GEOMETRIC SYMMETRY

SLIDES

ORDER FOR FRIEZE GROUPS

t	L
tg	LΓ
tm	V
mt	C
t2	N
t2mg	VΛ
t2mm	H

ORDER FOR WALLPAPER GROUPS

p1	p2	pm	pg	cm
pmm	pmg	pgg	cmm	
p4	p4m	p4g		
p3	p3m1	p31m		
p6	p6m			

GEOMETRIC SYMMETRY—SLIDES

010
(Cypriot Vase with the Name of Thales).

020
SONNET ABOUT THE RAIN - Dobrivoje Jevti , 1978.
B. Pavlovi , "On symmetry and asymmetry in literature", *Comp. and Math. with Applics.* **12B** (1/2) (1986), 197–227, at p.208 = Istvan Hargittai, *Symmetry Unifying Human Understanding*, Pergamon 1986, 197–227, at p.208.

030
Hedgehog
Edward Rolland McLachlan, *The Cartoons of McLachlan*, Private Eye 1973.

040
Palindrome.
THE END - Frederic Brown.
Martin Gardner, *The Ambidextrous Universe*, Penguin 1970, end of Chapter 5 (pp.50–51).

050
Palindrome
BLACK AND WHITE by J.A. Lindon.

Lived as a dog - o no! God, as a devil
  Doom lives ever, it's astir, Eve's evil mood,
Live, O devil, revel ever, live, do evil!
  Do, O God, no evil deed, live on, do good!

Howard W. Bergerson, *Palindromes and Anagrams*, Dover 1973, p.117.

060
m
The human anatomy according to ideal principles. Venice, Academy.
[N.B. Leonardo's notebooks were written backwards, from right to left].
Bruno Santi, *Leonardo*, Constable 1978, p.41.

070
m
Mixtec culture: a sacrificial obsidian knife with mosaic handle.
A two-handled mosaic serpent (below). These objects are believed to have been among the treasure presented to Cortés by Moctezuma.
Hammond Innes, *The Conquistadors*, Collins 1969, repr. by Fontana 1972, p.110.

080
m

(Russian imperial eagle).
Alexander Pushkin, *Boris Godunov* (Illustrated by Boris Zvorykin) (Introduction by Peter Ustinov), Allen Lane 1982, Back endpaper.

090
m
Flags of Europe I: 1, Denmark; 2, Norway; 3, Iceland; 4, Sweden; 5, Finland; 6, Greece; 7, Czechoslovakia; 8, Poland.
Numbers 1, 2, 3, 4 (and 5 apart from the badge) have symmetry m but number 7 needs inversion of red and yellow to go with the mirror operation.
G. Campbell and T.O. Evans, *The Book of Flags*, Oxford University Press 1950, Plate XI.

100
2
Fig. 129. M83. This picture of a face-on spiral galaxy was made of Kodak Vericolor II negative film, rather than by the three-colour superposition technique and shows much less intense but similar colours to the picture of NGC 2997 [Fig. 128 in the same book].
David Malin and Paul Murdin, *Colours of the Stars*, Cambridge University Press 1984, Fig. 129.

110
2m
Fig. 133. Centaurus A. Basically an elliptical galaxy with a population of yellowish stars, Cen A is crossed by a band of dust which reddens the stars still further. Formed from the dusty material, blue stars and pink H II regions can be perceived along the rim of the dust band.
David Malin and Paul Murdin, *Colours of the Stars*, Cambridge University Press 1984, Fig. 133.

120
2 (colour !)
Back cover and p.13. The yin-yang symbol [tai-ji] surrounded by the eight trigrams. This arrangement is known as the Sequence of Earlier Heaven, or the Primal Arrangement (Roland Michaud).
Neil Powell, *The Book of Changes: How to Understand and Use the I Ching*, Orbis 1979 reprinted by Macdonald & Co. under the Black Cat imprint.

130
2 (colour !)
Figure 6.8 portrays two ancient symbols belonging to the same group, the runic symbol for death and the well-known Chinese yin-yang symbol of universal duality.
P.S. Stevens, *Handbook of Regular Patterns*, MIT Press 1974, p.43, Figs. 6.8a and 6.8b.

