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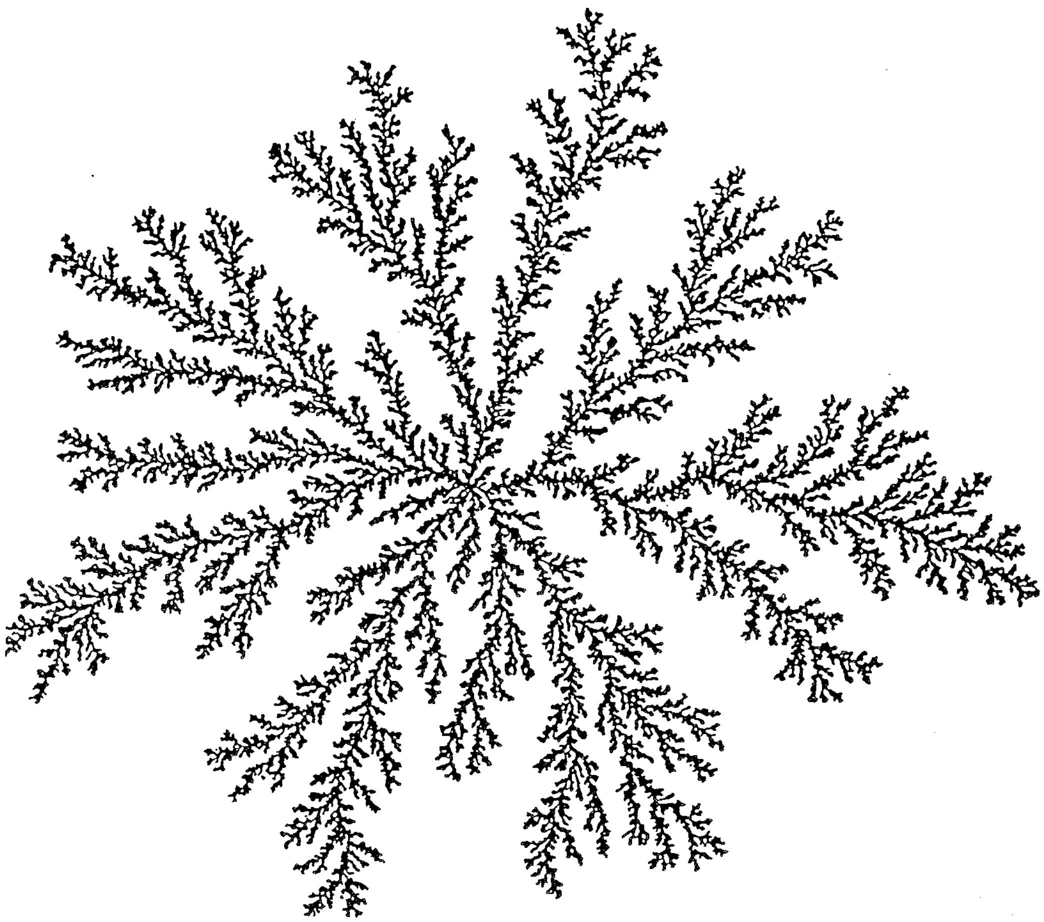

DLA fractal cluster
of 10^6 particles

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SYMMETRY IN EDUCATION

SYMMETRIC PATTERNS AND ETHNOMATHEMATICS IN THE SOUTH PACIFIC: INSPIRING RESEARCH AND HELPING EDUCATION

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Even a brief look at the decorative arts of the South Pacific island countries makes clear that it is an exciting treasury of symmetric patterns. This fact was also noticed by some mathematicians and anthropologists. Grünbaum and Shephard (1987) in their comprehensive mathematical monograph *Tilings and Patterns* refer to the art of this region and cite the survey by Guiart (1963) entitled *The Arts of the South Pacific*. Another interesting example can be found in the book *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis* by Washburn and Crowe (1988), where the first author is an anthropologist with some mathematical interest, while the second author, symmetrically, a mathematician with some anthropological interest. The jacket of this book is illustrated with a tapa (bark cloth) from Fiji, while the inside of front cover is decorated by another tapa from Samoa. Both of these are discussed briefly in the book (pp. 177 and 258-259).

1 A POSSIBLE FIJIAN INFLUENCE ON THE MATHEMATICAL CLASSIFICATION OF BLACK-AND-WHITE SYMMETRIC PATTERNS BY WOODS

More recently there is even an interesting speculation by Crowe about a possible Fijian influence on the very front line of symmetry studies in the Western world (cf., Crowe and Nagy, 1991, pp. 80-83; 1992, pp. 132-135 and 139). Before discussing it, we summarize some of the background topics. It is well-known for people interested in the mathematical classification of periodic patterns that there are exactly 7 types of frieze patterns (frieze or strip groups) and 17 types of wallpaper patterns (wallpaper or plane groups). We may also color them periodically, let us say with black and white, as in the case of the chessboard (check pattern) where the colors of the identical units alternate. Obviously such a coloring leads to a richer set of types. Indeed, there are exactly 17 and 46 types of black-and-white (two-colored) frieze and wallpaper patterns, respectively. (To avoid confusion note that crystallographers usually also include in their lists the degenerate cases, specifically the one-colored patterns, where the second color is not used, and the gray ones, where each unit is colored by both black and white; thus they refer to 17 + 7 + 7 = 31 frieze patterns and 46 + 17 + 17 = 80 wallpaper patterns.) The exhaustive lists of all the mathematically possible types of black-and-white (two-colored) frieze and wallpaper patterns were discovered independently

- by a group of German and Swiss crystallographers in 1929 indirectly: Hermann, Weber, Alexander and Herrmann in their subsequent papers in the major crystallographic journal, *Zeitschrift für Kristallographie*, spoke about two-sided patterns, although Weber illustrated the case of wallpapers by one-sided patterns using black and white triangles on a blank background where the colors refer to the two sides,
- by a British textile specialist, Woods (1935-36), explicitly: he dealt with two-colored patterns and illustrated all of the types with black-and-white tilings (mosaics).

While the German-Swiss works are widely known in the literature of mathematical crystallography and of symmetry analysis of decorative arts, there are very few references to the papers by Woods published in a textile journal of small circulation (the few references known to us are due, in chronological order, to Shubnikov, Donnay, Washburn, Grünbaum, Jablan, Opechowski). Crowe deserves great credit for the more recent popularization of Woods's work: he published an article about his life and work and reprinted his black-and-white tilings (Crowe, 1986; cf., Washburn and Crowe, 1988, front and back cover, pp. 5, 9, 63-64, 70-75). Crowe is right when he emphasizes that the papers by Woods, unlike the work of the German-Swiss crystallographers, anticipated the approach based on tilings, which dominated the later works by the Russian crystallographic school (Shubnikov, Belov, and others) and also gained an importance in geometry (Delaunay, Fejes Tóth, Heesch, Grünbaum and Shephard). Note that the importance of the study of tilings in the context of crystallographic symmetries was pioneered by Fedorov's monograph published in German in 1900 and the Russian school continued this tradition. Indeed, while they generalized the classical crystallographic symmetries as black-and-white and multi-colored symmetries, they frequently represented the 2-dimensional cases by colored tilings. May we add that Woods's term "counterchange symmetry" is very similar to Shubnikov's "antisymmetry", i.e., the combination of a geometric symmetry operation with color interchange: the white units are transformed into black ones of identical shape and vice versa (later we will return to the physical importance of this concept). Thus, Woods's terminology is an important step in the direction of later developments. There is no doubt that the approach by Woods has a great importance and, considering the fact that some great pioneers were aware of it, his papers could have some impacts.

Now we should turn to the possible 'Fijian connection'. When Crowe, together with this author, made a field trip in 1990 to Somosomo village, Taveuni island, Cakaudrove (Thakaundrove) province in Fiji, where the so-called Cakaudrove-style tapa is produced with black-and-white geometric patterns, he noticed a great similarity between the Fijian patterns and Woods illustrations (Fig. 1).

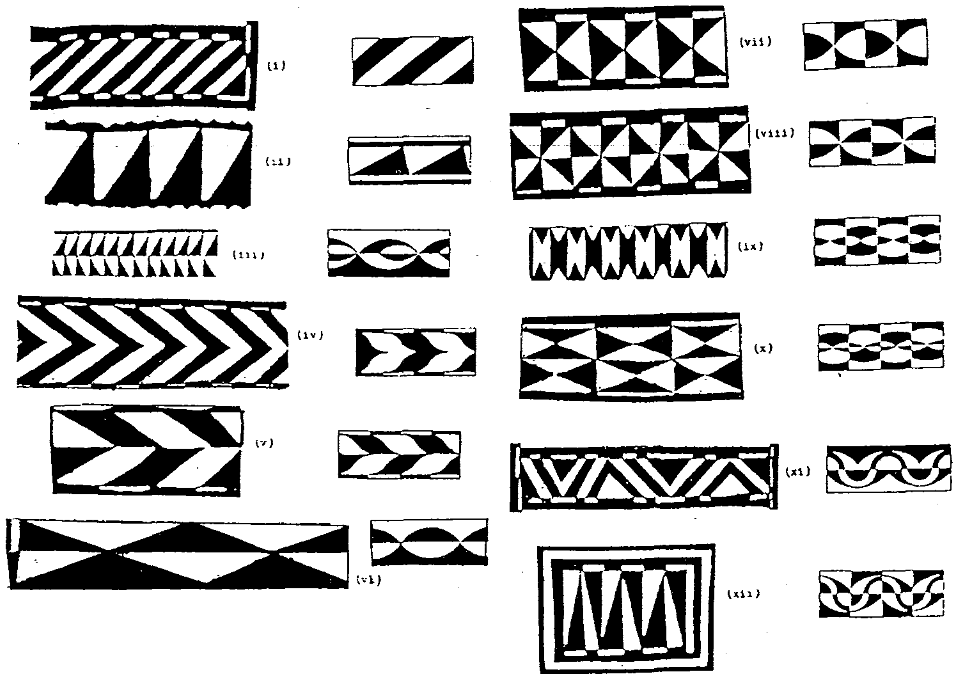

Figure 1: Fijian Cakaudrove-style frieze patterns (left) compared with Wood's tilings (right). Note that here we have 12 pairs: those types that are identified in tapas, partly in modern works, partly in historic collections (e.g., item [v] is in the Pitt Rivers Museum in Oxford). The exhaustive list has 17 types; all of them are presented by Woods (1935, pp. T207-T208), cf., Washburn and Crowe (1988, p. 71). Interestingly there are almost no changes in style if we compare 19th century works kept in foreign museums and contemporary works made by Fine Nailevu (b. 1923) of Somosomo village in the presence of Crowe and this author in 1990 (see here items [iii], [vii], [viii], and [ix]). This invariance of patterns is amazing and present an interesting insight for contemporary researchers into old traditions of the South Pacific. Note that Somosomo village is probably the only settlement in the world located on the international dateline. It is also the traditional residence of the current paramount chief of Fiji, Ratu Sir Penaia Ganilau, and his house is decorated by Fine Nailevu's works. (After Crowe and Nagy, 1991, pp. 80-81; 1992, pp. 132-133).

