Notes for Teachers

Science literacy is the most pressing curricular issue of our day from my perspective. In an ideal world, critical thinking skills and a basic awareness of how our world works would be second nature to both teachers and students. Such is not the case, however. I think we all recognize that teachers could use more help with these most challenging, yet rewarding, tasks.

This book is very much intended to be used as a reference resource or a "vitamin supplement" if you will. It is not designed to replace any math or science textbook at the high school, college, or university level. Rather, it is intended to be used in conjunction *with* current texts in *any* science classroom.

Each teacher will have his or her own ideas and strategies about how to incorporate this material into the curriculum. For example, the straightforward approach, one chapter at a time, will certainly work (but please don't ignore chapter 1!). But this is only one of many possibilities. One might also select questions based on a certain theme without regard to order of appearance in the text; that is, use this text primarily as a repository of good questions.

I am rather fond of using Fermi Questions to stimulate and challenge students. "A Fermi Question a day keeps science *ill*iteracy away" might be corny, but it also isn't a bad strategy. Once students get a hang of this type of question and the reasoning process, challenge individuals or groups of students to invent questions of their own. I find that, now and then, small prizes for the best question or for the solution "closest to the teacher's," provides added incentive.

In whichever way you decide to proceed, I wish you much success.

Chapter 1

How many piano tuners are there in the city of Chicago? — Enrico Fermi.

Introduction

If you are like me, you tend to skip Prefaces, especially if they are more than a page or two in length. But my reasons for writing this book are as important as its contents. And so I decided to sneak my rationale for undertaking this effort into the first chapter. True, *this* would be the Preface in most other books. But I hope you will excuse this not-so-clever ploy to get you to read my opinions on science literacy — we'll get to the more interesting material soon enough. It's just that I think that each of us should at some point reflect upon this important issue no matter what part we hope to play ultimately in society.

First of all, what is "literacy?" This turns out to be a very difficult term to define. A century ago, the image of the literate individual — at least in the English-speaking world — was someone who enjoyed a glass of well-aged port and a fine cigar, and who was well versed in the arts and humanities. He may have had more than a passing interest in the sciences, but this interest was not necessarily a prerequisite for being considered literate.

Times have changed, and so has the image of the literate individual. Like most things, literacy has taken on a more functional definition. Literacy at this point is not simply the purview of cigar-smoking, white males. Now, *every* citizen is expected to achieve a certain level of literacy in order to participate effectively in society; that is, to make contributions to and reap the benefits of a democratic society. And this includes some familiarity with the basics of contemporary mathematics and science.

The world at the turn of the 21st century is far more complex than it was at the turn of the 20th century or indeed at any other time in history. Much of this complexity is the result of technological advances which have been made possible largely because of scientific progress. There is a clear distinction to be made between technological literacy, and science (or scientific) literacy of course.[1] This is best illustrated by means of an example. Nearly every household now owns a VCR, and usually at least one person in the family knows how to program it. Being able to manipulate a VCR is associated with *technological* literacy. But having some idea how a VCR works is quite another matter and requires a capacity one could loosely identify with *science* literacy. It is quite possible that a chimpanzee could be trained to operate a VCR. But only a human can learn *why* it works. And coming to an understanding of how and why our world works is at the heart of what is meant by science literacy.

To reiterate, effective participation in contemporary society requires an individual — a literate individual — to have some facility with basic concepts in math and science. Not the integral calculus or quantum physics mind you; rather, the most elementary ideas of how our world functions. Implicit in "to participate in society" is meant "to be able to base one's decisions, both for oneself and for society, on an informed position." Since more and more issues on which society asks us to make decisions have an underlying scientific or technological component, then it is clear that a basic understanding of science and math is essential if one expects to participate fully and responsibly as a member of the society. By the way, an "informed" decision does *not* imply the "same" decision. Two informed people may reach quite different conclusions on the identical issue. But on what basis do people make decisions when they do not start from an informed position? And what happens when a majority of people no longer has the capacity to make informed decisions on important issues? Decisions are then made either in an uninformed manner, or by a smaller and smaller "elite" segment of society. Either way, one can appreciate why some experts worry that this trend could have very unfortunate consequences for a liberal democracy. (I have completely ignored the serious economic impact on a nation that fails to maintain a sufficiently literate workforce compared with its competitors.)

