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The Conquest of Space and the Stature of Man

Hannah Arendt

Has man's conquest of space increased or diminished his stature?"[1] The question raised is addressed to the layman, not the scientist, and it is inspired by the humanist's concern with man, as distinguished from the physicist's concern with the reality of the physical world. To understand physical reality seems to demand not only the renunciation of an anthropocentric or geocentric world view, but also a radical elimination of all anthropomorphic elements and principles, as they arise either from the world given to the five human senses or from the categories inherent in the human mind. The question assumes that man is the highest being we know of, an assumption which we have inherited from the Romans, whose *humanitas* was so alien to the Greeks' frame of mind that they had not even a word for it. (The reason for the absence of the word *humanitas* from Greek language and thought was that the Greeks, in contrast to the Romans, never thought that man is the highest being there is. Aristotle calls this belief *atopos*, "absurd.")[2] This view of man is even more alien to the scientist, to whom man is no more than a special case of organic life and to whom man's habitat—the earth, together with earthbound laws—is no more than a special borderline case of absolute, universal laws, that is, laws that rule the immensity of the universe. Surely the scientist cannot permit himself to ask: What consequences will the result of my investigations have for the stature (or, for that matter, for the future) of man? It has been the glory of modern science that it has been able to emancipate itself completely from all such anthropocentric, that is, truly humanistic, concerns.

The question propounded here, insofar as it is addressed to the layman, must be answered in terms of common sense and in everyday language (if it can be answered at all). The answer is not likely to convince the scientist, because he has been forced, under the compulsion of facts and experiments, to renounce sense perception and hence common sense, by which we coordinate the perception of our five senses into the total awareness of reality. He has also been forced to renounce normal language, which even in its most sophisticated conceptual refinements remains inextricably

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Hannah Arendt *(1906-1975) was a German-born American political philosopher known for her writings on totalitarianism, evil, and political action. Her works include* Origins of Totalitarianism *(1951),* The Human Condition *(1958),* On Revolution *(1963), and* Eichmann in Jerusalem *(1963).*

bound to the world of the senses and to our common sense. For the scientist, man is no more than an observer of the universe in its manifold manifestations. The progress of modern science has demonstrated very forcefully to what an extent this observed universe, the infinitely small no less than the infinitely large, escapes not only the coarseness of human sense perception but even the enormously ingenious instruments that have been built for its refinement. The data with which modern physical research is concerned turn up like "mysterious messenger[s] from the real world."[3] They are not phenomena, appearances, strictly speaking, for we meet them nowhere, neither in our everyday world nor in the laboratory; we know of their presence only because they affect our measuring instruments in certain ways. And this effect, in the telling image of Eddington, may "have as much resemblance" to what they are "as a telephone number has to a subscriber."[4] The point of the matter is that Eddington, without the slightest hesitation, assumes that these physical data emerge from a "real world," more real by implication than the world we live in; the trouble is that something *physical* is present but never appears.

The goal of modern science, which eventually and quite literally has led us to the moon, is no longer "to augment and order" human experiences (as Niels Bohr,[5] still tied to a vocabulary that his own work has helped to make obsolete, described it); it is much rather to discover what lies *behind* natural phenomena as they reveal themselves to the senses and the mind of man. Had the scientist reflected upon the nature of the human sensory and mental apparatus, had he raised questions such as *What is the nature of man and what should be his stature? What is the goal of science and why does man pursue knowledge?* or even *What is life and what distinguishes human from animal life?*, he would never have arrived where modern science stands today. The answers to these questions would have acted as definitions and hence as limitations of his efforts. In the words of Niels Bohr, "Only by renouncing an explanation of life in the ordinary sense do we gain a possibility of taking into account its characteristics."[6]

