PASCAL: HIS SCIENCE AND HIS RELIGION

R. Hooykaas

[*Translator's note:* The following article was written exactly half a century ago. We are proud to open our section 'Dutch Classics' with a piece that exemplifies the thought of one of the Grand Old Men of Dutch historiography of science. Reyer Hooykaas (born 1906) studied chemistry at the University of Utrecht. He taught himself the history of science through writing his doctoral dissertation on *Het begrip element in zijn historisch-wijsgerige ontwikkeling* ('The concept of element in its historical and philosophical development', 1933). He has since published a great many articles and books on such remarkably varied topics in the history of science as: science and religion; iatrochemistry; atomic theory; crystallography; uniformitarianism in geology; science and letters in Portugal at the time of the Voyages of Discovery; goals and methods of the historiography of science, and many others.

In 1945 Hooykaas was appointed to the first chair of the history of science to be created in the Netherlands, at the Free University of Amsterdam. In 1967 he became Professor in the History of Science at the University of Utrecht. He retired in 1976.

On the occasion of his retirement a collection entitled *Capita Selecta uit het werk van Prof. dr. R. Hooykaas* (Utrecht, 1976) came out, which contains a bibliography of his work up to that date. In 1983 the University of Coimbra published a collection of articles by Hooykaas (in English, German, and French) under the title *Selected Studies in History of Science* (663 pages).

The present article appeared in 1939 on pages 147-178 of the *Orgaan van de Christelijke Vereeniging van Natuur- en Geneeskundigen in Nederland* ('Journal of the Union of Protestant Physicists and Physicians in the Netherlands'; reproduced in the 1976 *Capita Selecta*). An English translation came out in 1952, on pages 106-137 of the *Free University Quarterly* (vol. 2). Here I have retranslated the entire piece, with the quotations being translated directly from Pascal's original language. (For passages from the *Pensées* Krailsheimer's beautiful translation in the *Penguin Classics* has been an ongoing source of inspiration and, here and there, emulation. I also wish to thank Hilary Marland for a final check-up of the entire text.)

This new version of the original 1939 article has been fully authorized by Professor Hooykaas, who also made a few alterations to his text first written fifty years ago. In due course this article will find a complement in the final chapter "The Thinking Reed" of a book Professor Hooykaas is completing at present (a reworked edition of the Gifford Lectures he gave some time ago). In addition to a brief summary of points made in the present article, the reader will find in that chapter extended discussions of such topics as: the nature of the 'heart'; the historicity of the

Tractrix 1, 1989, pp. 115-139.

gospel; dogmatism vs. scepticism; Pascal as an historian of science, and Pascal's character and literary style.

We feel that the present article may convey a sense of the singular passion familiar to all those who have had the privilege to attend Professor Hooykaas' lectures, whether in public or in private. Few topics have evoked his passion as an historian of science so tangibly as Pascal – not his favorite character in the history of science, but surely the one to express what Hooykaas holds to be key insights into the nature of science. These we wish to enable our readers to share. We are naturally aware that the text is not as recent as it once was. Yet we believe that the present publication may serve a dual purpose. It provides one more illustration of what depths of insight were within reach of those men and women who in decades before the history of science became a profession taught themselves how to go about such research in a truly historical fashion. We also believe that the present study brings to light insights into Pascal's thought that are fully worth pondering today.

H. Floris Cohen]

Il faut relever le courage de ces timides qui n'osent rien inventer en physique, et confondre l'insolence de ces téméraires qui produisent des nouveautés en théologie.
("We must lift up the courage of those timids who dare not invent anything new in physics, and confound the insolence of those who, in their rashness, produce novelties in theology."
Pascal, *Préface pour le Traité du Vide.*)

Introduction

The aim of the present study is to demonstrate that Pascal's scientific and his religious thought form one unified whole. He himself (1623-1662) kept the two apart with deliberate rigor, and much more systematically so than was customary in his time. Yet Pascal's science more than that of any of his contemporaries may be called 'Christian'. He is modest in what he wants his science to accomplish, and his awareness that mathematics and physics are just human activities stands in the way of any exaggerated expectations – these very traits of his are Christian. The same thing is revealed in a more positive sense too, when we juxtapose, in both his scientific and his religious thought, his realism; his submission to the factual; his qualified appreciation of Reason. It appears finally from his ability – unlike other great, Christian investigators of nature – to liberate himself from the pagan philosophers, Plato, Aristotle, Democritus. The greatest influence exerted upon him was Holy Scripture, together with those whom he regarded as its true interpreters

– Saint Augustine and bishop Jansenius.[1]

Pascal has remained 'modern'. We may apply to his own work what he demands of that of others: in reading it we do not meet a scholar in the first place – we find a man (fr. 29; see note 3). This is why, in what follows, we frequently let him speak in his own words. Yet even in so doing much effort is required to do him justice. He himself observed of his 'Apology' that, even though the contents were not new, the arrangement was (fr. 22). One and the same subject matter may produce a different, unintended effect through tendentious arrangement and selection, and this has also been the fate of Pascal's work. There is, for example, a sceptical Pascal, who despite himself clings to a religion he has really outgrown, just as there is an ultra-montanist Pascal, whose anti-Jesuitism is accidental rather than essential, and is in any case due only to sectarian influences.[2]

Pascal's thought, however, is catholic in the full meaning of the word. It makes no sense to accuse him of inconsistencies and to extract from his writings a purified Pascal. He is like the great source from which he draws his knowledge – Scripture, too, presents no system. As a result, every system-lover may find in it something he can employ for his own purposes, even though the whole is of course distorted thereby. The realism of the Bible penetrated Pascal's heart and soul. This is why he dislikes rectilinear modes of thought, projecting as they do only one or another aspect of truth. Full truth can be apprehended only by approaching her from all sides. Thus Pascal makes no attempt to produce an all-encompassing science, nor a closed philosophical system that explains everything, let alone a theology devoid of mysteries. Reason is justly employed if, and only if, she acknowledges that, ultimately, reality is accepted rather than comprehended.

Physics

Experience

The important question occupying Pascal in physics is that of the 'horror vacui'. According to the scholastic view no vacuum can exist, since nature 'abhors the void'. When we seem to perceive empty space, fine-grained matter is in fact still present. Descartes too, who put space and matter on a par, could not allow a vacuum. When Torricelli published his celebrated experiment, Descartes assumed that a so-called 'subtle matter' entered and left the wall of the glass tube and filled Torricellian space. Both with the scholastics and with Descartes it was chiefly objections of a theoretical nature that made them oppose the 'vacuists', that is to say, the adherents of the atomic doctrine, such as Gassendi.

In all this arguing hither and thither Pascal (and Roberval with him) adopts a

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[1] In his *Augustinus*, Jansenius (1585-1639; bishop of Ypres) presented a compilation of everything St. Augustine had written on grace, so as to combat the Pelagian errors that re-entered the church through the Jesuits (Molina). Jansenius contrasts a theology conceived as an historical science (knowledge of Scripture, the councils, and the Church fathers) to a theology that relies upon man-made, philosophical argument.

[2] Here is what Brunschvicg has to say about such a commentator: "[he] makes a subtle and quite touching effort to discharge Pascal of the crime of being corrupted by the doctrine or even the spirit of Jansenism" (*Pensées*, Tome I, p. xxxvii).

position of his own, since for him the resolution of this dispute cannot be made through rational argument, but only through experiments. "In physics experiments have greater powers of persuasion than reasoning has" (III, 199).[3] For him physics is above all an empirical science. "Let all disciples of Aristotle assemble all that is powerful in their Master's writings, and in those of his commentators, so as to account for these things by means of the abhorrence of the void, if they can. But if they cannot, let them acknowledge that experiments are the true Masters to be followed in physics" (III, 266).

Now several medieval scholars, and Descartes, too, insisted emphatically that experience is decisive. But with them one observes time and again how preconceived opinions obscure the pure interpretation of experience. Pascal, on the contrary, sticks to his empirical stance, and on occasion not even the severest positivist might improve upon him.

According to Pascal, all substances have weight, and the *weight* of the air is what causes the liquid in Torricelli's tube to ascend. But, so the scholastics object, elementary, never-yet-isolated, pure air is light, whereas ordinary air is heavy only because of the vapours and coarse matter that contaminate it. To which Pascal responds "that I do not know such pure air, which might well be hard to find. I speak only ... of air such as it is in the state in which we breathe it, without considering whether it is compounded or not. And it is this body, whether simple or compounded, that I call the air, and of which I say that it has undeniably weight" (III, 194). This recalls Lavoisier's definition of an element, a century and a half later. Lavoisier called a substance simple whenever he could not analyze it further; whether or not it was truly an element had to be left undecided. Lavoisier made somewhat more fuss about his positive method, though, and did not stick to it so strictly. Boyle, praised so often, was impeded by scepticism and atomism, and thus confined himself to noting that what we call simple and uncompounded need not be so. His own requirement to define only absolute elements lured him away from the question of what the elements are. Pascal was certainly no less critical, yet he did not allow the issue of an absolute vacuum to lure him away from his experimental basis. As far as he is concerned, an absolute vacuum may or may not exist, since this lies outside the domain of empirical checking. "By this word 'void' I always mean space void of all bodies that fall under the senses," he says (III, 255). Later as well as earlier panegyrists of empirical, positive method (e.g., Francis Bacon), sinned more against the facts than Pascal, who spoke about the method with greater modesty.

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[3] Quotations are taken from *Oeuvres de Pascal*, publ. par L. Brunschvicg *et al.* (Paris, 1914; 2me éd. 1923). The works and letters cited in the present study are the following:

- Expériences nouvelles touchant le vide (1647). Tome II, pp. 53-77.
- Réponse de Blaise Pascal au père Noël S.J. (19 oct. 1647). Tome II, pp. 77-127.
- Fragment de préface sur le Traité du Vide (oct.-nov. 1647). Tome II, pp. 127-145.
- Lettre a M. le Pailleur au sujet du P. Noël S.J. (févr.-mars 1648). Tome II, pp. 177-211.
- Traités de d'Equilibre des Liqueurs et de la pesanteur de la masse de l'air (1654). Tome III, pp. 143-266.
- Dix-huitième Provinciale (au Père Annat S.J. 24 mars 1657). Tome VII, pp. 3-57.
- De l'esprit géométrique (1658-1659). Tome IX, pp. 229-270.
- De l'art de persuader. Tome IX, pp. 270-290.
- Lettre de Pascal à Fermat (25 juillet 1660). Tome X, pp. 4-6.
- Pensées (Tomes I-III; Paris, 1904). Not quoted according to page numbers, but to the fragments ('fr.').

Reasoning

It would be wrong to infer from the above that Pascal eliminates all reasoning from physics while confining himself to descriptions devoid of 'causes'. If that were the case, one could not talk of science proper. When it is useful he introduces a center of gravity, even though he deems this just as unreal as the astronomers' constructions with circles.

