methods made horoscopic astrology a possibility for the first time. Incorporated into Zoroastrianism, astrology provided a vehicle for the spread of Babylonian mathematical procedures first into Greece and later into India and Hellenistic Egypt.

Such fascinating conjectures found no place in the London symposium, nor were several other areas of speculative prehistoric astronomy so much as mentioned: W. Hartner's idea that zodiacal motifs pervade the decorative arts of ancient Mesopotamia; H. von Dechend and G. de Santillana's claim that mythology records a preliterate knowledge of the precession of the equinoxes; or A. Marshack's belief that certain Ice Age artifacts chronicle an early lunar calendar. Unlike the megalithic yard, these suggestions cannot be put to a mathematical test, and the symposium was perhaps justified in excluding them. Nevertheless, as Mark Twain remarked in another connection, such speculations are "interesting if true, and interesting anyway."

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Transformations and Their Generalizations

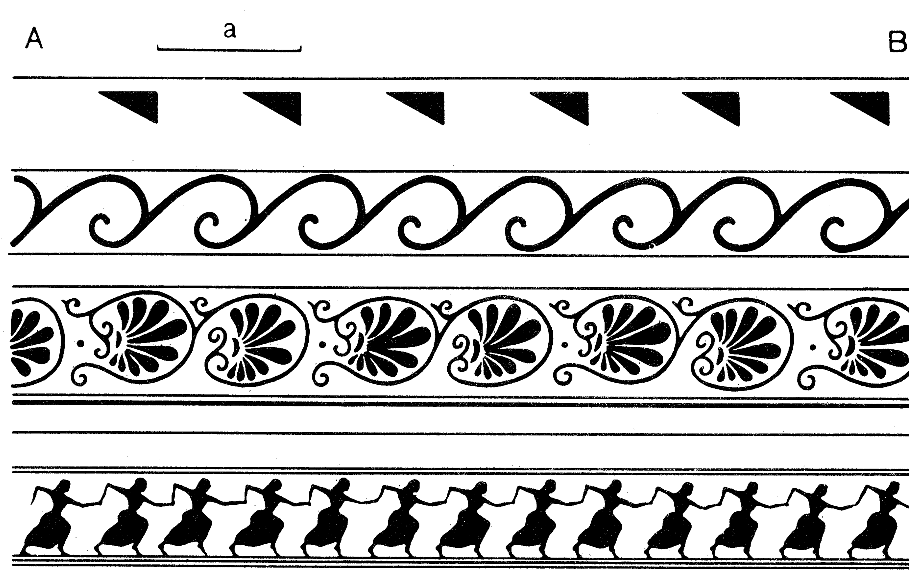
Symmetry in Science and Art. A. V. SHUBNIKOV and V. A. KOPTSIK. Translated from the Russian edition (Moscow, 1972) by G. D. Archard. David Harker, Transl. Ed. Plenum, New York, 1974. xxvi, 420 pp. + plates. $35.

This is an extraordinary book, dealing with symmetry in all its aspects and written for the nonspecialist as well as the specialist (crystallographer and physicist) in this domain of natural sciences. It is composed of 12 chapters. It starts with the symmetry of figures with a singular point in two and three dimensions (rosettes, blossoms of plants, and other biological objects, crystals, vectors, tensors)—crystallographic and noncrystallographic point groups. Then translations are introduced: in one direction (symmetry of one- and two-sided bands and of rods), in two directions (network and layer patterns, including two-dimensional continua and semicontinua), and in three directions (symmetry of spaces, especially space groups and discontinua and continua). More recent developments in symmetry theory are covered in the remaining three chapters, which are written by Koptsik alone. These developments include the theory of the extension of groups (by means of direct and semidirect products and quasi-products)—that is, the derivation of new groups from original ones—as applied to classical (Fedorov), antisymmetry (two-colored, Shubnikov), and colored-symmetry (Belov) space groups; the derivation of limiting groups of colored symmetry; and combination of the dissymmetrization and the symmetrization principles to form a single symmetry principle for composite systems.

As to the definition of symmetry, the principle given in Hermann Weyl's classic *Symmetry* (1952) is the most general: "Whenever you have to do with a structure-endowed entity . . . try to determine its group of automorphisms, the group of those element-wise transformations which leave all structural relations undisturbed."

