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

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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.