

MATHEMATICS, SCIENCE AND TECHNOLOGY AS  
ELEMENTS OF CULTURE <sup>1</sup>

E.J. Dijksterhuis

[*Translator's note:* The translation presented here is based upon the annotated edition of Dijksterhuis' lecture 'Wiskunde, Natuurwetenschappen en Techniek als Cultuurelementen' published by K. van Berkel in his Dijksterhuis anthology *Clio's Stiefkind* (Amsterdam: Bert Bakker, 1990), pp. 29-47. Van Berkel's introduction to the lecture is also reproduced in translation. I kindly thank E.J. Dijksterhuis heirs, K. van Berkel and Bert Bakker Publishers for their permission to use this edition, and Enid Perlin for her correction of the English translation.

B. Theunissen]

**Introduction**

The period of Dijksterhuis' activity as an historian of science (1920-1960) broadly coincides with a period of strong cultural pessimism in Dutch cultural history. There was a general conviction that western civilization was experiencing a crisis which might result in its downfall. The cultural historian, J. Huizinga, author of such works as *In de schaduw van morgen* (1935) and *Geschonden wereld* (1945), may well have been the most well-known representative of this tendency which, for that matter, was not restricted to the Netherlands.

In the 1950s, when he had gained wide recognition as an historian of science, Dijksterhuis took up this subject as well, and naturally his special perspective was that of the history of science. It struck him that the role played by the natural sciences sometimes received too little attention in the discussions on the crisis of culture. For example, H. Brugmans' work *Crisis en roeping van het*

*Westen* (1952), which attracted considerable attention at the time, failed to mention the names of Einstein, Rutherford, Lorentz, Heisenberg and Schrödinger, physicists "who have taken such an important part in bringing about the present situation in culture." Authors who did bring up the role of science discussed it only in general terms: science and technology were held responsible for numerous problems, yet the writers gave no evidence of understanding the nature and the history of the sciences. An example of this was the misconceived notion which some authors entertained about the nature of the mechanistic world picture upheld by science.

Dijksterhuis was not one of the cultural pessimists. He did not deny the negative aspects of the development of modern science and technology; he, too, felt the threat of the atomic bomb, regretted the disruption of silence by the radio and acknowledged the danger of humans being displaced by automation. Yet these disadvantages were not inevitable, nor were they inherent to science. The solution of the problems was not to be found in less science and technology, but in their further development and in a better understanding of the meaning and cultural importance of these stumbling blocks of the cultural pessimists.

Dijksterhuis predominantly played his part as philosopher of culture during the numerous lectures he gave all over the country in the fifties, in which he discussed such topics as 'The problems of science' and 'Reflections on science'. Most of these lectures were not published; often pieces of one lecture were used in others, or the one lecture merely paraphrased another. The lecture 'Mathematics, science and technology as elements of culture' originated in the same way, as Dijksterhuis indicates in the first footnote. Among his general lectures from the fifties this one provides the clearest view of the broad range of subjects which Dijksterhuis engaged in during his career: the cultural importance of science and technology, the methodological aspects of the natural sciences and especially the supposed opposition between science and cultural studies, the neglect of the history of science by historians, the role which science might play in closing the gap between literary and scientific circles, and the importance of secondary and university education in this respect.

K. van Berkel

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\* E.J. Dijksterhuis, review of H. Brugmans, *Crisis en roeping van het Westen. Twee en een halve eeuw Europese cultuurgeschiedenis* (1952), *De Gids* 115, 1952/II, pp. 485-487. The book is admirable, in Dijksterhuis' view, but also surprisingly one-sided: "It has the intention of describing the present crisis of culture from a cultural historical perspective, yet it consciously neglects one of the most important factors which have brought it about, to wit the rise and the prospering of the natural sciences" (p. 468).

The combination of words 'mathematics-science-technology' may nowadays sound so familiar to every-one that one might almost be tempted to lose sight of the diversity of its three components, yet to find it being connected with the term culture must surely strike one as paradoxical and can even induce vehemently hostile reactions. Culture, that indestructible word, that has triumphantly overcome the depreciation to which it was subjected in the years of occupation, evokes thoughts of a civilized, traditional way of living, of a calm and placid attitude to life attained by education and the company of kindred spirits, of familiarity with literature, music, art and philosophy. In a different sense, it can also be applied to circles of human society in which, under the influence of a well-defined and passionate faith, a special style of living, a firm stand with regard to life's events, has developed. Yet how can this term be connected with a discipline like mathematics, which is commonly characterized by the adjectives 'dull' and 'dry,'; with the natural sciences, which have taught us to take a cool and rational stance towards phenomena which in former times were the source of religious awe or of a feeling of cosmic unity; with technology, which has standardized and banalized human life in so many respects and which in its most recent development already threatens to become a direct menace to orderly human society?

The antithesis seems indeed irreconcilable and the claim expressed in the title of this essay is most certainly in need of elucidation and defence. In order to provide this, a definition of the meaning in which the word 'culture' is used here is required first of all. Refraining from all polemic against, or criticism of different descriptions, we shall start from the definitions given by Thomas Mann and Ortega y Gasset.

