Ethics, Science and Mathematics

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We have now reached a stage where manmade existential or near existen- tial risks are much higher than any risks posed by external nature. This state of affairs has been enabled by research conducted in the name of science and mathematics. Hence, questions of ethics can no longer be avoided in these do- mains. The need to set ethical limits is on the whole accepted. However the discourse is weakened by the absence of consensus on what type of research constitutes a threat, and on the related misunderstanding of what science and mathematics are about as well as by unscientific convictions about re- ality. Indeed science and mathematics continue to be regarded as objective pursuits of truth in a reality reduced to sense-perception, a reality where only the parts matter and their interactions as well as their impact on the whole and in turn the impact of the whole on the parts are neglected. For ethics to become an integral part of the research world, not only is a proper assessment of science and mathematics necessary, but the very question of freedom of thought and expression, the right of the individual to do as he pleases without any constraints, must be widely debated.

In this article, we first briefly discuss the nature of science and mathemat- ics. We argue that the two are fundamentally different activities. Therefore ethical concerns have to integrate these differences. After discussing the re- lation of truth with these subjects, in the last two parts we address questions of ethics. In particular we explain why its importance in the context of mathematics has now become critical.

# Science and Mathematics

The criticality of investigations of our sense-perceptible world was evidently recognized from early on since otherwise we would probably not have en- dured, or at best would have done so at a survival level. Their necessary characteristics if we want our conclusions to be reliable were well assessed

and sophisticated methodologies elaborated long before the Christian era, at least by some schools of thought.

So what is science? No definition can be fully satisfactory because as remarked by John Stuart Mill, “the definition of any term in science” being under incessant modification, “it may easily happen that a different set of characteristics will [in the future] be found to be better adapted”.1 Hence the definition should be sufficiently flexible to integrate the historical evolution of the characteristics of science, and allow for any future evolution beyond

our present imagination. Hence it is best to establish it on the common features of any reliable methodology: observation, as the subject matter im- plies, as well as reasoning, defined by Gordon Childe as “the ability to solve problems without going through a physical process of trial and error”.2 Con- clusions merely guessed intuitively from observation cannot be considered scientific until they are supported by reasoned arguments: obtaining satis- factory results might be sheer coincidence. Conversely, reasoning without solid empirical foundations, is not science. Note that the term ‘reasoned’ is more neutral than ‘rational’.

To further ascertain what science is, we need to have a clearer idea as to what the domain of science consists in. “Sense-perceptible world” or any other similar terminology conceals a fundamental aspect of science, namely the necessity to invent concepts such as atoms – one of the cornerstones of modern science. Although these concepts may, to begin with, be only partially suggested by observation, to be considered scientific their soundness must be confirmed by their perceptible describable effects. Nevertheless, we have no way of determining whether our concepts are veritable phenomena or pure constructs of the human mind to account for mundane experience. At the very least, they are indefinable from within science, a mathematical rendering being akin to translation into another language, not explanation. Conversely, not all aspects of our sense-perceptible world are amenable to reliable investigation. Reliability entails communicability so that it can be verified. Communicability limits the domain of scientific investigations. The latter must be limited to describable features. Absolute concepts such as heat or height, although they are certainly part of our experience of life, have no place in science for there is no way of ascertaining how two different individuals perceive them. What can be communicated and agreed upon is whether or not two sense perceptions of the same type are identical or different and to what extent, whether an object is hotter or colder, taller or shorter, than another one. In other words, only comparable attributes, namely those associated with pairs of opposites, and thus observable with reference to something else, are open to scientific scrutiny.

Verifiability as well as the necessity to ensure that the data obtained is

not accidental, imply a critical point: reproducibility. Observations must be repeatable in varying conditions, given that the exact same conditions never occur twice, and the conclusions must nonetheless sufficiently agree. Mere observation is not sufficient.

Another point worth insisting upon is that a concept or a phenomenon can be said to be understood with some degree of satisfaction only when so are both its intrinsic properties as well as its interactions with the larger environment, implying the need to study it both in isolation and in its natural surroundings over time and space since some effects may not be immediately noticeable. In summary,

*Science is the reasoned study based on reproducible and sufficiently reproduced observation of the describable attributes of the sense-perceptible world and of the concepts thereby inferred and justified by the investigation of their perceptible describable effects, a study which includes the interactions of the subject under study with its surroundings.*

Now, mathematics too emerged from observation and practical necessities of tackling patterns that appear to be quantifiable, in other words countable or measurable. To tame the interrelated notions of quantity and space, the concept of integral numbers and geometric objects were elaborated by dis- carding the particular nature of the objects at hand and by only keeping their quantity or their shape. Our ancestors realized that if our only interest is in quantity and not in other qualities of the particular objects involved, then there is basically no difference between 2 fingers and 2 equal lengths, or 5 fingers and 5 equal lengths, but that a group of 2 fingers differs from a group of 5 fingers. In other words, numbers arose from our recognition of patterns regarding quantity by making as effective as possible our most fundamental reasoning tool, namely comparison. The number 1 applies to all things taken singularly – one coin, one apple –, the number 2 to all combinations of things taken doubly, etc. To quote seventh century mathematician Brahmagupta: “If you want to write one, express it by everything which is unique as the earth, the moon; two by everything that is double, as for example black and

white; three by everything that is threefold”,3 and so on. Similarly for ge-

ometric objects: “squareness” applies to all shapes with four sides of equal length. As explained in the fourth century B.C. Mohist Canon,4 all things in one category or class, for instance all squares, display “mutual sameness”, though they may differ in size, colour, or material.