Incidentally, the most exciting similarity is not the shape of the repeated units (basic motifs), but the composition of the border lines at some of the friezes: a white unit is closed by a thin black segment and vice versa. This method is used frequently in Cakaudrove-style, while Woods – without an actual mathematical need – introduced the same method in some cases of his tilings (cf., Fig. 1, [iv] and [v]; also see two further examples in his exhaustive list). There are also some similarities between typical Cakaudrove-style wallpaper patterns and Woods's tilings; these are based, however, not on the border lines, but on the repeated units (Crowe and Nagy, 1992, pp. 135 and 139). Considering the fact that Woods studied mathematics at Oxford and the Pitt Rivers Museum in the same city has a Cakaudrove-style tapa with the described border-composition (Fig. 1, item [v]), it is highly possible that Woods had seen it. Moreover the tapa from Fiji could give him an inspiration for his works on classifying black-and-white patterns.

May we add here some further support to this speculation. Tapa is a very interesting form of textile and many comprehensive books on this subject refer to it. Textile fabric is usually defined as cloth made by combining fibers, which could be natural, i.e., of plants, animals, and rarely minerals (as in case of the asbestos), and synthetic. The typical method of producing textiles is weaving (the original Latin word *textilis* means "woven"). There are, however, other ways of interlacing fibers, such as knitting, lacing, netting, and braiding. Last but not least, there are noninterlaced textiles, including very old ones produced by ancient civilizations, which are made of fibrous layers by mechanical pressure, adhesive bonding, or some other ways. While in the earlier mentioned cases the fibers are well oriented, here we see a more or less random order. In case of felt, animal fibers, usually wool, are united by pressure (the term comes from the Latin *filtrum*, filter; also see *pellere*, to beat, to push, cf., the Greek *pelas*, near). Is there any noninterlaced textile where plant fibers are united? The answer is: yes, the tapa. This internationally used term for the South Pacific bark cloth came from the Tahitian language, where it was probably coined by the simple imitation of beating fibrous strips of barks by a wooden beater as "tap-tap-tap" (this form of coining a word is called in linguistics onomatopoeia). The Fijian word for tapa is *masi*, while the frequently used expression *masi kesa* means "tapa [which is] decorated". The source of fibrous strips is usually the inner white layer of the bark of the paper mulberry tree (*Broussonetia papyrifera*, which is used for papermaking in China and Japan). These fibers are not suitable for weaving, but it is easy to unite fibrous strips by beating and thus to make large fabrics. This simple form of making textiles, however, did not spread widely in the world, partly because the obtained cloth is not very strong, partly because the paper mulberry tree and other suitable plants, in large quantity and with strong fibers, are native only in a limited area. An interesting example is the case of the New Zealand Maoris who lost this craft after moving from various tropical islands to their present location with colder climate. In the same time, some of their Polynesian relatives who remained in tropical islands still produce tapas. Note that people often confuse the South Pacific tapa with the Chinese and Japanese handmade paper. Although both of them are made of the bark of the paper mulberry tree, the processes are very different. Papermaking is based on soaking the bark in water, then the obtained pulp is dried and pressed, while the tapa is a textile fabric made of fibrous strips of the bark by beating them together physically, without using a watery treatment. We summarized these basic ideas just to explain why the South Pacific tapa is so important for textile specialists when classifying fabrics according to the method of combining fibers. Woods (1904-1984), who spent most of his career working at the Department of Textile Industries of the University of Leeds and who published many articles in the *Journal of the Textile Institute*, obviously should have had some knowledge about tapa. He could even have seen related publications where Fijian tapas, kept in various Western museums, feature. It is hard to believe that he did not study the black-and-white geometric pattern of the Fijian tapa kept in the Pitt Rivers Museum located very close to his *alma mater* in Oxford. Moreover this could be the link between his early interest in mathematics and the later one in textiles, which connection is also emphasized in the general title of his four-part series of article "The geometrical basis of pattern design" (Woods, 1935-36).

2 DECORATIVE ARTS AND ETHNOMATHEMATICS

How could the South Pacific people develop such a rich set of patterns that excite mathematicians? How could they inspire – if the earlier speculation is correct – new discoveries in mathematics? As a preliminary approach to these questions, may we refer here to the fact that there are two kinds of mathematics:

- an intuitive one developed in the framework of arts and crafts and some other activities of everyday life,
- a scholarly one taught by professional teachers and developed in academic circles.

Obviously the first one is older and also a source of inspiration for the second one. In the beginnings these two were not separated at all. In the ancient Greek culture the tendency for separation was started in about the 6th century, B.C., and it was more or less completed in the time of Euclid in the 4th century B.C. with the birth of an abstract mathematics based on a deductive system. The craftsman's mathematics, however, never disappeared, although it was rarely documented in books (the information was passed from generation to generation during common work), and scholarly mathematics more or less ignored it. More recently, however, the need of applied mathematics, i.e., the mathematical treatment of various practical problems, created new interest in this old tradition. Educators of mathematics made another step by emphasizing the importance of *ethnomathematics*, a term coined by the Brazilian mathematician D'Ambrosio. Indeed, this is a very useful term to refer to the previously mentioned craftsman's mathematics and other mathematics-related activities of everyday life.

We suggest considering the achievements related to South Pacific patterns in the context of ethnomathematics or, more generally, ethnoscience because we also deal here with intuitive crystallographic ideas. The methods of composition in decorative arts obviously need ethnomathematical skills. Usually a basic motif is repeated by using geometrical transformations. In case of painted decorations, the artist often uses a stencil representing the basic motif or some other unit (e.g., the unit cell, i.e., a smallest unit that is suitable to build the entire structure by translations). The artist moves this stencil into newer and newer positions and creates a dense arrangement of equal copies of the motif, which activity usually leads to a periodic order. This process is very similar to crystallization when atoms (ions, or molecules) move in a solution and start an accumulation according to the densest packing. The periodic coloring of patterns is analogous to the tendency in some crystal-structures for the geometrically equivalent units to have different physical properties, e.g., positive versus negative magnetism, which can be represented by black-and-white coloring of the symmetric patterns. The earlier mentioned chessboard (or a check pattern) is a good example for such a black-and-white or two-colored symmetry, which is also called magnetic symmetry. This is the reason that the works by Woods have a great importance in both fields: crystallography and decorative arts. The similar result obtained by the German-Swiss group of crystallographers and by the textile specialist Woods is an exciting symbol of the fact that symmetry groups, including the black-and-white ones, can be approached from both directions: crystallography and decorative arts. In both fields the 'deep structure' of patterns (we adapt here Chomsky's term from linguistics) can be described by symmetry groups. The similar patterns presented by South Pacific artists and Western scientists demonstrate the fact that related results can be achieved in both ways: ethnomathematics and scholarly mathematics. Although the typical application of ethnomathematical ideas is to help in mathematics education, there are some special cases when the ethnomathematical achievements may inspire research results. The possible Fijian influence on Woods could be such a case. This type of inspiration is very rare, but not unparalleled: the German mathematician Heesch remarked that one of his discoveries was inspired by Islamic patterns, while the Dutch crystallographer MacGillavry discovered the incompleteness of a table of colored symmetries by the fact that she could not identify the symmetry groups of two periodic drawings by the artist Escher. Finally, we should note another similarity between crystallography and decorative arts: there is no perfect symmetry, just a general tendency for symmetry which is interrupted with various imperfectnesses. These may add new and in some cases useful properties to crystal-structures (e.g., semiconductors) and may make the patterns more beautiful (some experimental-psychological studies demonstrate that perfect symmetry is boring and people would prefer small violations of symmetry). Later we will return to this problem.

Let us discuss some general questions in connection with decorative arts. With some simplification it can be claimed that there are two major tendencies in decorative arts:
- the figurative tendency, where the artists try to give a true representation of objects, and they have a strong desire that these objects can be easily recognized,
- the non-figurative tendency, where there is no dominant connection with actual objects of our environment.

We should add immediately that these two tendencies are not strongly separated. Obviously, all figurative representations have some tendency toward geometrical abstraction, while the non-figurative shapes frequently have some associations with actual objects. As an interesting example, we may refer here to the beginnings of Escher's periodic drawings. The Dutch graphic artist first made a careful study of Islam ornaments, specifically Moorish patterns in Spain, and then he tried to substitute for the abstract shapes natural objects such as birds, fishes, frogs, lizards, etc. It is possible that he rediscovered images of animals that could also have inspired the old masters of Moorish patterns when they choose one or another shape. Note that in Southern America both types of patterns were produced in ancient times: 'Escher-like' periodic patterns with animals and abstract geometric ones.

Decorative arts have a special position in culture. This is the only form of the plastic arts (aside from architecture) that is widely practiced everywhere. The above statement is not true for painting and sculpture which have less importance in some cultures. Of course the border between decorative arts and the other two is a bit fuzzy: there are objects that can be considered in both ways. The lack of or limited use of painting and sculpture may have various reasons. In the case of Islam it is frequently although a bit mistakenly emphasized that the figurative representation is totally forbidden, and thus there is no painting and sculpture at all. In the *Koran* there are no direct statements about such a prohibition, just references against idolatry (cf., the *Old Testament*'s similar statements). True, the *Hadith*, the collection of traditional sayings of the Prophet, includes quotations that are interpreted as the prohibition of figurative representation. On the other hand, there is a less known, but rich iconographical tradition in Islam (see, e.g., Sir

Thomas Arnold's classical monograph *Painting in Islam: A Study of the Place of Pictural Art in Muslim Culture*, Oxford: Clarendon Press, 1928). A modern researcher of the subject also concludes that there is practically no period of Islamic culture when figurative representation was suppressed, with the singular exception of the religious sphere – mosques and mausoleums – where idolatry was feared (E. J. Grube, *The World of Islam*, London: Hamlyn, 1966, see pp. 11-12 and dozens of figurative paintings and some sculptures). This also means that the decorative arts still have a special position in Islamic culture as the only form of plastic arts used in religious buildings. The similar tendency in the case of many palaces, where geometric decorations feature, could be an influence of the religious architecture since most of them include small mosques or mausoleums. The Moorish palace in Spain, the Alhambra (14th c.), is frequently mentioned in connection with its rich geometric decorations. However, we cannot say that the figurative representation is totally absent in the Alhambra: there is a fountain at the center of one of its large courts that is supported by 12 stone sculptures of lions (this part of the palace is named the Lion Court).