How literate are we as a society? Put another way, how ready and able are we to take on the role of "responsible citizen" as we begin the 21st century? If we look at the findings of recent studies and surveys, the answer appears

[1] Some sources make an important distinction between *science literacy* which they identify with the memorization of facts and *scientific literacy* which they link to understanding. I use both terms interchangeably in the latter sense in this book.

to be, "not very." Science literacy surveys in Canada, the USA, and Great Britain provide most unsettling news. A large fraction of adults is unaware of the simplest scientific concepts and cannot correctly answer questions such as, "did dinosaurs and humans live at the same time?", or, "does Earth go around the Sun, or the Sun around Earth?". Moreover, there are a staggering number of people who seriously believe in pseudosciences — astrology, tarot cards, numerology — and a host of paranormal claims, from astrology to UFOs (as extraterrestrial craft whose crew abducts everything from cattle to politicians).

One has come to expect the popular media to indulge these predilections[2]. (After all, if profit is the "bottom line" and the paranormal sells well, then that's what the media will deliver. Unfortunately, this is terribly short-sighted on their part. If only they would educate, not just titillate!) But what is even worse is that many pseudosciences continue to be legitimized by our educational system. Everywhere I've lived, from Germany to various places in Canada and the USA, continuing or adult education programs inevitably include courses on astrology, tarot card reading, graphology, etc. Some are even subsidized by taxpayers. And occasionally, such material makes its way into college and university curricula, normally under the guise of "alternative ways of thinking."

A colleague and I decided to see how serious the situation was in our own small corner of the world, so we have carried out two recent surveys of first-year university students, six years apart, in order to sample their attitudes towards astrology and to determine whether they could distinguish the difference between astrology and astronomy. It turned out that a large fraction of these students, some of whom were science majors, believed in the principles of astrology and had serious difficulties in distinguishing astronomy from astrology. In fact the proportion of believers in astrology was not terribly different from the proportion in the general population as measured by polls. The most recent survey, moreover, indicated that belief in the paranormal has increased perceptibly. What does this say about our educational system? It says quite plainly that, at least in certain respects, it is failing our students and therefore failing society.

[2]Readers may want to check out John Allen Paulos' book, *A Mathematician Reads the Newspaper*, to see that even "respectable newspapers" are often guilty of serious slips in science literacy and in pandering to the paranormal.

Let me stress that it is not the pseudoscientific sympathies in this population that I find most troubling *per se*; it is rather the fact that we are not providing our students with the foundations to make informed decisions on these matters. If, for example, a student decides to pursue astrology seriously after studying the fundamentals of astronomy and science, then that's up to him or her. But if this student graduates from the educational system believing in astrology without ever having been challenged with the basics of astronomy and science, then this is *our* problem. We have failed to do our job. (An analogy may be made with smoking. Because of large-scale educational campaigns, few if any North Americans are unaware that smoking is deleterious to one's health. Yet millions continue to smoke. Why? I'm not qualified to answer this question; I'm sure it's complicated. But what is important is that North Americans are now able to make a decision about whether to smoke based on an informed position. In the case of the pseudosciences, many people cannot make an informed decision because the educational system has not provided them with the appropriate tools.)

But what about the "real world?" John Allen Paulos in his book *Innumeracy* illustrates just how the innumerate and scientifically illiterate fall prey to all sorts of scams, traps, cons, errors, etc. (The innumerate are "fair game" for just about everyone, governments included. One wonders, for example, what governments would do if deprived of revenue from lotteries and gambling casinos?) Given that our society is growing increasingly complex and dependent on science and technology, what results might we expect when our leaders are scientifically illiterate, or innumerate in Paulos's terminology? Do we want someone who cannot distinguish between a "million" and a "billion" spending our money? Not me!

Scientific illiteracy within the leadership of a country can have tragic consequences. Undoubtedly, we all have local horror stories in this connection. But perhaps the most disastrous instance I have ever encountered in this context was the so-called "Great Leap Forward" which was a policy implemented by Mao Zhedong in China in the mid-1960s. It was a misguided attempt to improve rapidly China's economic status in the world. You will have to consult a history text for the specific details of the "Leap," but suffice it to say that Mao Zhedong was profoundly scientifically illiterate, and his ill-devised plans, plans which were absurd from the perspective of today's average high school student, exacted a terrible toll on human life — in the tens of millions. Now we may not face quite the same dangers from scientifically illiterate leadership in a democracy, but the lesson is certainly worth remembering.