Then by studying the properties of the abstract concepts of integral num-

bers and perfect geometric shapes, more abstract concepts were inferred, no- tably irrational numbers such as *π* and *√*2 that cannot be written as ratios

of two integers, and so on. Their connection with our reality is more tenuous,

or approximative.

The manner in which the concept of number was evolved remains true of more elaborate mathematical objects. They are the conceptual generic labels given to attributes of objects that have been isolated by discarding other features. Hence, mathematics takes to an altogether different level the model-building feature of any language, where a word evokes a particular instance qualified by the universal or the genus, itself dependent on the in- dividual instance. As in ordinary language, but much more powerfully and clearly, the labeling process goes beyond generalization; it involves a process of abstraction and idealization of pure concepts which take on meaning when attached to particular articles. For example, the number 5 is just a generic label which acquires meaning when applied to specific instances, 5 fingers and so on. In short,

*Mathematics is the study of the relations between abstract concepts grounded on the notion of numbers.*

Indeed, it consists in the study of the properties of its abstracted concepts, properties it deduces and more generally infers, notably how they can be combined, if they can, what patterns they form, and the like. This it can do because, it is a very special kind of language, one that has its own in-built logic which enables deductions and inferences. New concepts thereby emerge; they are in turn studied, and so on. Alongside this abstraction process, at each level the novel concepts obtained and their theories are applied whenever this is feasible both inside and outside mathematics. Through applications, new insights are gained, new concepts developed, and the abstraction process continues.

Abstractness is one of the basic characteristics of mathematics, but there has never been any consensus on the level of abstractness that ought to be at- tained. It notably depends on the purpose assigned to mathematics, whether it is primarily regarded as a tool to investigate aspects of our reality, albeit a powerful tool, or whether it is defined as the study of these concepts, more for their own sake than for any other reason. Consequently, mathemati- cal approaches have varied between these two extremes. Counterbalancing their absence of meaning, mathematical statements are exact, another basic characteristic. When we give them meaning by applying them to particular physical instances, this exactness is usually lost. Conversely, mathemati- cally exact concepts and relations, when they are inferred empirically, follow from necessarily approximative measurements. This is well illustrated by the concept of differentiation. As pointed out by its twelfth century author, Bhaskara II, the “tatkalika-gati (instantaneous motion) of a planet is the motion which it would have, had its velocity during any given interval of

time remained uniform.”5 Hence there is a two way process, from abstract-

ness to real life approximation via exactness, and back – made possible by

the mathematical concept of infinity.

Before going further, some words are necessary about infinity, which re- mains all too often misunderstood. The infinite differs fundamentally from the extremely large, however inconceivable the extremely large may seem to us. We can go on adding numbers, but we can never reach infinity. The finite can be reached, infinity can only be approached. Like all else, it is abstracted from reality, from our mind’s conception of space as a continuum, and in turn mathematics helps to improve this conception. It notably provides science with the means to generalize beyond the conceivable, while amounting to a main difference between mathematics and science. Observations, science’s mainstay, being necessarily few, are by themselves less solid ground to do so. Generality in scientific statements is in some sense wishful thinking: we do not know whether or not Newton’s gravitation law applies universally or to what extent. Not so with mathematical statements: implicit in their ab- stractness is their universality. This is the strength of mathematics. This is why its results can be applied so widely. For example, there are infinitely many quadratic equations and their solutions take on a standard form appli- cable to all of them. The notion of infinity is so intricately interwoven within the fabric of mathematics that its thread cannot be pulled out without the entire fabric falling apart.

# Truth

Before addressing the question of ethics, it is necessary to clarify the connec- tion between truth and science or mathematics. For ethical considerations are irrelevant if these activities consist in “the disinterested search for truth”.6 Regarding science, this belief is founded on the strong assumption that truth, to quote Tolstoy, “rests on something external”,7 an assumption undermined by quantum mechanics: at the sub-atomic level, uncertainty is, to quote Dirac, not just a consequence of our own failings, of the disturbance created by observation, but “is inherent in the nature of things and can never be surpassed by improved technique or increased skill”.8 This does not neces- sarily mean that the assumption is incorrect since Heisenberg’s uncertainty principle may one day come to be seen as inappropriate, although so far, all scientific studies have only strengthened it. The point is that this assumption is of the order of the metaphysical, that it is unverifiable.

Even admitting the assumption, by their very nature, science and math- ematics are unlikely to lead to truths. Yet, as confessed by physicist Max Born, this belief, which has been central in modern times, only came to be “severely shaken” by the challenges posed by quantum mechanics, and all

too often continues to hold sway. Both observation and reasoning are human ways of making sense of the universe. To quote Heisenberg, “man’s argument

... cannot simply speak of nature ‘in itself’. Science always presupposes the existence of man.”9 The implications are not always apprehended.

Not only scientifically undefinable concepts, but assumptions from both within and outside science, are unavoidable. Scientific thinking cannot be conducted in a theoretical void. Science requires an a priori metaphysical framework. In Mendeleev’s words, “[e]ach scientist endeavors to translate the world view of the school he belongs to into an indisputable principle of science.”10 For instance, chemistry continues to be founded on the assump- tion that reactions follow the least path, namely that which “involve[s] the least change in atomic position and electronic configuration.” Yet, accord- ing to chemist Roald Hoffmann, this may not be satisfactory since “reaction pathways are inherently manifold”, and “[i]n general, the mechanism of a re- action can neither be directly observed, nor can it be deduced with absolute certainty on purely experimental grounds.”11 Thus our assumptions deter- mine to a large extent the science we get. A major focus of the science of ancient India was the human mind, whereas it is only recently that modern science has reintroduced consciousness as a valid scientific field. Moreover, within a philosophical context where the existence of free-will was central, the former aimed at a comprehensive form of knowledge to relate and unify the internal world to an intelligible scheme of the microcosm and the macro- cosm, and the interrelation of the parts and the whole was assumed. Thus the understanding obtained was very different from that obtained within a largely materialistic perspective.

