Here is a conundrum: What do “QWERTY” keyboards and the disappearance of 0.400 hitting in baseball have in common - (if you don’t know what a QWERTY is, just look at the first six letters in the upper left row of your keyboard)? Well, except for the obvious connection between any sports writer diligently reporting the accounts of past summer glories and deceptions, the answer has more to do with science writing than any sports at all. The link is a series of stories by Stephen Jay Gould, the epitome of popular (and highly successful) science essayist, on evolutionary trends. In his book “Bully for Brontosaurus”, Gould explores the evolution of type writers and comes to the conclusion that the “QWERTY” board, though very successful at surviving and imposing itself, is “drastically suboptimal” and by far less efficient than its contenders proposed as alternatives. In the evolutionary pathways that dealt with the disposition of little knobs we so often rely on today to express our written language (though fashionable, fountain pens seem somewhat archaic in this age of portable computer and hand held palm pilots), excellence has not been a “signature” of success. This seems untrue, however, of a sport’s phenomenon quite a few Americans are raving about: The disappearance of 0.400 hitting in baseball. In “Full House”, Gould goes to great lengths to explain how excellence, and not its disappearance, is responsible for this feature. To understand the point, one must recognize that the directionality, or lack of, of any relative number (or better said any ratio) is dependent on both its numerator and denominator. Simple math, that any high schooler will tackle with ease. Hence, as Gould’s argument goes, the disappearance of 0.400 hitting, a relative record in itself, is but a direct outcome of better hitters overall and a concomitant reduction in the general variation of hittings around the mean. In short the whole lot is getting to be so good that mostly everyone is up against the wall of human limits. Valid argument, it seems, if you like baseball. As a French-Canadian immigrant in this country, I could never really understand the hubbub around baseball and always thought it to be “much ado about nothing”. But then again, what should I know.

I must, however, admit not to be completely cool to sports in general. Yes indeed, I do believe that next to the Constitution, and Jazz, (and baseball...), basketball is probably one of the greatest and original accomplishments of American creativity (all right, I’ll digress and accept basketball was initially created by a Canadian, at the turn of last century...). Other
things get my clock ticking too. Football of course (I mean, the one form you actually play with the foot), and swimming. And above all, and for personal reasons, the Tour de France. The most grueling sport event there is on this planet has always lit my imagination from the time I was a young boy, sitting with my grand-father, watching Eddy Merckx grinding his pedals and literally destroying his competitors. During its slightly more than hundred years of history, only four men ever won that race five times (Merckx being one of them), and only one of them did it consecutively (Miguel Indurain, a tough Spaniard that twice paired wins on the Tour and the Italian Giro). Four more won it three times, two of which are Americans. So what? Well, the story becomes interesting when you have heroes. And though sports make a strange sort of heroes, when life and death is part of the equation, people tend to notice. The last three years, Lance Armstrong, a cancer survivor, managed to steal, literally, the Tour. He has been dubbed “extraterrestrial” for the prowess he showed on the road. So much determination, so much calculation and intensity, it is quite unreal and hard not to get involved with the race. But wonderment may also lead to incredulity. I happened to stumble on an article, late during the 2001 Tour, as Armstrong was honing on his 3rd yellow jersey finish on the Champs-Elysees. The article analyzed trends in “absolute” performances during the life of the Tour to suggest that the increased success at faster and more powerful performances of recent Tour winners could only be due to performance enhancing drugs. I accept the fact that this latter practice is more than widespread in numerous sports and thus will influence how far, how fast, and how high the human body may go. But I got curious about the trend described. Gould talks about how, eventually, all absolute records become limited, at some time, by physical constraints: the notion of a “right wall” beyond which human achievement can not naturally go. Nothing too exotic in this notion, but if performances are known to increase tremendously in the early history of any sport event, continuous and large improvements come to be dubious at some point. It must be something else. The trend can just not go on like this. It’s not the body, it’s the drug…

