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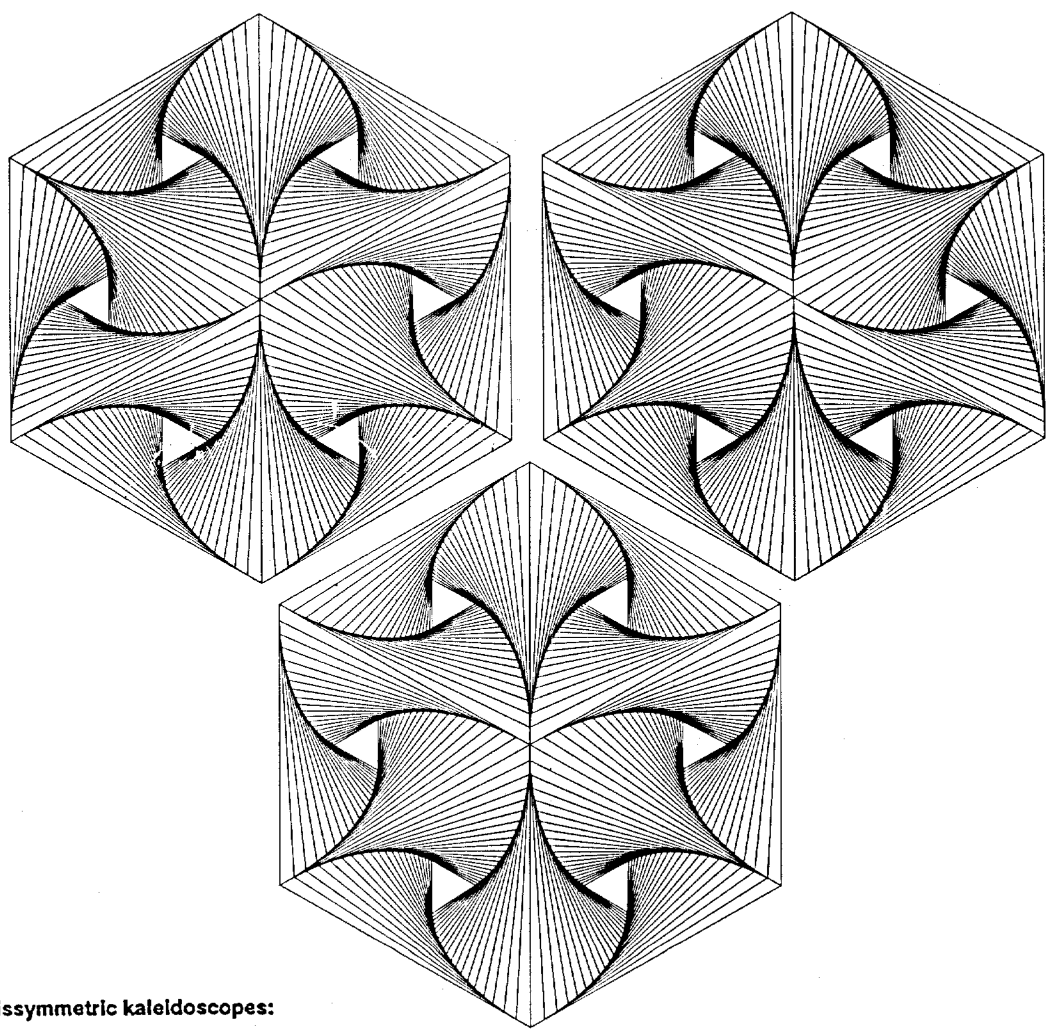
Symmetry: Culture and Science

SPECIAL ISSUE
Symmetry in a Kaleidoscope 1

The Quarterly of the
International Society for the
Interdisciplinary Study of Symmetry
(ISIS-Symmetry)

Editors:
György Darvas and Dénes Nagy

Volume 1, Number 1, 1990



Dissymmetric kaleidoscopes:
Hommage à Pasteur

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Symmetry: Culture and Science
Vol. 1, No. 1, 1990, 77-91

SYMMETRY IN EDUCATION

ON SYMMETRY IN SCIENCE EDUCATION

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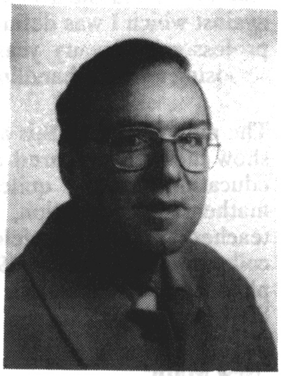

Fields of interest: History and philosophy of education (esp. 18th and 19th ct.), interdisciplinary education, philosophy of science, history of art (esp. architecture); collects graphics (fantastic baroque architecture), 20th ct. pottery.

Publications (see also list of references): Rousseau und die Verhaltensbiologie. (*Vierteljahrsschrift f. Wissenschaftliche Pädagogik* 57, 1981); Principles of environmental education as a basis of ethnospecific education. (ICSU-CTS-Conference "*Science and Technology Education* ...", Bangalore 1985, Health 32); Science theory -- Conceptual "versus" empirical study of scientific progress. (*Berichte des 11. Internat. Wittgenstein-Symposiums*, Wien 1987)

Books in preparation für 1989: Symmetry im Unterricht; Bausteine zur Anthropologie der Wissenschaft. (coll.papers on philosophy of science); (ed.) *Joachim Jungius und die Traditionen und Tendenzen einer "Praktischen Logik"*.

I. SYMMETRY AND CAUSALITY, OR: HOW TO BECOME AN EDUCATIONAL SYMMETRIST

Preprofessional Preludium

Since I was thirteen in 1953, the year that Wernher v. Brauns "Station im Weltall" appeared, it was certain for me that I would become a "space scientist", and I lived with these wellknown imaginations of limitless journeys through space in the same naive sense as v. Braun himself did in those days. In addition, thus preparing the next step of development, I sketched buildings of space centers, very dramatic, but completely disfunctional high tech fantasies.

In 1957 -- that admirable, sensitive starting consciously into culture age of seventeen -- I met with Frank Lloyd Wright's architecture. His spectacular structures, playing elegantly with technical and spatial fantasy, his convincing relation between repeated basic elements and their asymmetric grouping -- in fact a constant of modern architecture, but there related schematically to common reception mechanisms, with him an expression of individual, slightly zynical game -- since has continued to be a passionate love of mine. No doubt, I would become an architect! -- But it is hard to compete with F. Ll. Wright, and my own sketches rapidly demonstrated me my limits.

So when things became earnest at the end of school, the space scientist regenerated, now turned into a serious plan: to study physics (with its common obligatories

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mathematics and chemistry, and besides philosophy, education, and -- what remained from architecture -- history of art). When coming close to the end of this quite normal curriculum I had the good fortune to meet again, from the side of physics, with those problems I felt well attached to: with the laws of regular space and its irregular peculiarities, as they appear in optics and solid state physics. Esp. my diploma's thesis, that dealt with electron microscopy of crystal defects in semiconductors, strongly developed my feeling for physical consequences of symmetry arguments, and for their limits in crystal defects by thermic statistical laws, too. Happy enough, my institute -- led by the Clemens Schaefer disciple Johannes Jaumann -- laid great emphasis on understanding and solving problems by sophisticated common sense thinking, by symmetrical plausibilities and general laws guided trends, instead of just getting effects by formal calculation (not to speak of computers and the accompanying syndrome of letting them think instead of yourself, against which I was definitely immunized from the very beginning by my mathematics professors). Twenty years later I met with the same mixture of problems when opposing modern handling of selforganisation.