The influence of materialism on the course given to science is well illus- trated by the following example. Oparin and Haldane’s formulation of the conjecture that the organic molecules necessary for the emergence of life had been spontaneously generated in a hydrogen-rich, oxygen-poor atmosphere oriented subsequent studies about the earth’s early atmosphere. They aimed at finding a credible candidate of such an atmosphere where this spontaneous generation was possible. And indeed in the 1950s, it was experimentally shown that under a very specific type of what might be grossly described as methane soup, this can happen. As a consequence of this success, it was further forgotten that the premise of the thesis, namely a hydrogen rich primeval atmosphere, is an assumption even if organic molecules can emerge in it. The first experimental study to reconstruct this primeval atmosphere by using actual empirical evidence was only conducted in 2011. It indicates that on the contrary it could not have been as poor in oxygen as had been thought.12 This new result also relies on an assumption, but a weaker cor- roborated one, namely that initially, the atmosphere emerged from the gases

brought to the surface by volcanic activity.

As this example suggests, the connection between science and meta- physics is intricate. Modern science has increasingly distanced itself from the perspective of a reality resting on local realism and composed of material substances interacting according to mechanically rigid rules following from strict causality, towards a “radically new notion of unbroken wholeness of the entire universe”, where “a system cannot be analyzed into parts whose basic properties do not depend on the state of the whole system”, as ex- plained by David Bohm and Basil Hiley.13 This distantiation begun with quantum mechanics is now being confirmed by biology with the discovery that bacteria coming from outside our body impinge on our emotional and psychological makeup. For this obviously erases precise boundaries between individual identity, ‘I’, and the rest. In other words, scientific observation incessantly forces us to leave aside former suppositions and beliefs by call- ing into question their compatibility with reality. As remarked by Childe, man’s thought and behaviour are the outcome of his “reacti[on] to a spiritual environment as well as to a material environment.”1

In short, the collection and interpretation of data is conducted within some pre-existing theoretical framework, and the data indicates its strengths and weaknesses, its scope, namely the range of phenomena for which it is satisfactory, and the eventual necessity to rectify it or elaborate a totally new framework. Yet, while observation indicates the way, the process of observation cannot be disentangled from ideas and thus beliefs. “All obser- vation”, Darwin wrote, “must be for or against some view if it is to be of any service.”14 His advice to a junior colleague was: “let theory guide your observations”.

As Tagore wrote, science “can only organize into rational concepts those facts which man can know and understand. ... The evidence of his physical senses and that of his logic and his scientific instruments are both related to his power of comprehension.” And this power is very limited. We have alluded to the sub-atomic level. Samples analyzed with a microscope require prior preparation, notably dyeing, and thus we can also never know what the microscopic world is veritably like. Regarding the macroscopic living world, if consciousness does pervade it, then any observation of the living world may be changing the state of the system observed. At the very least, even in terms of purely material action and reaction, the cosmos is incessantly subject to innumerable forces, the impact of any given one is beyond our comprehension given that, as science itself tells us, the flapping of a butterfly’s wing in one place may have tremendous effects on distant phenomena. Hence, as Edward Carpenter aptly remarked, the “limit is at all times infinitely far-off”,15 so that improvements to our theories cannot be considered “approximations to

the truth”; all that can be said is that they are certainly more appropriate, but to what extent we do not know. What our ever deepening scientific understanding does is guide us away from untruths. Put differently, uncer- tainty is part and fibre of our understanding of nature, possibly of nature itself, and even gauging the extent of the uncertainty involved is ridden with uncertainty.

This brings us to the question of mathematics. The only mathematics developed so far is one with in-built second order logic. This raises questions as to its ability to describe the external world since the only description we can give of it is at least three valued, true, false, and uncertain, while math- ematical statements are only true or false. Thus we use probability to tackle uncertainty. However, its application rests on strong assumptions. The most common interpretation assumes that all single outcomes are equally likely. To quote Laplace, the “theory of chance consists in reducing all the events of the same kind to a certain number of cases equally possible – that is to

say, to such as we may be equally undecided about in regard to their ex- istence”.16 For example in thermodynamics, it is assumed that a molecule is equally likely to be in any position. However, such symmetry may not be part of the phenomena studied and such an assumption may make the mathematical model too approximative, and thus its domain of application too limited. In some other situations, a frequency interpretation is the only

possible, as in Mendelian genetics. However, this too is problematic. As it is not possible to repeat trials infinitely many times, it is assumed that were they repeated over and over again, this relative frequency would be reaching a definite value. Now, there are two ways of proceeding to find this value. We can proceed scientifically and infer the limiting value based on a large number of experimentally obtained frequency ratios. But then, we end up with a worse problem that in the rest of science since induction is inappro- priate to gauge what happens infinitely many times. Or, we may try to find the limit mathematically, but this necessitates approximations. Moreover, nothing guarantees that both methods will give the same answer. Since both involve uncertainties, we have a priori no way of knowing which result is more appropriate. As economist Maynard Keynes showed, the possible in- compatibility between the two answers can result in even greater issues. If probabilities in the context of events repeatable as many times as desired raise so many questions, assigning probabilities to events that occur once or only a few times can be expected to be even more problematic. The frequency interpretation is unsuited for this. So is the equal likelihood assumption since we cannot know that such phenomena display any regularity. In this case a probability value is subjectively assigned by the investigator depending on his personal assessment of an event in the future. Until the event actually

happens, there is no way of checking the quality of the assessment. After the event has happened, it has become fully certain, and this is no indication of the correctness of the probability assigned to it prior to its occurrence. Hence these assessments do not belong to the realm of science, but provide them with the veneer of scientific ‘respectability’ and apparent objectivity.