Mann's definition, which implies at the same time a determination of the concept of civilization, is to be found in a treatise entitled *Gedanken im Kriege*, which appeared in 1915, together with the essay *Friedrich und die grosse Koalition*. Since it was not included with later reprints of this essay — in the collections *Rede und Antwort* and *Altes und Neues* — it has not become widely known. At best its content appears to have penetrated indirectly by being mentioned in a polemic against Romain Roland, which is found under the caption *Gegen Recht und Wahrheit* in the *Betrachtungen eines Unpolitischen*.

Culture and civilization are regarded as opposites, as a pair of contrasts that is considered to be a manifestation of the eternal antithesis of nature and spirit. "Kultur," we are told, "ist Geschlossenheit, Stil, Form, Haltung, Geschmack, ist eine gewisse geistige Organisation der Welt, und sei das alles auch noch so abenteuerlich, skurril, wild, blutig und furchtbar. Zivilisation aber ist Vernunft,

Aufklärung, Sänftigung, Sittigung, Skeptisierung, Auflösung, — Geist."<sup>2</sup>

So culture, in this sense, is a qualification which does not imply any aesthetic or ethical value judgment; one can detest a particular culture aesthetically or abhor it morally — it does not thereby forfeit its right to be called a culture. The only condition for applying the concept to a particular society of humans is that this society has some distinct quality of its own, a specific characteristic which fundamentally marks it off from other forms of society.

Now this seems clearly to be the case with regard to what is commonly called western society, and unless all signs fail, it will become ever more clearly so in the future. Its particularity, its style, its form, its preference and its spiritual organization consist in its aim of controlling nature, which has so far been crowned with success and will set itself ever higher and more remote aims. For more than three centuries now, humankind in western Europe and its cultural satellites has had mathematical-empirical science at its disposal as a means of investigating the workings of nature and of compelling its forces into its service to an incomparably greater extent than in any other known period of history. The pace at which the development of this capacity proceeds had already quickened considerably in the nineteenth century, but in the twentieth century the acceleration has increased to such a degree that one really has a feeling of being on the brink of the realization of even many more possibilities than those that have materialized before our eyes. Already now, however, the mathematical-physical-technical nature of society has become so distinct that one can speak of a culture in Thomas Mann's sense.

Might Mann have intended this application, among others, of his concept in 1915? It is unlikely. At that time the term 'science' was associated first and foremost with 'Vernunft,' 'Aufklärung,' and also, owing to its influence on matters of world-view, of 'Auflösung,' which are all characteristics of 'Zivilisation.' Yet much has changed dramatically since then. Atomic theory, still in its infancy in 1915 and looked upon as merely an interesting extension of our knowledge of the structure of matter, has since become a world-dominating power which fills humankind with horror. The desire to penetrate deeper and deeper into the secrets of matter has taken a distinctly demonic, and thus far from civilized turn, which reveals itself in the fact that the source of energy to which it has given access, has mainly been pressed into the service of destruction until now.

Yet the demonic, the feeling that one is urged on by powers raised by oneself yet is unable to break away from their influence, however clearly one sees the

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\* Culture is unity, style, form, attitude, taste; it is a certain spiritual organization of the world, however adventurous, grotesque, wild, bloody and terrifying all that may be. Civilization, however, is reason, enlightenment, appeasement, sobriety, sepsis, detachment, — mind.

disaster they will bring upon us, is also a characteristic of culture in Thomas Mann's sense, just like the heroic, while civilization is essentially antidemonic and unheroic. Our technological society, however, displays both characteristics. Brought forth by technology, it can only live on by means of more technology and no-one who regrets this can fail to collaborate in it. Now that medical science has achieved a considerable improvement in general hygienic conditions and a notable prolongation of our life-span, one is sometimes seized by fear when considering the difficulties which all these advances will bring in their wake for humanity, yet this will never detain us from our endeavour to improve general conditions of health.

In this way there is a spiritual struggle going on in all kinds of areas, a struggle to which one definitely cannot deny an heroic quality, yet which is demonically compelled to strive for what it does not want and in many cases even abhors.

So when we survey the development of science and technology from the eighteenth century until the present and infer its probable future course, we have to conclude that science and technology are in the process of changing from the elements of civilization which they once were, into elements of culture. When later, in a history of cultures in Toynbee's sense, the rise, apogee and fall of western culture will be outlined, too, it will be designated as mathematical-physical-technical.

The view of culture that we have sketched is supported by considerations the Spanish philosopher Ortega y Gasset devoted to this concept. They can be found in his *Mission of the university*, a lecture given to students in Spain in 1930, which appeared in an English translation in 1944. Ortega defines culture here as the vital system of the ideas of a period, yet he immediately remarks, in agreement with what we learned from Thomas Mann regarding the possibility of a bloody, wild, repulsive and far from civilized culture, that practically nothing is said in this definition about whether or not the ideas and convictions in question are of an intellectual standard, and that there is therefore no essential connection between culture and science at all.

Now what in our opinion — Mann himself might have disagreed — could be concluded from Thomas Mann's definition of culture, is positively expressed by Ortega himself. Undoubtedly, culture is not identical to mathematics, science and technology, but it can in a particular situation be determined by these three areas of human activity, and he is convinced that this is the case in our present society. He considers physics (we may take this word to stand for the science of inorganic nature and consider it to include its essential expedient, mathematics, and its practical application, technology) as one of the great, essential instruments of the modern mind. Four centuries of intellectual work have cooperated in bringing it about; its tenets are closely tied to a cultivated human's understand-

ding of God, society, matter and what is non-material, and of whatever else is essential for an enlightened way of living. One can of course do without science in some situations, if one is a shepherd in the hills, for instance, or a slave, tied to the earth or to a machine. Yet if someone who wants to be a physician or a magistrate, a general, a philologist or a bishop, who, in brief, wishes to belong to the leading class of society, is not acquainted with the present world-picture of physics, he is an utter barbarian, however well he knows his laws, his medicines, his churchfathers. The same, for that matter, can be said with regard to biology, history and philosophy. Ortega concludes from this that the university must acquaint its students with these four vast domains of culture before or along with training for a particular profession. Only then can they be regarded as cultivated people who may be assumed to be aware of their own times.