The meaning of all this autobiographic stuff, justification of its being told here, is to show me well prepared to realize the interdisciplinary importance of symmetry for education, when I quite surprisingly found myself as an assistant professor for mathematics education, after I had modestly just asked my former mathematics teacher, Kurt Honnefelder, what professional chances there were at teachers' colleges; that was in 1965. (Apart from this I prepared my doctoral thesis in philosophy of education, but this has turned out to become an independentstring of life -- seemingly).

"New Math"

In 1965, I rushed right into flourishing "New Math" in school, a fashion that had been imported to Germany from America with a few years' delay. Let us remember its two roots!

The first, which is not so important for us here, was the postulate that there was a gap between mathematics in science and mathematics in schools that should be bridged by a basically new, a truly modern concept of mathematics in school. The reasons should be national welfare (esp. successful competition with socialist states) and individual emancipation by means of what was pretended to characterize modern civilization, science; the way to do so was approximation of the topics and styles of school mathematics to those of scientific mathematics. The latter was found to be grounded on certain basic structures and constructed from them deductively, whilst the topics of old fashioned school calculating took a rather peripheral place within this modern construct, which appears systematically seen very "late", too. Exp. the set of "Bourbaki's" structures were taken as the representative stream of modern mathematics, and its basic structures like sets, topological and arithmetical relations seemed to fit well into the aim of school mathematics to construct a system of knowledge that starts with simple basic ideas.

In fact, the latter idea marks the second root of New Math, and it will lead us immediately to symmetry, too: For the Bourbaki structural development of mathematics seemed to have a parallel in the development of the minds of children, as developmental psychology claimed, of whose various streams the works of Piaget had become the most prominent.

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With respect to his findings, it was not so surprising, I think -- in spite of what some educators said -- that these psychologically dealt structures could be expressed in terms of mathematics; for *if* you are in search of the structures of mind, and *if* mathematics is understood as the systematical elaboration of the structures of mind (as many philosophers ofmathematics take it), it might be *expected* that these structures of mind can be expressed in terms of their own systematization, mathematics.

Of really startling interest for educational purposes, however, was the pretended finding that there was a parallel between the *systematic* order of the construction of mathematics, in the sense of Bourbaki, and of the *chronological* order of the development of children's formal mind, as developmental psychology had pointed out. Now I called this idea an only *pretended* finding because in fact it was more something like a plausible hypothesis and an analogy, thus a program for future empirical research. Nevertheless, doubtful as it was in both respects -- really describing scientific mathematics or psychological facts(?) which both might be open for historicalchange? -- in spite of these doubts this hypothesis could have served as a basis for imaginative and fruitful curriculum construction in a normative sense just if it does *not* describea bold factum.

But we all remember what really happened instead: neither the one nor the other path, but a disastrous third one, that turned New Math a verbal formal drill, thus producing that the structural concept of school mathematics as a general concept has been omitted again and since has become a taboo on the conceptual level, though on the practical level it urged some reforms in classical syllabus of calculating, mainly towards techniques of problem solving.

I watched this misdevelopment with sorrow, for I felt very well what should have happened instead. If the structures of mathematics express the structures of mind, and were to promote them during the phase of their development (which in fact never ends, however), the development of the formal side were to happen by mechanisms of dealing with real objects -- which for other topical reasons should be "learned" -- but which parallel to this activity urge the development of formal structures in mind which may afterwards be abstracted and treated isolated if time has come to do so in a fruitful way. (This depends on age -- later on the autonomy of formal aspects might be more effective.) The educational task would have been to select, or construct, suitable objects, natural or artificial, that would promote this process best, and to accompany and steer pupils during their development. Symmetrical objects which render their structures open to the eyes immediately appear as eminently suitable for this general aim.

I met the same misunderstanding of formal objectives as topics of material learning later, when I returned to my own profession, physics, and to its education. Here, the stream of modern science for primary education had generated a lot of science-based curricula that bore the seed of formalistic misdevelopment, of "Superherbartianism" (Carl Schietzel) and verbal learning-fetishism within its very selfunderstanding -- with one exception (which nevertheless did not escape it, too); I mean the curriculum project "Naturwissenschaftlicher Unterricht in der Grundschule" of the Kai Spreckelsen group. It intended learning of scientific topics on the ground of certain basic and very general concepts (such as preservation, interrelation, corpuscularity) that characterize aspects of the resp. topics and give them an intellectual pattern that refers to that special unity of structures of mind and structures of empirical objects where it is hard to say whether these originate from one or the other side. We see: it was the same intention as that of New Math, and it seems clear -- but nevertheless

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did not work -- how to take place in educational reality. Structures do not "exist" autonomously, but only as the structures of those *realities* the structure of which they are, and our mind has evolved to be capable of them implicitly and work with them, and so, by working with them, happens their development, in a basic sense during all live; (furthermore however -- what makes him a *human* mind -- he is able to become conscious of these structures by abstracting them from reality and to systematize them, the result of which will be [explicit] mathematics).

Already during my solid state physics studies I had experienced the stimulating relation between topical considerations and formal "play", between strict calculation and problem solving by illustrating "with hands and feet". In mathematics education, my professor broadened this understanding by his love of group theory and its application *to* -- and vice versa its generation *by* -- ornaments. "The Wolf-Wolff" (1956) was continuously at hand and exhibited the wide horizon of symmetry in art and architecture, in biology, chemistry and formal symmetries in mathematics. We tried to implement this feeling within our students. But as far as we could see, most of them "learned" it as just another topic. So -- was it a suitable concept only for an elite, or is it of common importance? The question is still open, but the concept seems convincing, yet it has never been tested seriously.

Now an ideal is valid beyond the limits of possible reality. Symmetry as a ferment of holistic mental development -- perhaps I am the only educator who still is convinced of the charm and chances of "New Math" for school: as a possible concept to unify instruction, inner development and beauty.

Self-organisation

Meanwhile we live with another international fashion that has become a melting pot of hope for comprehensive unification of sciences under a general idea: "self-organisation", that gets of increasing importance in education, too.

By calling self-organisation, as a topic of contemporary science, a "fashion" I refer to its claims to be an new scientific stream, rendered possible only by new, during the last years developed methods (non-linear processes, "chaos"-theories), or even by complete new sciences ("synergetics"), and that it appears in the public with all features of a fashion show.

The recent discussion in the field is still quite complex and characterized by lack of clearness -- at an international workshop I participated last year, the term "non-linear" was used in at least five different meanings, without any attempts of discrimination --; if we try a bold résumé we might say that the term "selforganisation" refers to spontaneous processes of generation of order that happen far from thermodynamic equilibrium (Prigogine), thus conflicting with the 2nd thermodynamic law, that is said to postulate a general spontaneous increase of disorder in nature, which contradiction now may be explained by using new ideas of thermodynamics of irreversible processes.

In education, these ideas have become of increasing importance; they are said to have farreaching consequences as for the implementation of new topic, so for the treatment of classical topics like thermodynamics (change in valuing the basic laws), in biology (with respect to life as a spontaneous process gaining order like genetic code, metabolism...), and of course in -- what never will be far! -- philosophical "Weltbild".

