SYMMETRY
AS A
DEVELOPMENTAL
PRINCIPLE
IN
NATURE AND ART

Cover – Design and subject by Werner Hahn: “Mirror worlds” (1987, acrylic on canvas, 80 cm × 120 cm); refer to Figure 166 (page 67).

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SYMMETRY AS A DEVELOPMENTAL PRINCIPLE IN NATURE AND ART

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FOREWORD

Symmetry

by Prof. Dr. Rupert Riedl

What a strange world! The miracles of the incomprehensible stand side by side with the miracle of the unobserved. The world of symmetry belongs to both groups. On some occasions, symmetry cannot be explained down to the roots of its origin because it once must have been itself a prerequisite for the development of the cosmos and thus a prerequisite for its explanation. On other occasions we ourselves are symmetry, as is the world, according to whose measures we were created, and as are the structures we placed in it. The actual miracle lies in the fact that we are not amazed by this as a whole.

There are many examples of how art and literature were the first to foresee new concepts of the world. Maybe this will also hold true with conceiving the world of symmetry. Since we are faced here with something which could be called an instruction or a piece of information lying at the bottom of this world structure; a condition of form. Something that as a whole always exerts an influence on its parts.

However, this is not the way science intended to understand this world. In the vision of science, the world is similar to an enormous box of bricks in which anything that happens is the result of the properties of elemental components. This is why — according to science — any system needs only be reduced to its components in order to be fully understood. And since in this relation between levels it was only possible to gauge the powers and driving forces but not the instructions which endow the molds with their forms, science was of the opinion that the incomprehensible did not exist.

Today, this can be asserted simply because the development of the square on the chessboard of our intellectual history is subject to considerable change. The concept of order in Schrödinger's negative entropy has conquered this square, as have the information concept, Bertalanffy's concept of the entity of system. Both have already been at work for one generation. Biologists are not the only scientists who take the view that the superior systems determining shape, too, have to be considered in the process of understanding the structures of this world. Scientists dealing with the inorganic have taken up the concepts of complexity, history, instruction and organization.

In this transition, the phenomena of order or instruction in symmetry play an important role. In my capacity as a biologist, I recognize the symmetries of organisms as one of the principles necessary to achieve a maximum of order in the genetic material of every creature. This is a sign of the value of instruction as well as of the value of organization. Both are of vital significance and constitute evolutive constraints. And evolution needed thousands of millions of years in its highest forms to reduce its many symmetries to only a few.

However, as a biologist I am aware of the fact that these symmetries also developed our senses in the same way as the symmetries in their environment had become the driving force for the organization of its interpretations. And as were our senses, our consciousness also formed according to these symmetries. It is no wonder, therefore, that they reveal themselves in our emotions, thoughts and creativity. They even remain as a prerequisite of our aesthetic experience and can now be seen in that level of instruction where the recurring assumes new functions in the new, and the well-known and the predictable assume new functions in the unknown and the surprising. In fact, a world without symmetries is inconceivable to us. It would leave us unprotected in the face of the unpredictable. At this level, too, symmetry has a vital function, after all.

Symmetry has therefore been incorporated in all cultures and all arts and is thus a part of culture itself. It has been discussed in all humanities and has given rise to the most elaborate canons.

A world without symmetry is probably not possible at all, since symmetry would have been a prerequisite of its creation. However, the conditions for creation were by far not able to bring forth the forms of realization, in the same way as the prerequisites alone could not lead to discoveries and inventions. The entity of symmetry reveals itself only in the things that developed out of it.

Thus it is a great merit to have unrolled the phenomena of symmetries in their full breadth to a monumental work; whether in quanta, atoms, and crystals, or in corporeal forms, senses, and brains, or in the forms of all the artifacts that have originated from human activity. Only then will we become aware of our potentialities: the concert of relations that joins the inorganic and the organic, our sensibilities, our thoughts, and our deeds; that which reciprocally unites nature and culture in the human psyche.

INTRODUCTION

“...where nature ceases to bring forth new forms, man commences to create an infinite diversity of forms with the help of natural things, that is with the help of nature itself.”

Leonardo da Vinci

“If nature were not so thoroughly stereometrically in its inanimate beginnings, how would it ever rise to unpredictable and immeasurable life?”