140
2
m, 3m, 4m, (near bottom centre), 14m (top), 31m (or thereabouts)
An arrangement of diatoms from the South Pacific, photographed in polarized light $\times$ 150.
Eric Linklater, *The Voyage of the Challenger*, John Murray 1972 and Sphere 1974, p.228.

150
4
Fig. 20 *Aurelia insulinda*. Example of an organism possessing a four-fold symmetry axis (Haeckel).
A.V. Shubnikov and V.A. Koptsik, *Symmetry in Science and Art*, Plenum 1974, Fig. 20, p.20.

160
4
8. A sprig of Codlins and Cream (Epilobium hirsutum)
The whole plant grows to five or six feet
Iolo A. Williams, *Flowers of Marsh and Stream*, Penguin 1946 (King Penguin No. 27), Plate 8.

170
Fig. 1. The starfish Pentaceraster mamillatus, one of the most conspicuous inhabitants of deeper sand bottoms, is 20 to 25cm across and bright red or orange in colour. This individual was brought up from the bottom at 15m and photographed on the beach . [Jana Island].
Philip W. Basson, John E. Burchard, Jr., John T. Hardy, and Andrew R.G. Price (illustrated and designed by Lisa Bobrowski), *Biotopes of the Western Arabian Gulf*, Aramco (Dharan, Saudi Arabia) 1977, Fig. 1.

180
6m
W.A. Bentley and W.J. Humphreys, *Snow Crystals*, McGraw-Hill 1931 and Dover 1962.

190
2m, 3m, 6m
W.A. Bentley and W.J. Humphreys, *Snow Crystals*, McGraw-Hill 1931 and Dover 1962.

200
7m and 5m
(top left) *Antedon bifida* (top right) *Luida ciliaris* (always has 7 flattened rays)
(centre left) *Astropecten aranciacus* (centre right) *Astropecton irregularis*
(bottom left) *Ceramaster placenta* (bottom right) *Porania pulvillas*

A.C. Campbell (illustrated by James Nicholls), *The Seashore and Shallow Seas of Britain and Europe*, Collins 1976, p.241.

210
8m, 9m, 12m and 5m
(top left) *Crossaster papposus* (8-13 blunt rays) (12 shown)
(top right) *Solaster endeca* (7-13 rays) (9 shown)
(centre left) *Marthasterias glacialis*
(centre right) *Asteriasw rubens*
(bottom left) *Stichastrella rosea*
(bottom right) *Coscinasterias tenuispina* (6–10 rays often of very different lengths) (8 shown)
A.C. Campbell (illustrated by James Nicholls), *The Seashore and Shallow Seas of Britain and Europe*, Collins 1946, p. 245.

220
12
9. *Sea anemone* (*Halcampa chrysanthellum*).
[It] is very much enlarged and inhabits sandy and muddy places, burying its worm-like body and extending its tentacles at its surface.
T.A. Stephenson, *Seashore life and pattern*, Penguin 1944 (King Penguin No. 15), Plate 9.

230
20m (approx.)
Floating sea slug attacking a jellyfish, Great Barrier Reef.
David Attenborough, *Life on Earth*, Collins/British Broadcasting Corporation 1979.

240
Fig. 14–6 Asante brass weights in geometric shapes, used for measuring gold dust currency. Many of the designs have symbolic meaning; for example, a zigzag line represents the fire of the sun. British Museum.
C. Zaslavsky, *Africa Counts*, Prindle Weber and Schmidt 1973, p.176.

250
The Seven Friezes

L	L	L	L	L	L	L
L	Γ	L	Γ	L	Γ	L
V	V	V	V	V	V	V
C	C	C	C	C	C	C
N	N	N	N	N	N	N
V	Λ	V	Λ	V	Λ	V
H	H	H	H	H	H	H

260

Plate XV, Greek No. 1
Owen Jones, *The Grammar of Ornament*, John Day 1856 and Van Nostrand Reinhold 1982.

270
Plate VI. Egyptian No. 3
Owen Jones, *The Grammar of Ornament*, John Day 1856 and Van Nostrand Reinhold 1982.

280
Plate XCIII Leaves from Nature No. 3
Owen Jones, *The Grammar of Ornament*, John Day 1856 and Van Nostrand Reinhold 1982.