And the argument is never better served than by quantitative analysis. If you plot the average speed at which the Tour has been completed by its winners every year since 1919 (Fig. 1 below), you immediately realize that cyclists have indeed increased their performance by almost two fold in the last 80 years.
Nothing too surprising since bicycle building materials and weight have changed tremendously allowing huge leaps in performances. So has the training become more structured and almost “scientific”, based on athletes’ physiology and biomechanics. But something else is noteworthy in the increasing trend: The increase does not seem to taper off at a plateau where, you would think, the human extreme capacity lies. In fact, except for a large jump in the mid-1920s and a lag during the lack on competition of WWII, the steady increase seems almost linear with slight changes in slopes in the 60s to 70s and acceleration (linear again) in recent years. Some skeptical analysts will immediately invoke doping as a culprit for such suspect and unwavering improvement. That was the conclusion of such article I came to read. How else could you explain this continuous trend of excellence? It just isn’t possible. A two-fold increase in cyclists performances during the history of the Tour seemed indeed very suspicious. Well, I am naïve alright but curious anyway, so I checked if indeed there were some grounds for such a statement. Perhaps the analysis was, though well intended, fundamentally flawed. What we need to really compare is total time each winner took to complete the task throughout the history of the competition. And if you compare any absolute record through time (e.g. most track and field or swimming performances), you’ll observe initial steep changes followed by a tapering of record-shattering trends (see Fig. 2 below. The initial development of this argument was presented by Whipp and Ward as a

Figure 1: The steadily increasing average speed for winners of the Tour de France.
product of their analysis of the “gender gap” in athletic achievement (Whipp and Ward, 1992); *Nature*. 355: 25). And indeed, so did the total times for the Tour decrease accordingly and in a dramatic fashion to reach what seems to be a “right wall” of achievement.

![Men's swimming (100m Freestyle)](image1)

![Tour de France](image2)

**Figure 2:** The steadily decreasing world record times for 100m freestyle men swimmers (top) and winners of the Tour de France (bottom).

The analysis is thus complete and my fan’s mind rests quiet with some sense of security that “extraterrestrial” achievements (and hopefully doping) are not overtaking the world of sports (though I can rest about the first one, unfortunately I can’t about the second). However, to feel completely appeased, one final test must be performed on such “analysis”. What if… What if some variable, other than performance itself, had changed in the process of the
“experiment”? First concept that comes to mind, of course, is the constancy of the conditions that we are analyzing: here the Tour itself, or better said the length of the Tour. Lo and behold, when I looked at the historical “evolution” of the Tour’s distance, I realized that such highly mediatized improvements were but an artifact of erroneous analysis (Fig. 2 below).

Figure 3: The steadily decreasing total distances of the Tour de France (top) and direct relationship between average speed and total distance (bottom) - (where average speed of the Tour has always been calculated as total distance/total time)

Contrary to track and field and swimming distances, the total length of the Tour has been plummeting steadily, in an almost linear fashion at least during the last 50-60 years. Well, then, no wonder these guys were doing better. It’s science methodology at its most basic: if
anything is maintained equal, and you manipulate one independent variable, the dependent variable will react accordingly to the change, and in some cases linearly. On top of that, add the improved materials and techniques modern athletes are exposed to, and you’ve got “extra-terrestrial” wall-smashing records!

So, what’s the point. Not sports writing by any means, really, but an analogy for looking at trends and excellence. Sometimes, excellence when it is generalized leads to an overall rise in the performance of the whole (let’s say any population of batters or cyclists) and an apparent diminished relative performance of the individual (the denominator is just too large). In this case, outstanding performance or transcendence beyond the average is just too difficult to come about. Sometimes, on the other hand, the room for expansion into extraordinary achievement is wide and broad since the population’s performance is characterized by a low mean and a high variability around it.

When one looks at apparent trends in modern science and research, one can’t help but notice that higher numbers of Ph.D.’s in science and technology graduate without a job. As stated in an article from The Sciences (“Chutes and Ladders”, July/August 1996), an analysis by the American Chemical Society showed that new Ph.D. unemployment quadrupled in the mid-1980s to –90s to reach a high of 21% in 1995. And those figures do not include the rampant “underemployment” represented by thousands of post-doctoral appointments that do not lead to stable positions. The same article cites that the career options for traditionally trained Ph.D. scientists are not likely to expand in the future, and that the demand for traditional niches as the university and the industrial research laboratory will grow only slowly. Similarly, an article in Nature (“Investigating the Alternatives”, 1998, Vol. 393, p. 493-494) cites that only a minority of today’s Ph.D. graduates can realistically expect long term careers in university research. According to the author of the study, only one-third of those receiving doctorates in the US are expected to enter the academic tenure system. And it seems that more than half of new PhD graduates (much more than that proportion in some fields, like chemistry and engineering) now find jobs in non-academic settings. Are these trends, rampant un/under-employment and apparently lower opportunities, a mark of limitations in
science and research? Is there an upper limit of research (read knowledge), and have we bumped into it?