For him, air pressure is the true *cause* of the liquid ascending the barometer tube. He proved this by means of experiments with a variety of fluids. Heavy liquids ascend less than light ones, and the same liquid ascends less on a mountain than in the plane, because the air exerts less pressure. The last-mentioned experiment in particular – the observation made in 1648 upon the Puy de Dôme – is decisive for him, for it gives "perfect knowledge" of these phenomena. "This experiment has revealed that water ascends in pumps up to quite different heights, which vary with place and time, but always so in proportion to the weight of the air ... as an effect is proportional to its cause" (III, 265). The experiment shows that the weight of the air is the "true cause" of all phenomena that, up to then, had been ascribed to the imaginary cause of the 'horror vacui' – an insight, he writes, "that is never more to perish" (III, 266). Here Pascal shows great daring, and rightly so, because he is extraordinarily cautious in drawing his conclusions and in asserting nothing that does not stand on a solid foundation of factual data. And yet we see here how, for him, description does not exclude causal explanation.

On one hand, therefore, Pascal accords to the use of reasoning the place it deserves, whereas, on the other, he insists that it must stick to the requirements of strict logic. Not one term is employed by him without sharp definition. In his polemic against the Jesuit father Noël on the void, he reproaches the latter for employing the very thing defined in his definitions, for instance, when Noël asserts that "light is a luminary motion of rays composed of lucid, that is to say, luminous bodies"! (II, 100).

Reasoning by analogy

In 1663 Pascal published two pieces together (written around 1654), "Traité de l'Équilibre des Liqueurs" and "Traité de la Pesanteur de la Masse d'Air" (III, 194), which are masterpieces of logic. They look much alike one another, since analogical reasoning is employed throughout. The leading idea is that the mass of air, which through its weight is in equilibrium with a column of liquid, may be considered to be fully analogous to a mass of liquid in equilibrium with another liquid. Thus gases are conceived of as subtle fluids. It is true of all bodies that they have weight and that the laws of gravity are independent of the medium. Thus hydrostatics and pneumatics are intimately connected.

Once one has become aware of the consequences of the pressure exerted by a liquid, one is aware of the same in the case of gas pressure, for the two are "fully similar" (III, 206). "We have already seen [all effects of the weight of air] originating, as it were, in the preceding Treatise, since all these effects are nothing but particular cases of the general rule of the Equilibrium of Liquids" (III, 225). Thus every successive part of the argument in the second treatise begins something like this: "In order to explain how the weight of the air causes [a given phenomenon] I shall show

a similar [phenomenon] caused by the weight of water, which serves to make the reason of it perfectly plain" (III, 206).

A pair of bellows, sealed with cork, is hard to open in the air 'because of the horror vacui', the scholastics say. But experiment shows that a pair of bellows under water, with the end of the tube emerging above the water, is also hard to open – a phenomenon that, quite similarly, should be ascribed to a 'horror of the air'. From this consequence, however, the opponents appear to shrink back.

For Pascal, one important objection lies in the term 'horror vacui' itself. It allows us to transfer freely all sorts of personal sentiments to nature. Doing so provides us with handy, ready-made explanations; however, because nature neither feels nor lives we must avoid such expressions (cf. fr. 72).

Hypotheses

Pascal's attitude towards hypotheses follows from the above. He takes them seriously only if they lend themselves to experimental checking. So it is with the issue of the void. "Having demonstrated that none of those substances which fall under the senses and of which we possess any knowledge fill the apparent vacuum, my opinion, for so long as no one shows to me the existence of such a substance filling it, is that space is truly a vacuum, and devoid of all matter" (II, 73). As he explains later in a letter to Le Pailleur, he does not say "in decisive terms" that there is a vacuum, but only that he shall take any space as void until the presence of matter has been demonstrated (II, 183).

Unlike Descartes, Pascal does not deem space identical with matter. Both have three dimensions, but in addition to this a body is also mobile and impenetrable. Thus empty space stands half-way between body and nothing (II, 104). This assertion goes back to the 1647 letter to Noël, that is to say, to the very period of his life that it is still customary to call 'Cartesian'.[4] Descartes was aware, though, that not only scholasticism, but also his own theory was being attacked. Concerning Pascal's *Nouvelles expériences touchant le vide*, Descartes writes to Mersenne on 13 December, 1647: "It seems that he wants to combat my subtle matter" (II, 165). One of the purposes of this booklet was to meet the objection "that a substance which is imperceptible, unheard-of, and unknown to any of the senses, fills [Torricellian] space" (II, 75). When Noël responds that there is no physicist who assumes such a thing, Pascal answers: "[The assumption] is one of the most celebrated of our time, [and its author] posits for the entire universe a univeral matter, which is imperceptible and unheard-of, made of the same substance as heaven and the elements" (II, 105). This is an obvious allusion to Descartes' celestial matter.

Pascal strongly rejects rash hypotheses, even when these are not evidently erroneous. "It is not a very hard thing to explain how an effect may be produced by supposing the matter, the nature, and the qualities of its cause ... This is particularly

[4] Curiously, the work of Pascal's to which a Cartesian influence might most readily be ascribed ("De l'esprit géométrique") was written *after* the so-called definitive conversion of 1654. From beginning to end Pascal's attitude towards Cartesianism is one of opposition. This did not stand in the way of his adopting some of Descartes' thoughts, such as the place of fundamental concepts in mathematics; the coherence of the universe; the animal as a machine. In Pascal's handling, however, these thoughts acquire a scope and meaning of their own.

true when these have been adjusted so well that, from the figments that have been supposed, already evident truths are with necessity inferred" (II, 98). "If that mode of proof is accepted, it will not be hard to resolve the greatest difficulties. Both the attraction of the magnet and the tides of the sea will become easy to comprehend if it is allowed to make substances and qualities at will" (II, 96). Such fluids fail indeed to add anything new to the observed fact itself. Nothing is involved here but superfluous words, invoked to cover up our ignorance of the cause of a given phenomenon. "The imagination," Pascal says, "has the peculiarity that it produces, with equal expenditure of effort and time, both the greatest things and small ones" (II, 96).

Now the 'plenists' say: Please, demonstrate to us that this subtle matter does not exist. Pascal answers: Demonstrate that it does exist. All these types of matter have been invented just for the occasion, and "one cannot believe in them all alike without turning nature into a monster" (II, 97).

Even if all known phenomena are deducible from a given hypothesis, one still lacks full certainty – no more than 'probability' has been attained at best. Hypotheses are posited in order to find the cause of a phenomenon. Now there are three possible cases. If the negation of the hypothesis yields an absurdity, the hypothesis is true and lasting. If the confirmation of the hypothesis yields folly, the hypothesis is false. If neither the negation, nor the confirmation is absurd, the hypothesis is dubious. "For making an hypothesis evident it is not enough that all phenomena follow from it, whereas, if something follows from it that runs counter to even one of the phenomena this suffices for ensuring that it is false" (II, 99). He goes on to show that in most cases we are faced with the third case. One and the same phenomenon may have different causes, for example, a hot brick may have been exposed to fire or to the sun.

Thus he thinks that in man-made argument about the motion of the Earth and about the retrogression of the planetary orbits everything follows *perfectly* from the hypotheses of Ptolemy, of Tycho, and of Copernicus, even though not all three can be true. "But," he exclaims, "who would dare strike such a grave decision ... without the risk of erring ...?" (II, 100). He never went any deeper into this particular problem – he had no great interest in astronomy.

Kepler had granted that the three astronomical systems are on a par 'in genere', but that 'in specie' Copernicus' system explained more than the others.[5] Pascal's caution is understandable, since no conclusive experimental proof for Copernicus had been given, and because Kepler's motives are not fully compelling. Kepler's conclusions from astronomical observation are not founded upon a purely empirical basis, and this is why Pascal does not dare to make such a "grave decision" – he wishes to assert only things that are 'true and lasting'. Therefore he says in the *Pensées*: "I would prefer not to go too deeply into Copernicus' opinion" (fr. 218). No fear of Rome is expressed here. Remarkably, he gives no 'philosophical' or theological argument at all for his refusal to make a choice.

Here, once more, Pascal directly opposes Descartes. The latter had proclaimed the well-known medieval view that there are three hypotheses by means of which the astronomers explain all phenomena, without examining whether they correspond to

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[5] See R. Hooykaas, "Het Hypothesebegrip van Kepler" ('Kepler's Conception of Hypotheses'), *Orgaan van de Christelijke Vereeniging van Natuur- en Geneeskundigen in Nederland*, 1939, pp. 38-59; never translated.

truth (*Principia Philosophiae*, III, 15). Maybe a given hypothesis is far away from the truth, yet much has already been done when all that follows from it corresponds with observation (*Principia*, III, 44). And when, at heart, Descartes prefers Copernicus, he manages to find a clever way out in order to remain in conformity to the decree of the Inquisition.

How entirely different is Pascal's reaction! The lack of empirical data that allow for a decision prevents him from making a choice, but fear has nothing to do with this. Papal bulls too may be mistaken (VII, 53). And he tells the Jesuits: "It was in vain for you to obtain that Roman decree against Galileo, in which his opinion regarding the motion of the earth is condemned. It is not that decree that shall prove the earth to be at rest, and if there were observations that would prove that it is the earth that revolves, all men together would not prevent it from revolving, or would prevent themselves from revolving with it" (VII, 54).

Remarkably, in astronomical matters Pascal does not opt for the customary way out, that an hypothesis need not express reality because it is no more than an auxiliary construction facilitating calculation. He requires truth of an hypothesis, but the conditions it has to satisfy are so severe that they are almost never satisfied. A given hypothesis must correspond to all phenomena, and since these can never be known, we can never point to a true hypothesis with full certainty. One always risks its failure when faced with new phenomena. Secondly, its *negation* must yield an absurdity – it would not be easy to invent such an hypothesis, though!

It may seem now as if reason, rather than experience, is made the judge in physical matters after all. Does this fit Pascal's empiricism? Yes, it does, because, firstly, reason, operating thus in the empirical world, is not Descartes' theoretical reason with its innate ideas – it is a critical reason, which is nothing but the capacity to judge things correctly. Secondly, Pascal does not turn his position upside down by saying that conformity to reason is a sufficient motive for ascribing truth to an hypothesis. More than one plausible cause can be attributed to an effect. Science cannot be deductive. Correspondence with all phenomena known at present does no more than make an hypothesis probable. Strictly speaking, an inductive science leaves room only for probable hypotheses. One example of this would be provided by the astronomical systems of the world. Subtle matter cannot properly be allowed into the domain of probable hypotheses, however, since experience suggests rather of the void (in the empirical sense!). Moreover, such matter is in any case no more than a chimera.