This in particular illustrates the inadequacy of mathematics as a descrip- tion of external reality stemming from the approximation inherent to such a description, an inadequacy problematic on several counts. To begin with, it cannot take into account non-quantitative features, nor any specific quality of an object or organism, that which differentiates it, and thus the greater the distance with the inanimate world, the more mathematics becomes an unsuitable language.

This process of standardization is epitomized in the field of statistics, used to study large aggregates that cannot be individually scrutinized, a field which like probability is also ridden with issues stemming from the concept of infinity. Statistical methods consist in averaging out. Averages do not exist in reality. Statistics magnifies the issues inherent to mathematical applications. Not only does it assume that dissimilarities between the component parts of the phenomena under study can be ignored, but the models used follow from essentially subjective criteria. The population studied statistically has to be divided into non-overlapping groups according to selected traits, in other words, into strata, but there may be more than one reasonable way of determining strata boundaries and the number of relevant traits may be intractable. Moreover, to properly choose the sample size for each stratum, its percentage within the population needs to be known. Then, the sample needs to be chosen randomly within each strata – a random choice is in practice not at all obvious.

Even where mathematical methods are more appropriate, issues arise. To begin with, a hypothesis has to be spelt out in mundane language. The translation process into mathematical symbolism carries with it much loss of information. For example, Newtonian physics idealizes real objects to di- mensionless point particles, and the equations we get describe their idealized interactions. Moreover, even among quantitative features, a choice has to be made for mathematics can only deal with a very limited number of pa- rameters. Regarding the relationship between these parameters, namely the selected quantifiable features, only a very simplified version of this relation- ship can be formulated mathematically. Indeed to even have the hope of being solvable, the mathematical description of a scientific problem must be reducible to a less complex form. In other words, the transcription of the information in computational form must be amenable to abbreviations, to shorter sequences than the initial transcription. For this to be possible, the

features of the phenomena studied must display some repeated symmetry. This is in general far from being the case of most physical phenomena, let alone of biological or human ones. Sometimes chaos does display some order and hence can be analyzed for predictive purposes, sometimes not. How- ever, mathematics is unable to provide us with any means to determine a priori whether or not a system will be chaotically random. In short, mathe- matical assumptions, namely the selection of parameters and relations they satisfy, tend to be made for the sake of mathematical convenience, not for any justified scientific reason.

Furthermore, although equations do in theory have exact solutions, ex- cept in the simplest cases, they have to be tackled through contrived meth- ods that give us approximate answers and not exact solutions. This is most notably the case of the equations of motion of a system involving at least three interacting bodies like our solar system. To reduce the gap between our mathematics and our capacity to resolve equations, on the one hand, and real phenomena, on the other, we try to gradually reduce the approx- imation by taking into consideration more quantifiable features, namely by adding parameters – if this is at all possible. In physicist Valentin Ostro- vsky’s words, all mathematized sciences are “nothing else than a hierarchy

of approximations”.17 For example, consider the case of the non-relativistic

Schrodinger equation for the hydrogen atom. To “ensure better agreement with experiment”, one can instead use “the Dirac equation that takes rela- tivity theory into account.” To keep quoting Ostrovsky: “The Dirac equation does not account for the atomic interaction with the electromagnetic field. If one decides to go further and achieve higher accuracy ... one has to turn to quantum electrodynamics. Even the latter theory ... only allows calculat- ing properties of atoms and ions at some order of approximation over small parameters that characterize relativistic effects.”

The process of approximation goes even further. A whole series of approx- imations again occurs when retranslating our mathematical representation

into mundane language, for instance if the mathematics involves non-exact numbers such as *√*2 or *π*. In this retranslation, as seen in the context of quan-

tum mechanics, another problem might arise, that of interpretation since the

same set of mathematics can give rise to diverging scientific explanations; or to put it more mathematically, the correspondence between the mathe- matical part of a theory and its scientific interpretation is not necessarily one-to-one.

Moreover, mathematics need not be founded on empirical data. It is true that it emerged from empirical observation, and that its pursuit includes some rough diagrammatic or geometric representation of abstract ideas. Nonethe- less, like any language, mathematics need not be used to describe any per-

ceived reality; the patterns it describes can be as imaginary as we wish, as long as they display sufficient regularity to be mathematically amenable. This in particular is the case of axiomatic mathematics, where statements follow from basic premises that only need to be mutually coherent. The even- tual possibility of any physical application of an axiomatic theory depends on our perspective, on prior observed data, for instance which among the geometries – Euclidean, hyperbolic, or elliptic – to apply. None can be said to hold any intrinsic empirical truth. The mathematical truth referred to in an axiomatic context only refers to statements derived following the strict deductive rules of second order logic. However the premises do not conform to any truth. There is no self-evident basic premise from which to build mathematics. In fact, even the basic logical premise on which axiomatic mathematics is founded, namely the principle of the excluded middle, raises issues. According to it, a statement is either true or false, and in the lat- ter case its contrary must be true. This assumes that a statement is either absolutely true or absolutely false for all time, and so cannot be sustained empirically as empirical evidence cannot cover every possible instance. It may be that its contrary statement agrees with some amount of evidence. In other words, it might not be absolutely false. Thus from a realistic perspec- tive, the contrary of a statement may not contradict the original statement. What the above discussion suggests is that whatever may be our way of regarding mathematics, in contrast to science, which at least is a curious mix of subjectivity and objective, by its very nature, mathematics cannot be a tool for unraveling any eventual external truth, nor for that matter any inner truth beyond description and language, especially any strictly logical quanti- tative one. Mathematics is only valid within an a priori logical framework; a different logical system would result in a different mathematics with different

truth values.

