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W.R. Hess, the ophthalmologist

by A. Huber

(formerly the University of Zurich, Eye Clinic, CH-8091 Zürich), Stadelhoferstrasse 42, CH-8001 Zürich (Switzerland)

If for Walter Rudolf Hess order is the essential principle of all life, a similar principle of order can be traced in the personal biography of this great scientist and physician. Born 1881 in Frauenfeld, he spent his childhood in this city of eastern Switzerland, where - to use his own words - the whole surrounding was in full harmony with his psychic constitution. Already at the age of five he used to explore the fields and meadows, to collect plants, and every new specimen meant an exciting experience, for it was brought home and carefully classified with his father's help. The latter, professor of physics at the 'Gymnasium', gave him the opportunity to enjoy an early contact with classical physics which would be of great importance in his later life. During the years at the 'Gymnasium' his father allowed him to visit his laboratory and to help him in setting up the experiments for his classes. Already at this time Hess relized that the seemingly stationary processes in the so-called static systems were, in reality, a system of antagonistic forces resulting in dynamic equilibrium. During the last semesters at the 'Gymnasium' he decided to take up the medical profession which seemed to him the ideal way to apply sciences for the benefit of people. His first choice was the University of Lausanne, then Bern, the capital of Switzerland, then Zurich, Berlin and finally Kiel. Already during the first semesters at the university he published at the suggestion of W. Roux, the anatomist from the University of Halle, a paper entitled 'A mechanically induced conformity in the structure of the vascular system', a most fascinating contribution dealing with the relationship between hemodynamics and the morphological formation in the arterial system. In 1905, Hess received his degree in medicine at the University of Zurich. The choice of the place for his first internship was dictated by financial circumstances, which did not allow him to follow a study in theoretical medicine as he would have liked so much. He therefore took a post as resident in the state hospital of his home Canton with the department of surgery under the direction of Dr C. Brunner. There he soon became interested in the relationship between the morphological organization of the vascular system and the flow characteristics of blood factors determining circulatory phenomena. Hess constructed a convenient apparatus to measure blood viscosity for clinical use, the so-called *Viscosimeter.* Based on measurements with this original instrument were the results and conclusions published 1906 in a small treatise entitled 'Viscosity of the blood and the work of the heart'. The essence of this paper is the demonstration that the viscosity of the blood varies with the number of circulating erythrocytes. A further suggestion is that decreased viscosity of the blood can lead to turbulance. This basic and important paper was later accepted as his thesis by the medical faculty of Zurich.

After this first year of internship, Hess wanted to work in some branch of medicine which would give him sufficient time to devote himself to problems of basic research. A practice in ophthalmology seemed ideal in order to meet these requirements. He therefore seized early in 1906 the first opportunity to enter the department of ophthalmology at the University of Zurich as a resident working under Prof. O. Haab, an outstanding clinician and skilled ophthalmic surgeon. Although the mainly morphological orientation of research work in this department did not quite correspond to Hess' interests, he had ample opportunities to make diagnostic observations of more functional and dynamic character. Already in the first years at the University Eye Clinic of Zurich, he became engaged in the *problems of analyzing oculomotor disturbances.* In contrast to the old complicated techniques employed at that time for examing eye muscle palsies, he decided to develop a method which would give more objective results concerning the coordination of eye muscles. The instrument designed for this purpose has entered into practical ophthalmology as *Hess-coordimeter* and is still - albeit with some modifications - a standard instrument for the diagnosis of oculomotor disorders in daily practice. The principle of this coordimeter lies in the direct graphic representation of the relative movement conditions of both eyes. The patient to be examined is placed before a dark screen with red dots forming a square of nine points: he wears spectacles with a red glass on the one side and a green glass on the other. He is asked to point to the red dots with a green arrow which he holds in his hand. Because of the red-green spectacles he can recognize the red dots and the green arrow only with one eye. In the case of a oculomotor disorder, a coincidence between the subjective perception of the patient and the effective position of the dots does not exist. The points thus indicated by the patient in different gaze directions are plotted into a coordinate system for the right and for the left eye: characteristic 'motion' fields result. The smaller restricted field belongs to the eye with the paralyzed muscle. The paralyzed muscle itself can be diagnosed in the direction of the maximum deficit within the smaller field of gaze. The contralateral enlarged field indicates the overfunction of the contralateral synergist, whereas the contracture of the homolateral antagonist can be recognized by an overlapping of the restricted field in a direction opposite to the paralyzed muscle (fig. 1). These are all-important diagnostic clues for a successful surgical treatment of eye muscle palsies. The Hess-coordimeter furthermore allows a quantitative control of the course of eye muscle palsies and also an exact judgement of the effect of surgical interventions in paralytic and concomitant strabismus.