285
Granada. Sala de Reposo [del Bao]
[Baths. The Rest Hall or Hall of Repose in the Comares Palace Bath]
(Postcard)

290
p1
Plate X, No. 11. Ornament on the walls, Hall of the Abencerrages.
Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906.

300
p2
24.9a Peruvian textile design
24.9b Peruvian textile design
24.9c Peruvian textile design
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984.

310
pm (diamonds); cm (lozenges)
Plate 31
Plate 32
Victoria and Albert Colour Books. *Decorative Endpapers*, Webb and Bower 1985.

320
pg
M.C. Escher, Study for the lithograph "Encounter", pencil and ink 1944. Note that in this case it is impossible to bring, e.g., the two white men to coincidence by a rotation.
Caroline H. McGillavry, *Symmetry Aspects of M.C. Escher's Periodic Drawings*, International Union of Crystallography, Plate 3 = J.L. Locher, *The World of M.C. Escher*, Harry N. Abrams 1971, Fig. 123.

330
pg
Plate 9
Plate 10
Victoria and Albert Colour Books. *Decorative Endpapers*, Webb and Bower 1985.

340
cm
Plate V, No. 5. Ornament on the side of windows, Hall of the Two Sisters.
Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906.

350
cm
Plate IV, No. 4. Ornament at the entrance to the Ventana, Hall of the Two Sisters.
Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906.

360
cm
Plate XI, No. 12. Ornament in panels on the walls, Court of the Mosque.
Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906.

370
p2mm
Figure 27.4
(a) (top right) American Indian, Nez Percé
(b) (bottom left) Romanesque
(c) (bottom right) mosaic pavement, Florence baptistry
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984.

380
p2mg
Chinese lattice designs
25.7 (a) (top) (Dye N2b, p.215)

(b) (bottom left) (Dye I3b, p.157)

(c) (top right) (Dye 7, p.307)
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984.

390
p2gg
26.6 (a) Congo, Africa
26.6 (b) Italy, sixteenth century
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984.

400
c2mm
28.4 (a) (top) Japanese
28.4 (b) (bottom left) Italian, sixteenth century
28.4 (c) (bottom right) medieval design
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984.

410
p4
This pattern presents a tricky problem. It is formed by an array of starfishes, clams and snail shells. At first sight, one would mark as cell corners the points where four clams and four starfish meet. However, on closer inspection it is seen that the edges of this square are not true translations of the patterns; the snail shells halfway between these pseudocell corners are not repeated in identical orientation by such shifts.... On the other hand, the mid-point of the psueudocell, where four starfishes and four snail shells meet, is indeed a true fourfold rotation point....
Caroline H. MacGillavry, *Symmetry Aspects of M.C. Escher's Periodic Drawings*, International Union of Crystallography 1965, Plate 13.

420
p4mm
Octagon allovers, Buddhist temples, Mount Omei, Szechuan 1800-1900 a.d.
Fig. H 10a (top right)
Fig. H 10b (top right)
Fig. H 10c (bottom right)
Fig. H 10d (bottom right)
Daniel Sheets Dye, *Chinese Lattice Designs*, Harvard University Press 1937 and Dover 1974, p.149.

430
p4mm
34.6 (a) (top) Byzantine design
34.6 (b) (bottom left) tartan motif
34.6 (c) (bottom right) Mayan motif, Uxmal, Yucatan
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984, p.308.

440
p4g
M.C. Escher, Study of Regular Division of the Plane with Angels and Devils, Pencil, india ink, blue crayon and white gouache 1941.
Plate 6. The pattern has evidently fourfold rotation and mirror-symmetry.... It is seen that near the bottom of the picture there is a row of three fourfold rotation points. Of these, only the first and third are equivalent by translation; the surroundings of the three points are alternatively 'left' and 'right' since there are mirror lines running between them. Choose the point in the middle of this

row and find in the pattern three other fourfold points in the same orientation. These outline a square unit cell which is tilted at 45 to the borders of the picture. Caroline H. MacGillavry, *Symmetry Aspects of M.C. Escher's Periodic Drawings*, International Union of Crystallography 1965, Plate 6.

450
p4gm
33.6a (top) mother-of-pearl inlay motif, Turkey
33.6b (bottom left) Arabian
33.6c (bottom right) Arabian
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984, p.298.