# Ethics

If science and mathematics are not objective mirrors of any truth, then like any other activity, they must be connected with ethics. However, especially regarding fields of knowledge closely dependent on metaphysics, before af- firming any such connection, the very possibility of ethics has to be estab- lished.

## Free-Will

For ethics to have any meaning, we must have some freedom of thought and action. Were we merely puppets in the hands of an all-powerful God, fate or chance, or subject to inviolable laws governing the universe in which our actions take place, then freedom would only be an illusion. Therein lies the problem: on the one hand, we feel free, while on the other, notwithstanding our inability to reach any objective knowledge of nature, our experience tells us about the existence of such laws. Hence let us review some of the typical arguments advanced to reconcile free-will to seemingly inimical conditions.

Asian philosophies, except for the purely materialist ones, have argued for some degree of freedom in diverse fashion. Advaita (non-dualist) Ven- danta, i.e. based on the metaphysics of the eight century B.C. Upanishads, developed the concept of an infinite, changeless and everlasting Absolute Reality or Soul, the substratum of our changing temporal reality, which it pervades, a reality beyond causality and hence where reigns absolute free- dom, the concept of God not being one of omnipotence nor of omniscience; and the mind, although “entirely material” is “yet capable of coming into

intimate relation with the Soul”18 through the human soul, namely the em-

bodied Soul. Buddhism’s argument in support of free-will follows from its strong empiricism, which leads it to dismiss any absolutist notion, notably of an absolute reality, as well as unlimited uniformity and causality in time and space, yet without reducing consciousness to a by-product of matter. Determinism is also weakened in most Indian philosophies by the assertion that causal chains are without beginning in a universe eternally undergoing creation and destruction. Indeed, determinism certainly pertains to finite chains, but infinity is not of the same nature as finiteness, and thus the same arguments cannot apply in both cases. In contrast, in Chinese thought it is the other way round: the all pervading Tao does not regulate the world in a detailed causal relation, and immediate causality is denied, and thus creativity in the details is given a more explicit role. In some ways, this is how Alfred North Whitehead’s metaphysics also allows for freedom.

Unlike philosophies from further East, Christianity holds nature to be fully material and the human mind to be external to nature. This has gen- erated a conundrum for European philosophies: how can the mind act freely on a law governed nature to which it does not belong? Tolstoy attempted to resolve it by making a fine use use of the modern idea of limit, and goes beyond those provided by non-dualist philosophies, which for all their jus- tification of free-will, had left vague how it actually can manifest itself in physical reality. Determinism belongs to the realm of space and time, more precisely as stated by Descartes, to the flow of time: laws of nature are “rules

by which ... changes take place”.19 However, to use Tolstoy’s words, “[y]ou make your decisions in the present, and the present exists outside time; it is a tiny moment where two periods – the past and the future – meet”, in other words outside the realm of deterministic laws. Hence, “[i]n the present you are always free to make your choice”,20 a ”present” in which “man ... is always living”, and so21 “man is free”. 22

Tolstoy’s arguments rest on the same two contrary assumptions as most Indian philosophies, the denial of an omnipotent God and of the existence of a non-material of the soul. Belief in the former is not compatible with free-will. Nor is materialism since the question of freedom does not apply to matter and physio-chemical forces. Hence it is worth insisting that materialism is as much of a belief as any other, and contrary to misconceptions, science in no way has or can show it to be factual. As already seen, science cannot reflect reality, and hence cannot affirm any truths about it, and is moreover confined to a very specific aspect of the sense-perceptible reality, and thus can even less affirm anything about any eventual reality beyond it.

## Scientific Ethics and Ethical Science

Now that it has been established that only one of two extreme standpoints can result in the refutal of free-will, we can carry on with our discussion of ethics. The case of science and mathematics being different, we begin with the former.

The connection of science with ethics reflects the intricacies of its relation with metaphysics. Science, by definition, warns us when we are definitely wrong, namely when the gap between our theories and reality becomes too significant, in other words observable by available technical means, and when applications will therefore generate alterations to natural conditions resulting in disorder likely to jeopardize the conditions necessary for human life. In other words, because of the role of observation, science implies what our ethics should be if we wish the human species to endure.

This, until the nineteenth century, has to varying extent been recognized by some schools of philosophy and science. In Asian philosophies, because of their admonition of harmony with a nature which man is integrally part of, human behaviour and thus practical ethics has to be in agreement with nature. In Europe, this was reasserted in the sixteenth century by Giordano Bruno and Galileo. Some hundred years later, French philosophers continued on this line by setting out in their Encyclopedia that the sciences “have taught us the duties of mankind”.

The converse, namely science’s dependence on ethical considerations, im- plicit in philosophies resting on the concept of inner truth and harmony, is

superfluous within a perspective where science is taken to mirror nature not in its totality, but at least parts of it. However issues arise because the top- ics amenable to scientific inquiry are innumerable, and thus the choice has to be founded on a priori criteria. This is usually conceded. What is not is that any criterion is bound to have an ethical dimension. For instance, Henri Poincaré argued it was internal to science. He claimed simplicity and “intellectual beauty” as the guidelines for a choice, equating the two: “sim- plicity ... is beautiful” he wrote.23 He did acknowledge that simplicity is not easy to recognize, but not that his criteria are heavily laden with values. For they validate military research: it may display far greater simplicity than solar physics for instance and the mathematics behind it may be as beautiful as any other mathematics, with the caveat that beauty is a very subjective quality influenced by cultural paradigms. Here his reference is to a particular form of esthetic beauty; beauty may equally be regarded as purely ethical or even spiritual. Moreover simplicity, from “easier to study” can rapidly take on other dimensions and become associated with the avoidance of complica- tions that may stem from any challenge to the status quo, in other words, as implied by Tolstoy, with what is more “profitable”.24 Another criterion frequently advanced to justify such a view is curiosity. However, as argued by Sundar Sarukkai,25 it too is heavily subjective and related to ethics. Any attempt to disconnect science from ethics raises more questions than it an- swers. For instance, why was so much attention paid to nuclear physics but not to solar physics?

