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Ethics and Science

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Abstract: Consideration of possible bearing of ethics on scientific activity as such – *i.e.* beside moral or legal conditions on applications of science and avoidance of frauds or superficiality – lead to the conclusion that scientists, particularly chemists, ought to ponder the choiceworthiness of every free action they undertake in the pursuit of scientific knowledge, for it may involve tampering with the harmonious evolution of nature and society, indeed with human beings themselves. It seems unavoidable that a decision should be based on the fundamental values of the tradition of mankind, expressed by the three Platonic values. Such a foundation, unfortunately, cannot show a way to eliminate all risks of wrong choices. Since, nevertheless, to contribute to the increase of knowledge is a professional and moral duty of a scientist; the latter is usually obliged to take a decision. He must be aware that his personal responsibility may be engaged.

Keywords: *ethical values for science, choiceworthiness and research decisions, rules of conduct, risk of research choices, responsibility of researchers.*

1. About the title

This paper, as its title says, is devoted to ethics and science; it is not primarily a reflection on ‘ethics of science’ or on ‘ethics in science’, as might be expected in view of public concern about science and technology. The reason is that a considered standpoint on that concern requires that it be known if and in what sense science and ethics have something to do with one another. Everybody would probably agree that moral problems are posed by the use of the applications of science by nonscientists (*e.g.* weapon industry) and by possible fraudulent or other unscrupulous behavior of scientists; but there it would seem that problems are related to human nature, traditions, and socio-political systems rather than to the specificity of science; therefore, the latter only comes into play when it comes to the details of a particular case, not in general ethical considerations. On the other hand, that there should be moral problems inherent in doing science is by no means obvious; indeed, it is quite a novel view, and it took thinkers like Max Weber (1864-1920) to begin a process which ended by suggesting that even highly rationalized basic science is not certain to be free from ‘judgments of value’ (*Werturteile*), as implied by the belief that genuine scientific activity lies beyond the reach of moral scruples, its aim being knowledge. Weber

showed already around 1900 to those willing to listen that this was not the case for human sciences;[1] the debates on biomanipulations and the principles that should regulate them are showing, if need be, that the sciences of nature are by no means outside the scope of his analysis.

Today, especially with the ubiquitous presence of chemistry and the rise of molecular biology, there is a widespread tendency to suspect that, indeed, one way or the other, doing science as such is related to ethics. The first strong signal in that direction came from a great molecular biologist, Jacques Monod, who went as far as claiming that an ethic for our age was to be founded on scientific knowledge.[2] His work showed that the pointer of philosophical reflection had moved from the extreme of a rigid separation of the Platonic values – truth, justice, and beauty[3] – to the other extreme, their unification under the banner of science. Monod was avowedly only a cultivated man, not a philosopher, and was a declared materialist; but he believed in reason, and his book had the great merit of stirring up a dispute that has led many scientists to take more seriously than before the need for a serious personal stand on the relation between ethics and science.

We shall try here to single out at least some of the specific features of a perspective that separates as far as possible what may be called ‘ethical aspects of doing science’ from ethical problems that today people associate with the progress of science and technology, but have been with us since the dawn of humanity, for every technological achievement (iron tools, gunpowder, *etc.*) was put to bad use by the perverse side of man. Of course, there is overlap between the two classes of problems.

2. Ethic and ethics

We must begin with a discussion of words used in connection with our theme. There are in English, as in the other languages shaped by the Greek, Roman, and Christian tradition, several terms associated with values, duties, obligations, interdictions; most used is surely the adjective ‘moral,’ but nouns such as ethic, ethics, deontology, morals, with and without reference to science, are current in newspapers, magazines, and journals. This frequent recurrence means that the question of morals continues to be important, despite claims that ethical rules are just systems of taboos; on the other hand, the accompanying lack of sensitivity to the precise meanings of words is a symptom of the loss of culture by affluent societies.[4] Examination of a good dictionary helps to clarify the differences on the basis of current usage, and provides a list of key notions on which the whole subject rests.[5] We shall focus our attention on ‘ethics’ and related key concepts. The acceptations of that word given by our dictionary are four. Excluding those common-usage acceptations for which we shall use different expressions (‘system of moral principles’ and ‘moral principles, as of an individual’), two seem to be relevant to our subject:

(a), the rules of conduct recognized in respect to a particular class of human actions or a particular group, culture, *etc.* (ex. medical ethics);

(b) that branch of philosophy dealing with values relating to human conduct, with respect to the rightness or wrongness of certain actions and to the goodness and badness of the motives and ends of such actions.

In our society, most people only think of ‘ethics’ in the first acceptance, if at all, without pausing to consider that today rules of conduct are largely decided by opinion makers and political correctness groups. As a matter of fact, it would seem that in the context chosen here freedom of judgment presupposes that one should make up one’s mind on at least two problems: (i), whether or not rules of conduct are required in science; (ii) what aspect of ‘doing science’ they should refer to. These problems lie within the scope of ethics in sense (b), which is the sense we shall have in mind henceforth, unless the context makes clear that the other acceptance is involved.