460
p3
Plate XLVIII No. 58. Mosaic from the portico of the Generalife.
Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906.

465
p3
Postcard with caption "La Alhambra (Granada) Estucado".

470
p3m1
30.3 (b) (top left) Persian
30.3 (c) (bottom right) Chinese (Dye C12b, p.79)
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984, p.267.

480
p31m
31.4 (a) (top left) Chinese
31.4 (b) (top right) Chinese (Dye C5a, p.72)
31.4 (c) (bottom) Russian
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984, p.275.

490
12m or 4m (top); p6 (bottom)
Plate XLII , Moresque No. 4 (Do not confuse with Plate XLII*, Moresque No. 4*)
No. 6 (top) ≅ Albert F. Calvert, *The Alhambra*, John Lane, The Bodley Head 1906, Plate LXXVIII, No. 106, Part of the Portico of the Court of the Fish Pond.
No. 5 (bottom) ≅ Calvert, *op. cit.*, Plate LXXX, No. 108, Ornaments on the walls, House of Sanchez.
Owen Jones, *The Grammar of Ornament*, John Day 1856 and Van Nostrand Reinhold 1982.

500
p6mm
36.6 (a) (left) An ancient design from the palace at Nimrud, Mesopotamia
36.6 (b) (right) A Japanese design
P.S. Stevens, *Handbook of Regular Patterns*, M.I.T. Press 1984, p.328.
510

p6mm
44. Some of the myriads of elegant basalt columns that make up the Giant's Causeway in Antrim, Northern Ireland. Most, but not all, are hexagonal. (Institute of Geological Sciences photograph).
Peter Francis, *Volcanoes*, Penguin 1976, p.220.

520
p6mm
Plate 10 B. Polygonal jointing in Tholeiitic Basalt lava. Giant's Causeway.
H.E. Wilson, *Regional Geology of Northern Ireland*, H.M.S.O. 1972.

530
p6mm
Plate 52. Workers of the dwarf honey bee gnawing wax off an abandoned comb and putting it into their leg baskets (see p.95).
Karl von Frisch (with the collaboration of Otto von Frisch), *Animal Architecture* (translated by Lisbeth Gombrich), Hutchinson 1975, p.97.

540
p6mm
Plate 49 (top left) Comb built by bees whose antennal tips had been amputated. The cells are irregular; their walls are excessively thick in some places, excessively thin in others, and there are holes. (See p.92). Plate 50 (top right) Bee with baskets filled with pollen. (See p.83). Plate 51 (centre) Bee with baskets filled with propolis. (See p.94). Plate 52 (bottom) Workers of the dwarf honey bee gnawing wax off an abandoned comb and putting it into their leg baskets. (See p.95).
Karl von Frisch (with the collaboration of Otto von Frisch), *Animal Architecture* (translated by Lisbeth Gombrich), Hutchinson 1975, p.97.

550
pg$'$ (black and white)
Fig. 137 (above) M.C. Escher, Study of Regular Division of the Plane with Horsemen, Indian Ink and Watercolour 1946 (Magic Mirror, Fig. 225)
Fig. 138 (below), M.C. Escher, Horsemen, Woodcut in three colours 1946 ($\cong$ *Magic Mirror*, Fig. 224 $\cong$ *Graphic Work*, Fig. 6)
J.L. Locher (ed.), *The World of M.C. Escher*, Harry N. Abrams 1971.

560

Colour plane symmetry
This is a more typical case of colour symmetry.
The pattern is composed of fishes in four different colours and orientations. All the fishes of one colour have the same orientation and surroundings, so there is one fish of each colour per cell. . . .
[Discussed also by Arthur L. Loeb, *Color and Symmetry*, Wiley 1971, Chap. 22, pp.162–165]
Caroline H. MacGillavry, *Symmetry Aspects of M.C. Escher's Periodic Drawings*, International Union of Crystallography 1965, Plate 37.

