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Science and Hope

> Two men came to a hole in the sky. One asked the other to lift him up . . . But so beautiful was it in heaven that the man who looked in over the edge forgot everything, forgot his companion whom he had promised to help up and simply ran off into all the splendour of heaven.
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> from an Iglulik Inuit prose poem, early twentieth century, told by Inugpasugjuk to Knud Rasmussen, the Greenlandic arctic explorer

I was a child in a time of hope. I wanted to be a scientist from my earliest school days. The crystallizing moment came when I first caught on that the stars are mighty suns, when it first dawned on me how staggeringly far away they must be to appear as mere points of light in the sky. I'm not sure I even knew the meaning of the word 'science' then, but I wanted somehow to immerse myself in all that grandeur. I was gripped by the splendour of the Universe, transfixed by the prospect of understanding how things really work, of helping to uncover deep mysteries, of exploring new worlds - maybe even literally. It has been my good fortune to have had that dream in part fulfilled. For me, the romance of science remains as appealing and new as it was on that day, more than half a century ago, when I was shown the wonders of the 1939 World's Fair.

Popularizing science - trying to make its methods and findings accessible to non-scientists - then follows naturally and immediately. *Not* explaining science seems to me perverse. When you're in love, you want to tell the world. This book is a personal statement, reflecting my lifelong love affair with science.

But there's another reason: science is more than a body of knowledge; it is a way of thinking. I have a foreboding of an America in my children's or grandchildren's time - when the United States is a service and information economy; when nearly all the key manufacturing industries have slipped away to other countries; when awesome technological powers are in the hands of a very few, and no one representing the public interest can even grasp the issues; when the people have lost the ability to set their own agendas or knowledgeably question those in authority; when, clutching our crystals and nervously consulting our horoscopes, our critical faculties in decline, unable to distinguish between what feels good and what's true, we slide, almost without noticing, back into superstition and darkness. The dumbing down of America is most evident in the slow decay of substantive content in the enormously influential media, the 30-second sound bites (now down to 10 seconds or less), lowest common denominator programming, credulous presentations on pseudoscience and superstition, but especially a kind of celebration of ignorance. As I write, the number one video cassette rental in America is the movie *Dumb and Dumber. Beavis and Butthead* remains popular (and influential) with young TV viewers. The plain lesson is that study and learning - not just of science, but of anything - are avoidable, even undesirable.

We've arranged a global civilization in which most crucial elements - transportation, communications, and all other industries; agriculture, medicine, education, entertainment, protecting the environment; and even the key democratic institution of voting - profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power is going to blow up in our faces.

A Candle in the Dark is the title of a courageous, largely Biblically based, book by Thomas Ady, published in London in

1656, attacking the witch-hunts then in progress as a scam 'to delude the people'. Any illness or storm, anything out of the ordinary, was popularly attributed to witchcraft. Witches must exist, Ady quoted the 'witchmongers' as arguing, 'else how should these things be, or come to pass?' For much of our history, we were so fearful of the outside world, with its unpredictable dangers, that we gladly embraced anything that promised to soften or explain away the terror. Science is an attempt, largely successful, to understand the world, to get a grip on things, to get hold of ourselves, to steer a safe course. Microbiology and meteorology now explain what only a few centuries ago was considered sufficient cause to burn women to death.

Ady also warned of the danger that 'the Nations [will] perish for lack of knowledge'. Avoidable human misery is more often caused not so much by stupidity as by ignorance, particularly our ignorance about ourselves. I worry that, especially as the millennium edges nearer, pseudoscience and superstition will seem year by year more tempting, the siren song of unreason more sonorous and attractive. Where have we heard it before? Whenever our ethnic or national prejudices are aroused, in times of scarcity, during challenges to national self-esteem or nerve, when we agonize about our diminished cosmic place and purpose, or when fanaticism is bubbling up around us - then, habits of thought familiar from ages past reach for the controls.

The candle flame gutters. Its little pool of light trembles. Darkness gathers. The demons begin to stir.

There is much that science doesn't understand, many mysteries still to be resolved. In a Universe tens of billions of light years across and some ten or fifteen billion years old, this may be the case forever. We are constantly stumbling on surprises. Yet some New Age and religious writers assert that scientists believe that 'what they find is all there is'. Scientists may reject mystic revelations for which there is no evidence except somebody's say-so, but they hardly believe their knowledge of Nature to be complete.