In this way my title has been vindicated, and its concomitant thesis proved. Has it really? A cheap victory, I hear you mutter. From among the countless definitions of culture you have picked two which concur with the way in which you want to use the word yourself, and then it is of course an easy job to prove the thesis you framed.

There is some truth in this objection. Some, not much, because it is certainly significant that such definitions can indeed be found and that they are used by authors who have definitely gained an understanding of culture, whatever this term may signify, whereas one of them has expressly inferred the thesis contained in my title as a conclusion from his definition. Let us give full weight to the criticism, however, and have a fresh look at the matter, not, this time, by starting from a preconceived definition, but by consulting our every day experience. So let us turn to circles in society which in common parlance are bearers of culture, circles of men and women of letters, linguists, historians, classicists, theologians, and question them about the attitude they adopt towards mathematics, science and technology: whether they consider them spiritually on a par with their own work, and whether they feel the spiritual lack deriving from a possible absence of familiarity with this world of thought. Leaving exceptions aside and going by rough impressions, there is no doubt whatsoever as to how this question will be answered. The idea of mathematics is simply abhorrent to these circles; technology is appreciated only if, and in so far as it renders life agreeable and prolongs it; science is respected for making technology possible, but is no more than the latter judged and valued from a different perspective than that of utility. The idea of a certain equivalence between the work of mathematicians, physicists and technologists and that of artists, literary people and historians, is not even taken into consideration; the unfamiliarity with that other world is more likely to be acknowledged with a certain pride, almost as a merit, than to be recognized as a shortcoming. In these circles, which according to general opinion are competent judges of matters of culture, my thesis does

not have the slightest chance of being accepted.

This is of course as cheap a success for the other side as the first one was for me. We have begun by designating particular circles as pre-eminent bearers of culture, and in this way we have implicitly defined culture in such a way that mathematics, science and technology cannot be elements of it.

What does this discussion boil down to? To nothing more, but also to nothing less than the fact, definitely not unimportant, that there is in our times a dismaying lack of agreement over the spiritual value of three fields of human activity which influence society to the highest possible degree and which therefore put their mark upon our age. Let me take this difference of opinion, rather than the discussion over the term culture, for the theme of my further considerations.

I wish to begin by remarking that, in Germany and in our country at least, there is a discernable widespread effort to stress and express the contrast between mathematics, science and technology on the one hand and all other areas of learning on the other, by dividing all fields of knowledge into two, or at most three groups. The inorganic sciences and technology, sometimes with and sometimes without mathematics, then end up in the same group, which is separated by sharp boundaries from the others.

One can have the humanities as distinct from science, the natural sciences as distinct from the cultural sciences or the human sciences. Besides this, some people distinguish a group of formal sciences, mathematics and logic, which others, *mirabile dictu*, include among the natural sciences; and there have also been attempts to class the life sciences in a separate group. In our country a classification in  $\alpha$  and  $\beta$  fields is *en vogue* nowadays, often tacitly identified with the distinction between humanities and natural sciences.

All these divisions suffer from the destructive defects that, firstly, no criterium of classification is given; secondly, that not every field of knowledge is allotted one, and only one place; and thirdly, that they never include a table in which one can see where a particular discipline has ended up. The classification in  $\alpha$  and  $\beta$  fields also has the particular weakness that it is apparently inspired by a rough and contingent division of school types, whereas such a division, if one wants to make it, should rather be based on a given, well-considered classification of the sciences.

It is curious to see how light-heartedly, generally speaking, this classificatory terminology is applied, as if it resides in the nature of things and simply has to be accepted, whereas each critical investigation proves its inadequacy. If, to use Erich Rothacker's phrase,<sup>\*</sup> one characterizes the spiritual sciences or cultural sciences — these two terms are not infrequently used interchangeably, although

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<sup>\*</sup> Erich Rothacker (1888-1965), German philosopher.

the thinker who coined the latter, Rickert,<sup>\*</sup> expressly rejected the former — by stating that they are concerned with a world created or generated by humans, then it is an obvious conclusion to designate mathematics as a pre-eminently spiritual science, because in no other field does the human mind go about its business so arbitrarily and with so little resort to an outer world. If one considers the natural and cultural sciences as being divided by the fact that the former deal in a generalizing way with nature, in which nature is not to be looked at from a perspective of value, while the latter are concerned in an individualizing way with matters which are pursued and cultivated on account of the value attached to them, then the conclusion forces itself upon us that the technical sciences are pre-eminently cultural sciences, since they only bring forth, by means of general insights provided by the natural sciences, special things which are valued in human society or which are at least value-related. One has to arrive at the same conclusion if one defines culture as victory over nature. Yet each time the conclusion one draws is not in keeping with the intention of the classification. If, finally, one appeals to the characteristic of a succinct form of understanding or, with some affectation, of *verstehen*, in order to characterize the spiritual sciences (as is customary nowadays), then one must face the objection that the opposition between natural and spiritual science is grounded in the fact that the former is characterized by its object, the latter by its method. Apart from that, the supporter of the classification as defined in this way, has to take it upon himself to prove that all disciplines that are commonly called spiritual sciences, as for instance linguistics, history and economics, predominantly apply the method of *verstehen*.