3. Branches of ethics and conduct

Ethics is divided into two branches. One is deontological ethics, which deals with right action and the nature of duty, without regard to motives or ends. A brief reflection shows that what people now call ethics, as in the expression ‘medical ethics,’ is a sloppy replacement of the more difficult but more precise word ‘deontology,’ a list of rules of conduct whose critical analysis is precisely the object of deontological ethics. The other branch is axiological ethics, which deals primarily with the value of the motives and ends of any action.

Clearly, it is important here to specify what is meant by ‘conduct’. Roughly speaking, conduct and behavior are synonyms, but, on closer inspection, one sees that, while the latter includes instinctive responses to situations of all kinds, the former refers to the pattern of choices a man makes in his relations with other people, nature, the godhead, inasmuch as it may cause damage and unhappiness, or violate what the ancient Romans called *fas*, what conforms to the will of the gods. In short, a person’s conduct in a particular circumstance is the ensemble of deliberate, responsible choices or decisions he makes in those circumstances. There may be alternatives one ought to choose or reject even if they cannot be classed as ‘good’ or ‘bad’ by ordinary standards. There may be alternatives that are just a matter of taste or fashion, and the like, and thus do not depend on any interdiction or obligation. Therefore, actions making up the conduct of a person should be classed as right, indifferent or ethically irrelevant, wrong. Note again that ‘right’ includes ‘good,’ and ‘wrong’ includes ‘bad,’ but the former distinction is more general: for example the decision to spend a free hour watching TV rather than taking a walk might be unwise, and therefore wrong, while not necessarily bad. Right and wrong may be seen as associated with wisdom, while bad and good are associated with morals; but since wisdom presupposes the free, critical adoption of moral standards and rules as well as a sense of responsibility and duty, it seems appropriate here to think of ethics as the science which studies in general right and wrong rather than good and evil. As pointed out in definition (b) above, ‘good’ and ‘bad’ may be reserved to motives and ends. An extensive examination of the cases in which the good-bad pair is more appropriate than the right-wrong one is outside the scope of this paper; here we may be content with the traditional acceptations without further discussion.

4. Risk and responsibility

In connection with deontological ethics as applied to scientific research, let us anticipate the surprising claim that, in principle, any scientific experiment involves a measure of risk, and therefore of responsibility. The principle on which this claim rests is that any action interfering with the spontaneous evolution of nature or the ordinary mechanisms of changes in human society is liable to cause some undesirable effect. It implies, of course, the consideration that, at variance with intuitive beliefs, decisions cannot rest simply on yes-no alternatives, but must be made by weighing against each other a variety of positive and negative factors; so that there may be actions for which moral scruples would be little justified, others for which personal tastes may be allowed to influence a decision, others which definitely involve a serious responsibility. A formal theory of the whole matter is to be found starting from notions extensively discussed by eminent philosophers and logicians, from Aristotle to G. H. von Wright; we shall use for them the terms ‘risk,’ ‘gain,’ ‘choiceworthiness,’ and ‘responsibility’. All we need here is the following schematic summary, which shows which notions come into play and how they are related to each other. We note explicitly that the mathematical equations presented below imply in no way that we are adopting a utilitarian viewpoint, except in a merely analogical sense; when, for example, we speak of ‘effects’ we are indeed thinking of changes of the state of matters resulting from a person’s action, but not that their ethical evaluation should be carried out in terms of usefulness to personal or collective welfare.

Let $P(n)$ denote the probability of a negative effect and $W(n)$ a measure of its gravity. Then, in a semi-qualitative description assuming linear dependencies, the risk $R(n)$ is given by

$$R(n) = W(n) \times P(n) \quad (1)$$

This is a short-hand form of the statement that, *ceteris paribus*, the risk associated with an action whose negative consequences are minor but highly probable should be considered equal to the risk associated with an action whose negative consequences are major, but much less probable. Responsibility arises from ‘taking the risk’, *i.e.* from the decision to perform that particular action.

Equation (1) provides an answer to the objection that, by attributing an ethical import to any action of a scientist as scientist, we might make science impossible. It shows, for one thing, that testing nuclear theory by an atomic explosion is quite different from trying to see if a milligram of a new chemical compound ignites under mild conditions. The claim that there is always some risk when pre-existing equilibria are disturbed remains valid, but it is part of the human condition that one should take considered risks. The whole point rests on the participle ‘considered’, which points to the fact that a genuinely educated man – *i.e.* a person brought up with the habit of prudence and courage in addition to mere instruction – does not shun risks just because they are risks, but weighs them against possible advantageous results (the ‘gain’), and then accepts the responsibility for his decision. In fact, for given action, not only a risk R but also a gain G should be expected. It can be quantified [in the same spirit as for equation (1)] by the expression:

$$G(p) = D(p) \times P(p) \quad (2)$$

where $D(p)$ denotes the desirability of the expected positive outcome and $P(p)$ denotes the probability of that outcome. The choiceworthiness $C(n,p)$ of the action involved can then be expressed as

$$C(n,p) = G(p) / R(n) \quad (3)$$

This equation expresses the idea that a particular action is to be preferred to another if the risk is lower and/or the gain is higher.