Science is far from a perfect instrument of knowledge. It's just the best we have. In this respect, as in many others, it's like democracy. Science by itself cannot advocate courses of human action, but it can certainly illuminate the possible consequences of alternative courses of action.

The scientific way of thinking is at once imaginative and disciplined. This is central to its success. Science invites us to let the facts in, even when they don't conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see which best fit the facts. It urges on us a delicate balance between no-holds-barred openness to new ideas, however heretical, and the most rigorous sceptical scrutiny of everything - new ideas and established wisdom. This kind of thinking is also an essential tool for a democracy in an age of change.

One of the reasons for its success is that science has built-in, error-correcting machinery at its very heart. Some may consider this an overbroad characterization, but to me every time we exercise self-criticism, every time we test our ideas against the outside world, we are doing science. When we are self-indulgent and uncritical, when we confuse hopes and facts, we slide into pseudoscience and superstition.

Every time a scientific paper presents a bit of data, it's accompanied by an error bar - a quiet but insistent reminder that no knowledge is complete or perfect. It's a calibration of how much we trust what we think we know. If the error bars are small, the accuracy of our empirical knowledge is high; if the error bars are large, then so is the uncertainty in our knowledge. Except in pure mathematics nothing is known for certain (although much is certainly false).

Moreover, scientists are usually careful to characterize the veridical status of their attempts to understand the world - ranging from conjectures and hypotheses, which are highly tentative, all the way up to laws of Nature which are repeatedly and systematically confirmed through many interrogations of how the world works. But even laws of Nature are not absolutely certain. There may be new circumstances never before examined - inside black holes, say, or within the electron, or close to the speed of light - where even our vaunted laws of Nature break down and, however valid they may be in ordinary circumstances, need correction.

Humans may crave absolute certainty; they may aspire to it;

they may pretend, as partisans of certain religions do, to have attained it. But the history of science - by far the most successful claim to knowledge accessible to humans - teaches that the most we can hope for is successive improvement in our understanding, learning from our mistakes, an asymptotic approach to the Universe, but with the proviso that absolute certainty will always elude us.

We will always be mired in error. The most each generation can hope for is to reduce the error bars a little, and to add to the body of data to which error bars apply. The error bar is a pervasive, visible self-assessment of the reliability of our knowledge. You often see error bars in public opinion polls ('an uncertainty of plus or minus three per cent', say). Imagine a society in which every speech in the *Congressional Record,* every television commercial, every sermon had an accompanying error bar or its equivalent.

One of the great commandments of science is, 'Mistrust arguments from authority'. (Scientists, being primates, and thus given to dominance hierarchies, of course do not always follow this commandment.) Too many such arguments have proved too painfully wrong. Authorities must prove their contentions like everybody else. This independence of science, its occasional unwillingness to accept conventional wisdom, makes it dangerous to doctrines less self-critical, or with pretensions to certitude.

Because science carries us toward an understanding of how the world is, rather than how we would wish it to be, its findings may not in all cases be immediately comprehensible or satisfying. It may take a little work to restructure our mindsets. Some of science is very simple. When it gets complicated, that's usually because the world is complicated - or because *we're* complicated. When we shy away from it because it seems too difficult (or because we've been taught so poorly), we surrender the ability to take charge of our future. We are disenfranchised. Our self-confidence erodes.

But when we pass beyond the barrier, when the findings and methods of science get through to us, when we understand and put this knowledge to use, many feel deep satisfaction. This is true for everyone, but especially for children - born with a zest for knowledge, aware that they must live in a future moulded by science, but so often convinced in their adolescence that science is not for them. I know personally, both from having science explained to me and from my attempts to explain it to others, how gratifying it is when we get it, when obscure terms suddenly take on meaning, when we grasp what all the fuss is about, when deep wonders are revealed.

In its encounter with Nature, science invariably elicits a sense of reverence and awe. The very act of understanding is a celebration of joining, merging, even if on a very modest scale, with the magnificence of the Cosmos. And the cumulative worldwide build-up of knowledge over time converts science into something only a little short of a trans-national, trans-generational meta-mind.

