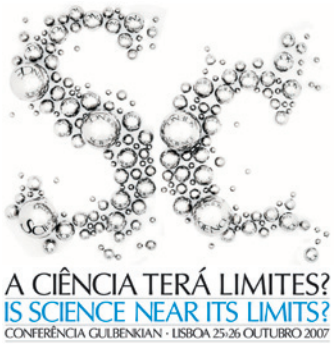

Is Science nearing its limits?

George Steiner

» apenas a conferência proferida é citável

We can neither date nor localize precisely the origins of western science. Pragmatic discoveries in agriculture, in navigation, in the working of metals, in the establishment of the calendar evolve from the inception of soc ial life. Science is something related yet altogether different. It is the disinterested, non-utilitarian, speculative pursuit of verifiable knowledge, of theoretical constructs which may or may not generate subsequent application. It is the obsessive investigation of conic sections at the cost of personal survival, as in the iconic case of Archimedes. Do we pause often enought to consider the utter strangeness, the enormity (in the proper sense of that word) of the western pursuit of pure science ? Which, together with music and pure matnematics constitutes both the absurdity and the glory, the uncaninness and the dignitas of our condition. Do we take time to reflect on what does appear to be the singularity of this adventure, originating in seventh and sixth-century Asia Minor, Ionia, Greece and Sicily, though very possible with contributory elements derived from Sumeria and Egypt ? How arresting is the contrast between Athens and Jerusalem, between the evolution of Greek science and mathematics on the one hand and the virtual ly complete abstention from this option in Judaic ethics and sensibility. We can only speculate, somewhat uncomfortably, as to the causal impetus behind the wonders of the life of the systematic, theoretical intellect from the pre-Socratics onward. I say 'uncomfortably' because the decisve factors may have been those most alien to the naivetés of our current 'political correctness'. Disinterested speculative inquiry, the generation of disinterested hypotheses (in Kant's sense of this crucial epithet) depends on a complex of natural and social circumstances. These most probably comprise an adequate diet, notably in respect of proteins, a temperate climate, the orders of leisure needed for reflection and intellectual debate. In turn, these blessings, the settings for reasoned discourse in the agora or the academy, may well have necessitated both slavery and the general relegation of women to a domestic status. The world of Pythagoras, Empedocles, Plato and Euclid was an immensely special and privileged one. The material and psychological milieu on which it depended was available neither, say, in the Cameroons nor on the steppes of Asia. But whatever the underlying dynamics, the implosive genius of Greek science, inseparable as it was from metaphysical and poetic modes of discourse, was the morning light of the western pursuit and criteria of reasoned truth. As Lucretius reminds us, this pursuit remains what is pre-eminent in that rapacious, unfinished mammal we call 'man'.

From the outset, however, certain ambiguities and shadows attach to this instauration. The tree of scientific knowledge can bear strange, even toxic fruit. How does the dramatic leap of cerebral mastery over nature, of scientific logic so often deterministic, relate to our moral insights, to morality and political wisdom in action ? Does it relate at all ? Is there something monstrous in the co-existence of scientific progress and of individual and social barbarism ? In the mere fact that scientific theories and findings, as these modulate into social practice, can lead to either good or evil, that they are fundamentally neutral, value-free ? These questions trouble Greek thought. They find archaic expression in the myth of Prometheus, in Aeschylus' intimations that the titan's gift of science to man is inseparable from arrogant fatality, from what the renaissance will designate as Faustian 'overreaching'. In the celebrated choral song on the nature of man in Sophocles' Antigone, a text on which, according to Heidegger western destiny turns, the daemonic thrust of scientific and technological achievement leaves human beings dangerously unhoused and at odds with themselves. Aristophanes' caustic satire on scientific speculation and cosmological vainglory remains unsurpassed. Nowhere are the conflicts latent between abstract knowledge and ethical conduct, between the speculative play of thought in physics or mathematics and the application of rationality to political, civic ends more deeply felt than in Plato. Here again, there may be a consequential parting of the ways as between the often tragic sense of man in Plato and the robust, scientifically oriented empiricism of Aristotle. One point is certain: it did not require Los Alamos for science to lose its innocence. Pace Dr.Oppenheimer, it never had it.