Induction

His very awareness of what inductive science in essence is about makes Pascal cautious. "In all things for which proof consists of experiments rather than of arguments ('demonstrations') no universal assertion can be made but through the general enumeration of all parts or of all different cases. This is how, when we say that diamond is the hardest of all bodies, we mean by this all those bodies of which we have knowledge" (II, 144). "[Nature], even though always equal to herself, is not always equally well known. The experiments which render her intelligible become continually more numerous ..." (II, 136).

His empiricism notwithstanding, he conceives of nature as an entity that exists

by itself and that obeys laws. Our knowledge of those laws increases all the time, with true science as an ultimate aim never attained yet ever more closely approximated. This perennial incompleteness of science does not, however, lead him to sceptical resignation – he pursues scientific knowledge to the extent that it can be had, not refraining from making statements about it, as we have already seen in the cases of the 'void' and of the 'air'.

Descartes believed that empirical science is deductive, just like mathematics. This is why he thought that, after him, science might still expand in width, but not in depth. Pascal is more modest. His very insight into the inductive nature of science makes his historical judgment mild. Lavoisier, that great man of positive chemistry, blamed his predecessors for having supposed more than they could prove. Here, in contrast, is Pascal's, much milder judgment: "[The ancients] lacked luck in experiment rather than force of reasoning ... Did they not have good reason to say that all corruptible bodies are enclosed in the sublunar sphere, since in the course of so many centuries they had never yet observed corruption or generation taking place outside that space? But must we not ascertain the contrary, now that the entire earth has seen with its own eyes how comets enflame and vanish far beyond that sphere?" (II, 141-2). "On the topic of the void they were right in saying that nature does not bear it ...; [in so judging] they did not mean to speak of nature other than in the state of which they bore knowledge ... If the novel experiments had been known to them they might well have found fit to affirm what they did find fit to deny because the void had not yet made its appearance ... Thus, without contradicting [the ancients], we may ascertain the contrary of what they said" (II, 143-4). No need to argue any further that here we hear *Pascal's* rather than the ancients' ideas! Yet we can also see that he might have made a great historian of science, with his lack of condescension towards his forebears and with his sympathetic understanding of their work and thought.

Authority

In Pascal's physics experience is number one, with abstract argument following as the second in rank – authority, on the contrary, is not granted any place whatsoever in science. In physical matters solely argument and experience are admitted to the demonstration – the invocation of authority is useless here (II, 132-4). "Whatever power antiquity has, truth, however recently discovered, always takes precedence, because she is always more ancient than all opinions men have had about her – we misjudge the nature of truth when we imagine that she began at the time when she began to become known" (II, 145).

Nature exists independently of the opinions humans may form of her, and this is why, in matters scientific, Pascal not only opposes the authority of antiquity but also that of clerical dignitaries. Their pronunciations cannot alter established facts. This applies to science as well as to those scholarly disciplines in which what a given writer has written is the key thing. One may in principle arrive at full knowledge of the latter category – the possibility of adding anything to them is ruled out from the start (II, 131).

The factual content of writings that serve as sources may not be falsified any more than scientific fact. When Pascal has shown the Jesuits how foolish it is to

establish by decree that the Earth stands still, he continues as follows: "You see therefore, Father, what the nature of factual things is, [and it follows] that, if those five propositions are not in Jansenius' [works], it is impossible to extract them therefrom" (VII, 55).[6]

Mathematics

The historical and theological sciences are founded upon authority or upon completed sources, Pascal maintains, thus contrasting them with mathematics and physics – the sciences which become known through Reason (with a possible basis in experience). The latter are subject to further extension, and authority plays no role (II, 131-2). In empirical science the role of Reason is secondary, whereas in mathematics it dominates absolutely. Whatever unreservedly positive Pascal has to say about Reason is said in connection with mathematics, which he calls 'géométrie'. Not only geometry proper, but arithmetic and mechanics too, fall under his concept of 'géométrie'.

Pascal's discussion of definitions already makes clear the difference between mathematics and physics. Definitions are made in order to give things names, not to indicate their natures. Definitions-of-things already assert something – "they are [really] propositions, not at all free, but subject to contradiction." Geometry, however, works only with definitions-of-name, which are "truly free" (IX, 253). This is why "geometry is almost the only one among man's sciences to produce infallible [demonstrations] ... whereas all the others, out of a necessity of nature, are in some sort of confusion" (IX, 242-5). Here the difference between mathematics and empirical science is demarcated with singular precision – the advantage of mathematics is its liberty to define, as it were, the rules of the game, whereas in empirical science the human mind is confronted with a datum that is not of its own making. Thus mathematics may safely embark on its deductive course and provide authentic proofs. Empirical science lacks this ability, since it provides proofs solely through experiment and, therefore, lacks full logical transparency. Roberval, with whom Pascal was closely connected, says that mathematics is superior to physics "because it has what physics also has in that it is true, immobile, and invincible, but in addition it is not so hidden to man" (II, 50).

The best method to find the truth, Pascal says, is therefore the method of geometry. However, it is not yet the ideal method! He goes on to picture what that method would be like: "This true method ... would be to define all terms and to prove all propositions." But such a method can never be carried through, for "what transcends geometry is beyond us" ("ce qui passe la géometrie, nous surpasse"; IX, 242-245).

To define and to prove everything is "absolutely impossible," according to Pascal, since the fundamental concepts upon which human reasoning is erected are inexplicable. "Hence man finds himself in a state of natural and everlasting impotence to handle any science whatsoever in an absolutely perfect fashion" (IX, 246).

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[6] These were five theological propositions, which Pascal and the followers of 'Port-Royal' denied Jansenius to have taught. Pascal considers 'Jansenism' as a Jesuit construction enabling the latter, through a subtle reversal of roles, to accuse 'Augustine's disciples' of heresy.

Mathematics comes closest, even though it cannot prove its axioms (II, 91) and cannot define its principal objects (IX, 249). The latter must, therefore, be presupposed, and yet, Pascal maintains, mathematics is "perfectly veritable," since it presupposes nothing that is not "clear" and established by "natural light" (IX, 246).

Let us now follow Pascal in his reflections on the undefinable objects of time, motion (in mechanics), number (in arithmetic), and space (in geometry). Of these, mathematics gives no definitions-of-things (which are really theorems), but only definitions-of-name, which are entirely free. Any attempt undertaken despite this to define fundamental concepts would produce darkness rather than light. One inevitably lapses into the folly of defining a word with the very same word, as in definitions of Being (Being *is* ...), or in Noël's definition of light. 'Nature', however, accommodates the existence of undefinable things in providing man with an idea of the same object that he has when employing the name, so that without more words a clearer understanding is achieved than could be accomplished by any explanation. Thus the simple objects of mathematics are self-evident in a way that lacks the persuasion of proof (for there is nothing for Reason to comprehend), yet is no less certain for that. Everything mathematics represents to us is, therefore, perfectly certain, either through 'natural light' or through proofs (IX, 254).

The axioms are established, in Pascal's view, by 'natural light'. They are *certain* when they impose themselves upon the mind so clearly that it *cannot* doubt them, for example, when equal things are added to other equal things their sums are also equal. When things are made to follow by proofs ('démonstrations') reached through compelling logic they are also certain, for example, the three angles of a triangle equal two right angles. All other theorems are uncertain (II, 91). Therefore, physical theorems too lack complete certainty (insofar as they are not regarded by Pascal as direct, factual data). Maybe mathematical axioms, which are necessary, 'natural' foundations, provide an example of what he takes for a true hypothesis. If he had shared Kepler's mathematical speculations, he might have been more favorably inclined toward the idea that in physics too there are 'true hypotheses'![7]

In mathematics Pascal grants Reason an important place. Yet this exceedingly logical science ultimately reaches its limits in that it must face undefinable basic concepts. Reason does not enter until these have been established: "Principles are sensed, whereas propositions are concluded" (fr. 282). Reason is at first enthroned by him, but ultimately 'nature' sustains her (cf. IX, 246: "nature sustaining her when understanding fails").

Pascal's favorite illustration of these insights is by means of the infinite. According to him, the natural clarity of the infinitely large and the infinitely small has more persuasive force than a lengthy discourse. Because we cannot *imagine* infinite divisibility we easily take it as impossible. But man tends to deny the incomprehensible (IX, 259). However, "everything that is incomprehensible does not cease to exist," Pascal says in his *Pensées* when discussing infinite number (fr. 430). Even in his most rationalist mood he eventually reveals his empiricism and realism.[8]

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[7] Hooykaas (n. 5), p. 50.

[8] Undeniably, "De l'esprit géométrique" largely matches Descartes' conception of the foundations of mathematics. However, Pascal's 'natural light' is not sovereign, and here he is closer to Augustine than to Cartesius. Outside the realm of pure mathematics the difference becomes particularly manifest, since Pascal acknowledges mathematical certainty only within the mathematical domain. I disagree,

The art of persuasion must follow geometrical method, because "outside of [geometrical] science and of what imitates it there are no true demonstrations" (IX, 287). Geometrical truths are "quite natural and within our reach" (IX, 228). These terms by no means imply, however, that all such truths are comprehensible or transparent. They imply only that we have been created in such a way as to be incapable of resisting these truths. The soul receives these geometric rules (both proofs and axioms) through 'esprit' and 'coeur': the 'mind' accepts the proofs, just as the 'heart' (immediate intuitive knowledge, that is) accepts the principles.

It may now seem as if Pascal, in positing the 'heart' as the ultimate source of knowledge, really opts for a foundation in 'feeling' rather than in Reason. Yet he is fully aware that sentiments, which blossom out from our rich imagination, do not belong to science: "Men often take their imagination for their heart" (fr. 275). Add to this man's depraved will: "in an all too ordinary experience, the imperious soul, while boasting to act only with reason, follows in a shameful and rash choice what the corrupted will desires, whatever resistance the overly enlightened mind may oppose to this" (IX, 275). And he goes on to say that "outside of geometry ... there are almost no truths on which we always remain in agreement" (IX, 277). Hence the method of the art of persuasion must be geometric; it should employ nothing but fully self-evident axioms.

Remarkably, Pascal does not suppose that man's depraved will may falsify the 'natural' principles of mathematics as well. Mathematics is the only realm where the 'heart' functions properly. Leibniz, whose general opinion of human nature is far more optimistic, says that if man had an interest in falsifying the foundations of mathematics he would do so. For the rest, Leibniz's confidence in Reason is greater than Pascal's, and his interpretation of the argument of the infinite is the very opposite. For him, our acceptance of the infinite on rational grounds leads to its subjection to Reason. In Pascal's view, Reason cannot comprehend the infinite, yet denying the infinite would lead to absurdity. Thus infinity stands above Reason, whereas to deny it is counter to Reason. In this way, Reason can help us decide between two opposites which, nevertheless, she cannot dominate since they are both beyond her grasp.

