Future program and from the *La France s'engage* foundation. We're also fortunate to benefit from support from a number of public institutions such as the Inserm; the Faculty of Medicine of Paris Descartes University, thanks over the years to deans Even, Berche, and Friedlander; universities Paris Descartes, Paris Diderot, Sorbonne Paris Cité, which today all are incorporated under the University of Paris, whose presidents Christine Clerici, Frédéric Dardel, and François Houllier have each shown us wonderful support in their successive tenures. The University of Paris awards the diplomas that the CRI designs and teaches (see Annex for information on these). The incorporation of these foundational universities under the University of Paris umbrella won the University of Paris an IDEX project, i.e., a government-funded award for excellent initiatives, which will be piloted by its vice president for research, Édouard Kaminski, and its first president, Christine Clerici. The uniting of the universities will strengthen their standing in the world and perhaps enable the CRI to work even more effectively at transforming universities. I would like to stress the fact that presidents Frédéric Dardel and François Houllier were members of the CRI's doctoral-program board, thus they support us all the more so

as they know our internal structure and have seen the impact the CRI has on students. Along with these university presidents and some their predecessors who have also showed us so much support, I must thank my employer the Inserm, whose presidents and directors general both past and present include Claude Griscelli, Christian Bréchet, André Syrota, Yves Lévy, and Gilles Bloch, with the help of Thierry Damerval and today Claire Giry. They have continually supported our commitment to innovative projects.

We also receive support from the City Hall of Paris, which we first got to know through Guillaume Houzel, a friend and board member. The city has provided us with our ideally located premises and supported our projects in so many ways. We must thank in particular current Mayor of Paris Anne Hidalgo and former Mayor Bertrand Delanoë; deputies Jean-Louis Missika and Marie Christine Lemardeley; 4<sup>th</sup> Arrondissement Mayor Ariel Weil; and Carine Saloff-Coste and her teams in the city's Office of Economic Development and Employment. They have helped us not only with finding the unique campus we now occupy but also with making our MOOCs; equipping our classrooms, labs, and offices; creating our Augmented Gymnasium; starting the *Savanturiers*; and overall helping us become part of the broader Paris ecosystem.

Support from our innovative patrons has also been crucial, first and foremost among them being the Bettencourt-Meyers family. Several of our various sites over the years have enjoyed visits from Liliane Bettencourt, Françoise Bettencourt Meyers, Jean-Pierre Meyers, and their sons Nicolas and Jean-Victor. Nicolas Meyers's

recent visit to our campus and the interest he showed in the CRI's different activities have left their mark on our teams and testify to the family's commitment to our work. We have been able to develop an ever more constructive and friendly relationship with foundation members and executives, namely secretary general Armand de Boissière and director general Olivier Brault, whom we see regularly. Our collaboration over the years with the foundation's executive team has driven the CRI's development considerably, namely our work with former Project Manager Flora Donsimoni, former Audit Manager Bénédicte Gallon (now the CRI's secretary general), and current chief scientific officer Laura Ferri Fioni.

The quality of our relationship with the Bettencourt Schueller Foundation, France's top charitable organization, has given the CRI a financial foundation that has enabled it to develop far beyond what I could have ever imagined. The foundation finances not only a large part of our operations as well as our education and research programs but also all of the important work that went into building our 5,000-square-meter campus in the Marais district in Paris. Our campus is in a former private mansion owned by the City Hall of Paris that the city will let us occupy for the next 50 years. The location provides not only classrooms and offices but also 55 dormitories for students and young researchers.