Poincaré went further. His defense of the motto “science for science’s sake” symbolizes the vision given form in the nineteenth century of a science existing in a hermetically sealed bubble of its own objectivity. Not only was the dependence of science on ethics denied, but, contrary to former times, also the inherence of ethics in science. “There can no more be immoral science than there can be scientific morals” can be read in *The Value of Science*.26 His conclusion is only a corollary of a culture which asserts the right to absolute freedom of action and does not recognize that debating the case of free-will is not sufficient. It is necessary to debate the aim of free-will, a debate that is central to most Asian philosophies.

So what exactly does this ethics implied by science consist of and how can we estimate what it is? Some ethical standpoints are indicated by the very nature of science, others by its theories. While its nature may be lasting, its theories are not. So to what extent can we found ethics on the latter? We can because this very characteristic of science highlights an essential aspect of ethics: ethics too cannot be static. Like religion, on which it is largely founded, it must evolve with knowledge that brings to light untruths. So what ethics is implied by current science?

Its theories tell us that too much disorder is incompatible with life, that human life can only exist within a limited range of conditions, only as long as a fragile balance is maintained, that this fragile balance is being increasingly affected by over-exploitation and by pollution, namely by the untoward man- made disturbance of the natural equilibrium that has made our emergence possible – untoward from our perspective –, that, as remarked by Desmond Morris, the “more truly violent species all appear to have exterminated them- selves”.27 From early days, there has been “continual tension between man’s natural condition and his true character”, between the unavoidability of the laws of survival physical man is subject to, and what Tagore calls “his extras that reveal his glory”: “a greater portion of the activities of his life is engaged in crossing the boundaries of a passive existence where there is a provision for enough, but not for the feast.”28 However, as the above implies, the quality and extent of his extras in the external world is of critical importance. Only in his inner world can he be unbounded. Notwithstanding the overshadowing of this point by Poincaré’s defence of “excess”, without which, according to him, we “would surely die of ennui”, scientific theories are confirming what we have long known and has been succintly stated by Lao Tsu: “To know when to stop is to preserve ourselves from danger.”29

Excess follows when one perspective is pushed to its limit while its oppo- site is jettisoned. Science tells us excess can be avoided by finding a a viable equilibrium between opposites, not a static equilibrium but a dynamic one. Its very nature consists in doing so in more ways than one: science amounts to a reconciliation between mind’s freedom and the limitations imposed by nature, between particular observations and universal principles, between in- dividuation and generalized standardization, between a reductive approach and a holistic one. Thus science merely confirms the admonition given by sages from all cultures and times, but an observation-based reasoned confir- mation is welcome because science can indicate when we are too off-balance.

# The Distortion of Science and the Role of Mathematics

Poincaré’s discourse in particular obscures that more than a choice between topics, between approaches, the choice is essentially between remaining on a scientific path or deviating from it while claiming allegiance to science. In- deed, without going into a historical analysis of its development, the frame- work within which science, mathematics and technology developed in Europe since the middle ages has increasingly become one of profit maximization,

regardless of the views of individual scientists and philosophers. Such a framework demands incessant and increasing material growth and must have the means to enable this growth, in other words to produce at an increas- ing rate. The quality and consequences on mankind and his habitat are irrelevant. This in turn requires increasingly more energy and increasingly greater efficiency. Hence, the necessary technology must perforce rely on advanced research. However, because the result is incessant and increases the alterations to the conditions making human life possible, as the previous discussion on science implies, this research is perforce less and less of a sci- entific character. In particular while it continues to be based on observation, the data provided is now all too often insufficient, not reproduced and not reproducible, while contrary data is discarded; as for its reasoning, it is in- creasingly illogical and full of contradictions. It is to this distortion of science that we owe the perils threatening the future of humanity. It is encouraged by science policies, in particular funding criteria and the culture of prizes ini- tiated by a forefront industrialist of the nascent military-industrial complex, Alfred Nobel. These encourage research based on criteria congenial for the ideal of profit maximization in its present stage of financial capitalism.

Mathematics is what made the implementation of this possible by provid-

ing the connection between science and technology as well as by enabling the development of the necessary economic practices. Because precise measure- ments are necessary for technological applications, this initially resulted in the strengthening of the mathematization of the physical sciences, followed by applications of mathematics unfounded on solid empirical data once scien- tific studies were less and less able to sustain the profit-oriented perspective. The outcome of the demands of technology within such a perspective was the birth of computer science, namely the amalgamation of physics, math- ematics and technology. The creation of this new subject has been critical. In contrast, the unity between science, mathematics, philosophy and ethics until the 1830s has not been rekindled despite the urgency of a reassessment of science. This said, because computer science only involves the science of the inanimate world, it has been beneficial for us on more than one count. Any detrimental orientation is due not to the physics of the hardware, but to the mathematics of the software.