Yet whatever these ambiguities, which are persistent in the Augustinian-Pascalian strains of Christianity, one axiom has been central: it is that o the limitless progress, of the inherent forward motion in the pure and applied sciences. There can be setbacks, regressions imposed by superstition or censorship. There can be errors, even long-standing, such as Ptolemaic models of celestial motion or the phlogiston theory of gases and combustion There can be problems apparently resistant to solution and conjectures in enduring search of proof. But the primordial, as it were organic motion is forward. Virtually by definition, theories become more verifiable and the actual sum of knowledge increases. By next week, the sciences will have discovered, will have mapped and understood something as yet uncertain or undiscovered this week. Even a routine scientist will, if he belongs to a competent team, find himself on an upward escalator. In turn, technology progresses concomitantly with the sciences on which it is founded. For the scientist, tomorrow is always more fruitful, more interesting than yesterday. The humanist in the west looks backward. The proposition may be induct-

-ively untenable, but how many of us sincerely believed that another Plato, another Dante or Shakespeare or Michelangelo or Mozart will arise from among us ? Today's school-children manipulate algorithmic concepts and instruments which would have baffled Gauss or Einstein. It is this radical difference in the arrow of time which separates what have been called, too readily perhaps, 'the two cultures'.

It is not only the concept of progress which is axiomatic in western science: it is that of constant, unlimited progress. Here we should pause a moment. We take for granted this unboundedness. It is in fact a profoundly enigmatic, indeed scandalous assumption, bearing in mind the metaphysical sense of Greek skandalon. Men have run the mile in ever decreasing, fractiona time. But they will never run it in, say, two minutes. Physiological imperat ives impose boundary conditions. Biological life may well be prolonged, even markedly, but death will not be eliminated. In the arts and humanities, in literature or music, the category 'progress' has only technical relevance. New raw materials are provided for the architect, painter or sculptor. Music can be made electronic. But in no substantive respects have we progressed beyond Homer or Shakespeare, beyond Plato or Bach. Art, philosophic debate spiral in enduring contemporaheity. They solicit time reversals. Just now, the Odyssey seems to come after Joyce's Ulysses. It is only in the sciences and in the technologies which they inform that progress is both a verifiable truth and , we assume, limitless. The validating paradigm is that of mathemat ics. Whether mathematical theorems and proof correspond to emprical realities or futurities or whether they are autonomously-generated systems, axiomatic constructs carrying within their rules the deployment of the next step, remains a vexed epistemological debate.But the acta of mathematics do indeed look to be unbounded. Neither neuro-physiological nor social and historical circumstance set up any frontiers. In so far as it grows out of mathematics, science is taken to be analogously infinite. The human brain will doubtless come up against insolubles and undecidables; it will wrestle with profound paradoxes and indeterminacies. But overall, and however gradual the evolution of the human cortex, the sciences proceed with essentially unexamined confidence from horizon to horizon. Not only is this a fantastic singularity in human experience. It intimates a daemonic strangeness, a deepening chasm between scientific and common understanding and, tragically perhaps, between scientific-technological instrumentalities and the apparently lamed, even static forces of morality and political means. The unimpeded thrust of the sciences mocks the snail's pace, the recurrent bestiality of our humanitas.

To this day, the assumption of the unlimited has been triumphantly justified. It has launched the greatest argosy of western man, his proudest voyage. From the ziggurats of Babylon to our space probes, from the conjectures of Galen to the genome, from the theorem of Pythagoras to the proof of Fermat's intuition. Unbounded crossings "through seas of thought" and of experiment. After Galileo and Kepler's seminal insight that nature speaks mathematics, the accelerando in the cadence and reach of the sciences became exponential. As did the achievements of technology, themselves, as Hegel pointed out, charged with metaphysical implications. The celestial mechanics of Newton abd Laplace became the allegory of reason itself. The electro-magnetic insights of Faraday, Darwin's theory of evolution affirmed the positivism, the theoretical and utilitarian confidence which underwrite western culture and its claims to planetary domination. Science, technology energize the educational ideals, the market economies and, significantly, the methods of war which characterize modernity. Observe how the dynamics of the exact and applied sciences extend into philosophy, into politics, into social theory. Assertions of 'scientific' structure and verifiability, whether legitimate or not, are fundamental to the positivist programme of Auguste Comte, to Marx's analyses of history and society, to Leninism and to psychoanalysis. Lévi-Strauss calls his somewhat dusty quarters at the Collège de France a "laboratory". The scientific served as pass-word to intellectuality maturity and prestige.