I have discussed some of the more theoretical reasons for writing this book, but I have compelling practical reasons as well. It is a simple fact that many of the students who enter my university and other universities across North America are not as well prepared in the fundamentals of math and science as they could be. (I'm sure this is an old story, but it seems to be getting worse with time.) There is some weakness in the "basics," to be sure, but with hard work, this deficit can be overcome. What is often more difficult to surmount, however, is the lack of what I refer to as "scientific common sense" — something students never seem to have enough of from the perspective of their teachers.

One of the most common failings among first-year science students is their inability to judge whether an answer is reasonable or not. (I'm sure that every teacher has a favourite list of outrageous answers by students.) It is also clear that this phenomenon is not confined simply to average students at average schools. Survey results involving both non-science and science majors at top US universities are just as frightening; many students are unable to estimate or unaware of simple quantities such as the population of their country.

Granted, the ability to know whether an answer is reasonable — *i.e.,* the ability to estimate — is traditionally associated with scientific maturity. But why should students have to wait, sometimes until graduate school, before honing this particular skill? Why not begin in high school and with all students, for the ability to estimate is a skill to be cultivated not only among scientists, but in all (scientifically) literate people.

I have never believed that common sense is entirely innate either. It always helps to know a thing or two about the subject at hand and about the world in general before applying one's "common sense." The same holds for scientific common sense. For the overwhelming fraction of us, it is an acquired skill, and a very important one. But like physical exercise, it requires regular practice to develop and improve and doesn't necessarily have to be unpleasant and boring.

This is why I wrote this book — to address one important aspect of science literacy in upper-year high school and first-year university students by encouraging and developing their estimation skills, and, as a result, improving their scientific common sense. I have tried to accomplish this using interesting examples taken from the everyday world, as well as from elementary concepts in the physical sciences. You will have to decide for yourself whether I have succeeded. And even if I have failed, then at least there are lots of great questions scattered throughout the book, enough to stimulate and challenge the intellect and satisfy one's curiosity!

The next chapter, the *real* Introduction, contains a number of my favourite examples and anecdotes illustrating innumeracy or science illiteracy. While most may seem light-hearted, they are also indicative of the serious nature of the problem society faces; difficulties, it is hoped, readers will hereafter avoid.

Chapter 2

A nickel ain't worth a dime anymore. — Yogi Berra

Baseball is 90 percent mental. The other half is physical. — Yogi Berra

The Sun will rise at 5:15 this morning, and we're expecting a ton of sunshine today. — heard on a Toronto radio station.

Examples and Anecdotes

Since this book is ostensibly about numeracy and science literacy, I offer the following definition from the Oxford dictionary:

> *Numeracy: the characteristic of being acquainted with the basic principles of mathematics and science.*

Just what these "principles" are, and what "being acquainted with" means, however, are somewhat contentious, as you might expect. It is therefore better to approach this subject by describing what science literacy *is not*. So I will begin by illustrating **in**numeracy and science **il**literacy using examples which I've collected from "real life" over the past few years. These are meant to be enjoyed, even savoured. But at the same time, you should try to identify what is inherently wrong with each of the following stories, if anything, as well as the lead-off quotations in this and other chapters.

a) To compete with the quarter-pound hamburger of a well-known fast-food chain, another chain offered its customers a "one-third-pound burger." The new "one-third-pound burger," however, didn't sell that well because too many people thought that a quarter-pound burger was bigger than a one-third-pound burger.

b) In a radio interview, a person extolling the virtues of eating peanut butter said that the average North American eats 100,000 peanut butter sandwiches in a lifetime. (The interviewer, by the way, accepted this claim without hesitation.)

c) A bankruptcy lawyer in the USA in 1990-91 billed clients for an average of 1,200 hours of work a month — from a low of 851 hours to a high of 1,547 hours.

d) A customer came into a Vancouver photo shop complaining that his camera and flash were not working properly; all the slides were black. It turned out that he was trying to photograph the North Shore mountains [a few km away] from an upper floor of a downtown hotel, at night, and with a flash.

e) The Dominion Astrophysical Observatory in Victoria, British Columbia, once received a call from a fellow who had noticed a bright light low in the sky and wondered what it was. The caller was adamant that it couldn't be a star because "it moved." When asked how far it had moved, the caller replied "about four inches." To justify this he said, "It moved from one side of a telephone pole to the other." The on-duty astronomer correctly pointed out to the man that telephone poles are thicker than four inches. "Not at one hundred yards they aren't!" was the reply.

f) A person was visiting a farmer on whose field was discovered a very old rock. Upon being shown the rock, the person asked whether the farmer knew how old the rock was. "Four billion and five years" was the immediate reply. When asked how he knew this, the farmer said, "Well, the scientists told me that it was four billion years old, and that was five years ago."

g) A bumper sticker I saw in Santa Cruz, California in the mid-1980s read: *Women Against the Atom.*

h) In 1990, an advocate for the homeless claimed that homeless people die at the rate of 45 each second in the USA.