The above expressions hold even in the case of absolute interdiction ("do not kill") or absolute obligation ("help a man in danger"), if the risk and the gain, respectively, are assumed to be practically infinite.

We emphasize that, as is typical of all formalizations, equations (1) to (3) are helpful, for they summarize and to some extent quantify the problems from which ethics should start; but, as to conceptual content, they do no more than pointing clearly to the central problems: the nature and hierarchy of desirable and undesirable outcomes of an action, the grounds on which their importance is to be estimated, the criteria and validity of probability estimates.

5. About rules and means

Probability estimates would seem to require considerations that do not fall within the scope of ethics proper, whereas W and D obviously do, because of their dependence on the desirability notion. However, they seem to be related to goals, and therefore to values, rather than rules. Where, then, are the rules hidden? The answer is provided by the remark that an ethical rule corresponds to an ‘if...then’ statement of a certain kind.

Even what we call absolute rules presuppose a condition under which they come into play. "Thou shalt not kill," in connection with a decision, may be taken to mean: "If one of the possible outcomes to be considered is death of a human being, assign to it infinite undesirability W ." If you think of the frequently recalled exception of self-defense, then the rule "thou shalt not kill" also illustrates the importance that have in the evaluation not only goals, but means; possible ‘undesirability’ of the means used to achieve a goal should be included in W of equation (1). This is an extremely important point for scientists, because the argument that knowledge is good in itself is often used to justify without further discussion highly

questionable practices, such as buying volunteers for the testing of biological effects of new chemical substances – not to speak of the cynical master rule that "what you can do you may do".

The example of "thou shalt not kill" is perhaps also an excellent example of the fact that even apparently self-evident rules demand reason for their application, if one thinks that uncritical application of that rule might end with paradoxes (*e.g.*, microbial parasites should be tolerated). In general, most rules admit of a more or less strict application, especially depending on circumstances; then it is even clearer that ethical rules are criteria for determining the desirability or undesirability of a possible outcome of a choice. Margenau speaks of a 'protocol' behavior to which actual behavior ought to conform as much as possible.^[6] It is in the nature of the case, however, that a variable but never negligible measure of personal evaluation remains. This personal factor need not be merely subjective, because it may be based on experience, and the fact that the brain machinery is capable of associative thinking may be the main reason why a rigorous formalization is not possible.

However that may be, it should be clear that the rules constituting the ethical protocol are criteria of desirability of a certain outcome, but do not tell on what grounds it is desirable. This question belongs to the branch of ethics called axiology, which, as mentioned, deals with values. Let us, therefore, enter that perilous field.

6. About values

About fifty years ago, the view that the very distinction between good and evil is generated by taboos called 'ethical rules' became the major tenet of powerful intellectual lobbies of the East and the West; thus the idea that there could be normative values (such as justice) on which responsible decisions or choices should be founded was successfully put out of circulation. If ethics in general was considered a 'soft science', axiological ethics was seen at the same level as a zoology of fantastic creatures.

Even if that view had more than a merely ideological foundation, the fact would remain that in real life we are faced with decisions, which demand reflection and sometimes courage. As shown by equations (1) to (3), those decisions can be examined in the context of the theory of games. This makes sense only if the outcomes of a game are classed according to their desirability; therefore, it is not possible to circumvent the claim that decisions presuppose that there should be goals toward which a chosen course of action should tend. It seems legitimate to define a 'value' precisely as a general goal that is particularly desirable in itself and can be associated with sufficiently precise rules of conduct at least on the basis of tradition.

According to a practically universal consensus, the fundamental goal of human actions is personal happiness. Unfortunately, it is difficult to take happiness as the goal of any particular action or sequence of actions, the more so as it could be in contrast with the happiness of others. Happiness, according to Margenau's study, should rather be taken as a general criterion of validity or principle of validation of an actual ethical behavior based on certain norms. Margenau claims that such a validation cannot be applied to values as such. It would seem that, on the contrary, the first part of Plato's Republic is precisely an attempt to prove that justice is a normative value logically descending from the idea that the basic goal is happiness. Underlying this apparent disagreement there is probably the fact that justice is not a value at the same title as, say, life, because it implies at the same time a state of matters (as in 'a just society') and a guiding principle for conduct (as in 'behave according to justice'); whereas life itself is simply something whose respect or preservation should be ranked very high in the preferences determining our choices.