I once put it this way to foundation director Olivier Brault: "The unbelievable generosity of the Bettencourt Schueller Foundation allows members of the CRI to be generous to others in turn." By financing specific programs and our transdisciplinary activities, the Foundation allows us to stay true to our values, think outside

the box, and bring new projects to life that can go on to find other sources of funding. This is how we've been able to take on projects from students, teachers, and researchers as well as start-ups and organizations, working for the common good in the fields of education and health. Among these are the *Savanturiers*; SynLab, working in education; Sapiens, training teachers to be teacher-researchers; The Conversation, an online media outlet that works toward developing quality journalism by reinforcing the link between scientists and citizens; Hub IA, which brings together experts in artificial intelligence; iGEM, which organizes student competitions in synthetic biology; Just One Giant Lab, an open-science platform; and Wax Science, which is involved in questions of gender.

In addition, the foundation helps us strategize and works with us in bringing structural ideas to maturity, and this without meddling in our selection processes for projects, students, or researchers. They simply invite us to put in place rigorous, benevolent procedures both for building an efficient, autonomous organization and helping prepare for tomorrow's world.

Some partners from the private sector have also put their faith in us, believing as well in the CRI's vision and missions. Among these are Paul Friedel at Orange Labs and Henri de Castries, former Chairman and CEO of AXA.

I must here also share my gratitude for the hundreds of researchers, teachers, students, and committed staff who have contributed their energies to help us maintain the open platform for innovation and creativity that is the CRI. One of our collaborators from the start has been

doctor and biochemist Pierre Sonigo, a pioneer in cloning and HIV sequencing. Pierre, along with Anne Atlan, organized the “interdisciplinary spring school”<sup>ccxvi</sup> on Île Berder, and among those present were also physicist and CNRS Silver Medal winner Stéphane Douady and CNRS Bronze Medal winner for his work in genome analysis Eduardo Rocha. Pierre Sonigo is also a member of the CRI’s board of directors, along with Guillaume Houzel, Christelle van Ham, Ariel Lindner, Grace Neville, and Armand de Boissière.

I’d also like to thank the group of students and researchers led by Alice Richard and Livio Riboli-Sasco who helped us develop not only our children’s programs Science Festival and Paris-Montagne but also our high school program Science Ac’, which helps teens in low-income areas get acquainted with scientific research. Of course, I can’t here thank everyone who has believed in and taken up our project, giving it energy and helping it grow, yet without their help, the CRI wouldn’t have become what it is today.

I’ve learned so much through my work, but it’s with loved ones that we learn all of life’s most precious lessons, by turns essential, practical, routine, and foundational: what it is to live with others, the tenderness and sweetness of intimate relationships, joy in new birth, and pain in parting. It seems important then that I especially thank my loved ones: my parents, grandparents, uncles and aunts, sisters and cousins, my wife Angèle, my children Bosco and Sophia, our nephews, and all the members of our big tribe who have taught me so much. Usually one focuses on the important contributions of one’s forebearers, and while I wish in no way to detract from the

essential lessons my own have taught me, it seems that at every stage in my life I have also learned a great deal from my peers, namely my sisters Antonia, Angela, and Julia. I can say the same of the new generation, starting with my children, but also the students who have worked in my lab or at the CRI, who have helped me to better understand how much the world has changed over the course of the past few years.

Recently I have been getting invited to write official reports on the learning society, which we can define as a society in which what you learn can facilitate what others learn, as we are social beings who enjoy sharing what we've learned and this effort is made easier and easier with technology. I've learned a lot throughout my life, and especially while writing those reports. I would here like to thank my coauthors Catherine Becchetti-Bizot, Guillaume Houzel, Gaëll Mainguy, and Marie Cécile Naves, as well as all those who have contributed to collective reflection on the topics discussed, those whom I interviewed as well as met in conferences, online, through exchanges thanks to our MOOCs, or who reached out to me to share stories and thoughts after reading the first edition of this book.

I want to therefore thank all those who share their ideas for the purpose of building a learning society. It will be that much more of a success because we'll be more conscientious of the ways we learn and be better and better able to learn how to learn, both individually and collectively. Because I've learned so much trying to build the learning society, it's only natural that I now share what I've learned so that others can learn from it if they find it speaks to them.