That the question proposed here makes no sense to the scientist *qua* scientist is no argument against it. The question challenges the layman and the humanist to judge what the scientist is doing because it concerns all men, and this debate must of course be joined by the scientists themselves insofar as they are fellow citizens. But all answers given in this debate, whether they come from laymen or philosophers or scientists, are non-scientific (although not anti-scientific); they can never be

demonstrably true or false. Their truth resembles rather the validity of agreements than the compelling validity of scientific statements. Even when the answers are given by philosophers whose way of life is solitude, they are arrived at by an exchange of opinions among many men, most of whom may no longer be among the living. Such truth can never command general agreement, but it frequently outlasts the compellingly and demonstrably true statements of the sciences which, especially in recent times, have the uncomfortable inclination never to stay put, although at any given moment they are, and must be, valid for all. In other words, notions such as life, or man, or science, or knowledge are pre-scientific by definition, and the question is whether or not the actual development of science which has led to the conquest of terrestrial space and to the invasion of the space of the universe has changed these notions to such an extent that they no longer make sense. For the point of the matter is, of course, that modern science—no matter what its origins and original goals—has changed and reconstructed the world we live in so radically that it could be argued that the layman and the humanist, still trusting their common sense and communicating in everyday language, are out of touch with reality; that they understand only what appears but not what is behind appearances (as though trying to understand a tree without taking the roots into account); and that their questions and anxieties are simply caused by ignorance and therefore are irrelevant. How can anyone doubt that a science enabling man to conquer space and go to the moon has increased his stature?

This sort of bypassing the question would be very tempting indeed if it were true that we have come to live in a world that only the scientists "understand." They would then be in a position of the "few" whose superior knowledge entitles them to rule the "many," namely, all non-scientists, laymen from the scientist's point of view—be they humanists, scholars, or philosophers—all those, in short, who raise pre-scientific questions because of ignorance.

This division between the scientist and the layman, however, is very far from the truth. The fact is not merely that the scientist spends more than half of his life in the same world of sense perception, of common sense, and of everyday language as his fellow citizens, but that he has come in his own privileged field of activity to a point where the naïve questions and anxieties of the layman have made themselves felt very forcefully, albeit in a different manner. The scientist has not only left behind the layman with his limited understanding; he has left behind a part of himself and his own power of understanding, which is still human understanding,

when he goes to work in the laboratory and begins to communicate in mathematical language. Max Planck was right, and the miracle of modern science is indeed that this science could be purged "of all anthropomorphic elements" because the purging was done by men.[7] The theoretical perplexities that have confronted the new non-anthropocentric and non-geocentric (or heliocentric) science because its data refuse to be ordered by any of the natural mental categories of the human brain are well enough known. In the words of Erwin Schrödinger, the new universe that we try to "conquer" is not only "practically inaccessible, but not even thinkable," for "however we think it, it is wrong; not perhaps quite as meaningless as a 'triangular circle,' but much more so than a 'winged lion.'"[8]

There are other difficulties of a less theoretical nature. Electronic brains share with all other machines the capacity to do man's work better and faster than man. The fact that they supplant and enlarge human brain power rather than labor power causes no perplexity to those who know how to distinguish between the "intellect" necessary to play good checkers or chess and the human mind.[9] This, indeed, proves no more than that labor power and brain power belong in the same category, and that what we call intelligence and can measure in terms of IQs has hardly any more to do with the quality of the human mind than being its indispensable *conditio sine qua non.* There are, however, scientists who state that computers can do "what a human brain cannot *comprehend*,"[10] and this is an altogether different and alarming proposition; for comprehension is actually a function of the mind and never the automatic result of brain power. If it should be true—and not simply a case of a scientist's self-misunderstanding—that we are surrounded by machines whose doings we cannot comprehend although we have devised and constructed them, it would mean that the theoretical perplexities of the natural sciences on the highest level have invaded our everyday world. But even if we remain in the strictly theoretical framework, the paradoxes that have begun to worry the great scientists themselves are sufficiently serious to alarm the layman. Whereas the often mentioned "lag" of the social sciences with respect to the natural sciences or of man's political development with respect to his technical and scientific know-how is no more than a red herring drawn into this debate; it can only divert attention from the main problem, which is that man can *do*, and successfully do, what he cannot comprehend and cannot express in everyday human language.