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I certainly will not try a systematic criticism in what is just an autobiographical sketch. I will only mark some aspects of astonishment that I developed "spontaneously" and which relate to our topic, symmetry, and are as I hope evident immediately.

- In contrast to the opinion that selforganisation is a recent topic rendered possible only by developing special (of course: computerbased) methods, modern (post-Galilean) science to a large extent just has developed *by* dealing with such processes. In certain respect we might even say that science is identical with the attempt to explain processes of selforganisation. Indeed, if we try "to explain what may happen in nature in a natural way, effected by those laws that constitute nature", this looks like a description of selforganisation, but really quotes 13th century's Albertus' Magnus definition of *science*. And if we illustrate this general scientific aim by examples like the explanation

  - of structure and genesis of planetary system (Keplers laws, Newton-Kant-Laplace theory),

  - of crystal structure and growth (see next chapter),

  - of evolution of genetic code (Watson/Crick), of life (Darwin), of culture (Herder) --

we see that they are characterized by aspects of selforganisation -- and by symmetry to a great extent.

- It seems to me a strange enterprise to try to explain processes of generation of order (whatever that may be) it is not clearly elaborated a term, anyway!) just by means of a scientific approach which explicitly was developed to install most general laws for processes of disorder; why not better start with methods constructed for order? I certainly do not say the reverse attempt must fail -- this would be contradicted by the doubtless success with suitable problems -- but it is an unnatural attempt that raises a false image in the public.

- Beyond the beforementioned problems of the style of performance, the used relation between disorder and the second law is only an analogy, not a scientific finding, because one may *never* get scientific extensions from common sense interpretations of a scientific law, but only more or less vague analogies, which afterwards need scientific proof -- or suffer refutation.

- In this case the "disorder" interpretation is wrong, for this interpretation originally has been used by Boltzmann only to render a didactically simple illustration of the simplest case in statistical thermodynamics, namely the behavior of a system of *independent* particles. Processes of selforganisation, however, do not happen with independent particles but with such that are related to each other by *forces*. It is possible, indeed, to specialize the laws of thermodynamics that way, that they comprise also the processes of interacting particles, and this certainly becomes a sportive caprice of scientists, the stronger the forces will be.

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- But starting with methods specially designed for *interacting* particles, the *general* consequence will be the very *reverse* of the common interpretation of entropy's law: *The general tendency in nature are processes of self-organisation*, that are guided by the symmetries of forces of the interacting particles, differentiated by the regular variations of these symmetries, and only *disturbed* by the statistical laws of the particles' temperature dependent movement.

Thus, selforganisation leading to symmetrical structures, is an *expression of causality in nature.*

II. NIELS STENSEN AND THE SYMMETRY OF STRUCTURES, OR: THE CRISIS OF ATOMISM IN 17TH CENTURY

I want to go back now to the roots of the symmetry -- selforganisation -- relation on the occasion of a recent event. On October 23rd, 1988, Niels Stensen (Nicolaus Steno) has beendeclared a "Beatus" (that means a Saint with provisionally regional veneration) by the Roman Catholic Church. Of course, this honor was dedicated to him mainly in appreciation of his deeply religious life esp. after his conversion from protestant belief and for his merits as a catholic priest and finally as bishop in the "mission" areas of Northern Germany after Thirty Years' War. But quite naturally, this event also draw the attention of scientists on Stensens scientific merits again.

Born in Copenhagen in 1638, Stensen is well recommended as the founder of paleography, of modern geology, and of scientific crystallography, but his first, and fabulously rapid, career was in comparative anatomy, in which field he traced basically new paths in understanding the innersecretory system and the mechanisms of muscles, the brain, and the reproductive system.

In dissecting a shark's head in Florence in 1667, he noticed the relation between the shark's teeth and certain similarly looking findings ("glossopetra") from landscapes far from the sea, that hitherto had been understood as a "play of nature", but which he now tentatively identified as fossile relics of equal animals that had come to that strange place "somehow" (as Hooke in his "micrographia" had vaguely stated already two years before).

Stensen on his side used this first step of insight for travelling through the environments of Florence for the next two years, investigating the conditions of petrefaction and the laws of landscape's development and change. He published his results in a preliminary paper, the "Prodromus" (Stensen 1669) that contains the basic principles of modern geology (Scherz 1971) -- but those of crystallography as well. For Stensen, investigating the form and laws of growth of crystals, is the first to make *measurements* with crystals, and thus gets the law of constant angles between the crystals' surface planes, that, as is well known, became the cornerstone of phenomenological crystallography (other steps on its way to structural science are: the law of rational indices about 1800, the zone law, crystal systems, group theory of crystal symmetry, Laues law 1912; for details of the chemical strain see Schmidt 1987, p 147ff).

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One would expect that Stensen, as some of his forerunners had already tried (or later on Haüy in fact did), would have used atomistic ideas in order to explain his law, but strange enough he did *not*, though he was very well informed about the atomistic ideas before and around him, as Schneer (1971) has pointed out. This strange fact still needs sufficient explanation, since Schneer in doing so stopped half way, and we will try to do this here, because it will give us interesting hints for the use of symmetry in science.

Christoph Meinel recently (1988) has described the development of atomistic theories through seventeenth century, changing from a deadly personal risk, for its common understanding as "materialistic", to a commonly accepted theoretical background in chemistry and natural philosophy. The arguments in favor of atomism referred to philosophical epistemology as well as, mainly, to empirical findings, but these arguments must be considered of mere declamatory character, since Meinels critical examination of them comes to the conclusion, that the epistemology was classical, the empirical facts well known since long times, and the "derivations" of atomism lacked inductive strictness.

Now, Meinels call for *strictness* in inductive arguments, for "proofs" of atomism, certainly is too strong a demand. That induction in science is no logical method in a common opinion of methodologists; rather it is a complex texture comprising deductions, plausibilities, fashions, innate laws and historical ideas, which usually leads to conviction, but rarely to a true experimentum crucis (Feyerabend 1975, Klein 1983). So the next step in understanding should be to see "by what exact mechanism the corpuscular theory, despite the obvious lack of experimental support, was able to win so many adherents among those who considered themselves empirical scientists" (Meinel 1988, p.103), but this explanation lacks, too.

Meinel in his considerations excludes the stream of crystallographical attempts towards atomism, but we should mention it here, because here things were even worse: atomism raised true difficulties which could not be overcome till late 19th century. Already in 1611, Kepler tentatively had given the well known atomistic explanation of snow crystals: a honeycomb -- like structure of densely packed spheres indeed would have given the observed hexagonal angles of snowflakes, but Kepler refuted this idea as a "nothing" not only for philosophical reasons, but also because his explanation met the problem, how then to explain the many *different* angles of other crystals, and this continued to be the problem for all similar attempts through 17th century by Descartes, Bartholin, Hooke (references see Schneer 1971), and still Dalton for his atomistic ideas had to confine himself to the laws of constant and multiple proportions, but did not manage to derive any truly explanatory structural images of molecules.

So there was a "decline of corpuscular theory during Newton's age" (Heller 1970, p. 86); nevertheless "both theories existed side by side: a doubtful atomism, and a theory of immaterial forces. The unity of physics had gone lost though physicists weren't conscious of it" (Heller 88). "Corpuscular ideas kept their popular validity, because they seemed conspicuous and simple, but their scientific power was small, because they could not be expressed in mathematical terms, and hardly could be combined with mechanical principles". (Heller 87, my transl.) This continued to be the case until late 19th century when the marked limits of mathematics as well as those of mechanicism were overcome.