In some other cultures the limitation of painting and sculpture is connected with other factors. For example, nomadic people would have difficulties in carrying big paintings or heavy sculptures, while fragile miniatures would not survive long periods. In other places the typical materials and tools necessary for painting and sculpture are not easily available. In all of these cultures the decorative arts have a special emphasis: exactly this form of art attracts the majority of artistic creativity of the people. This concentration of creativity, which is less distributed among other forms of plastic arts, could lead to an unusual richness of decorative arts. Although they still may use figurative elements in decorative arts, the lack of stronger traditions in painting and sculpture, as well as of the special skills in making figurative representations (at least among a group of artists-craftsmen), may lead to the preference of abstract geometric motifs. It should be noted, however, that these are not definitely abstract geometric motifs on purpose: the artists frequently associate their motifs with objects of nature and the artificial environment. We discussed such a possibility in case of Moorish motifs adapted by Escher, and now we give here more explicit examples from the South Pacific. A frequently observable swastika-like motif with four black triangles around the center of a white square (see it in Fig. 1, [viii], left-side frieze) would be considered by most people as an abstract geometric shape. It has, however, a widely known name in Tonga referring to a figurative origin: "two birds". The same motif in the Cakaudrove-style of Fiji is called "South wind". (Note that this motif is also frequently used in Africa.) In Cakaudrove all geometric motifs have names and some of them are associated with objects of nature such as *bati-ni-i'a*, teeth of the fish; *bati-ni-vasua*, edge of the *Tridacna* clam [shellfish]; *dogo-lo'i*, bent mangrove; *drau-ni-niu-musu*, leaf of coconut which is broken, *savu-musu*, waterfall which is broken. Other names are associated with artificial objects (e.g., comb, rope, railing of the bridge), while the names of a smaller group refer to functions during the composition (e.g., closing the waterfall pattern); see the full set of the currently used motifs and their names in the paper by Crowe and Nagy (1992, pp. 143-144). However, these names are not widely known any more: many of the Fijians would consider the corresponding motifs as geometric ones. We may observe here a transition from an originally figurative tendency to a non-figurative one: for the artist it is still figurative representation in some sense, while the public consider it as non-figurative. A similar tendency can be observed in another field, in the case of some complicated Chinese and Japanese characters, where the original ideas represented graphically are not clear even for the well-educated native speakers. These were figurative characters in ancient times, but, during various modifications (simplifications, combinations, etc.), they partly lost this meaning. Although the people know the actual meanings of these characters, they cannot fully explain their graphical origins. The difficulties are also connected with the fact that about 80-90 per cents of the currently taught and widely used 1,800-2,000 characters (the total number is more than 50,000) are not simply pictographic, but phonetic-ideographic or even just phonetic, i.e., only a part of the character has some association directly or indirectly with the actual meaning, while the remaining part, or even the entire unit, refers to another character – and another 'graphical story' – with similar pronunciation (cf., the funny English label "4 sale", which cannot be understood without discussing the word "four" and the similarity of its pronunciation to the preposition "for"). This is the reason that many of the sophisticated characters, which were fully figurative for their creators in early ages, became, at least partly, geometric sets of strokes for modern people. Note that this author believes that the effective teaching of such characters, especially for adult foreigners, should be based on the historic etymology and not on the memorization of geometric systems of strokes. Unfortunately large numbers of textbooks do not follow this rule.

In the case of figurative decorative arts the basic motif is carefully elaborated and thus it has an emphasis. The properties of this motif may strongly limit the arrangement of its repeated copies. For example, if this motif is symmetric, most of the entire pattern follows this symmetry. Often the natural position of the represented object(s) of the basic motif also influences the pattern. For example, if horses are repeated on a wallpaper, it would be strange to have some of them upside-down, although this is not a definite rule (see some drawings by Escher ruled by geometry, not by nature). In the case of non-figurative decorative arts there is less emphasis on the basic motif; its shape is not determined by concrete objects, and the artists have more freedom in arrangement. This is the main reason that the non-figurative decorative arts are rich in symmetries. The Islamic ornamental art is frequently surveyed from the point of view of geometry and symmetry (Abas, Belov, Bourgoin, Bulatov, Critchlow, El-Said and Parman, Gómez at al., Grünbaum at al., Hankin, Lalvani, Makovicky, Müller, Norman, Otto, and others). There are also some similar works about African art (Crowe, Gerdes, Zaslavsky) and Native American art (Campbell, Jernigan, Washburn, Witherspoon, Zaslow). Now we would like to add to this list the decorative arts of the South Pacific. Note that in the cases of the Australian aborigines and the New Zealand Maoris there are some important symmetry-related studies (Crowe, Lucich, as well as Donnay, Doyle, Hanson, Knight, respectively).

3 SYMMETRY-RELATED RESEARCH AND A UNIVERSITY COURSE AT THE UNIVERSITY OF THE SOUTH PACIFIC

When this author moved to the University of the South Pacific in 1989 for a long period, one of his main motivations was an interest in symmetric patterns and, more generally, in the ethnomathematics of the region. On one hand, we were glad to see that all the covers of the mathematics textbooks published by the University of the South Pacific are decorated by Escher's drawings; on the other hand, we were sorry to see that the exciting geometrical patterns of the South Pacific were not used for similar purposes. The most striking examples of symmetric patterns can be seen in case of the tapas, but there are some other fields of arts and crafts, including mat-weaving, string-lashing, tattooing, wood-carving, that present interesting symmetries. (Note that *tattoo* is again an international word that was adapted from Polynesia, cf., Tahitian, Tongan, Samoan *tatau*.) We initiated an ethnomathematical research project at the university. We also understood, however, that this is not only mathematical work, but also anthropological. Many of the fields considered are not yet investigated from the point of view of patterns, the motifs and their names are not yet cataloged, and, surprisingly to us, the university has no department of anthropology or ethnography. In addition to this, some of the traditional crafts are dying out, consequently we are in the last moments to record them. We also realized that there is an international interest in connection with such projects. The joint field trips with Crowe (Department of Mathematics, University of Wisconsin at Madison, U.S.A.) in 1990 led to some new discoveries and also to the joint papers that were already referred to in connection with Woods (Crowe and Nagy, 1991; 1992).

We also developed for third year mathematics students a special topic course: *Symmetries, Patterns, and Polyhedra*. This course was given in the second semester of 1990 (note that the academic year in Fiji, similar to many countries in the Southern Hemisphere, runs from February to December). The required texts included some chapters of Coxeter's already classical book *Introduction to Geometry* (Reprint of the 2nd ed., New York: Wiley, 1989) and of Grünbaum and Shephard's *Tilings and Patterns: An Introduction* (New York: Freeman, 1989). The latter one is the abbreviated teaching edition of their monograph of 1987. More than 20 students enrolled in this class, and this author was glad to see that the ethnomathematical context and some intuitive geometric ideas could give a new inspiration to them. Indeed, in the field of pattern mathematics – this term was coined by Zaslow, an American chemist who authored many fine works on symmetry in Native American design – the people of the South Pacific have a special tradition. This statement is also true in case of the Indian community of the region. The traditional Indian design is very rich in abstract geometric shapes. *Mandalas*, *yantras*, and *chakras* are geometrical diagrams representing various forces and energies of the cosmos in a very abstract form and are also used as meditative tools (see about this topic the article "Symmetry in Hindu philosophy" by Trivedi in this quarterly, Vol. 1, No. 4, pp. 369-386, 1990). Note that the Indian community of the South Pacific kept the oral traditions, rather than the philosophical ones. Thus, most of the Indian students never have heard about the philosophical background of these diagrams, but they know some of the related geometric symbols from their arts and crafts. The average result of this course was better than in the case of the most third year courses in mathematics. We also dealt with research problems and the interest of the students was very encouraging. One of them, Surya Prakash, solved an open problem by discovering a new type of tiling. We hope to continue sometime this form of teaching using ethnomathematical ideas.

Last but not least, we should return to the question of non-perfect symmetries. The artists and craftsmen of the South Pacific do not use sophisticated tools: their symmetric patterns are far from being perfect structures. For example, we observed that during the decoration of rectangular tapas they do not estimate carefully the space to be filled, which often leads to some extra place at corners that is too small to introduce a full copy of the basic motif. The artists, instead of trying to eliminate these imperfectnesses in the pattern by preliminary measurements, developed rather a special skill of filling such blank places with appropriate elements of the motifs. There are many other fields of arts and crafts where a similar tendency of dissymmetry, i.e., the lack of perfect symmetry, can be observed. In some cases this tendency has a purpose: to create a higher level of balance by ignoring the perfect symmetry. This is a problem that needs more investigation. Here we just mention one field that gained some attention among anthropologists, but has not yet been investigated from the point of view of symmetry. The people of the South Pacific had a special skill in navigation. They were able to migrate to very distant islands. The common canoe in the South Pacific – which surprised the crew of Captain Cook during their voyage – has an outrigger on one side to help the stabilization of the main hull; it is a 'dissymmetric catamaran'. Or, if you wish, this is an intuitive discovery of Pierre Curie's dissymmetry principle...

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SYMMETRIC GALLERY

SYMMETRY IN FIJIAN MATS

Mats are functional utilities in which all the production and processing of the raw material, panadanus, are exclusively carried out by women. Mat designs are always in black and white - brown is normally not used.

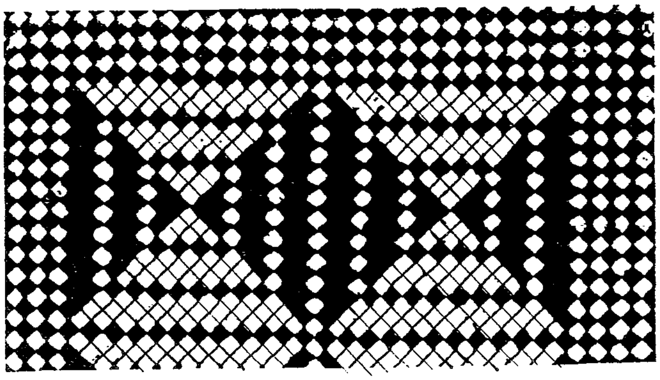
Young women learn existing designs by observation and by 'trial-and-error' to achieve quality weaves and designs. Special designs particular to a geographic area are seen in other areas when women marry, re-settle, or travel.

Mats are used for floor covering, sleeping, ceremonies, and as items of exchange. Women without mats were traditionally deemed 'poor', and women without mat weaving skills were deemed unsuitable for marriage.

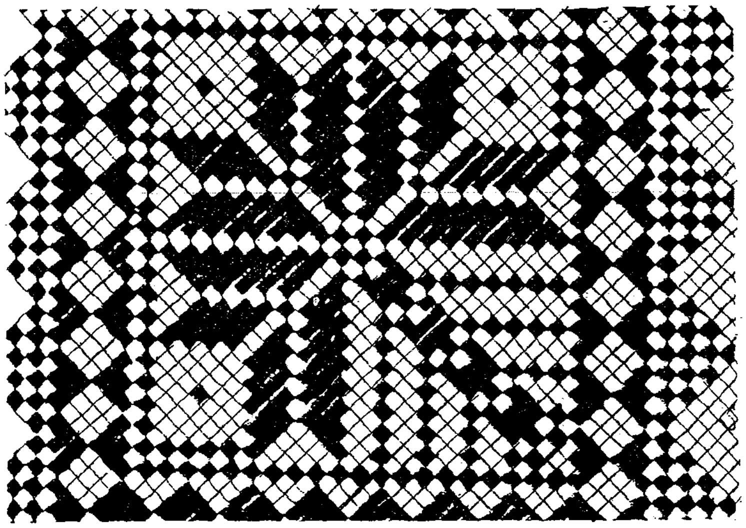
Cema Bolabola
University of the South Pacific,
Suva, Fiji

The enclosed here patterns are based on the works of the late Makereta Sotutu. This section is dedicated to her memory. - (Eds.)