It may be noteworthy that among the scientists it was primarily the older generation, men like Einstein and Planck, Niels Bohr and Schrödinger, who were most acutely worried about this state of affairs

which their own work had chiefly brought about. They were still firmly rooted in a tradition that demanded that scientific theories fulfill certain definitely humanistic requirements such as simplicity, beauty and harmony. A theory was still supposed to be "satisfactory," namely, satisfactory to human reason in that it served to "save the phenomena," to explain all observed facts. Even today, we still hear that "modern physicists are inclined to believe in the validity of general relativity for aesthetic reasons, because it is mathematically so elegant and philosophically so satisfying."[11] Einstein's extreme reluctance to sacrifice the principle of causality as Planck's Quantum Theory demanded is well known; his main objection was, of course, that with it all lawfulness was about to depart from the universe, that it was as though God ruled the world by "playing dice." And since his own discoveries, according to Niels Bohr, had come about through a "remolding and generalizing [of] the whole edifice of classical physics . . . lending to our world picture a unity surpassing all previous expectations," it seems only natural that Einstein tried to come to terms with the new theories of his colleagues and his successors through "the search for a more complete conception," through a new and surpassing generalization.[12] Thus Max Planck could call the Theory of Relativity "the completion and culmination of the structure of classical physics," its very "crowning point." But Planck himself, although fully aware that the Quantum Theory, in contrast to the Theory of Relativity, signified a complete break with classical physical theory, held it to be "essential for the healthy development of physics that among the postulates of this science we reckon, not merely the existence of law in general, but also the strictly causal character of this law."[13]

Niels Bohr, however, went one step further. For him, causality, determinism, and necessity of laws belonged to the categories of "our necessarily prejudiced conceptual frame," and he was no longer frightened when he met "in atomic phenomena regularities of quite a new kind, defying deterministic pictorial description."[14] The trouble is that what defies description in terms of the "prejudices" of the human mind defies description in every conceivable way of human language; it can no longer be described at all, and it is being expressed, but not described, in mathematical processes. Bohr still hoped that, since "no experience is definable without a logical frame," these new experiences would in due time fall into place through "an appropriate widening of the conceptual framework" which would also remove all present paradoxes and "apparent disharmonies."[15] But this hope, I am afraid, will be disappointed. The categories and ideas of human reason have their ultimate source in human sense experience, and all terms

describing our mental abilities as well as a good deal of our conceptual language derive from the world of the senses and are used metaphorically. Moreover, the human brain which supposedly does our thinking is as terrestrial, earthbound, as any other part of the human body. It was precisely by abstracting from these terrestrial conditions, by appealing to a power of imagination and abstraction that would, as it were, lift the human mind out of the gravitational field of the earth and look down upon it from some point in the universe, that modern science reached its most glorious and, at the same time, most baffling achievements.

In 1929, shortly before the arrival of the Atomic Revolution, marked by the splitting of the atom and the hope for the conquest of universal space, Planck demanded that the results obtained by mathematical processes "must be translated back into the language of the world of our senses if they are to be of any use to us." In the three decades that have passed since these words were written, such translation has become even less possible while the loss of contact between the physical world view and the sense world has become even more conspicuous. But—and in our context this is even more alarming—this has by no means meant that results of this new science are of no practical use, or that the new world view, as Planck had predicted in case the translation back into ordinary language should fail, "would be no better than a bubble ready to burst at the first puff of wind."[16] On the contrary, one is tempted to say that it is much more likely that the planet we inhabit will go up in smoke as a consequence of theories that are entirely unrelated to the world of the senses, and defy all description in human language, than that even a *hurricane* will cause the theories to burst like a bubble.

It is, I think, safe to say that nothing was more alien to the minds of the scientists, who brought about the most radical and most rapid revolutionary process the world has ever seen, than any will to power. Nothing was more remote than any wish to "conquer space" and to go to the moon. Nor were they prompted by an unseemly curiosity in the sense of a *temptatio oculorum.* It was indeed their search for "true reality" that led them to lose confidence in appearances, in the phenomena as they reveal themselves of their own accord to human sense and reason. They were inspired by an extraordinary love of harmony and lawfulness which taught them that they would have to step outside any merely given sequence or series of occurrences if they wanted to discover the overall beauty and order of the whole, that is, the universe. This may explain why they seem to have been less distressed by the fact their discoveries served the invention of the most murderous gadgets than disturbed by the shattering of all their most cherished ideals of