Why have I dwelt on this matter at such great length? It is because in all the proposed classifications there is an evident lack of understanding and appreciation of mathematics and the natural sciences, and because the forced tenacity with which they are retained despite all the criticism they have already encountered, is a symptom of the same lack of understanding. For one should have no illusions on this point: the depreciation of matter as compared to mind, which was raised to the status of doctrine by Plato and which intruded into Christianity via neo-Platonism, has, in past and present, produced the effect that a science that engages the material is looked upon as an activity of a lower spiritual order, and this testifies to a gross underestimation of the part taken by the creative human mind in bringing about the scientific world-picture and the technical applications of scientific insights. For this reason too much attention has been paid to the internal methodological differences between the fields of knowledge (which, for that matter, exist just as well within the circle of natural sciences), and the unmistakable unity in mental attitude among students of the

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<sup>\*</sup> Heinrich Rickert (1863-1936), Neo-Kantian German philosopher.

most diverse disciplines has been neglected.

The same fatal inclination to stress the differences instead of noticing the similarities can also be discerned in our school system, namely, in the passion with which the distinction between  $\alpha$  and  $\beta$  is cultivated. It is taken for granted that each school type is divided into an  $\alpha$  and a  $\beta$  branch; the division is even applied to school types like the AMS\* which do not even exist as yet. In this way people are infused already in their youth with the idea that this distinction is in the very nature of things; besides, the division is often linked with highly undesirable matters of prestige; both sides look down upon each other and it frequently occurs that teachers encourage these feelings through their remarks on other disciplines. The impressions acquired at school often linger on throughout life and help to cultivate the attitude of hostile imperviousness to certain fields of thought.

A phenomenon as striking as this incorrect attitude towards a group of sciences which fully deserve general attention and interest because of their spiritual accomplishments, and because they more than others put their mark on our society, elicits an historical discussion.

Has this attitude, evinced among wide circles of educated people, always existed, and if not, when did it come into being? The first question can definitely be answered negatively. There is no question of it before the beginning of the nineteenth century. In the seventeenth and eighteenth centuries many men of learning moved most unrestrainedly from one discipline to another without any awareness of crossing real boundaries. In the eighteenth century all civilized circles took a lively interest in the sciences in all their diversity; scientific training was considered a normal constituent of intellectual education. Technology was valued just as highly and it was not exceptional for highly educated intellectuals to perform manual tasks.

The turn-about reveals itself in the beginning of the nineteenth century and is evident first and most clearly in philosophy. In the eighteenth century philosophy was still closely tied up with mathematics and the natural sciences. For Kant Euclidean geometry and Newtonian mechanics were essential components of the philosophical system.

German *Naturphilosophie* of the early nineteenth century preserved this close connection in principle, but when its course turned out to be unprofitable for science while science itself, free from its philosophical leash, appeared to be able to make fast headway on its own initiative, the connection was severed. General-

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\* AMS = Algemene Middelbare School (general secondary school). The AMS formed part of the reform plans proposed by the minister of education, G. Bolkestein, in 1940. In the 1950s these plans were still under discussion and the AMS was then envisaged with two sections: the mathematical-physical and the social. The AMS never materialized, but some of the ideas underlying it have been incorporated into the modern Dutch school system.

ly speaking, philosophy in the nineteenth century has hardly bothered at all with the results of mathematics and science, notwithstanding the fact that a mathematical discovery like non-Euclidean geometry, for example, should have been food for thought to Kantian philosophers. Change has only come about through the fact that science, towards the end of the nineteenth century, brought forth its own philosophers, who searched for their starting points in the results of science and found them there.

In the nineteenth century, an unfavourable influence on the appreciation of mathematics and science has also been exercised by the humanistic *gymnasium*, in which 'humanistic' is to be understood in a sense that has almost dropped out of use nowadays, namely that of being inspired by classical antiquity. This was a highly curious phenomenon. In Greek antiquity mathematics and astronomy had been held in high esteem and science had been strongly implicated in philosophy. One might have expected the *gymnasium* to have given much attention to these disciplines, recognizing elements of classical education in them. The reverse was the case. It is not so long ago that mathematics was merely tolerated at the *gymnasium* and that science did not count at all. No-one seems to have realized how utterly un-Greek this attitude really was.

There can be no doubt that the one-sided humanism which dominated pre-university as well as university education in the nineteenth century, also contributed to the low social esteem in which the students of the technical sciences were held by learned circles. It did remain true to its origin in this way, for the Hellenes did not judge the matter differently. Weak attempts, made at the beginning of the nineteenth century in our country, to attach technical education to the university, have failed. When later the Polytechnic School of Delft was established, university circles were not at all prepared to consider the engineers educated there as equals; it took until the beginning of this century before the education of engineers was considered to be part of higher education.

Also remarkably one-sided is the point of view of historians in the nineteenth century, and often in the twentieth as well. Although the development of mathematics and science has been a very influential factor in world history at least from the year 1500 onwards, they have hardly taken notice of it. Students of history remained preoccupied with dynastic, political and military events, which still represent the core of history for countless people. Later on historians broadened their outlook to include the economic and the social; yet the study of the history of scientific thought remained with the students of the sciences themselves.