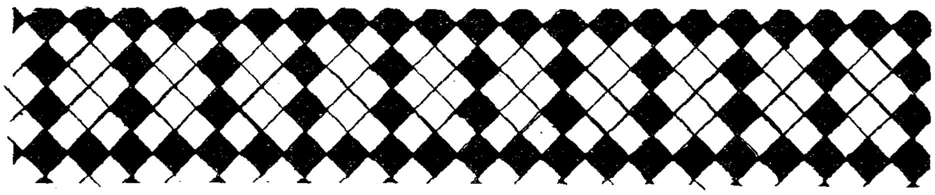
The following mat designs with Fijian names and English translations were taken from the book by the USP Fiji Center: *Na ibe vakasomo: E vica na somo mai na vei yasa i Viti*, Suva, Fiji: USP Fiji Centre, 1990, vii + 46 pp.



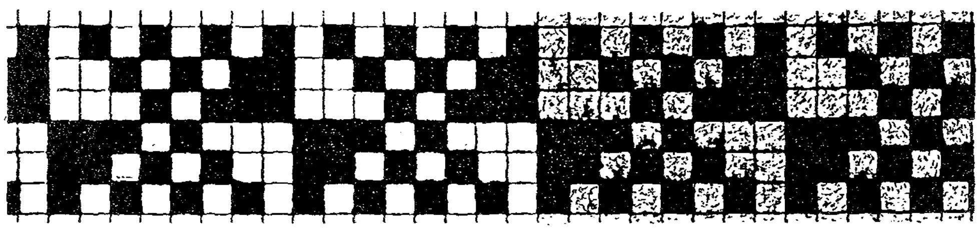
Daimani: Diamond.



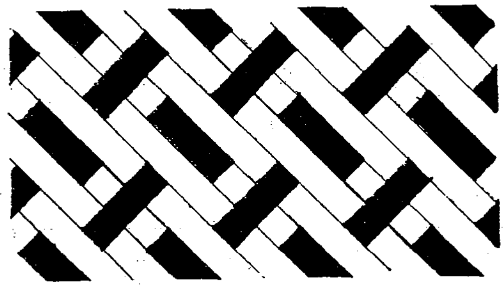
Drau ni lauci: Leaf.



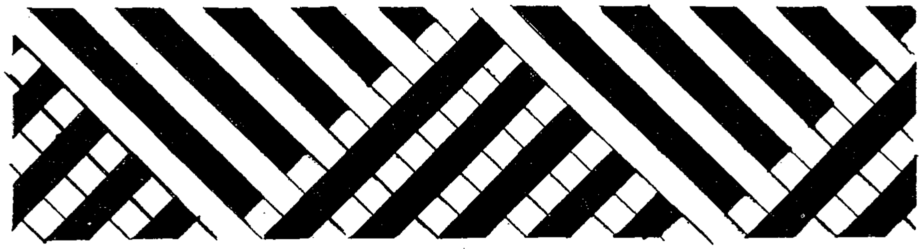
Kalavo: Rat.



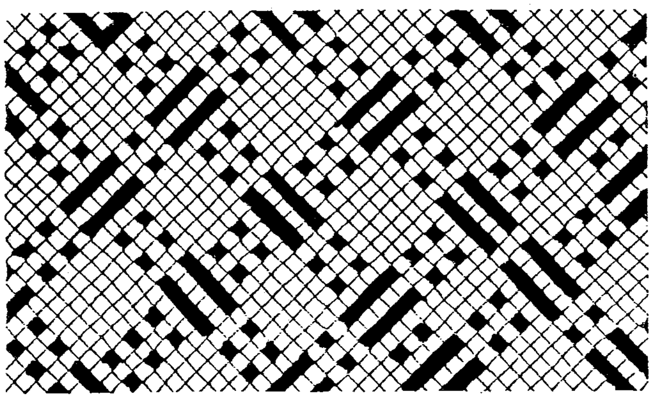
Kuba: Reed.



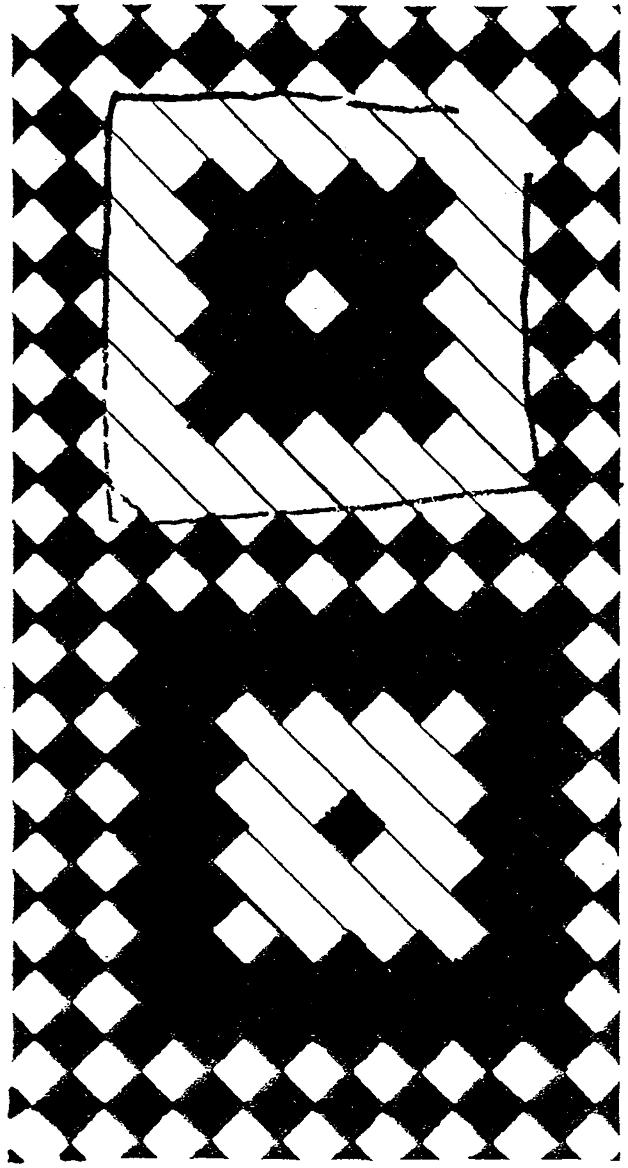
Vakadiviliviili.



Vakano: Ono island pattern.



Vulaqeti: Cardigan/blanket.



Waqa-Ni-Iloilo: Reflection.

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SYMMETRO-GRAPHY

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BIBLIOGRAPHY

BIBLIOGRAPHY OF TEXTBOOKS AND MONOGRAPHS RECOMMENDED FOR INTERDISCIPLINARY COURSES ON SYMMETRY AT THE UNIVERSITY LEVEL

Part 2

Interdisciplinary textbooks and monographs on symmetry are listed in Part 1 (this volume, No. 2, pp. 211-219). Here we consider more specialized monographs with some interdisciplinary outlook (Section 3) and books on dissymmetry, broken symmetry, asymmetry (Section 4).

Introductory notes: Principles of selection

It is difficult to make strict rules for selecting books of interdisciplinary interest. Sometimes works referring to a concrete discipline still have an interdisciplinary importance. For example, a book on crystallographic symmetry groups is useful not only for crystallographers, but for all people interested in solid state physics, crystalphysics, crystalchemistry, and materials science. As a general principle: we consider those books that have some interest outside the main discipline of the author. Thus, we do not list books on, let us say, symmetries in particle physics or orbital symmetry in chemistry, because these ones are rarely used by people who do not work in those fields.

3 More specialized monographs with some interdisciplinary outlook

3.1 History of science, philosophy, psychology

Altmann, S. L. (1992) *Icons and Symmetries*, Oxford: Clarendon Press and New York: Oxford University Press, xii + 104 pp. [History of mathematics and physics].

Burckhardt, J. J. (1988) *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 Zurich, in German], Basel: Birkhäuser, 195 pp.

Hommel, H. (1987) *Symmetrie im Spiegel der Antike*, [Symmetry as Reflected in the Antiquity, in German], Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Philosophisch-Historische Klasse,· Jahrgang 1986, Bericht 5, Hieldelberg: Winter, 59 pp.

Leyton, M. (1992) *Symmetry, Causality, Mind*, Cambridge, Mass.: MIT Press, x + 630 pp.

Piersa, H. (1990) *Symetria i jej funkcje poznawcze w fizyce*, [Symmetry and its Congnitive Functions in Physics, in Polish], Lublin, Poland: Wydawnictwo KUL [Katolicki Uniwersytet Lubelski], 257 pp.

Scholz, E. (1989) *Symmetrie, Gruppe, Dualität: Zur Beziehung zwischen theoretischer Mathematik und Anwendungen in Kristallographie und Baustatik des 19. Jahrhunderts*, [Symmetry, Group, Duality: On the Connection between Theoretical Mathematics and Applications in Crystallography and Structural Design of the 19th Century, in German], Basel: Birkhäuser and Berlin: Deutscher Verlag der Wissenschaften, 406 pp.

Sodnomgombo, D. and Khvan, M. P. (1981) *Filosofiya i simmetriya*, [Philosophy and Symmetry, in Russian], Ulan Bator, Mongolia: Gosizdat, 206 pp.

Urmantsev, Yu. A. (1974) *Simmetriya prirody i priroda simmetrii (Filosofskie i estestvennonauchnye aspekty)*, [Symmetry of Nature and the Nature of Symmetry (Philosophical and Scientific Aspects), in Russian], Moskva: Mysl', 229 pp. [Philosophy, Biology, System approach].

Van Fraassen, B. C. (1989) *Laws and Symmetry*, Oxford: Oxford University Press, xv + 395 pp.; French trans., *Lois et symétrie*, Mathesis [Series], Paris: Vrin, in prep. [Philosophy, Physics].

Yaglom [IAglom], I. M. (1988) *Felix Klein and Sophus Lie: Evolution of the Idea of Symmetry in the Nineteenth Century*, Boston: Birkhäuser, vii + 237 pp. [History of mathematics and physics].

Also see the old books in Section 2.1.1, as well as many works in Section 4 on the philosophical aspects of symmetry and asymmetry.

3.2 Exact sciences (mathematics, crystallography, physics, and chemistry)

3.2.1 Structure of matter (atomic or molecular level), applications of group theory

Baggott, J. E. (in prep.) *Perfect Symmetry: The Accidental Discovery of a New Form of Carbon*, Oxford: Oxford University Press. [Buckminsterfullerene].

Bernal, I., Hamilton, W. C., and Ricci, J. S. (1972) *Symmetry: A Stereoscopic Guide for Chemists*, San Francisco: Freeman, viii + 180 pp.

Bhagavantam, S. (1966) *Crystal Symmetry and Physical Properties*, London: Academic Press, x + 230 pp.