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Stensen was the first to move into that direction, esp. for overcoming mechanistic limits. He did so by means of his characteristic combination of sensitive empirical confinement and elegant imagination that is so typical for his scientific personality. He was too careful a methodologist and hat too much truly crystallographic knowledge about crystals (Schafranowsky 1971) as to be consent with a merely declamatory explanation of what he had *seen*; and with stupendous structural instinct he concentrates on the *surfaces* of crystals in order to explain their regular growth (Stensen 1669, ed. Scherz 1967, 68f). By considering both, the influence of the inner forces on the already existing crystal surfaces, and the possible material transport in the surrounding solution, and illustrating what happens by a "magnetic" analogy, he comes to a "hypothesis of oriented forces" to direct the growth of crystal surface (Schneer 1971, 293).

What is the meaning of this idea? Stensen, in need for an explanation of regular surfaces, neglects all those too simple atomistic suggestions of his contemporaries which he knew very well. Instead, he gives a kind of explanation which we might call a "structural phenomenological" one, and that we might declare to be the first step towards a field concept of matter -- in what respect?

Up to Stensen, the question what atoms "look like" was a matter of geometric arguments, metaphysical ones with the postulate of regular (platonic) bodies, or descriptive ones resulting hard spheres; anyway, atoms were supposed to be solid bodies in the sense of Descartes' metaphysics: hard, impenetrable substantial portions, occupying a certain spatial portion. But here, arguing had to stop, for there were no further arguments based on experience to differentiate these ideas, and there was no sensual evidence, since atoms were defined as "invisibly small". So in fact it was a correct decision to neglect all this and to confine himself to a theoretical image of qualities directly accessible to observation. Mere correctness however turned out to have been ingeniousity, since Stensen emphasized just that aspect, orientation of *forces*, which later on in fact became the basis to overcome mechanicism; but it lasted for another two centuries -- and needed all empirical data gathered since for elaboration -- until atomism could be integrated into that "Field" concept. Atoms then lost their character of being "a-tomos", i. e. indivisible entities, but became empirical "minimalia", portions of matter with soft surface and internal structure: no longer defined by sharp boundaries, but by the sphere of influence; no longer impenetrable bodies, but centers of interacting forces; no longer geometrical objects, but defined by oriented forces; in brief: defined by the *symmetries of their fields*.

Let us try some educational consequences. If we examine school text books of physics or chemistry for secondary I level on how they deal with atoms, we will find the same kind of argumentation -- or: non-argumentation -- as in 17th century science (Klein 1975, part I): They play the same role as a background theory of general validity, but as a mere information which the pupils are talked; into plausible indeed in some sort of simple persuasion by means of lack of alternatives, but far from being gained as general ideas by inductive guessing on base of firm experience, and reversely, also far from making use of these ideas by deducing macroscopic phenomenological effects.

Usually, this kind of basic atomistic information is continued with informations about scientific knowledge of the *structures* of atoms which suffer from the same insufficiency: not to be gained by active imagination about already existing knowledge nor being used for the prediction of effects; especially not accompanied by a feeling for the various aspects of a "symmetry of forces" concept of the atom.

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The analysis of Stensen's problem showed us the copiousness of a restrictive yet imaginative "play" with general ideas that is not limited by what we "know for sure". Of course, the genius of Stensen, as of every great scientist, cannot be imitated; careful help of the teacher has to take its place to set pupils' mind free for critical imagination.

III. "GAMES WITH RULES", OR: SYMMETRY AS FERMENT OF MENTAL DEVELOPMENT

I want to sketch now some ideas for implementation of symmetry in education. From the beginning of my work in science education I have developed such ideas and tested them on various school levels. Only few fragments have been published yet (e. g. Klein 1980, 1986), but I hope to present a book on the subject in summer, 1989. Part of the concept recently has been integrated into the Hamburg Comprehensive School, Secondary I General Science Syllabus (Freie und Hansestadt Hamburg, 1988). The full range of possible interdisciplinary role of symmetry cannot be treated here for reasons of briefness; I want to confine myself to some remarks on primary mathematics and secondary science.

Symmetry in school should not be considered as just another topic of instruction for learning by heart; it will show its full richness only when taken as a general horizon of mental development, a vivid and multifunctional ferment of mental formation ("Bildung"). With respect to science education, two further views should act as general background ideas:

- The idea that our mind, as the medium of understanding the world, is the product of its interaction with the world; thus mind receives its shape by the experience of the world during its development, individual or general (in evolution); but reversely, that the mind also shapes the conception ofthe world, by applying its structures to the world (the idea of Kant).

- The consciousness that the empirical order in nature (e.g. symmetry), and the control of natural processes towards this empirical order by natural laws (selforganisation) are just two different aspects of the same thing.

Finally, considering the realization in school, the basic postulate would be to keep away from mere verbal instruction, but to aim for a participation of the whole personality of pupils. Esp. in lower classes, this may best be achieved, artless and very suitable to the topic, by true manipulating work with appropriate materials and techniques. Preferable exp. for scientific modeling would be types of material which do not command a *special* interpretation (e.g. "this is a NaCl-model"), but those types which, by its various "bricks", "building elements" or whatever, just show certain symmetrical qualities, but otherwise are free for concrete interpretation (to my knowledge, the most versatile material in this respect is "Geomix" from Ratec/Frankfurt).

The advantage of this feature is that constructing and modelling activities get the character of games that follow certain rules, yet have an earnest background (it is not necessary to declare a certain activity to be "art" or "mathematics" or "chemistry", not even in the mind of the teacher!) A vivid variation of the different levels of meaning seems a most important method to promote both, formal development, and topical learning.

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These four basic axioms in mind, symmetry might be considered an outstanding medium of education, since it fulfils nearly all formal requirements which might be marked for fertile topics of instruction:

- It aims at *interdisciplinary* approach since it deals first with formal conditions of understanding applicable to all possible objects of experience;

- It renders *basic*, *constituting* objectives, thus relating structures of mind with structures of objects;

- It relates objects of learning to each other, thus rendering possible *shaped*, *understanding* learning;

- All formal laws raise from and remain closely related to *sensual experience*;

- A deep feeling of comfort is raised by having symmetrical orders open to our senses; this affects our sense of *beauty*;

- Learning with symmetries may be based on *action*, and action will continue to give a basis of understanding for complicated problems: the promoting unity of action, of sensual and intellectual activity in understanding will be experienced;

- These activities may be abstracted and *formalized* towards mathematics, simple enough, yet basic, thus *evolving* the mathematical interpretation of the world;

- On the other side, they are applicable for detailed *concretization*, but with basic principles as promoters;

- These problems also cover *all school levels*, but its typical subjects are not too far from traditional school topics, so that implementation would not raise serious difficulties: it is more a *new spirit* than new contents that are aimed for.

Of course, there will be, and shall be, some subjects which school hitherto does not deal with , or subjects, that will be introduced "too early", and teachers might be in fear of additional stress, and of enlargement of already overcrowded curricula. This would be an unnecessary fear, since, you remember, the intention is not to introduce problems artificially, but that the problems *introduce themselves*, so that it would be an artificial obstacle to keep them from affecting pupils' minds: the intrinsic logic and inner dynamics of the symmetries of the used materials, methods ... should (nearly) always generate the problems being treated, thus creating a sort of *selforganisation of problems*, so that the result, though it demands hard motoric and intellectual work, should be joy and relief.

