even some scientific periodicals, are filled today with vast and nebulous schemes for the regimentation of scholars in the great war against chaos and ignorance. Useful work, like the production of the atomic bomb (if you call that useful), may be done by such organization. But the great advances of knowledge are not made by such means. They are, rather, the product of individual effort, free, unpredictable in their nature and in their consequences. They are the products of minds like Newton, Einstein and Pauli: "Voyaging through strange seas of thought alone."

Such a plan or, rather, lack of plan for the advancement of knowledge violates all the instincts and preconceptions of the adminstrative type of mind. It is not orderly, but, rather, haphazard. I can only say that the whole process of evolution on this planet has, so far as we can see, been an unexpected one. It may conform to some divine plan, but it does not follow any plan of human devising. There is nothing in the *Bible* about the exclusion principle or the atomic bomb, though the author of "Revelations" would doubtless have equipped the Four Horsemen of the Apocalypse with the latter device had he known about it.

Robert Louis Stevenson was once asked what was the moral to one of his stories. "My moral?" he replied, "I have no moral: it is God's moral that I am trying to understand." So with our scientists. It is nothing less than the mind of God they are seeking to penetrate.

All educational institutions, all societies of scholars, are devoted to this high quest. It is with this in mind that we have tried to make conditions here such that they can devote themselves to it in the single-minded way that is not always possible elsewhere. It is in line with our fundamental purpose that we have chosen Pauli to be a member of our Faculty. We hope that he will make his career here and that the exclusion principle will not be the last or the greatest of his contributions to physics.

Encomium

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IT IS DIFFICULT TO IMAGINE what the history of physics would have been without the influence of Pauli during the last twenty-odd years. As another Nobel laureate recently expressed it, "Pauli for many years has been the conscience and criterion of truth for a large part of the community of theoretical physicists." Thus, there is complete unanimity the world over that Pauli has amply deserved the recognition now accorded his work by the Royal Swedish Academy, to whose hands, by Nobel's will, the distribution of the Nobel Prize for Physics is entrusted. . . .

I think it is very fortunate that through the accident of Nobel's birth the lot to bestow this highest international honor for scientific achievement fell to Sweden, one of the Scandinavian countries. Indeed, these countries march in the vanguard of civilization; nowhere on this planet has man come nearer to the fulfillment of his dream of a happy and free life, with justice and equal opportunity for all, where good prevails over evil, and beauty and truth can shine and are loved. In physics and mathematics in particular the Scandinavian countries have, during the last decades, contributed more than their share to the advancement of our knowledge. It is enough to mention one name, that of Niels Bohr, who has exerted the most extraordinary influence upon the development of physics and on the whole generation of younger physicists in the last thirty years. Pauli himself is his disciple.

The impression prevails that it has been harder for a theoretical than for an experimental physicist to win the Nobel laurels. One obvious reason is that it is more difficult to assess at an early stage the importance of a theoretical discovery. When modern quantum physics came into being around 1925, one often spoke of it as boys' physics—"Knabenphysik." Indeed, at the time neither Heisenberg, nor Dirac, nor Pauli were over twenty-five (de Broglie and Schrödinger were somewhat older). It is gratifying that now all the boys who enacted this great scientific drama have been crowned by the Swedish Academy.