Historians estimate that ninety percent of all those men and women who could call themselves 'scientists' were alive and at work in 1945. Shortly thereafter the money needed to maintain the cooling system in the nuclear research facilities of a leading American university exceeded the total budget of that institution only a few years before. Correspondingly, the social lustre, the economic rewards, the investment both public and private in research and development in both the pure and the applied sciences have multiplied continually. The wonders and application (be they ambiguous) of atomic physics, of molecular biology, of cosmological modelling and exploration have confirmed the sovereignty of science over our understanding and exploitation of the world we inhabit. Fascinatingly, there may have been only two instances in which a brilliant technological advance has been suspended for reasons both contingent and not wholly transparent: Concorde and the hovercraft. Elsewhere, theoretical and technical progress has led, literally, to the planets and the galqxies, to the inmost fabric of the chemistry of life, mathematical constellations justly called 'transfinite'. No end has been in sight.

Though I lack the necessary qualifications - what scientific schooling I had ended in disappointment - I have taken the liberty of suggesting this converzatione in Lisbon in order to ask: is the limitless still before us ? Or are there signs, however difficult to interpret, of a possible crisis in science's hitherto axiomatic postulate of unbounded progress ? Are there any serious hints that scientific theory and praxis are running up against walls, against boundary conditions of a fundamental, conceivably insuperable order ? Even to raise this question may invite ridicule, for it touches on taboos, on dogma which have been the guarantors, the re-insurers of our civilization and its best hopes. But it is the necessary cancer of the spirit its generative restlessness, to raise questions even if an answer seems unlikely or even damaging.

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The polarities of macrocosm and microcosm, the stance of man on a meridian equidistant from both are an ancient edifice. As is the supposition that symmetries, even occult, obtain between the spheres of the immense and of the miniscule, a supposition afforded rational expression in Bohr's planetary model of the atom. The development, as it were contrapuntal, of the telescope and the microscope in the sixteenth and seventeenth centuries flung open the doors on these opposite, dialectically contrasted infinities. The optical telescope became the radio-telescope and the observatory in space. Leeuwenhoek's lenses evolved to become the electron microscope. The 'infinite spaces' which frightened Pascal had their counterpart, no less unbounded, in the infinitesimally minute forms of organic and inorganic matter. Gulliver's travels allegorized both dimensions. Today, however, it is conceivable that the gates are closing. Even the most powerful of radio telescopes, let alone optical instruments, are nearing the confines of our observable universe. Light-waves emitted within roughly calculable time after the Big Bang are still recapturable. But innumerable galaxies are slipping over the horizon of any potential observation. Hypotheses as to the finitude of our local cosmos, proposals, currently fashionable, regarda limitless number of parallel 'universes', will belong to what Bertrand Russell and Wittgenstein carefully defined as the 'mystical'. Correspondingly, it does look as if microscopic observation, however indirect, is nearing its confines (I have heard mention of 10^{-40} angström). The presumptive worlds beyond any such barrier will remain inaccessible.

Should this prove to be so, the epistemologicsl and the psychological consequences could be incalculable. The prison-house for man would continue to be immense; the intermediate phenomenologies would richly justify theoretical and experimental study; but it would be a prison-house none the less.

Qf a closely related though far more speculative order is the possibility that there are, barring unforseeable mutations, inherent limitations to the analytic and interpretative capacities of the human brain. That there may be orders of complexity, of 'strangeness' as far beyond our understanding as, say, language is to virtually all species of animal life. Even if phenomenal evidence were forthcoming, we might not be organized or, as is now said, 'wired' either to register or to interpret it. What empowers the postulate that the resources of the brain are constantly progressing, let alone unbounded ? Marx's assertion that men only pose those problems to which they can find answers is a double-edged consolation. Suppose that these are not the decisive or most fruitful problems. How would we know ? The effects of immutable limitation on individual and social psychology are unpredictable. There is a hint of derangement in the mere possibility of a never-ending treadmill . The only text, perhaps, adequate to this termination is that of Odysseus' last and fatal voyage in Inferno XXVI:infin che il mar fu sopra noi richiuso ('till the sea was closed above us').

One of the principal perplexities to which this conference will turn does seem to compact these manifold issues.