The limits of science

The limits of empirical science

It has become clear from the above how much Pascal hated human presumption in science. His aversion to the idea that human Reason were capable of building empirical science *a priori* grew steadily. He observed with anger how the science of his day, whether peripatetic or Cartesian, overstepped the limits set to Reason. His loose notes headed 'vanity of the sciences' (fr. 67) and 'a letter on the folly of man's science' (fr. 74) testify to the plans he had, in his *Apology of the Christian Religion*, to speak his mind on the false pretensions of fake science. The philosophers (which term includes the physicists, as was customary in his day) with their love of system go

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therefore, with various points in Cassirer's treatment (in *Das Erkenntnisproblem*) of Pascal and Descartes.

on making theses and antitheses, thus "resembling those who make blind windows for the sake of symmetry" (fr. 27). They believe they can explain everything, and they are never at a loss for an answer, yet what do they really know, for all their fine systems, of the soul, or, if that is too lofty an aim, of matter? "What have they learned about it, those great dogmatists who know everything?" (fr. 73). In his *Traité de l'Equilibre des Liqueurs* he recounts how the makers of pumps already knew for a long time that water cannot be pumped up to any height, that is to say, that the so-called abhorrence of the void does not begin to operate until a certain limit has been reached. And he continues with the scornful outcry: "Simple Artisans were capable of pronouncing guilty of error all those great men whom we call Philosophers" (III, 263). Their smart-aleck, know-all philosopy deserves nothing but derision: "To mock philosophy, that is true philosophizing" (fr. 4).

Aversion to Descartes' system seems prominent in Pascal's thought, and he shares it with his friend, Roberval. For him Descartes was an exemplary, really abhorrent case of how far Reason can go in nimbly providing plausible yet untestable explanations of everything, finding for each hole a nail. Pascal's niece, Marguérite Périer, says that "he could not suffer this way of explaining the formation of all things, and he said quite often: 'I cannot forgive Descartes, for in his entire philosophy he would gladly have been able to do without God'" (fr. 77; *Pensées*, I, 98).

Descartes, in his *Principia Philosophiae*, had explained the genesis of all things in great detail by means of the mechanical philosophy. In general terms, Pascal is willing to accept mechanicism as a principle of explanation. However, he is soberly aware that the time for filling in details had not yet come: "Descartes. – One must say at large: 'These things happen through their shapes and their motions'; for that is true. But to say which ones, and to construct the machinery – that is ridiculous, because it is useless and uncertain and awkward" (fr. 79). Yet this was precisely what Descartes did. For example, in explaining magnetism he assumed the existence of particles of such a shape and motion that magnetic phenomena can be made to follow from them. However, and this is true of each set of phenomena, no testing of the hypothesis was possible.

Pascal blames Noël for excogitating substances with properties neatly devised in such a way as to lead to truths that had already been evident beforehand. Thus ebb and flood, but also magnetism, can easily be 'explained'. These objections to Noël are meant as a side-attack on Descartes as well (see II, 96, 98). According to Menjot (1689), Pascal qualified Descartes' system as a "Romance of Nature" (*Pensées*, I, 97), and Descartes himself as a 'Doctor of Reason'.

Pascal does not reconstruct the genesis of the world, subsequently going on to believe in the figments of his own imagination. His sole aim is to observe the world as it is *now*, and to establish as many laws of the world's operations as he can. For him natural science is inductive and empirical, and that is why we should not try to get too much out of it. ("To write against those who go too deeply into science"; fr. 76). The inductive nature of science implies that its domain, as opposed to that of theology, widens steadily. As a result, the human mind will always regard the investigation of nature as a task not yet fulfilled. Nature in its infinite riches grants us no repose. The human mind "will sooner tire of conceiving than nature of furnishing" (fr. 72).

Since we do not know the 'whole', building a comprehensive system leads nowhere. And this is the more true as we go back in time, so finding less and less

data. "How many stars which, before, did not exist for our philosophers has the telescope revealed to us! They freely took Scripture to task over its great number of stars, saying: 'There are only 1022 of them, we know it [i.e., from Ptolemy's catalogue]'. – There are herbs on earth, and we see them. – From the moon we would not see them. – And there are hairs on those herbs, and in those hairs little animals; but beyond that, nothing. – Oh, presumptuous men! – The compounds are made up of elements, but not so the elements. – Oh, presumptuous men; there is a subtle point! – We must not say that there is what we do not see. – Thus we must speak like the others, but not think like them" (fr. 266).

So it is possible that there exist many more things than we have observed. But this should not lead us into making definite assertions about those unknown things (fr. 260). Pascal's standpoint is this: as long as I cannot demonstrate that something does exist, I assume that it does not. This is not of course very satisfactory, for we do not like to acknowledge our impotence. But not all hope for the future is cut off thereby, because the perfection of mathematics, physics, and medicine increases with time and with our efforts on their behalf (II, 131-132). The point is that Pascal prefers to have no explanation rather than one that is premature. All those matters for magnetism, light, and so on, are nothing but a refuge for our ignorance.

Experience testifies to the existence of the void. But, so it is exclaimed, I cannot *comprehend* how something can be devoid of matter! This, then, is the true and proper root of the hypothesitis from which both scholastics and Cartesians suffer. *Reason* cannot bear to be incapable of fully penetrating nature. Therefore she attempts, before the proper time has come, to build a system – inevitably, such a system rests on rational rather than on experimental arguments. Reason, in her pride, cannot bear the existence of data she cannot comprehend, and that is how she arrives at such silly definitions as 'light is a motion of luminous matter'. "The nature of light is unknown," Pascal says; "of all those who have tried to define it, not one has satisfied any of those who seek tangible [that is to say, experimentally verifiable] truths." He speaks about "what little knowledge we have about the nature of these things" (II, 93-94).

In Pascal's time it was asserted that the elements (water, air) have no weight in their proper place, although outside it they have. Here we meet one more example of man's curious method of covering up his ignorance: "Because man could not comprehend why we do not sense the weight of water, yet was unwilling to admit so much, he rather said that it has no weight [in its proper place], so as to satisfy his vanity by the ruin of truth" (III, 260). To be sure, it is much more interesting to comprehend everything. But the very first thing to do is to accept experimental data, even though they are incomprehensible. What is incomprehensible does not cease to exist: this is Pascal's root conviction.

The limits of mathematics

In mathematics too, Pascal sticks to his bottom line that we must accept the incomprehensible. The treatment of the infinite in "De l'esprit géométrique" is a case in point: "[Certain individuals] could not possibly conceive an infinitely divisible content, from which they conclude that it is not infinitely divisible. It is a natural illness of man to believe that he is in direct possession of the truth. This is why he is always

disposed to deny all that is incomprehensible to him, whereas in fact his natural knowledge is confined to lies – he should not take anything for true but those things of which the contrary appears to him false ... [In such a case] he may frankly affirm the original statement, however incomprehensible it is" (IX, 259). Here we are compelled by necessity to replace the proof of truth by the negation of error!

No lapse into irrationalism is occasioned hereby. No, Reason herself must acknowledge that infinite divisibility is just incomprehensible to her, whereas the opposite – finite divisibility – is not only above Reason, but also against Reason. For instance, one might ask "whether two indivisibles touch one another." If they do so everywhere they are identical, but if not they must have parts. The one proposition is quite as incomprehensible as the other, so "let them acknowledge that it is not by our capacity to conceive these things that we must judge upon their truth, since, these two opposite statements being equally inconceivable, it is nevertheless certain by necessity that one of the two is true" (IX, 259-260).

Thus Pascal treats the infinitely large and the infinitely small on a par with inexplicable facts of nature, in that the former, too, are 'natural facts'. "This effect of nature, that before seemed impossible, should make you know that there may be other ones that you do not yet know," he says when discussing a similar topic, and he continues with: "Do not draw from your apprenticeship the conclusion that nothing remains for you to know, but rather that infinitely much remains for you to know" (fr. 231). This is a hard message to be swallowed by the disciples of Descartes and of Aristotle – 'the master of those who *know*'. However far they believe to have advanced in their rational explanation of the world, Pascal relegates them to the school benches ('apprenticeship'!).

The very titles of their works, such as "De omni scibili" ('On all that can be known') or "On the principles of philosophy" (cf. Descartes' *Principia Philosophiae,* 1644) already betray their presumption (fr. 72). The principles are the very things we must simply accept, and too much talk obscures rather than elucidates them. "Our soul is cast into our body, where it finds number, time, dimensions. It reasons upon this, calling it nature, necessity, and cannot believe another thing" (fr. 233). Thus it is with the facts in empirical science as it is with the foundations of mathematics, in that Reason must be silent, whereas the 'heart' testifies to their truth. "We know the truth not only through reason, but also through the heart. It is through the latter that we know first principles, and it is in vain for reason, which takes no part in this, to attempt to combat them" (fr. 282).

Even though these basic principles are incomprehensible, the certainty the heart possesses of them is no less than the certainty provided by reason. As with empirical science, mathematics ultimately must stop, the former before facts that are no less evident for being incomprehensible, the latter before axioms and undefinable objects that are no less incomprehensible for being evident. Thus in mathematics too, Pascal arrives in the end at his proposition that "everything that is incomprehensible does not cease to exist" (fr. 430). This is equally true for him in physics (the void, the propagation of light, magnetism) as it is in mathematics (axioms, the infinite) and in religion (God, the Fall of Man, redemption).

This is why Reason should not fancy that she might encompass the fullness of reality: "We may blow up beyond imaginable spaces our conceptions – we only bring forth atoms, at the expense of the reality of things" (fr. 72). That is to say, if Reason digs too deeply she overshoots her mark, and her results fail to match reality. Pascal

has a very high idea of Reason, and he takes her down only when she demands absolute sovereignty for herself. Three things work together in producing our knowledge: sense experience, reason, and the heart, hence (if for no other reason) Reason cannot be supreme. For Pascal concrete reality is always superior to abstract Reason, just as Being is superior to the understanding we have (or believe we have) of what Is.

Pascal is very early in defending the fullness of reality against the method of scientific abstraction whenever science, in overstepping the limits set to it, takes the entire world as being subjected to it, brushing aside as unimportant whatever fails obligingly to comply. Such erroneous usage of scientific method, that had started with Descartes, reached its zenith in the 19th century. Pascal, on the contrary, reinstates immediate experience and understanding to their lawful place at the side of a purely intellectual, abstracted conception of the world.