I will now give a survey of topics I treated in schools on the various levels I had access to. I should illustrate them by pictures, but where to stop, or which to select! On the other hand, this restraint could be an advantage: instead of being limited, your imagination could be inspired -- so feel free in imagining!

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Preschool Level

Activities should *prepare* symmetry exercises by concentrating on *topological* aspects of action and imagination in space, such as:

- Orientation in space (up -- down, left -- right, before -- behind, inclined, diagonal, through, around ...)

- Spatial relations between different objects.

- Connect different objects ("trains", garlands), let them close (chains, necklets, fences), cross each other (bridges, warps), encircle areas, erect boundaries ...

- Study qualities of simple geom. bodies: balls (look alike from all directions), bricks (different types: cubes, blocks, pyramids, bars; different views: surfaces, edges, corners); stable and unstable positions

- Generation of lines by stringing points, of planes by shifting bars (or whirling bars around your fingers, or around axes, or ...), covering space by shifting planes, asf.

Do not drill the children to do certain exercises, but let the challenge of material do the job; vary problems; embed them into "meaningful" games, into narratives, artistic activities; or, at different occasions, abstract them and make them conscious. Very important: make them speak about what they do, this gives implicit selfreference; but do not intend a canonic, or even "professional" terminology, on the contrary: intend a versatile common language, rich with associations, yet precise.

All these are well-known axioms of preschool teaching; just make them rich, and be sure they will effect implicitly what you intend.

Primary Level

The New Math reform of primary mathematics, in spite of its condemnation, in fact resulted a considerable enrichment of classical geometry and of calculating towards activities with symmetry and structures. Apart from regional differences, one nevertheless might criticize in general:

- that they do not go far enough; especially the symmetries of space usually are lacking -- for bad reason: aversion of teachers against true actions ("no time", "no materials") and the difficulty of illustrating them in textbooks. The latter however is the reason for their importance: symmetry operations in space would need a fourth dimension -- the simulation of line-symmetry in (dim n) by a true operation, turning around an axis on (dim n+1), is no longer possible -- so action in space needs also imagination.

- A further criticism is that symmetries are fixed on future *mathematical* use, but neglect the colorful enrichment they could gain by looking on biology, on arts, on music and dancing; in reverse direction, artistic activities, or the beauties and functions of biological objects, lack the deepening by structural insight, which would lead immediately into mathematics. (In general, the

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split into the "two cultures" caused a completely unwarranted fear of mathematics teachers to lose "strictness" by artistic fantasy, of teachers in arts, to hinder "creativity" by disciplined reflection on the process of creation -- numerous books on ornament construction in art nouveau, many of which have been reprinted recently, show the contrary.)

- Finally, the innermathematical use of symmetries in school is too poor, too: the study or the construction of ornaments is shown immediately to lead to classical geometrical problems, whilst the autonomous value of symmetry problems, e.g. first steps into group theory, are estimated low -- grace to the flop of New Math, but without reason, since group theory denotes the structures of our space of experience.

To turn to the subjects of primary instruction now, symmetry would appear especially as a matter of "mathematics", but with respect to the *media* by which it should be introduced, mainly as a matter of "art".

In fact, at this level an approach of a certain systematic character should introduce the various types of symmetry operations. First would be finite symmetries: line symmetry and rotational symmetries; their combinations constitute the full range of rotational structures and fulfil the axioms of cyclic groups. When studying them (in the sense of: playing with them), notice how originally non-symmetry problems come into consideration, too: rotational subgroups and submultiples; line symmetries of rotations, and odd and even numbers; order of rotational symmetry, and fractions and angles.

To add shifting operations (translatory symmetry) will cause infinitely extended ornaments: strings in one dimension, mosaics in the plane, finally lattices in full space. It is an enormous step for children of age eight or nine to understand what really it means to say just "and so forth", and to operate with it -- this needs careful elaboration. New types of symmetry operation will arise from this addition, fulfilling the group axioms again, now resulting the two types of (Felix) Klein's four element group; so the structure of space, insofar it is constituted by symmetry operations, is group theory on Klein's group.

Now construct regular figures by means of rotational symmetry: you get regular polygons; extend this to spread over the whole plane: mosaics; or into third dimension: polyhedra (regular or semiregular, -- the latter are at the intellectual limits of primary children).

Take the simplest and most general one of the polyhedra, a parallel-epiped, and shift it translatory into three independent direction over whole space, and children will get first experiences with lattices; construct regular aggregates of bricks, of matchboxes, cells; for oblique epipeds, take ball -- and -- rodlets-structures, they immediately render experience with symmetry centers, mirror type symmetry in space and the crystallographic law of rational indices -- this happens nearly automatically.

"Automatically" -- that is the key-word for the suitable *methods* of dealing with all these things; for indeed by no means it is intended to go ahead by direct, systematical learning; instead, all these subjects should evolve intrinsically from the structures of materials and methods, most of which, as already mentioned, with classical categories in mind would fall under the topic of "arts".

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The intention with all of them is that the resulting symmetries are automatically generated by the used techniques, so that the more or less surprising effect causes the question why that is so, and what are the details. Well known in this respect, and possessing a lot of literature, generating line symmetry is paper folding, gluing, blotting; for rotational symmetry is folding through centers, puttering with straw ... Regular mosaics are constructed with "elementary ornaments" (paste board or wood) which are encircled and added to each other by continuously repeated rules of symmetry operations. Translational symmetry of all types is most easily achieved by constructions with bricks or spheres regularly pierced and tied together by rodlets (Geomix-type).

Of course, all plane ornaments may also be drawn or painted freely on paper, but then it is a conscious *decision* to regularity instead of an instrinsic automatism of elements or techniques. In some techniques, one finds even both; in Javanese batik, for instance, the restraint to regular design in spite of free "painting" technique serves as a medium of contemplation (Haake), whilst the modern, semiindustrial technique of stamping the pattern with a "cap" represents instrinsic regularity, the laws of which must be considered during production and afterwards are fixed (the same holds for European "blue print" on textiles with wooden stamps, whilst wide spread "potato print" allows both types of design.) The various techniques of weaving, by its different rules of interweaving warp and welt, render convincing examples how a mere technical process implies different symmetrical textures.

Of course, these *active* methods should be paralleled by studying an contemplating *given* ornaments and works of art, by pictures or better with the originals. Take them from murals or textiles, from potteries, weapons, furniture or stained glass. To combine the study of textures with meaning, for instance, when enjoying a Gothic window for its fine edging, tell the narrative of the pictures in the fields, too -- imagine why the medieval artist has combined them!

Secondary Level

This is the appropriate age to experience the dependance of structures in nature from symmetries, and this will last as an "open end" situation -- its ours, too.

You may start with "lattices", on basis of linear and plane translatory symmetry, as mentioned in the preceding chapter; this would be adequate if an extended phase of primary level work with symmetries lacks (as I presumed for the Hamburg syllabus).

You may also start with particles of highest symmetry, spheres, which would restitute the 17th century atomistic approach, with anticipated success today, however, since knowledge increased since to steer this process of learning. In Germany, there is a lot of conceptual work in this direction (Grosser/Bauer 1985, Schmidt 1987) which one might call a "starting chemistry with structures"-concept ("Strukturorientierter Chemieunterricht").