570
M.C. Escher, *The Graphic Work of M.C. Escher*, Oldbourne 1961, Fig. 20
Bruno Ernst, *The Magic Mirror of M.C. Escher*, Ballantine 1976, Fig. 244
J.L. Locher (ed.), *The World of M.C. Escher*, Harry N. Abrams 1971, Colour Plate VII and Fig. 239

580
Tilings
(Frontispiece) Johannes Kepler (1580-1630) is well known for his pioneering work in astronomy. He also made fundamental contributions to the theory of tilings, and some of his ideas have still not been fully investigated. We reproduce here tilings from his book *Harmonica Mundi* (volume 2) published in 1619. The tiling marked Aa can be extended over the whole plane as shown in Figure 2.0.1 and described in Section 2.5.
Branko Grünbaum and G.C. Shephard, *Tilings and Pattern*s, Freeman 1987.

590
Tilings
Figure 8.0.1. An attractive and ingenious pattern of squares from Islamic art (Bourgoin [1879, Plate 13]) perfectly coloured in four colours. The pattern is of type PP48A and it can be perfectly k-coloured if k has one of the values $3n$, $6n$, n^2, $2n^2$, $3n^2$ or $6n^2$ for a positive integer n (see Senechal [1979a]).
Branko Grünbaum and G.C. Shephard, *Tilings and Pattern*s, Freeman 1987.

600
Regular solids
M.C. Escher, Study for the wood engraving "Stars", Woodcut 1948.
J.L. Locher (ed.), *The World of M.C. Escher*, Harry N. Abrams 1971, Fig. 151.

610
Regular solids
M.C. Escher, Stars, Wood engraving 1948.
M.C. Escher, *The Graphic Work of M.C. Escher*, Oldbourne 1961, Fig. 51
Bruno Ernst, *The Magic Mirror of M.C. Escher*, Ballantine 1976, Fig. 209
J.L. Locher (ed.), *The World of M.C. Escher*, Harry N. Abrams 1971, Fig. 152

620
Regular solids
A. Holden, *Shapes, Space and Symmetry*, Columbia University Press 1971, Plate opposite p.1.

630
Fig. 26. Skeletons of various radiolaria (after Haeckel).
BUT see H.S.M. Coxeter, Review of "Symmetry" by H. Weyl, *American Mathematical Monthly*, **60** (1953), 136–139.
A.F. Wells, *The Third Dimension in Chemistry*, Oxford: Clarendon Press 1956.

640
Regular solids
Fig. 46. Here (Fig. 46) is his [Kepler's] construction, by which he believed he had penetrated deeply into the secrets of the Creator. The six spheres correspond to the six planets, Saturn, Jupiter, Mars, Earth, Venus, Mercurius, separated in this order by cube, tetrahedron, octahedron, dodecahedron, icosahedron.
H. Weyl, *Symmetry*, Princeton University Press 1952.

650
Table 9. The thirteen semi-regular (Archimedean) polyhedra and their duals (a) truncated octahedron (b) truncated icosahedron (c) great rhombicuboctahedron or truncated cuboctahedron (d) snub cube (e) truncated tetrahedron (f) cuboctahedron (g) icosidodecahedon (h) small rhombidodecahedron (i) small rhombicosidodecahedron (j) truncated cube (k) truncated dodecahedron (l) truncated dodecahedron (m) snub dodecahedron.
Open University Technology/Mathematics Course TM 361, *Graphs, Networks and Designs*, TM 361–13 Geometry, p.36.

660
Table 10. Some examples of space filling systems.
Open University Technology/Mathematics Course TM 361, *Graphs, Networks and Designs*, TM 361–13 Geometry, p.46.

670
Crystal
Fig. 191. The fourteen Bravais lattices. If we assume spherical symmetry for the lattice points, the space groups of the fourteen Bravais lattices will be (1) P1 (2) P2/m (3) C2/m (4) Pmmm (5) Cmmm (6) Immm (7) Fmmm (8) P6/mmm (9) R3m (10) P4/mmm (11) I4/mmm (12) Pm3m (13) Im3m (14) Fm3m. The capital letters denote the translation groups: P, R primitive lattices; C lattices centred in the face cutting the edge c; F face centred lattices; I body-centred lattices. (1) is triclinic, (2)–(3) monoclinic, (4)–(7) orthorhombic (8) hexagonal (9) trigonal (10)–(11) tetragonal (12)–(14) cubic.
A.V. Shubnikov and V.A. Koptsik, *Symmetry in Science and Art*, Plenum 1974, p.205.