J. W. von Goethe

Since 1970, using the methods of trial and error, supposition and refutation, I have attempted to establish formal results for my sculptural thinking and work on the foundation of nature observations.

Using sculptural experiments with variable form-colour pictorial signs, I arrived, via perception of movements and configurations, at a procedure for constructing forms exclusively by means of reflections (“symmetrizations”) and distortions (“transformation”, “asymmetrization”). These results were surprising, and attracted a great deal of attention (see Chapters 5–5.4).

A method for changing forms was discovered by means of sensory concepts (perception, experience) in two and three dimensions. This method allowed derived configurations to originate which resembled previous and intermediate forms, despite the variety of structural designations. I thus intuitively and spontaneously arrived at the following assumption (a provisional truth), which is of outstanding theoretical and practical usefulness: The symmetrical structures of spatial and temporal order in nature may reflect an important factor for evolutionary changes in nature. The hypothesis, deriving from the will to knowledge, that symmetrization and asymmetrization are the architects of evolution in the realm of natural events presented itself as downright compelling in view of quotidian understanding and especially biological background knowledge.

Creative symmetrization can be defined as an evolutionary process which forms regulatorily derived, structurally new entities. Here, symmetrical and/or asymmetrical refraction leads to the emergence of newly structured and differentiable mirror-image/polar equalities synthetically combined into a network. Here, compared with the old, disrupted symmetrical totality of events, the new form of symmetry can obtain a selectional advantage from the symmetrization (which is often linked with asymmetrization).

Pictorial examples (Figs. 150–170; Sections 5.2 and 5.3) illustrate how, as desired, form-related, not form-identical but derived forms can be developed from a two- and three-dimensionally structured original form (basal form) via intermediate forms (bridging forms). In the midline-orientated sensory constructions which unfold in the course of time, special, unique, and surprising things appear — spontaneously, conspicuously, and unexpectedly — through self-reflections.

In order to examine whether the hypothesis that symmetrization and asymmetrization might prove to be true as a principle of formation and construction in nature, or whether it does not agree with reality, I began, parallel to practical sculptural work, an intensive study of the literature on problems of symmetry and evolution.

After two manifestos, in 1971 (see 5.3.1) and in 1972 (see 12.2.1), the first part of the book entitled *On the Concept and Significance of Symmetry* (Chapters 1–5.4) was completed by 1975. In it, the content and the role of the symmetry phenomenon was placed as the center of interest. A study of the literature revealed that hitherto there had not been any general evolutionary theory of symmetry. Thus,

the task was to conceive of the symmetry phenomenon directly as a heuristic principle which could serve to permit a number of new insights into the laws that govern nature and culture.

In the 20th century heretofore, symmetries were mainly interpreted, and often defamed, as “quiescence, stasis, invariability” (Section 5.1), and as “rigidity, pedantry, boredom, death” (Section 3.4). In order to free themselves from the “millenia-old burden” of the allegedly “static, rigid symmetry” (M. Seuphor), so-called modern artists and sculptors discovered the possibilities of equilibrium in the asymmetrical. P. Mondrian was thoroughly in error when he wrote, in 1924: “Symmetry characterizes things as separated; therefore, a universal formation of the universal must reject symmetry”. W. Baumeister was of the opinion that symmetry “no longer meets the requirements” of the arts today (Section 3.4). Without recognizing that symmetry is a fundamental principle, modern art took the path that led to abstraction. M. Duchamp was one of the few to rebel against the lack of symmetry in the form world of the avant garde: “The entire century was based on asymmetry and deformation — the “bottle-dryer” (as ready-made, W. Hahn) rehabilitated symmetry” (see Fig. 67).

I was able to demonstrate that — in contrast to the Renaissance — art and science in the modern period no longer constitute Siamese twins. Abandoning the field of natural reality, painters invented an artificial reality that no longer had any connection with the phenomena of nature. Likewise, they discarded symmetry and perspective, a process that had begun with P. Cézanne. With him, the father of classical modernism, which defamed the products of nature as “deception”, there began the process of forcible dissolution of form in visible objects, a process which can be interpreted as “antirational.” The pictorial composition of cubism, for instance, became more and more lacking in perspective and focal points. The art philosophy of Cézannism and cubism, with its increasing destruction of symmetry and perspective, took as its erroneous point of departure an “*a priori* knowledge” (D.-H. Kahnweiler) of geometrical figures: spheres, cones, cylinders, upon which — according to Cézanne — everything in nature should be “modelled”; colors would order themselves “as great noumena, corporeal ideas, beings of pure reason, as they please”, according to Cézanne, the disciple of Kant. (On the error of art philosophy, see 11.8.2, 11.8.4)