Born and educated in Vienna, Wolfgang Pauli started his scientific career in Munich under Arnold Sommerfeld. Perhaps I am among the first with whom he established scientific contacts, for the first papers he published dealt with a unified field theory of gravitation and electromagnetism which I had propounded in 1918. He dealt with it in a truly Paulinean fashion—namely, he dealt it a pernicious blow. Pauli's article on relativity theory, written in these years for the *Mathematical Encyclopaedia,* is a mature and masterly work which shows the author in full command of both the mathematical and physical aspects of the subject; and yet it was the work of a young man of twenty. After having earned his Ph.D. in Munich, Pauli migrated to Göttingen, since the time of Gauss a center of mathematical and physical research, where Max Born and James Franck were teaching at that time, and from there he went to Copenhagen and came under Niels Bohr's strong formative influence. From 1923 to 1928 he was *Dozent* at the University of Hamburg, and since then he has occupied a chair for theoretical physics at the Eidgenössische Technische Hochschule at Zürich. The year 1935–1936 he spent as a visiting professor at our Institute. In 1940, immediately after the invasion of Denmark and Norway by the Nazis, when it was clear that all the other neutral European countries were in danger of being overrun by the swastika, the Institute made an effort to bring Niels Bohr and Pauli to this country. Bohr considered it his patriotic duty to stay in Copenhagen, but we were lucky enough to get Pauli. I hope he does not regret that he came, even though Switzerland was spared the fate of being invaded by Hitler's hordes.

Let me now cast a quick glance over Pauli's principal achievements in physics—although a mathematician is hardly entitled to speak about them with authority. We mathematicians feel near to Pauli since he is distinguished among physicists by his highly developed organ for mathematics. Even so, he is a physicist; for he has to a high degree what makes the physicist: the genuine interest in the experimental facts in all their puzzling complexity. His accurate, instinctive estimate of the relative weight of relevant experimental facts has been an unfailing guide for him in his theoretical investigations. Pauli combines in an exemplary way physical insight and mathematical skill.

As I have already mentioned, Pauli began his work in the sign of relativity theory. Although he later returned to this theory on one or two occasions, his main work, by which he should be judged as a creative physicist, is in quantum physics. Here it is natural to distinguish the periods before and after the Heisenberg-Schrödinger break-through to a consistent quantum theory of the atom in 1925. In the time before this dramatic event one had to operate with Niels Bohr's models and a compromise that Bohr vaguely formulated as the Principle of Correspondence, and to find one's way through the maze of spectroscopic facts more by divination ("Schnauze" is Pauli's word for it) than by theory. It is remarkable that in this period Pauli scored some of his greatest successes. For instance, he saw that the so-called hyperfine structure of spectral lines is to be ascribed to a quantum character of the nucleus rather than to the electronic shell of the atom. But above all, his investigations concerning the Zeeman effect gradually led him to the discovery of the exclusion principle, according to which no two electrons may be in the same quantum state. This was a very bold conception. The exclusion principle, strange and incomprehensible as it is from the standpoint of classical physics, is decisive for an understanding of the periodic system of chemical elements. It is a lasting achievement, which will hardly be affected by any future changes of our physical theories.

One would expect that in stable equilibrium each electron revolving around the nucleus occupies the lowest possible energy level, according to the Planck-Bohr quantum rule. Instead, when we run over the chemical elements in their natural order, we find that only the first two electrons, in hydrogen and helium, are bound in this lowest state. Then a sort of saturation seems to be reached. The next element, lithium, has only one valence electron. As the spectra show, the eight electrons from lithium to neon are all bound in the next higher level, and with neon again a closed shell which can admit no further electrons, seems to have been completed. It is these fundamental facts which Pauli's exclusion principle explains. In developing it he had to overcome an accessory difficulty. When he started his work the quantum state of an electron was characterized by three quantum numbers. But that led to shells of 1, 4, 9 . . . electrons instead of 2, 8, 18 . . . , as we find in nature. He accounted for this "duplicity" by a fourth quantum number of the electron. Shortly afterward, Goudsmit and Uhlenbeck suggested that this quantum number had its origin in an angular momentum, a spin of the electron. Again it was Pauli who, once the foundations of the new quantum mechanics were established, first succeeded in describing correctly the nature of this momentum, which is radically different from that of a spinning top and not to be accounted for by classical concepts.