necessity and lawfulness. These ideals were lost when the scientists discovered that there is nothing indivisible in matter, no α-*tomos*, that we live in an expanding, non-limited universe, and that chance seems to rule supreme wherever this "true reality," the physical world, has receded entirely from the range of human senses and from the range of all instruments by which their coarseness was refined. From this, it seems to follow that causality, necessity, and lawfulness are categories inherent in the human brain and applicable only to the common-sense experiences of earthbound creatures. Everything that such creatures "reasonably" demand seems to fail them as soon as they step outside the range of their terrestrial habitat.

The modern scientific enterprise began with thoughts never thought before (Copernicus imagined he was "standing in the sun … overlooking the planets")[17] and with things never seen before (Galileo's telescope pierced the distance between earth and sky and delivered the secrets of the stars to human cognition "with all the certainty of sense evidence").[18] It reached its classic expression with Newton's law of gravitation, in which the same equation covers the movements of the heavenly bodies and the motion of terrestrial things on earth.[19] Einstein indeed only generalized this science of the modern age when he introduced an "observer who is poised freely in space" and not just at one definite point like the sun, and he proved that not only Copernicus but also Newton still required "that the universe should have a kind of center," although this center, of course, was no longer the earth. It is, in fact, quite obvious that the scientists' strongest intellectual motivation was Einstein's "striving after generalization," and that if they appealed to power at all, it was the interconnected formidable power of abstraction and imagination. Even today, when billions of dollars are spent year in and year out for highly "useful" projects that are the immediate results of the development of pure, theoretical science, and when the actual power of countries and governments depends upon the performance of many thousands of researchers, the physicist is still likely to look down upon all these space scientists as mere "plumbers."[20]

The sad truth of the matter, however, is that the lost contact between the world of the senses and appearances and the physical world view had been re-established not by the pure scientist but by the "plumber." The technicians, who account today for the overwhelming majority of all "researchers," have brought the results of the scientists down to earth. And even though the scientist is still beset by paradoxes and the most bewildering perplexities, the very fact that a whole technology could develop out of his results demonstrates the "soundness" of his theories and hypotheses more convincingly than any merely scientific observation or experiment

ever could. It is perfectly true that the scientist himself does not want to go to the moon; he knows that for his purposes unmanned spaceships carrying the best instruments human ingenuity can invent will do the job of exploring the moon's surface much better than dozens of astronauts. And yet, an actual change of the human world, the conquest of space or whatever we may wish to call it, is achieved only when manned space carriers are shot into the universe, so that man himself can go where up to now only human imagination and its power of abstraction, or human ingenuity and its power of fabrication, could reach. To be sure, all we plan to do now is to explore our own immediate surroundings in the universe, the infinitely small place that the human race could reach even if it were to travel with the velocity of light. In view of man's life span—the only absolute limitation left at the present moment—it is quite unlikely that he will ever go much farther. But even for this limited job, we have to leave the world of our senses and of our bodies not only in imagination but in reality.

It is as though Einstein's imagined "observer poised in free space"—surely the creation of the human mind and its power of abstraction—is being followed by a bodily observer who must behave as though he were a mere child of abstraction and imagination. It is at this point that all the theoretical perplexities of the new physical world view intrude as realities upon man's everyday world and throw out of gear his "natural," that is, earthbound, common sense. He would, for instance, be confronted in reality with Einstein's famous "twin paradox," which hypothetically assumes that "a twin brother who takes off on a space journey in which he travels at a sizable fraction of the speed of light would return to find his earthbound twin either older than he or little more than a dim recollection in the memory of his descendants."[21] For although many physicists had found this paradox difficult to swallow, the "clock paradox," on which it is based, seems to have been verified experimentally, so that the only alternative to it would be the assumption that earthbound life under all circumstances remains bound to a time concept that demonstrably does not belong among "true realities," but among mere appearances. We have reached the stage where the Cartesian radical doubt of reality as such, the first philosophical answer to the discoveries of science in the modern age, may become subject to physical experiments that would make short shrift of Descartes' famous consolation, *I doubt, therefore I am*, and of his conviction that, whatever the state of reality and of truth as they are given to the senses and to reason, you cannot "doubt of your doubt and remain uncertain whether you doubt or not."[22]