The disastrous consequences of the isolation of mathematics and science with respect to other spiritual activities rarely becomes more clearly apparent than when we discuss historical figures from a time in which one had no idea at all of the possibility of such isolation. Somebody may be talking, for instance, about

the influence which Descartes' thinking has had on world history — a tremendous influence, which may be applauded by one person and regretted by another. Now we amplify the argument by explaining how important the consequences of Descartes' success have been in expressing the analytic geometry of the Greeks in algebraic terms, how significant his changes of algebraic symbolism, how much our view of his personality can be clarified by acquainting ourselves with his reflections on the circulation of the blood and with his efforts to have hyperbolic lenses ground. This causes astonishment. We are told that we are talking about Cartesian metaphysics, about his two substances, his proofs of God's existence, his foundation of morality. How greatly this atmosphere is violated by suddenly starting to talk about the rejection of the homogeneity requirement for algebraic equations, about the heartbeat, about valves in the nerves and about the grinding of lenses!

Not so long ago this reaction was the rule. I am not at all sure that it does no longer arise, even though Descartes himself said: "Toute la Philosophie est comme un arbre, dont les racines sont la Metaphysique, le tronc est la Physique et les branches qui sortent de ce tronc sont toutes les autres sciences, qui se reduisent à trois principales à sçavoir la Medecine, la Mechanique et la Morale."<sup>3</sup>

It is time now to look at matters again from the opposite point of view and to observe that the isolation we are talking about is not just a consequence of undeserved misjudgment. The natural sciences of the nineteenth centuries have certainly contributed their share to this misjudgment, and mathematics as well as technology, each in its own fashion, are still doing so at present. Nineteenth-century physics, in some kind of victorious intoxication, often raised successful scientific theories to the status of dogmas dictating our world view and in this way has had a malign influence on human thinking generally. The materialistic metaphysics it produced has evoked a distrust of its influence which was certainly not unwarranted at that time. Its transgressions into the domains of the historical and the social sciences worked to the same effect. A factor of a completely different nature was the ever closer relationship with mathematics. Thereby, its expositions came to share the strongly symbolic manner of expression which this discipline had already employed for a long time, and this deterred the uninitiated.

Of the three factors mentioned, the first two can be said to have lost their influence in our time. The modern physicist is anything but dogmatic, he is well aware of the provisional nature of all his theories and thus he can surrender

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\* The whole of philosophy is like a tree, of which the branches are metaphysics, the stem is physics, and the branches which spring from the stem are all other fields of knowledge, which can be reduced to the three most important ones, namely, medicine, mechanics, and ethics.

them in the light of new facts, with a peace of mind in doing so which outsiders do not understand at all. He is far from presenting his momentary views as eternal truths. Rash attempts to apply scientific lines of reasoning to fields that by their nature do not lend themselves to such treatment, have likewise disappeared. In so far as it does occur, as for instance in linguistics, psychology and economics, the initiative is taken by the students of these disciplines themselves.

The third factor, on the other hand, is in force more strongly than ever in our time. Mathematical symbolism, apart from mathematics, does not dominate only the sciences, but has already become indispensable for certain areas of philosophy. We should stress immediately that the development that has brought this about was absolutely inevitable. The more mathematics and science progressed, the clearer it became that colloquial language, which is intended for completely different purposes, was no longer adequate for the expression of the subtle and complex lines of reasoning they employed. It is important to point out that we have here an important cause of the alienation we are dealing with. Mathematical symbolism is simply bound to baffle the uninitiated.

One should not underestimate the effect of this. Only several decades ago no appreciable proficiency in handling mathematical symbols was needed to study formal logic. There was some letter symbolism in the traditional names for the patterns of the syllogism, *Barbara*, *Celarent*, *Darii*, etc., and Euler's conceptual schemes were borrowed from geometry, but this has never caused anybody any real trouble. Nowadays, however, it takes a special training and prolonged technical practice, and whoever cannot or will not absorb this, is bound to remain a stranger to what must be regarded as one of the most fundamental of the sciences.

The same deterrent effect that emanates from the symbolism of the mathematicians is created by the jargon of the technologists. The existence and use of separate professional languages and journals doubtlessly bears much of the blame for the intellectual isolation which gradually excludes mathematics, science and technology from general spiritual life.

More important than fixing the blame, however, is the consideration of the possibilities for putting an end to this undesirable situation. Many people think that the 'popularization of science' offers such a possibility. Books are published and lectures organized in which an expert is supposed to explain in an intelligible way to a lay audience what the theories of modern physics are actually about, or how a startling scientific or technical discovery has been made. Especially for the serious listeners or readers from other disciplines, who are in principle willing to acquaint themselves with the mathematical-physical-technical world of thought, this usually ends in bitter disappointment because they feel, and correctly so, that the most fundamental part, which simply cannot be expressed when the use of mathematical symbols and technical terminology is

entirely dispensed with, is being withheld from them. Besides this, it appears to have become extremely difficult for many scholars to talk in a comprehensible way about their profession to a lay audience. It is moving to see how they usually begin by doing their utmost, yet they often make the mistake of underestimating the mental capacities of their listeners or readers, thereby irritating them thoroughly. Yet when the most essential part of the argument comes up, they feel helpless and quickly make light of difficulties that are much more serious than those to which they devoted so much time in the beginning. The outcome is often the exact opposite of what was intended. Direct attempts to bridge the distance which separates the expert and the lay person in the fields under discussion, seem to be bound to fail. At best they give an illusion of insight and the higher the supposed layman himself has been educated in a different field, the less satisfied he will be. He has made no spiritual contact with the world of thought that is unfamiliar to him and therefore has not been convinced that essential values in the spiritual history of humankind are involved.