Dmitriev, I. S. (1976) *Simmetriya v mire molekul*, [in Russian], Leningrad [Sankt-Peterburg]: Khimiya; 124 pp.; Rev. English trans., *Symmetry in the World of Molecules*, Moscow: Mir, 1979, 147 pp.; German trans., *Symmetrie in der Welt der Moleküle*, Leipzig: Deutscher Verlag für Grundstoffindustrie, 1987, 146 pp.

Fedorov, E. S. (1949) *Simmetriya i struktura kristallov: Osnovnye raboty*, [Symmetry and Structure of Crystals: Basic Works, in Russian], Ed. by A. V. Shubnikov and I. I. Shafranovskii, Klassiki nauki [Series], Moskva: Izdatel'stvo Akademii Nauk SSSR, 630 pp.; English trans., *Symmetry of Crystals*, ACA Monograph, No. 7, New York: American Crystallographic Association, 1971, x + 315 pp. [Basic works of late 19th century, including the discovery of the 230 crystallographic space groups].

Fujita, S. (1991) *Symmetry and Combinatorial Enumeration in Chemistry*, Berlin: Springer, ix + 368 pp.

Hochstrasser, R. M. (1966) *Molecular Aspects of Symmetry*, New York: Benjamin, xiii + 355 pp.; Russian trans., Khokhshtrasser, R., *Molekulyarnye aspekty simmetrii*, Moskva: Mir, 1968, 384 pp.

Jaffé, H. H. and Orchin, M. (1965) *Symmetry in Chemistry*, New York: Wiley, x + 191 pp.; Reprint, Huntington, N.Y.: Krieger, 1977, x + 193 pp.; German trans., *Symmetrie in der Chemie: Anwendung der Gruppentheorie auf chemische Probleme*, Heidelberg: Hüthig and Stuttgart: UTB (Uni-Taschenbücher), 1973, 186 pp.; Japanese trans., *Gunron nyuumon: Kagaku ni okeru taishou*, Tokyo: Toukyou Kagaku Doujin, 1966, 191 pp.; Reprint ed., ibid., 191 pp.; Russian trans., Dzhaffe, G. and Orchin, M., *Simmetriya v khimii*, Moskva: Mir, 1976.

Kettle, S. F. A. (1985) *Symmetry and Structure*, Chichester, England: Wiley, x + 330 pp.; Paperback ed., ibid., 1989.; 2nd ed., *Symmetry and Structure: Readable Group Theory for Chemists,* in prep.; German trans., *Symmetrie und Struktur: Eine Einführung in die Gruppentheorie*, Teubner Studienbücher, Stuttgart: Teubner, in prep.

Ladd, M. F. C. (1989) *Symmetry in Molecules and Crystals*, Chichester, England: Ellis Horwood and New York: Halsted Press, 274 pp.

Loeb, A. L. (1971) *Color and Symmetry*, Wiley Monographs in Crystallography, New York: Wiley, xiii + 179 pp.; Reprint, Huntington, N.Y.: Krieger, 1978, xiii + 179 pp.

Ludwig, W. and Falter, C. (1988) *Symmetries in Physics: Group Theory Applied to Physical Problems*, Springer Series in Solid-State Sciences, Vol. 64, Berlin: Springer, xi + 461 pp.

Mead, C. A. (1974) *Symmetry and Chirality*, Topics in Current Chemistry, Vol. 49, Berlin: Springer, iv + 88 pp.

Schonland, D. S. (1965) *Molecular Symmetry: An Introduction to Group Theory and its Uses in Chemistry*, London: Van Nostrand, xii + 298 pp.; French trans., *La Symétrie moléculaire*, Paris: Gauthiers-Villars, 1971.

Senechal, M. (1990) *Crystalline Symmetries: An Informal Mathematical Introduction*, Bristol: Hilger, xii + 137 pp.

Shubnikov, A. V. (1951) *Simmetriya i antisimmetriyą konechnykh figur*, [Symmetry and Antisymmetry of Finite Figures, in Russian], Moskva: Izdatel'stvo Akademii Nauk SSSR, 172 pp.; English trans. [together with some other works], Shubnikov, A. V., Belov, N. V., et al., *Colored Symmetry*, Ed. by W. T. Holser, New York: Macmillan and Oxford: Pergamon Press, 1964, xxv + 263 pp. [Antisymmetry = 2-colored or black-and-white symmetry].

Steinborn, D. (1993) *Symmetrie und Struktur in der Chemie*, [Symmetry and Structure in Chemistry, in German], Weinheim, Germany: VCH, xv + 435 pp.

Vainshtein, B. K. (1979) *Sovremennaya kristallografiya*, Tom 1: *Simmetriya kristallov, Metody strukturnoi kristallografii*, Moskva: Nauka, 383 pp.; English trans., *Modern Crystallography 1: Symmetry of Crystals, Methods of Structural Crystallography*, Springer Series in Solid-State Sciences, Vol. 15, Berlin: Springer, 1981, xvii + 399 pp.; 2nd enlarged ed., ibid., in prep.

Zheludev, I. S. (1976) *Simmetriya i ee prilozheniya*, [Symmetry and its Applications, in Russian], Moskva: Atomizdat, 286 pp.; 2nd enlarged ed., Moskva: Énergoizdat, 1983, 303 pp.; Japanese trans. of the 1st ed., *Taishousei to sono ouyou*, Tokyo: Koudansha, 1979, 303 pp.

A list of additional books, which are slightly less interdisciplinary, is available upon request.

3.2.2 Other mathematics and/or physics

Arai, A. (1993) *Taishousei no suri*, [Mathematics of Symmetry, in Japanese], Tokyo: Nihon Hyouronsha, 221 pp.

Bunch, B. (1989) *Reality's Mirror: Exploring the Mathematics of Symmetry*, New York: Wiley, xi + 286 pp.; Japanese trans., *Jitsuzai no kagami: Shinmetorii no sekai*, Tokyo: Seidosha, in prep.

Elliott, J. P. and Dawber P. G. (1979) *Symmetry in Physics*, Vol. 1, *Principles and Simple Applications*, Vol. 2, *Further Applications*, London: Macmillan, xix + xviii + 557 pp. [Vol. 1, pp. 1-280; Vol. 2, pp. 281-557]; Russian trans., Élliot, D. and Dober, P., *Simmetriya v fizike*, Tom 1, *Osnovnye printsipy i prostye prilozheniya*, Tom. 2, *Dal'neishie prilozheniya*, Moskva: Mir, 1983, 364 + 410 pp.

Genz, H. (in prep.) *Principles of Symmetry in Physics*, Berlin: Springer.

Harter, W. G. (1993) *Principles of Symmetry, Dynamics, and Spectroscopy*, New York: Wiley, xxii + 846 pp.

Holden, A. (1971) *Shapes, Space, and Symmetry*, New York: Columbia University Press, viii + 200 pp.; Reprint, New York: Dover, 1991, 200 pp. [Polyhedra].

Holod, P. I. and Klimyk, A. U. (1992) *Matematychni osnovy teorii symetrii*, [Mathematical Foundations of Theory of Symmetry, in Ukrainian], Kiyiv [Kiev]: Naukova dumka, 366 pp.

Kompaneets, A. S. (1978) *Simmetriya v mikro- i makromire*, [Symmetry in the Micro- and the Macro-Worlds, in Russian], Moskva: Nauka, 207 pp.

Morita, M. (1980) *Taishousei genri: Busshitsu to uchuu o shihaisuru migi to hidari*, [Symmetry Theory: Matter and Universe Ruled by Right and Left, in Japanese], Tokyo: Koudansha, 228 pp.

Schmutzer, E. (1972) *Symmetrien und Erhaltungssätze der Physik*, [Symmetries and Conservation Laws of Physics, in German], Braunschweig: Vieweg and Berlin: Akademie-Verlag, 165 pp.; Russian trans., Shmuttser, É., *Simmetrii i zakony sokhraneniya v fizike*, Moskva: Mir, 1974, 159 pp.

Schottenloher, M. (1993) *Geometrie und Symmetrie in der Physik*, [Geometry and Symmetry in Physics, in German], Wiesbaden: Vieweg, to appear.

Wigner, E. P. (1967) *Symmetries and Reflections*, Bloomington, Ind.: Indiana University Press, viii + 280 pp.; Many reprints; German, Hungarian, Russian trans. [Physics, Philosophy].

Yale, P. B. (1968) *Geometry and Symmetry*, Holden-Day Series in Mathematics, San Francisco: Holden-Day, xi + 288 pp.; Reprint, New York: Dover, 1988.

Zee, A. (1986) *Fearful Symmetry: The Search for Beauty in Modern Physics*, New York: Macmillan, xiv + 322 pp.; Reprint, New York: Collier Books, 1989, xiv + 322 pp.; Japanese trans., *Uchuu no dezain genri: Pariti, geeji, kuouku*, Tokyo: Hakuyousha, 1989, 438 pp.; German trans., *Magische Symmetrie: Die Ästhetik in der modernen Physik*, Frankfurt am Main: Insel, 1993, 360 pp.

Also see the books in Sections 4.1 and 4.3 on broken symmetry and asymmetry in physics, as well as Petukhov (1981) in 3.3 on biomechanics. A list of additional books, which are slightly less interdisciplinary, is available upon request.

3.3 Descriptive sciences (biology, mineralogy, geology) and technical applications

Bobrowski, L. (1987) *Dyskryminacja symetriczna w rozpoznawaniu obrazów: Teoria, algorytmy, zastosowania w komputerowym wspomaganiu diagnostyki medycznej*, [Symmetric Discrimination in Recognition of Images: Theory, Algorithms, Application in Computer-Assisted Medical Diagnostics, in Polish], Wroclaw: Ossolineum, 170 pp.

Charnov, E. L. (1993) *Life History of Invariants: Some Explorations of Symmetry in Evolutionary Ecology*, Oxford: Oxford University Press, xv + 167 pp.

De Michele, V. (1972) *Crystals: Symmetry in the Mineral Kingdom*, London: Orbis Books, 80 pp.

Dubrov, A. P. (1980) *Simmetriya funktsional'nykh protsessov*, [Symmetry of Functional Processes, in Russian], Moskva: Znanie, 64 pp. [Biology, Biophysics - with some challenging ideas].

Dubrov, A. P. (1989) *Symmetry of Biorhythms and Reactivity*, New York: Gordon and Breach, ix + 268 pp. [Biology, Biophysics - with some challenging ideas].

Jocobsohn-Lask, L. (1924) *Die Kreuzung der Nervenbahnen und die bilaterale Symmetrie des tierischen Körpers*, [The Crossing of Neural Pathways and the Bilateral Symmetry of the Animal Body, in German], Abhandlungen aus der Neurologie, Psychiatrie, Psychologie und ihren Grenzgebieten, Heft 26, Berlin: Karger, 125 pp.

Makagonov, E. P. (1991) *Simmetriya srostkov mineralnykh individov*, [Symmetry of Systems of Single Minerals, in Russian], Moskva: Nauka, 193 pp.

Malakhov, A. A. (1965) *L_5-simmetriya zhizni*, [L_5-Symmetry of Life, in Russian], Sverdlovsk: SredneUral'skoe knizhnoe izdatel'stvo, 60 pp. [L_5-symmetry = 5-fold rotational symmetry].