The principal idea is just to *put together a lot of spheres* of provisionally same size (made from styropore, wood, or metal), and to look what will happen. There will be densely packed, hexagonal plane layers, which when stacked up will result densely packed spherical lattices; there are two of them, the plane centered cubic and the hexagonal densest lattices (plus the energetically interesting bodycentered cubic).

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The spheres of course are meant to represent particles of spherical symmetry, i. e. particles which commit equal forces into all directions. This is the case for electrically charged particles, ions (with stripped or added electrons) and metals (with some electrons delivered to the "electron gas").

The three mentioned lattices indeed are the typical structures of metals, and the study of lattice gaps and configuration groups will get a lot of chemical problems, while plausible arguments on stacking faults, dislocations and particle exchange lead immediately on problems of plastic flow and of alloys, thus to metallurgy and solid state physics.

Ions, to their side, are characterized by usually different particle radii, and in fact, when throwing together spheres with different size (preferred ratio of radii are 1 : 2 [for NaCl-lattice] and 3 : 4 [for CsCl-lattice]), the main types of salt crystals will immediately result.

Isolated molecules are constituted by atoms which commit directed forces, so their symmetry is low, and also shows a great variety of subtypes. But the very representative of them is the *tetrahedron* configuration, since the symmetry of four equivalent forces, which is preferred as the symmetry of the four electron pairs of the rare gas shell, shows this shape (Klein 1980). Tetrahedral forces may be represented by all carbon models, or, as a "merely symmetry"-particle, with Geomix by a tetrahedron brick or a tetrahedral pierced sphere. Consequent use of symmetrical orientation of neighbors in Tetrahedral configurations will automatically lead to wide regions of organic chemistry. Nearly all subjects of basic organic chemistry are enclosed, but also subjects which rarely if ever will appear in school -- like cyclo-alcanes or polyhedral alcanes -- and modern important materials like silicates and silicone come into view by the automatisms of modelling by means of symmetry.

The tetrahedral configurations may also be extended infinitely into three dimensions, so that there will result the structures of diamond, semi-conductors and ice, with structural approach to their interesting problems.

Parallel to these structural games, and their interpretation as and application in "classical" themes of science education there should be rich experiences and activities with topics connecting phenomena with structures as Keller (1980) proposed for crystal growth.

Let this be enough for a gross sketch of the fruitful problems which may be generated and mastered by symmetry considerations in science education. I have confined myself to natural science here for reasons both of briefness as of competence; I hope the comprehensive role of symmetry was clear enough, though.

This comprehensive role does not mean, however, that it should happen mainly within comprehensive -- so called "interdisciplinary" or "integrated" -- courses; though frequently favored, this aim usually can result only a more or less diffuse unit of a whole. In contrast, education on secondary level should make use of the full clearness and differentiation of knowledge and problem-solving that is rendered possible by the discursive nature of mind and which happens most effective "classically", namely in different topics.

"Different", however, must not mean "isolated". It was my main intention here to stress the understanding that also during those phases of parallel strings of instruction, these strings should not forget their common roots.

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Symmetry then may act as a background organizer of learning that holds students' minds together and protects them from the stupidity of learning into separated boxes.

Thus, instead of becoming more or less efficient instruction, learning would keep its character as a possible medium of true cultural formation. By its intrinsic beauty, symmetry would connect knowledge with morality -- and that would be the *humane* task of Symmetry in education.

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Symmetry: Culture and Science
Vol. 1, No. 1, 1990

SFS: SYMMETRIC FORUM OF THE SOCIETY (BULLETIN BOARD)

A regularly updated electronic mail version of this forum is also available. Send all correspondence to SFS *and requests to its electronic mail version to* Dénes Nagy *(Department of Mathematics and Computing Science, University of the South Pacific, P.O. Box 1168, Suva, Fiji; Fax: +679 301-305; E-mail: d.nagy@usp.ac.nz). Coeditor* Jarek Woloszyn *(Department of Literature and Language, University of the South Pacific, P.O. Box 1168, Suva, Fiji).*

The SFS *is a place where our members may exchange information or discuss related problems, as in the case of the classical* agora *or* forum, *which was usually a symmetric place in the modern geometrical sense. Although our "written forum" lacks the possibility of personal interactions, this bulletin board may serve as preparation for discussions during forthcoming symposia or meetings of ISIS-Symmetry. Each member may send short notes, usually limited to two hundred and fifty words, about any question which is directly or indirectly connected with the interests of ISIS-Symmetry or its membership. News about recent publications, promotions, and address changes are welcomed. Please give the full bibliographic description of publications (see the conventions in the note "Instructions for Contributors"). Copies of publications (preprints, reprints, etc.) are also welcomed; in these cases the corresponding notices will be prepared by the editors.*

Announcements of events or proposals for projects can be longer, up to five hundred words. Our members are encouraged to send notes about such ideas, planned projects, readings, etc., which may inspire other members, or even lead to joint projects. These items should have a short and informative title, and at the end, the name, mailing address, fax number, and electronic mail (e-mail) address, if any, of the author(s).

Reviews are not published here: those items belong to the section Symmetro-graphy. *It is, however, the usual practice that some publications of our members occur twice in the quarterly: a short notice about the fact of publication here, and a review later in the* Symmetro-graphy *(obviously that section is not limited just to our members' publications). Comments on the papers published in this quarterly and letters of general interest should be directed to* Reflections: Letters to the Editors. *Unfortunately the limited space in this section does not make it possible to publish all notes, and we also reserve the right to edit or shorten them. The notes here do not necessarily reflect the views of ISIS-Symmetry, but only those of their authors. Unsigned items are written by the editors. Correspondence to* SFS *may be sent by airmail, fax, or electronic mail (characters which cannot be transferred or are not available in the standard system [ASCII] should be indicated in a reasonable way).*

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ANNOUNCEMENTS

ISIS-Symmetry Symposium and Exhibition, 1992

The forthcoming symposium of ISIS-Symmetry will be organized in Hiroshima, Japan, on August 17-23, 1992. In the very near future the details will be announced with the usual call for papers. In connection with the shaping of the program and related events we turn to our readers with various requests:

Call for workshop topics

The Symposium, similar to the First ISIS-Symmetry Symposium (Budapest, 1989), will include plenary sessions (mornings), research workshops (afternoons), and entertaining workshops (evenings). We may have two kinds of research workshops:

- minisymposia with brief contributions, followed by extensive discussions,
- panel-discussions where there are no formal contributions, or the submitted papers are summarized by the chairperson(s) and discussed together with the authors and other interested participants.

The entertaining workshops should supplement the main program with arts and crafts, demonstrations of toys or games and other joint activities which may generate interest even after a tiring day. In Budapest Miura's origami and Kajikawa's synergetic workshops attracted many people; in both cases the participants not only enjoyed the presentation, but also built their own models.

Interdisciplinarity and *informality* should dominate the workshops, although the form of minisymposia gives some opportunity to discuss technical details, as well. Suggestions for workshop topics (minisymposia, panel-discussions, and entertaining programs) are welcomed. Each suggestion should include a brief description of the topic and a list of possible contributors and participants.

Call for kaleidoscopes

We plan a workshop with an exhibition "Kaleidoscope and Symmetry". We kindly ask our readers to inform us if you own or have access to interesting kaleidoscopes. Please send a brief description of the item(s). We would also appreciate any related information (names of collectors, inventors, shops, etc.).