The priority of personal happiness seems to be the reason why the name of value is given to concepts that make it possible to establish a priority scale for ends or means expected (possibly because influential people say so) to ensure progress toward happiness. Current values in affluent societies are money, power, physical pleasure, respect for other 'conscious human beings' at the physical and social level, and the 'environment'; in the past, also values to which many still pay lip service – justice, wisdom, beauty,

love of one's country, mutual affection of the members of a family – did play a role in the major decisions of many people, and were the fundamental values for such great scientists as Einstein and Schrödinger.

If values cannot be freely chosen or pursued by individuals – a state of matters that can be realized not only by force, but by making good education extremely expensive or unavailable –, there can still be (and usually there are) rules of conduct imposed by the legislators with the aim of realizing a stable and efficient social system. Even then, anyway, there must be things or relations or states of matters more desirable than others, which may be called 'social values'.

In sum, we may assume that rules of conduct always presuppose values, *i.e.* targets that are especially desirable in themselves. Let us now apply this conclusion and the above general considerations to science. It seems clear that we can restate our problem as follows: is it correct to look at the specific activity of a scientist as requiring rules of conduct? What values should those rules be based on?

7. Scientific research as an ethically laden activity

As mentioned, there are grounds for concern about science and technology. However, this does not mean that our specific problem, ethical issues inherent to doing science as such, makes sense; further exploration is needed. To this end, let us consider a precise issue, experimenting for merely scientific purposes. Since doing science is good insofar as it increases our knowledge, why should experimenting for strictly scientific purposes be cause of concern to scientists? In what sense and to what extent should a scientist try to establish if the decision to perform a particular experiment or group of experiments is right or wrong? We shall claim that these questions do make sense on the grounds that any interference with a pre-established equilibrium is ethically relevant. We shall also try to show, on the basis of the above analysis, that this claim is not in contrast with good sense, and is not of the same kind as, say, the claim that, since it cannot be proven with certainty that heating food above the boiling temperature of water does not produce carcinogenic substances, roasting and frying should be forbidden by law.

It might be thought that after all the example of medicine provides a concrete answer to the first question about the conduct of a scientist as scientist. One could claim that a medical doctor, as a mere expert, has no moral problems: he knows that under certain conditions, a patient may die, and under other conditions, he may be healed. It is because he has to apply his knowledge that moral considerations come into play. Suppose he is offered ten million dollars to let a patient die; he will accept, if the value to which he gives the highest priority is money, though maybe after some hesitation; he will flatly refuse, if he sincerely accepts the Hippocratic oath. On this example, it would seem that values only come into play when an application is made. Since we are interested in sciences like chemistry, where it is not in the same capacity that the experts look for new knowledge and make applications, it might seem that these sciences are indeed outside the scope of ethics. However, it is not so, because there are decisions involved in basic science. Perhaps the most frequent one is choice of a research subject, another is the decision to make results public; not too rare is blind resistance or uncritical acceptance of new theories, both attitudes being cause of great damage to the advancement of science.^[7] Even more significant is that certain manners of doing research as such give the sensation that they are wrong, although one cannot pinpoint exactly where the sick point is.

Let us consider simple scientific activities. A mineralogist makes a tour with his hammer, and in a certain site, suspecting that he may find interesting minerals, starts hitting the rock. His aim is merely scientific; his action causes minor local changes in the rock. Is his action good, indifferent, or bad? How would we judge that same action if he were only playing with his hammer while waiting for a colleague? On what grounds could we claim that his action is morally indifferent, at least in the latter case?

Here is another example. Having found the structural formula of an unknown steroid derivative particularly elegant, an organic chemist decides without further deliberation to prepare the corresponding substance.

Is this an ethically irrelevant choice? Should he worry about the possibility that he be tempted to sell his procedure to a pharmaceutical firm, which may then use the new substance as a growth factor for farm animals, and the like? Obviously, scruples of this kind might paralyze research completely, and most researchers feel that this would have in the long run negative consequences. However, this is precisely the reason why a critical analysis in terms of ethics is required.

Since conscious, deliberate action is an essential part of being human, we may assume that any man has to act in order to play the role in society that circumstances of free choice have assigned to him (or her). This is not a moral obligation: it is rather a fact, even in the case of a Buddhist monk. The general rule we might use as a foundation for further discussion is rather the following: "since you have to act, do so in such a way that your actions be as right as possible." This rule demands that one should be guided by the orientative equations (1) to (3) after giving their right-hand members a precise significance. That significance is already hinted at by the terms 'desirable' and 'undesirable' used above. Now, a value is something highly desirable. There are also situations or outcomes of actions that are undesirable and give rise to risks; for them the term 'ills' could be used, but perhaps the term 'n-values' (where n stands for 'negative') is more appropriate in the present context; we can then speak of p-values and n-values.