I let myself get talked into writing this book because I wanted to contribute in my own way to this collective reflection on the new modes of learning in 21<sup>st</sup> century, even though I had trouble finding the time to do so. This book is by nature unfinished because I can have only a partial, personal vision on the subject. After all, the 21<sup>st</sup> century is far from over.

Someone else may have written this book differently, and I would be glad to hear her approach, as it would be yet another addition to this complex subject. Likewise, at other points in my life I would have written the book differently because I'm constantly learning more and more and learning how to learn. It would be interesting perhaps to have others add to this book as they see fit using our new ways of communication thanks to technology. Then we could create a collective work where everyone could be the heroes and heralds of new ways of learning. New technologies make this easier than ever to do. As we experienced with our MOOCs, those who enrolled in the MOOC participate in research on new ways of learning by sharing their lessons and reflections.

In a similar vein, we're organizing a learning-planet festival, which, like World Music Day, invites everyone to celebrate ways of caring for oneself, others, and the planet. The festival will take place during the week of the United Nations' International Day of Education on January 24. It will be a place for celebrating what we've learned and the people and things that helped us learn, whether it's a grandmother, a friend, a colleague, a game, or an exploration of the beauty of the world. It's up to each person how to celebrate. This learning could be within one's own family, at school, at a university, at work, or in a neighbor-

hood. The celebration will be a moment to reflect collectively and share ideas on the 1,001 ways to learn in the 21<sup>st</sup> century. Reflecting on what we've learned can help us ask questions about how we want to learn and to share these thoughts digitally. Disseminating these lessons can put us in touch with neighbors who could potentially become caring mentors. It's up to each person to decide how to celebrate and discuss the new ways of learning we have at our disposal, as well as discuss how these new ways of learning can complement the traditional methods, which have shown the full extent of their capabilities. It would be interesting to be able to organize Sustainable Development Games to celebrate all those who are working for the future of the planet and sharing in open source the best ways to contribute to the coming transitions.

More and more people kept asking me to write a book, and so, to do my part to “let a hundred flowers bloom; let a hundred schools of thought contend,” to use an expression from Mao, it seemed important to me to get my ideas out and pass on the knowledge that I have. Film director Judith Grumbach was the first one to talk to me about writing a book, during filming for her documentary *Une idée folle*, which she invited me to be a part of. She was involved in the first interactions I had that led to the writing of this book. Of course, the book wouldn't have been possible without the trust, friendship, and professionalism of Emmanuel Davidenkoff, a master of the maieutic if ever there was one. He helped give my ideas shape on the written page, and no doubt had I tried to write the book on my own it wouldn't have been nearly as readable. For this version of the book, I want to thank Timothy Stone, who translated this book into English. It

was a pleasure to interact with him throughout the translation process and work to keep the spirit of the book alive while changing the language and adapting references to another cultural context. I also have to thank my editor Philippe Robinet, who was willing to test out new ideas with us at various stages throughout the process. Furthermore, writing this book was an even greater pleasure thanks to the careful and caring readers in our test audience, particularly Mariam Chammat, Judith Grumbach, Ariel Lindner, Gaëll Mainguy, Marine Montégut, and my father Dominique Taddei, to whom I owe so much. Through the process I also discovered all the people in the publishing industry who make the connection between the author and the reader possible, i.e., illustrators, printers, editors, marketers, and bookstores. I want to thank them, as they contribute to the learning society in their own way.

In the case of this book, we asked them to do something that is only marginally practiced. Some of you perhaps noticed on your own that we used both masculine and feminine pronouns in generic contexts. This is something that I believe in, as do many other gender-parity activists. It may be out of the ordinary for some people, and for those who were seeing it here for the first time, we humbly thank you for understanding why this choice was important to us. It's my hope that for the good of everyone, this small practice will become more frequent and contribute to bringing about a more equal society, not just in our laws but also in reality.