'Spirit' comes from the Latin word 'to breathe'. What we breathe is air, which is certainly matter, however thin. Despite usage to the contrary, there is no necessary implication in the word 'spiritual' that we are talking of anything other than matter (including the matter of which the brain is made), or anything outside the realm of science. On occasion, I will feel free to use the word. Science is not only compatible with spirituality; it is a profound source of spirituality. When we recognize our place in an immensity of light years and in the passage of ages, when we grasp the intricacy, beauty and subtlety of life, then that soaring feeling, that sense of elation and humility combined, is surely spiritual. So are our emotions in the presence of great art or music or literature, or of acts of exemplary selfless courage such as those of Mohandas Gandhi or Martin Luther King Jr. The notion that science and spirituality are somehow mutually exclusive does a disservice to both.

Science may be hard to understand. It may challenge cherished beliefs. When its products are placed at the disposal of politicians or industrialists, it may lead to weapons of mass destruction and grave threats to the environment. But one thing you have to say about it: it delivers the goods.

Not every branch of science can foretell the future - palaeontology can't - but many can and with stunning accuracy. If you want to know when the next eclipse of the Sun will be, you might try magicians or mystics, but you'll do much better with scientists. They will tell you where on Earth to stand, when you have to be there, and whether it will be a partial eclipse, a total eclipse, or an annular eclipse. They can routinely predict a solar eclipse, to the minute, a millennium in advance. You can go to the witch doctor to lift the spell that causes your pernicious anaemia, or you can take vitamin B_{12}. If you want to save your child from polio, you can pray or you can inoculate. If you're interested in the sex of your unborn child, you can consult plumb-bob danglers all you want (left-right, a boy; forward-back, a girl - or maybe it's the other way around), but they'll be right, on average, only one time in two. If you want real accuracy (here, 99 per cent accuracy), try amniocentesis and sonograms. Try science.

Think of how many religions attempt to validate themselves with prophecy. Think of how many people rely on these prophecies, however vague, however unfulfilled, to support or prop up their beliefs. Yet has there ever been a religion with the prophetic accuracy and reliability of science? There isn't a religion on the planet that doesn't long for a comparable ability - precise, and repeatedly demonstrated before committed sceptics - to foretell future events. No other human institution comes close.

Is this worshipping at the altar of science? Is this replacing one faith by another, equally arbitrary? In my view, not at all. The directly observed success of science is the reason I advocate its use. If something else worked better, I would advocate the something else. Does science insulate itself from philosophical criticism? Does it define itself as having a monopoly on the 'truth'? Think again of that eclipse a thousand years in the future. Compare as many doctrines as you can think of, note what predictions they make of the future, which ones are vague, which ones are precise, and which doctrines - every one of them subject to human fallibility - have error-correcting mechanisms built in. Take account of the fact that not one of them is perfect. Then simply pick the one that in a fair comparison works best (as opposed to feels) best. If different doctrines are superior in quite separate and independent fields, we are of course free to choose several - but not if they contradict one another. Far from being idolatry, this is the means by which we can distinguish the false idols from the real thing.

Again, the reason science works so well is partly that built-in error-correcting machinery. There are no forbidden questions in science, no matters too sensitive or delicate to be probed, no sacred truths. That openness to new ideas, combined with the most rigorous, sceptical scrutiny of all ideas, sifts the wheat from the chaff. It makes no difference how smart, august or beloved you are. You must prove your case in the face of determined, expert criticism. Diversity and debate are valued. Opinions are encouraged to contend - substantively and in depth.

The process of science may sound messy and disorderly. In a way, it is. If you examine science in its everyday aspect, of course you find that scientists run the gamut of human emotion, personality and character. But there's one facet that is really striking to the outsider, and that is the gauntlet of criticism considered acceptable or even desirable. There is much warm and inspired encouragement of apprentice scientists by their mentors. But the poor graduate student at his or her PhD orai exam is subjected to a withering crossfire of questions from the very professors who have the candidate's future in their grasp. Naturally the students are nervous; who wouldn't be? True, they've prepared for it for years. But they understand that at this critical moment, they have to be able to answer searching questions posed by experts. So in preparing to defend their theses, they must practise a very useful habit of thought: they must *anticipate* questions. They have to ask: where in my dissertation is there a weakness that someone else might find? I'd better identify it before they do.