Whether Heisenberg's Indeterminacy Principle, whether the ineluctable interference of the act of observation with what is being observed at the level of particle physics - notions which Einstein famously abhorred - put$ inherent limitations on any empirical mapping of the sub-atomic and the aetiology of creation, remains a vexed topic. It is in the 1970s that String Theory begins its imperious take-over. It is estimated that it has fuelled some ten thousand papers, a gaggle of colloquia and the politics of academic tenure. To its proponents it is the Holy Grail, the 'final theory' unifying force and matter in a quantum model of gravity. Embracing both gravity and quantum mechanics in that coherent, unified construct which had so long eluded General Relativity. The jubilation has been clamorous, the professional rewards stellar. No matter if more and more dimensions have to be added to the intial paradigm (some 'stringers' speak of twenty-nine, making Ptolemaic epicycles seem abstemious).No matter if a hybrid known as 'split supersymmetry' has hived off from the original matrix.But perhaps the problem lies deeper (I quote eminent dissenters). So far, not a single new testable prediction has been made; not a single genuine theorerical puzzle has been resolved. It is, foretold Feynman, "crazy nonsense". At best,"a new version of medieval theology" (Sheldon Glashow). To some its conjectures "are not even wrong". Critics have spoken of a "confidence trick", with the media-hyped stress on 'confidence'. When vibrating membranes were added to strings, the high priest of the new cult allowed that that the M in M-Theory might stand for

"magic, mystery, or membrane, according to taste."

It would be egregious impertinence for a layman to voice an opinion. But a much larger question arises. String theorists have concdeded, often with an aura of satisfaction, that their proposals cannot, will never be susceptible of experimental proof or refutation. Some have gone further, suggesting that no adequate thought-experiment will be devised either in verification or falsification of what is, in essence, a mathematical explanation of our universe. One need not be a dogmatic adherent to Karl Popper's definition of science as open to experiment and rebuttal, to perceive that what is at stake is the very concept of science itself as it has prevailed ir the west over the millennia. If String Theory is immune to either proof or cancellation, if it is nothing but a mathematical game of great beauty and arbitrary license ("it can be made to mean anything" comments one ranking cosmologist), then is it a science ? This is far more than a question of semantics. It goes to the nerve-centres of western rationality as it has been understood and enjoined since Aristotle and Bacon. Will a particular conception of formal beauty, an aesthetics after Kant, come to replace the status of experimental data and empirically controlled prediction ? Is there obsolescence in the classification of science as science ? As one philosophically-oriented French astronomer has put it: "Today,astronomy is encountering metaphysical questions for which it has no answers. It must pass the baton to philosophy."Or as Steven Weinberg has argued, it is not discoveries about nature which now seem most compelling; it is discoveries about science itself."

The second major crisis is one of internal cohesion and communication. Traditionally, the sciences, theoretical and applied, Could be systematically ordered and interrelated. Life sciences, physics, the organic and the inorganic could be demarcated and located along principal conceptual and methodological axes. The baroque but also Comte's atlas of the pursuit of knowledge delighted in elaborate taxonomies and concordances. Reciprocities and nodal synapses could be deliniated. Encyclopedia and functional order as the philosophes and Hegel set them out. This diagrammatic exposition is no longer practicable. Physical chemistry, neurophysiology, biochemistry, geophysics, astrophysics and now astro-biology, molecular biology are examples of novel conjunctions. Their lineaments are constantly fluid. Moreover, within every field the ramifications, the sub-sections are now so manifold that they subvert any consistent totality. At a rate of fragmentation and multiplication which can be statistically projected, each specialization fissions into sub-specializations which in turn ramify. Branching out from their classical stem, the sciences within science become more and more minutely, technically segmented. A new academic discipline, a new journal and professional association will within predictable

and accelerating time generate further journals, each devoted to a particular sub-division. In radiation oncology alone, there are now said to be some forty ranking journals or bulletins (among them, I believe, one edited in Hiroshima).

