The Seven Wonders of the World
Steven Pinker
Convocation Address, McGill University
June 7, 1999

Chancellor Chambers, Principal Shapiro, Professor Marley, teachers, fellow alumni, fellow almost-alumni, families, friends:

In my life I will receive no greater privilege than the honorary degree from this great institution and the invitation to address you today. I am connected to McGill up, down, and sideways, by countless relatives, neighbors, friends, and students who have taught and learned here. Twenty-three years ago I took part in this ceremony when I received my bachelor's degree in psychology. Forty-five years ago I also took part in this ceremony, though I am only forty-four. Yes, my mother was handed her bachelor's degree while she was pregnant with me. Decades before women played Mozart to their bellies to help their fetus's neurons, McGill University was literally being imprinted into my brain. Thank you for having me back a third time, and for bestowing this immeasurable honor.

For those of you who receiving degrees outside the womb, what can I tell you about the long-term value of your years of hard work here? What's the payoff for the all-nighters, the food at the union, the trudges up Peel Street in Montreal snowstorms, the McGill Daily?

It isn't the particular facts or skills you have acquired. If you are an optimist about human progress, many will be obsolete when you reach my age. In my case, I give you B. F. Skinner's theory of behaviorism, IBM 360 Assembly language programming, and Marxist economics.

It also isn't mastery of some academic discipline, because these disciplines are fictions. Knowledge is a continuous landscape, and is divided into specialties for the convenience of deans and so the registrars can itemize the bill they send to your parents. When I receive an article on the brain areas for language, or on cross-cultural studies of reasoning, I sit paralyzed in indecision and despair, not knowing whether to file it under neuroscience or linguistics, under anthropology or cognitive psychology.

Perhaps for a few of you the degree is no more than a credential for entry into a profession or professional school. But it is not clear how long the modern university will be needed to provide that service. Some predict that with advances in artificial intelligence and internet technology, students of the future will be able to learn technical material from providers anywhere in the world, and that the increasingly expensive club called the teaching university will wither.

My own view of the value of a degree is different. A century ago the American philosopher and psychologist William James wrote,

> It takes . . . a mind debauched by learning to carry the process of making the natural seem strange, so far as to ask for the why of any instinctive human act. To the metaphysician alone can such questions occur as: Why do we smile, when pleased, and not scowl? Why are we unable to talk to a crowd as we talk to a single friend? . . . Why, in a room, do [people] place themselves, ninety-nine times out of a hundred, with their faces towards its middle rather than to the wall? Why do they prefer saddle of mutton and champagne to hard-tack and pond-water? Why does the maiden interest the youth so that everything about her seems more important and significant than anything else in the world?

To a psychologist like me these are excellent questions, but that is not my point. My point is that a purpose of a university education is to debauch your mind with learning, to make the familiar seem strange, to get you to ask questions about why things are the way they are as opposed to some other way they could be.

Educated people can use their newly honed inquisitiveness in many ways. I have been fortunate to have had the opportunity to teach, to study language and thought, and more recently, to share the ideas of my field with the general public. Since I started writing popular science, I have been had many dealings with the mass media, but two of them stand out. One was a lunch with a documentary film-maker named Ken Dryden, who turned out to be the Ken Dryden, the immortal goalie for the multiple-Stanley-Cup-winning Montreal Candiens during my days at McGill. The other was an invitation to be featured in a BBC television series called The Seven Wonders of the World. In each half-hour show, a scientist was asked to describe the seven most remarkable things he or she had learned, and the filmmaker illustrated them with footage and music. Previous participants had chosen, among other wonders, the sidewinder snake, space travel, DNA, the fortress at Sigiriya in Sri Lanka, the microchip, Bach's Toccata and Fugue in D Minor, and the flight of the albatross. The filmmakers rejected my first suggestion – the 1976 Montreal Canadiens – but they did film my other choices: the camera, the bicycle, irregular verbs, stereoscopic vision, combinatorial systems, language acquisition in children, and consciousness.

I would love to explain what makes each of these wonders so wonderful, but you have heard enough interminable lectures over the last three years, so I'll talk about just one, combinatorial systems. A combinatorial system is an inventory of simple elements and a set of rules that combine them into complex structures. Examples include chemical compounds, DNA, music, chess games, computer programs, mathematical and logical formulas, and human language.