During his residency at the department of ophthalmology in Zurich, Hess was also occupied with the problems of *stereoscopic vision* which already at that time represented for him an instructive example of the integrative function of the central nervous system. Recognizing the disadvantages of the stereoscopes, he tried to develop a procedure for making *stereoscopic photographs* which should produce stereopsis without the help of an instrument. For this purpose he constructed a system of contiguous, microsopically fine lenses which are joined together in a continous surface, much like the surface of an insect's eye. This lens system is imprinted on a photographic film (thickness equivalent to the focal length of the individual lenses) on the side opposite the emulsion. Such a stereofilm is suitable for taking a stereoscopic pair of pictures so that the result is seen as a genuine stereoscopic photograph (fig. 2). Care must be taken that the copying light comes at the angle at which the image is to be subsequently viewed. This special requirement of the copying process can be satisfied by using a copying apparatus with corresponding windows. In fact, such photographs give a distinct stereoscopic effect without the help of an instrument. Unfortunately further development and improvement of these stereoscopic photographs was halted by World War I.

After three years of residency in ophthalmology and a brief study period in Paris, W. R. Hess decided to take over *the practice of an ophthalmologist in the little*

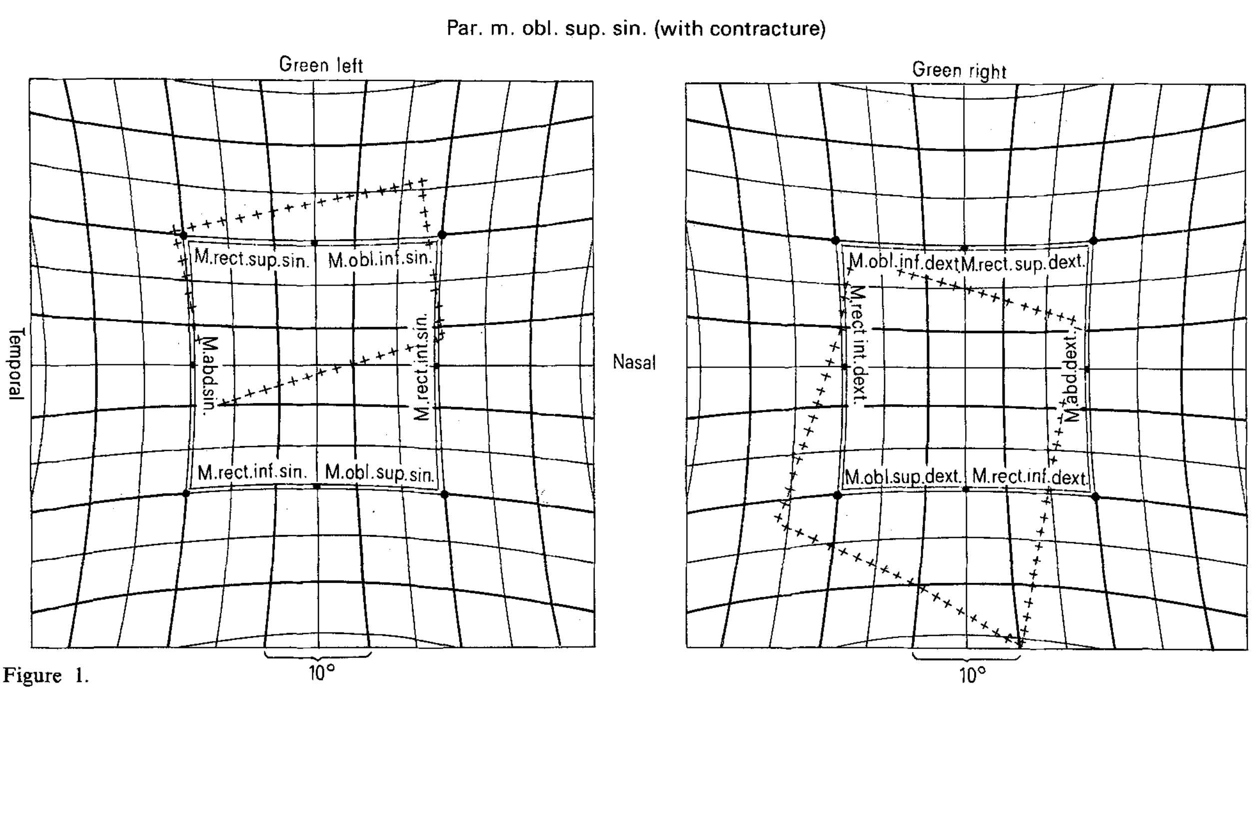

Figure 1.