Certainly, if there is such a limit it must not be lying in the capacity of the brain to explore and comprehend the yet unreachable (for if popular presumptions about how we use our brains are right, we only exploit a fraction of our potential cognitive and analytical capacities, and therefore are situated closer to a lower limit, or left wall, with ample room for development and improvement). The upper limit of scientific knowledge, or right wall, lies in our way to master our thoughts and knowledge about the natural world, but may be imposed, as well, by social and financial constraints. Like the apparent improvement in the Tour de France’s performances, more than one variable is at play here. And among these are the ways we conduct our business of understanding the world. Change in human sociological endeavours, like the scientific process and inquiry, is far from being chance-based as in natural evolution, but is directional and self-influencing. Gould even states that cultural change (remember that science and how we perform it, is a cultural activity) is fundamentally Lamarckian in essence: “Any cultural knowledge acquired in one generation can be directly passed to the next by what we call, in the most noble word, education”. Cultural inheritance thus enhances the broad base of knowledge. Once you know something, you can build on it, and progress is the norm. So it might just seem natural to think that the overall basis of our knowledge, as it increases, brings its keepers closer to an overall increased excellence and thus reducing variation. 0.400 hitting anyone?

It is pure speculation on my behalf to imagine that the “evolutionary” trend in scientific research, if there is any, is one of increasing variation rather than landmarked progression towards an identified and virtually attained excellence. The fact that many new doctors are not finding jobs, except as underpaid post-doctoral fellows, could be the result of increasing achievement in science and thus of similarly increasing demands in the excellence of its practitioners. Under this light, post-doctoral fellowships may thus appear as a necessary prolongation of the educational system that “bonify” recent doctoral graduates with a couple of additional years of study. Is this a direct outcome of overall excellence requiring even higher and sharper skills in a job market that is already ultra-specialized? Not! And I don’t
think that anyone would admit with a straight face that the R&D system, whether in academia or the private sector, is not highly influenced by social, economic, and even political constraints. The end of the Cold War, which has refocused spending for national security, has hammered pitilessly at the expanding scientific and technological workforce, particularly the fresh one out of school. Does that mean that our recent involvement in the political turmoil of the Middle East will increase, once again, government spending and create a new bear market for scientists? Tough and highly inappropriate question at this time. But how about the recent recognition in the US for a pressing need to address demographic projections that will entrain large fluxes of baby-boomers’ kids out of high schools and into colleges? That, indeed, already affects employment opportunities as institutions of higher education get prepared for the “human wave” they anticipate is coming their way. Moreover, the direction of the R&D system today, though waxing and waning in magnitude, does not seem to promote a conservation of old practices. The *Ivory Tower* is grappling for a new definition, a new paradigm of operation. As Academia and the private R&D sector redefine themselves in light of the conditions that surround them, they seem to be generating a new breed of scientists. One that is more aware of the vastness of knowledge (and lack of) and most importantly of interconnections within that knowledge. In universities, new programs are built on multidisciplinary approaches; in the private sector, new positions make use of the flexibility of the agile doctoral minds (or demand such flexibility and analysis potential). Even new scientists are taking matters into their own hands and redefining modern scientific and technological avenues. Doctor Cynthia Robbins-Roth starts her own book “Alternative Careers in Science – Leaving the Ivory Tower” by sating that when she first entered the classic path to becoming an academic scientist, she never dreamed that she would stray so far from that path. Of course, her own history has told her otherwise. But can we assume that this trend is any indication of increased excellence? If yes, then, how can we reconcile the idea of a rise in general scientific excellence (based on the progress of knowledge) and the probability that variation in scientific endeavours is expanding as well rather than contracting as we move towards this excellence? I would explore this paradox by stating that we are probably far removed from our right wall of intellectual limitation, and that a transgression into excellence (increased knowledge) does not forbid increased variation (just as natural evolution seems to lead towards diversity rather than complexity – Gould, 1998).
So the new paradigm is not one of evolving into the *Ivory Tower* in the first place, but one of diversity as we still pursue excellence. General excellence has indeed raised the bar on both the quality of the work performed by degree seekers and the expectation for higher skills from the employment sector. The motto is “If you want to keep counting and classifying new species, make sure you are the best at it in the world”. On the other hand, you might as well start becoming appealing to a multifaceted, multidisciplinary orientation of research. In short, you better pull out those “jack-of-all-trades” attributes that are needed to address the complex situations in modern research and related jobs. Once again, excellence does not necessarily oppose variation, at least not all the time.