If your answer is "there's nothing wrong with any of the above," then this book is for you. If you can identify the problem(s) in some or possibly all of these vignettes, then you are off to a good start and you are definitely headed for the advanced material.

The problems with these stories and the anecdotes which introduce most chapters, (all of which are based on actual incidents I've recorded over the past few years), is that they betray an uncomfortably low level of understanding of basic concepts in math or science. I am not talking about tripping over a subtle point in particle physics, number theory, or gene splicing, but with the most *elementary* concepts. Like you (possibly), I find many of these innumerate vignettes "cute" and perhaps even humorous. But when one realizes that average and often reasonably well educated people are involved, then this really is a sad state of affairs.

Before identifying the scientific *faux pas* involved in each of the above, I would first like to recall two incidents that took place when I was a child that helped to give me an early appreciation for what I would now call numeracy or science literacy. Perhaps you can recall a similar story or stories in your own life. I warn you, they're not very earth-shattering. But when I look back, these incidents made a definite impression on me that I think had a positive effect on my attitude towards the world.

The first instance occurred in grade five when I was about ten years old. The teacher asked the class, "which is heavier, a ton of bricks or a ton of feathers?" The resulting discussion lasted several minutes as various students expressed their opinions on the matter. I think I favoured, as did most students, the ton of bricks. The answer, of course, is "neither." A ton is a unit of mass and equal masses are equal, whether they are made up of bricks, feathers, or politicians. Those who understood the concept of mass (or weight) could immediately answer this question correctly. Those who didn't understand it were likely to give an absurd answer. It was that simple.

Even earlier, when I was in grade three or four I think, my mother had qualified to be a contestant on an afternoon TV game show, along with a handful of other people. A skill-testing question was asked each of the contestants to determine who would win the grand prize — not a lot of money in the mid-60s. The big question was, "if 20 ping pong balls were placed side-by-side in a straight line, how long would the line be?" As it turned out, my mother didn't give the closest answer and so didn't win the grand prize that afternoon, although she did a lot better than most of the contestants. (What would your answer have been by the way?)

So what is the point of these two stories? In the "feathers and bricks" story, the point is that there *are* answers to certain questions in this world, but to be aware of these answers one must first comprehend some basic concepts about our world: in particular, to understand how the physical world works, one must first appreciate how to measure it. Not knowing the answer to this question in grade five is probably harmless enough. But what if someone in power and with responsibility for making a decision which required a basic understanding of numbers or of the physical world were similarly disadvantaged; what then? The situation might not be nearly so harmless, I think you'll agree.

The point of the second story is not "become scientifically literate and win cash prizes." It is that one of the immediate benefits of understanding the basics of our world is the ability to estimate things which we might initially believe to be completely overwhelming or perhaps even impossible. While we may never need to know the length of a line made by 20 ping pong balls in real life, we may have to know how much paint to buy to paint the apartment, or to decide whether we're abnormal because we haven't eaten 100,000 peanut butter sandwiches in our life.

In the following chapters it is my intention to introduce the reader to the physical world in a way in which it probably hasn't been introduced before. The gist of this approach is to develop estimation skills using a particular type of problem, often called a "Back of the Envelope" or "Fermi" question. To answer such questions, one must first organize the specific problem in one's mind; "what information do I require to answer the question, and once I have the information, how do I use it to obtain an answer? How will I know whether the answer is reasonable; what 'ball-park' answer do I expect?" This is precisely the sort of thing I meant by scientific common sense earlier. This skill is enormously useful not only in the study of the physical sciences, but in life itself.

What is a Fermi Question? Philip Morrison, in a Letter to the Editor of the *American Journal of Physics* in 1963, said it best in the following excerpt in which he is commenting on the training of undergraduate physics majors:

> It is by no means possible to specify the training and readiness of

> a prospective graduate student by a mere list of topics. There is a kind of power over the theoretical and experimental studies in which he has engaged which is difficult to define, but whose presence is perhaps more important than much knowledge which is more formal and complete. There is one test for such power which is at the same time a remarkably apt method for its development. That is the estimation of rough but quantitative answers to unexpected questions about many aspects of the natural world. The method was the common and frequently amusing practice of Enrico Fermi, perhaps the most widely creative physicist of our times. Fermi delighted to think up and at once discuss and to answer questions which drew upon deep understanding of the world, upon everyday experience, and upon the ability to make rough approximations, inspired guesses, and statistical estimates from very little data. ...
>
> Such questions can of course be found for nearly any level of education. ... [The] conception of experiments and the formation of theoretical hypotheses are activities which are well simulated by asking and answering good Fermi questions.

