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Letter to my Grandchildren

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Dear Henry, Linus, Maya, Leela, Kaspar, Anarkali and Neerja, and I'm not forgetting my step-grandchildren, Hannah, Gordon, Courtney, Jake, Kate, Emily, and Nina

I worry a great deal about how you, my offspring after two generations, are going to fare in your lifetimes, living in this remarkable world in which we find ourselves. Putting aside for a bit guesses about the various things that may or may not happen, one thing seems certain: both the physical world we are living in and the culture by which we live in it are changing very fast, arguably faster than they ever did during the entire history of mankind. For millennia, almost all children lived the same way their parents did, hunting, farming, buying, selling or bartering like their parents. They formed families and perpetuated a seemingly constant way of life. Generation by generation, changes occurred but they were incremental. Wars and famines periodically disrupted life but life recovered. I believe that none of this is true now. It is now *all disruption* and life is never going to go back to what it was even when I was born, let alone to a stable mythical past of contented people living in peace and plenty. I want all of you to be as well prepared as possible for major challenges in your lifetimes. To do this, you need to spend some serious time and thought on why so much is changing and where it may lead. It is going to affect you profoundly. You must not be blind to the challenges nor must you loose hope.

One obvious reason for all this rapid change is that mankind has been so incredibly successful in bending nature to its needs and wishes. Way back at the beginning of the neolithic, they found new sources of food through grains and domesticated animals. Soon after, metals were harnessed for axes and swords. Skipping ahead, it was a mere century ago that the magic of electricity and electromagnetic waves were harnessed for our use, leading to illuminating the world, then telephones, radio, TV, transistors, lasers, and eventually computers. Shortly after this advance started, antibiotics were discovered and medicine began to really work for the first time, leading to the unravelling of the biochemical secrets of our bodies. Each advance was exciting but also had huge impacts on our culture. After transforming a hunting culture into a farming one, and then using metal plows and finally gas powered engines, now something like 3% of our work force can produce all our food and we can spend immense sums instead on entertainment and tourism. This is happening not merely fast but at an accelerating pace. One simple reason is that there are more people in the world making these discoveries and inventions so they are more frequent. But it also feels like the power this is giving mankind is intoxicating and a large part of our culture cannot stop drinking from this faucet.

There are two technologies in particular that are on the cusp of changing our lives in a truly profound way: first the construction of fully intelligent robots and second the mastery of biochemistry so that we can design our babies to have any desired shape or skills. I know this sounds like science fiction but I think you are wearing blinders if you don't take a hard look at what is going on now. Let me start with robots.

Arguably, the most impressive specific skill that AI (artificial intelligence) has achieved to date is the ability to accurately translate nearly anything from any one language to any other language. The reason this is remarkable is that, because languages differ so much in how information is presented, to translate a sentence accurately, you must understand it. And to understand it, you must know many pieces of basic information about the world. Every sentence has a context, including a situation in the world with a speaker and a listener. The recent algorithms learn how to translate from digesting massive amounts of bilingual text, just as a baby listens and sees the world

continuously for a couple of years and then begins to speak and understand. The AI program learns from massive textual data, finding good values for over a billion numbers that express its knowledge. These numbers have no meaning to us, only the computer knows how to use them. That algorithms can learn in some way the meaning of a sentence is a huge step. In the early days of AI, people used to wring their hands over the seemingly impossible difficulties of codifying "common sense" knowledge. These algorithms have now done a good bit of this. What has not been done yet is to endow programs like this with ears and eyes plus their accompanying interpretation programs, and arms ands legs to move and hold things plus their programs for doing this. Then you'll have a smart robot. Maybe it will turn out that something big is still missing in our algorithms. But it all begins to seem within reach.

Try to imagine a world in which robots not only can replace human workers in almost every job but in which they talk to you, one on one, seemingly exactly the same way another human would. Sounds like great fun and certainly good for lonely people. But you'll also begin to ask questions: you'd want to know what *motivates* the robot, can you trust it, does it have emotions (or understand yours)? The robot must certainly have been given drives by its programmer but maybe, with all its knowledge and eventually experience, it will express these drives in unexpected ways. And maybe some cultures, especially some religions, will declare making such robots illegal or immoral. And will we feel inferior if the robot can do so many things much better than we can and has taken away so many jobs? How this will work out is a gigantic unknown, but, my grandchildren, it is likely to begin happening in your lifetimes. An exciting adventure indeed.