With this convention, our next step is to assume that, (a), there can be concurrent or competitive p-values, (b), positive and negative degrees of importance can be assigned to p-values and n-values, respectively, – albeit as partly subjective estimates – depending on general principles and concrete circumstances. We cannot pause on a detailed analysis of these assumptions. Suffice it here to point out that the basic values can be ordered according to general priority and to relevance to the given choice; and that the same general value (say, money) usually has a variety of connotations, and may be more or less desirable depending on competing aims (performing one's duty, saving a life, *etc.*). The above assumptions make it possible to use equations (1) to (3) as references for reflection on specific cases; but the question remains: what are the values in question?

The above examples suggest the following argument, which is worth great attention even if it is so simple and so paradoxical as to sound ridiculous. Let us grant that science in today's sense (except, of course, mathematics) is not a mere observational, but also an operational enterprise.^[8] Therefore, even in the seemingly innocuous process of theory verification it involves a perturbation of the status quo of nature. That perturbation may be small, but today we know better than the scientists of fifty years ago – we know that self-amplified fluctuations are always possible, and any interference with the delicate equilibrium of nature, however small, may have great consequences. For what is called here equilibrium is not equilibrium in the mechanical sense, it is rather a slowly changing stationary state that depends on the incessant, coherent activity of all the components of the global ecosystem, and one can never tell with absolute certainty that an 'avalanche effect' cannot take place, the scientist playing a role similar to that of a skier causing a disastrous avalanche simply by passing on the snow in a certain place at a certain time. This means that in principle any action of a scientist, except perhaps passive recording of observations (as in astronomy before space travel), is liable to have serious consequences.

The above refers explicitly to disturbances of the coherent spontaneous mechanisms of nature. But in fact, the systems one should think of in connection with interferences are both nature and society, as the man in the street feels instinctively, inasmuch as they are unitary systems in which what we have called here equilibrium is preserved by continuous exchange of matter, energy and information among its parts. Of course, ethics proper should primarily study person-to-person relations, but it would not seem that this is relevant to the object of strictly scientific choices; although, of course, there is a 'deontology' of science that regulates that side of the world of science.

In connection with nature, two different points should be considered: negative consequences of an interference that can directly affect man, and effects on nature at large, with no immediate damage or danger to the human species. Should a scientist care about the latter side of the matter? This is an extremely difficult question, because no answer can be given unless it is decided on what grounds the status quo of nature may be a value, *i.e.* something desirable. Also with regard to society we can have two kinds of perturbations. One is when experiments are made that involve human beings, the other is the

disturbance to society resulting from the availability, indeed even just the announcement of scientific results. Against largely irrational anti-science attitudes caused by concerns in this connection, should one be content with the statement that possible unpleasant consequences are a necessary evil, or is there more to say?

As regards theoretical science, there are at least two sorts of actions or omissions that seem to be ethically relevant: the already mentioned failure to examine with an open but critical mind new conjectures or concepts; and the nature and form of the publication of certain explanations of facts, which may give as 'scientifically proven' a tentative proposal. A case in point is the theory of evolution: those scientists who have made it into a sort of religious dogma have done far more damage to genuine science than its opponents.

8. Current values and their drawbacks

Let us now try to spend a few words, as impartially as possible, on how three values often invoked by the mass media – veneration of nature, knowledge, justice – fit into the picture just drawn. The first one was mentioned as the basic one in 1994 by a Nobel laureate, Rita Levi-Montalcini,^[9] the second one for the same function in 1970 by another Nobel laureate, Jacques Monod,^[10] the third by Einstein. Levi-Montalcini followed the famous neurophysiologist R. W. Sperry, a declared positivist, in suggesting^[11] that a system of values could be drawn from science on the basis of a number of axioms. There is in this suggestion a very serious difficulty:^[12] If values are characterized by being 'desirable', how is it possible to claim that science, which shuns whatever depends on human choices, determine what should guide those choices? That is possible only in a deterministic frame, but then there are no free choices, and what is the sense of looking for values? One should rather declare that ethics and morals are nonsense, as many intellectuals actually do, and that deviations from what seems to be the right conduct are pathological phenomena to be treated as such. By contrast, in a discussion on ethics freedom of choice must be assumed as a fact, albeit, if preferred, only for the sake of the discussion.

There is, however, one main point in Sperry and Levi-Montalcini's arguments that is worth attention. They advocate an axiom according to which there is in nature, or better in the universe at large, a great coherent design that man ought to defend and protect, not degrade and destroy. They refer in this way to that universal harmony in time and space that we have mentioned above in connection with experiments, and promote it to the role of a value. What is logically unacceptable is the claim that the implicit *Werturteil*, the judgment of value, is imposed by science. Science can at best provide very clear hints to that effect, hints which today are even more compelling than when Sperry wrote,^[13] Sperry's claim could then be construed as the declaration that not only does research imply choices, but those choices are 'ethically laden' inasmuch as they must respect at least one value, the coherence in space and time of the universe, particularly of nature.