Natural religion

During his final years Pascal confined his interest exclusively to spiritual life. He regarded physics as useless, and mathematics too – even though previously his favorite – was finally abandoned as well. In August, 1660 he writes to Fermat that geometry, although "the highest exercise of the mind," seems to him so devoid of use that he would not walk two paces on its behalf. True, some two years previously the field had still occupied him, but there was a very special reason for that and now that it has been satisfied he is unlikely ever to devote his thoughts to mathematics again (X, 4). The special reason that resulted in his final work in mathematics was that it gave him occasion to show the world that his 'conversion' had not rendered him scientifically impotent – the submission of the intellect does not entail a decrease of intellect.

Henceforth the purpose of his life was directed entirely towards inner religion. His only remaining task in the outer world was, so he decided, to write a defense of Christian belief. By this means, he wished to call back on its way toward Christ a human race that had estranged its innermost self from God and sought its salvation in formalist religious observance or in libertinism. It is customary to take this 'second conversion' for a wholesale transformation of Pascal's mode of thought. I think rather that the emphasis had indeed shifted, yet what he had had to say on empirical science, mathematics, and religion at a previous stage by no means contradicts the *Pensées*. The difference is that in this work the expression of his 'Thoughts' is not made to serve a scientific purpose. His appreciation of science changed quantitatively rather than in a qualitative sense.

Nature and man

When we consider Pascal's scientific writing in close connection with the *Pensées* it is striking that, although a strict believer, he fails to do what many investigators of nature of less strictly orthodox views have been doing up to the present day – to search in science for powerful pointers towards the Creator. Only in "De l'esprit

géométrique" does he allude to the two infinities in between which we find ourselves placed, saying that these may teach us a just appreciation of ourselves, inspiring us towards meditations worth far more than all there is further to mathematics (IX, 270).

In his *Pensées,* Pascal assesses what natural science, and natural knowledge in general ('connaissances naturelles'), may teach man. These, he asserts, point to God, but only in an *indirect* manner. If even these very sciences were not true, there would be no truth in man at all, but if they are, this should inspire humiliation (fr. 72).

He shows us that all our knowledge is partial and incomplete. As compared to the infinity of things that are to be known our knowledge is as nil, just as the longest duration does not carry us one step closer to eternity. "Before entering into grandiose researches of nature, let [man] sit down for once and consider her in earnest, and let him look at himself as well ..." (fr. 72). At once he reaches out for his favorite example – infinity overwhelms man and stuns the mind. The earth is just a point in our solar system, which in its turn is a point in the universe, insofar as we can observe it at all. But when observation comes to a standstill, thought goes on. Nature, however, reaches much farther than even our boldest imagination, which "will sooner tire of conceiving than nature of furnishing." Here is another miracle: the smallest insect has legs, with veins, through which blood flows, filled with humors, made up of drops, and so on. The smallest thing we can imagine is once again a chasm, maybe a new solar system. Our body is nothing as compared to the universe, but in respect of the infinitely small it is itself a universe. Thus we are suspended between two chasms, the infinite and nothingness. Whoever has made himself thoroughly aware of this will tremble in face of these miracles, and "I believe that, as his curiosity changes into admiration, he will be disposed rather to contemplate them in silence than examine them with presumption."

"What then is he to do, if not to perceive some appearance of the middle of things, in an eternal despair of knowing either their beginning or their end? ... Failing to contemplate these infinities, man has rashly given himself to the investigation of nature, as if he has any proportion to her. It is an odd thing that he has wished to comprehend the principles of things and to arrive from there at the knowledge of everything, inspired by a presumption as infinite as his object" (fr. 72). Apparently, Pascal is thinking here once more of deductive science with its delusion that, through Reason, we know the principles of nature and that, with these as our starting-point, we may comprehend all phenomena. He clearly opposes his own, inductive conception of science to this: "All the sciences are infinite in the range of their researches," he says, and this includes mathematics, too. But then this very state of things must indeed render it impossible to arrive at complete knowledge: When we consider ourselves, "our intellect occupies the same rank in the order of intelligible things as our body in the whole range of nature" (fr. 72). Therefore, the infinitely large or the all, as well as the infinitely small or nothingness, lie beyond our horizon.

Whenever we lay one foundation this demands another foundation: "Whatever fixed point we believe we may cling to staggers and leaves us; and when we follow it, it eludes our grasp, slips away, and flees eternally before us ... This is the state that is natural to us, and yet it is the most contrary to our inclinations – we burn from desire to find a firm footing, an ultimate, lasting base on which to build a tower rising up to infinity, but our whole foundation cracks and the earth opens up into the depth of the abyss." This is a beautiful picture of man's eternal search for full,

integral understanding; his urge to penetrate as it were into the essence of things; the search for the philosopher's stone – a search that, time and again, seemed 'almost' fulfilled, yet ultimately gave way to a sobering awareness that the horizon had been pursued.

Pascal regards the philosophers' urge as a godless presumption: "The author of these wonders understands them; no one else can ... Once we know better, we understand that, since nature has engraved her own image and that of her author on all things, they almost all share her double infinity." Here, then, is one cause, in Pascal's opinion, of why it is impossible fully to comprehend nature.

Now man, compelled to acknowledge that the *whole* is outside of his reach, might yet be ambitious enough to want to know at least those parts with which he is 'in proportion'. It is not hard to predict Pascal's response. Because our knowledge of nature is inductive, the possibility remains open of surprising, novel ideas which, in their turn, may alter in retrospect our conception of things already known. Therefore, the growth of science in width, which is one of Pascal's favorite notions, entails a growth in depth as well. This implies that, as long as the 'whole' remains unknown, we cannot, strictly speaking, know the 'part' either. Thus Pascal's response is: "The parts of the world are all so related and linked together that I think it is impossible to know one without the other and without the whole."

In addition to this, things are simple, whereas man is compounded of two opposite natures, soul and body. "Instead of receiving ideas of these things in their purity, we color them with our qualities and stamp our own composite being on all the simple things we contemplate ... [Thus] nearly all philosophers ... speak spiritually of corporal things and corporally of spiritual ones, for they boldly assert that bodies tend to fall, that they aspire towards their center, that they flee from destruction, that they fear a void, that they have inclinations, sympathies, antipathies, all of which pertains only to things spiritual. And when they speak of minds and souls, they consider these as being in a place, and attribute to them movement from one place to another, which are things pertaining only to bodies ... Yet this is the thing we understand least: man is to himself the greatest prodigy in nature, for he cannot conceive what body is, and still less what mind is, and least of all how a body can be joined to a mind. This is his supreme difficulty, and yet it is his very being" (fr. 72).

"This would undoubtedly suffice if Reason were reasonable. She is reasonable enough to confess that she has not yet found anything firm, but she has not yet given up hope of achieving it. She is as ardent as ever in this search, and she feels assured that she carries in herself the forces that are necessary for such a conquest" (fr. 73). These man-made systems, for which there is nothing that they do not know, will not grant God a place without great reluctance and hesitation. And this is why Pascal cannot forgive Descartes: "In his whole philosophy he would have liked to do without God; but he could not help allowing Him a snap of the fingers to set the world in motion; after that he had no more use for God" (fr. 77).

The contemplation of nature should serve to rob 'dogmatic' man of his certainty about himself. If his will, in its wrongheadedness, did not resist, his awareness of emptiness, his loss of a false self-assurance, might turn him towards God. This is how science 'indirectly' points towards God, through its very limitation and impotence!

Now Pascal deems man's arrogance and his proud will more powerful than the persuasion carried by Pascal's argument. If God's grace does not curb the will, no more than hesitant, reserved acceptance is to ensue at best – coming down, as a

rule, to a posture of optimism ('we have not quite reached the goal yet'). It is true: the builders of the Tower of Babylon are not easily discouraged. With almost touching zeal they build a new system on the ruins of its predecessor.

God and Nature

Does not nature also point towards God in a *straightforward* and more positive sense? Here is a source of great concern, for "I look around everywhere, and I do not find anything but obscurity – nature offers me nothing but occasion for doubt and unrest," Pascal says when introducing man in his search for God. "If I saw no sign there of a Divinity, I would confine myself to the negative; if I saw signs of a Creator everywhere, I would repose at peace in the belief in Him. But, seeing too much for denial and too little for assurance, I am in a lamentable state, where I have wished a hundred times over that, if a God sustains nature, she should mark this unequivocally, and that, if the signs in nature are deceptive, she should fully suppress them" (fr. 229). Apparently Pascal sympathizes with this unbeliever, in whom he acknowledges the honest agnostic. But now enter the believers, and when these address the unbeliever "their first chapter is to prove the Divinity from the works of nature" (fr. 242). "I admire the boldness of these persons when they undertake to speak of God," he says. "I would not be surprised at their enterprise if they were addressing their discourse to the believers, for those with living faith in their hearts can certainly see at once that everything which exists is entirely the work of the God they worship. But for those in whom this light has gone out and in whom we are trying to rekindle it, people deprived of faith and grace, examining with such light as they have everything they see in nature that might lead them to this knowledge, but finding only obscurity and darkness; to tell them, I say, that they have only to look at the least thing around them and they will see in it God plainly revealed; to give them no other proof of this great and weighty matter than the course of the moon and the planets; to claim to have completed the proof with such an argument; this is giving them cause to think that the proofs of our religion are indeed feeble, and reason and experience alike tell me that nothing serves better to make them despise it" (fr. 242).

"'But do you not say yourself that the sky and the birds prove God?' – 'No'. 'And does your religion not say so?' – 'No, for ... it is true [only] for certain souls to whom God gives this light'" (fr. 244). "If the world existed in order to instruct man about God, his divinity would shine forth on all parts in an incontestable manner ... What does appear marks neither total exclusion nor a manifest presence of divinity, but the presence of a God who hides himself" (fr. 556; cf. fr. 194; fr. 242). Thus in Pascal's view proofs of God's existence from nature or from natural science are *uncertain*.

They are *useless* as well. "If a man were persuaded that the proportions of numbers are immaterial, eternal truths, depending upon a primary truth in which they subsist and which is called God, I should not consider him advanced very far towards his salvation" (fr. 556). Pascal deems Deism, whose God is "simply the author of geometrical truths and of the order of the elements" (fr. 556) to be almost as far removed from true religion as atheism.

Deist man admires his own Reason in what he is good enough to regard as the creation of the Highest Reason. Mathematics and empirical science, if conceived well

and if aiming to be truly reasonable, dethrone Reason, though: "The final step of Reason is to acknowledge that an infinity of things surpass her" (fr. 267). Empirical science achieves this through an awareness of its ineluctable incompleteness, whereas mathematics accomplishes the same through the acknowledgement that its axioms and basic objects are irreducible.

"If the things of nature surpass her, what are we to say of those things that are above nature," Pascal asks (fr. 267). If Reason is incapable of accounting fully for empirical science and mathematics, how could a reasonable 'natural' religion pass muster? Reason itself, together with experience, taught Pascal that science and mathematics must drop many pretensions when facing incomprehensible reality. Reason itself, together with experience, led him towards a preference for the agnostics (not for dogmatic atheists!) over the adherents to a religion founded upon human Reason.