One of the wonders of a combinatorial system is that it can generate an open-ended set of objects, each with unique properties. That distinguishes it from a blending system, in which the properties of a mixture are an average of the properties of the ingredients, like red paint and white paint forming pink paint. In the combinatorial system underlying chemical compounds, a hundred-odd elements combine to form all the stuff in the universe – every solid, powder, liquid, vapor, and goo. In genetics, just

four DNA bases combine to form the instructions for building (as Genesis put it) every herb bearing seed, every tree bearing fruit, and every fish of the sea, fowl of the air, beast of the earth, and everything that creepeth upon the earth, wherein there is life. In music, a few dozen keys on a piano can produce every melody and harmony in the Western idiom. In language, a hundred thousand words can be combined by the rules of syntax into sentences that make up every book that ever has been written or will be written, and to express every effable human thought. Indeed the words themselves are products of a combinatorial system of vowels and consonants, made all the more powerful by alphabetic writing. In 1632 Galileo wrote,

> But surpassing all stupendous inventions, what sublimity of mind was his who dreamed of finding means to communicate his deepest thoughts to any other person, though distant by mighty intervals of place and time! Of talking with those who are in India; of speaking to those who are not yet born and will not be born for a thousand or ten thousand years; and with what facility, by the different arrangements of twenty characters upon a page!

The other wondrous feature of a combinatorial system is the combinatorial explosion: the breathtaking number of different entities that such a system can generate. To be precise, it is a number that grows exponentially with the number of possible elements in the combination. According to legend, the vizier Sissa Ben Dahir claimed a humble reward from King Shirham of India for inventing the game of chess. All he wanted was a grain of wheat to be placed on the first square of a chessboard, two grains of wheat on the second, four on the third, and so on. Well before they reached the sixty-fourth square the king discovered he had unwittingly committed all the wheat in his kingdom. The reward amounted to four trillion bushels, the world's wheat production for two thousand years.

King Shirham was not the last person to fail to appreciate a combinatorial explosion. As a boy, John Stuart Mill was alarmed to deduce that the finite number of musical notes, together with the maximum practical length of a musical piece, meant that the world would soon run out of melodies. At the time he sank into this melancholy, Brahms, Tchaikovsky, and Rachmaninoff had not yet been born, to say nothing of the entire genres of ragtime, jazz, Broadway musicals, blues, country and western, rock and roll, samba, reggae, and punk. We are unlikely to have a melody shortage anytime soon because music is a combinatorial system. If each note of a melody can be selected from, say, eight notes on average, there are 64 pairs of notes, 512 motifs of three notes, 4,096 phrases of four notes, and so on, multiplying out to trillions and trillions of musical pieces.

The same arithmetic applied to language explains why we will never run out of new things to say. Suppose you have ten choices for the word to begin a sentence, ten choices for the second word (yielding a hundred two-word beginnings), ten choices for the third word (yielding a thousand three-word beginnings), and so on. (Ten in fact is a good esimate of the number of word choices available to a typical person at each point in composing a meaningful sentence.) The number of sentences of twenty words or less is 1020 : a one followed by twenty zeros, that is, a hundred million trillion, or a hundred times the number of seconds since the birth of the universe.

As I mentioned, life itself is a combinatorial system, and that fact changes our understanding of our very existence. In his recent book *Unweaving the Rainbow*, the biologist Richard Dawkins writes:

> We are going to die, and that makes us the lucky ones. Most people are never going to die because they are never going to be born. The potential people who could have been here in my place but who will in fact never see the light of day outnumber the sand grains of Arabia. Certainly those unborn ghosts include greater poets than Keats, scientists greater than Newton. We know this because the set of possible people allowed by our DNA so massively exceeds the set of actual people. In the teeth of these stupefying odds it is you and I, in our ordinariness, that are here.

As your last assignment at McGill, I ask each of you to compile your own seven wonders of the world. If you can't, I suggest you immediately return your new degree and demand a refund. For if a university education has any purpose at all, it is to expose you to so many magnificent discoveries and acts of creation as to make it hard to stop at seven.

As a writer who has relentlessly sought explanations for every instinctive human act, from why children say comed and foots to why grownups fall in love, I am sometimes asked by journalists whether this diminishes my own experience. Aren't we sometimes better off not knowing how things work, they ask, so as to preserve our sense of mystery and awe? I confess to being dumbfounded by this mentality. Could anyone enjoy a sunset less when they come to understand that white light is a mixture of colors, or lose the beauty of a flower when they learn that it is the plant's way of tricking an insect into spreading its pollen? For me, understanding how the world works can only add to the richness of being alive. It is like seeing in color rather than black and white, or listening to music in stereo rather than mono. I hope that is true for you, too, whose minds have now been debauched by learning. I wish each of you a brilliant career, a happy life, and an appreciation of the wonders of the world.