Here we hit upon the crux of the matter, because what is most important to us is this conviction, not one's knowledgeable ability about concrete scientific results. The mistaken attitude with regard to the exact and technical sciences, so frequently in evidence, does not reside in a lack of appreciation of the fruits that human society can reap from these sciences, nor in the absence of some kind of superficial interest, but in a lack of insight into the spiritual values they represent. Too much attention is being paid to what mathematics, science and technology bring forth, too little to what they are, to the mental attitude with which they are studied, to the person who conducts the investigation.

I shall try to clarify my intention by means of an example. You are a layman in astronomy and one night you are outside and watching the stars. You are accompanied by an astronomer, who tells you something about what his discipline has to say about the heavens, — a good deal about distances, sizes, temperatures, chemical composition of bodies which can be observed as luminous points, and even more about objects which are invisible to the naked eye. What do you feel? Predominantly a vague emotion that one usually denotes by the word 'interested': you express this by letting out the cries of astonishment that huge numbers usually elicit, and you assure your guide that all this is highly remarkable and instructive. If it ends here — and it usually does — you might as well have stayed inside and left the astronomer alone. By tomorrow you will have forgotten the pieces of information you were given, and if you try to recall them, you will notice that they are in fact a matter of complete indifference to you. All those facts which you claimed to find so interesting turn out to be not important enough for you to remember them. For that matter, you have never known them; you only heard them.

There is a different way of looking at the stars, though. You begin by freeing

your mind of everything you know or think to know about them, of everything you have heard, parroted, learned and believed from your youth onwards. You ask yourself what it actually is that you see: a huge vault with luminous points which appear to move slowly if you keep on looking long enough. You have a feeling of standing at its centre. Again, the astronomer is at your side, and this time he only tells you this one thing: that, contrary to appearance, you are not standing still in the centre of a large dome, but that you are on an almost spherical body which moves through a boundless space containing numerous other bodies. He also reminds you of the way in which this insight was reached. You let the contrast sink in between this knowledge and what the senses seem so irrefutably to teach. What do you feel now? Not the vague impression of something interesting, because you 'knew' it — as far as that goes — all along, but on the contrary a most distinct shiver of awe. Now this is not a religious feeling or a sense of cosmic order; for it is not clear why a universe with an immovable earth in its centre would testify less to a creative power or to cosmic order than an unlimited space with a seemingly chaotic distribution of bodies. It is respect for the human mind, which on the strength of its own intrinsic qualities has arrived at the insight that appearances do not represent the true course of events, and which, following an indestructible urge to know, and building in each generation upon what the earlier generation had already found, moves on further and further along a seemingly endless road, which it feels compelled to follow by an aspect of its being which it truly values.

What I said here with regard to astronomy applies to every branch of science: the spiritual value is not so much in the result as such, but in the fact that, and in the way in which, it has been achieved. Astronomy presents the purest case, because it has few applications that are of practical importance for society, which enables the human urge to understand nature to express itself without being mixed with the striving for technical control of nature. In the case of physics and chemistry the applications demand a great deal of attention; when we judge these according to their social-ethical value, they add an extra dimension to our thinking, as it were, yet we can and must keep this dimension apart from the one discussed first, which stretches out into the past of science. If we limit ourselves to the latter and compare again the earliest known stages of the contemplation and investigation of nature with those of the present, then the same reaction as that to which astronomy gave rise occurs, a reaction of admiring respect for what the human mind has accomplished. In approximately 400 B.C. Democritus tendered the hypothesis that the reality beyond the observable natural phenomena resides in the size, position, number and motion of unobservably small particles in an empty space. By working out this idea, by varying it, adapting it to new data, testing it and revising it over and over again, humankind has achieved this mastery over nature of which physics and chemistry

have provided so many proofs that it would be useless to mention any particular one of them. This mastery is of the utmost importance for human society. The historical study of its origin adds an essential element to what we might call the biography of humankind; it acquaints us with the fundamental aspect of our nature which consists in the desire not to accept the facts of material nature at face value, but to learn to know and control them, and in the potential for ingenuity, intelligence and stamina which enables us to satisfy this desire.

To acquire this knowledge of humankind, the history of technology is just as important as the history of mathematics and science, and whoever neglects it will fail to gain a complete view of humanity. In writings which elucidate the great dangers of an ongoing technicalization of society, it has become something of a habit to present matters as if technical humanity can do just about anything it might want to at the moment. Our engineers stop at nothing, we read. In reality, of course, they stop at a great many things. How little do the authors who write in such a way and who have perhaps never seen the inside of a laboratory, know of the long and painful struggle against the recalcitrance of matter which has to be fought time and again in order to achieve the technical and economical realization of a science-based idea. How little do they understand particularly the specific ethos of technical work, which is not determined by the motive of the material profit the pursued invention may yield, but only by the same desire to control nature that is the driving force of science and that is in essence allied to the need to investigate the earth to its greatest heights and greatest depths. Therefore it does not make much difference to a technician whether, from the perspective of his other human qualities, he sees the result he is trying to achieve as a blessing for humanity or as a curse. As a technician he only knows the struggle against matter and in this struggle he represents an essential aspect of human nature.