town of Rapperswil near Zurich. There, he practiced from 1909 to 1912 as eye specialist, being in charge at the same time of a small eye department at the General Hospital of Glarus. Why this decision to go into practice? Hess, according to his own words, wanted to be independent and thought that the work as a practical ophthalmologist would give him ample time to do research work on the side. In fact, he set up a laboratory in which he spent all his free time working on problems of hemodynamics, particularly in relation to blood viscosimetry, and on problems of motor coordination. However the increasing demands of the practice and especially the many professional consultions left him with less and less time to persue his scientific interests. A deep conflict resulted between his sense of duty to provide for his family and his longings for pure science. Finally a critical decision had to be made when *a position* became available for him *at the Institute of Physiology in Zurich.* The move was made in 1912 when W.R. Hess with his young family went back to Zurich to become an assistant under Prof. Gaule, director of the Institute of Physiology at that time. He regarded the years of residency and especially also the time spent in ophthalmological practice always as an 'important plus' for his start in physiology. In 1913, in order to obtain his venia legendi, he presented to the medical faculty a treatise dealing with an idealized model for an optimal vascular energy system for purposes of comparison with the performance of conditions prevailing in a living circulatory system. Unfortunately the outbreak of World War I interrupted much of his scientific work. Nevertheless, Hess could visit for some time the laboratory of Max Verworn, Pflügers successor in Bonn, with whom he had many daily private discussions about animal physiology and teaching methods in general. After returning to Zurich, he was again called for further military service and regretted not being able to continue the experimental work aimed at clarifying the adaptation of blood supply to the changing requirements of individual organs. In 1916 Hess was asked to take the charge of the lectures and laboratories of the Physiological Institute because Prof. Gaule had to resign for reasons of poor health.

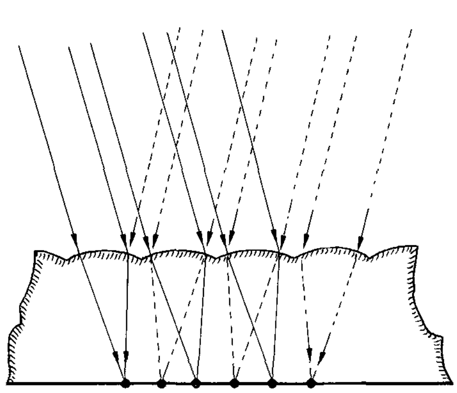

Figure 2.

In 1917, the Zurich Faculty of Medicine officially entrusted to him the Chair of Physiology.

From that moment, W.R. Hess was responsible for the development of physiology at the University of Zurich where he did all his fundamental research work up to the year of his retirement in 1951. During this long period of research and teaching, he had the occasion to travel to various countries and to participate in many scientific meetings which provided him numerous personal contacts and important insights for evaluating the work of other colleagues and institutions.

Ophthalmological problems occupied W.R. Hess during his entire scientific life. In connection with experimental work on the physiology of the diencephalon, he observed in cats complete or partial (homonymous) defects of visual perception as a consequence of an experimentally produced local lesion in the diencephalon without any injury to the 'classical' central visual pathways. From these observations he inferred a capacity of the central visual apparatus to react when influenced by the diencephalon, whereupon he then discussed the principle of regulated reaction readiness in similar observations from human pathophysiology.

The eye, which is moved in all planes of space by three pairs of eye muscles, was for W.R. Hess an ideal example of an organization of the movement forces which operates quantitatively in geometrical term. The organization demonstrated in the motor system of the eye was, for him, also valid for the motor activity of head and body. His considerations led Hess to construct theoretical models by which he tried to clearly reconstruct in detail the relevant physical conditions for the biomotor system and to devise the scheme of an organization whose output is comparable with biological reality. Hess postulated that an organized pattern of muscle forces underlies the motor behavior of organisms. These relationships he thought were best illustrated by the gaze movements. The eye-ball in its socket is movable in all planes of space. The moving forces originate from three pairs of muscles which are oriented in all three planes. The biological performance consists in directing the optical axes to an interesting object in the visual field. The organization is first demonstrated as a model which gives to the eye freedom of movement in all directions from the primary position. A second model describes the organization which provides freedom of movement for every possible initial position of the eye. Here, the eyes must represent a decisive factor in the coordinating function. Instead of the simple relationship between the central motor field and the individual muscles, a selecting organ is introduced. Each functional unit in the central motor field maintains a manifold of potential connections with the representation of effector muscles. Whatever functional unit out of the multiplicity of possible impulse transmissions is to be activated in a concrete case, it is dependent upon the momentary position of the eye because the direction of pull of individual muscles is determined by the momentary position. A short examination of the functional *model of the organization of the oculomotor system* (represented in the 'Motor system as an organization problem', Biologisches Zentralblatt *61* (1941) 546-572, may give further details (fig.3). S