The consequence is a growing break-down in internal communication. Specialists in more and more circumscribed fields find it difficult to communicate with their immediate scientific neighbours. Taxonomies, experimental techniques, mathematical instrumentation divide and sub-divide generating specific languages foreign to the colleague even in a nearby area. Radio-astronomers hesitate to express their views on the physics of the solar system or the chemistry and mineralogy of meteorites. The expert on bowel cancers declines to comment on pulmonary pathologies. All too often the bio-chemist talks to neither. The tentacular proliferation of journals, which run into the tens of thousands, of electronically disseminated précis, of data-banks, of messages on the Internet and the Web, of computerized search-mechanisms have aggravated the crisis. Such is the daily input of specialized information that there is now a distinct risk of collapse inward. Too often the significant and the trivial cannot be sorted out either rapidly or with certitude. Reduplication proliferates. It is becoming nearly impossible to have a general conspectus/ and over-view in any but an impressionistic, perfunctory sense. It is said that after Leibniz only J. Robert Oppenheimer was capable of envisioning science as a whole, of knowing where a new finding or unsolved problem 'fitted in' (to the which distinction I would want to add the name of the dishevelled, polymorphic genius George Gamow).

On a somewhat different but related plane, science is finding it more and more awkward to achieve serious communication with the community at large. This dilemma goes back to the mathematicization of the natural and applied sciences after Galileo and Newton. The search for a common language has largely aborted. The educated laity derives what insights it has into scientific progress and methods of understanding from often irresponsible and trivializing journalism. Those able to bridge the gap - a Medawar, a Freeman Dyson - are exceedingly rare. This incommunicado grows with the scandalous non-numeracy of education and what passes for adequate culture. Nothing compels society even in the so-called developed world to explore even rudimentary mathematical concepts and methods (look around the table and ask your guests or indeed yourself to define a 'mean average' or an elipse). Yet the implications are little short of disastrous. Advances in molecular biology, in bio-genetics, in the understanding of geological processes affect, will affect personal and collective existence at every crucial juncture. They will shape moral and legal options, economics, political control, therapy and psychology. Who can confidently predict the social implications

of the genome projects, of genetic manipulation, of neuro-chemical interventions in heredity and memory ? Informed debate, on which our future may well depend, requires homework on the part of the layman. It also requires the will to communicate lucidly and with an awareness of the social context on the part of the scientists. The prospects on either side do not look bracing.

The third crux may well be the most radical but it is also the most difficult to place. Certain insoluble paradoxes and potential contradictions in formal logic, in the theory of groups had been noticed in the late nineteenth and early twentieth centuries. These,however, were small clouds on an otherwise serene horizon. 'The greatest step in human thought since Aristotle and Descartes' read the Harvard citation for Kurt Gödel's honoris causa. Virtually unnoticed, Gödel had announced his theorems in Kant's city of Königsberg during an obscure congress of mathematical logicians in 1931. Even today the shock is far from being absorbed. Gödel showed that no mathematical system can be reduced to axiomatic self-consistency.In every such system there will be propositions which can neither be proved nor disproved. Nor can there be proof of the internal consistency of the axioms from which that or any other system is derived. There will always have to be, as it were, an import from without. The consequences for all exact and pure science are, if you will allow the play on words, incalculable. The proud edifice of systematic decidability as it had stood since Euclid has been undermined. Roger Penrose has recently demonstrated that Gödel's theorem renders illusory any essential analogy between mechanical computation and the operations of the human cortex. No less illusory is any cosmological 'Theory of Everything' as promised by Hawking. 'Everything' is a hybrid whose logical foundations must remain, at key points, arbitrary and contingent. Unawares, the philosopher of culture, Adorno, gave a lapidary translation of Gödel, when he professed that 'all totality is a lie'.

Mathematics and the sciences now know that there are in logic, in the laws of thought as these seem to be imprinted in the human brain, constraints on, limitations to both totality and proof. Even at its most sovereign, as in Darwinian evolution, theory remains theory. The incommensurable, the undecidable, the indeterminate are not accidents of history to be overcome. They lie at the heart of the scientific enterprise. They are the 'black matter' of reason. Thus there are problems which will remain insoluble or, at best, subject to inconstant hypotheses whatever the methodological or pragmatic advances in human knowledge. Contrary to the confident assumptions of Bacon and Laplace, our picture of the universe will always remain in substantial part conjectural, perhaps mirroring, as Kant believed, the particular, local structure of our intellect. The barrier seems to run through

Königsberg ! String Theory, the modelling of consciousness as neuro-chemical and electro-magnetic may signal the as yet unaknowledged collision with the undecidable. One is reminded of Heidegger's impatient boutade: 'the sciences are trivial. All they give us is possible answers. It is the questions that matter.'