You sit in at contentious scientific meetings. You find university colloquia in which the speaker has hardly gotten thirty seconds into the talk before there are devastating questions and comments from the audience. You examine the conventions in which a written report is submitted to a scientific journal for possible publication, then is conveyed by the editor to anonymous referees whose job it is to ask: did the author do anything stupid? Is there anything in here that is sufficiently interesting to be published? What are the deficiencies of this paper? Have the main results been found by anybody else? Is the argument adequate, or should the paper be resubmitted after the author has actually demonstrated what is here only speculated on? And it's *anonymous:* the author doesn't know who the critics are. This is the everyday expectation in the scientific community.

Why do we put up with it? Do we like to be criticized? No, no scientist enjoys it. Every scientist feels a proprietary affection for his or her ideas and findings. Even so, you don't reply to critics, wait a minute; this is a really good idea; I'm very fond of it; it's done you no harm; please leave it alone. Instead, the hard but just rule is that if the ideas don't work, you must throw them away. Don't waste neurons on what doesn't work. Devote those neurons to new ideas that better explain the data. The British physicist Michael Faraday warned of the powerful temptation

> to seek for such evidence and appearances as are in the favour of our desires, and to disregard those which oppose them . . . We receive as friendly that which agrees with [us], we resist with dislike that which opposes us; whereas the very reverse is required by every dictate of common sense.

Valid criticism does you a favour.

Some people consider science arrogant - especially when it purports to contradict beliefs of long standing or when it introduces bizarre concepts that seem contradictory to common sense; like an earthquake that rattles our faith in the very ground we're standing on, challenging our accustomed beliefs, shaking the doctrines we have grown to rely upon, can be profoundly disturbing. Nevertheless, I maintain that science is part and parcel humility. Scientists do not seek to impose their needs and wants on Nature, but instead humbly interrogate Nature and take seriously what they find. We are aware that revered scientists have been wrong. We understand human imperfection. We insist on independent and - to the extent possible - quantitative verification of proposed tenets of belief. We are constantly prodding, challenging, seeking contradictions or small, persistent residual errors, proposing alternative explanations, encouraging heresy. We give our highest rewards to those who convincingly disprove established beliefs.

Here's one of many examples: the laws of motion and the inverse square law of gravitation associated with the name of Isaac

Newton are properly considered among the crowning achievements of the human species. Three hundred years later we use Newtonian dynamics to predict those eclipses. Years after launch, billions of miles from Earth (with only tiny corrections from Einstein), the spacecraft beautifully arrives at a predetermined point in the orbit of the target world, just as the world comes ambling by. The accuracy is astonishing. Plainly, Newton knew what he was doing.

But scientists have not been content to leave well enough alone. They have persistently sought chinks in the Newtonian armour. At high speeds and strong gravities, Newtonian physics breaks down. This is one of the great findings of Albert Einstein's Special and General Relativity, and is one of the reasons his memory is so greatly honoured. Newtonian physics is valid over a wide range of conditions including those of everyday life. But in certain circumstances highly unusual for human beings - we are not, after all, in the habit of travelling near light speed - it simply doesn't give the right answer; it does not conform to observations of Nature. Special and General Relativity are indistinguishable from Newtonian physics in its realm of validity, but make very different predictions - predictions in excellent accord with observation - in those other regimes (high speed, strong gravity). Newtonian physics turns out to be an approximation to the truth, good in circumstances with which we are routinely familiar, bad in others. It is a splendid and justly celebrated accomplishment of the human mind, but it has its limitations.

However, in accord with our understanding of human fallibility, heeding the counsel that we may asymptotically approach the truth but will never fully reach it, scientists are today investigating regimes in which General Relativity may break down. For example, General Relativity predicts a startling phenomenon called gravitational waves. They have never been detected directly. But if they do not exist, there is something fundamentally wrong with General Relativity. Pulsars are rapidly rotating neutron stars whose flicker rates can now be measured to fifteen decimal places. Two very dense pulsars in orbit around each other are predicted to radiate copious quantities of gravitational waves, which will in time slightly alter the orbits and rotation periods of the two stars.