Petukhov, S. V. (1981) *Biomekhanika, bionika i simmetriya*, [Biomechanics, Bionics, and Symmetry, in Russian], Moskva: Nauka, 238 pp.

Shafranovskii, I. I. and Plotnikov, L. M. (1975) *Simmetriya v geologii*, [Symmetry in Geology, in Russian], Leningrad [Sankt-Peterburg]: Nedra, 144 pp.

Sukhanov, V. B. (1968) *Obshchaya sistema simmetrichnoi lokomotsii nazemnykh pozvonochnykh i osobennosti peredvizheniya nizshikh tetrapod*, [in Russian], Leningrad [Sankt-Peterburg]: Nauka, 227 pp.; English trans., *General System of Symmetrical Locomotion of Terrestrial Vertebrates and Some Features of Movement of Lower Tetrapods*, New Delhi: Amerind, [Published for the Smithsonian Institution and the National Science Foundation, Washington, D.C.], 1974, vii + 274 pp.

Sulima, Yu. G. (1970) *Biosimmetricheskie i bioritmicheskie yavleniya i priznaki u sel'skohozyaistvennykh rastenii*, [Biosymmetrical and Biorhythmical Phenomena and Characteristics of Agricultural Plants, in Russian], Kishinev, Moldavia [Moldova]: Izdatel'stvo Akademii Nauk Moldavskoi SSR, 148 pp.

Ufimtsev, G. F. (1991) *Gornye poiasa kontinentov i simmetriya rel'efa zemli*, [Mountain Belts of Continents and Symmetry of the Relief of the Earth, in Russian], Novosibirsk: Nauka, 168 pp.

Yushkin [IUshkin], N. P., Shafranovskii, I. I., and Yanulov [IAnulov], K. P. (1987) *Zakony simmetrii v mineralogii*, [Laws of Symmetry in Mineralogy, in Russian], Leningrad [Sankt-Peterburg]: Nauka, 333 pp.

Also see the books in Section 4.2 on asymmetry in biology, as well as Tímár (1979) in 3.4.3 on human proportions.

3.4 Art and the humanities

3.4.1 Anthropology

Lucich, P. (1987) *Genealogical Symmetry: Rational Foundations of Australian Kinship*, Armidale, New South Wales: Light Stone Publications, xxxi + 684 pp.

Witherspoon, G. and Peterson, G. (in prep.) *Dynamic Symmetry and Holistic Asymmetry in Navajo and Western Art and Cosmology*, American Indian Studies, Vol. 5, New York: Lang.

Also see the books in Sections 2.2.2 and 2.2.3 on pattern analysis. In connection with physical anthropology, cf., Tímár (1979) in 3.4.3 and Schneider (1973) in 4.2.

3.4.2 Architecture and design

Baglivo, J. A. and Graver, J. E. (1983) *Incidence and Symmetry in Design and Architecture*, Cambridge, England: Cambridge University Press, xi + 306 pp.

Bairati, C. (1952) *La simmetria dinamica: Scienza ed arte nell'architettura classica*, [Dynamic Symmetry: Science and Art in Classical Architecture, in Italian], Milano: Editrice Poltecnica Tamburini, 100 pp.

Hambidge, J. (1926) *The Elements of Dynamic Symmetry*, New Haven, Conn.: Yale University Press and New York: Brentano, xx + 140 pp.; Reprint, New Haven, Conn.: Yale University Press, 1948, xvii + 133 pp.; Reprint, New York: Dover, 1967, xvii + 133 pp. [Dynamic symmetry = a system of proportions based on square roots of integers; there are further books on this topic by Hambidge].

Kalayan, H. (1988) *The Architectural Information through Symmetry*, Amman: Department of Antiquities, The Hashimite Kingdom of Jordan, 89 pp.

Kambartel, W. (1972) *Symmetrie und Schönheit: Über mögliche Voraussetzungen des neueren Kunstbewusstseins in der Architekturtheorie Claude Perraults*, [Symmetry and Beauty: On Possible Prerequisites of the New Artistic Consciousness in the Theory of Architecture of Claude Perrault, in German], München: Fink, 179 pp.

Kask, T. (1971) *Symmetrie und Regelmässigkeit: Französische Architektur im "Grand Siècle"*, [Symmetry and Regularity: French Architecture in the "Grand Siècle", in German], Basel: Birkhäuser, 157 pp.

Meunié, L. (1968) *L'Architecture et la géométrie: Symétries et rythmes harmoniques*, [Architecture and Geometry: Symmetries and Harmonic Rhythms, in French], Paris: Vincent, Fréal, 93 pp.

Ressa A. (1990) *Chiese barocche in Piemonte: Nella evoluzione delle figure planimetriche a simmetria centrale*, [Baroque Churches in Piemonte: On the Development of the Layout-Figures in Central Symmetry, in Italian], Roma: Quasar, 210 pp.

Smolina, N. I. (1990) *Traditsii simmetrii v arkhitekture*, [Traditions of Symmetry in Architecture, in Russian], Moskva: Stroiizdat, 343 pp.

Szambien, W. (1986) *Symétrie, goût, caractère: Théorie et terminologie de l'architecture à l'âge classique, 1550-1800*, [Symmetry, Taste, Character: Theory and Terminology of Architecture in the Age of Classicism, 1550-1800, in French], Paris: Picard, 232 pp.

3.4.3 Painting

Funck-Hellet, C. (1950) *Composition et nombre d'or dans les oeuvres peintes de la Renaissance: Proportion, symétrie, symbolisme*, [Composition and Golden Number in the Painted Works of the Renaissance: Proportion, Symmetry, Symbolism, in French], Paris: Vincent, Fréal, 111 pp. [Some of the analyses are wayward].

Scheibler, I. (1960) *Die symmetrische Bildform in der frühgriechischen Flächenkunst*, [Symmetric Picture-Form in the Early Greek Art of Surface-Decoration, in German], Kallmünz, Germany: Lassleben, 131 pp.

Tímár, L. (1979) *Albrecht Dürer: Della simmetria dei corpi humani*, [in English], Budapest: Chemical Works of Gedeon Richter, 64 pp.; Hungarian version, ibid., 1979. [On Dürer's book on human proportions].

Also see MacGillavry (1965) and Schattschneider (1990) in Section 2.2.3 on the graphic art of M. C. Escher, Witherspoon and Peterson (in prep.) in 3.4.1 on Navaho painting and its modern adaptation.

3.4.4 Music

Karakulov, B. I. (1989) *Symmetriya muzykalnoi sistemy: O melodii*, [Symmetry of the Musical System: On the Melody, in Russian], Alma-Ata, Kazakhskoi SSR [Kazakhstan]: Nauka, 129 pp.

Lendvai, E. (1993) *Symmetries of Music: An Introduction to Semantics of Music*, Compiled and ed. by M. Szabó and M. Mohay, Kecskemét, Hungary: Kodály Institute, 155 pp.; German and Hungarian trans., in prep.

Massenkeil, G. (1962) *Untersuchungen zum Problem der Symmetrie in der Instrumentalmusik W. A. Mozarts*, [Studies on the Problem of Symmetry in the Instrumental Music of W. A. Mozart, in German], Stuttgart: Franz Steiner, vii + 145 pp., 106 examples of notes.

Melchert, H. (in prep.) *Symmetrie: Form im Rezitativ der Bachschen Matthäuspassion*, [Symmetry: Form in the Recitative of Bach's "St. Matthew Passion", in German], Ed. by R. Schaal, Veröffentlichungen zur Musikforschung, No. 17, Wilhelmshaven, Germany: Noetzel.

Schröder, H. (1902) *Symmetrische Umkehrung in der Musik: Ein Beitrag zur Harmonie- und Kompositionslehre, mit Hinweis auf die hier technisch notwendige Wiedereinführung antiker Tonarten im Style moderner Harmonik*, [Symmetrical Inversion in Music: A Contribution to the Study of Harmony- and Composition-

Theory with a Reference to the Here Technically Necessary Reintroduction of Ancient Keys in the Style of Modern Harmony, in German], Publikationen der Internationalen Musikgesellschaft, Beihefte, Heft 8, Leipzig: Breitkopf und Härtel, 128 pp.; Reprint, Walluf, Germany: Sändig.

Werker, W. (1922) *Studien über die Symmetrie im Bau der Fugen und die motivische Zusammengehörigkeit der Präludien und Fugen des "Wohltemperierten Klaviers" von Johann Sebastian Bach*, [Studies on the Structural Symmetry in the Fugues and the Motivic Relationship between the Preludes and Fugues in Johann Sebastian Bach's "The Well-Tempered Clavier", in German], Leipzig: Breitkopf und Härtel, vii + 356 pp.; Reprint, Walluf, Germany: Sändig, 1969.

3.4.5 Literature

Etkind, E. G. (1988) *Simmetricheskie kompozitsii u Pushkina*, [Symmetrical Compositions of Pushkin, in Russian], Parizh [Paris]: Institut d'études slaves, 84 pp.

Fedynyshynets, V. (1989) *Symetriya poezii: Khudozhnie oformlennya avtora*, [Symmetry of Poetry: Artistic Presentation of the Author, in Ukranian], Uzhhorod, Ukraine: Karpaty, 93 pp.

Greenberg, M. (1986) *Corneille, Classicism, and the Ruses of Symmetry*, Cambridge, England: Cambridge University Press, xv + 189 pp.

Knight, W. F. J. (1939) *Accentual Symmetry in Vergil*, Oxford: Blackwell, x + 107 pp.; Reprint, New York: Garland, 1979, x + 107 pp.

Montgomery, R. L., Jr. (1961) *Symmetry and Sense: The Poetry of Sir Philip Sidney*, New York: Greenwood Press, vii + 134 pp.; Reprint, ibid., 1969, vii + 134 pp.

Spillner, B. (1971) *Symmetrisches und asymmetrisches Prinzip in der Syntax Marcel Prousts*, [Symmetric and Asymmetric Principle in the Syntax of Marcel Proust, in German], Frankfurt am Main: Hain, xii + 223 pp.

Also see the books in Section 4.4 on broken symmetry and asymmetry in linguistics, literature, and semiotics.

4 Interdisciplinary books on dissymmetry, broken symmetry, asymmetry, including asymmetry of brain and asymmetry of time

Note the differences between these concepts:
(1) dissymmetry is the lack of some elements of symmetry (cf., Pasteur's molecular dissymmetry) or the small deviation from the perfect symmetry (cf., P. Curie's principle of dissymmetry),
(2) broken symmetry is the occasional violation of an existing or suspected symmetry (cf., Lee and Yang's broken symmetry in particle physics),
(3) asymmetry is the total lack of symmetry.
(In connection with antisymmetry, or black-and-white symmetry, in crystallography, cf., Shubnikov (1951) in Section 3.2.1).

4.1 General

Akopyan, I. D. (1980) *Simmetriya i asimmetriya v poznanii*, [Symmetry and Asymmetry in Cognition, in Russian], Erevan, Armenia: Izdatel'stvo Akademii Nauk Armyanskoi SSR, 132 pp.