My discovery of a new view of *symmetry as a developmental principle* produced in me an encyclopedic sense of joyous discovery. Looking above and beyond the boundaries of various disciplines, I was able to demonstrate that symmetry is a fascinating phenomenon which, consciously or unconsciously, provides perennial stimulation and challenge. I recognized that today, after a long pause, it has become possible to readapt art to the sciences, and vice versa, by means of an evolutionary concept of symmetry. In view of the artistic evidence I had collected on the reality of those form-creating master builders: symmetrization/asymmetrization — with whose aid the artist no longer works according to nature, but rather in the same manner as nature itself — we can state that the new art *ars evolutoria* (see below) can function as an example for the sciences. The obsolescence of classical modernism, including its theory and philosophy of art, is also revealed by its inability to keep pace with the development of theories in the natural sciences, e.g. the scientific and cultural significance of the theory of evolution, doubtless the most important single theory in modern science. The “displaced (“ver-rückt”) reference system of modern painting,” in which “the concepts of the sensory world are no longer valid” (W. Haftmann), has hitherto not been able even to approximate the “unity of the world” (W. Heisenberg). The “displacements” of modernism have not been able to illuminate the “meaning of existence” for enlightened and scientifically educated 20th-century man (see 12.3).

In Part 1 of my book (completed in 1975), I concentrated on the phenomenon of symmetry, a phenomenon which could hardly be more manifold. Here, an object of knowledge was taken up which promised to overcome the fragmentation of science into individual disciplines, and of thinking and action into specializations that had become mutually unintelligible. Symmetry, if viewed as evolutionary instead of non-dynamic, appeared to me as being the Ariadne’s thread that can show us the way out of the labyrinthine realms of science, out of the old and the new unclearness of our world. The concepts of symmetrization/asymmetrization could indeed be a royal road leading to a new unity of science.

Part 2 of my book: *On the Problem of Organic Form Development* (Chapters 6–7.2.2), dealt particularly with biological questions. Here I discussed the points of contact between form-developing processes in nature and art that provide a theory of form, its development and its transformations. Emphasis was placed on the idea of symmetry at the beginnings of a dynamic, organic theory of form: Goethe, de Candolle, Darwin, and others (see 7.1–7.1.5). Plant teratology proved to be a treasure trove for *a posteriori* symmetrizations and asymmetrizations that can be observed today (Section 7.2.1). It was

ascertained that living nature behaves like an artist who does not permit himself to be restricted to the merely useful: The “mutation-selection theory” was surmounted (Sections 7.2–7.2.2).

The collection of new and increasingly precise data on perception and knowledge in regard to the postulated reality of symmetry then led to a further development of the “evolutionary theory of symmetry” (*Evolutionary Symmetry Theory*; EST) in Part 3 of my book: *Evolutionism/Ars Evolutoria — Theory of Light/Color and Form, Morphogenesis, Morphomutability, and Morphoevolution as Causal Form Theory* (Chapters 8–13). My purpose here was to present for discussion the facts and problems of an evolutionary concept of symmetry in its applicability to many fields of dead and living nature, to the liberal arts and natural sciences, and to society. It was my desire to stimulate a discussion of the *Evolutionary Symmetry Theory* that would transcend the boundaries of individual disciplines.

The knowledge gained through the interaction of discoveries, new evidence (often experimental), and theoretical concepts was concentrated on the paramount importance of symmetry for understanding evolutionary events in nature and art. In many areas, this knowledge produced convincing arguments, e.g. the conviction that inter- and trans-disciplinarity in symmetry research leads to a recovery of scientific perceptual abilities which are hindered by individual disciplinary developments, by atomization into individual fields.

Transdisciplinarity involves the development of an overarching paradigm encompassing a number of scholarly disciplines. The theory of symmetrization and asymmetrization as a theory of form, formation, and form-variation/mutation (“evolutionism”, “neo-evolutionism”) illustrates a transdisciplinary framework. The components of this theory (modern painting, art theory, evolutionary biology, natural philosophy, psychology, geometry, physics, chemistry, cosmology, music, etc.) are not only linked internally and closely interwoven through integration by the theme “symmetry”; in addition, the disciplines (monodisciplinary fields) are subsumed in the transdisciplinary concept “symmetry” under a supradisciplinary paradigm. Superintegration as the ideal of a unified science would be attained if all science could be reduced to a general theory of form.