Joseph Taylor and Russell Hulse of Princeton University have used this method to test the predictions of General Relativity in a wholly novel way. For all they knew, the results would be inconsistent with General Relativity and they would have overturned one of the chief pillars of modern physics. Not only were they willing to challenge General Relativity, they were widely encouraged to do so. As it turns out, the observations of binary pulsars give a precise verification of the predictions of General Relativity, and for this Taylor and Hulse were co-recipients of the 1993 Nobel Prize in Physics. In diverse ways, many other physicists are testing General Relativity, for example by attempting directly to detect the elusive gravitational waves. They hope to strain the theory to the breaking point and discover whether a regime of Nature exists in which Einstein's great advance in understanding in turn begins to fray.

These efforts will continue as long as there are scientists. General Relativity is certainly an inadequate description of Nature at the quantum level, but even if that were not the case, even if General Relativity were everywhere and forever valid, what better way of convincing ourselves of its validity than a concerted effort to discover its failings and limitations?

This is one of the reasons that the organized religions do not inspire me with confidence. Which leaders of the major faiths acknowledge that their beliefs might be incomplete or erroneous and establish institutes to uncover possible doctrinal deficiencies? Beyond the test of everyday living, who is systematically testing the circumstances in which traditional religious teachings may no longer apply? (It is certainly conceivable that doctrines and ethics that may have worked fairly well in patriarchal or patristic or medieval times might be thoroughly invalid in the very different world we inhabit today.) What sermons even-handedly examine the God hypothesis? What rewards are religious sceptics given by the established religions - or, for that matter, social and economic sceptics by the society in which they swim?

Science, Ann Druyan notes, is forever whispering in our ears, 'Remember, you're very new at this. You might be mistaken. You've been wrong before.' Despite all the talk of humility, show me something comparable in religion. Scripture is said to be divinely inspired - a phrase with many meanings. But what if it's simply made up by fallible humans? Miracles are attested, but what if they're instead some mix of charlatanry, unfamiliar states of consciousness, misapprehensions of natural phenomena and mental illness? No contemporary religion and no New Age belief seems to me to take sufficient account of the grandeur, magnificence, subtlety and intricacy of the Universe revealed by science. The fact that so little of the findings of modern science is prefigured in Scripture to my mind casts further doubt on its divine inspiration.

But of course I might be wrong.

Read the following two paragraphs - not to understand the science described, but to get a feeling for the author's style of thinking. He is facing anomalies, apparent paradoxes in physics; 'asymmetries' he calls them. What can we learn from them?

> It is known that Maxwell's electrodynamics - as usually understood at the present time - when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise - assuming equality of relative motion in the two cases discussed - to electric currents of the same path and intensity as those produced by the electric forces in the former case.

> Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relative to the 'ether', suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.

What is the author trying to tell us here? I'll try to explain the background later in this book. For now, we can perhaps recognize that the language is spare, technical, cautious, clear, and not a jot more complicated than it need be. You would not offhand guess from how it's phrased (or from its unostentatious title, 'On the Electrodynamics of Moving Bodies') that this article represents the crucial arrival of the theory of Special Relativity into the world, the gateway to the triumphant announcement of the equivalence of mass and energy, the deflation of the conceit that our small world occupies some 'privileged reference frame' in the Universe, and in several different ways an epochal event in human history. The opening words of Albert Einstein's 1905 paper are characteristic of the scientific report. It is refreshingly unselfserving, circumspect, understated. Contrast its restrained tone with, say, the products of modern advertising, political speeches, authoritative theological pronouncements - or for that matter the blurb on the cover of this book.

Notice how Einstein's paper begins by trying to make sense of experimental results. Wherever possible, scientists experiment. Which experiments suggest themselves often depends on which theories currently prevail. Scientists are intent on testing those theories to the breaking point. They do not trust what is intuitively obvious. That the Earth is flat was once obvious. That heavy bodies fall faster than light ones was once obvious. That blood-sucking leeches cure most diseases was once obvious. That some people are naturally and by divine decree slaves was once obvious. That there is such a place as the centre of the Universe, and that the Earth sits in that exalted spot was once obvious. That there is an absolute standard of rest was once obvious. The truth may be puzzling or counterintuitive. It may contradict deeply held beliefs. Experiment is how we get a handle on it.