Caglioti, G. (1983) *Simmetrie infrante nella scienza e nell'arte*, [Broken Symmetries in Science and Art, in Italian], Milano: CLUP, 182 pp.; German trans., *Symmetriebrechung und Wahrnehmung: Beispiele aus der Erfahrungswelt*, [Symmetry-Breaking and Perception: Examples from the Empirical World, in German], [With a preface by H. Haken], Braunschweig: Vieweg, 1990, x + 200 pp.; English trans., *The Dynamics of Ambiguity*, Berlin: Springer, 1992, xx + 170 pp.; Russian and Japanese trans., in prep.

Caillois, R. (1973) *La Dissymétrie*, [Dissymmetry, in French], Paris: Gallimard, 96 pp.; Japanese trans., *Hantaishou*, Tokyo: Shisakusha, 1991, 152 pp.

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Shubnikov, A. V. (1961) *Problema dissimmetrii material'nykh ob"ektov*, [The Problem of Dissymmetry of Material Objects, in Russian], Moskva: Izdatel'stvo Akademii Nauk SSSR, 55 pp.

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Also see Witherspoon and Peterson (in prep.) in 3.4.1 on symmetry and asymmetry in Navaho art and cosmology.

4.2 Chemistry and biology, including asymmetry of brain

Bentley, R. (1969-70) *Molecular Asymmetry in Biology*, Vols. 1-2, New York: Academic Press, xii + 322 + xiii + 566 pp.

Bianki, V. L. (1985) *Asimmetriya mozga zhivotnykh*, [Asymmetry of the Brain of Animals, in Russian], Leningrad [Sankt-Peterburg]: Nauka, 295 pp.

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Saito, Y. (1979) *Inorganic Molecular Dissymmetry*, Inorganic Chemistry Concepts, Vol. 4, Berlin: Springer, ix + 167 pp.

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Vartanian, G. A. and Klementev, B. I. (1991) *Khimicheskaya simmetriya i asimmetriya mozga*, [Chemical Symmetry and Asymmetry of the Brain, in Russian], Leningrad [Sankt-Peterburg]: Nauka, 150 pp.

Also see Ivanov (1978) in 4.4 on the asymmetry of brain.

4.3 Physics, including asymmetry of time

Boccara, N. (1976) *Symétries brisées: Théorie des transitions avec paramètre d'ordre*, [Broken Symmetries: Theory of Transitions with Parameter of Order, in French], Actualités scientifiques et industrielles, Vol. 1378, Paris: Hermann, 274 pp.

Davies, P. C. W. (1974) *The Physics of Time Asymmetry*, Berkeley: University of California Press, xviii + 214 pp.; Paperback ed., ibid., 1977, xviii + 214 pp.; Japanese trans., *Jikan no butsurigaku: Sono hitaishousei*, Tokyo: Baifuukan, 1979, xiv + 219 pp.; Reprint ed., ibid., 1982, xiv + 219 pp.

Forster, D. (1975) *Hydrodynamic Fluctuations, Broken Symmetry, and Correlation Functions*, Frontiers in Physics, Vol. 47, Reading, Mass.: Benjamin, xix + 326 pp.; Reprint, Redwood City, Calif.: Addison-Wesley, 1989, xxiv + 326 pp.

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4.4 Linguistics, literature, semiotics

Andrews, E. (1990) *Markedness Theory: The Union of Asymmetry and Semiosis in Language*, Sound and Meaning: The Roman Jakobson Series in Linguistics and Poetics, Durham, N.C.: Duke University Press, viii + 220 pp.

Fido, F. (1988) *Il regime delle simmetrie imperfette: Studi sul "Decameron"*, [The Rule of Imperfect Symmetries: Study of the "Decameron", in Italian], Milano: Angeli, 151 pp.

Freund, J. (1991) *Broken Symmetries: A Study of Agency in Shakespeare's Plays*, Worcester Polytechnic Institute Studies in Science, Technology, and Culture, Vol. 8, New York: Lang, xvii + 214 pp.

Ivanov, V. V. (1978) *Chetnoe i nechetnoe: Asimmetriya mozga i znakovykh sistem*, [Even and Odd: The Asymmetry of Brain and Sign-Systems, in Russian], Moskva: Sovietskoe radio, 184 pp.; German trans., *Gerade und Ungerade: Die Asymmetrie des Gehirns und der Zeichensysteme*, Stuttgart: Hirzel, 1983, 221 pp.; Hungarian trans., *Páros és páratlan: Aszimmetria az agyban és a jelrendszerben*, Budapest: Kozmosz, 1986, 263 pp.

Shapiro, M. (1976) *Asymmetry: An Inquiry into the Linguistic Structure of Poetry,* North-Holland Linguistic Series, Vol. 26, Amsterdam: North-Holland, xiv + 231 pp.

Additions to Part 1

To 2.1.2 (General works with systematic surveys; Works published after 1952)

Hargittai, I. and Hargittai, M. (in prep.) *Symmetry: A Unifying Concept*, Bolinas, Calif.: Shelter Publications.

Rosen, J. (in prep.) *Symmetry in Science: An Introduction to the General Theory*, New York: Springer.

Sivardière, J. (in prep.) *La Symétrie en mathématiques, physique et en chimie*, [Symmetry in Mathematics, Physics, and Chemistry, in French], Grenoble Sciences, Saint-Martin-d'Hères (Isère), France: PUG.

To 2.2.2 (Pattern analysis: comprehensive surveys)

Jablan, S. V. (1984) *Teorija simetrije i ornament*, [in Serbo-Croatian], Beograd: APXAIA, 344 pp.; Rev. English trans., *Theory of Symmetry and Ornament*, Beograd: Matematički institut, in prep.

To 2.2.3 (Pattern analysis: special fields)

Abas, S. J. and Salman, A. S. (in prep.) *Symmetries of Islamic Geometrical Patterns*, Singapore: World Scientific.

McDowell, R. B. (in prep.) *Symmetry: A Design System for Quiltmakers*, Lafayette, Calif.: C and T Publishers.

Tarayan, Z. R. (1989) *Simvoly simmetrii ornamenta v armianskom prikladnom iskusstve*, [Symbols of Ornamental Symmetry in Armenian Applied Arts, in Russian], Erevan, Armenia: Izdatel'stvo Akademii Nauk Armyanskoi SSR, 198 pp.

Dénes Nagy

SYMMETRIC REVIEWS 4.4

The "Symmetric Reviews" (SR), as a regular subsection, publishes notes on books and papers. These are not conventional reviews; their main goal is to emphasize the connections with symmetry and, in some cases, the required background.

Correspondence should preferably be sent to both the section editor (for reviewing) and the Symmetrion in Budapest (for the data bank).

SR 4.4 – 1 (Ethnomathematics: Polynesian, languages)
Begg, A[ndy] J. C., ed., *Mathematika Pasefika: Vocabulary Database (Version 2.0)*, [in English, Maori, Cook Islands Maori, Fijian, Hawaiian, Niuean, Samoan, Tokelauan, Tongan, Tahitian, Tuvalu, Wallis and Futuna], Unesco Conference, 17-24 November 1991, Hamilton, New Zealand: Centre for Science and Mathematics Education Research, University of Waikato, 1991, iii + 157 pp.

This is a remarkable step in the framework of an ongoing project to develop a school mathematics vocabulary in many languages spoken in Polynesia. As a first step, a list of basic terms was prepared in English with definitions. The main goal is to find the equivalent of these terms, if any, in the languages under consideration. Bill Barton and Te Taura Whiri i te Reo Mâori (Maori Language Commission) prepared the Maori version of the original list, while the Department of Education of Tokelau provided the Tokelauan vocabulary. In addition to this, Stephen Williams, a student-researcher, made searches in further dictionaries. (Note that, according to the list of the references, he had no access to many fine dictionaries, e.g., Hawaiian, Tahitian, Tongan, Niuean). In the second circle, the participants of the *Mathematika Pasefika Conference*, mostly education officers and some interested teachers and researchers, contributed to extend and sometimes correct to original database in their languages: the result is the present version 2.0. The organizers invited delegates from many countries of the region. There were no representatives, however, from Hawaii or Tokelau, while the French Polynesian delegation came from Tahiti with no member from the distant Wallis and Futuna. Thus, some of the listed languages show rather the goals than the actual results: the places for the expressions in Hawaiian, Tuvalu, and Wallis and Futuna are still empty at all keywords in the dictionary. In addition there are just few expressions in Tahitian and Tongan. (The latter is a bit surprising because there is a strong tradition to teach mathematics using the Tongan language; moreover, there is a scientific dictionary in Tongan published by Futa Helu at the 'Atenisi University in Tonga.) The book, after an introduction, has three major parts: (1) *Word lists* (pp. 4-24), numbers, ordinal numbers, fractions, months, seasons, days, polygons, polyhedra, angles, compass directions, time, money, prefixes, mass (weight), length, area, volume and capacity, traditional counting, traditional measurement of length, pre-mathematics vocabulary (color, size); (2) *Dictionary, A-Z* (pp. 25-146); (3) *Concept maps* (pp. 147-157), mathematics, number, operations, relations, algebra (and calculus), measurements and units, shapes, transformations, statistics, equipments (this part is in English only). The *Dictionary* part includes many symmetry-related terms, e.g., axis of symmetry, centre of rotation, congruent, cube, equilateral triangle, glide reflection, golden section, grid, group (algebraic structure), half turn (180°), identity transformation, invariant, inverse element, inverse operation, invert (turn upside down), line of symmetry, line symmetry, mid-point of a line segment, mirror line, order of symmetry, palindrome, pattern, proportion, reflect, reflection, regular polygon, regular polyhedron, rotation, sphere, square, symmetrical shape, symmetry, tetrahedron, translation, upside down (inverted). Incidentally, we think that the definition of symmetry as "the property of mapping onto oneself with a reflection or a rotation" (p. 134) is incomplete even at level of school mathematics. We do not see any reason to specify here just reflection and rotation as possible mappings, and thus to exclude translation and glide reflection, which are also given keywords in the dictionary, as well as listed among the basic isometries at the concept map "Transformations" (p. 155). There are also some other minor problems (e.g., some definitions are a bit fuzzy, see regular polyhedron, similar figures, etc.) that can be easily corrected in later versions. We hope very much to see the further developments of this project: it provides an invaluable handbook not only for the obvious target, the educators of mathematics in Polynesia, but also for all people in the world interested in mathematical thinking and related ethnomathematical, historical, and psychological aspects. Because of the great importance of this book, it will be reviewed in more detail later. Illustrations: various figures illustrating keywords of the *Dictionary*, ten concept maps, and the geographical map of the region (inside back cover). References: 14 (p. 1). Address: Andy Begg, Centre for Science and Mathematics Education Research, University of Waikato, Private Bag 3105, Hamilton, New Zealand.

SR 4.4 – 2 (Ornamental art: Fijian; Ethnomathematics: Fijian, geometric design; Anthropology: Fijian, textiles)
Crowe, Donald W. and Nagy, Dénes, Cakaudrove-style *masi kesa* of Fiji, *Ars Textrina*, 18 (1992), 119-155.