Here are only some of the results and aspects of my transdisciplinary consideration of symmetry:

- Evolution of a form is unthinkable without total disdain for, and renunciation of, form. Dissolution of form in the sense of a transformation of totalities via symmetrization/asymmetrization is in the service of a morphoevolution (Section 8.1 ff.).
- Cell division in uni- and multi-cellular animal and plant organisms can be interpreted as mirror-image symmetrization. Likewise, in meiosis and DNA doubling I recognized symmetrizing formational processes. M. Eigen has postulated a mirror-image symmetry in the structure of the “Ur-gene”/“proto-gene” (Section 10.3.5.4).
- The demonstration that changes of dimension and proportionality in ontogenesis and phylogenesis are primarily based on symmetrizations linked with asymmetrizations (Section 10.3.4 ff.).
- Light proves to be a causal factor in symmetroclastic and symmetrogenic morphogenesis and morphomutability (see *Fucus serratus* as an example; Sections 10.3.4.6, 10.3.5.3, 10.5 f.).
- The hypothesis of the inherently symmetrical and potentially bisexual “Ur-ur-ur...cell”/“proto-proto-proto...cell”. Sexuality as a mechanism for triggering form-giving symmetrization (Section 10.3.6 ff., Section 10.4.4). Love as an act of symmetry (Section 10.3.4.2).
- Model concepts on symmetrization. Evolution from unicellular to multicellular organisms via morphologically “primitive” diplocells, tetrad and octet forms (Sections 10.4–10.6).
- Demonstration that the master builders symmetrization/asymmetrization are the foundations for perception of objects and orders as well as discernment behavior, cultural evolution (Chapter 11 ff.).
- Discovery of double-mirror sight as binocular double stereoscopic vision that can be used to develop a symmetrization theory of perception via a plethora of controllable reproducible experiments with forms and colours (Section 11.6 ff.).
- Mirror-image symmetry as a law of form and composition, and the “principle of precision” in Gestalt psychology (Section 11.6.5).
- Symmetrizations as the basis of all cogitation and memory (Section 11.9.4).
- Experiments indicating that white visible light has a symmetrical structure (Section 11.7).

- Refutation of the dogmatism of “absolute and blind chance” (J. Monod). Order in chaos (Section 11.9.6).
- Ethicization via social symmetrization (Section 11.9.7, Chapter 13).
- Evolutionism as the third basic direction in philosophy, being neither materialism nor idealism (Section 12.2.3).
- Evolutionism as a unification of ambivalences: “great realism” — “great abstraction” (Section 12.2).
- Symmetry as a developmental principle in music. Foundation of a *musica evolutoria* (Section 12.5).
- The light-matter/antimatter-energy primary model (“Urform model”) of evolution as a key figure in clarifying evolutionary processes, providing access to a “graphic atomic dynamics”. Protomorphology and protomorphogeny which deny that the universe began from nothing, and postulate the dissolvable multiunity of the infinitely small in dynamic geometry: Ur-ur-ur/proto-proto-proto...symmetrization center, Ur-ur-ur/proto-proto-proto...geometry, Ur-ur-ur/proto-proto-proto...three-dimensionality, Ur-ur-ur/proto-proto-proto...mathematicity, etc. (Sections 12.6 and 12.7).

The results of my investigations thus overcome disciplinary limitations and embarrassments: The “dynamic concept of symmetry” and the method of interdisciplinary parallelizing makes it possible to attain an overarching pervasion of the “key theme: symmetry” in the fields of art, the humanities, and the natural and social sciences, a comprehensive integration and unification of the reality of art and the laws pertaining to it, together with the reality of nature and the laws governing it. This new direction in art: *ars evolutoria* or *evolutionism*, originally called “harmonic art” or “symmetrism”, is, owing to its direct provision of experience, outstandingly suitable for making us aware of the fascination of symmetry as an evolutionary construction principle in nature and culture.