This book then represents an attempt to introduce students to the world of (elementary) Fermi Questions, of the form used in an event by the same name in the annual York University Science Olympics.[3] While the remaining chapters contain a couple of hundred questions with which to whet one's appetite, they also furnish a discussion of the basic scientific principles required to solve the problems, or to address ideas with which students often have difficulties or have shown particular interest. Because the questions themselves are rather disparate in nature, the scientific topics covered may seem "incomplete" to some. I apologize in advance for this.

Some of the questions in this book necessarily reflect cultural or geographical biases. For example, by "North America" I normally mean "Canada and the USA." If the context of the question is puzzling, please reword it in a way with which you're more comfortable. Americans, for example, might substitute 'the USA' for 'Canada,' and 'Americans' instead of 'Canadians,' etc.

[3] Purists may argue that most of the questions in this book are not *bona fide* Fermi Questions, and they would be correct. More accurately, this book is an attempt to develop elementary estimation techniques using "Fermi-like" questions.

The following chapters are arranged in order of level of material. In each chapter, a section is followed by questions which challenge the student to estimate important quantities based largely on the preceding material. At the end of each chapter are a number of general questions judged to be approximately at the right level of difficulty and content. As I will emphasize time and time again, what is important in the context of this book is developing a facility for *understanding* the empirical world rather than for memorizing facts, something which is unfortunately promoted in too many curricula. That is why I find this approach so useful; it's fun (I hope) and an exact answer isn't the most important thing, a concept which the average student finds rather tough to accept at first, but to which he or she adapts quickly.

Chapter 3 is an introduction to to the "basics": scientific notation, units, and most important of all, practise with elementary estimation. Chapter 4 provides a more in-depth study of the background and techniques used in more sophisticated estimation so that the reader can tackle Fermi Questions with a scientific content and that are scattered throughout chapters 4 and 5. Chapter 5 is for advanced concepts, particularly 'energy.' Appendix B contains some "solutions" to selected questions that are marked by an asterisk in the text. The scientific content of the later chapters is not intended to be exhaustive or comprehensive by any means, but only as a vehicle with which to introduce a student to some of the basics which often arise in the context of solving Fermi Questions.

Some of you will seek even greater challenges after dispatching these questions. I commend you for your ability and enthusiasm. There are very few compendia of Fermi-like questions, so far as I am aware, but I will draw your attention to the *American Journal of Physics*, Vol. 53, p. 615. In this letter you will find references to Edward M. Purcell's *Back of the Envelope* column which he wrote from January 1983 through July 1984. As editor, Dr. Purcell compiled a number of excellent, though quite advanced, "back of the envelope" questions. In fact, I have pirated a handful of the simplest ones (altering them slightly) and included them in this book.

Before leaving this chapter, let's look at the lead-off stories again. I promise that even if you don't appreciate what "lessons" they teach or why they are humorous at this point, you will after you master the next couple of chapters.

a) The "one-third-pound" burger didn't sell well according to a marketing group which looked into the situation, because people thought that 1/4 is larger than 1/3. Pretty amazing, isn't it? After all, fractions are taught rather early in school. It's hard to come up with an explanation for such a shocking example of mathematical illiteracy. I guess some people thought that since '4' is larger than '3' ...

b) I am not sure whether the person being interviewed was a member of a peanut lobby group, but it isn't likely that anyone could eat 100,000 sandwiches in a lifetime. If one were to eat one sandwich a day, each day of the year for 70 years, then this makes about 25,000 sandwiches. I don't know about you, but I draw the line at one peanut butter sandwich a day. Although peanut butter sandwiches are a far cry from more serious social fare, the ability to check more subtle claims made by the propaganda to which we're becoming increasingly exposed is an important skill which we should all develop.

c) A 31-day month has only 744 hours. Thus, this lawyer had been getting away with billing clients for, on average, 400 more hours work per month than was physically possible. Such fraudulent behaviour is unacceptable and I presume he was suitably reprimanded. But what about the innumerate clients who had been paying the lawyer's bills without a word of protest?

d) If the complaining customer had read the instructions which came with his flash, or perhaps even written on the back of the flash unit itself, he would find that the flash is effective to a few meters at best. Trying to photograph mountains a few kilometers away in the dark with the flash is not unlike trying to jump over the Grand Canyon on a skateboard. Why didn't he know better?

e) The person who called up an observatory to report that the unidentified "bright light" moved four inches, the width of a telephone pole, showed a profound ignorance of the world *and* had a "units problem." This is a common difficulty with students and something we shall work on in some detail in the next couple of chapters. Four inches is four inches, no matter what the distance.