The magnitude of the space enterprise seems to me beyond dispute, and all objections raised against it on the purely utilitarian level—that it is too expensive, that the money were better spent on education and the improvement of the citizens, on the fight against poverty and disease, or whatever other worthy purposes may come to mind—sound to me slightly absurd, out of tune with the things that are at stake and whose consequences today appear still quite unpredictable. There is, moreover, another reason why I think these arguments are beside the point. They are singularly inapplicable because the enterprise itself could come about only through an amazing development of man's scientific capabilities. The very integrity of science demands that not only utilitarian considerations but the reflection upon the stature of man as well be left in abeyance. Has not each of the advances of science, since the time of Copernicus, almost automatically resulted in a decrease in his stature? And is the often repeated argument that it was man who achieved his own debasement in his search for truth, thus proving anew his superiority and even increasing his stature, more than a sophism? Perhaps it will turn out that way. At any event, man, insofar as he is a scientist, does not care about his own stature in the universe or about his position on the evolutionary ladder of animal life; this "carelessness" is his pride and his glory. The simple fact that physicists split the atom without any hesitations the very moment they knew how to do it, although they realized full well the enormous destructive potentialities of their operation, demonstrates that the scientist *qua* scientist does not even care about the survival of the human race on earth or, for that matter, about the survival of the planet itself. All associations for "Atoms for Peace," all warnings not to use the new power unwisely, and even the pangs of conscience many scientists felt when the first bombs fell on Hiroshima and Nagasaki cannot obscure this simple, elementary fact. For in all these efforts the scientists acted not as scientists but as citizens, and if their voices have more authority than the voices of laymen, they do so only because the scientists are in possession of more precise information. Valid and plausible arguments against the "conquest of space" could be raised only if they were to show that the whole enterprise might be self-defeating in its own terms.

There are a few indications that such might indeed be the case. If we leave out of account the human life span, which under no circumstances (even if biology should succeed in extending it significantly and man were able to travel with the speed of light) will permit man to explore more than his immediate surroundings in the immensity of the universe, the most significant indication that it might be self-defeating consists in Heisenberg's discovery of the uncertainty principle. Heisenberg showed

conclusively that there is a definite and final limit to the accuracy of all measurements obtainable by man-devised instruments for those "mysterious messengers from the real world." The uncertainty principle "asserts that there are certain pairs of quantities, like the position and velocity of a particle, that are related in such a way that determining one of them with increased precision necessarily entails determining the other one with reduced precision."[23] Heisenberg concludes from this fact that "we decide, by our selection of the type of observation employed, which aspects of nature are to be determined and which are to be blurred."[24] He holds that "the most important new result of nuclear physics was the recognition of the possibility of applying quite different types of natural laws, without contradiction, to one and the same physical event. This is due to the fact that within a system of laws which are based on certain fundamental ideas only certain quite definite ways of asking questions make sense, and thus, that such a system is separated from others which allow different questions to be put."[25] From this he concluded that the modern search for "true reality" behind mere appearances, which has brought about the world we live in and resulted in the Atomic Revolution, has led into a situation in the sciences themselves in which man has lost the very objectivity of the natural world, so that man in his hunt for "objective reality" suddenly discovered that he always "confronts himself alone."[26]

The remarks of Heisenberg seem to me to transcend by far the field of strictly scientific endeavor and to gain in poignancy if they are applied to the technology that has grown out of modern science. Every progress in science in the last decades, from the moment it was absorbed into technology and thus introduced into the factual world where we live our everyday lives, has brought with it a veritable avalanche of fabulous instruments and ever more ingenious machinery. All of this makes it more unlikely every day that man will encounter anything in the world around him that is not man-made and hence is not, in the last analysis, he himself in a different disguise. The astronaut, shot into outer space and imprisoned in his instrument-ridden capsule where each actual physical encounter with his surroundings would spell immediate death, might well be taken as the symbolic incarnation of Heisenberg's man—the man who will be the less likely ever to meet anything but himself and man-made things the more ardently he wishes to eliminate all anthropocentric considerations from his encounter with the non-human world around him.