Moreover, *ars evolutoria* is based on Goethe, who appraised art as a “true mediatrix”, as the “most worthy interpretress” of natural reality (concept of style, see 11.8). The art style *evolutionism*, which is directed towards the “unity of entirety”, contains, as an integrative perspective, aspects of the following fundamental stylistic directions: realism (cogitation), surrealism (emotion), expressionism (sensibility), and constructivism (intuition) — all reflections of basic human psychosomatic structures — in an overall synthesis (“reanimation of modernism”; see Sections 12.2.4 and 12.4).

The style *ars evolutoria*, with the variants “neo-cubism”, “neo-Baroque”/“neo-mannerism”, as well as “atomism” (“pointillistic evolutionism”), provides a possibility for presenting and elucidating additional comprehensive connections that previously could not be expressed in art.

On the one hand, I used the expressions *ars evolutoria* and *evolutionism* synonymously as stylistic concepts in this book, but in addition, in Part 3 I achieved an actualization and extension of the 19th-century term “evolutionism” in regard to a philosophy of nature and culture. In my pictorial work, and also in my book, the scientific attitude and the artistic vision are not antithetical. Since the search for unity in nature on an evolutionary basis requires transdisciplinary points of view and hypotheses in order to obtain knowledge of the symmetry/asymmetry phenomenon, and since there are many points of contact with the Renaissance, especially with the searchers and artists — Leonardo da Vinci and Albrecht Dürer, the purpose of my book is to found a *Neo-Renaissance* as a “belligerent movement”.

This new concept for a new style and a new epoch: “Neo-Renaissance” as a constant challenge to cultural reflection, thus designates a new beginning for a comprehensive and evolutionary knowledge of the world obtained by a union between science and art. In view of the linking and interaction of the two, my book places critical emphasis on the art and cultural history of modernism: a plea for a positive, culture-forming attitude towards art. (On the dilemma of avant-gardism, together with its “kingmakers”, see 11.9.9, 12.3, 13.) I hope to establish and encourage a dialog between institutions, disciplines, and persons involved in cultural activities of the present who so far have carefully avoided taking one another seriously.

In addition, the book is intended to lead to a new understanding and consensus between competing world views, and between the cultural and natural sciences. On the basis of the universality of the form-creating and form-changing evolutionary factors: symmetrization/asymmetrization, and in agreement with the *evolutionary epistemology*, perspectives also emerge for a new and progressive philosophical direction, with the goal of “social symmetrization”, i.e. ethicization by means of growing knowledge (see 11.9, 11.9.7, 13). The *Neo-Renaissance* is convinced that man and society are capable of further education and development in the direction of perfection. It advocates the surmounting of the “fragmentation of our world view” (R. Riedl) by building a bridge between nature and mind.

Thus it is important “to have unrolled the phenomena of symmetries in their full breadth to a monumental work; whether in quanta, atoms, and crystals, or in corporeal forms, senses, and brains, or in the forms of all the artifacts that have originated from human activity. Only then will we become aware of our potentialities: the concert of relations that joins the inorganic and the organic, our sensibilities, our thoughts, and our deeds; that which reciprocally unites nature and culture in the human psyche.” (Riedl; see the preface of the book).

In the hope that artistic creation and theoretical reflection in the new movement *Neo-Renaissance* (science art, neo-modern art; see Chapter 13) will not be understood by only a few, the present book, despite the unusual multiplicity of aspects and projects contained in it, is intended as an introduction to this new material for the interested layman. In spite of all the documentary evidence that it presents, the book is possibly too short in places. However, a presentation of all the data would have made the book even more voluminous, and thus less appealing to the large circle of readers it was written for.

In publishing these practical and theoretical research results, I hope not only to motivate the knowledgeable reader to recognize new tasks, but also to invite him to make suggestions for improvements in, and further developments of, the material presented here.

Although the German first edition of my book on symmetry (Hahn, 1989/1995) already contained the above preface, I would like — as a sort of epilogue — to remark the following on this edition:

My book on symmetry, which has been called “giant opus” (Sitte), “monumental work” (Irrgang), “opus magnum” (Der Spiegel) and “masterpiece” (Nagy) (“in the footsteps of Leonardo”, according to Ohff, Der Tagesspiegel, Berlin), has meanwhile been recognized as the key work on an *Evolutionary Symmetry Theory* (EST). In 1991, inspired by an excellent book review (Großmann 1990), I started the “Action/Initiative EST”, which in 1993 resulted in the successful “International Frankfurt Symposium *Evolutionary Symmetry Theory — Self Organization and Dynamic Systems*” (Hahn 1994, Hahn/Weibel 1996; see as well Gutmann 1996, Wuketits 1996).