Two small biographical corrections may be inserted at this point: Weber was a Swiss, not (as is implied on p. 189) a German, crystallographer, and Emmy Nöther certainly was not (as she is called on p. 341) "Klein's successor," except perhaps in a quite general sense, as a member of the Göttingen school headed by Hilbert and Weyl.

In the book many examples from the kingdom of art are given. This is treated in the last chapter, which was of special interest to the reviewer because he has given several lectures and courses on "symmetry in nature and art" at the University of Bern and at the C. G. Jung-Institute in Zürich (see "Symmetrie und Form," *Mitt. Naturforsch. Ges. Bern* **1940/41**, 5; "Die Idee einer Struktur der Wirklichkeit," *ibid.* [N.F.] **14**, 141 [1957], translated in *Main Curr. Mod. Thought* **26**, 67 [1970]). It is quite clear that the concept of symmetry is of general philosophical importance in the field of *Erkenntnistheorie*, and the reviewer has detected certain analogies between elements of symmetry and archetypes, both being conceptual or formal factors assembling the material and the psychic, respectively, in a meaningful, regular way. They form, in a general sense, a group. The symmetry elements, like the archetypes, are abstract and intangible, and first become manifest when they are charged with a definite content. This can



One-sided bands with one translation axis. "We must remember . . . that the concept of 'band,' like that of 'rosette' . . . is used as a . . . scientific term rather than in the everyday sense . . . Let us consider an infinite series of equal figures, plane or three-dimensional, disposed relative to one another as indicated [above]. If the whole row . . . is moved through a distance a along the straight line AB . . . so that one of the figures coincides with its neighbor, the whole set of figures will assume a new position differing in no way from the original. The straight line AB is called the *translation axis* . . . Since displacement by a distance a does not introduce any changes, it may be repeated as many times as desired. The displacement . . . may take place in the direction AB or in the reverse direction BA with the same result. Since it is not the actual line AB but its orientation in space which is of importance . . . any straight line parallel to AB can be taken as the translation axis. The set of all parallel translations creates a new symmetry class, a translation group for our infinite figure. The shortest distance a through which the row of figures can be translated and still come into coincidence with itself is called the *elementary translation* or *period*. The translation axis, denoted by the same letter a, is a symmetry element encountered only in infinite figures . . . The type of one-sided bands described here is often encountered in applied art and architecture, and may be particularly recommended [where] it is desired to . . . emphasize forward motion, e.g., in the decoration of underground subway passages and intersections intended to produce a flow of people in one direction." [From *Symmetry in Science and Art*] happen in a wide variety of ways, whereby the multiplicity of manifestations of reality is produced.

In the book examples from poetry (stanzas from Pushkin's *Eugene Onegin*), music, architecture, and other arts are treated in an interesting metrical manner, showing the analogy with one-dimensional and other structures. For music the locus classicus is the rearrangement of the several fugues of Bach's "Kunst der Fuge" according to symmetry principles by Wolfgang Graeser (1924).

The references given at the end of the book are numerous, valuable, and up to date. They give, inter pares, a vivid impression of the activity of Russian science and philosophy in the realm of special and general symmetry.

This clearly written, beautifully illustrated book will become a standard work for all who are interested in unifying branches of natural sciences and of art, and we must be grateful to the translator, the editor, and the publisher for having produced such a precious publication.

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Mammals in Motion

How Mammals Run. Anatomical Adaptations. P. P. GAMBARYAN. Translated from the Russian edition (Leningrad, 1972) by Hilary Hardin. Halsted (Wiley), New York, and Israel Program for Scientific Translations, Jerusalem, 1974. xiv, 368 pp., illus. $26.75.

Most of the bones and muscles of mammals and other vertebrates are directly adapted to the functions of locomotion, and it follows that anyone interested in how mammals have evolved needs to know a good deal about how they move around. In the past, there have been two parallel ways of approaching mammalian locomotion. Morphologists have accumulated innumerable data on the differences between the limb bones and muscles of various mammals, but these data have been related to actual behavior mostly by the loose procedure of comparing animals in different "locomotor categories"—fast runners vs. slow runners, hovering bats vs. swift-flying bats, bipedal primates vs. brachiating primates, and so on. On the other hand, students of behavior from Muybridge onward have recorded locomotion on film and developed elegant and precise systems for recording limb movements and footfall sequences, but few have gone on to seek morphological or adaptive correlates of observed differences in locomotor behavior.