We should now form a clear idea of the link between these considerations and the aim of our lecture. Mathematics, science and technology are elements of culture; this was the thesis expressed in the title. We have seen that this thesis is unassailable if one starts from a particular definition of culture, and unacceptable if a different one is chosen. Then I dropped the word 'culture' and began to talk about the alienation with regard to the mathematical-physical-technical sciences that we find in so many educated and civilized contemporaries. I have tried to point to the disquieting element in this, and it has turned out to reside in the fact that, if no attention is paid to this aspect of human thought, an essential aspect of humanity is neglected, one which determines the nature of our society to a high degree. This means that I can formulate my title in a different way now: mathematics, science and technology are fundamental expressions of humanity. We can leave it to those who like to quarrel about words whether or not they want to see them as elements of culture.

Let us take care, however, not to be too easily satisfied. Philosophical, word-clad speculation is always in danger of drifting astray. In mathematics and science one runs up against a clear and inescapable contradiction in such a case — in technology, against the realization that something will not work. While talking one can steer clear of a whole lot of contradictions, however, and meanwhile one can keep on thinking that everything is going very well. Let us therefore call upon criticism again. It can come from two sides, the religious and the socio-ethical.

The first criticism takes exception to the overtones of glorification of human reason, human ingenuity and human will that it discerns in the argument. It wonders whether it was diabolical pride that seduced western man to penetrate into the secrets of nature and to take possession of the powers of nature, and whether there are signs that this pride will soon lead to a terrible catastrophe, *gladius Dei super terram, cito et velociter*.<sup>4\*</sup> We have heard this line before. It is evident in the myth of Prometheus in which the arch-technician is punished in a terrible way by the gods for having stolen the heavenly fire and having given it to humans. It is expressed in the Horatian *audax omnia perpeti gens humana ruit per vetitum nefas*,<sup>5\*\*</sup> in Augustine's warning against the *concupiscentia oculorum*,<sup>6\*\*\*</sup> which has also brought forth the scientific urge to know. It is a view which has had a considerable influence in the history of the natural sciences and has been responsible for many conflicts between science and religion. Yet this view is of a classically heathen rather than of an essentially christian nature.

It may be true that technology is a consequence of the Fall, yet the fact remains that the Creator has instructed humanity as follows: "Be fruitful and multiply, and fill the earth and subdue it" (Gen. 1:28). Since this subduing did not appear feasible by way of magic, human ingenuity and human energy had to do it. For Jews and Christians, technology is in principle vindicated in this way.

Further, it is a thoroughly Christian notion that nature is a revelation of God and that the study of nature is therefore a Christian duty. It is certainly true that Christians have not always realized this and that religious circles have often — not only in the first centuries of our era when neo-Platonic influences were still at work, but also in later centuries — displayed a hostile attitude towards the investigation of nature. This attitude has however been combated time and again precisely by Christians and one can observe that it has in principle been over-

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\* the sword of God over the earth, rapid and swift

\*\* with a recklessness shrinking from nothing, humankind, heedless of the gods, plunges into all that is forbidden

\*\*\* the cupidity of the eyes

come at present. The Christian view of life in our time leaves room for a straightforwardly positive acceptance, for complete openness regarding its results.

Moreover, the idea that admiration for what the human mind can accomplish would be incompatible with the notion of humans as created beings, can be adequately refuted by referring to the views of Kepler. Since the world is God's *Abbild* and humankind his *Ebenbild*, the ideas that guided God at the creation are reflected in the human mind. The human mind is made to trace the quantitative relations which the Creator has put into his creation, and therefore the study of mathematical physics is a form of divine worship. Thus the high appreciation of the asset which mathematics, science and technology are to the human mind, can be easily reconciled with a Christian world-view.

The socio-ethical criticism strikes a completely different chord. Disquieted by hearing somebody sing the praises of technology and of the sciences that make it possible, it calls him to order. Are you blind with your eyes open, it asks; don't you see the fatal consequences of technology for humankind and don't you fear the even more fatal ones that threaten us? Has not technology brought forth the mass human, who unthinkingly plays with the toys it has put at his disposal and who has become insatiable in his desires like a spoilt child? Has it not banalized our lives, enthroned entertainment, estranged humanity from nature, impoverished our emotional life? And, now that Prometheus has stolen fire from the gods once again, does it not enable humankind to commit outrages which may destroy the whole culture of which it forms part? Can something be an element of culture and a threat to culture at the same time?

Nothing would be easier than to have this requisitory go on and on; likewise, nothing would be easier than to counter it with a long defence in which the endless array of benefactions which the natural sciences and technology have bestowed on humanity, and from which the critics also gratefully benefit, would be recounted. Yet neither of these courses contributes to the investigation in which we are involved, which is primarily about the intrinsic spiritual value of these sciences, and only secondarily about its practical value. One should not confound the categories.