Cakaudrove (Thakaundrove) is a province of Fiji at the Eastern part of this island country, while *masi kesa* is the Fijian word for tapa (bark cloth) which is decorated. This paper is based on the results of an anthropological and ethnomathematical field work of the authors, both are originally mathematicians, in the region. The Cakaudrove-style tapa is decorated usually with black-and-white geometrical motifs. After a brief introduction and a short discussion of the *masi kesa* in Fiji, the mathematical backgrounds of pattern analysis are summarized. This includes both the history of this topic and some technical details addressed to the non-specialist reader. Specifically, all of the possible 7 types of strip patterns (friezes) and 17 types two-dimensional patterns (wallpapers) are discussed using the original figures of Niggli and of Pólya, respectively, and giving the modern notation for them. In the latter case a flow chart is also provided, which is a useful tool to identify the symmetry-types of periodic patterns (it is adapted from Washburn and Crowe, *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis*, Seattle, Wash.: University of Washington Press, 1988). Following this survey, a catalog of black-and-white pattern types used in Cakaudrove is given. Specifically 12 of the total 17 types of two-color strip patterns and 12 of the total 46 types of two-color two-dimensional patterns are presented. The Cakaudrove patterns are compared with the figures by Woods, a textile-specialist, who firstly described the exhaustive list of two-color patterns in 1935-36 and illustrated them with tilings. The similarity of some striking details and the fact that Woods studied in Oxford where one of the museum has a Cakaudrove cloth lead to the speculation that "[...] Woods had seen Cakaudrove *masi kesa* and was influenced by what he had seen when he invented his patterns." (p. 134; see some further notes on this topic in the paper "Symmetric patterns and ethnomathematics in the South Pacific: Inspiring research and helping education" by D. Nagy in this issue). The stencils of basic motifs used by Fine Nailevu of Somosomo village, Taveuni island, Cakaudrove – the authors call her"the professor of *masi*" – are cataloged, too, giving their Fijian names with English translation and various comments. While the literature on symmetry of patterns focus, with a few exceptions, on global symmetries, the method of stenciling the Cakaudrove patterns demonstrate the importance of local properties in the construction of global symmetry (p. 126). On the other hand, just to consider the 'check-list' of motifs would be misleading, because the regional characters are frequently expressed in the overall pattern, i.e., in the global symmetry (p. 141). Illustrations: 15 (including many multiple figures). References: 21. Address: Donald W. Crowe, Department of Mathematics, University of Wisconsin, Madison, WI 53706, U.S.A.; Dénes Nagy, refer to the Board of ISIS-Symmetry.

Dénes Nagy

There are many disciplinary periodicals and symposia in various fields of art, science, and technology, but broad interdisciplinary forums for the connections between distant fields are very rare. Consequently, the interdisciplinary papers are dispersed in very different journals and proceedings. This fact makes the cooperation of the authors difficult, and even affects the ability to locate their papers.

In our 'split culture', there is an obvious need for interdisciplinary journals that have the basic goal of building bridges ('symmetries') between various fields of the arts and sciences. Because of the variety of topics available, the concrete, but general, concept of symmetry was selected as the focus of the journal, since it has roots in both science and art.

Symmetry: Culture and Science is the quarterly of the *International Society for the Interdisciplinary Study of Symmetry* (abbreviation: *ISIS-Symmetry*, shorter name: *Symmetry Society*). ISIS-Symmetry was founded during the symposium *Symmetry of Structure* (*First Interdisciplinary Symmetry Symposium and Exhibition*), Budapest, August 13-19, 1989. The focus of ISIS-Symmetry is not only on the concept of symmetry, but also its associates (asymmetry, dissymmetry, antisymmetry, etc.) and related concepts (proportion, rhythm, invariance, etc.) in an interdisciplinary and intercultural context. We may refer to this broad approach to the concept as *symmetrology*. The suffix *-logy* can be associated not only with knowledge of concrete fields (cf., biology, geology, philology, psychology, sociology, etc.) and discourse or treatise (cf., methodology, chronology, etc.), but also with the Greek terminology of proportion (cf., *logos*, *analogia*, and their Latin translations *ratio*, *proportio*).

The basic goals of the *Society* are
(1) to bring together artists and scientists, educators and students devoted to, or interested in, the research and understanding of the concept and application of symmetry (asymmetry, dissymmetry);
(2) to provide regular information to the general public about events in symmetrology;
(3) to ensure a regular forum (including the organization of symposia, congresses, and the publication of a periodical) for all those interested in symmetrology.

The Society organizes the triennial *Interdisciplinary Symmetry Congress and Exhibition* (starting with the symposium of 1989) and other workshops, meetings, and exhibitions. The forums of the Society are *informal* ones, which do not substitute for the disciplinary conferences, only supplement them with a broader perspective.

The Quarterly - a non-commercial scholarly journal, as well as the forum of ISIS-Symmetry - publishes original papers on symmetry and related questions which present new results or new connections between known results. The papers are addressed to a broad non-specialist public, without becoming too general, and have an interdisciplinary character in one of the following senses:
(1) they describe concrete interdisciplinary 'bridges' between different fields of art, science, and technology using the concept of symmetry;
(2) they survey the importance of symmetry in a concrete field with an emphasis on possible 'bridges' to other fields.

The Quarterly also has a special interest in historic and educational questions, as well as in symmetry-related recreations, games, and computer programs.

The regular sections of the Quarterly:
- **Symmetry: Culture & Science** (papers classified as humanities, but also connected with scientific questions)
- **Symmetry: Science & Culture** (papers classified as science, but also connected with the humanities)
- **Symmetry in Education** (articles on the theory and practice of education, reports on interdisciplinary projects)
- **SFS: Symmetric Forum of the Society** (calendar of events, announcements of ISIS-Symmetry, news from members, announcements of projects and publications)
- **Symmetro-graphy** (biblio/disco/software/ludo/historio-graphies, reviews of books and papers, notes on anniversaries)

Additional non-regular sections:
- **Symmetrospective: A Historic View** (survey articles, recollections, reprints or English translations of basic papers)
- **Symmetry: A Special Focus on ...** (round table discussions or survey articles with comments on topics of special interest)
- **Symmetric Gallery** (works of art)
- **Mosaic of Symmetry** (short papers within a discipline, but appealing to broader interest)
- **Research Problems on Symmetry** (brief descriptions of open problems)
- **Recreational Symmetry** (problems, puzzles, games, computer programs, descriptions of scientific toys; for example, tilings, polyhedra, and origami)
- **Reflections: Letters to the Editors** (comments on papers, letters of general interest)

Both the lack of seasonal references and the centrosymmetric spine design emphasize the international character of the Society; to accept one or another convention would be a 'symmetry violation'. In the first part of the abbreviation *ISIS-Symmetry* all the letters are capitalized, while the centrosymmetric image iSIS! on the spine is flanked by 'Symmetry' from both directions. This convention emphasizes that ISIS-Symmetry and its quarterly have no direct connection with other organizations or journals which also use the word *Isis* or *ISIS*. There are more than twenty identical acronyms and more than ten such periodicals, many of which have already ceased to exist, representing various fields, including the history of science, mythology, natural philosophy, and oriental studies. ISIS-Symmetry has, however, some interest in the symmetry-related questions of many of these fields.

continued from inside front cover

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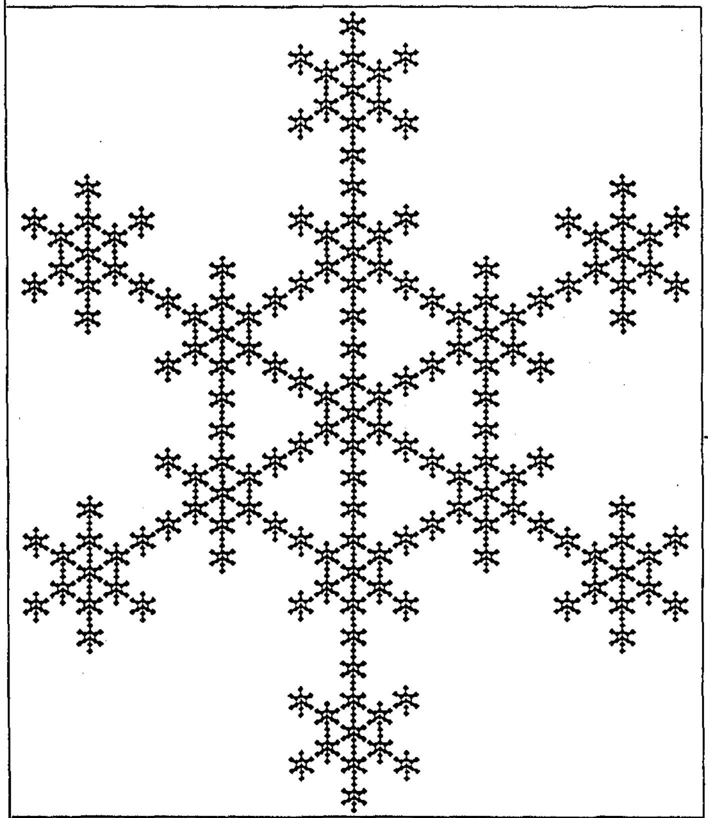

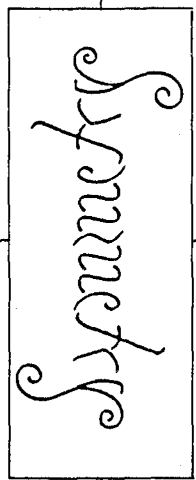

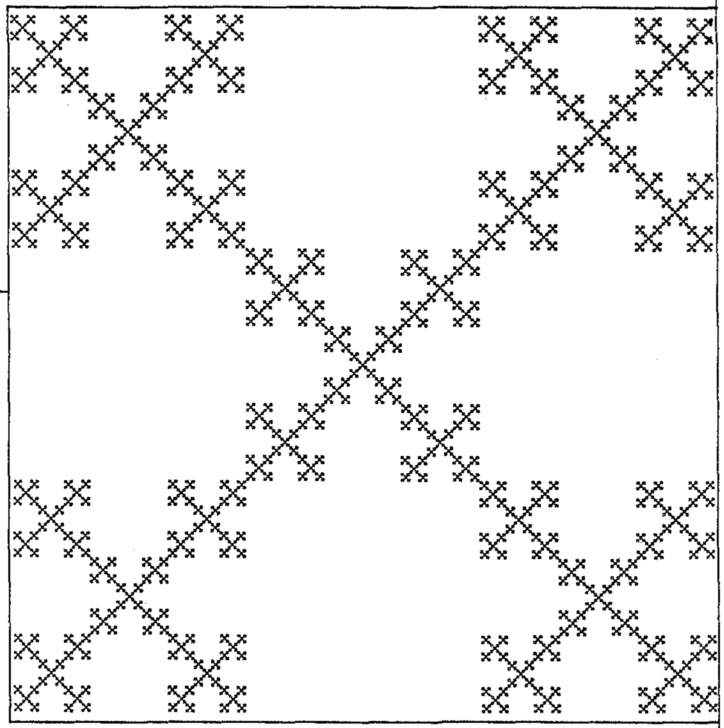

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