## Towards a Changing Relationship Between Science and Mathematics

To understand this, the role of mathematics needs to be better assessed. Mathematics has enabled the shift from land-based merchant capitalism to

financial capitalism. For profit-maximization beyond a certain point requires the severance of finance from the reality of commerce and production. This began in the Renaissance, with the elaboration of double-entry bookkeeping, made popular and precise in Luca Pacioli’s *Summa* in 1494. As explained respectively by economists Michael Chatfield and Hugh Robertson, it “pro- moted the concept of the business firm as a separate entity whose purpose was profit maximization”.30 For, “the man who devotes himself to transactions on a book-keeping basis has only one aim “the increase of values comprehended only quantitatively.” The actual commodities, “the realities of commerce”, whether spices or salt, “become mere shadows, they become unreal and the apparent reality seems to lie in book-keeping ciphers.”31 This paved the way for an abstract capitalism where finance prevails over commerce, being no longer grounded in the reality of human activities, and gave it an appearance of objectivity, the objectivity of quantification.

Since then, the abstraction of the economy has only increased thanks to mathematics. Economics, short for economic science, was during the industrial revolution legitimized as a scientific discipline by its increasing mathematization and axiomatization to give it the appearance of the ‘exact sciences’. This amounts to reducing the human world to the inanimate one, and thus to a by-product of matter: mathematics uniformizes and cannot ac- count for human factors. An inquiry whose scientific nature is not in doubt can on occasion be made mathematical and axiomatic, but the converse does not hold, namely mathematization or axiomatization cannot turn a subject into science. Notwithstanding this objection, by regarding it as science, all of science’s characteristics have come to be associated with it. This has oriented not only methodologies, but content and perception. In particular, while ob- servation in the human realm is unlikely to be reproducible at will, studies of this realm have come to be all too often regarded of the same nature as those of the natural world, obscuring their strong subjective foundation on values. For instance the current markers evaluating the health of the economy, the GNP (gross national product) and GDP (gross domestic product), only take into account contribution to capital, in other words only “monetary transac- tions”, while discarding “anything that does not involve the direct exchange of money”: the “breakdown of the social structure and the natural habitat” is thus a gain, as the costs they generate – social, legal, police, protection, repair, medical, etc. – give rise to such transactions; in particular, “crime adds billions to the GNP”.32

The point is that we cannot increase the amount of matter available on our planet. This is one of the constraints of the reality we are part of and which we cannot alter. We cannot produce matter from nothing, we can only transform matter. And compared to human timescales, matter is produced

at a very slow rate by the biosphere by using the energy it gets from the sun. Hence within such a framework, passed a certain threshold, financial wealth has to become abstract. As by now natural and human resources have been squeezed to their limits, the relationship between finance and the economy has perforce become reversed. From the economy’s favoured tool finance has become its driving force. The outcome is not just a furtherance of its severance from production, but from reality.

This virtualization of finance has been enabled by information technolo- gies stemming from computer science shaped accordingly. These are giving the impression that the economy too can be virtualized, in other words, severed from physical constraints. Present fortunes increasingly rest not on constructive productivity, but on the generation of replications of one-time written software programs, or merely on applications of already existing pro- grams permitting the centralized control of networks. Given the increasing absence of any compatibility with reality, the consequences are necessarily worsening living conditions making it essential to control opinion, hinder and manipulate dissent. This too we owe to mathematics through informa- tion technologies, which are enabling widespread surveillance as well as the blurring between virtuality and reality, between truth and untruth.

Alongside, the merger of the science of the inanimate world and of technol- ogy has thanks to mathematics enabled the merger of the science of life and of technology into bio-engineering, by making possible huge genetic databanks. The reductionism this time involved is of such a degree that the outcome is prototypical of the distortion of science in more ways than one. It notably ignores major scientific conclusions reached in biology since the last century: that single or small groups of genes do not act in an isolated manner, that a whole range of associated transformations are necessary for the hybrid to be viable and adapted to its environment, namely that genetics is far from being the key to evolution, epigenetic factors or horizontal genetic exchange through bacteria that are yet far from being understood play a role. Put differently, the attempted operation to alter one or more specific genes, a far from precise operation, often results in unforeseen effects, for example the impairment of a plant’s immune system. We are witnessing here a transfor- mation of our perception of life into that of a huge computer whose underlying programs can be transformed at will by a biology become equated to the de- velopment of techniques to alter life’s code. Thereby the mechanistic vision of nature has been adapted to the new technological phase we have entered,

one where, according to Jeremy Rifkin,33 the “bundles of relationships” in

an incessant state of becoming through creation, which Whitehead had con- ceived of to replace the notion of static isolated substance, have become flows of information, and creative evolution a question of “computational ability”,

the ability to process complex data represented in computational form. In short, after denying the soul, a distorted version of science has now reduced the human mind not just to its computational ability, but to one of a very special kind, adapted to man-made calculating machines. Ethics has been totally removed from the conception of humankind: ethics is not algorithmic, nor a consequence of mechanical rules.

Artificial intelligence represents the fulfillment of this vision, of the latest stage of a gradual reversal of the relationship between between mathematics and science, reflecting that between finance and the economy. Soon, human beings will be genetically engineered and fitted with electronics to suit the norms of perfection and the monitoring requirements of a society dedicated to the pursuit of wealth, enabling not just a control of free expression, but of free thought. Can this actually happen?

## The Fallacy

There is a basic fallacy in the replacement of both outer and inner realities by a machine-made virtuality. Namely, as warned by Dickens,34 “[r]ealities are not phantoms” and so “there is the greater danger of their breaking in” sooner or later.

It is not possible to live on virtual wealth, it must be converted into real wealth. Regular conversions bring about worsening crises not for wealth, but for civil society since there is no longer sufficient material goods to sustain wealth, thereby worsening its pauperization. Increasing energy production requires increasing matter since efficiency has physical limits. Thus from crises to crises, from bailouts of banks with public money to further bailouts, from unsustainable natural and social exploitation to environmental and so- cial disasters, the entire socio-economic system is bound to eventually col- lapse.