The Pauli principle reveals a general mysterious property of the electron, the importance of which is by no means limited to spectroscopy. Pauli himself applied it to the statistics of particles in a degenerate gas, thus explaining the paramagnetic properties of such gases. A paper on the paramagnetism of metals laid the foundations for the quantum mechanical theory of electrons in metals. A step of great consequences, for which Dirac's quantum theory of radiation had paved the way, was taken in a joint investigation by Pauli and Heisenberg on the quantization of the field equations: thereby wave mechanics passed from the theory of a single particle to that of the interaction of an indefinite number of particles. Pauli's studies of the intimate relationship between spin and statistical behavior of particles naturally led him to investigate the dynamics of the meson. The meson is now a generally accepted particle in nuclear physics. Of a more dubious character seems an invention of Pauli's, the most elusive of all elementary particles, which he dubbed neutrino, and others call Paulino. It is a particle without charge and mass, which nevertheless seems to be indispensable if the laws of conservation of energy and angular momentum are to be safeguarded. Here are question marks for the future.

My brief account is far from complete. I have not mentioned Pauli's two great articles on quantum theory, written for the *Handbuch der Physik* in 1925 and 1933. Enormous, but difficult to assess, is the influence Pauli has exerted by correspondence and discussion. In view of the discontinuous leaps by which theoretical physics develops, the stream of his scientific production has been remarkably steady. Indeed, when I compare the theoretical physicist with the mathematician I find that the former has a much harder lot. If the mathematician cannot solve a problem, he modifies it until he can solve it; no impenetrable reality limits the freedom of his imagination. So he is liable to succumb to Peer Gynt's temptation: " 'Go around,' said the crooked." Not so the physicist. He has to face the hard facts of nature. The problem of the atom must be solved straightforwardly; otherwise, no further progress is possible. Therefore, theorectical physics has affluent periods when, after persistent efforts, a new stage of theoretical interpretation has been reached, as was the case, for instance, in 1925; then there is all of a sudden plenty of highly satisfactory work for the theorist. But this alternates with stagnant periods where nothing else seems possible than to wait patiently for the slow accumulation of new facts by the experimentalists—facts which refuse to fall into any recognizable theoretical pattern. I have the greatest admiration for the courage and ingenuity with which Pauli has met this intriguing situation.

Another tension tells on the theoretical physicist—that between pure science and applications. He is a theorist and thereby committed to the contemplative life and its ideals. As Dilthey once said, "das vom Eigenleben unabhängige Glück des Sehens" is one of the most primitive and basic blessings of our existence. True, the physicist's contemplation is not a purely passive attitude—it is creative construction, but construction in symbols, resembling the creative work of the musician. On the other hand, science, since it discloses reality, is applicable to reality. Thus it is called upon to serve for the benefit and malefit of mankind. Its technical applications are used to make man's life more comfortable and more miserable, to build and to destroy. To what extent shall and can the theorist take responsibility for the practical consequences of his discoveries? What a beautiful theoretical edifice is quantum physics—and what a terrible thing is the atomic bomb! When they helped to develop the latter, did the physicists do nothing but their duty as citizens of a country engaged in total war, or did they prostitute their science? I think the experience of the last years has shown that there is little danger that the call of national duty will not be heeded by the scientists when the life of the nation is at stake, but that there is great danger indeed that in the fight for the basic values of our existence we may lose these values themselves; that the relentless pursuit of science—strange antinomy!—may imperil its very foundations in man's life. Pauli has all his life been deeply interested in philosophy. The wisdom of the Chinese sages seems to have a special appeal for him. No wonder that his sympathies are with those who are not willing to sacrifice the spiritual for the secular, and who are not willing to accept efficiency as the ultimate criterion. . . .

Scanning Science—

New honors are being bestowed upon the discoverers of argon. First came the Barnard gold medal of Columbia College, then the $10,000 Hodgkins prize, then the prize of 50,000 francs from the French Institute and now it is announced that Lord Rayleigh and Professor Ramsay have been made Knights of the Legion of Honor, by order of the French Government.

—14 February 1896