Because of its historical significance and since no falsification (i.e. defeat of my theories) has been presented as of yet, the present edition is the *original version* of the work (Hahn, 1989) translated into English *without alterations*; neither in the text (Chapters 1–12.7) nor in the figures (Figs. 1–689c and the 10 colour plates) have alterations been made. However, Chapter 13 with 10 sections has been added to the English edition so that a supplement had to be made to the subject index, the author index and the bibliography. The following *keywords* (see Chapters 13–13.6) reflect further development of the main ideas of the basic work.:

asymmetrization/symmetrization principle (hypothesis, reciprocal mechanism), social asymmetrization/symmetrization (asymmetrizing initiative and resymmetrization), iso- and aniso-symmetrization, initial or primary asymmetrization, secondary asymmetrization (transformation), science art (neo-modern art/trans-modern art/ultra-modern art), auto-evolution, self-organization, evolutionary aesthetics, evolutionary geometry (bifurcation morphology), evolutionary humanism, neo-evolutionism, holo-evolutionism, holistic natural theory, universal theory of evolution, ethical universalism.

In the past nine years, the results of the work were widely spread, particularly in the Germanophonic regions. Meanwhile (on 14 May 1992) I received a certificate from the President of the German patent office granting me a patent for the “mirror construction” (see 11.6.6, Fig. 434); In my book I attach particular significance to the double mirror-experiments. In view of the scientific and artistic success of my book, I would be delighted, if the reader of the English edition of the work took the same view as Professor Dr. Dr. Gerhard Vollmer did, who — after reading the book — remarked in 1991:

“(…) we have to do with a marvellous compilation, an encyclopedia full of life, full of inspiration, full of ideas, full of references, associations, relations. I feel unreserved admiration for this gigantic, lovingly compiled and splendidly got up work. Congratulations to you on the completion of the work and its richness of content. As far as my knowledge goes, there is no other work that could stand up to comparison.”

My book provides a broad foundation for further discussions, cooperations, empirical studies and theoretical reflections in natural sciences, humanities, philosophy, modern art and music (see Hahn/Weibel 1996). With regard to the English edition, I hope for a similar judgment from the part of the reviewers, in analogy to the judgment of renowned chaos researcher, Siegfried Großmann (Großmann 1990):

“During 20 years of compilation, Hahn succeeded in creating an admirable book in which he traces the enormous treasure of observations made in nature and culture back to a few underlying structural principles. (...) The content is not merely contemplative, not mere curious observation, but the demonstration of a comprehensive hypothesis, devised as the result of experimental and theoretical research: symmetry as a far-reaching, leading, structuring, causal element of evolution, as the idea lying behind nature and culture. (...) The book is full of suspense and worth-while reading: symmetry as Ariadne’s thread through nature and art as ‘cause, source and driving force of evolutionary dynamics’. (...) Interdisciplinarity and general course of studies at their best. Literature as a link between science and art. Strongly recommendable.”

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Gladenbach, May 1998

For Sleglinde, Melanie and Oliver

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I extend my gratitude to all those who supported me with advice, interest and goodwill during the many years of my research. I am particularly grateful to Professors Werner Hofmann, Rupert Riedl, István Hargittai, Dénes Nagy, Hermann Haken and Arne Wunderlin, Friedrich Wilhelm Gutmann and Peter Weibel, Rudolf Wille as well as to Dr. Franz M. Wuketits for their support and interest in my works. Cordial thanks to (university) Professor Dr. Rupert Riedl, chairman of the department of zoology at the University of Vienna, for his introductory remarks to the world of symmetries; a “very readable, genuine introduction” (according to Peter Sitte in a review).

Moreover I would like to thank the publishing house *World Scientific Publishing Co Pte Ltd*, Singapore, for their assistance in publishing the extended English edition of my book on symmetry, which will be distributed worldwide. The book provides a sound basis for further reflexion at different levels and in various disciplines of the natural sciences as well as the cultural sciences. It would be a great pleasure for me to see this work continued — now on a global scale (also see Hahn 1990, 1992/1995, 1994, 1997; Hahn/Weibel 1996).

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