At a dinner many decades ago, the physicist Robert W. Wood was asked to respond to the toast, 'To physics and metaphysics'. By 'metaphysics', people then meant something like philosophy, or truths you could recognize just by thinking about them. They could also have included pseudoscience. Wood answered along these lines: the physicist has an idea. The more he thinks it through, the more sense it seems to make. He consults the scientific literature. The more he reads, the more promising the idea becomes. Thus prepared, he goes to the laboratory and devises an experiment to test it. The experiment is painstaking. Many possibilities are checked. The accuracy of measurement is refined, the error bars reduced. He lets the chips fall where they may. He is devoted only to what the experiment teaches. At the end of all this work, through careful experimentation, the idea is found to be worthless. So the physicist discards it, frees his mind from the clutter of error, and moves on to something else.*

The difference between physics and metaphysics, Wood concluded as he raised his glass high, is not that the practitioners of one are smarter than the practitioners of the other. The difference is that the metaphysicist has no laboratory.

For me, there are four main reasons for a concerted effort to convey science - on radio and TV, in movies, newspapers, books, computer programs, theme parks and classrooms - to every citizen. In all uses of science, it is insufficient - indeed it is dangerous - to produce only a small, highly competent, well-rewarded priesthood of professionals. Instead, some fundamental understanding of the findings and methods of science must be available on the broadest scale.

*** As the pioneering physicist Benjamin Franklin put it, 'In going on with these experiments, how many pretty systems do we build, which we soon find ourselves obliged to destroy?' At the very least, he thought, the experience sufficed to 'help to make a vain Man humble'.**

- Despite plentiful opportunities for misuse, science can be the golden road out of poverty and backwardness for emerging nations. It makes national economies and the global civilization run. Many nations understand this. It is why so many graduate students in science and engineering at American graduate schools - still the best in the world - are from other countries. The corollary, one that the United States sometimes fails to grasp, is that abandoning science is the road back into poverty and backwardness.
- Science alerts us to the perils introduced by our world-altering technologies, especially to the global environment on which our lives depend. Science provides an essential early warning system.
- Science teaches us about the deepest issues of origins, natures and fates-of our species, of life, of our planet, of the Universe. For the first time in human history we are able to secure a real understanding of some of these matters. Every culture on Earth has addressed such issues and valued their importance. All of us feel goosebumps when we approach these grand questions. In the long run, the greatest gift of science may be in teaching us, in ways no other human endeavour has been able, something about our cosmic context, about where, when and who we are.
- The values of science and the values of democracy are concordant, in many cases indistinguishable. Science and democracy began - in their civilized incarnations - in the same time and place, Greece in the seventh and sixth centuries BC. Science confers power on anyone who takes the trouble to learn it (although too many have been systematically prevented from doing so). Science thrives on, indeed requires, the free exchange of ideas; its values are antithetical to secrecy. Science holds to no special vantage points or privileged positions. Both science and democracy encourage unconventional opinions and vigorous debate. Both demand adequate reason, coherent argument, rigorous standards of evidence and honesty. Science is a way to call the bluff of those who only pretend to knowledge. It is a bulwark against mysticism, against superstition, against religion misapplied to where it has no business

being. If we're true to its values, it can tell us when we're being lied to. It provides a mid-course correction to our mistakes. The more widespread its language, rules and methods, the better chance we have of preserving what Thomas Jefferson and his colleagues had in mind. But democracy can also be subverted more thoroughly through the products of science than any pre-industrial demagogue ever dreamed.

Finding the occasional straw of truth awash in a great ocean of confusion and bamboozle requires vigilance, dedication and courage. But if we don't practise these tough habits of thought, we cannot hope to solve the truly serious problems that face us and we risk becoming a nation of suckers, a world of suckers, up for grabs by the next charlatan who saunters along.

An extraterrestrial being, newly arrived on earth - scrutinizing what we mainly present to our children on television and radio and in movies, newspapers, magazines, comics and many books - might easily conclude that we are intent on teaching them murder, rape, cruelty, superstition, credulity and consumerism. We keep at it, and through constant repetition many of them finally get it. What kind of society could we create if, instead, we drummed into them science and a sense of hope?