True religion

True religion on man

Pascal's realism, so obvious in his mathematics and his physics, is equally striking when he talks about religion. He demands the same thing of science as he demands of religion – not that it be entirely rational, nor that it be entirely irrational, but rather that it accept reality as it is, rather than obscuring reality by means of figments of its own making.

Religion speaks about God and about man – about the Creator and about creation. Man is not in a position to 'prove' whether what is being said about God is right. Insofar as one can speak here of 'proof' at all, the only fitting proof is through 'negation'. Pascal employs this in cases when a given thing does exist yet goes beyond our understanding (cf. fr. 230), such as the infinite in mathematics, and also infinite God.

When considered from the side of man, true religion must satisfy two requirements. One is the acknowledgement that God is 'hidden' (see fr. 585); the other, knowledge of human nature (fr. 442; fr. 433: "for a religion to be true it must have known our nature").

Now Pascal paints human nature in its typical ambiguity; Reason in its impotence and limitation on the one hand, its greatness on the other – it is, after all, Reason itself that is capable of realizing its own impotence. Man is only a speck in the universe, but he surpasses the universe in that he knows that he exists. He is abject, but he is great because he knows it (fr. 416). In short, he is made up of contradictions, "glory and dregs of the universe" (fr. 434), "an incomprehensible monster" (fr. 420).

Other questions assail him: Why do I live here, in the very infinity of space? Why do I live now, in the very infinity of time? Whence do I come, and whither am I going? (fr. 194, 205, 206, 693). In this lies the liberty of sovereign man; this is what is called 'casting off the shackles'! Pascal scornfully exclaims. When the answers of philosophers and theologians pass critical muster with him, they appear to be vacuous, because Reason herself disavows them. Only "pyrrhonism is true" (fr. 432), and solely the despondent agnostic might be right, if there were not something inside

us that signals to us that there *is* truth, even though we do not know her. For when Reason has driven us into scepticism in face of the solutions offered by false Reason, the time has come for the Heart to claim its dues. When we examine our true state by means of natural Reason, Pascal says, we arrive either at the dogmatic philosophers, or at the pyrrhonists (the sceptics). But "Nature [that is to say, that which is innate in us] confounds the pyrrhonists, and Reason confounds the dogmatists" (fr. 434). The dogmatists violate reality and get entangled in contradictions, whereas the pyrrhonists fail, despite their loud protestations to the contrary, to extinguish the weak sparklet of original light that has remained in their heart. "We have an incapacity for proof which no amount of dogmatism can overcome. We have an idea of truth which no amount of pyrrhonism can overcome" (fr. 395). Knowing with certainty is equally impossible for us as 'absolute not-knowing'. "All these contradictions, which seemed to remove me more than anything from the knowledge of any religion, are the very thing that has guided me most readily towards the true religion," Pascal now goes on to say (fr. 424). For, manifest as these contradictions are, there is only one religion that accounts for the origin of man's dual nature – of both his abjectness and his greatness. This religion is the Christian one, for it is the only religion that knows our true nature.

All men pursue happiness, and both our desire and our impotence to fulfill it cry out to us that previously there has been true happiness in man, of which nothing but empty vestiges remain. God is the good that has been lost, yet man seeks to fill the gap with everything except God – one with authority, another with science, a third with pleasure (fr. 425). All solutions the philosophers offer, however, are unsatisfactory, because they fail to dicover the cause, and, therefore, do not know the remedy, of our impotence to attain the true good.

Therefore we must listen to Divine Wisdom, which tells us that we were created good and perfect, full of light and intellect. Once we beheld God's majesty. But man could not bear his bliss. He claimed to be independent, on a par with God. That is why God let go of him, and now he is left with no more than the vaguest awareness of his Creator; with an impotent intuition of the happiness of his first nature, while abjectness and blindness and desire have become his second nature (fr. 430). In the Fall of Man Pascal finds the cause of all contradictions and of all our dissatisfaction – here is the cornerstone of Pascal's theology.

True religion on God

The second characteristic of true religion is its acknowledgement that God is a hidden God: "Any religion that does not say that God is hidden is untrue" (fr. 585).

In this too, Christian religion is in keeping with reality. Pascal makes no effort to 'prove' God metaphysically, whether from nature or by means of his natural intellect. Because God has hidden himself to man, there is nothing that points to Him with certainty, yet turning this into a reproach at Christian religion is to blame the Church for a view shared with its opponents, Pascal says (fr. 194). Here he may have been too optimistic – there have surely been Roman Catholic theologians who expressed themselves otherwise. But Pascal was one of those who abhor 'novelties' in theology and who try, inside the walls of the Roman Catholic Church, to follow the line of Holy Scripture and of Saint Augustine. When speaking of 'the' Church, he

always means those in the Church who are faithful to orthodox doctrine. For him, Pelagians and semi-pelagians, with all their loud-mouthed talk, do not speak on behalf of the Church! Against these men he appeals to Holy Scripture.

"Scripture ... says ... that God is a hidden God and that, because of the corruption of nature, he has left [man] in a state of blindness from which he can escape only through Jesus Christ, without whom all communication with God is taken away" (fr. 242). "No canonical author has ever used nature to prove God," he says: "David, Solomon, etc., never said 'there is no void, therefore there is a God'" (fr. 243). This is an allusion to a statement made by Hugo de Groot (Grotius), in which it is said that the functional arrangement of the universe – expressed, for example, in the abhorrence of the void – points to God (*Pensées*, II, 178).[9]

True religion is founded on revelation

Christian religion reveals, not only the cause of our estrangement from God, but also the path toward restoration. Here too, natural religion is powerless. Because of sin hardly a dim light of his Creator has been left to man (fr. 430). God became man so as to become one with us. We see how, in Incarnation, God comes to us, because we are incapable of coming to Him. In Christ twilight is restored to the full light of day: "All those who seek God without Jesus Christ, confining themselves to nature ... find no light whatsoever that satisfies them" (fr. 556).

'But', so the objection runs, 'it is incredible that God might become one with us'. This is the ultimate pretext of man in his unwillingness to see that there is only humble acceptance in face of God's revelation. At first he resisted openly, in an impious manner, and now he does the same, though piously and in apparent defense of God's honor. For, so he reasons, it is sacrilegious to assert that God, the Unfathomable, the Infinite, the Sublime, has become one with us through Jesus of Nazareth! Pascal saw through piety of this sort, though. Intolerable presumption, so he thinks, lies hidden behind such seemingly humble reasoning. "What entitles this animal, so well aware of his own weakness ... to keep God's mercy within limits suggested by his own fancy?" (fr. 430).

This is the essence of Revelation – it must either be accepted wholly or rejected wholly. If it is the word and act of God, it is above the critique of Reason. Man-made religion is not really religion in the sense of service to God, and the true choice is between revelation and agnosticism.

Just as empirical science rests on real facts, whether or not these can be rationally interpreted, just so true religion, in Pascal's view, is founded upon facts (Fall of Man, redemption), even though these go beyond our intellect. The 'historical' nature of Christianity is an established fact for Pascal. This is why he attaches great value to the prophecies of the Old Testament. The true God is not the chimerical God of the philosophers – this figment of the human intellect – nor the author of geometrical truths. Rather He is the God of Jesus Christ, who reveals Himself in the history of salvation and enters into a personal relationship with man. "God of Abraham, of Isaac, of Jacob, not of the philosophers" (Mémorial).

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[9] The answer to the question of whether Pascal acknowledges a 'natural theology' depends on one's understanding of the term. One might answer 'no' when confronted with many Catholics or Latitudinarians, whereas 'yes' is the proper response to dialectical theology.

Revelation has not been created by the human mind, therefore one is neither allowed to subtract from it nor to add to it. Hence his opposition to the Jesuits and their followers. These men introduce 'novelties' in ethics and in theology, thus rendering Christ's cross vain through their sophistry and their opposition to the authority of Scripture. But in the very domain where the intellect is entitled to speak out, in physics, the same men oppose progress with an appeal to authority! He attacks this radically wrong attitude in his *Traité du Vide* (1647). "In theology ... authority ... is inseparable from truth," he says. Things that are fully incomprehensible to Reason have perfect certainty when they are in Holy Scripture, whose "principles are above Nature and Reason." Because of this, and because "man's mind is too weak to arrive there through its own effort, [man] can arrive at this lofty insight only if he is carried there by an all-powerful and supernatural force. It is not the same with subjects that fall under the senses or under reasoning. Here authority is useless, and only Reason is in a position to know them ... Since subjects of this type have a proportion to the scope of the mind, here is where the mind finds full liberty to expand" (II, 131-2). Therefore, we "lament the blindness of those who, instead of reasoning or experiments, bring forward nothing but authority by way of proof in physical matters ... and [we] shrink back in horror from the malice of others, who, instead of the authority of Scripture and of the Fathers, employ nothing but reasoning in theology" (II, 133). With these assertions, Pascal takes the side of Jansenius who, in his *Augustinus* (Tome II, Liber prooemialis), had pointed out that heretics are in the habit of seeking support in philosophical reasoning rather than in Holy Scripture and in the Church Fathers. Their efforts to elucidate the mysteries of the faith by means of argument serve only to introduce errors of pagan origin.

Reason, the Heart, and Faith

What respective parts do Reason and the Heart take in faith? The two cardinal facts of the Fall of Man and of redemption are as real as they are incomprehensible. Pascal does not think that whatever had previously been beyond the intellect to fathom is now elucidated by Christian revelation. Reason might well find occasion in this to elevate itself once more (fr. 581). If the intellect is being employed wisely, though, it must acknowledge that there is more that pleads for Christian faith than against it, so that it cannot recommend not to follow faith.

Pascal does not consider the 'proofs' for Christian faith "absolutely convincing" (fr. 564). This is why, for him, the 'divine truths' do not fall under the 'art of persuasion'. Things divine are exalted beyond measure above nature, and God alone can place these things in the heart in a manner that pleases *Him* ("De l'art de persuader," IX, 271).

Might it be with these things as it is with the foundations of mathematics? Does our heart perhaps testify to the right foundations of religion? After all, Pascal does affirm that "it is the heart which senses God, and not Reason ... Faith is God sensed by the heart, not by Reason" (fr. 278). Thus here once more the Heart serves as the source of our knowledge.

But how, then, is it possible for Pascal to exclude faith from the 'art of persuasion', which, after all, is mathematical in its method? The reason for this lies in the depravity of the Heart. It may function well in mathematics (since it finds no

advantage in pursuing the wrong way), but, because of sin, it has no more than a 'confused light of its author' – its religious sentiments are vague. It feels more certain of the axioms of mathematics than of good and evil: "Outside of geometry ... there are almost no truths on which we always remain in agreement" (IX, 277). Left to itself, the Heart leads us into error. The Heart does not acknowledge true religion as cordially as it acknowledges mathematics, and God's grace is needed to convert it and lead the will in another direction (cf. fr. 581 and IX, 273).