Naturally — it should be superfluous to say this, but one can never arm oneself sufficiently against misunderstanding — naturally this view of the matter does not in the least imply an underestimation of the enormous problems with which science and technology in their modern development confront us, problems which should already have been evident to our nineteenth-century predecessors if they had focused less one-sidedly on the advantages and had not been preoccupied exclusively with utility and power. It was not my task to talk about this, however. My assignment was of a more encouraging nature, and that is why I have accepted it gladly. At present it is no longer superfluous to say anything

positive about science and technology again. Little by little matters have gone so far that faces cloud over and the tone of conversation is muted if these words are mentioned. Joy and satisfaction are considered symptoms of an incomprehensible superficiality, consciousness of sin is accepted as the only dignified attitude.

This situation induces me to recall a line of Pascal. Speaking of humankind and its capabilities he says:

*S'il se vante, je l'abaisse; s'il s'abaisse, je le vante; et je le contredis toujours jusqu'a ce qu'il comprenne qu'il est un monstre incomprehensible.*<sup>7\*</sup>

Where mathematics, science and technology are concerned, we are in a period of abasement; I believe I have acted in Pascal's spirit by countering this with a word of admiration.

Is it not remarkable and significant that I can refer to Pascal, of all people, in this discussion, which as we saw might evoke criticism because of the element of hominism, of glorification of humankind that one may find in it — Pascal, whom nobody will want to accuse of overestimating the value of human things? And it definitely does not stop at the quotation I have just given. I wish to recall two fragments dealing with the 'thinking reed':

*L'homme n'est qu'un roseau, le plus faible de la nature; mais c'est un roseau pensant. Il ne faut pas que l'univers entier s'arme pour l'écraser: une vapeur, une goutte d'eau suffit pour le tuer. Mais, quand l'univers l'écraserait, l'homme serait encore plus noble que ce qui le tue, parce qu'il sait qu'il meurt et l'avantage que l'univers a sur lui; l'univers n'en sait rien.*

*Toute notre dignité consiste donc en la pensée. C'est de là qu'il faut nous reveler et non de l'espace et de la durée, que nous ne saurions remplir. Travaillons donc à bien penser: voilà le pricipie de la morale.*<sup>\*\*</sup>

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\* If he praises himself, I shall abase him; if he abases himself, I shall praise him; I shall continue to contradict him, until he finally understands that he is an incomprehensible monster.

\*\* Man is just a reed, the weakest of nature; but he is a thinking reed. There is no need for the entire universe to arm itself in order to crush him; a vapour, a drop of water suffices to kill him. Yet when the universe would crush him, man would still be more noble than that which killed him, because he knows that he dies and what advantage the universe has over him; the universe knows nothing of this.

All our dignity thus consists in our thinking. From here we should uplift ourselves, and not from space or from time, which we cannot fill anyway. So let us try hard to think well: this is the principle of morality.

And somewhat further on:

Par l'espace l'univers me comprend et m'engloutit comme un point; par la pensée, je le comprend.<sup>8\*</sup>

Perhaps I could have achieved the goal I set myself in this lecture better by remaining silent and merely urging you to meditate on the thoughts of Pascal.

Finally there is the practical question of whether all we have said gives rise to concrete conclusions and recommendations. I shall name three:

1 The differentiation into separate fields of study in pre-university education should be avoided as much as possible. The more specialized the sciences become and the higher the requirements in each separate field in secondary education, the less need there is to anticipate this specialization in pre-university education. It would be better to aim at general cultural education. In so far as differentiation is deemed inevitable, one should ameliorate its customary ill effects by trying hard to keep in touch with, and cultivate the appreciation of the fields that are discarded or no longer of central interest.

2 In secondary education, the methodological differences between the fields of knowledge should not be stressed to such a degree that the awareness of the fundamental unity in mental attitude of all scientific workers suffers from it; it should definitely not become a matter of prestige.

3 Neither the pleasure which technology can give nor the fear it can inspire should ever make one forget the purely spiritual value of the mathematical, scientific and technological accomplishments which make its progress possible.

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\* Through space the universe contains and devours me like a point; through thought, I contain it.

## NOTES

1. This article is a rewritten version of a lecture held for the Sociëteit voor Culturele Samenwerking (Society for Cultural Cooperation) in The Hague on 3 January 1955. The subject I was requested to cover at several points necessitated the repetition of views that had already been advanced and published earlier. The reader may thus excuse the fact that now and again observations turn up which can also be found in the articles "Grensverschuivingen in de Orbis Scientiarum," *Faraday* 21 (7), 1952 pp. 3-21; "Historische wording en actuele situatie van de universiteit," *Het Gemenebest*, July-August 1954, pp. 11-34, and "De wetenschap in het leven van mens en maatschappij," *De Gids* 117, 1954, II, pp. 100-121.
2. Curiously, the connection of the members of the nature-spirit pair with those of culture-civilization is sometimes made in exactly the reverse way. From a *Zandloper*-article in the *NRC* (a column in a daily newspaper, BT) I take the remark that the French essayist André Suarès contrasts culture with civilization as the free spirit against necessity-bound nature, as value against utility, and — with a chauvinism typical of French authors, for which they are always forgiven so much more easily than Germans are for their analogous exaggerations — as a spiritual France against a Germany which can only thrive materially.
3. Descartes, *Les principes de la philosophie*, Oeuvres, IX b 14.
4. Thomas Mann, *Gladius dei in Tristan*.
5. *Oden*, I 3.
6. *Confessiones*, X 35.
7. *Pensées*, ed. Brunschvicg Fr. 420.
8. *Ibid.*, Fr. 347, 348.