This does not signify, of course, that momentous scientific progress will not continue, that work of the first order will not evolve, even in hitherto uncharted fields. Bio-genetics, information theory, particle physics may conjoin at seminal points in the further exploration of the brain. Understanding of the neutrino, of dark matter is as yet preliminary. Higgs's boson awaits capture. We know less of the depths of our oceans than we do of the surface of the moon. Medical research in particular is in a formidable phase which may allow substantive improvements in epidemology, in the correction of inherited defects, in the very span of normal life. Technology has its autonomous, economically energized impetus. Nor is there any reason to suppose that higher mathematics, whatever the tremours in its logical foundations, will decelerate in its meteoric play. Even the Riemann Hypothesis may yield its obstinate secrets.

None the less it may be legitimate to step back for a moment in the hope of arriving at a larger view. So as to take in better what the Rockefeller University intended when it hosted a conference entitled "Is Science Under Siege ?"

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The symptoms are complex and difficult to evaluate. Undergraduate enrollment in the 'hard' sciences such as physics and mathematics have declined, often sharply. Government funding for fundamental research has been reduced or made subject to restrictive, interfering legislation (stem-cell resarch is a graphic instance). The facilities, both financial and practical - laboratory space, equipment - for the training of young scientists have become constrained. The success rate for grant applications on which the professional advancement of young scientists absolutely depend is now estimated to be as low as ten or fifteen percent. Respectable colleges and universities are shutting down or amalgamating science departments, notably in such classical disciplines as chemistry or geology or botany. One illustrious British university finds itself with seven tenured posts in chemistry and less than a dozen doctoral students. The altogether fundamental teaching of the sciences in secondary schooling is in a parlous state. Given his salary-structure and low prestige, the instructor far too often represents the most disappointed, mediocre element in the spectrum. The able mathematician goes into finance and the money-markets. The defeated enters school-teaching, thus spreading, consciously or not, the miasma of boredom.

But the subversion lies deeper. Philosophy has fallen out of love with science. The receptive concordance of science and philosophy in Poincaré, Bergson or Bertrand Russell is long past. Sartrian existentialism ignores science. The two commanding voices in twentieth-century philosophic thought regard the sciences as ultimately trivial. By asserting that "science does not think", Heidegger expresses the conviction that it has nothing to tell us either about man's ontological and metaphysical status or about the fundamental significance, the epistemological status of therealities it innocently investigates and manipulates. Trained as an aeronautical engineer, at home in mathematics and profoundly engaged with its logical foundations, Wittgenstein never tired of saying that science could not solve, would never solve the truly important problems of human existence which are ethical. Nor could science enlighten us as to the aesthetic which, like Kant, Wittgenstein related closely to morality. Such critiques invite consideration and reply at the highest level. Far more vulgar, but perhaps more consequential, is the disenchantment with science in western culture at large. It stems not only from the tragic rôle which nuclear physics assumed in and after the second world war or from its inevitable rôle in the technologies of armament. This diffuse but elemental disappointment arises from the feeling, whether justified or not, that science has not kept its promises: that disease, hunger, social injustice and barbaric conflicts continue to plague mankind at a time when science and technology, when research and development swallow enormous economic resources towards incomprehensible ends (the activities of CERN are a case in point). The moon-landings have not inspired a single literary text or work of art of real quality. Climate changes and the disasters which they are already generating seem beyond scientific-technological arrest; indeed science and technology may be contributing factors. The fear of genetic programming for political, even military ends is now widespread. A small but not negligible number of men and women are abdicating from scientific careers with a sense of bitter emptiness.

The stakes are high, for the assault is not so much on science as it is on reason itself. We are engulfed in irrationalism, in superstition, in the most primitive forms of credulity. Some twenty million Americans are convinced that Elvis Presley has risen from the dead. The financiers of Wall Street and the City of London arrange their furniture according to the ordinance of pseudo-Oriental animism. The wife of a British prime minister wears amulets against cosmic rays. There are in the United States three times as many registered astrologers as there are physicists. Faith-healing and every brand of mystical therapy rakes in hundreds of millions in profit. Terming themselves 'life councilors' unscrupulous gurus feed on the abject neuroses of the privileged. /Fundamentalism, at whose hysterical core lies

/Observe the cunning mendacity of such designations as Christian Science and Scientology.