Turning to the second block buster, recall that the biochemistry of the body consists in its DNA, its proteins and a few other molecules that fill the body. Many people assume that when DNA and its code for producing proteins were discovered, we had solved all the basic problems of biochemistry. Actually, that was just the beginning. We need to discover why DNA produces what proteins when, what are all the things each of these proteins do in all different types of cells in the body, and through what sorts of complex chemical reactions. And how the cells coordinate with each other in the exquisite dance we call

gestation. For example, no one has a clue where on the genome is the information that says we should have *five* fingers, not four or six. But there is good reason to expect that all this is going to be worked out within a generation or two because literally hundreds of research labs around the world are working on it.

Exciting news: a recent advance has transformed the theoretical study of genes into a branch of medical *engineering*, namely the invention of the tool called CRISPR/Cas9, or simply Crispr. Every living cell more advanced than a bacteria manufactures numerous enzymes with which it manipulates and sometimes corrects gene sequences. Now scientists have created another such molecule: this one crawls along the genome looking for a precise sequence of the four bases G, A, T and C. Then it replaces the next base with another that you can choose, in other words it *edits* your genome. Applications of this tool replacing bases causing disease are an obvious application and are now a hot area of work.

Who said one should stop at curing diseases when there are so many genetically controlled things about our lives and bodies that we wish were better? For starters, living longer would be nice. In Babylonian times, the mythical Gilgamesh, haunted by his fear of death, went on the first quest for the secret of eternal life. Given that tortoises live several hundred years, there seems no obvious reason why humans can't. Genetic modifications for this are sure to become a hot potato for Crispr or its successors. Stronger, smarter, more beautiful children, why not? Of course, it's likely to be expensive. And certainly, once a small group of people perfects itself in this way, it will prefer to inbreed. Maybe one line will be bred to live in low gravity environments in space and will relinquish the possibility of returning to earth. Aha, so much for mere racial differences, now *homo sapiens* can really divide into multiple species. Phew, now we ask, is this going to be a utopia or a dystopia? But many things in this direction are sure to become reality for you, my Grandchildren. Pandora's box has already been opened a crack. Yet another exciting adventure!?

So much for the goodies we are being seduced by now but that also may turn and really mess up the way we live. There are also better known problems and opportunities that are already part of our lives and testing the resilience of human nature. I am thinking, on the one hand,

of climate change on earth and, on the other, of space travel as a potential safety valve. Taking climate change first, one must acknowledge that it has been caused by things we wished for but that then unexpectedly turned against us. Chief among these was the mantra of perpetual growth, and its corollary, our growing population that has spread over the whole earth, reshaping it for our purposes. This growth fuels our need for more agricultural land and it fuels our need for more power. In service of the first, we cut down and continue to cut down much of the earth's forests which absorbed CO_2 and pursuing the second we burned and continue to burn vast quantities of hydrocarbons, adding more CO_2 to the air. The result is a global warming. An object lesson is the most extreme CO_2 rise that occurred 370 million years ago, creating a hellish earth that killed some 80% of living species.

Climate change and sea level rise will also give rise to hundreds of millions of climate refugees. The UN Refugee Agency (UNHCR) estimates that there are now 20 million refugees and, including people displaced within their own country, some 75 million people fleeing crime, war, drought etc. But here, my own hope is that world wide problems like the present pandemic and the consequences of climate change will eventually spur some joint action. I have believed for some time that this will happen when a sufficiently huge climate related catastrophe occurs; but now, I have a prediction -- the trigger will be when sea level rise plus hurricanes destroy a major part of the super-wealthy's mansions that line the coast of Florida. We can either simply stop emitting such quantities of CO_2 or we may well be able to invent a way to sequester CO_2. Both are possible though both solutions likely to be expensive. With fingers crossed, and I trust you all join me, I have faith that this will not bring down civilization.

As the earth becomes jammed to its gills with its 7.8 billion people, expected to rise to at least 11 billion before leveling off, the idea of colonizing space is sure to become attractive. The other day I was watching a video of astronauts zipping around the space station in zero gravity, hanging out, playing games and laughing and it all seemed so natural. All that's lacking is a way to make money in space and then, like the investors who financed the pilgrims, people will pour money

into space/asteroid/planetary settlements. Once again, perpetual growth will seem possible.

Well, my Grands, the old curse "May you live in interesting times" certainly applies to you and your generation. But it will be fascinating and I hope I have convinced you that standing back to imagine the really big picture of where humanity is going is worthwhile. Please always bear in your hearts a crucial intangible factor that lies behind all the above technical stuff, the *power of love* — a force at your sides even in darkest, most confused times.