I learned to be progressive on this issue, as well as others talked about in the book, thanks to how I was raised. I grew up in a Corsican family in which this has been a

topic of debate since before I was born. In many places in the world, progress on these issues isn't always smooth sailing, but Corsican culture holds certain cardinal values: curiosity about the world and others, thus respect for others; the marketplace of ideas; and taking action for just causes, being able to fight injustices, and defending those who are treated unjustly. I was always told that a life without responsibility toward others is no life at all and that we have to work so that others can have a life worth living. I was so fortunate to learn so much throughout my life, and this means my responsibility to help others learn is that much greater.

My roots are in Corsica, my heart is in Avignon, and my adoptive home is Paris. I'm French, European, and a citizen of the world. Like everyone, I'm part of a long line of *Homo sapiens* and an even longer line of living organisms, and like the rest of the planet, I am made of stardust. I'm a civil servant and therefore I am paid to contribute to the common good. I love games, and I've been given the opportunity to bet on the future in such a way that I don't have to get angry with myself when I make mistakes. I'm a researcher, and I have been fortunate to be able to learn through research and try to share that opportunity with other learners of all different ages and all different backgrounds. When I embarked on this path, one that seemed to be attracting more and more people, I was told that I was a social entrepreneur. Since these ideas were capable of being scaled up, I was asked to contribute to several official reports. Because these topics piqued the interest of some, I was asked to give lectures and answer more and more interviews, and then write this book, thus becoming an author. As much as I am able, I wear all these different

hats and assume all the responsibilities that go along with them, and I am so thankful to everyone who has aided in each stage of transformation.

I would also like to thank everyone who is taking action to contribute to making the planet we share, our sole space vessel for the foreseeable future, a place where present and future generations can flourish through learning and through enabling others to learn and find the solutions they need to move forward. Together, let's learn to take care of ourselves, others, and the planet. Then we'll be able to find our *ikigai*, thus give meaning to our lives and actions. In our MOOC on the learning planet, a number of educators shared with us that their or their school's *ikigai* was to help other learners find their *ikigai* as a way of overcoming the challenges, both present and future, that they face together. I personally embrace this dynamic and live by a variant of the inscription on the Panthéon: "A grateful planet honors its collective intelligence."

## Notes

1

### WHY WILL WE LEARN DIFFERENTLY IN THE 21<sup>ST</sup> CENTURY?

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## 6

### A HOW-TO GUIDE FOR A LEARNING PLANET

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## CONCLUSION

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In 1997, reigning world-chess champion Garry Kasparov lost in a match against IBM supercomputer Deep Blue. "It is a depressing day for humankind in general," noted *The Guardian*. Twenty years later, Kasparov hammered the point home, saying, "Unlike in the past, when machines replaced farm animals, manual labor, now they are coming after people with college degrees." Right now, we are living through a major evolutionary transition. Developments in artificial intelligence and discoveries in genetics are presenting challenges that our species has never had to face before. How can we make sure that education and research keep pace in this rapidly evolving world? What role do humans play in a world of machines? How can we work with technology to develop both our individual abilities and our collective intelligence? François Taddei makes a case for (r)evolution in knowledge. He takes us through the inner workings of the brain—our best friend and at times worst enemy when it comes to learning—and explores the best ways to start asking if not the right questions, then at least good questions.

Taddei likewise calls on us to create learning societies in order to face the major transitions underway. He investigates ways we can learn with one another through cooperation, drawing on how living organisms have cooperated since life began. Close to home, this means creating learning communities and learning cities while on a global scale he calls for the advent of a learning planet.



*François Taddei is an engineer, biologist, and researcher at the Inserm where he received the Inserm Research Prize. He founded the Center for Research and Interdisciplinarity (CRI) in Paris for exploring new ways of learning, teaching, and doing research. In April of 2018, he submitted to the French government a plan to cocreate a learning society.*