It is at this point, it seems to me, that the humanist's concern with man and the stature of man has caught up with the scientist. It is as though the sciences had done what the humanities never could have

achieved, namely, to prove demonstrably the validity of this concern. The situation, as it presents itself today, oddly resembles an elaborate verification of a remark by Franz Kafka, written at the very beginning of this development: Man, he said, "found the Archimedean point, but he used it against himself; it seems that he was permitted to find it only under this condition." For the conquest of space, the search for a point outside the earth from which it would be possible to move, to unhinge, as it were, the planet itself, is no accidental result of the modern age's science. This was from its very beginnings not a "natural" but a universal science, it was not a physics but an astrophysics which looked upon the earth from a point in the universe. In terms of this development, the attempt to conquer space means that man hopes he will be able to journey to the Archimedean point which he anticipated by sheer force of abstraction and imagination. However, in doing so, he will necessarily lose his advantage. All he can find is the Archimedean point with respect to the earth, but once arrived there and having acquired this absolute power over his earthly habitat, he would need a new Archimedean point, and so *ad infinitum*. In other words, man can only get lost in the immensity of the universe, for the only true Archimedean point would be the absolute void behind the universe.

Yet even if man recognizes that there might be absolute limits to his search for knowledge and that it might be wise to suspect such limitations whenever it turns out that the scientist can do more than he is capable of comprehending, and even if he realizes that he cannot "conquer space," but at best make a few discoveries in our solar system, the journey into space and to the Archimedean point with respect to the earth is far from being a harmless or unequivocally triumphant enterprise. It could add to the stature of man inasmuch as man, in distinction from other living things, desires to be at home in a "territory" as large as possible. In that case, he would only take possession of what is his own, although it took him a long time to discover it. These new possessions, like all property, would have to be limited, and once the limit is reached and the limitations established, the new world view that may conceivably grow out of it is likely to be once more geocentric and anthropomorphic, although not in the old sense of the earth being the center of the universe and of man being the highest being there is. It would be geocentric in the sense that the earth, and not the universe, is the center and the home of mortal men, and it would be anthropomorphic in the sense that man would count his own factual mortality among the elementary conditions under which his scientific efforts are possible at all.

At this moment, the prospects for such an entirely beneficial development and solution of the present predicaments of modern science

and technology do not look particularly good. We have come to our present capacity to "conquer space" through our new ability to handle nature from a point in the universe outside the earth. For this is what we actually do when we release energy processes that ordinarily go on only in the sun, or attempt to initiate in a test tube the processes of cosmic evolution, or build machines for the production and control of energies unknown in the household of earthly nature. Without as yet actually occupying the point where Archimedes had wished to stand, we have found a way to act on the earth as though we disposed of terrestrial nature from outside, from the point of Einstein's "observer freely poised in space." If we look down from this point upon what is going on on earth and upon the various activities of men, that is, if we apply the Archimedean point to ourselves, then these activities will indeed appear to ourselves as no more than "overt behavior," which we can study with the same methods we use to study the behavior of rats. Seen from a sufficient distance, the cars in which we travel and which we know we built ourselves will look as though they were, as Heisenberg once put it, "as inescapable a part of ourselves as the snail's shell is to its occupant." All our pride in what we can do will disappear into some kind of mutation of the human race; the whole of technology, seen from this point, in fact no longer appears "as the result of a conscious human effort to extend man's material powers, but rather as a large-scale biological process."[27] Under these circumstances, speech and everyday language would indeed be no longer a meaningful utterance that transcends behavior even if it only expresses it, and it would much better be replaced by the extreme and in itself meaningless formalism of mathematical signs.

The conquest of space and the science that made it possible have come perilously close to this point. If they ever should reach it in earnest, the stature of man would not simply be lowered by all standards we know of, but have been destroyed.