As to Monod, he founded his ethical view on two axioms: (i), there is no absolute moral rule – for that would imply that there is a creator, and, according to Monod, blind chance is the only rational explanation for novelties in the universe –; (ii), man is a free agent, and has to choose between the Darkness and the Kingdom, but he can only do so with reference to a value that is inherent in science, namely knowledge. It is not obvious that these two axioms are consistent with one another, but it is interesting that Monod considers knowledge a value that is inseparable from science. Actually, since a value is something desirable, and desirability cannot be proven by scientific methods, what he really meant was like this: If you do science it is because you believe that knowledge is desirable; therefore, knowledge (of the sensible world) is a value; indeed, it is the only objective value, because it is obtained by science, which offers verifiable statements.

In a way, Monod's outlook is different from Sperry's: for Monod is concerned with ethics in the sense of Rousseau and Hobbes, as related to the rules of conduct towards others, not so much towards nature. In other words, while Sperry laid stress on science and nature, Monod, perhaps without realizing it, laid

stress on science and society. Science affects society in a variety of ways, from merely technological openings to data and concepts leading to changes in the dominant *Weltanschauung*. What Monod claimed, in the last analysis, was that a *Weltanschauung* based on science could accept only one value, namely knowledge.

But is it not desirable that a man should avoid actions that may damage other men, even in the pursuit of knowledge? It seems clear that social implications of doing science cannot be kept out of the picture, nor can science tell us anything about damage. The latter is a consequence of an action that is not gratifying to whatever is damaged, but science tells us that lions kill zebras, wolves kill (and not in a painless way) buffaloes, intraspecific fights take place, and so on. Thus, even violence can be justified on the argument that science proves it a fact of nature. We shall not dwell on this point here because it would require a long and difficult discussion of what we read *in* nature as distinct from what we read *into* nature; suffice it to recall that science only observes in nature facts which, if they resulted from human deliberate choices, would be classed as violence; to claim that therefore there is violence in nature is applying an anthropomorphic point of view. Actually, there are scientific grounds for believing that human society should not be looked at as something contrasting with nature, for *Homo sapiens* is an animal species, albeit a rational one, and man's free will is an aspect of the ecological niche assigned to him by nature. [14] However, this does not eliminate the point that the perfect harmony of society should be a value as much as knowledge.

9. Examples from chemistry

In a journal devoted to the philosophy of chemistry, the reader would perhaps have expected more references to chemistry. There are two reasons for our actual choice. One is that this paper has been intended as an aid to situate the question of ethics and science in a broader context. The other is that the field in which the greatest ethical concerns have been expressed is biology, in particular molecular biology, and, while it would be ridiculous to claim that the latter is a chapter of chemistry, there can be no doubt that it relies a lot on biochemistry. Nevertheless, I wish to give some examples, drawn from the history of chemistry, of what it means to be a true scientist, for whom research is a commitment.

My first example is Emil Fischer, one of the greatest chemists in the history of science. At variance with many great physicists, Fischer was not interested in general theory or philosophical speculations; it is most probable that his secondary education (which at that time provided a boy of eighteen, through humanities and philosophy, ability in clear, critical thought) played an essential role in his creativity; but that was all. "He confined his energy to affairs of chemistry," explained Martin Onslow Forster, in the memorial lecture delivered to the British Royal Society in 1920, two years after the end of the first world war; [15] and yet his human qualities, particularly his enthusiasm for his research were so deep and sincere, that, "the veneration surrounding his name in this country [Britain] could scarcely have been less, in depth and sincerity, than that acknowledged by his fellow countrymen." Forster goes on to summarize the incredible achievements of Fischer, mainly in biochemistry, but also in industrial chemistry to assist his country through the war. And he gives a hint to the spirit with which that man devoted his whole life to chemistry in his conclusion: "As the war continued, he had become gravely concerned at the diversion of young chemists to its requirements, and the consequent injury to the scientific spirit of the new generation. To assist in combating this danger and the accompanying embarrassment to teaching institutions arising from the diminished value of money, he raised a considerable fund, which, in his own words, constituted 'der letzte Dienst den ich der deutschen Wissenschaft leisten kann', – the last service I can do German science.