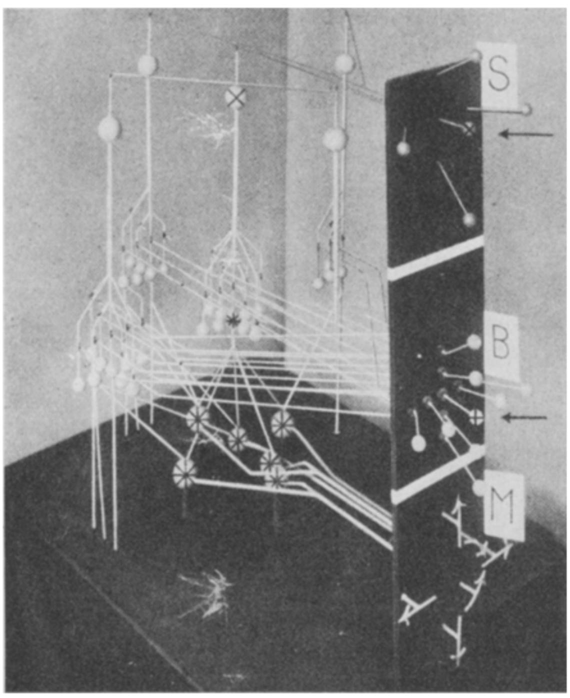

Figure 3.

means the visual field with 5 points, B the gaze field with 9 points and M the single eye muscles with their directions of traction. The five spheres in the upper part of the model represent geometrically defined visual rays in the central receptor system. Each of these representatives is in relation with representatives of defined eye positions. The impulse transfer occurs only where visual impulse and position impulse coincide; thus the combination of forces which is adequate to the position of the eyes can be chosen and transferred to the oculomotor nuclei. In explaining his model, Hess said, 'there is strict geometric order of relations'. The spatial position of the representatives, however, is irrelevant: *the model is a quantitatively valid image of an order which manifests itself in performance.* How far the model can be translated into morphological details, is a question per se. W.R. Hess would certainly be very much pleased to see the results of modern morphologic and electrophysiologic research on the oculomotor system realized by the contributions of Akert, Henn and Büttner in Zurich or by the computer model of oculomotor function of Robinson in Baltimore.

It was highly fortunate that W.R. Hess - even for a short time - was an ophthalmologist. He has given ophthalmology not only an instrument of great practical value but also many original new insights into basic problems. In recognition of his merits the *Swiss Ophthalmological Society had the pleasure of bestowing on him honorary membership* in autumn 1971. The following words of Hermann v. Helmholtz seem to serve as a 'credo', summarizing the way of thinking and working of W.R. Hess: 'When examining the phenomena of nature it is necessary to think up to the end and not to stop half-way'.

Vascular smooth muscle: Intracellular aspects of adrenergic receptor contraction coupling

by J.C. Rüegg

Department of Physiology II, University of Heidelberg, Im Neuenheimer Feld 326, D-6900 Heidelberg (Federal Republic of Germany)

For over three decades (1920-1950), W.R. Hess had been interested in the regulation of smooth muscle, because he recognized that smooth muscle in one of the principle 'effector-organs' of the autonomous nervous system.

I. Synergistic coordination of smooth muscle (Hess[14])

In 1946, v. Euler discovered that the sympathetic nerves exerted their influence on the contractile state of smooth muscle by releasing noradrenaline and adrenaline as transmitters[11]. Hess and his colleagues studied the effect of these substances on isolated smooth muscle. To Hess, it seemed quite puzzling that the same substance, e.g. adrenaline could contract one smooth muscle, while relaxing an other one. While the underlying mechanism for this diversity was not understood, it made, nevertheless, sense to Hess from a teleological point of view. Was it not to the advantage of a dog during 'fight or flight' - he asked - that the increased adrenaline levels in the blood should cause contraction of the spleen and the spleen vessels, while