Thus there is a climax. "We know ... the existence and the nature of the finite, because we too are finite and extended. We know the existence of the infinite and do not know its nature, because it is extended as we are, but not with our limits. But we know neither the existence nor the nature of God, because he has neither extension nor limits. However, through faith we know his existence, through glory we shall know his nature. Now I have already shown that one may well know the existence of a thing without knowing its nature" (fr. 233).

'Natural light' may not, therefore, grant us perfect certainty of God's *existence*, but faith does. Yet it is not even accorded to the believer to penetrate into the secrets of God's *essence* – for him too, God remains "infinitely incomprehensible" (fr. 233).

Belief is of a higher order than theoretical knowledge. Yet, although faith is not simply reasonable, it does not for that exclude Reason from its domain. "Two excesses: to exclude reason, to admit nothing but reason" (fr. 253). The final step Reason can make is to grant that an infinity of things of nature are beyond her – how much more so are the things above nature beyond her! (fr. 267). Reason itself rejects 'dogmatism', that is to say, man's rational religions; the Heart rejects pyrrhonism, which desires to be 'neutral'; God's grace changes the Heart so as to make it *desirous* of receiving revelation. Even though salvation cannot be obtained through Reason, but only through God's grace, Reason may nevertheless serve to combat its own errors and thus to subject itself. Pascal says, with Augustine: "Reason would never submit unless she judged that there are occasions when she ought to submit" (fr. 270). Reason finds the fitting occasion for this in religion: "We reserve for the mysteries of the faith, which have been revealed by the Holy Ghost itself, the submission of the intellect that carries our creed to mysteries hidden to Reason and the senses" (II, 92).

This is how Reason may be of help to Pascal in writing an apology of Christianity – the very religion that humiliates Reason most. The aim of the apology is no more than to take away the obstacles facing the intellect and thus prepare the field for the seed sown by the Spirit. In his vindication of the Christian religion Pascal combated with great passion the false pretenses of Reason in science and philosophy and religion. He did not replace rationalist doubt with rationalist religion, nor did he allow religion to take its refuge in sheer emotion. He was the apologist of revelation.

Conclusion

Pascal is above all a Christian realist.[10] He combats rationalism in empirical science, mathematics, and religion, without lapsing into irrationalism. He does not despise Reason – his scepticism touches only the excessive pretensions of Reason and the presumption of man. He opposes to these an empirical realism: what is incomprehensible to Reason does not therefore cease to *be*. The experimental data of physics, and the foundations of mathematics, must be accepted. Pascal draws this modest posture from a deeply rooted, Christian belief in the reality of creation, however incomprehensible or ill-understood it may be.

His religion stands on the same basis as his science. This does not mean that he borrows direct 'proofs' for faith from science. 'Proofs' *against* faith would not have disturbed him, either. Here too, he is a realist, so his orthodoxy is not due to chance. Religion must know human nature, and it must be founded upon historical fact. It may not rest upon man's words about God, but only upon God's word to man, that is to say, upon revelation.

Distinct as the domains of matter, of intellect, and of the heart are from one another, in all alike Pascal passionately championed reality, however unfathomable reality may be. This is what allows us to speak, in Pascal's case, of Christian science.

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[10] According to certain Roman Catholic authors, Pascal retracted his Jansenism. It is pointed out in support of this that his relations with Port-Royal had cooled off considerably during the final years of his life. Also, the priest who attended him on his death-bed reported that he died at peace with the Church. The estrangement, however, resulted rather from Pascal being a more consistent Jansenist than the Jansenists themselves – he disapproved of their willingness to make concessions. He must also have been displeased with the Cartesian rationalism displayed by certain Jansenists. It stands to reason that, in the face of death, the issue of Jansenism lost much of its importance for Pascal, just as it stands to reason that he agreed completely with the doctrine of the Roman Church, and wished to die at peace with it. The Jansenists in any case never intended to do anything else but defend Roman orthodoxy. There is, therefore, no reason at all to imagine, with J. Chevalier and others, an anti-Jansenist development in Pascal, or to talk of his ultimate recantation. There was nothing to recant, since Jansenism was a construction of the Jesuits. Nor did Pascal ever recant the 'Lettres Provinciales' condemned by Rome. (When studying the pertinent literature, one gains the general impression that a bad conscience about the Jansenists, together with a sense of regret about leaving Pascal to them, drives a number of Roman Catholic authors to take as orthodox in him what they condemn as heretical in Port-Royal).

Pascal was a Jansenist (Augustinian) Roman Catholic. Therefore, the last thing one should do is to attribute to him any sympathy for Protestantism. His ideas on relics and on the sacrament, as well as his retirement from the 'world', remove him far from the Reformation. His philosophy of Scripture, though, is closer to the Reformation, particularly where his unflinching defense of the doctrine of Grace is concerned. Not only Luther and Calvin, but Baius and Jansenius too, display a close affinity to Saint Augustine and to Saint Paul. In one respect – the one that forms the chief topic of the present study – Pascal's ideas are even more biblical than was true of most Protestants of his time. Beza and Melanchthon allotted much room to scholastic philosophy in the Geneva and Wittenberg curricula, and in Pascal's own time the great, Reformed theologian, Voetius, sought the support of Suarez' scholastic philosophy in his fight against Cartesianism. Pascal, on the contrary, was directed by his scriptural point of view to free himself from the burden of the Greek inheritance and to resist Cartesianism. Twentieth century Protestant theology has made attempts to free itself from Platonic or from Cartesian metaphysics. It is not, however, entitled to refer to Pascal if it wishes to substitute for rationalist systems no more than an irrationalist philosophy.

'Of Ships and Stars and Isles'
A socioeconomic approach to scientific navigation

Elly Dekker

Review of: C.A. Davids, *Zeewezen en Wetenschap. De wetenschap en de ontwikkeling van de navigatietechniek in Nederland tussen 1585 en 1815* ('Seafaring and Science. Science and the Development of Navigational Technology in the Netherlands between 1585 and 1815'). With a summary in English (Amsterdam/Dieren: De Bataafse Leeuw, 1985; ISBN 90-6707-113-7), 518 pp., ill.

The problem considered in this book is presented in the introduction as a special case of the more general problem of the acceptance of scientific knowledge outside the scientific community. As such we can only welcome this study. Much has been said about the influence of scientific thought on the socioeconomic scene but little has been done so far to clarify the processes involved. Surely the immediate impact of modern scientific thought, and especially of the intensively debated scientific revolution that took place in the seventeenth century, on the socioeconomic developments was limited. Up to 1750 the progress of technology was still guided by practitioners and their empirical methods. The fact that navigation is considered as a notable exception to this only underlines the interest of the present study. The approach taken by the author to tackle this interesting problem is described by him in the English summary included in the book as follows (p. 378):

> The book consists of three parts, the first of which deals with science. It discusses the concept 'science', explains the hypotheses mentioned above [a number of general assumptions about the acceptance of science], and describes the way these can be tested. The theoretical part is followed by a empirical one, focussing on seafaring. It presents a description, as accurate and complete as possible, of the development of navigation technology in the Netherlands between the end of the sixteenth century and the beginning of the nineteenth. In the third part, theory and 'reality' are juxtaposed. It examines what elements of navigation technology originated from science, how these scientific findings came to be adopted, and to what extent the adoption process can be explained through the factors dealt with in the first part of the book.

This truly is an ambitious programme and one in which historians, sociologists, philosophers and historians of science and technology are offered interesting views on topics which they are usually confronted with from a different angle. I shall try in this review to indicate the respective interest of this book for each of these groups.

What is science? In the justification of the definition of scientific knowledge applied in this book two points are noteworthy. The first is that the author infers from the present general depression in the philosophy of science that it is not possible to distinguish between scientific and other forms of knowledge by the cognitive power of the former. The other point is the Kuhnian emphasis on sociological processes in science. These two elements pave the way to a very practical definition of scientific knowledge which is characterized firstly by the *process* by which the knowledge is obtained and secondly by its recognition by the community of *producers*. The production process must follow an evolutionary scheme based on a specific notion of how empirical research should be carried out, namely from

observation through formulation of hypotheses and deduction (prediction) towards a test. Moreover, knowledge thus obtained should be labelled scientific only when it is acknowledged as such by the practitioners of science. We shall return to this definition later on.

Another essential element of the study is its approach to the investigation of the acceptance of science by the 'users'. Here again the author employs the thesis that intrinsically no distinction can be made between scientific and non-scientific knowledge. Consequently, the sociological theories of T. Valkonen, L.A. Brown and others concerning the acceptance of social or technical innovations should be applicable to scientific knowledge as well. In plain language, the basic characteristics of these theories are that acceptance of an innovation will follow, provided the 'users' are firstly aware of the innovation, secondly willing to accept it and thirdly capable of doing so. Most of the available theories are based on a certain freedom of choice on the part of the 'user'. In complex organizations such as the VOC (Dutch East Indies Company), however, this condition is not necessarily met. Therefore the author also takes into account a number of hypotheses derived from existing theories developed for the adoption of innovations within organizations. Finally, the author considers the existence of a certain privileged position of science in society. Here the sociological theory of J. Ben-David is taken as the starting point for the analysis of this phenomenon.

With the points of departure clearly defined the author subsequently turns to the empirical part: the description of the navigational technology employed by Dutch seamen from 1585 till 1815.

This description is indeed what the author claims: as accurate and complete as possible. It mentions systematically the different techniques within the reach of the navigators, such as the method of dead reckoning, its improvement by cartographical means, the development of the compass and adaptations made to it for measuring the magnetic variation, the instruments applied to measure the latitude and the whole array of solutions proposed during this period for the problem of finding the longitude. For each of these the author investigates how the particular technique came into being, to what extent it was supported in learned circles and to what extent it was actually used by the sailors. An impressive variety of source material is used for this purpose, including probate inventories of seafarers, inventories of ships, log books and travel accounts, records of companies and published contemporary sources on science and navigation. Many of these records are investigated here for the first time and in doing so the author not only adds tremendously to the existing literature on navigation technology in the Netherlands, but at the same time abolishes a number of myths which have dominated it. One such myth is the often quoted conservatism of seamen. As far as I can see the account given here is practically complete. I can think only of three minor aspects of navigation technology that are lacking. One of these is the development of a Dutch version of the mariners astrolabe around 1600 through a shift of its ballast from the bottom to the top of the instrument, probably for the purpose of increased stability against winds. No mention is made of this presumably technological improvement, let alone how it came about. Also absent is a description of the so-called traverse board. In a discussion on the use of logbooks or journals (p. 152) the author notices that only in a few cases mention is made of a journal in the probate inventories, which could mean that the

seafarers involved did not keep a record during their journeys. Yet for the dead reckoning skippers undoubtedly needed some record of their course. The traverse board might have been the means by which the course was recorded. Finally, little or nothing is said of the explorations by Dutch navigators from 1595 till 1602 of the southern celestial sky. These activities were carried out on the initiative of Petrus Plancius and provided for the first time quantitative data of the Southern Cross and more than 100 stars around the south pole. Now, was this knowledge actually used by Dutch navigators? Were for instance the very bright stars Fomalhaut and Achernar mentioned in the journals? Or must we conclude from the fact that they are not mentioned in Davids' book, that this particular piece of scientific knowledge was not applied by Dutch navigators?