My second example is C. J. Pedersen, an American born in Korea in 1904 from a Norwegian father and a Japanese mother. He was assigned in 1987 a Nobel prize for his work on crown ethers, the first adventure in what is now supramolecular chemistry. In his Nobel lecture, he pointed out that his first decision to work at those molecules was motivated by the beauty of its formula. Considerations on this

side of chemistry can be found in the work of another Nobel prize, Roald Hoffmann.[16]

My third example is again a famous German chemist, Hermann Staudinger. He realized in 1925 that macromolecules are molecules that have novel properties just because of their size, and was bitterly attacked by his colleagues because of this idea. Once, after a lecture, he concluded the discussion with a lapidary remark: "Hier steh' ich, ich kann nicht anders," – here I stand, I cannot do otherwise. He was assigned in 1953 a belated Nobel prize precisely for that discovery.

These examples of values at work in chemical research have a general significance, because they show that the ethical dimension of science is not a cage of interdictions, but the wise evaluation of choiceworthiness of actions and standpoints. Fischer's example shows how a man can serve knowledge and humanity because he loves his discipline; Pedersen's example shows how a subtle sense of proportion may suggest choices that are wise and creative; Staudinger's example shows that science requires courage and faithfulness to truth.

10. A conclusion

We asked ourselves at the beginning whether one could speak of an ethical dimension of doing science that would be there even if research were carried out just for the sake of knowledge. We have found that the answer is positive, simply because in research a man is faced all the time with choices that are not necessarily indifferent from the moral point of view. He has to respect values, and knowledge is not the only value, nor does it justify the means used to attain it. It would seem that three values at least are supported by scientific observation and should be taken into account when making choices that could go against one of those values: harmony of nature, knowledge, harmony of society. Every decision should be aimed to contribute as much as possible toward enhancing the impact of those values.

However, is that so easy? Take, for example, the refusal of violence, justified by reverence to nature, for example. Except for some admirable simplists, no one would think that extension of that refusal to lice and intestinal worms is reasonable; if so, where shall we draw the line? Take another example, diagrams given in a general biology textbook that illustrate the different forms of sexual response in normal human females;[17] how can the contempt of privacy required in order to obtain that sort of information, and the disruptive psychological effects on the image of women in the (usually immature) students' minds be justified? Somebody might perhaps construe a case for its scientific value; but surely a good case is needed.

In both examples, what is necessary is to evaluate the factors appearing in the right hand side of equations (1) to (3). It seems clear that the three values we have just isolated are not always in agreement, and the desirability of each may depend on the specific case (*e.g.* violence to cockroaches vs. violence to alligators).

The general approach to ethics that Einstein for one considered the best goes back to almost twenty-four centuries ago, and is essentially that of Plato. Plato's idea was that the most desirable thing for man, is personal happiness. He offered proof that the winning strategy in view of happiness was pursuit of justice, warning at the same time that such a proof could only persuade people educated enough to be able to form personal judgments; which means that justice cannot go without the love of knowledge and beauty, which is love of harmony. The circle is thus closed to include both Sperry's and Monod's values.[18]

I shall not make an attempt to discuss in more detail than done above the Platonic values as guiding values of a scientist. Even less shall I pause on that extended version of justice that is love of other human beings, accepted by our society at least in milder versions such as solidarity, humanitarianism, *etc.* I shall mention, however, that it makes doing (and publishing) genuine science an obligation towards fellow human beings, albeit only for people who have the necessary ability and qualifications. Let me emphasize again,

however, that consideration of possible bearing of ethics on scientific activity as such – *i.e.* besides moral or legal conditions on applications of science and avoidance of frauds or superficiality – leads to the conclusion that a scientist ought to ponder the choiceworthiness, as defined in equation (3), of every free decision he makes in the pursuit of scientific knowledge, inasmuch as it may involve tampering with the harmonious evolution of nature and society. It seems reasonable to suggest that this evaluation should be based on the traditional fundamental values common to all great civilizations. It cannot in general indicate a way to eliminate all risks; therefore, since to contribute to the increase of knowledge is a professional and moral duty of a scientist, the latter is often obliged to choose among possibilities that involve risks, so that in the very activity of research he engages his personal responsibility.

All this may sound formidable, but, I repeat, risks and responsibilities are part of the human condition: even driving a car involves them. In connection with scientific research, it needs emphasis because many a scientist considers research obviously right or at least innocuous as long as he is not directly involved in applications. This is simply not correct. A different habit of the mind – what used to be called a ‘virtue’ – is necessary, and the virtue involved is wisdom, which is the result of an educated, critical but highly positive approach to life.

11. Inspiration from the past

As an envoy of this study, it seems proper to recall the attention of the readers on two quotations that express in the words of great scientists the significance of doing science. The first one is taken from a lecture Einstein gave late in his life, and illustrates the claim that doing science is a commitment of the scientist as a person, not just a profession:[19]

Although I am a typical loner in daily life, my consciousness of belonging to the invisible community of those who strive for truth, beauty, and justice has preserved me from feeling isolated. The most beautiful and deepest experience a man can have is the sense of the mysterious. It is the underlying principle of religion as well as all serious endeavors in art and science. He who never had this experience seems to me, if not dead, then at least blind. To sense that behind anything that can be experienced there is something that our mind cannot grasp and whose beauty and sublimity reaches us only indirectly and as a feeble reflection, this is religiousness. In this sense, I am religious. To me it suffices to wonder at these secrets and to attempt humbly to grasp with my mind a mere image of the lofty structure of all that is there.