Indeed, the discrepancy between theory and reality, at least the reality of the conditions necessary for human life, is time dependent. It worsens with time, a handful of generations being more than negligible in the natural timescale. This is also the case of the theories on which are based the physical alterations to this reality incompatible with human life. Already in much less than a century, the effects have become inescapable and are only increasing, leading to believe that all too soon this planet may become uninhabitable for us.

Occasionally, the discrepancy between theory and reality can be too large, namely the theory all too false, so that applications fail from the outset to attain the desired goal. This is the case of artificial intelligence: it was recently found that machine recognition capabilities is limited.35 In other

words the reduction of the human mind to an algorithm is too unrealistic. However this failure does not preclude our over-reliance on computers, except that it may result in errors that may gradually become unmanageable. And the consequences of applying theories based on a reductive perception of the human mind might undermine the latter in such ways as to leave our species without its main survival tool.

# The Future of Science and Mathematics

On the whole, “the roots of the ... peril lie”36 in a distorted version of science, not in science as was argued by the late Jonathan Schell. Hence, it is essen- tial to distinguish this distortion from science and to put an end to research conducted in the name of science, but which does not amount to science. In particular this means that before any application, research should be con- ducted within a natural environment over both time and space. It also means putting an end to research unfounded on observation and experimentation reproducible at will.

The distortion of science can mainly be brought to light by a proper scientific education that imparts not only technical knowledge, but includes discussions regarding the nature of science and its relationship with ethics and metaphysics. Once science will have been reinstated in its proper place and scholarly pursuits will have been provided with a congenial environment, scientists will at last be free to concentrate on constructive topics of their own choice, not waste their talents and efforts countering the falsehoods elaborated and propagated in the name of science. In this context, industrial pursuits will perforce not be of a damaging nature, but for the benefit of humanity and be undertaken in the spirit and manner exemplified by Edison, who had come to recognize, decades before any pure scientist, where lay the potential of science and of its applications, as well as understood that

“monkey[ing] with”37 science has unavoidable consequences.

Regarding mathematics, the problem is twofold. On the one hand, the issue is a particular case of the distortion of science. In other words its appli- cations must be founded on bona fide reproducible scientific analysis. On the other hand, via software, its applications are now to a large extent indepen- dent of science. Although, as seen, the extreme damage of these applications may be averted because of the wrong assumptions they are founded on, yet the full extent of their incompatibilities with the continuation of human so- cieties, although a matter of commonsense, may not come to be accepted before the occurrence of inordinate damage.

Hence it is, even more than science, necessary to found mathematics on

ethics at a time when it may imperil our future. Yet this is not at all obvious. In the context of science, Tolstoy argued for human welfare as a criterion, and this is what also many scientists, for instance Boyle, Faraday and Mendeleev, had in mind. However, several issues arise. Many studies initially undertaken for other reasons have after a period of time, sometimes a very long time, contributed to welfare. There is also no consensus on what welfare consists in. The complexity of the ethical dimension is highlighted by military research at a time when it is critical to de-legitimize the use of force as a means of international relations. Its consequences may be regarded as exclusively destructive and thus it may be thought that general agreement to put an end to it can be reached. However, as history shows so far this has not been the case. Individuals and leaders with purely destructive aims have always been part and parcel of humanity, and this has always forced military research as protection against them, raising the question as to who is destructive and who is not. Once again it is unrealistic in present circumstances to expect consensus on the answer. Fortunately, military research does not on the whole satisfy the characteristics of science since it is not founded on experiments reproducible at will. As this shows, it is essential to put an end to research amounting to a distortion of its methods, both through legislation and policies, which may prove relatively easier than implementing ethical safeguards. For we have not fully grasped the significance of the momentous shift that now enables us to destroy all human life, and have continued with ‘business as usual’, not realizing that ethics is no longer just a matter of academic discussions.

However this does not resolve the question regarding mathematics. As in-

creasingly suggested, ethics should be part of mathematical education, which should also bring about a realization of the nature of mathematics and of its consequences. This may well lessen the problems, but will not put an end to the imperilment of humanity’s future. Indeed within a context of profit- maximization, the various material temptations or simply the need to survive financially are too strong imperatives. Hence, alongside ethics, mathematics and the natural sciences, what needs to be understood is the nature of the subject of economics, and more generally of what are known as the human sciences. It is in particular critical through education to bring back the real- ization that these studies are highly subjective and reflect the values they are founded on, since, unlike science, they have no in-built mechanism forcing them to a minimal realism. In particular, there is no inevitability in the type of economy we have. It is the outcome of human choices. The entire gamut of issues inherent to mathematical applications must especially be highlighted in this context.

More than anything the history of mathematics highlights how even ‘pure’

research is oriented according to what society considers important. Differen- tiation arose in the twelfth century in India within the context of astronomy, at a time when its importance stemmed from religious reasons. This paved the ground for Newton’s mechanics, which is very much embedded within a certain economic perspective which perforce needed more efficient technol- ogy. In contrast, despite the development by Jain and Buddhist logicians in sixth century B.C. of higher order logic, and the far-reaching work in this direction in the last century by their Western descendants, mathematicians have never considered the elaboration of a mathematics based on even third order logic. Yet, given the many drawbacks of probability it is now critical to find alternative ways to account for uncertainty. A mathematics within which a proposition is either true or false is inappropriate for a science which must inevitably include true, false and uncertain statements. A higher-order mathematics will not dethrone probability for it too will usher in new sets of questions, which will then need to be addressed, but it will efficaciously com- plement probability: if it corroborates our present scientific theories, then this will provide unhoped for evidence in their support; if, on the contrary, it does not, then the reason for the conflict will need to be analyzed, and greater prudence exercised regarding their scope.

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