What the person meant to say was that the light moved a certain angle on the sky, an angle subtended by a telephone pole at 100 yards. As an astronomer, I can't tell you how many people don't seem to realize that stars *do* appear to move. In fact they appear to move once around Earth in about a day.

f) A wonderful example of innumeracy (and probably apocryphal). When the scientists informed the farmer that the rock was four billion years old, their uncertainty was undoubtedly very large, perhaps as much as a few hundred million years. By adding the 5 years that elapsed since it fell in the field, all the zeros in four billion then became significant. You'll find out what this means in the next chapter. But here is perhaps a clearer analogy; suppose you are told that your teacher is 32 years old. In five minutes, a friend asks you the age of your teacher. If you said, 32 years and 5 minutes, this would be a bit silly. Ditto for the age of the old rock.

g) This ranks right up there as one of the most outrageous examples of scientific illiteracy I've ever encountered. I think we all know what the bumper sticker *meant* to say. But what it *does* say is absurd; women, as well as men, bricks and feathers, are composed of atoms. Thus, to be against "the atom," is to be literally against oneself, something this group never intended I'm sure (although one can never be certain in California).

h) One hopes that this was just an honest error and that the advocate was not trying to employ hyperbole or exaggeration — one of the most common and annoying innumerate afflictions of our day — to prove his point. At this rate, nearly four million people in the USA would die each day, and the population of the entire country would be wiped out in less than three months. Even 45 deaths per hour leads to over one thousand deaths per day, and nearly four hundred thousand per year. The annual number of deaths due to traffic accidents is several times less than this, so it is hard to imagine that this could be true. At 45 deaths per day, over sixteen thousand homeless would die each year. I am not an expert in this field by any means, and the death of even one

> homeless person is a tragedy of immense proportions, but people who prey on the innumeracy of the public to make their point are ultimately their own worst enemy. Once they are discredited, who will listen to them seriously again?

There is one last story I'd like to relate of this sort. In 1996, a large cola company announced a promotion in which one could accumulate points that were redeemable for merchandise by buying its products. The initial commercial advertising this campaign featured a well known fighter jet which, so the clip said, could be had for 7 million points. A jet was clearly out of the question if one accumulated points by purchasing cola alone. However, one also had the option of buying points at $0.10 each.

A numerate and enterprising university business student soon realized that an investment of $700,000 was sufficient to buy 7 million points and, at least according to the ad, to obtain the $25 million jet.

Needless to say, the cola company was not amused when it was presented with the student's request accompanied by the receipt for 7 million points. (Very soon after the promotion began, the company changed its commercial so that 700 million points were now required to obtain the jet.)

I am not aware of how the court case turned out, but one thing is for sure, the cola company in question would be well advised to hire *numerate* individuals to design its promotions in the future!

Finally, I selected the lead-off quotations for this chapter for an important reason; to illustrate that I do have a sense of humour. When it comes to innumerate gems, surely no one holds a candle to the magnificent Yogi Berra, former New York Yankee player and manager. I have included a number of Yogi's delightful quotations in Appendix A that have anything vaguely to do with math or science. I cannot guarantee that they are absolutely accurate or even that they are "genuine Yogi" for that matter. (It should be noted that because of the amazing richness of our language, most of these *do* make sense on some level, which is certainly part of their charm.)

There is absolutely nothing wrong with the last quotation either. Sure, we have known for a few hundred years that the Sun doesn't rise, rather it is the Earth's rotation which causes the Sun to appear above the eastern horizon each morning. And sunshine isn't measured in tons (although see Chapter 5!).

While these quotations may not be mathematically or scientifically accurate, they contain legitimate and colourful figures of everyday speech — poetic license if you will. The point I'd like to make is that there are very important strides to take *vis-à-vis* science literacy, but we should not be overly zealous to the point of losing our sense of humour in the process.

And now let us begin.