Call for Ambigrams

Douglas R. Hofstadter's ambigrams became the symbols of our First Symposium in Budapest, 1989 (see also the section *Reflections: Letters to the Editors*). We would like to develop this feature into a tradition; moreover, we plan an *ambigram exhibition* at the symposium. Ambigrammists and prospective ambigrammists, please send a short note about your interest.

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International Fedorov Conference, 1991

The *International Fedorov Conference, Centenary of Space Groups: Present State and Future* together with a symposium *Symmetry in Modern Crystallography* will be organized in Leningrad, May 14-18, 1991. The preparation of these events are marked by a strong participation of the membership of the Soviet Branch of ISIS-Symmetry. Thus K.V. Frolov, V.A. Frank-Kamenetskii, and I.I. Shafranovskii are members of the Presidium of the Organizing Committee. The Program Committee is chaired by V.A. Frank-Kamenetskii and V.A. Koptsik, while R.V. Galiulin, S.V. Petukhov, and N.P. Yushkin are also members of the Organizing or the Program Committees. Indeed, ISIS-Symmetry – as a co-organizer of the event – will hold meetings during the symposium.

The program of the conference will focus on crystallography. The symposium, however, will also consider those scientific and artistic fields where the crystallographic symmetries play a role. An evening program will be "Symmetry in Music".

For more information, please contact the Organizing Committee, Leningrad Mining Institute, SU-199026 Leningrad, 21st Line No. 2, U.S.S.R., or Olga G. Smetannikova, Scientific Secretary, Department of Crystallography, Leningrad State University, University Embankment 7/9, SU-199034 Leningrad, U.S.S.R.

Fedorov Institute

The Fedorov Institute in Leningrad has been re-established in a new form under the leadership of Galina I. Dolivo-Dobrovolskaya. The location of the Institute is very close to the office which was used by E.S. Fedorov himself and which has been preserved almost in the original form through decades by I.I. Shafranovskii (Leningrad Mining Institute). *SFS* will regularly inform our readers about the developments in connection with this old-new institute. For more information, please contact G.I. Dolivo-Dobrovolskaya (Leningrad Mining Institute, same address as above).

Call for Selected Bibliographies

The Bibliographic Project of ISIS-Symmetry invites our authors and readers to submit – preferably by electronic mail or on floppy diskette – the lists of their symmetry-related publications, as well as any bibliographies and information which are associated with the field; see the details in the section *Symmetro-graphy*.

Addresses of members

As a supplement to this Quarterly we will publish the list of our members. It will include the name, mailing address, phone number, fax number, electronic mail address, as well as the disciplinary and interdisciplinary interests of each member (as requested in the application form). We kindly ask our members to update their data at our Office in Budapest. (If someone prefers not to list his/her phone number, please inform us.)

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SYMMETRIC NEWS

Reflections on the first ISIS-Symmetry Symposium (Budapest 1989)

The monthly scientific program *Ochevidnoe, neveroyatnoe* [Obvious, Incredible] of the Soviet Central Television, hosted by the well-known scholar Professor Sergei P. Kapitsa, devoted two complete programs to the symposium in Budapest. It is really unusual in the history of this very popular television program, watched by tens of millions, to give so much time to one symposium. Moreover, the program was repeated twice, making it available for the audience of all three main channels (three times two hours on symmetry!). The majority of the program was shot in Budapest at the conference center, in various lecture rooms, at the exhibition in the Hungarian National Gallery, and was extended by comments from the studio by local experts. The program is also available on video-cassette. Please contact Mr. Vladimir M. Vozchikov at the Soviet Central Television, Moscow, Ostankino.

There are also some reviews of the same symposium, among others, in the *Japanese Scientific American* by Yasushi Kajikawa, in *Leonardo* by Arthur L. Loeb, in *Nauka Urala* [Ural's Science] by Nicolai P. Yushkin, and in *Polyaisthesis* by Hanan Bruen; in Japanese, English, Russian, and German, respectively. We kindly ask of our members to send a copy of any further review of this symposium, because we would like to compile a bibliography of these items for the convenience of the membership. Moreover, we would like to learn from the critical remarks.

The Office of ISIS-Symmetry in Budapest has some extra copies of the proceedings (extended abstracts [see on the back cover]) of the Budapest symposium, (*Symmetry of Structure*, 2 volumes, 656 pp.). The price of the complete set is US$15.00 for members, US$30.00 for others (please add US$4.00 for postage).

ISIS-Symmetry flyers and leaflets

Board Members Mary Harris, Peter Klein, and Janusz Rębielak made available flyers on ISIS-Symmetry in their countries. Mary Harris uses a "symmetric" play on words *ISIS IS*. Klein's and Rębielak's flyers are in German and Polish, respectively. Although the Society's only official language is English, flyers or leaflets in other languages are also welcomed. These may significantly help the regional activities, and we encourage other Regional or Project Chairpersons to follow these examples. Obviously, some of the regional meetings can be conducted in local languages.

Symposium on Symmetry, Tempe, Arizona, April 21, 1990

Bert Zaslow (Department of Chemistry, Arizona State University), who is the Chairperson of Pattern Mathematics of ISIS-Symmetry, organized a mini-symposium during the 34th Annual Meeting of the Arizona-Nevada Academy of Science. The program – running for the whole afternoon (1:45-5:00 p.m.) – included six lectures:

- D. Burnstein: Gravity, symmetry and asymmetry in astronomy
- A. Swimmer: Symmetric Pfaffians
- B. Zaslow: The geometric and color symmetry of Pracas decorations
- I.L. Wolf: Global precedence in point group symmetry patterns
- K. Balasubramanian: Symmetry in East Indian temples and architectures
- D.J. Pinkava: Phyllotaxy and symmetry

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The abstracts of all these lectures (and also of a seventh on "Quasicrystals" by D.F. Nachman, which was not given) are available in the proceedings: *Journal of the Arizona-Nevada Academy of Science*, 25 (1990), Supplement, 23-25. Although many events took place at the same time, the President of the Academy spent the afternoon at this symposium. The relaxed atmosphere helped the discussions. Bert Zaslow, who chaired the whole meeting, distributed copies of ISIS-Symmetry leaflets to interested persons.

Symmetry Seminars in Poland

The Polish Branch of ISIS-Symmetry decided to organize seminars headed by Board Members Janusz Rębielak and Jan Mozrzymas. Some of the papers presented there will be published in this Quarterly, while a brief description of the programs will be available in this section. The first meeting of the seminar was held at the Institute of Architecture and Town Planning, Technical University of Wrocław, in April 26, 1990. After a general discussion on goals and activities of the Society, Janusz Rębielak gave a lecture entitled "The construction of symmetric space structures". The student section of the Polish Branch of ISIS-Symmetry is organized by Agnieszka Glura. For more information, please contact Janusz Rębielak, Regional Chairperson (for his address, refer to the list of the Board).

RepTiles and FunTiles

There is a very nice way of encoding periodic tilings in the form of Delaney-Dress symbols, which are finite connected $n+1$ colored graphs with functions defined on their nodes (where n is the dimension of the space being tiled). I have developed a number of computer programs that generate and manipulate the symbols. Using this software, we have solved many types of classification problems concerning tilings of the plane, sphere, hyperbolic plane, and now, even of 3-dimensional space. Andreas Dress has some students working on programs that take Delaney-Dress symbols as input and produce, as output, the pictures of the tilings encoded by the symbols. Two such programs have been completed. One program, called *RepTiles*, written by Olaf Delgado, does periodic tilings of the plane, whereas the other, called *FunTiles*, written by Klaus Westphal, can do tilings of the sphere, hyperbolic plane and the Euclidean plane. To be precise, FunTiles only can draw a fundamental region of the tiling and it indicates how the symmetry group of the tiling is to be applied to the drawn fundamental region.