The other quotation concerns the connection between discovery of the secrets of nature and caution in presenting results without due caution and sense of proportions. Certain pieces of information, in the hands of politically biased or merely superficial intellectuals and journalists may be used to favor acceptance of their ideological claims. Regardless of whether those claims are good or bad, a scientist should not allow this use of science. Therefore, the following warning by Girolamo Fracastoro (1478-1553), the famous doctor and scholar from Verona who already in the first half of the 16th century fought against the doctrine that the course of illnesses was controlled by the stars, should be the object of a long reflection, including meditation on the decline of general education in our society:[20]

It seems that those things that being deeply concealed in Nature belong more specially than others to the realm of things divine and celestial should be the object of reticence and silence, or at least communicated not only modestly but as it were with a measure of decency; for it seems that it would not be without a measure of offense that one would repeat in public what Nature herself has wished to be profoundly hidden.

Notes

- [1] Cf. R. Popp: 1999, 'Wertfreiheit', in: P. Precht & F.P. Burkard (eds.), *Metzler Philosophie Lexikon*, Metzler, Stuttgart; and V. Heins: 1999, 'Max Weber', in: F. Volpi (ed.): *Großes Werklexikon der Philosophie*, Kröner, Stuttgart; M. Weber: 1919, 'Wissenschaft als Beruf'; printed in: M. Weber: 1922, *Gesammelte Aufsätze zur Wissenschaftslehre*, Mohr, Tübingen, pp. 524-55 (7th edn. 1988, pp. 582-613).
- [2] J. Monod: 1970, *Le hasard et la nécessité*, Paris, Seuil.
- [3] Plato: *The Republic and other Works*, trans. B. Jowett, Oxford U. Press, Oxford, 1871 (reprint: Garden City, New York: Doubleday 1959).
- [4] W. Pfaff: 2001, 'Culture counts', *International Herald Tribune*, 17 Feb. 2001, p. 6.
- [5] *The Random House Unabridged Dictionary*, s.v. 'ethics'.
- [6] H. Margenau: 1964, *Ethics and Science*, Van Nostrand, New York.
- [7] Cf. e.g. M. Planck: 1948, *Wissenschaftliche Selbstbiographie*, Barthol, Leipzig.
- [8] This is in contrast with the idea of science that was dominant till the 18th century, as is clear from the work of Kant.
- [9] R. Levi-Montalcini: 1994, 'Il grande disegno', *Universitas* (Rome) **15**-2, 58-61; from *Technology Review*, 1994, issues 63-64.
- [10] Monod, *op. cit.*
- [11] R. W. Sperry: 1972, 'Science and the problem of Values', *Perspectives in Biology and Medicine* (U. of Chicago, USA), **16**, 1.
- [12] This point too was clearly stated by Henri Margenau (*op. cit.*), who claimed that values can only emerge from the historical experience of mankind, and then be validated as mentioned above.
- [13] The author of this paper has devoted a book to them: G. Del Re: 2000, *The Cosmic Dance*, Templeton Foundation Press, Philadelphia, PA.
- [14] Del Re: *The Cosmic Dance*, *op. cit.* Of course, in an existentialistic perspective one could speak of man's *Geschick* (specific aptitude) in the context of being, and in a religious perspective one could speak of a design of God to which man is expected to co-operate.
- [15] M.O. Forster: 1920, 'Emil Fischer Memorial Lecture', *Proceedings of the Royal Society*, **117**, 1157-1201.
- [16] R. Hoffmann: 1990, 'Molecular Beauty', *The Journal for Aesthetics and Art Criticism*, **48** (3), 191-204.
- [17] W.K. Purves & G.H. Orians: 1987, *Life: the science of biology*, Sinauer Ass., Sunderland, MS.
- [18] Reading *The Republic* (*op. cit.*) should be a unique experience for any person with a minimum of education because of its actuality even in its description of the ills of democracy.
- [19] Cited by D. Brian: 1996, *Einstein, a life*, Wiley, New York, p. 234.

[20] G. Fracastoro: ca. 1540, *Scritti inediti*, ed. by F. Pellegrini (Verona 1955), p. 207: "Quae abditissima in natura sunt ad divina praesertim et caelestia pertinentia aut reticenda quidem et silentio continenda videntur, aut propalanda certe non modo modeste sed quodammodo verecunde; nam quae et natura ipsa occultissima esse voluit non sine quadam iniuria videntur palam proferri."

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