680
Crystal
Fig. 73. The 47 simple forms which crystals may take: (1)–(7) Pyramids; (8)–(14) bipyramids; (15)–(21) prisms (22), (23), (25) tetrahedra; (24), (26), (28) trapezohedra; (27) rhombohedron; (34) scalene triangle; (33), (35) scalenohedra; (31) dihedron; (32) pinacoid; (23), (29), (36)–(47) simple forms of the cubic system; (23) tetrahedron; (29) cube; (30) octahedron; (36) trigonal tristetrahedron; (38) pentagonal tristetrahedron; (39) rhombic dodecahedron; (40) pentagonal dodecahedron; (41) tetrahexahedron; (42) hexatetrahedron; (43) didodecahedron; (44) tetragonal trisoctahedron; (45) trigonal trisoctahedron; (46) pentagonal trisoctahedron (47) hexoctahedron.
A.V. Shubnikov and V.A. Koptsik, *Symmetry in Science and Art*, Plenum 1974, p.205.

690
Figs. 69 & 70. Here are two Laue diagrams (Figs. 69 and 70), both of zinc-blende from Laue's origianl paper (1912); the pictures are taken in such directions as to exhibit the symmetry around an axis of order 4 and 3 respectively.
H. Weyl, *Symmetry*, Princeton University Press 1952.

700
Crystal
14. Fluorspar
15. Fluorspar
N. Wooster, *Semi-precious Stones* (with sixteen coloured plates by Arthur Smith), Penguin 1952 (King Penguin No. 65), Plates 14 & 15.

710
Crystal
12. Iron pyrites
13. Fluorspar 'Bluejohn'
N. Wooster, *Semi-precious Stones* (with sixteen coloured plates by Arthur Smith), Penguin 1952 (King Penguin No. 65), Plates 14 & 15.

720
Spiral
NAUTILOIDS, GONIATITES AND CERATITES [on left] 64 *Orthoceras* [top left]; 65 *Nautilus* [top right of left]; 66 *Glyphioceras* [bottom left]; 67 *Ceratites.* LIASSIC AMMONITES [on right] 68 *Promicroceras* [top right of left]; 69 *Phylloceras* [top right]; 70 *Dactilioceras* [bottom right of left]; 71 *Harpoceras.*
J.F. Kirkaldy (Photographs by Michael Allman), *Fossils in Colour*, Blandford Press 1967, revised 1975.

730
Spiral

Plate XXXV Shell, Logarithmic Spiral and Gnomonic Growth (Photographs: Kodak Ltd)
Plate XXXV gives two examples of X-rayed shells, showing clearly the directing spiral of *Nautilus Pompilius* and the gnomonic growth of *Triton Tritonis* (p.97). Gnomonic growth means growth from inside outwards as opposed to agglutination as is common in crystal [paraphrased from p.90].
M. Ghyka, *The Geometry of Art and Life*, Sheed and Ward 1946, reprinted by Dover 1977, p.101.

740
Spiral
Fig. 44. For everybody looking at this picture (Fig. 44) of a giant sunflower, *Helianthus maximus*, the florets will naturally arrange themselves into logarithmic spirals of opposite sense of coiling.
H. Weyl, *Symmetry*, Princeton University Press 1952.

750
Helical
(334) No. 23 HIGH PETERGATE, c. 1779 (left) (helical)
(334) No. 62 LOW PETERGATE, c. 1725 (right)
Royal Commission on Historical Monuments, *City of York. Volume 5: The Central Area*, H.M.S.O. 1981, Plate 196.

760
Helical
J.D. Watson, *The Double Helix: A New Critical Edition*, Weidenfeld and Nicholson 1981, p.121.

770
Helical
G. Nass, *The Molecules of Life*, Weidenfeld and Nicholson 1970, p.35.

780
Conical spiral
HOLOSTOMATOUS AND SIPHONOSTOMATOUS GASTROPODS
110. Left, *Turitella*, Right *Cerithium*
Bartonian (Upper Eocene), Gisois, Normandy, France $\times 1\frac{1}{4}$.
J.F. Kirkaldy (Photographs by Michael Allman), *Fossils in Colour*, Blandford Press 1967, revised 1975.