In recent years, however, many morphologists have begun approaching mammals with movie cameras and electromyographic apparatus as well as with scalpels and calipers, and we are beginning to learn a great deal about the correlations between the kinetics of motion and the musculoskeletal machineries that produce the motion. In the West, this new work is being done mostly on primates and bats, and to some extent on marsupials and monotremes; so it comes as a pleasant surprise to learn of the parallel Soviet work summarized in this book, which has been directed toward ungulates, carnivores, rodents, and lagomorphs.

Gambaryan's analysis of locomotor morphology in these terrestrial mammals relies heavily on exactly the kind of studies of gaits and footfall patterns that have not led to many morphological insights in the hands of his Western predecessors. He begins by summarizing previous work in the analysis and description of symmetrical gaits, culminating in the synthetic system devised by Sukhanov (whose 1968 magnum opus has also just appeared in English translation). Gambaryan's principal interest, however, is in asymmetrical gaits—that is, those in which the gait cycle begins with the movement of both forelimbs, followed by the movement of both hind limbs. These are of particular importance for two reasons: they are the characteristic high-speed gaits of terrestrial mammals, and they are unique to the class Mammalia. Gambaryan divides asymmetrical gaits into two basic types: the ricochet, in which the hind limbs begin to move forward immediately after pushing off and land before the forefeet leave the ground; and the gallop, in which the forefeet push off while the hind feet are still in the air.

Many students of locomotion would have stopped there, or gone on to demonstrate (to nobody's surprise) that kangaroos are adapted for the ricochet and cheetahs are not; but Gambaryan proceeds to draw some very large and ingenious phylogenetic inferences that are central to much of what follows. The ancestors of the therian mammals (marsupials and placentals), he argues, must already have had asymmetric gaits—either the gallop or the ricochet. But the ricochet is less efficient than the gallop, because it necessitates putting more of the propulsive force into vertical oscillations of the center of gravity (Fig. 1). Therefore, since the less advantageous ricochet could not have evolved from the gallop, the ricochet is the primitive fast gait of mammals. Gambaryan goes on to attack the notion that primitive mammals were arboreal, arguing that if they had been slow-climbing animals they would never have developed asymmetrical gaits (since stride length is greater in symmetrical gaits), and that if they had been leaping about in the trees they would have developed the gallop instead of the ricochet (since change in the length of the ricochet changes the footfall pattern and so requires greater coordination in leaping varying distances, and arboreal leaping favors gaits in which the forelimbs touch down first). He concludes that primitive mammals lived on the forest floor, feeding by digging through the litter with their forelimbs while supporting themselves on their hind limbs, and that this explains the evolution of asymmetrical gaits as well as the characteristic mammalian posture, in which the limbs support the body from underneath.

All of this strikes me as tenuous, and many objections could be raised: Jenkins

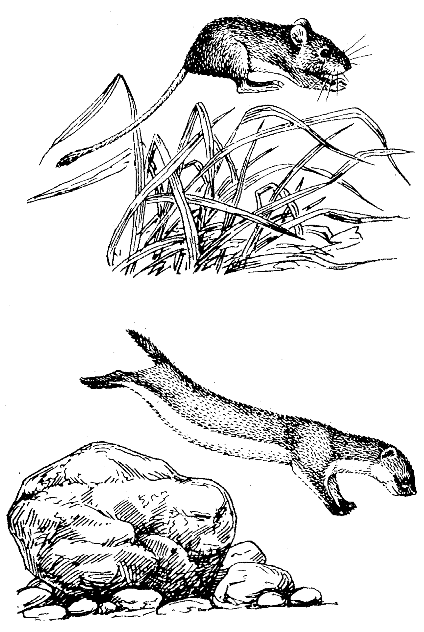

Fig. 1. Asymmetrical gaits of mammals. The rodent (top) illustrates the ricochet, in which the hind limbs are brought forward together immediately after they leave the ground. The mustelid (bottom) illustrates the "extended flight" phase of the gallop, which is permitted by an increase in the propulsive thrust provided by the forelimbs, and which allows obstacles of a given height to be cleared with a lower center of gravity than that required by the ricochet. [From *How Mammals Run*]