the hatred of rational thought, of adult dissent, is on a global march. Islam has repudiated science over centuries. Christian fundamentalism is now a major factor in American public and political affairs. Its attempts to censor Darwinism and bio-genetic research are all too manifest. Where its dynamics of faith are atrophied or moribund, organized religion breeds intolerant obscurantism. Where angels have ceased to fly, UFOs take over. Where Moses' staff fails to draw living water from the rock, the dowser practices his fraudulent tricks. The infantile cosmology and rites of the New Age are in fact as old as are witch-doctors and drugged shamans. Why bother to think, to study difficult languages, to exercise critical doubt when you can read the Da Vinci Code, invoke Harry Potter's Wizards or head for narcotic revelation in the crime-sodden slums of Nepal ? In short: the noon of Greek classical questioning, the pride and scruple of analytic inquiry as in Descartes, in Hume or in Kant are in often abject retreat. In so many respects the current climate of consciousness, albeit saturated by technological sophistication, is more prone to demonology than were the Middle Ages.

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As Lenin famously asked: 'what then shall we do ?' Knowing that there are no straightforward let alone guaranteed answers.

Some measure of culpability does attach to the sciences and their trumpeters. At salient points, arrogance has been blatant. It is simply fatuous to proclaim that the identification of bosons will yield "the key to the universe". It is intellectually, possibly morally dishonest to rule, by magisterial fiat, that any question as to time prior to the Big Bang is illegitimate nonsense. Loud promises in regard to cures for Alzheimer's, for many types of cancers have, time and again, proved premature. Not only must the sciences explain themselves far more transparently (exactly what does justify the mountainous investment in giant accelerators such as CERN ?). The sciences must be prepared to engage, on terms intelligible to educated women and men, in the moral, political, social debates which their findings and sequent applications entail. Molecular biology, genetics, the neurological investigation of the cortex raise conflictual issues directly pertinent to the life of the individual and of the community. Scientists - and this will arouse hostility - must learn to 'lose some of their time' in didactic, forensic and civic debate with their often ignorant, prejudiced and traumatized societies. The self-isolation of vital branches and institutions of research from the communities which sustain them, the readiness of scientists to accept censorship and concealment in the name of national security, have been ominous. The charades which surround the possible impact of cloning are a case in point. A common language, a shared acceptance of responsibility beyond the patronizing manipulation of the media must be found.

In turn, as I have tried to show elsewhere, our concept of indispensable literacy must be thoroughly revised. Without a proper degree of numeracy, no one should regard themselves as educated, as equipped to participate in the decision procedures, in the rewards and crises of modern life. The innumeracy, the more or less self-satisfied abstention of the vast majority of the public and its political spokesmen from any grasp of even rudimentary mathematical, which is to say scientific, concepts verges on the scandalous. Those who are capable of teaching mathematics to our children, of waking in us some immediate sense of the great adventure that is mathematical conjecture, should be financially rewarded and socially honoured. Even demanding mathematical concepts and proofs can be taught historically. What saga is more thrilling than, say, the discovery of non-Euclidean geometries, of algebraic geometry or Fermat's so-called 'last' theorem ? What is more instructive of the ingenuities and limitations of our mental life than the notion of the undecidable, of that which cannot be proved, now or never ? How deaf is the human ear which cannot hear what has justly been called "the music of the primes"; how myopic the human eye which, as a famous American poem put is in regard to Euclid's Elements, has not "looked on beauty bare" ?For if there is validity to Keats's axiom that truth is beauty and beauty truth, it is in mathematics and the exact sciences that we shall find it.On a humbler but vital level, only numeracy elevates much of modern economics, sociology, demography, an informed response to architecture above triviality and the agendas of the media. Nothing here is new Plato inscribed above the doors to his academy the maxim that no one ignorant of geometry should enter. A terrible laziness infects our ways.

Encompassing such measures is the central issue of reason, of its fragility. Are we aware of the damage, possibly irreparable, which the triumph of pornography and narcotics, which the brutal despotism of noise, of incessant trash input is inflicting on the brain, notably on the brain of the young during seminal stages in its nurture and development ? Whatever its dilemmas and potential limitations, science has been, science remains the luminous child of reason. The threat of political madness, of infantile fanaticism has rarely been more insistent. Nor the therapy of science, of reasoned tolerance which science embodies more necessary.

If this colloquium makes some modest contribution to this argument, it will have been justified.

George Steiner