Notes

1 This question was asked for a "Symposium on Space" by the editors of *Great Ideas Today* (1963) with special emphasis on what "the exploration of space is doing to man's view of himself and to man's condition. The question does not concern man as a scientist, nor man as a producer or consumer, but rather man as *human*."

2 *Nicomachean Ethics*, book VI, ch. 7, 1141a20 ff.

3 Max Planck, *The Universe in the Light of Modern Physics*, 1929. Quoted from *Great Ideas Today*, 1962, p. 494.

4 As quoted by J. W. N. Sullivan, *Limitations of Science*, Mentor Books, 1949, p. 141.

5 See Sullivan's *Atomic Physics and Human Knowledge*, New York, 1958, p. 88.

6 Ibid., p. 76.

[7] Planck, op. cit. p. 503.

[8] See Planck's *Science and Humanism*, London, 1951, pp. 25-26.

[9] John Gilmore, in a sharply critical letter when this article first appeared in 1963, puts the matter very nicely: "During the last several years we have in fact succeeded in writing computer programs that enable these machines to exhibit behavior that anyone not familiar with the makeup of the programs would unhesitatingly describe as intelligent, even highly intelligent. Alex Bernstein, for example, has devised a program that enables a machine to play spectacular good checkers. In particular, it can play better checkers than Bernstein. This is an impressive achievement; but it is Bernstein's and not the machine's." I had been misled by a remark of George Gamow—see note 10—and have changed my text.

[10] George Gamow, "Physical Sciences and Technology," in *Great Ideas Today*, 1962, p. 207. Italics added.

[11] Sergio de Benedetti, as quoted by Walter Sullivan, "Physical Sciences and Technology," in *Great Ideas Today*, 1961, p. 198.

[12] Bohr, op. cit., pp. 70 and 61 respectively.

[13] Planck, op. cit., pp. 493, 517, and 514 respectively.

[14] Bohr, op. cit., pp. 31 and 71 respectively.

[15] Ibid., p. 82.

[16] Planck, op. cit., pp. 509 and 505 respectively.

[17] See J. Bronowski, *Science and Human Values*, New York, 1956, p. 22.

[18] See *The Starry Messenger*, translation quoted from *Discoveries and Opinions of Galileo*, New York, 1957, p. 28.

[19] See Einstein's *Relativity, The Special and General Theory* (1905 & 1916), quoted in *Great Ideas Today*, 1961, pp. 452 and 465 respectively.

[20] Walter Sullivan, op. cit., p.189.

[21] Ibid., p. 202.

[22] I quote from Descartes' dialogue "The Search after Truth by the Light of Nature," where his central position in this matter of doubting is more in evidence than in the *Principles*. See E. S. Haldane and G. R. T. Ross edition of his *Philosophical Works*, London, 1931, vol. I, pp. 324 and 315.

[23] I owe this definition to John Gilmore's letter, mentioned in note 9. Mr. Gilmore, however, does not believe that this imposes limitations on the knowledge of the practicing physicist. I think that Heisenberg's own "popular" statements bear me out on this point. But this is by no means the end of this controversy. Mr. Gilmore as well as Mr. Denver Lindley believes that the great scientists may very well be wrong when it comes to evaluating philosophically their own work. Mr. Gilmore and Mr. Lindley accuse me of using the scientists' statements uncritically, as though they could speak about the implications of their work with the same authority as they talk about their subjects properly speaking. ("Your confidence in the great figures in the scientific community is touching," says Mr. Gilmore.) This argument, I think, is valid; no scientist, no matter how eminent, can ever claim the same soundness for "philosophical implications" he or somebody else discovers in his work or in his utterances about it as he could claim for the discoveries themselves. Philosophic truth, whatever it may be, is certainly not scientific truth. Still, it is difficult to believe that Planck and Einstein, Niels Bohr, Schrödinger and Heisenberg, all of whom were puzzled and greatly worried about the consequences and general implications of their work as practicing physicists, should all have been subject to the delusions of self-misunderstanding.

[24] In *Philosophic Problems of Nuclear Science*, New York, 1952, p. 73.

[25] Ibid., p. 24.

[26] In *The Physicist's Conception of Nature*, New York, 1958, p. 24.

[27] Ibid., pp. 18-19.