You may also regard this whole argument as completely redundant in view of a skeptical attitude as to what can still be performed anew in science discovery. You may be a fervent believer in the fact that “the glory days of science are already over” as John Horgan states in “The End of Science”. In his view, scientific progress lies now exclusively in mere technological advances of what we already know and for which we already hold constructed sound and upheld theories. This argument is not any different than that promoted by James Clerk Maxwell in his inaugural lecture at the University of Cambridge at the end the 19th Century, in which he stated that “all the great physical constants had been approximately estimated and all that remained for future physicists was to push the decimal a few notches further”. That argument, of course, was to be smashed in the following decades by Plank’s theory of black body spectra, Einstein’s revisions of time, space, and gravity, and Bohr’s quantum theory.

Then you have the optimists like Sir John Maddox, editor emeritus of *Nature*, who argues in “What remains to be discovered”, that science is “nearer to its beginning some 500 years ago then its end”. Sir Maddox contends that the fundamental riddles that will animate scientific research in the future will revolve around the mysteries of the origin of the universe and its construction, the origin of life on Earth (and outer space?), and the location of the mind and its elusive alter ego, the consciousness. However, beyond these grand yet unanswered questions, we need to recognize as well some puzzles that put a check on our understanding
of major phenomena that contribute to the complex structure of our planet, biotic and abiotic conditions alike. For example, how can we predict with accuracy the path of a hurricane beyond the time scale of a few days (let alone predicting their birth and life span in the future)? How do “memories” of weather (temperature shifts absorbed by the vast oceanic thermohaline circulation) get activated and generate global changes in the climate system? We do know, now, that such changes occur on times scales of a few millennia if not centuries (maybe decades). But what are the triggering conditions, the (in)famous forcing factors? Is it circulation itself? Is it greenhouses gases? On a parallel train of thought, will we ever be able to crunch the enormous interrelationships of chaotic systems like those of the global climate, biological succession patterns, or even pest and fire outbreaks? Indeed, we gloat we know most about life on Earth, but still as much as 90% of all species on this planet may still be unknown to us (what a great relief for those that find solace in classification and taxonomy). And what about biological events that nag our ignorance. Consider red tides for a second. What is responsible for these vast outbursts of productivities in entirely different parts of aquatic systems? Is it pollution, increased nutrient inputs, changes in physical environmental conditions (salinity and/or temperature), desert dust storms, or simply a sign of decreased immunodeficiency of an ecosystem as a whole? (But of course, for that you’d have to accept ecosystems as living entities, as the Gaia theory proposes, an intellectual approach that is definitely not for the skeptics). And last (here, but not among the vast quantity of questions yet to be formulated), how can we explain inversions in Earth’s magnetic field? What really triggers them? How long does it take for them to settle in? Could they be responsible for anything else than geophysical processes (e.g. global changes that lead to massive ecological change, read extinctions)?

John Horgan’s words to the search for answers to these mysteries are: “some observers contend that unconfirmable, far-fetched theories are science’s vitality and boundless possibilities, I see them as signs of science’s desperation and terminal illness”. You may agree. It’s really a personal choice. I, for one, will side with Sir John Maddox who himself contends that “science, which keeps on asking Aristotle’s questions (How is the universe constructed? Where is the mind?), has repeatedly been surprised that questions not previously asked suddenly take prominence. As in the past, the questions that will engage
science 500 years from now are questions we do not yet have the wit to ask”. And for all of us PhD academics, take the advice from Cynthia Robbins-Roth “don’t let anyone tell you that science is a dead end, now that becoming a full-tenured professor is out of reach”. Or is it?

“The most beautiful experience we can have is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science” – Albert Einstein