Viewed against the bulk of data provided by the author these are minor points. The survey given here has all the characteristics of good scholarship. It will serve many studies and discussions on navigational technology for years to come, irrespective of whether one agrees or disagrees with the subsequent use the author made of it in his book.

The historiographic part of this study described above forms the backbone on which the analysis of the acceptance of scientific knowledge by the Dutch seafaring community given in the third part of the book is based. There we also find the application of the theoretical presuppositions made in the first part.

Before discussing some of the conclusions presented in the third part of the book, I shall first exemplify the use of the definition of scientific knowledge as it is used there. Among the many claims that were put forward to solve the problem of finding the longitude at sea is the method proposed by the Dutch cartographer Petrus Plancius at the turn of the sixteenth century. The principal idea underlying this method was based on the general belief that a relation existed between the longitude and the variation of the compass. In England in particular this idea received much attention. Plancius' method, Davids claims, must be considered as a product of science. Now, it certainly can be considered as a product of the required evolutionary scheme of thought: it started with an observational phase from which an hypothesis was derived which then again was put to the test. But Plancius' ideas never gained the consensus of the scientific community at large. Among the opponents were Blaeu, Metius, and Stevin. Strict application of his own criteria implies therefore that Plancius' method should *not* be called scientific by the author. That it nevertheless is labelled as such is justified by him because of the importance that was attached by Simon Stevin to the variation for navigational purposes. However, in his *Havenfinding* Stevin did plead for a totally different use of the phenomenon: a sailor already knowing his latitude can use the variation of the compass to decide whether he must continue his trip to the West or to the East. Such 'havenfinding' is far removed from Plancius' intention to find the longitude.

The example quoted here elicits a few remarks on Davids' definition of scientific knowledge. One of its good aspects is that the definition is general enough to avoid distinctions between different sorts of scientific activities. Debates on the very truth of nature are of course a different kind of enterprise compared to the efforts to find a solution for the longitude problem. In technology practical considerations often have the upper hand. The question as to whether the Earth itself is rotating or not is not so vital to navigational technology as it is to astronomy. The so-

called timekeepers method is based on an empirical relation between the time difference at places of different longitudes which can be explained equally well by a geocentric as by a heliocentric world picture. The difference in goal should not, I think, be decisive in the definition of scientific knowledge. In the present case it is clear that Plancius was not in the first place trying to explain the geomagnetic field. Yet by exploring the variation of the compass on a global level and by making a daring hypothesis on its global distribution, Plancius contributed to the early development of the theory of geomagnetism in a way that truly can be said to be scientific. The very fact that contemporaries such as Blaeu, Metius and Stevin did not agree with the applicability of his results should not change this conclusion. Why not? In my opinion one should not stretch the Kuhnian emphasis on the sociology of science too far. Originally, the consensus among a particular group of scientists on a 'pattern of values' is introduced by Kuhn as a criterion for the normal practice of science. Recognition by scientists becomes only a valuable rule once a notable 'pattern of values' is established. The criterion is not particularly relevant when *changes* in the so-called 'patterns of values' are to be described. During such changes controversy rather than consensus characterizes the opinions held by the practitioners of science. The criterion used here, that only knowledge accepted as scientific by a group of practitioners of science can be labelled as 'scientific' does not do justice to the fact that in periods of change or, what in my opinion is comparable, in periods of reconnaissance of a new field, no clear pattern of values is recognized. This certainly applies to the efforts made at the end of the sixteenth century in research on the magnetic variation of the compass. The fact that no consensus existed on the global distribution of this variation should certainly not exclude it as a veritable product of science. Therefore, I do agree with Davids' conclusion on this point, albeit for different reasons.

Another example of the consequences of the definition of science concerns navigational instruments such as the cross staff, the mariners astrolabe, the sextant, etc., many of which are termed scientific by Davids. The use of instruments in science itself depended very much on the branch concerned. In the seventeenth century they became a crucial tool of natural philosophy and it is through this development some historians argue that the truly scientific instrument came into being only in the second half of the seventeenth century. Such instruments – for example the telescope and the microscope – are generally distinguished from the already existing class of mathematical instruments such as the astrolabe and the quadrant. These latter instruments were used in astronomy and surveying and many of these also found application in navigation (after appropriate adaptation). Although not employed as an investigative tool like the first class of instruments mentioned above, I think that we may call them scientific. The basic elements employed in their construction are derived from the science of mathematics. However, such a cognitive approach is not recognized in Davids' study. The recognition that these mathematical instruments are products of scientific knowledge is justified by Davids because instruments such as the astrolabe and the cross staff had already for centuries been part of the traditional equipment of astronomers and described as such by scientists. In contrast, the conversion of the cross staff in 1660 by the Dutchman Joost van Breen into the so-called 'mirror bow' is labelled as non-scientific. It appears that it was not exhaustively described by scientists at the time mainly because after 1630 the orientation of scientists on practical matters disappeared (p. 373). This questionable classification

demonstrates clearly that in the absence of cognitive criteria the Kuhnian emphasis on the sociology of science results in a notion of scientific knowledge that more than anything else reflects the trends in the scientist's inclination to show an interest in technological problems. The octant, a navigational instrument that like the 'mirror bow' uses the principle of the reflection of light in order to increase the accuracy of the measurement of the angles between distant objects, was invented at a time when scientists renewed their interest in the development of instruments. Indeed, it was amply discussed by members of the Royal Society and Davids subsequently classifies it as a scientific product.

The examples described here illustrate the kind of problems I have encountered in reading the book. Yet, apart from a few exceptions I can go along with the conclusions obtained by applying the particular definition of scientific knowledge used, but often for reasons quite different from those advanced by the author. This, I think, may be taken as an indication that in practice reasonable consensus exists on what scientific navigation is really about, which in turn implies that a sufficient basis is present to attack the final problem of the book, which is the actual acceptance of scientific knowledge by the Dutch seafaring community.

Before testing the applicability of the sociological theories to the historical observations made in the book, the decision-making process on matters of scientific navigation is investigated on its voluntary character. It appears that in some branches of shipping, notably in the Asia trade and in the Dutch Navy, during the period concerned, a transition took place from free to involuntary decision-making. The demands imposed by the examination systems proved to be especially instrumental in this respect. In addition the regulations prescribed by for instance the VOC became more severe and left less to be decided by the navigators themselves.

The process of the adoption of scientific knowledge on a voluntary basis is studied from the supply- as well as from the demand-side. The sociological theory of T. Valkonen, related to the demand side, stands the test well. The conditions needed for acceptation – awareness, willingness and capability – were always fulfilled in the historical cases studied. Contrary to this, the author finds no clear basis to support the theory of L.A. Brown for the supply-side. The active influence of 'diffusion agencies' described in this theory could not be confirmed.

Sociological theories concerning the introduction of innovations in complex organizations with a high degree of centralization and formalization are not found to stand the historical test well. Contrary to theory, it appears that the complicated structures did *not* hinder the introduction of navigational novelties. Advisers on navigational techniques were left sufficient room to introduce them. It was particularly in such organizations, the author claims, that science gained a favoured position during the eighteenth century. This development is explained firstly by the rise of a so-called scientistic movement in the second half of the eighteenth century and secondly by an overlap between decision-makers and members of scientific societies.

The conclusions roughly outlined above are probably of special interest in sociology. I was most intrigued by the conclusion reached in this book that in the Netherlands 'institutionalization' did not, as predicted by J. Ben-David's theory, follow a scientistic movement but preceded it. I think this conclusion is correct, provided the concepts employed here do apply to science at large. But is it also true for scientific navigation? Nowhere in this book are we confronted with the question

of the institutionalization of navigation as a science, that is, the transition from the art of navigation to the science of navigation. Some historians maintain that such a transition took place in the eighteenth century. It would mean that only then a certain 'pattern of values' came into being, which was recognized by a group of practitioners of scientific navigation. It would also mean that within the seafaring community this group gained special status. Seen from this perspective the discrepancy between the development in scientific navigation and the theory of J. Ben-David might be less severe.

Looking at the above results from the point of view of the historian I can not suppress a certain amount of disappointment. Why or why not were the navigators willing to accept certain scientific applications? Or in the case of new methods being forced upon them, why did their bosses decide in favour of the new methods? The present approach can answer these questions only in more general terms: the decision-makers must have believed that acceptation was to their advantage. What were the advantages these people believed in and why? After all the trouble taken in this study the outcome in this respect is not very explanatory. Then why did the author persist in following this route? The answer to this question may be contained in the end of the epilogue.

Between 1000 BC and 600 AD Polynesian navigators succeeded in finding their way over the Pacific Ocean without the aid of modern navigational technology. If the Polynesians could find their way across a huge ocean without the complicated technology that was developed in Europe during the last five centuries, why then could the European navigators not do without it? And if they could indeed have navigated without science like the Polynesians, why then were modern scientific techniques still accepted by the sailors? Were they forced to accept? This is, in a nutshell, the hidden background query against which the development of navigational techniques in the Netherlands have been studied in this book.

The wonder and admiration for natural skills which are based on traditional knowledge only (in our example of wave pattern, currents and natural features of the sea) often go hand in hand with doubts about the need for modern western techniques. I note here, however, that the Pacific navigators appear also to have used the remarkable circumstance that in the Pacific Ocean groups of islands are so widely spaced that they can be located by sailing to a point at which they see a specific star directly overhead at its zenith. May we not call this scientific? Of course not, if the definition in this book is applied. Yet, one wonders what would have happened if this wonderful characteristic would have come to the knowledge of European navigators. What would Plancius have done with it? Would he have accepted it as scientific? I bet he would.

This book contains a wealth of historical material together with the application of theoretical sociological concepts to it. As such it amply merits the attention of students of either discipline. The opinions advanced in the book are sometimes rather provoking. This certainly will serve to incite more scientific thinking in the interdisciplinary field opened up so well by the author. Therefore, I heartily recommend this book to historians, social scientists, historians of science, and all those who are otherwise interested in navigation in the sixteenth to eighteenth centuries.

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