RepTiles runs on an Atari ST and on Unix using Unix's PLOT routines. We hope to produce an MS-DOS version soon. *FunTiles* runs on MS-DOS and on Unix, again using Unix's PLOT routines. *FunTiles* is very new and not really in the state to be given to other people yet. *RepTiles* is older and more developed. If you are interested, we will gladly send you a copy of either program. (See also the related bibliography in the section *Symmetro-graphy*.)

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KUDOS! (THANKS, NEW APPOINTMENTS, PROJECTS, ETC.)

The Editors wish to thank **John Hosack** (Suva, Fiji) and **William S. Huff** (Buffalo, New York) for their "symmetric" (regular) help of almost infinite order during the preparation of this issue of the Quarterly.

Paulus Gerdes (Mozambique) accepted the position of Rector (President) of the Instituto Superior Pedagógico, Maputo, and left his earlier position as Dean of the Faculty of Mathematical Sciences, Eduardo Mondlane University. Kudos, moreover kudos squared, because he made a significant contribution to the scholarly life of Africa by editing the *AMUCHMA-Newsletter* (African Mathematical Union, Commission of the History of Mathematics in Africa), available free of charge in Arabic, English and French versions. This periodical is very useful for interested people, giving regular information, for example, about meetings, research interests, suggestions for further research, education, and literature. We find especially useful the section "Have you read?", where not only current, but also old or even classical works are listed and reviewed briefly. We will maintain close connection with the *AMUCHMA-Newsletter*, sharing the "symmetrically" interesting ideas. For more information, please turn to Paulus Gerdes (see his address at the list of the Board of ISIS-Symmetry).

Koji Miyazaki (Japan) accepted the position in the Department of Graphics, College of Liberal Arts, Kyoto University (Yoshida, Sako-ku, Kyoto 606, Japan), not long ago. His well-known book *An Adventure in Multidimensional Space* (New York: Wiley, 1986), an interesting synthesis of artistic and mathematical ideas, gives his old address in Kobe. We hope he will continue his symmetric adventures in various spaces.

Emanuel Dimas de Melo Pimenta's (Portugal) new compact disk *Digital Music* has been released very recently by Mode (U.S.A.). The CD includes four pieces: *Rings, Rozart, Structures II, Short Waves 1985*. Note that it is a part of a series of records (Mode 21), which also includes the CDs of John Cage (Mode 1/2, 3/6, 17) and George Crumb (Mode 20). The music was recorded in Pimenta's Studio. The CD is accompanied by a small booklet, which is an optimum compromise, revealing something of the mathematical methodology of the composer, but without over-explaining it. Another piece of news from Pimenta (kudos squared!) is that he completed the manuscript of the English version of his book *Tapas* published originally in Portuguese.

Itsuo Sakane (Japan) organized (again!) a very successful scientific-artistic exhibition in his home country entitled *Wonderland of Science-Art: Invitation to Interactive Art* (November 1989). The participants included not only Japanese artists, but also many overseas pioneers of the field from both Northern America and Europe. Sakane also moderated a one-day symposium with the artists. The well-illustrated catalog is published by the Committee for Kanagawa International Art and Science Exhibition. Another news item from Sakane is that he accepted a professorship at the newly built campus of Keio University in April of 1990, where he teaches "Art and Science" courses (Faculty of Environmental Information, Keio University at Shonan Fujisawa Campus, 5322 Endoh, Fujisawa 252, Japan) . We wish him success in this new position, as well as continuation of his interest in organizing exhibitions.

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Dennis Sharp (Epping Green, England) has recently been appointed as Executive Editor of *World Architecture* which is published in London on behalf of the International Academy of Architecture (IAA), and as one of the Directors of a research group concerned with architectural theory and criticism of the same Academy. Another current engagement of Dennis Sharp is the production of a new journal *Architecture and Building Book Review*. Items for review should be sent to his office: 1 Woodcock Lodge, Epping Green, Hertford SG13 8ND, England. Kudos cubed!

NEW PUBLICATIONS

Those works which are reviewed in Symmetro-graphy *are marked by asterisk (*).*

Johann Jakob Burckhardt, *Die Symmetrie der Kristalle: Von René-Just Haüy zur kristallographischen Schule in Zürich.* [The Symmetry of Crystals: From René-Just Haüy to the Crystallographic School in Zürich, in German], Basel: Birkhäuser, 1988, 195 pp. (*)

Giuseppe Caglioti, *Symmetriebrechung und Wahrnehmung: Beispiele aus der Erfahrungswelt.* [Symmetry-Breaking and Perception: Examples from the Empirical World, in German], Trans. from Italian by G.-A. Pogatschnigg, Braunschweig: Vieweg, 1990, *x* + 200 pp. (*)

Donald W. Crowe, *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis.* Seattle: University of Washington Press, 1988, *x* + 299 pp. (coauthor: Dorothy K. Washburn)

Werner Fischer and **Elke Koch,** New surface patches for minimal balance surfaces. Parts 3 and 4, *Acta Crystallographica*, A45 (1989), 485-490 and 558-563.

[Many participants of the First ISIS-Symmetry Symposium (Budapest 1989) remember the two lectures of the authors, as well as the exhibition of the not only geometrically, but also visually, interesting models of minimal surfaces. These two articles – written "symmetrically" by Fischer and Koch, Part 3, and Koch and Fischer, Part 4 – include some photographs of the same models.]

Werner Hahn, *Symmetrie als Entwicklungsprinzip in Natur und Kunst.* [Symmetry as a Developmental Principle in Nature and Art, in German], Königstein: Langewiesche, 1989, 320 pp. (*)

Slavik V. Jablan, *Theory of Symmetry and Ornament.* [Preprint Edition], Belgrade: Mathematical Institute, 1989, 261 pp.

Roger V. Jean, *Mathematical Approach to Pattern and Form in Plant Growth.* [in Chinese], Beijing: Academic Publisher, 1990, 18 + 224 pp. (*)

Vojtěch Kopský, Subperiodic groups as factor groups of reducible space groups. *Acta Crystallographica*, A45 (1989), 805-815; Subperiodic classes of reducible space groups. ibid., 815-823.

Klaus Mainzer, *Symmetrien der Natur: Ein Handbuch zur Natur- und Wissenschaftsphilosophie.* [Symmetries of Nature: A Handbook on the Philosophy of nature and Science, in German], Berlin: Gruyter, 1988, *xii* + 739 pp. (*)

Dénes Nagy, Dynamische Symmetrie (Goldener Schnitt) als Organisationsprinzip im Raum und Zeit. [Dynamic symmetry (golden section) as an organizing principle in space and time, in German with English summary], *Polyaisthesis*, 4 (1989), no. 1, 88-102 and 113.

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Erzsébet Tusa, Bartók und die Naturformen: Der goldener Schnitt. [Bartók and the forms of nature: The golden section, in German with English summary], *Polyaisthesis*, 4 (1989), no. 1, 78-87 and 113.

Nik Warren, editor, *IS Journal*, nos. 7-8 (1989). It is a bi-yearly publication of International Synergy.